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Geoscience Australia
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National Oceans Office

FINAL REPORT

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Vicki Passlow, John Rogis, Alison Hancock, Mark Hemer, Kriton Glenn, Ahsanul Habib

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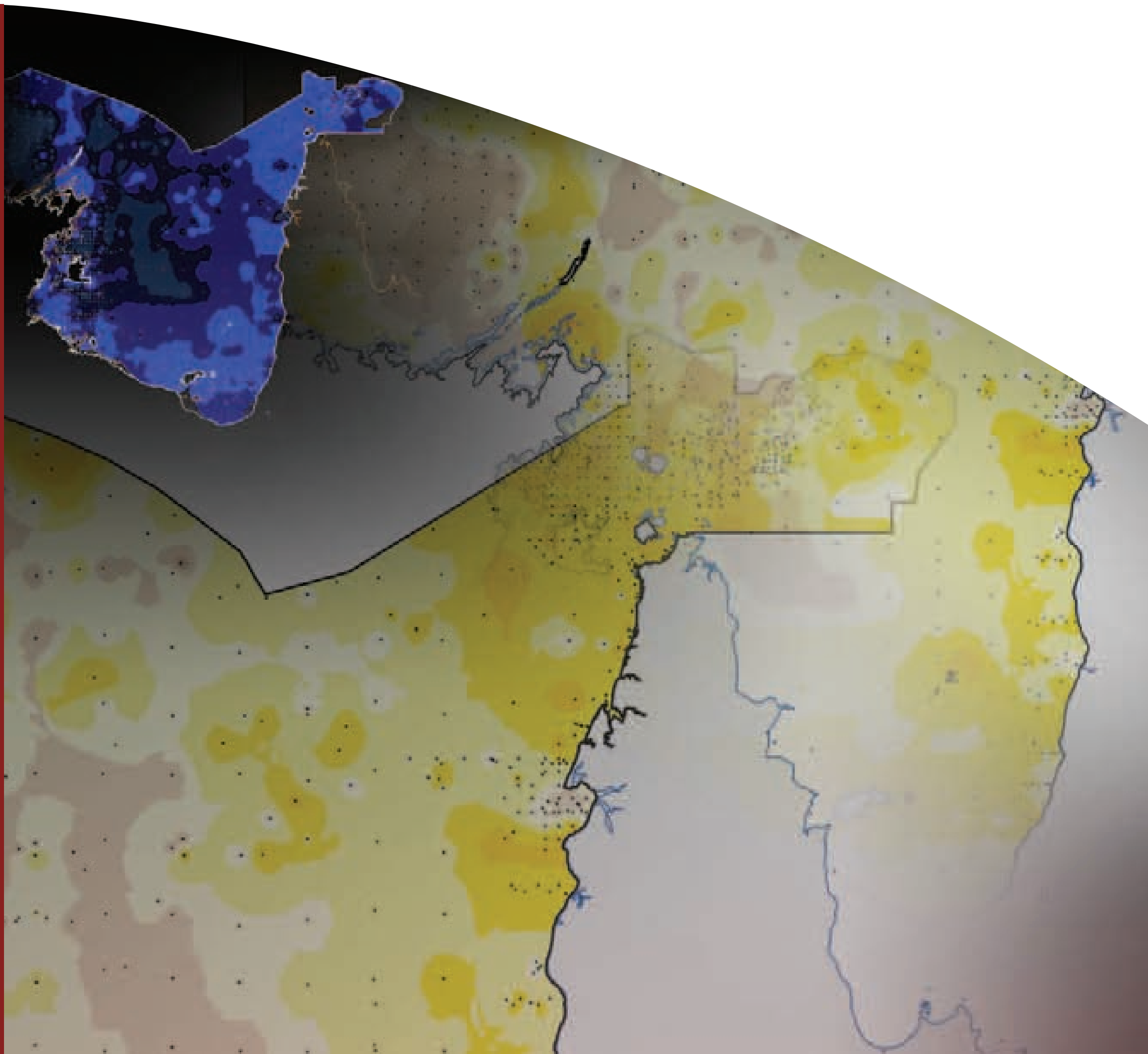

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NATIONAL MARINE SEDIMENTS DATABASE AND SEAFLOOR CHARACTERISTICS PROJECT

GEOSCIENCE AUSTRALIA
RECORD 2005/08

by

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1 Summary

The National Marine Sediments Database and Seafloor Characteristics project is a collaborative effort between the National Oceans Office and Geoscience Australia. The aims of the project were:

- to locate, identify and collate existing information on the nature and distribution of marine sediments within the Australian Marine Jurisdiction;
- to develop the MARS sediments database within Geoscience Australia and populate it with collated data to provide a national fundamental dataset, with publicly-available data;
- to analyse and map readily available sediment data for the Northern Planning Area as a first priority to provide information for the Northern Region marine bioregionalisation;
- to analyse and map an agreed selection of sediment data for the Australian region to provide information for the National Benthic Marine Bioregionalisation;
- to detail in maps estimates of sediment mobilisation due to waves and tidal currents for Australian waters less than 300 m depth;
- to strategically analyse the role of sediments and other seafloor characteristics information in marine bioregionalisations and, based on an assessment of relative benefits, recommend options for further research and data collection; and
- to interact with the National Marine Bioregionalisation Integration project teams to ensure sediments and other seafloor characteristics information is applied correctly in the National Benthic Marine Bioregionalisation.

The creation of the MARS database marks the transition to a new era of easy internet access to quantitative seafloor information. This is the first project to critically assess the quality and coverage of Australia's seafloor sediment data on a national scale. The initial phase of the project was the identification and collation of sediment data. The compilation of data generated from the scientific analysis of samples (quantitative data) was given priority, as these data would allow seafloor sediment characteristics to be assessed, modelled and presented with greater confidence than previously attempted. In total, 80 individuals representing 38 organisations were contacted. By the end of the data collation phase, the MARS database contained about 25,000 samples for which 138,000 properties had been recorded. This represents a significant advance in making quantitative sediment data available to researchers, stakeholders and managers alike.

Maps of sediment properties were produced using validated quantitative data for two regions: the Northern Planning Area (NPA) and the whole of the Australian Marine Jurisdiction, excluding external territories. These maps show the distribution of measured grain size data (weight percent gravel, sand and mud), calculated mean grain size, as well as sediment classification based on the Folk scheme (Folk, 1954), and carbonate content. Mean grain size data for six of the marine domains were used to model sediment mobility in waters less than 300 m depth, using Geoscience Australia's GEOMAT package. The results of the modelling were produced as maps of tide and wave exceedance, and an energy regime regionalisation.

As a direct result of this project, the MARS database is now an important scientific and educational resource for those requiring detailed information on seafloor sediment characteristics within the Australian Marine Domain areas. The maps generated by this project show the level of detail and type of presentation possible when using quantitative data, but significant gaps in measured data coverage were also identified. Some 70% of the total marine domain remains unmapped in terms of measured sediment data. Much of this area is off the continental shelf, although gaps in the data coverage on the shelf are significant, particularly in the South-west and West-central Marine Domains

Strategic directions for improving the data coverage include the analysis of existing sediment samples from Australian and overseas repositories. A valuable resource of seabed samples stored in Australia and overseas has been identified. These samples, if analysed, have the potential to double the existing overall measured data coverage for Australia's Marine Domains and would provide a cost-effective way of generating new data. The South-west Marine Domain would provide a useful pilot study to test the utility of analysing existing material.

Reanalysis of existing samples would provide consistent and appropriate data, particularly for sediment mobility modelling, where the parameters measured are not necessarily the most appropriate to model sediment behaviour. Enhanced collection of existing data requires further development of relationships with data owners. Funding in support of this would facilitate collection of non-digital data, particularly from universities.

In addition to continued acquisition of sediment data, continuing research into the links between geological properties and biota is important to better inform the use of geological proxies in bioregionalisation. Geological data have obvious benefits: even with significant gaps in quantitative sediment data, the coverage is still far greater than for biological data.

Additional development of the GEOMAT model would allow it to be better applied to bioregionalisation. In particular, the ability to calculate the mobilisation for a full spectrum of grain sizes would enable the model to predict the minimum grain size which is mobilised for some significant period of time. This would provide a better understanding of the fate of sediment input to the continental shelf and how this relates to a regionalisation based on dominating energy regimes.

2 Introduction

This is a collaborative National Oceans Office – Geoscience Australia project aiming to locate, identify and collate existing information on the nature and distribution of marine sediments within the Australian Marine Jurisdiction, thereby adding to the existing body of knowledge on the nature of the sea floor. Its focus is on the continental shelf and off-shelf areas, recognising that these areas are the most poorly-defined and therefore a priority for enhancement. This information is a key input to the Australian Government's National Marine Bioregionalisation Work Program.

Geoscience Australia has developed a marine sediments database (MARS) as the framework for the ongoing collection and maintenance of marine sediment data in Australia. This database has been developed under the Geoscience Australia corporate data model, in line with the ANZLIC metadata standards. The database will be promoted as a National Fundamental Marine Dataset. Custodianship of the marine sediments dataset will be maintained by Geoscience Australia. A primary aim of the data being included in a National Fundamental Dataset is that it be publicly available at the marginal cost of transfer.

The key objectives of this project were:

- to identify, as far as possible, sources of marine sediment sample information held by Australian and international research groups and private, corporate entities that are available to be entered into a national marine sediments database;
- to collate, analyse and map Australia-wide sediment data for grain size and carbonate content as first priorities, followed by other variables as a key information input to the national marine bioregionalisation;
- to collate, analyse and map readily available sediment data for the Northern Planning Area as a first priority to provide information for the Northern Region marine bioregionalisation;
- to populate a National Marine Sediments Database (MARS) with data collated;
- to detail in maps estimates of sediment mobilisation due to waves and tidal currents on the Australian continental shelf to aid marine bioregionalisation;
- to interact with the National Marine Bioregionalisation Integration project teams to ensure sediments and other seafloor characteristics information is applied correctly in the National Benthic Marine Bioregionalisation; and
- to strategically analyse the role of sediments and other seafloor characteristics information in marine bioregionalisation and, based on an assessment of relative benefits, recommend options for further research and data collection.

In addition, key outputs to be summarised and reported on in the Project Report include:

- strategic review of the findings, elaborating on the role of sediment mapping and analysis in supporting the benthic bioregionalisation and including any

recommendations for improvements in the mapping and application of sediments data to support both bioregionalisation and marine management;
- maps from phases 1 and 2 (discussed below) as well as maps showing spatial coverage and type data in MARS, used for the project;
- identification of key gaps in coverage and data attributes for marine sediments, and implications for application of seafloor characteristics information to marine management. These will be evaluated in the context of the likely benefits to accrue from investment in any additional resource appraisal activities;
- directions and opportunities for improved and partnership-based data management and data access. These will be done within the context of existing arrangements and policy under the Marine Data Group and the Commonwealth Office of Spatial Data Management. Any recommendations will build on the role of Geoscience Australia as the Data Custodian, including its parallel and ongoing work to build, populate and manage for Australia the sediments database and its activities to ensure sediments are included as a National Fundamental Marine Dataset;
- improvements in information provision and application to management, recognising the need to generate increased community and user understanding of marine environments, marine management needs and the benefits of ecosystem based management. This analysis will build on the role, capabilities and possible refinements considered appropriate for analysis and information display systems such as GEOMAT;
- background, description of input data and analysis methods, results, discussion and R&D gaps;
- Web-accessible information; and
- Web-accessible versions of all maps and the final project report arising from this project will be delivered to the National Oceans Office.

The work of the project was carried out in two phases. The first phase consisted of data collation and database population. The second phase involved interpretation of the data. The data collation phase was designed to build on and use data that Geoscience Australia had already been collating for inclusion in MARS. This was to be achieved through the identification of data holdings in other organisations. Key outputs from this phase were

- the identification of sources of marine sample data;
- a prioritised data list for population of MARS, focussing on the Northern Planning Area, followed by the whole of Australia and based also on data quality;
- collation and formatting of data;
- population of MARS.

The second phase of the project consisted of an analysis phase to deliver mapped data for both the Australia-wide and Northern Region Marine Bioregionalisation activities being carried out by the National Oceans Office. Interpreted data products from this phase included:

- Coverages for mean grain size, carbonate, mud, sand and gravel content;
- Coverages of sediment type;

- Gridded grain size distributions for input into the GEOMAT sediment mobility modelling package;
- Coverages of sediment mobility derived from GEOMAT analysis; and
- Visual estimates of uncertainty in each of the maps.

Throughout the project, regular reports were provided to the National Oceans Office through written progress reports and presentations to the Bioregionalisation Working Group. This report constitutes the Final Report for the project. Geoscience Australia project staff involved in the different components of the project are listed in Appendix 1.

3 Methods

3.1 Data Collection and Collation

Geoscience Australia contacted about 80 individuals associated with 38 organisations during the course of this project. Details of these organisations are provided in Appendix 2, and their responses are summarised as follows:

- Positive response, data supplied (10 organisations)
- Positive response, but
  - No suitable data (12 organisations)
  - Intellectual Property Issues (3 Consultants)
  - No staff or resources available to compile data (3 organisations)
  - Sediment data collected in support of other research, and not compiled, incomplete dataset (1 organisation)
  - Supply of data not a high organisational priority (1 organisation)
- No response (6 organisations)
- Negative response
  - Researchers not finished with their work, and not comfortable with releasing any data (1 group)
- International online database searches
  - Data downloaded successfully (6)
  - Relevant data not accessible (1)

Few organisations have maintained their marine sediment data in readily accessible electronic formats, requiring Geoscience Australia to rely on written data sources to supplement its existing marine sediment dataset. Site visits by Geoscience Australia staff to a number of key data holders were arranged to assist with data compilation and to copy written data.

The manual data entry workload was greater than anticipated, resulting in Geoscience Australia concentrating its efforts on compiling numeric datasets on the continental shelf – that is those datasets where the gravel/sand/mud content of the sample had been measured by methods such as sieve analysis. These were the datasets required for Geoscience Australia's GEOMAT sediment mobility modelling - a key project task.

Data were collated and formatted onto spreadsheets by Geoscience Australia data entry staff during the MARS database development phase, and subsequently loaded into MARS once database development was complete.

3.2 MARS Database Development

The MARS database has been developed by Geoscience Australia within the Oracle application. Development of the MARS web interface is continuing, with web access scheduled for February 2005. This report and all maps produced will be accessible on the Geoscience Australia web site. All files have also been provided to the National Oceans Office in web-accessible format.

MARS is based within the Geoscience Australia Corporate Data Model, which has been developed in line with ANZLIC data standards. MARS is built on several tables, designed to store survey metadata, sample metadata and sample analyses and results, including seafloor photographs and videos.

Initial scoping of the database was carried out in 2002/2003, prior to the commencement of this project. The database was originally intended as a repository for in-house data; its aim was to hold a wide range of sample metadata, sample and result types. Development of the forms commenced in September 2003. Some difficulties were encountered in the development process due to the need to tie in with corporate database projects. Testing and modification of the initial data entry forms were carried out in late 2003.

The proposed migration of all Geoscience Australia database Forms to Oracle Forms version 9i was hampered by a major fault in the Oracle application which made it unworkable for our purposes. As a result, Geoscience Australia's corporate database administration group decided to revert to Oracle Forms version 6i across the whole organisation. The forms redevelopment was carried out in late December – early January, and forms were available for use in February, following additional testing. Data loading into MARS was delayed by 1-2 months while this issue was resolved, although data collation continued.

Since MARS was developed within the Geoscience Australia Corporate Data Model, it was designed to capture a wide range of data types across the different disciplines within Geoscience Australia and store the data in a single repository. The database is structured so that it can accept many different types of data, including lithological and biological variables. Although the major priority for this project was to capture grain size and carbonate data, MARS has the capability to hold much more. Currently MARS holds grain size, carbonate content, elemental analysis, conventional carbonate dating, isotope analysis, geochemical data, water current data, CTD data, lithology data, biogenic silica, biostratigraphic data, and sediment composition data.

3.3 MARS Data Entry

Data compilation and formatting during the MARS database development period was carried out using customised spreadsheets. Geoscience Australia had a team of up to 5 data entry personnel working on this task at various stages of the project. Data in customised spreadsheet format can be readily entered into MARS using loading scripts. MARS data loading using this method commenced in April 2004 with data for the Northern Planning Area loaded initially, followed by numeric grain size data from all sources for the remaining area of Australia. Data loading is continuing for all other sediment properties (such as descriptions, age dates and geochemistry) for past Geoscience Australia research cruises off the continental shelf together with additional data from all other sources.

Extensive work was done on defining standard terminology for data types and properties, such as units of measure, sample types, and references. This effort was required to ensure a consistent approach by data entry staff. Data entry and loading formats were also defined to provide a guide for data entry staff. Quality assurance rules have been developed for checking that data meets specific quality standards. Additional enhancements to the database to record data quality are being developed. An extensive data quality review was carried out prior to mapping the data (see Section 3.5 below). While the sediment grain size data varied in the methods used to generate it, this is unlikely to be an issue, since different methods vary in their degree of detail rather than in the degree of accuracy. The determination of sediment properties such as mean grain size or mode are more likely to be influenced by the method used, since they are directly affected by how detailed of the results on which they are based. The method of determination was recorded for samples, so that the effect of the method can be assessed.

At the end of June 2004, the MARS database contained about 25,000 samples for which 138,000 properties had been recorded. Geoscience Australia will continue to accept and add data to MARS in the normal course of its work. The break down of data sources is as follows:

40% of sample points are from GA, AGSO and BMR surveys.
30% of samples points were obtained from the CSIRO
15% of sample points came from Ocean Science Institute Reports
9% of sample points came from papers and reports from the University of Sydney
0.1% from Geological Survey of Queensland
0.5% from Queensland Northern Fisheries
2.5% from Parks and Wildlife Commission of the Northern Territory
1% from Department of Natural Resources and Environment, Vic
1% from University of Western Australia
0.9% from Western Australia Department of Fisheries

Coordinate locations for some marine sediment sampling programmes were not directly recorded, with researchers plotting sample locations directly onto maps. In these cases, Geoscience Australia scanned the original maps and georeferenced the images using world coordinates. Sample points were then digitised using GIS software so that location coordinates could be determined. All location data was checked using GIS to ensure correct location. The method used to determine location can be recorded in the database as a guide to accuracy. Where possible, this information has been recorded for the data within MARS.

3.4 Map Production and Presentation

Maps were produced for two regions: the Northern Planning Area (NPA) and the whole of the Australian Marine Jurisdiction, excluding external territories. For the purposes of presentation of results, the whole of Australia was broken down into Marine Domains. The Marine Domain names used in this report (Fig. 3.1) are based on the Large Marine Domain names and locations provided by the National Oceans Office. Some boundary modifications were made by Geoscience Australia, in consultation with the National Oceans Office, to accommodate the Northern Planning Area, which now covers the revised Northern and newly created Torres Strait Planning Areas.

The individual datasets used to prepare the different maps and the data processing carried out for each are discussed below. Validated data were imported into ArcGIS for processing and presentation. Details of the processing carried out in ArcGIS are provided in Appendix 3.

3.5 Map Production –Sediment Grain Size Properties and Sediment Type

3.5.1 Gravel/Sand/Mud% and Folk Sediment Type Classification

The Australia-wide dataset used for seabed sediment texture map production comprised about 7,800 sample locations. Maps were produced for gravel, sand and mud contents of the seabed, presented as a percentage by weight of the total sample. The data was compiled by:

- Querying the MARS database to obtain all numeric grain size information
- Compiling the results into gravel, sand and mud%
- Checking that each sample had all three components reported, and that the sum of these components were in the range 95% - 105%
- Checking for and resolving duplicate sample issues

The sediment classification proposed by Folk (1954) has been used to present information on the sediment type. It is based on a triangular diagram that has been divided into sediment textural groups based on measured percentages of gravel, sand and mud constituents (Fig. 3.2). This provides a method of describing samples with a complete range of mixtures of the three components and deriving a single description and classification value. These descriptive "values" can then be readily presented on one map.

Grain size data for the West-central Marine Domain was supplemented by regional polygons derived from work published by James *et al* (1999).

3.5.2 Measured Carbonate Content

The Australia-wide dataset used for carbonate map production comprised about 4,500 sample locations. It was compiled by:

- Querying the MARS database to obtain all numeric bulk carbonate information
- Checking for and resolving duplicate sample issues

Presentation of carbonate content for the North-east Marine Domain was supplemented by georeferenced data points from Maxwell (1968) that were not part of the MARS database.

3.5.3 Mean Grain Size Data

MARS was interrogated to obtain data from locations which either had a recorded mean grain size, or alternatively a grain size distribution with a weight or volume concentration in three or more grain size categories. The consequent dataset totalled 7995 sample locations. Additionally, mean grain sizes were estimated from James *et al.* (1999) for the region off the western coast of Australia between latitudes of approximately 32°S and 23°S. These regions were gridded at 0.0361° spacing, and contributed 6835 points to the mean grain size dataset. The consequent number of data points for which quantitative mean grain size or grain size distribution information was available from within the Australian Large Marine Domains totalled 14830 points.

At locations with a grain size distribution, and no recorded mean grain size, the mean grain size was determined using the method of moments as outlined by Lindholm (1987). In the case where the grain size distribution consisted of only mud, sand and gravel fractions, the mud fraction was assumed to have a median grain size of 0.031 mm, the sand fraction was assumed to have a median grain size of 0.375 mm, and the gravel fraction was assumed to have a median grain size of 3 mm.

Mean grain size is mapped in 13 categories, based on commonly used sedimentological descriptions (Krumbien & Sloss, 1963). Discussion of the maps for each of the large marine domains (Section 4.2) is based on the terminology for the different mean grain size classes. The size classes were selected to provide detailed information on grain size characteristics and to provide detailed input into the GEOMAT model. The grain size classes used are shown below.

0 – 0.002 mm	Fine-medium Clay	Mud
0.0021 – 0.004 mm	Coarse Clay	
0.0041– 0.008 mm	Very Fine Silt	
0.0081 – 0.016 mm	Fine Silt	
0.0161 – 0.031 mm	Medium Silt	
0.0311 – 0.063 mm	Coarse Silt	
0.0631 – 0.125 mm	Very Fine Sand	Sand
0.1251 – 0.250 mm	Fine Sand	
0.2501 – 0.500 mm	Medium Sand	
0.5001 – 1.000 mm	Coarse Sand	
1.0001 – 2.000 mm	Very Coarse Sand	
2.0001 – 4.000 mm	Granules	Gravel
>4.0001 mm	Pebbles and larger	

3.6 Map Production – GEOMAT Modelled Output

In addition to the fundamental descriptive variables of bed morphology, grain properties, sediment composition and biogenic constituents, physical hydrological processes, such as swell waves, tides and ocean currents, are responsible for controlling the introduction, dispersal and deposition of sediments in the marine environment. Such information is important to assist with defining bioregions. Geoscience Australia's GEOMAT (GEological and Oceanographic Models for Australia's ocean Territory) package simulates the initiation of grain movement on the continental shelf under the influence of tidal currents and surface swell waves. Using this information, the relative importance or strength of these physical processes can be deduced, to assist with defining bioregions for Australia's continental shelf.

The area of Australian margin over which GEOMAT computations have been carried out is defined as that area within the Australian Large Marine Domains beyond the surf zone and extending to water depths less than 300 m (hereafter referred to as the Australian GEOMAT region). This area contains all of the continental shelf, and some extra area of deeper water to ensure that calculations are always carried out beyond the maximum depth at which waves are able to "feel" the seafloor, and tidal currents sufficiently weak as to not mobilise sediments. GEOMAT computations have not been carried out for the South-west Marine Domain, where quantitative grain size information is unavailable.

3.6.1 GEOMAT - Threshold Exceedance Due to Swell Waves

Surface ocean waves, such as ocean swell and other wind-generated waves, consist of orbital motions of water, which diminish in radius from the sea-surface to the seabed. In shallow waters, these orbital currents are felt at the seabed. This orbital motion at the seabed translates to a shear stress, capable of mobilising sediments and initiating bedload and suspended load transport. When the shear stress at the bed just exceeds the critical value required for initiation of motion (the threshold current speed), sediment particles will begin rolling and/or sliding whilst remaining in continuous contact with the bed (bedload transport). As the water velocity increases, increased turbulence can lift the sediment particles into the water column initiating transport as suspended load. The threshold current speed is a function of the mean grain size.

Wave-induced sediment threshold exceedance provides an estimate of the percentage of time that surface waves are capable of mobilising sediments on the seabed. Details of the methods used to compute the wave-induced sediment threshold exceedance are contained in Appendix 4.

3.6.2 GEOMAT - Threshold Exceedance Due to Tidal Currents

Steady currents, such as those associated with tidal motion, exert a shear stress on the seabed, ie. they impose a force on the bed material in the direction of flow. The faster the water velocity, the greater the shear stress.

Tide-induced sediment threshold exceedance provides an estimate of the percentage of time that tidal currents are capable of mobilising sediments on the seabed. Details of the methods used to compute the tide-induced sediment threshold exceedance are contained in Appendix 4.

3.6.3 GEOMAT - Energy Regime Regionalisation

Waves or tides (or both) may influence sediment mobilisation on continental shelves. Of interest here, is which process dominates on the Australian continental shelf, and how this might relate to the definition of bioregions. Combining the wave and tidal exceedance estimates into a ratio allows an assessment of the relative spatial importance of these two mechanisms in mobilising bottom shelf sediments.

Six energy regime categories (as defined by Harris *et al*., 2000 and Porter-Smith *et al*., in press) have been identified. Regions where neither wave nor tidal currents are capable of mobilising bed sediments are classified as “zero-mobility” regions. Regions where either waves or tides mobilise the bed sediment are classified as “waves only” or “tides only”, respectively. Regions where both waves and tides are capable of mobilising sediment are classified as “wave-dominated”, “tide-dominated”, or “mixed”, depending on the relative amount of time for which each process is able to mobilise sediments on the seabed.

“Wave-dominated” regions are defined as those locations where the percentage of time of wave induced mobilisation is more than 3 times greater than the percentage of time of tide induced mobilisation. Similarly, “tide-dominated” regions are defined as those locations where the percentage of time of tide induced mobilisation is more than 3 times greater than the percentage of time of wave induced mobilisation. Finally, “mixed” regions are defined as those locations where the ratio of wave/tidal percentage time exceedance is between 1/3 and 3. The spatial distribution of the six categories provides a regionalisation based on the dominant energy regime within the Australian GEOMAT region.

4 Results

4.1 Data Collection and Collation

4.1.1 Existing Data and Sample Custodians

The main custodians and sources of seafloor sediment data and samples from the mid to outer continental shelf and off-shelf areas are:

- CSIRO Marine Research, as summarised in its MARLIN online database. Seafloor data has been collected through combined Royal Australian Navy (RAN)/CSIRO oceanographical cruises from 1959, fisheries studies using its own and chartered vessels, and from its role as the Marine National Facility Manager since 1985.
- the Australian Oceanographic Data Centre (AODC)
- Geoscience Australia and its predecessors – the Australian Geological Survey Organisation (AGSO) and the Bureau of Mineral Resources (BMR)
- Colorado University/Sydney University/AODC AuSEABED database, initially compiled by the Ocean Sciences Institute (OSI).
- Researchers utilising Australian Marine National Facility cruises
- The Lamont-Doherty Earth Observatory (LDEO), Columbia University, curators for samples collected by the research vessels *Vema* and *Robert Conrad*.
- The Antarctic Research Facility, Florida State University (ARFFSU), curators for samples collected by the research vessel *Eltanin*.
- The US National Geophysical Data Centre (NGDC), who provide an online searchable database of worldwide Marine and Lacustrine Geological Samples
- the EUROCORE initiative, European based and providing a searchable database identified as EU-SEASED that includes samples collected by European vessels from Australian waters
- the World Data Centre for Marine Geology and Geophysics, Gelendzhik, Russia (WDC-Russia) holding data on 1026 Russian cruises and 63,700 geological sampling stations, some collected in Antarctic and Australian waters.
- Collaborative cruises by Australian researchers with International Research Vessels
- The Deep Sea Drilling Project (DSDP, 1968-1983) and the Ocean Drilling Program (ODP, 1985-2003). These have been followed by the Integrated Ocean Drilling Program (IODP), which will commence shortly.

The CSIRO commenced its cooperation with the RAN on oceanographic research cruises in 1959. Up until the formation of the AODC in 1964, 34 cruises were completed using the HMAS *Diamantina* and HMAS *Gascoyne.* Close cooperation continued with the RAN (through the AODC) up to the late 1970's/early 1980's, through the use of the HMAS *Diamantina*, HMAS *Gascoyne* and HMAS *Kimbla*. *Gascoyne* and *Kimbla* cruise details are not currently included in CSIRO's MARLIN database, although cruise reports are generally available from the CSIRO library. The R.V. *Franklin* commenced as the Marine National Facility in 1985 and operated in this capacity until 2002. The F.R.V. *Southern Surveyor* commenced operations in about 1990 primarily as a fisheries research vessel. Sediment samples were collected in support of various fisheries research activities with this vessel, especially in the Gulf of Carpentaria and South-east Australia. In February 2003, a refurbished R.V. *Southern Surveyor* became Australia's new Maritime National Facility. It is owned and operated by CSIRO, and managed by P&O Maritime Services.

The AODC was formed in 1964 as a section of the Hydrographic Service of the Royal Australian Navy (RAN). The centre was established to improve the communication of oceanographic data within the Australian Defence Forces (AODC, 1983). It had a strong relationship with the civilian marine science community and its published Bulletins provide summaries of Australian oceanographic studies from its inception in 1964 to the early 1980's when publication of the Bulletins ceased. During this period, research cruises were often undertaken with RAN ships along similar lines to the current National Facility cruises. The AODC's involvement with the civilian marine science community changed in the early 1980's, with the advent of the Marine National Facility managed by the CSIRO, and the AODC's role in the establishment of the OSI with Sydney University. Currently, "in addition to operating as the Defence Oceanographic Data Centre, the AODC operates as the National Oceanographic Data Centre for Australia within the guidelines established by UNESCO's Intergovernmental Oceanographic Commission (IOC). In performing this role, the AODC participates in various national and international oceanographic data collection, exchange and management programs (Australian Spatial Data Directory (ASDD website).

Geoscience Australia, then the Bureau of Mineral Resources (BMR), commenced seafloor sediment sampling in the late 1960's. Since that time, it has collected many seafloor cores, grabs and dredges from over 200 cruises using a variety of vessels. The R.V. *Rig Seismic* was Geoscience Australia's main research vessel. It chartered from 1984 to 1998. Its main focus was on evaluating Australian offshore petroleum prospectivity, and it collected a large number of seafloor sediment cores in support of these programs. Seafloor grain size and carbonate contents were not determined for many of these cores, as they were not required for the projects at the time. Geoscience Australia operates a sedimentology laboratory with comprehensive facilities, which is presently operating at maximum capacity to process samples from current research activities. It also has cold storage facilities for seafloor cores and samples, together with a room temperature rock store. An audit of the cold storage area is nearing completion.

The OSI was established in 1983 as a joint initiative between the University of Sydney and the Defence Department. It no longer exists. The purpose of the arrangement was to "foster fundamental research on the physical nature of the ocean and its floor" (AODC, 1983). The HMAS *Cook* was used as a research platform for some of the OSI's project work. Funding for the OSI was also sought externally through research contracts and grants. Research results were published in either a Technical Report series (numbered 1-32) or a Report Series (numbered 1-56). The auSEABED project was a joint research programme of the OSI and the AODC and managed by Dr Chris Jenkins, who was its main developer. auSEABED is a collection of marine sediment datasets from many sources. A programme called dbSEABED then “mines” relevant information out of auSEABED and outputs tables that can be mapped with a GIS. The system offers an extensive geographic coverage. The accuracy of the output is variable, as the dbSEABED programme converts text-based visual observations to a format that is combined with the results of scientific sample analysis (AODC website). Dr Jenkins relocated to the USA during 2000/2001 and is now based at the Institute for Arctic and Alpine Research (INSTAAR) at the University of Colorado. Here, he has continued the development of his databases, adding Global Ocean Substrates (goSEABED) and usSEABED amongst others. He is continuing to maintain auSEABED from his US location. Geoscience Australia has discussed the possibility of a cooperative data sharing arrangement with Dr Jenkins, but complex issues regarding Intellectual Property rights and third party non-disclosure agreements could not be resolved within the timeframe of this project. A data sharing agreement may be possible in the future.

Researchers have been using Australian National Facility cruises to collect seafloor samples since the mid 1980’s. They are responsible for their own sample analysis schemes and sample storage. The standard of reporting to the managing group is variable, with some researchers not providing details of sample locations or descriptions in their reports. About 50 cruises spanning the period from mid 1985 to the end of 2000 have collected sediment samples as part of their research effort. Only about 30% of these have reported sample locations and general descriptions of sediments in their cruise reports submitted to the National Facility Manager.

Researchers at the Lamont-Doherty Earth Observatory (LDEO) were at the forefront of the development of deep sea coring techniques and equipment. Their work in the early 1950’s was instrumental in reducing the time taken for the seafloor sediment coring process from 8-10 hours to about 3 hours per core. The LDEO’s research vessels the R.V. *Vema* (1953-1980) and R.V. *Robert Conrad* (1962-1988) circumnavigated the globe collecting thousands of cores from the world’s oceans, including those within Australia’s marine jurisdiction. These cores are stored in LDEO’s facilities at Columbia, and made available for any legitimate research purpose, with the proviso that the results and copies of any publications resulting from the research be made available to LDEO. At about the same time, the USNS Eltanin (1962-1972) collected cores in the higher southern latitudes, also within Australian waters and Antarctica. These cores are stored at Florida State University (FSU) and are also made available to the marine research community in a similar manner to the LDEO core holdings. The AODC was closely involved in the coordination of cruise legs for these vessels in Australian waters. These seafloor sediment cores are a valuable resource that has not been fully evaluated as yet. Geoscience Australia estimates that about 400 cores are located within the Large Marine Domains, mostly collected in deep water areas off the continental shelf.

Russian cruises to the Antarctic commenced in the mid 1950’s with the icebreaker R.V. *Ob* acting as a resupply vessel for the USSR Antarctic base and a research vessel during transit. The USSR was also a key participant in the International Indian Ocean Expeditions of the 1960’s with the research vessels R.V. *Ob* and R.V. *Vityaz*. Cruise tracks for these vessels pass through Australian waters, and an unknown number of samples were collected. These vessels had laboratory facilities on board which were capable of undertaking detailed sediment analysis (Lisitzin, 1972).

Research vessels from other countries, particularly France and Germany, have carried out collaborative research in Australian waters. These cruises have offered access to expertise and facilities, such as deep sea swath mapping, which were not available on Australian research vessels. Similarly, Australia's participation in the Ocean Drilling Program (ODP) has provided the benefit of projects targeting the sedimentological history of the continental margin.

4.1.2 Data Collection Issues

Most of the organisations/individuals contacted have supported the establishment of a non-commercial National Marine Sediment Database by Geoscience Australia. However, a common response to our request for data was that there was a lack of staff and/or resources available to collect and collate the data within the timeframe required for this project. In some cases, organizations have changed their structures and disbanded their marine groups. Geoscience Australia has relied on assistance provided from some staff now working in different fields for data provision in these cases.

Marine groups within Universities and State authorities are now operating on reduced funding and are not always able to compile their sediment data on request. Financial assistance was offered to a number of institutions, but this activity could not be organised within the project data entry timeframe. Many of our earlier marine researchers were not computer literate, or computer technology was in its infancy when a number of important marine surveys were undertaken. Sample locations were often plotted directly onto maps, and results for sample analysis handwritten onto sheets. These may be the only archival records of the surveys and were often retained by the individual researchers. A 6-12 month lead time would be required to schedule this work for holiday periods when students would be available for extended time periods, and when provision can be made for supervision. Today, few institutions have the facilities or resources to deal with non-electronic datasets.

Issues have also arisen with electronic datasets that have been archived on computer systems and storage media that are now redundant. The records may still exist, but the effort and resources required for data holders to locate, read and convert them to current electronic formats for inclusion in MARS could not be addressed for this project.

Some researchers closely guard their data. It is their livelihood and they do not want to release it before they have completed their research. This was the response to Geoscience Australia's request for seafloor sediment data from the collaborative research group studying cool water carbonate development on Australia's southern and western margins. This dataset, comprising about 700 sample locations, has been collected by the group over a 10 year period using seven National Facility cruises. It covers the western edge of the South-east large marine domain, and the majority of the continental shelf in the South-west and

Western-central Marine Domains. The group has published a number of papers summarising the main outcomes of their research. Results presented indicate that the majority of their samples may not have been analysed for grain size. Published grain size summaries from one paper (James *et al*., 1999) covering the majority of the continental shelf in the Western-central Marine Domain have been included in Geoscience Australia's maps showing grain size properties, and incorporated into the GEOMAT model in order to extend its coverage. This data has not been incorporated into MARS as the locations and values for the original data points were not available.

A common outcome symptomatic of project-based work is the lack of continued organisational ownership and archiving of the basic data used to create the final reports. This effect is also mirrored in the preparation of research theses, and in the retirement of key marine researchers, where the results of many years of work are summarised in reports and publications, but the underlying datasets are not systematically recorded or retained. There are examples where efforts have been made to preserve and archive historical documents while the data is extracted and transferred to electronic format. One example is that of the work of Dr Peter Roy, formerly of the NSW Geological Survey and Sydney University. His work on marine geology is currently retained in two rooms at Sydney University. On the other extreme, our enquiries indicate that most of the basic data collected by marine researchers at the Queensland Geological Survey is not readily available as staff have been reassigned or left the organisation after the closure of their marine group and the basic data may have been lost.

4.1.3 National Security Issues

National security issues were raised in talks with Defence personnel. The main issues relate to the density of sediment data points in areas of strategic military interest, including approaches to shipping ports. A general guide to acceptable data densities could be obtained from the distribution of 'descriptions of the bottom' points shown on Hydrographic Office bathymetry charts. These densities vary according to map scale. A sample distribution not less than about 250 m apart in sensitive areas was given as a guide. This density is unlikely to be achieved by MARS for the continental shelf and deeper waters.

The process of having a database accepted as a National Fundamental Dataset, and subject to the Australian Government Policy on Spatial Data Access and Pricing, includes a referral by the Office of Spatial Data Management (OSDM) to the Defence Imagery and Geospatial Organisation (DIGO) for national security clearance. They will advise on any access restrictions that may be required.

4.1.4 Data Access Agreements and Copyright Issues

During the course of our collection and collation of data from external (non-Geoscience Australia) sources, we have had to address the Intellectual Property (IP) rights of the data owners. Geoscience Australia has drafted an agreement to cover these issues, but uptake and acceptance have been slow.

One Agreement has been executed. This is with the Northern Territory Government, who have not restricted third party access to the dataset, but stipulated that no commercial benefit can be derived from the data without their consent and approval. This clause restricts this dataset being made freely available through a website.

Organisations have been willing to provide datasets for research purposes, but not immediately address the issue of web access to their data. Geoscience Australia accordingly has had to safeguard most datasets until agreements have been finalised. It has been necessary for Geoscience Australia to provide such safeguards in order for the data owners to release their datasets for this project, and in a few important cases we could not provide sufficient assurances for some researchers to release their data for the bioregionalisation work and incorporation in MARS. This was the case for the group researching cool water carbonate provinces in the Great Australian Bight and Central/South Western Australia. While they were supportive of the database and for their data to be lodged with it, they were not prepared for this to occur prior to completion of their research.

4.2 Data Types and Coverage

4.2.1 Data Types

Seafloor sediment data types fall into two broad categories - descriptive (qualitative) and numeric (quantitative). The degree to which samples are examined and reported is governed by the method used to collect them, the technology of the day, the purpose of collection and the areal coverage required.

Samples for qualitative datasets are the easiest to collect and compile. Examples of these are the Royal Australian Navy (RAN) Hydrographic Office bathymetry charts, where ‘descriptions of the bottom’ are noted. There are tens of thousands of these descriptions for Australian waters. Qualitative data is a valuable resource due to its geographical coverage. Studies have been undertaken to demonstrate the value of qualitative data in compilation of sediment type charts (Hamilton, 1999). Geoscience Australia determined that the process and validity of assigning quantitative values to qualitative data could not be assessed and achieved within the timeframe of this project, and would be of limited value for GEOMAT modelling input. Its efforts therefore have been concentrated on compiling information on quantitative sediment data, as well as identifying samples that have already been collected and may still be available for grain size analysis in the future.

The resulting quantitative dataset has allowed Geoscience Australia to examine and report with detail and confidence on seafloor sediment texture over much of the continental shelf.

4.2.2 Quantitative Data Coverage – a National Overview

The method used for assessing quantitative data coverage in this report has been to initially categorise the sample location as being either on or off the continental shelf, followed by grouping according to sample separation distance. The definition of continental shelf used in this case is the geomorphic continental shelf (Harris *et al*., 2004). The separation categories used were:

- Less than 25 km apart
- Less than 50 km apart
- Less than 100 km apart

At a coarsest scale, ie a spacing of less than 100 km between samples, there are sufficient data points to allow some interpolation between samples at the scale of a marine domain. A better resolution is obtained where the distance between samples is less than 25 km. At this sample density, it is possible to create meaningful interpolation for an individual marine domain or over the entire Australian marine region.

National coverage for samples with quantitative grain size data is shown on Figure 4.1 and summarised in Table 4.1. Most samples are located on the continental shelf. At the coarsest sample spacing (sample points <100 km apart) 77% of the total shelf area can be mapped. Off the shelf, at the coarsest sample spacing, only 14% of the area can be mapped. There are large areas containing no quantitative data.

Table 4.1. Data coverage summary for seabed samples where grainsize has been measured. Detailed Domain statistics are provided in Appendix 5A.

	Coverage for Grain Size Data Samples					
	<25 km apart		**<50 km apart**		**<100 km apart**	
	km2	**%**	**km2**	**%**	**km2**	**%**
On Shelf	764,912	39%	1,218,228	62%	1,513,821	77%
Off Shelf	151,257	3%	310,949	7%	620,294	14%
TOTAL	**916,169**	**14%**	**1,529,286**	**24%**	**2,134,115**	**33%**

National coverage for samples with carbonate data is shown on Figure 4.2 and summarised in Table 4.2. Most samples are again located on the continental shelf. At the coarsest sample spacing (<100 km apart) 62% of the shelf area can be mapped. Off the shelf, at the coarsest sample spacing, only 14% of the area is covered. There are also large areas containing no data.

Table 4.2. Data coverage summary for seabed samples where carbonate content has been measured. Detailed Domain statistics are provided in Appendix 5B.

	Coverage for Carbonate Data Samples					
	<25 km apart		**<50 km apart**		**<100 km apart**	
	km2	**%**	**km2**	**%**	**km2**	**%**
On Shelf	614,857	31	948,135	48	1,215,704	62
Off Shelf	151,604	3	307,590	7	622,560	14
TOTAL	**766,461**	**12**	**1,255,725**	**19**	**1,838,264**	**29**

4.3 Sediment Maps

In the following sections, sediments have been described in relation to geomorphic features, in particular the major geomorphic units of continental shelf, slope and abyssal plain. These terms are based on definitions in Harris *et al.* (in press) and are defined in the Glossary, in addition to other geomorphic terms used in this report.

4.3.1 Northern Planning Area

The Northern Planning Area (Fig. 4.3) extends from west of the Goulburn Islands in Arnhem Land to include the Torres Strait area in the east and covers an area of approximately 572,000 km^2. The continental shelf here is largely continuous between Australia and Papua New Guinea and covers an area of 551,000 km^2 representing 96% of the total area. A small area of continental slope (4% or 21,000 km^2 of the whole Northern Planning Area) is present to the northwest of the Arafura Shelf.

Sample density

Sample density for grain size data is variable across the region (Fig. 4.1), reflecting the sampling intensity of the different studies carried out. At the coarsest scale (sample spacing <100 km), 99% of the total area of this area can be mapped. At the finer scale (sample spacing <25 km), only 40% of the total area can be mapped. This equates to 41% of the continental shelf and 7% of the continental slope being covered by quantitative data.

The density of grain size samples is greater on the outer Arafura Shelf, in the south-western area of the Gulf and along a band extending across the southern and eastern margins, and across most of Torres Strait. The central and northern areas of the Gulf, extending onto the Arafura Shelf, have a more variable sample coverage. Gaps in the data occur on the inner Arafura Shelf and along the southern margin of the Gulf of Carpentaria.

Sample density for measured carbonate data is much more restricted (Fig. 4.2). At the coarsest scale (<100 km spacing) 47% of the total area can be mapped. At the finer scale (sample spacing <25 km), only 20% of the total area can be mapped. This equates to 20% of the continental shelf and 3% of the slope being covered by quantitative data. While sample coverage on the Arafura Shelf and Torres Strait is similar to that for grain size data, the coverage in the Gulf of Carpentaria is much reduced. Here, samples with carbonate data are restricted to a band along the eastern margin and a single point in the north. This is due to sediment samples collected in the western Gulf not having been analysed for carbonate content.

Measured Gravel Content

Gravel content across the Arafura Shelf (Fig. 4.4) is generally 1-20%, with a large area to the north of zero gravel. Gravel content is similarly 1-20% over much of the Gulf of Carpentaria. Large regions of zero gravel occur along the eastern margin, from Weipa southwards and through the central west of the Gulf. In the southern and western Gulf, sediments with gravel content of 20-40% are associated with islands and reefs. In central Torres Strait, gravel content is 1-20%. To the north and south, patches of 20-40% increase locally to 40-60%. There are no areas of zero gravel content in Torres Strait.

Measured Sand Content

Sand content on the Arafura Shelf is variable (Fig. 4.5). In the central and north-western areas it is 1-20% and 20-40%, respectively. In the southwest, along the

Arafura Sill and to the north-west, sand content ranges from 40% up to 80-100%. In the western half of the Gulf of Carpentaria, from Groote Eylandt to the northern margin, sand content is 1-20% or 20-40%. Sand content increases in a broad arc extending south from Groote Eylandt across the south and east. Here sand content is typically 40-80% increasing to 80-100%, particularly along the eastern margin.

Measured Mud Content
Mud content over this region (Fig. 4.6) is essentially the reverse of sand content. Over the north-west Arafura Shelf, mud content is between 60-80% and 80-100%. In the central part of the shelf, mud content is between 20-40% and 40-60%. In the lowest southwest content is 20-40%; while over the Arafura Sill and to the north-west of the Sill, mud content is 1-20% to 20-40%.

In the western half of the Gulf of Carpentaria, mud content ranges from 40-60% to 80-100%. Sediments with mud content of 1-20% to 20-40% form an arc extending from the south-western corner along the southern margin and across the eastern half of the Gulf. Distinct localised areas of 40-60% occur adjacent to many of the rivers along the eastern margin. On the western side of Torres Strait, mud content is generally 1-20%, while in the east it is generally 20-40%, with localised increases to 40-60%.

Measured Mean Grain Size
The map of measured mean grain size (Fig. 4.7) shows that with the exception of the south-western part of the Arafura Shelf and the Arafura Sill, mean grain sizes are predominantly medium to very coarse silt. In the southwest, the mean grain size is very fine to fine sand. Over the central Arafura Sill, the means are in the coarse sand range. Away from the central sill and to the northwest, grain size ranges from fine to medium sands.

The central western portion of the Gulf of Carpentaria is dominated by mean grain sizes of coarse to very coarse silt, as is much of the area to the east of the Arafura Sill. Elsewhere the Gulf is dominated by mean grain size in the sand range. Sediments in the centre range from very fine to fine sand, with some patches of medium sand. Around the periphery there are large areas of medium to coarse sand interspersed with fine to medium sand.

In Torres Strait, sediment mean grain sizes are dominated by sands. On the western side of the Strait, these are medium to coarse sand, while to the east they are fine to medium.

Folk Classification
The Arafura Shelf is covered in sandy mud and mud over the northern portion, with gravelly muddy sands on the northern periphery (Fig. 4.8). On the central portion of the shelf, extending east to the Arafura Sill, there is a mix of gravelly mud, sandy mud and slightly gravelly sandy mud. In the southwest, slightly gravelly muddy sand dominates. Sediments over the Arafura Sill mainly comprise gravelly sand, slightly muddy gravelly sand or gravelly muddy sand. The Sill is flanked to the east and the northeast by sandy mud and muddy sand.

The Gulf of Carpentaria shows distinct differences west to east. The western half is a mix of slightly gravelly sandy mud and sandy mud interspersed with gravelly muddy sand and gravelly sand. Localised mud, muddy sand and slightly gravelly mud are also present. South of Groote Eylandt, the sediments consist predominantly of slightly gravelly muddy sand, slightly gravelly sandy mud, slightly gravelly sand and gravelly muddy sand. Minor slightly gravelly sand, muddy sandy gravel, muddy gravel and mud are also present.

The eastern half of the Gulf is dominated by gravelly muddy sand, gravelly mud and slightly gravelly muddy sand. Muddy and sandy gravels are localised in the north and adjacent to Mornington Island. From Mornington Island there is a wide arcuate band of finer-grained sediments, extending along the eastern margin to approximately 13°30' S. This band comprises muddy sand, sandy mud, sand and minor mud.

The western side of Torres Strait is dominated by gravelly sand with localised muddy and sandy gravel. On the eastern side, gravelly muddy sand is more important, with gravelly sand and slightly gravelly muddy sand also important. To the north-east, the latter becomes more abundant. Sandy and muddy gravel, and slightly gravelly sand are locally abundant in the east, adjacent to reefs and islands.

Measured Carbonate Content
A band of carbonate content of 20-40% extends north-east across the Arafura shelf from the west (Fig. 4.9). The remaining shelf sediments typically contain 40-60% carbonate except for the northeast, which contains 60-80%. Along the eastern margin of the Gulf of Carpentaria, carbonate content is 20-40% or 40-60%. Patches with 1-20% carbonate occur to the south of Mornington Island and offshore of some river mouths along the south and eastern coastline. A band of sediment with carbonate content of 40-60% to 60-80% extends west and north of Mornington Island. To the north, close to Torres Strait, carbonate content increases to 80-100%. With the exception of minor patches in the northeast, carbonate content throughout Torres Strait is 80-100%.

4.3.2 North-east Marine Domain
The North-east Marine Domain extends from Cape York to south of Gladstone on the Queensland coast (Fig. 4.10) and covers an area of approximately 1,236,000 km^2. Continental shelf comprises some 223,000 km^2 or 18% of the total area.

Sample Density
Sample density of grain size data in the North-east Marine Domain is shown in Figure 4.1. At the coarsest scale (sample spacing <100 km), 26% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), only 13% of the total area can be mapped. This equates to 63% of the continental shelf and 2% of the deeper-water areas being covered by quantitative data. The only samples from the slope occur at the southern end of the region.

Sample density for grain size data is generally greater along the inner half of the shelf, particularly in the north and south. The lowest sample density occurs on the shelf in the region of the southern Great Barrier Reef (GBR), approximately from Townsville south to Yeppoon. Here the bulk of samples have been collected along widely-spaced transect lines. Minor data gaps are present in-shore on the shelf. Samples are rare in the slope, rise and abyssal plain regions.

The distribution of samples for which measured carbonate content data are available is more limited (Fig. 4.2). At the coarsest scale (sample spacing <100 km), 26% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), only 14% of the total area can be mapped. This equates to 64% of the continental shelf and 3% of the deeper-water areas being covered by quantitative data. With the exception of a few sample points in the north and the southern part of the region, the bulk of carbonate data has been derived from Maxwell (1968). This dataset predominantly covers the continental shelf of the GBR region, extending onto the upper slope in the south. A large data gap is present in the north, off Cape York Peninsula. In the south, sample density is greater on the continental shelf, but reduced on the upper slope.

Measured Gravel Content

The gravel content of sediments along most of the continental shelf in the South-east Domain is 1-20% (Fig. 4.11). A wide band in the north, offshore Cape York Peninsula contains 60-80% gravel. Within the GBR there are rare areas of 20-40%. A band extending north-east from Bowen and south along the outer shelf contains 20-40% to 40-60% gravel. Adjacent to Broad Sound and Shoalwater Bay gravel content is mainly 20-40%. Large areas with zero gravel content occur on the outer continental shelf and upper slope east of Gladstone.

Measured Sand Content

East of Cape York Peninsula the sand content of sediments ranges from 40-60% to 60-80% and increases on the outer shelf to 80-100% (Fig. 4.12). On the outer shelf and upper slope, from Shelburne Bay to Cape Direction, sand content ranges from 20-40% to 40-60%. Similar concentrations extend across the shelf from Cape Direction to Princess Charlotte Bay. On the shelf from Princess Charlotte Bay to Townsville sand content is 40-60% to 60-80%.

From Townsville to Shoalwater Bay, sand content on the central and, in places, the outer shelf increases to 80-100% including on the inner and mid shelf offshore Mackay and on the outer shelf north-east of Shoalwater Bay. South of Shoalwater Bay, sand content is 80-100% across the entire shelf. On the slope, in the region of the Capricorn Channel, sand content grades from 60-80% down to 20-40%. The exception to this occurs in samples along a transect running east off Shoalwater Bay. Sand concentrations along this transect increase from 40-60% to 80-100%.

Measured Mud Content

Mud content along much of the North-east Domain ranges from 20-40% to 40-60% on the inner shelf and 1-20% on the outer shelf (Fig. 4.13). Areas of the inner shelf with concentrations of 60-80% occur in Princes Charlotte Bay, north of Cairns, south of Bowen and adjacent to the southern Whitsunday Islands. South of the Whitsunday Islands, a band containing 20-40% mud extends southeast along the mid-shelf. Areas with zero mud content occur south of Shoalwater Bay extending across the shelf to the southern margin of the South-east Domain. Sediments in the Capricorn Channel typically contain 40-60% to 60-80% mud. South of the Channel samples contain zero mud.

Measured Mean Grain Size
Between Cape York Peninsula and Cape Direction on the outer shelf and upper slope, mean grain sizes are in the coarse sand range (Fig. 4.14). Two lobes of coarse sand occur northeast and southeast of Cape Melville. Otherwise sediments on the shelf from Cape York south to Hinchinbrook Island have a mean grain size of fine sand. From Townsville to the Whitsunday Islands, mean grain sizes are fine to medium sands, with the coarser sediments located mid-shelf.

From the Whitsunday Islands to Shoalwater Bay, both inshore and on the outer shelf mean grain sizes are coarse sand, coarsening locally to gravels. On the mid shelf and in the Capricorn Channel sediments are very fine to fine sands. South of Shoalwater Bay, coarse sands dominate the shelf. On the slope, means range from fine sands to very coarse silts, except for coarse to very coarse sands north-east of the Capricorn Channel.

Folk Classification
South of Cape York to Mackay, inner shelf sediments typically comprise slightly gravelly sandy mud and slightly gravelly mud intermixed with gravelly muddy sand and minor gravelly sand (Fig. 4.15). Gravelly mud is present locally as large patches on the inner and mid shelf. The outer shelf is typically characterised by a mix of gravelly sand and slightly gravelly sand with some areas of gravel and muddy gravel.

From Mackay to Shoalwater Bay, inner shelf sediments consist of slightly gravelly sand, sandy gravel and gravelly sand. Mid shelf sediments are dominated by slightly gravelly muddy sand, gravelly muddy sand and slightly gravelly muddy sand. Outer shelf sediments comprise a mix of gravelly sand, slightly gravelly muddy sand and muddy gravel. South of Shoalwater Bay the shelf is dominated by gravelly sand and slightly gravelly sand with minor sand and sandy gravel. On the slope in the area of the Capricorn Channel sandy mud, mud and muddy sand dominate, except for the deeper slope where slightly gravelly sand, gravel and sandy gravel are present.

Measured Carbonate Content
Along northern Cape York Peninsula, carbonate content on the inner shelf is 1-20% but increases offshore from 40-60% to 60-80% (Fig. 4.16). A similar pattern occurs from Princess Charlotte Bay to Shoalwater Bay. Concentrations in this region are typically 60-80% or 80-100%. Inshore concentrations are 20-40% or locally 1-20%. From Shoalwater Bay south, the shelf is characterised by concentrations of 20-40% to 40-60%. Sediments of the mid and outer shelf have carbonate concentrations of 80-100%, except for an area of 60-80% mid shelf offshore of Gladstone.

4.3.3 Eastern-central Marine Domain

The Eastern-central Marine Domain extends from north of Fraser Island, Queensland to Bermagui on the south coast of New South Wales (Fig. 4.17). The area included in this region covers 653,000 km^2, of which 60,000 km^2 or 9% is continental shelf.

Sample Density

The density of samples for grain size data in the Eastern-central Marine Domain is shown in Figure 4.1. At the coarsest scale (sample spacing <100 km), 23% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), only 11% of the total area can be mapped. This equates to 88% of the continental shelf and only 4% of the deeper-water areas being covered by quantitative data. Sample density runs parallel to the coastline, with the highest density adjacent to the coast and lowest on the outer shelf and upper slope. There are no significant gaps in data coverage on the shelf. In contrast, the slope has a minimal coverage, and the rise and abyssal plain are effectively unsampled.

Sample densities for measured carbonate content data are essentially the same as for grain size data, with the majority of samples in the region having been analysed for carbonate content (Fig. 4.2).

Measured Gravel Content

Gravel content in the sediments of the slope is generally 1-20% (Fig. 4.11). Offshore of Port Macquarie sediments contain 40-60% gravel. On the outer shelf offshore Fraser Island gravel concentrations are 20-40%, increasing to 40-60% to the south. Offshore Port Macquarie gravel concentrations are 20-40% to 40-60%. Other scattered small patches of increased gravel content occur along the southern Queensland and northern NSW shelf.

Areas with zero gravel include the inner shelf and adjacent to the islands of North and South Stradbroke and Morton Bay Island; the southern half of Fraser Island and inner to mid-slope and outer shelf near Sydney.

Measured Sand Content

Sand content over much of the shelf is 80-100% (Fig. 4.12). On the outer shelf from north-east of Fraser Island to the north-east of Stradbroke Islands sand content is 60-80%. On the outer shelf and upper slope of northern NSW, there are pockets of 60-80% sand content.

From Port Macquarie to Newcastle, sand content on the shelf ranges from 1-20% to 40-60%, and is lowest in the north. On the upper slope off Sydney, sand content is 60-80% in contrast to the adjacent shelf, where values are 80-100%. South of Sydney along the south coast of NSW, sand content ranges from 60-80% to 80-100%, with sand content of 20-40% to 40-60% near-shore.

Measured Mud Content

The mud content of sediments in the Eastern-central Marine Domain is typically 1-20% (Fig. 4.13). From north of Fraser Island to the Solitary Islands there are large areas of zero mud content over much of the inner and mid shelf. A large band of zero mud content extends across the shelf south of Southwest Rocks. From Port Macquarie south, the band is restricted to the mid to outer shelf and gradually narrows to a band on the outer shelf only. Two additional bands of zero mud extend across the shelf south of Jervis Bay and south from Bermagui. Slope sediments off Yamba and Sydney have mud content of 20-40%, increasing to 60-80% off Yamba.

Measured Mean Grain Size.
Mean grain size of sediments on the continental shelf is predominantly medium sand (Fig. 4.14). On the outer shelf and upper slope southeast of Fraser Island coarse sands grade locally to very coarse sand and gravel on the upper slope. Coarse sands also occur north-east of North Stradbroke Island and in scattered patches on the mid to outer shelf in northern NSW, particularly between Southwest Rocks and Ballina; south and north-east of Jervis Bay and offshore Bermagui. Sediments with fine sand mean grain size are limited on the shelf adjacent to Newcastle, but are present on the slope offshore Sydney.

Folk classification
Sediments on the shelf to the north of Fraser Island comprise sand, slightly gravelly sand and gravelly sand (Fig. 4.15). From Fraser Island to Sugarloaf Point there is a similar mix of sediment types. However, sand is more dominant, especially in the region north of Moreton Island to the NSW/Queensland border. Sediments on the outer shelf and upper slope are similar, but large areas of coarser sediments are present. These are typically gravels, sandy gravel or slightly gravelly sandy mud. Areas of fine-grained sediments are also present on the slope. These include mud, slightly gravelly muddy sand or muddy sand. From Sugarloaf Point south, inner shelf sediments typically include areas of slightly gravelly muddy sand. Outer shelf sediments are dominated by slightly gravelly sand and gravelly sand with less common sand and muddy sandy gravel.

Measured Carbonate Content
North of Fraser Island, carbonate content is 1-20% increasing to 20-40% on the outer shelf and upper slope (Fig. 4.16). South of Fraser Island, inner to mid slope concentrations are 1-20% to 20-40%, while on the outer shelf and upper slope concentrations increase from 40-60% to 60-80% or 80-100%. Along the NSW coast, concentrations are typically 40-60% or 60-80%. Concentrations of 1-20% are restricted to the inner shelf in the area from Sugarloaf Point to Sydney.

4.3.4 South-east Marine Domain
The South-east Marine Domain extends from Bermagui on the south coast of New South Wales to the Fleurieu Peninsula in South Australia and covers a total area of 1,194,000 km^2. A total of 18% or 219,000 km^2 of the area is continental shelf, including Bass Strait and the continental margins adjacent to Tasmania (Fig. 4.18).

Sample Density
Sample density for grain size data in the South-east Marine Domain is shown in Fig. 4.1. At the coarsest scale (sample spacing <100 km) 33% of the total area is able to be mapped. At the finer scale (sample spacing <25 km), only 12% of the total area can be mapped. This equates to 88% of the continental shelf and only 3% of the deeper-water areas being covered by quantitative data.

The highest concentration of grain size samples occurs along the margins of NSW, Victoria and Tasmania and through much of Bass Strait. Sample density is lower in central Bass Strait. Samples are concentrated on the continental shelf, with the exception of the South Australian shelf where samples are sparse. Sampling of the continental slope is restricted to a few transects offshore South Australia and western Tasmania. Two of these transects provide a small number of samples from the abyssal plain.

The density of samples which have measured carbonate content data (Fig. 4.2) is essentially the same as the density of grain size samples.

Measured Gravel Content

Along the southern NSW and Victorian coasts as far as Mornington Peninsula, gravel content is generally 1-20% and 20-40% offshore southern NSW (Fig. 4.11). Along the Victorian coast, there are patches of sediment with zero gravel content. A larger region of zero gravel occurs adjacent to the Bass Canyon.

West of Mornington Peninsula on the inner shelf, sediments generally contain zero gravel. Further offshore the gravel content is 1-20%. Samples from the South Australian coast range from 1-20% to 20-40% gravel content.

Measured Sand Content

Sand content (Fig. 4.12) along the southern NSW and Victorian coastlines is 80-100%. Sand content is also 80-100% across the north-west of Bass Strait south-west of King Island and to the east of the Bassian Rise. Sand content decreases from 60-80% to 20-40% through the centre of Bass Strait, with the lowest concentrations located to the south. Sand content around the eastern, southern and western margins of Tasmania is more variable, ranging from 60-80% to 80-100%.

Sand content in slope sediments is generally lower than on the shelf. Sand content ranges from 20-40% and 40-60% off Victoria and eastern and southern Tasmania. Off western Tasmania and South Australia, sand content is between 1-20% and 40-60%. Exceptions are samples from east of Cape Howe (80-100%) and south-west of Tasmania (60-80 and 80-100%).

Measured Mud Content

Over much of the continental shelf of southern NSW and around Tasmania, the mud content of sediments (Fig. 4.13) is 1-20%. In Bass Strait concentrations in the northern area and to the west of the Bassian Rise are 1-20%. Mud content is higher in the southern central area from 20-40% through to 60-80%. In the western Bass Strait and over the Bassian Rise sediments have zero mud content. Areas of zero mud content also occur on the NSW coast, along the Victorian coastline west of Port Phillip Bay and south-west of Tasmania.

On the continental slope mud content increases with water depth from 20-40% to 60-80% offshore eastern Victoria and east and south of Tasmania. Areas of zero mud are present east of Cape Howe and off south-west Tasmania. Further west, transects off western Tasmania, western Bass Strait and South Australia show a rapid increase in mud content from 40-60% to 80-100% with water depth.

Measured Mean Grain Size
Mean grain sizes on the shelf along the southern NSW and Victorian coastlines are typically medium sands (Fig. 4.14). Around the eastern, southern and western margins of Tasmania, sediments range from medium to coarse sand. Within Bass Strait there is a central band of very fine to fine sand. In the south this band encloses a central area of coarse to very coarse silt. To the east and west of this central region mean grain sizes are medium to coarse sands, as are sediments on the South Australian shelf. Sediments on the slope typically grade with water depth from very fine sands to clays. Exceptions are off Cape Howe, where medium sands occur at depth and off south-west Tasmania where medium to coarse sands occur at depth.

Folk Classification
Shelf sediments through much of the southeast region comprise a mix of slightly gravelly sand, gravelly sand with muddy sandy gravel (Fig. 4.15). Sand is common on the inner shelf, especially along the Victorian coastline and around King and Furneaux Islands in Bass Strait. Patches of gravel and sandy gravel occur along the western Tasmanian margin and south-east of King Island. In central Bass Strait, sediments are dominated by slightly gravelly sandy mud, slightly gravelly muddy sand and gravelly mud. On the South Australian shelf sediments are coarser and include sandy gravel, gravelly sand and slightly gravelly sand.

Sediments on the slope typically comprise sandy mud, muddy sand, slightly gravelly muddy sand and mud. Exceptions to this include east of Cape Howe (slightly gravelly sand and gravelly sand), adjacent to Bass Canyon (predominantly slightly gravelly muddy sand) and off south-west Tasmania (slightly gravelly sand, gravelly sand and sandy gravel).

Measured Carbonate Content
Carbonate content across the Victorian and Tasmanian shelf, including Bass Strait, is 60-80% to 80-100% (Fig. 4.16). Exceptions to this occur on the eastern Victorian coastline, east of King, Flinders and Cape Barren Islands, where carbonate concentrations are 40-60%, and in the main embayments along the Tasmanian margin, including Macquarie Harbour, where concentrations range from 1-20% to 20-40%.

Along the South Australian shelf, carbonate content is 40-60% to 60-80%. Carbonate concentrations on the slope range from 60-80% to 80-100%. Off western Bass Strait concentrations for the deepest sites are 1-20% to 20-40%. Carbonate in sediments from the slope in South Australia varies from 40-60% to 60-80%.

4.3.5 South-west Marine Domain

The South-west Marine Domain extends from Kangaroo Island in South Australia, across the Great Australian Bight (GAB) to Perth, Western Australia (Fig. 4.19). It covers an area of 1,054,000 km^2 of which 307,000 km^2 or 29% is continental shelf.

Sample Density

Sample density of grain size data in the South-west Marine Domain is shown in Figure 4.1. At the coarsest scale (sample spacing <100 km), only 6% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), only 0.3% of the total area can be mapped. This equates to 0.41% of the continental shelf and 0.3% of the deeper-water areas being covered by quantitative data. Samples with quantitative data occur only in a small area of the central GAB (transect and single point to the west) and west of Kangaroo Island (single point). The whole region represents a significant gap in the sediment dataset.

Data density for samples with measured carbonate content is lower than the grain size data density (Fig. 4.2), as less than half the samples have been analysed. At the coarsest scale (sample spacing <100 km), only 5% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), only 0.1% of the total area can be mapped. This equates to 0.011% of the continental shelf and 0.1% of the deeper-water areas being covered by quantitative data.

Measured Gravel Content

The gravel content of samples from the continental shelf in the GAB is 1-20% (Fig. 4.11). Gravel content from the sample adjacent to Kangaroo Island is 40-60%. Samples from the continental slope all contain zero gravel.

Measured Sand Content

Sand content of sediments on the continental shelf in the GAB is 80-100%, decreasing to 60-80% on the outer shelf. In the sample west of Kangaroo Island, sand content is 40-60% (Fig. 4.12). Sand content in sediments on the slope is 20-40%, with only 1-20% sand present in the deepest sample.

Measured Mud Content

Mud content of sediments on the inner to mid-shelf is zero (Fig. 4.13). Sediments on the outer shelf contain 1-20% mud. On the upper slope, mud content grades rapidly from 20-40% to 60-80%. Mud content of the deepest sample is 80-100%.

Measured Mean Grain Size

Shelf sediments in the one transect of the GAB are medium sands (Fig. 4.14). Coarse sand occurs west of Kangaroo Island. On the slope, mean grain size ranges from very fine sand to very coarse silt.

Folk Classification

Shelf sediments in the one transect of the GAB consist of gravelly sand with slightly gravelly muddy sand and very minor gravelly muddy sand (Fig. 4.15). West of Kangaroo Island, the sediment is sandy gravel. On the continental slope, sediments are primarily sandy mud, with mud at the deepest site.

Measured Carbonate Content

Sediments in the South-west Marine Domain contain 80-100% carbonate (Fig. 4.16) except in one site on the inner shelf of the GAB, where carbonate concentration is 60-80%.

4.3.6 Western-central Marine Domain

The Western-central Marine Domain extends along the Western Australian margin from Perth in the south to North West Cape in the north (Fig. 4.20), and covers an area of approximately 547,000 km^2. The continental shelf covers 12% or some 63,000 km^2 of the total area.

Sample Density

Density of grain size data in the Western-central Marine Domain is shown in Figure 4.1. At the coarsest scale (sample spacing <100 km) 1% of the total area of this domain can be mapped (Fig. 4.1). At the finer scale (sample spacing <25 km), only 0.11% of the total area can be mapped. This equates to 1% of the continental shelf and 0.02% of the deeper-water areas being covered by quantitative data. Sample points are limited to a small area on the shelf south of North West Cape. The whole region represents a significant gap in the dataset.

Maps of grain size for the region have been supplemented by mapped grain size data from James *et al*. (1999). This has allowed the maps of sediment properties to be extended from North West Cape south to Perth. The data from this region cover the shelf and a portion of the upper slope. Detailed data from within Shark Bay are also included.

A different set of samples is available for measured carbonate content (Fig. 4.2). These samples are from Shark Bay and a small area of continental shelf to the south. Samples are concentrated within Shark Bay, with few on the adjacent shelf. At the coarsest scale (sample spacing <100 km), 6% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), 2.3% of the total area can be mapped. This equates to 20% of the continental shelf and only 0.03% of the deeper-water areas being covered by quantitative data.

Measured Gravel Content

Variations in gravel content in the Western-central Domain form a pattern of bands parallel to the coastline (Fig. 4.11). In the south, a band of 20-40% gravel runs offshore from Perth to Dongara. A second, narrower band with 40-60% gravel, running further offshore, intersects the Houtman Abrolhos islands. Gravel content around the reefs increases to 60-80% and locally to 80-100%. Outside of this band, on the outer shelf and upper slope, there is a narrow band of 20-40% gravel. A band of zero gravel is present to the west along the whole area. Adjacent to and north of Shark Bay, there is a wide band of sediments with 1-20% gravel over the shelf and upper slope. West of these sediments, the band of zero gravel is present, continuous with sediments further to the south. Sediments in the region of Ningaloo Reef and to the south of the reef contain 60-80% gravel.

Measured Sand Content

From Perth to south of North West Cape, the patterns of sand content along the central west margin form bands largely parallel to the margin (Fig. 4.12). On the shelf sand content is 40-60%, decreasing to 20-40% on the outer shelf and upper slope. Around the reefs of the Houtman Abrolhos, sediments contain no sand, but outside these islands sand content increases 20-40% in a narrow band.

North of the Houtman Abrolhos a narrow band of sediments with 60-80% sand runs close to the coast. In this area and further north, adjacent to Shark Bay, arcuate bands with 40-60% and 60-80% sand extend onto the outer slope and upper shelf. Sediments in the region of Ningaloo Reef vary from the regional pattern. A very narrow band with zero sand occurs close to the shore, south of the Reef. A band of 60-80% sand content runs southwards parallel to the shore. To the north-west of Ningaloo Reef sediments contain 80-100% sand.

Measured Mud Content
A band of sediment with zero mud content parallels the margin (Fig. 4.13). South of Shark Bay, this band extends over the shelf onto the upper slope. Near Shark Bay it narrows considerably, widening again to the north. From the Houtman Abrolhos south, this band is flanked on the slope by a narrow band of sediments with 60-80% mud content.

North of the Houtman Abrolhos a wide band of sediments with 0-20% mud content extends over the outer shelf and slope. Adjacent to Shark Bay, sinuous bands of sediments with 20-40% and 60-80% mud occur. These are flanked on the outer shelf and upper slope by sediments containing 1-20% and by the band of sediments with 60-80% mud which extends from the south.

Measured Mean Grain Size
Mean grain size distributions form a pattern of bands generally running parallel to the coastline (Fig. 4.14). North of Perth the shelf is covered by coarse sands. This band runs along the inner shelf as far as Dongarra on the coast where it tapers to the north-west, widening out across the shelf north of the Houtman Abrolhos. On the outer shelf and upper slope, a double band of gravels runs north from Perth intersecting the Houtman Abrolhos and extending to the base of Shark Bay**.** On the inner shelf north of Dongarra, mean grain size is medium sand. This band also extends north as far Ningaloo Reef. Seaward of the gravels, a band of very coarse silt extends along the slope as far north as Ningaloo Reef.

From Kalbarri north the shelf is covered by a band of very fine sand that runs between the bands of gravels and silt and extends north to Ningaloo Reef. This band is intersected in the south by a sinuous band of coarse sand. West of Ningaloo Reef, sediments have a mean grain size of coarse sand. From Ningaloo Reef south along the coastline there is a thin band of clays. In Shark Bay, mean grain sizes grade from medium sand within the main bays to very coarse sand in the north.

Folk Classification
Very few data points are available in this region area for the Folk sediment classification; only points in the region of Ningaloo Reef have been considered (Fig. 4.15). Sediments inshore adjacent to and south of Ningaloo Reef consist of slightly gravelly sand; gravelly sand is present to the west and north-west of the Reef.

Measured Carbonate Content
This data set covers the larger Shark Bay area and several points off North West Cape (Fig. 4.16). Carbonate content of sample points off North West Cape ranges

from 60-80 and 80-100%. Carbonate content within the southern section of Shark Bay is 60-80%. Further north, around Cape Peron North, concentrations are 1-20%, increasing to 40-60% in a band extending north along the mainland coastline.

4.3.7 North-west Marine Domain

The North-west Marine Domain extends along the north-west margin of the continent, from North West Cape in Western Australia to Cape Londonderry in the Northern Territory (Fig. 4.21).

Sample Density

Sample density for grain size data in the North-west Marine Domain is shown in Figure 4.1. At the coarsest scale (sample spacing <100 km), 43% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), 18% of the total area can be mapped. This equates to 31% of the continental shelf and 11% of the deeper-water areas being covered by quantitative data.

Density of grain size data is highest over the Rowley Shelf. Further to the north, density over the Rowley and Arafura shelves is more variable. The bulk of samples are located on the mid to outer continental shelf and upper slope. There is a significant lack of samples on the inner shelf, the continental slope and abyssal plain.

Data density for measured carbonate data is similar to the overall sample density (Fig. 4.2). At the coarsest scale (sample spacing <100 km), 43% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), 15% of the total area can be mapped. This equates to 23% of the continental shelf and 10% of the deeper-water areas being covered by quantitative data.

Measured Gravel Content

For much of the southern continental shelf the gravel content is 1-20%. A band with gravel content of 40-60% occurs north and northwest of Broome, extending across the outer shelf and onto the slope. On the northern half of the continental shelf, gravel content is generally 20-40%. Irregular bands of gravel varying from 40-60% to 60-80% extend across the shelf onto the slope. Gravel content of 80-100% is associated with reefs and islands. Areas of zero gravel occur on the slope west and northwest of Barrow Island and more extensively on the central southern and northern slope. Otherwise, gravel content on the slope is generally 1-20%.

Measured Sand Content

On the southern half of the shelf, sediments generally contain 80-100% sand, with the exception of localised areas on the inner to mid shelf. On the continental slope, sand content reduces from 60-80% to 40-60% and locally to 20-40%. From Broome over the northern half of the shelf, sand content is more variable, generally 40-60% to 60-80%. Sand content on the upper slope is similar, with the exception of an area with 80-100% in the far north. Across both the shelf and slope localised patches of 1-20% and 80-100% sand content occur.

Measured Mud Content
Mud content over much of the continental shelf is 1-20%. Extensive areas with zero mud content occur along the southern half of the shelf and on the central shelf offshore Broome, extending out to the slope. Off York Sound two lobes of sediment, containing 40-60% and 60-80% mud respectively, extend across the shelf. Mud content of sediments on the continental slope ranges from 20-40% to 60-80%. Mud content on the shelf and slope in the far north of the region of the region is 20-40%.

Measured Mean Grain Size
Mean grain size of sediments on the southern continental shelf is generally medium to coarse sand. Over the northern half of the shelf mean grain size is typically coarse to very coarse sand. Localised gravels correspond to the reefs and islands. In the far north of the region fine to medium sands occur. On the slope in the southern half of the region mean grain size ranges from very coarse silt to fine sand. However in the north, sediments on the slope are similar to those on the shelf, with the exception of an area off King Sound, where fine sands grade to very coarse silt with depth.

Folk Classification
On the shelf south of Broome sediments generally comprise gravelly muddy sand, slightly gravelly sand and gravelly sand, with minor sand. Around Dampier, sediments are slightly gravelly muddy sand. North of Broome, the mid to outer shelf comprises sandy gravel, gravelly sand and gravel, while the inner shelf contains gravelly mud and gravelly muddy sand. Continental slope sediments generally comprise muddy sand and sandy mud. Sand occurs on the outer shelf, off Browse Island. On the southern Bonaparte Shelf, the sediments comprise gravelly mud, muddy sand and gravelly muddy sand.

Measured Carbonate Content
Carbonate content of the sediments across the shelf and slope over most of the area is 80-100%. In the north off King Sound and offshore York Sound; carbonate content grades to 60-80%.

4.3.8 West-northern Marine Domain

The West-northern Marine Domain extends from Cape Londonderry in north-west Western Australia to the Goulburn Islands, east of Darwin (Fig. 4.22). The total area of the region is 279,500 km^2, of which 89% or 250,000 km^2 is shelf.

Sample Density
Sample density for grain size data in the West-northern Marine Domain is shown in Figure 4.1. At the coarsest scale (sample spacing <100 km), 92% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), only 51% of the total area can be mapped. This equates to 53% of the continental shelf and 34% of the deeper-water areas being covered by quantitative data. Samples are more concentrated over the Arafura Shelf. Over the Sahul Shelf sample density reflects the pattern of broadly-spaced sample transects. Gaps in the distribution of samples occur mainly in the inner shelf and include a significant gap in Van Diemen Gulf.

The sample density for measured carbonate content is slightly lower than that of grain size data (Fig. 4.2). At the coarsest scale (sample spacing <100 km), 89% of the total area of this domain can be mapped. At the finer scale (sample spacing <25 km), 41% of the total area can be mapped. This equates to 42% of the continental shelf and 32% of the deeper-water areas being covered by quantitative data.

Measured Gravel Content
Over the Sahul Shelf gravel content is 1-20%. In Joseph Bonaparte Gulf, along the inner shelf to the north and north-east of Cape Londonderry, gravel content ranges from 40-60% to 60-80%. Gravel content of 40-60% to 80-100% occurs between Darwin and Melville Island. North and north-east of Melville Island there is a band of zero gravel extending to the north-east. Elsewhere over the shelf and slope gravel content is 1-20%.

Measured Sand Content
Over the Sahul Shelf sand content is variable. The central part of the shelf has 1-20% to 20-40%, increasing to 40-60% to the south. North of Joseph Bonaparte Gulf, a wide band of 60-80% sand extends north over the Van Diemen Rise. North of Melville Island a band of 1-20% to 20-40% sand extends across the Arafura Shelf.

Measured Mud Content
On the western side of the Sahul Shelf mud content ranges from 1-20% on the inner shelf to 60-80% over the mid to outer shelf. Elsewhere mud content is 1-20% to 20-40%. A pronounced band of 80-100% mud runs from Melville Island east-north-east across Arafura Shelf. On the slope adjacent to the Arafura Shelf mud content ranges from 20-40% to 40-60%.

Measured Mean Grain Size
On the western Sahul Shelf, sediments are fine sand, with patches of very coarse silt on the central and outer shelf. Adjacent to Joseph Bonaparte Gulf and over much of the eastern Sahul Shelf, there are medium to coarse sands. The exception to this is an area on the central shelf with very fine to fine sand. Between Darwin and Melville Island sediments vary from gravels in the central area, to coarse sands in the east and west. Over the Arafura Shelf, sediments range from medium to very coarse silt. On the slope to the north, mean grain size is fine sand.

Folk Classification
Sediments over western half of the Sahul Shelf are predominately gravelly muddy sand and slightly gravelly muddy sand with sandy gravel, muddy gravel and sand on the inner shelf. On the mid and outer shelf, sediments comprise mainly mud, sandy mud and gravelly mud. Between Darwin and Melville Island the sediments are predominantly gravel and sandy gravel. On the Arafura Shelf, north of Melville Island, there is a band of mud and sandy mud. To the north on the slope, the sediments comprise gravelly muddy sand, slightly gravelly sand and slightly gravelly sandy mud.

Measured Carbonate Content
From Joseph Bonaparte Gulf to the north there is a band of sediments, containing 20-40% to 40-60% carbonate, extending across the shelf. Carbonate content elsewhere on the Sahul Shelf ranges from 60-80% to 80-100%. East-north-east of Melville Island, carbonate content is 20-40%. Sediments on the slope to the north contain 60-80% carbonate.

4.4 GEOMAT Modelling

The wave induced threshold exceedance map for the Australian marine domains is presented in Figure 4.23, with data represented by 10% increments from 1 – 100%. The tidal induced threshold exceedance within the Australian GEOMAT region for observed mean grain size is presented as a map (Fig. 4.24), with data in 10% increments from 1 – 100%. A map showing regionalisation based on dominant energy regimes within the Australian GEOMAT Region is shown in Figure 4.25.

4.4.1 Northern Planning Area (NPA)

Wave Induced Exceedance
In the NPA, surface ocean waves are capable of mobilising sediments of mean grain size at least once during the 5 years (1997-2002) over ~90% of the Australian GEOMAT region (Table 4.3; Fig. 4.26). However, 64.4% of the region is mobilised for <1% of the time period modelled (5 years) and is likely to be a result of one significant storm during the period. Locations which indicate higher wave induced threshold exceedance (>1%) are nearer to the coast, or within the shallow waters of Torres Strait, and indicate the strong correlation between wave-induced sediment mobilisation and water depth.

Table 4.3. Areas within the Northern Planning Area where the sediment mean grain size threshold is exceeded due to surface ocean waves. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Northern Planning Area. This area totals 557,080 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	359,240	64.4
>1, <=10%	97,662	17.5
>10, <=50%	32,483	5.83
>50, <100%	11,162	2.00
=100%	133.7	0.024

Tidal Induced Exceedance
In the NPA, tidal currents are capable of mobilising sediments of mean grain size at least once during a spring-neap tidal cycle over ~53% of the Australian GEOMAT region (Table 4.4; Fig. 4.27). The locations of highest tidal induced threshold exceedance in the Australian GEOMAT region is contained within the Northern Planning Area on the Arafura shelf, where tidal currents are predicted to mobilise the fine-medium silts almost 100% of the time period modelled. Very few oceanographic field studies have been carried out in this region, and consequently it is difficult to verify this result.

High tidal-induced exceedance is observed in Torres Strait, and is correlated with observations of large sandwaves which are formed by strong tidal currents. Although there are local areas of no tidal induced exceedance within Torres Strait, this is expected to be a result of the coarse resolution of the tidal model not resolving the narrow channels between the many reefs in the area.

In the Gulf of Carpentaria, only the fine-medium silts in the western-central gulf are mobilised by tidal currents (approximately 10% of the time period modelled). Elsewhere in the Gulf, the diurnal tidal currents are not sufficiently strong to mobilise sediments of mean grain size.

Table 4.4. Areas within the Northern Planning Area where the sediment mean grain size threshold is exceeded by tidal currents. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Northern Planning Area. This area totals 557,080 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	7,476	1.34
>1, <=10%	105,640	19.0
>10, <=50%	150,200	27.0
>50, <100%	34,037	6.11
=100%	81.3	0.015

Energy Regime Regionalisation

The energy regime within the Northern Planning Area is variable (Table 4.5; Fig. 4.28). The majority of the "Tide-Dominated" and "Tide-Only" areas (43% and 5% of the area within the Australian GEOMAT region, respectively) are located on the Arafura shelf and in the Northern Gulf of Carpentaria. The southern Gulf of Carpentaria is generally characterised as "Waves-Only", and this area accounts for most of the 40.7% of the GEOMAT region in the area which is categorised as such. This is an indication that sediment mobilisation in the southern Gulf is dominated by storm events. Although not categorised as "Mixed", strong spatial gradients between "Waves-Only" regions and "Tide-Dominated" regions within Torres Strait suggest that waves and tides both have significant influence on the mobilisation of sediments in the Strait. Consequently, the Strait would best be described as a "Mixed" environment.

Table 4.5. Areas within the Northern Planning Area of six difference energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Northern Planning Area. This area totals 557,080 km2.

Category	Area km^2	% <300 m
Zero Mobility	29,353	5.24
Waves Only	227,840	40.7
Waves Dominate	2,860	0.51
Mixed	29,436	5.26
Tides Dominate	240,800	43.0
Tides Only	29,927	5.34

4.4.2 North-eastern Marine Domain

Wave Induced Exceedance

In the North-eastern Marine Domain, surface ocean waves are capable of mobilising sediments of mean grain size at least once during the 5 years (1997-2002) over ~87% of the Australian GEOMAT region (Table 4.6; Fig. 4.23). Over 50% of the Area, positioned along the GBR and near to the coast, is mobilised by waves for more than 1% of the time period modelled, indicating that the shallow reef waters along the Queensland coast are strongly influenced by wave motion.

Table 4.6. Areas within the North-eastern Marine Domain where the sediment mean grain size threshold is exceeded due to surface ocean waves. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the North-eastern Marine Domain. This area totals 254,677 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	88,834	34.9
>1, <=10%	78,704	30.9
>10, <=50%	23,490	9.22
>50, <100%	22,780	8.95
=100%	8,111	3.18

Tidal Induced Exceedance

In the North-eastern Marine Domain, tidal currents are capable of mobilising sediments of mean grain size at least once during a spring-neap tidal cycle over ~39% of the Australian GEOMAT region (Table 4.7; Fig. 4.24). The two locations which indicate significant tidal-induced exceedance (>10%) are Broad Sound, offshore from Rockhampton, and the narrow channels within the Northern GBR, east of Cape York. These regions are both characterised by sediments with a mean grain size in the medium sand range.

Table 4.7. Areas within the North-eastern Marine Domain where the sediment mean grain size threshold is exceeded by tidal currents. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the North-eastern Marine Domain. This area totals 254,677 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	1,814	0.71
>1, <=10%	16,924	6.65
>10, <=50%	54,357	21.34
>50, <100%	24,328	9.55
=100%	1,192	0.47

Energy Regime Regionalisation

“Tide-Dominated” and “Tides-Only” areas account for 24% and 3% of the area respectively within the Australian GEOMAT region portion of the North-eastern Marine Domain (Table 4.8; Fig. 4.25). Broad Sound and the northern GBR are observed to account for the majority of these areas. The remainder of the Australian GEOMAT region in which sediments are mobilised in the North-eastern Marine Domain (~49%) indicates that sediments of mean grain size are mobilised by waves only.

Table 4.8. Areas within the North-eastern Marine Domain of six difference energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the North-eastern Marine Domain. This area totals 254,677 km^2.

Category	Area km^2	% <300 m
Zero Mobility	38,790	14.3
Waves Only	130,230	48.4
Waves Dominate	3,859	1.44
Mixed	22,302	8.30
Tides Dominate	65,357	24.2
Tides Only	8,296	3.09

4.4.3 Eastern–central Marine Domain

Wave Induced Exceedance

In the Eastern-central Marine Domain, surface ocean waves are capable of mobilising sediments of mean grain size at least once during the 5 years (1997-2002) over ~66% of the Australian GEOMAT region (Table 4.9; Fig. 4.23). Sediments of mean grain size are mobilised for >1% of the time over 36% of the shelf area during the 5 year period. This indicates the relatively constant wave activity in the Tasman Sea.

Table 4.9. Areas within the Eastern-central Marine Domain where the sediment mean grain size threshold is exceeded due to surface ocean waves. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Eastern-central Marine Domain. This area totals 71,408 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	20,801	29.1
>1, <=10%	17,242	24.1
>10, <=50%	4,403	6.17
>50, <100%	3,695	5.18
=100%	991.5	1.39

Tidal Induced Exceedance

In the Eastern-central Marine Domain, tidal currents are capable of mobilising sediments of mean grain size at least once during a spring-neap tidal cycle over ~1% of the Australian GEOMAT region (Table 4.10; Fig. 4.24). This is a result of the micro-tidal ranges, and consequent low tidal current velocities on the continental shelf in the domain.

Table 4.10. Areas within the Eastern-central Marine Domain where the sediment mean grain size threshold is exceeded by tidal currents. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Eastern-central Marine Domain. This area totals 71,408 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	69.5	0.10
>1, <=10%	349.0	0.49
>10, <=50%	246.2	0.34
>50, <100%	42.24	0.06
=100%	1.0	0.001

Energy Regime Regionalisation

Mobilisation of sediments of mean grain size on the seabed by tidal currents is almost nil in the Eastern-central Marine Domain (Table 4.11; Fig. 4.25). Thus, almost the entire area which is mobilised (~70%) is characterised as a "waves-only" region.

Table 4.11. Areas within the Eastern-central Marine Domain of six difference energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Eastern-central Marine Domain. This area totals 71,408 km^2.

Category	Area km^2	% <300 m
Zero Mobility	20,765	30.7
Waves Only	46,248	68.3
Waves Dominate	290.1	0.43
Mixed	403.0	0.59
Tides Dominate	34.3	0.05
Tides Only	6.45	0.01

4.4.4 South-east Marine Domain

Wave Induced Exceedance

In the South-east Marine Domain, surface ocean waves are capable of mobilising sediments of mean grain size at least once during the 5 years (1997-2002) over ~64% of the Australian GEOMAT region in the Area (Table 4.12; Fig. 4.23). Approximately 25% of the shelf area has sediments of mean grain size which are mobilised for >1% of the time period modelled, and these are located along the entire coastline, particularly along the west coast of Tasmania, and in south-western Victoria.

Table 4.12. Areas within the South-east Marine Domain where the sediment mean grain size threshold is exceeded due to surface ocean waves. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the South-east Marine Domain. This area totals 223,035 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	86,518	38.8
>1, <=10%	40,733	18.3
>10, <=50%	8,706	3.90
>50, <100%	5,459	2.45
=100%	504	0.23

Tidal Induced Exceedance

In the South-east Marine Domain, tidal currents are capable of mobilising sediments of mean grain size at least once during a spring-neap tidal cycle over ~25% of the Australian GEOMAT region (Table 4.13; Fig. 4.24). Only two areas indicate significant (>1%) tidal-induced exceedance, and these occur on the shallow banks on the eastern and western sides of the Bass Basin. Strong tidal currents are well documented on these shallow banks (Fandry *et al*., 1993).

Table 4.13. Areas within the South-east Marine Domain where the sediment mean grain size threshold is exceeded by tidal currents. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the South-east Marine Domain. This area totals 223,035 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	2,690	1.21
>1, <=10%	16,461	7.38
>10, <=50%	2,069	12.1
>50, <100%	8,728	3.91
=100%	123	0.06

Energy Regime Regionalisation

The majority of the areas characterised as “Tide-Dominated” and “Tide-Only” regions, accounting for 21.9% and 2.5% of the area within the Australian GEOMAT region, respectively, are located on the shallow banks on either side of Bass Basin (Table 4.14, Fig. 4.25). The remaining area of the Australian GEOMAT region in the South-east Marine Domain where sediments of mean grain size are mobilised is categorised as “Waves Only”.

Table 4.14. Areas within the South-east Marine Domain of six difference energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the South-east Marine Domain. This area totals 223,035 km^2.

Category	Area km^2	% <300 m
Zero Mobility	37,419	20.4
Waves Only	89,909	48.9
Waves Dominate	905	0.49
Mixed	10,650	5.79
Tides Dominate	40,333	21.9
Tides Only	4,602	2.50

4.4.5 South-west Marine Domain

Wave Induced Exceedance

Due to the low coverage of quantitative grain size data in the South-west Marine Domain, wave induced exceedance was not determined for this region.

Tidal Induced Exceedance

Due to the low coverage of quantitative grain size data in the South-west Marine Domain, tidal induced exceedance was not determined for this region.

Energy Regime Regionalisation

Although wave and tide induced exceedance were not computed for the South-west Marine Domain, the majority of the region could be expected to be a “Waves-Only” region, given the low tidal ranges in the area, and the large swell waves which continually impinge upon the southern coast of Australia. The largest and longest period waves to occur on the Australian continental shelf are found off the west coast of Australia, in the GAB, and off western Tasmania, within which the South-west Marine Domain is contained.

4.4.6 Western–central Marine Domain

Wave Induced Exceedance

In the Western–central Marine Domain, surface ocean waves are capable of mobilising sediments of mean grain size at least once during the 5 years (1997-2002) over ~54% of the Australian GEOMAT region (Table 4.15, Fig. 4.23). Approximately 33% of the shelf area has sediments of mean grain size which are mobilised for greater than 1% of the time period modelled, and these are located along the entire coastline. These results reflect the continual ocean swells from the Indian Ocean which impinge on the West Australian coast every year.

Table 4.15. Areas within the Western-central Marine Domain where the sediment mean grain size threshold is exceeded due to surface ocean waves. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Western-central Marine Domain. This area totals 98,976 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	20,973	21.2
>1, <=10%	21,708	21.9
>10, <=50%	7,604	7.68
>50, <100%	3,037	3.07
=100%	107	0.11

Tidal Induced Exceedance

In the Western–central Marine Domain, tidal currents are capable of mobilising sediments of mean grain size at least once during a spring-neap tidal cycle over less than 1% of the Australian GEOMAT region (Table 4.16, Fig. 4.24). Weak tidal currents occur on the continental shelf as a result of the low tidal ranges in the region.

Table 4.16. Areas within the Western-central Marine Domain where the sediment mean grain size threshold is exceeded by tidal currents. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Western-central Marine Domain. This area totals 98,976 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	44.6	0.05
>1, <=10%	164.1	0.17
>10, <=50%	353.2	0.36
>50, <100%	126.9	0.13
=100%	1.12	0.001

Energy Regime Regionalisation

The Western-central Marine Domain (Table 4.17, Fig. 4.25) is predominantly categorised as a “Waves Only” region (58.9% of the shelf area). The remainder of the Australian GEOMAT region within the Area is characterised as a “zero mobility” region (40.3%), indicating that the seabed is mostly below the depth at which waves are able to mobilise sediments; the seabed is a low-energy environment.

Table 4.17. Areas within the Western-central Marine Domain of six difference energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Western-central Marine Domain. This area totals 98,976 km^2.

Category	Area km^2	% <300 m
Zero Mobility	39,319	40.3
Waves Only	57,518	58.9
Waves Dominate	179	0.18
Mixed	383	0.39
Tides Dominate	177	0.18
Tides Only	83	0.08

4.4.7 North-west Marine Domain

Wave Induced Exceedance

In the North-west Marine Domain, surface ocean waves are capable of mobilising sediments of mean grain size at least once during the 5 years (1997-2002) over ~34% of the Australian GEOMAT region (Table 4.18, Fig. 4.23). Approximately 16% of the shelf area has sediments of mean grain size which are mobilised for >1% of the time period modelled, and these regions are located near to the coast.

Table 4.18. Areas within the North-west Marine Domain where the sediment mean grain size threshold is exceeded due to surface ocean waves. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the North-west Marine Domain. This area totals 398,506 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	72,238	18.1
>1, <=10%	42,952	10.8
>10, <=50%	12,689	3.18
>50, <100%	8,334	2.09
=100%	713.0	0.18

Tidal Induced Exceedance

In the North-west Marine Domain, tidal currents are capable of mobilising sediments of mean grain size at least once during a spring-neap tidal cycle over ~72% of the Australian GEOMAT region (Table 4.19, Fig. 4.24). The majority of the shelf area (~71%) has sediments mobilised for significant portions of time period modelled (>1%). A large portion of Australia's macro-tides are contained within the North-west Marine Domain. Along the north-west coast of Australia, a maximum tidal range of 12.5 m is reached in Collier Bay, King Sound (Easton, 1970). On the adjacent shelf, the tidal model predicts maximum tidal current speeds up to around 1.5 ms^{-1}. On the outer North West shelf, tidal currents are predicted to mobilise sediments with a mean grain size of between 2-4 mm in approximately 200 m water depth. In the North-west Marine Domain, high tidal induced threshold exceedances are strongly correlated with regions of the strongest tidal currents.

Table 4.19. Areas within the North-west Marine Domain where the sediment mean grain size threshold is exceeded by tidal currents. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the North-west Marine Domain. This area totals 398,506 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	4,882	1.23
>1, <=10%	35,332	8.87
>10, <=50%	218,720	54.9
>50, <100%	28,590	7.17
=100%	593.5	0.15

Energy Regime Regionalisation

The North-west Marine Domain is predominantly characterised as a “Tides Only” (~52% of the Australian GEOMAT region within the Area) or “Tides Dominate” (~21%) region (Table 4.20, Fig. 4.25). A narrow strip near to the coast is characterised as “Waves Only”, however this is a result of the tidal model not being able to resolve the currents near to the coast, and consequently, only waves are predicted to mobilised sediments there. It is expected in these regions near to the coast, tides are also capable of mobilising sediments of mean grain size, and could be classified as “Mixed”. Approximately 12% of the Australian GEOMAT region within the domain is not mobilised by waves or tides, and these areas are located on the outer shelf.

Table 4.20. Areas within the North-west Marine Domain of six difference energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the North-west Marine Domain. This area totals 398,506 km^2.

Category	Area km^2	% <300 m
Zero Mobility	46,597	12.1
Waves Only	47,913	12.4
Waves Dominate	1,171	0.30
Mixed	8,082	2.10
Tides Dominate	79,235	20.6
Tides Only	202,150	52.5

4.4.8 West-northern Marine Domain

Wave Induced Exceedance

West-northern Marine Domain, surface ocean waves are capable of mobilising sediments of mean grain size at least once during the 5 years (1997-2002) over ~41% of the Australian GEOMAT region (Table 4.21, Fig. 4.23). Approximately 12% of the GEOMAT region within the Area has sediments of mean grain size which are mobilised for >1% of the time period modelled, and these regions are located close to the coast.

Table 4.21. Areas within the West-northern Marine Domain where the sediment mean grain size threshold is exceeded due to surface ocean waves. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the Northern/Timor Marine Domain. This area totals 267,079 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	78,174	29.3
>1, <=10%	22,033	8.25
>10, <=50%	6,631	2.48
>50, <100%	2,711	1.02
=100%	65.2	0.024

Tidal Induced Exceedance

West-northern Marine Domain tidal currents are capable of mobilising sediments of mean grain size at least once during a spring-neap tidal cycle over ~80% of the Australian GEOMAT region (Table 4.22, Fig. 4.24). For almost all of this domain, tidal induced threshold exceedance is >1%, and like in the North-west Marine Domain, this is a result of the macro-tides in the region driving strong tidal currents capable of mobilising sediments with a mean grain size in the range of coarse sand.

Table 4.22. Areas within the West-northern Marine Domain where the sediment mean grain size threshold is exceeded by tidal currents. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the West-northern Marine Domain. This area totals 267,079 km^2.

% Exceedance	Area km^2	% <300 m
>0, <=1%	1,716	0.64
>1, <=10%	32,518	12.2
>10, <=50%	153,610	57.51
>50, <100%	26,384	9.88
=100%	43.3	0.016

Energy Regime Regionalisation

The West-northern Marine Domain is predominantly classified as “Tides Only” (48.5% of the Australian GEOMAT region within the Area) and “Tide Dominated” (29.2%) region (Table 4.23, Fig. 4.25). As in the North-west Marine Domain, a narrow strip near to the coast is characterised as “Waves Only”. This is a result of the tidal model’s inability to resolve the currents near to the coast, and consequently, only waves are predicted to mobilise sediments there. Again, given the large tides in the region, it is expected that tides are able to mobilise sediments of mean grain size in this near coast zone. Consequently this near coast zone may best be categorised as “Mixed”. Approximately 11% of the shelf area is not mobilised by waves or tides, and these areas are located on the outer shelf

Table 4.23. Areas within the West-northern Marine Domain of six difference energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region (<300 m water depth) within the West-northern Marine Domain. This area totals 267,079 km^2.

Category	Area km^2	% <300 m
Zero Mobility	31,079	11.4
Waves Only	25,636	9.4
Waves Dominate	503	0.18
Mixed	3,744	1.37
Tides Dominate	79,551	29.2
Tides Only	132,080	48.5

4.5 Reporting on the Project

A significant component of the project was the reporting phase (phase 3). During the course of the project, Geoscience Australia reported progress to the National Oceans office through informal reporting, as well as in two written progress reports and in presentations to the Bioregionalisation Working Group.

The initial presentation to the Bioregionalisation Working Group was in July 2003. This presentation outlined the project as then scoped; as the presentation was made prior to signing the Memorandum of Understanding on the project. The expected scope of the work over the three phases of the project was outlined; existing datasets and potential data holders were discussed.

A second presentation to the Bioregionalisation Working Group was given in March 2004. The presentation outlined progress with the data collation and database population phase and discussed implications of the dataset on the mapping and interpretation phase, then about to commence.

Briefing notes were provided for the following Bioregionalisation Working Group meeting in June 2004. These notes outlined progress with the data collation and database population and the data interpretation and analysis phases.

The first written progress report was compiled in November 2003. This report presented a summary of progress with the data collation and database population task, outlined negotiations with data holders and reported on database development. The second progress report was compiled in February 2004. The report outlined progress on discussions with data holders, data collation and formatting, and database development. Progress towards the data interpretation and analysis phase was discussed.

4.6 Integration With the Bioregionalisation Project

A requirement of this project was that the data generated would be incorporated into the Bioregionalisation Integration Project with regard to developing a national benthic bioregionalisation. To facilitate this, Geoscience Australia was expected to work closely with Bioregionalisation Integration Providers to ensure that outputs were available in a timely fashion and appropriate form for use in the Integration Project.

All maps of the sediment parameters generated as part of this project were included in the layers of data available to the integration providers prior to the first integration meeting. The main results of this project have been provided to the Geoscience Australia members of the integration team and aspects of the sediment data discussed with them to ensure that data were being appropriately applied and interpreted. As such, the sediment data have been incorporated in the development of the national benthic bioregionalisation in helping define the Level 3 – Geomorphic Units boundaries. A member of the sediment project also participated in the preliminary integration meetings to provide advice on the applicability of the data.

The products from this work are being integrated with other datasets to further enhance the regionalisation based on sediment data. Geoscience Australia has carried out a statistical analysis of sediment properties, where available, with bathymetric data and interpreted geomorphic provinces to enhance the applicability of geological data to bioregionalisations. The relationships are described in Section 5.3 of this report. Furthermore, relationships between the sediment properties and the different types of geomorphic features have been incorporated in the development of the national benthic bioregionalisation.

5 Discussion

5.1 Strategic Review of Findings

This is the first project to critically assess the quality and coverage of Australia's seafloor sediment data on a National scale, concentrating on measured sediment properties. As a direct result of this project, the MARS database is now an important scientific and educational resource for those requiring detailed information on seafloor sediment characteristics within the Australian Large Marine Domains.

5.1.1 Gaps in quantitative data coverage

The total area covered by Large Marine Domains is about 6,447,000 km^2 (Fig. 3.1). Based on the coarsest resolution of sample points (<100 km), grain size data cover about 33% of this area (Fig. 4.1) and carbonate data about 29% (Fig. 4.2). The remaining 67-71% of the marine domain areas where no quantitative data were available were assessed for their potential to yield further quantitative data. Three broad categories were identified:

- Unavailable data - areas where quantitative data exist, but were not available for inclusion in MARS
- Untested samples - areas where seafloor samples have been collected, but not analysed - these may be available for future analysis
- No samples - no untested samples identified

Unavailable data were identified in the Western-central Marine Domain, where data occupy 21% of this area (Fig. 5.1). Here, the data provide coverage for most of the continental shelf and shallower off shelf regions. These data extend to the south into the South-west Marine Domain. Here, they occupy 1.6% of this area, also on the continental shelf and shallower off shelf areas. These data are held by the University of South Australia/Queens University/Curtin University collaborative research group studying cool water carbonate development on Australia's southern and western margins.

About 1,600 seafloor samples (mostly cores) that are currently kept in Australian and overseas storage facilities have not been analysed for grain size and carbonate content. The majority have been collected from off shelf locations. Variation in sediment properties and characteristics in off shelf areas is generally less than that found on the shelf. Accordingly, an increased separation distance of 200 km has been used here to assess the potential coverage of these samples. At a 200 km spacing, an additional 45% of the total Large Marine Domain area could be covered with quantitative data should a selection of these samples (about 1,000) be tested (Fig. 5.1). The domain coverages that would benefit the most are the South-west (an additional 71% coverage) and the Western-central (an additional 72% coverage).

Seafloor samples are not available for around 20% of the total Large Marine Domain area. There are apparent data gaps for some key shelf areas, especially in the South-west and parts of the North-west Marine Domains (Fig. 5.1). The deeper water (abyssal) areas off the east coast of Australia spanning the North-east (23% no data), Eastern-central (47% no data) and South-east (19% no data) Marine Domains are also sparsely covered.

5.1.2 Directions and Opportunities in Data Acquisition

Options for improving data acquisition for MARS fall into two categories. One is to continue to build on the initial work carried out under this agreement to acquire existing data. The second is the acquisition of newly-generated data. Included in this second category is the generation of new data from analysis of untested samples, as discussed above.

Existing Data

Part of the problem with acquiring existing data is need to build relationships with researchers to encourage them to provide data. This is partly an issue of trust, and many are reluctant to contribute to another government program. Part of the work required is greater publicity of the database and its potential benefits. Presentations were made during the project to sedimentological audiences, and continued contact is necessary.

The broader issue of access to data is unlikely to be solved in the short term. Individual agreements will need to be negotiated with each institution, as the needs of each are likely to be different. The development of the MARS website will be a further way to publicise the database as well as benefits to potential users. The proposed Oceans Portal will also be a vehicle for increasing publicity of MARS.

It quickly became obvious that financial support was necessary to allow university researchers willing to contribute in principle to the project to employ students to collate or enter data. The timing of such work is also crucial, as researchers are typically unwilling or unable to take on additional work, such as data collation, during term time. The availability of students for employment during vacation times is also a consideration.

An extensive Northern Marine Domain sediment dataset, which was provided to Geoscience Australia by CSIRO's Cleveland Office, was collected over a 20-30 year period in support of fisheries research and compiled from a number of archived project databases. Other sediment samples are known to have been collected by the CSIRO in support of fisheries studies in the North-west and South-east Domains, with the results archived in a similar manner to the Northern Marine Domain data, but these have not been compiled to date. Organisations such as the CSIRO and AIMS should be encouraged to compile their existing sediment sample data to facilitate MARS population

Collaborative arrangements with key research groups such as CSIRO Marine Research, AIMS and the researchers from Adelaide/Queens/Curtin Universities studying cool water carbonate development in southern Australian waters, would facilitate data acquisition.

Newly Generated Data

New sediment data is generated from a number of sources. A major one is through the use of the Marine National Facility. Under current guidelines (http://www.marine.csiro.au/nationalfacility/application/SS_Application_Pack.pdf, 2004), principal investigators are required to submit a Voyage Summary within a month of completing the voyage. Data generated by on-board instruments is submitted to AODC and CSIRO as appropriate. Principal investigators have first call on samples and data collected by researchers' own equipment, after which samples and data are expected to be made available to others. Geological and geophysical data and samples are required to be lodged with Geoscience Australia.

These new provisions will reduce issues of data not being made publicly available and will aid in the acceptance of MARS. However, there will be a lead time before such data will begin to be provided and can be incorporated into the database. The provision of data guidelines by Geoscience Australia will aid in the submission of data by researchers.

Marine data are collected by a range of other Government agencies. The only agency that collects sediment samples is the Hydrographer's Office. Negotiations with the Hydrographer to supply samples to Geoscience Australia have been undertaken in the past and agreement in principle is currently in place. This would provide actual sample material which could be analysed for grain size. However, Geoscience Australia's first priority is to service its own project requirements and thus has very limited capacity to process additional samples. There would be benefit also in Geoscience Australia providing some education to the Navy on sample collection methods to improve the quality of samples and data.

Generating new sediment data from samples not analysed is a cost-effective method of achieving significant quantitative data coverage over poorly covered domains. This is most likely to be of benefit for the South-west and Western-central Marine Domains, where samples have been collected from the continental shelf. The South-east Marine Domain would also benefit from holdings of samples in overseas and Australian repositories (including Geoscience Australia), many of which would provide additional data from the poorly-sampled deeper water areas.

Consideration should also be given to retesting samples using current techniques in order to obtain consistent data formats, as advances in sediment analysis techniques over the last 30 years has resulted in a variety of methods being used to determine the same sediment property. This has little significance for mapping grain size at the level of gravel, sand and mud content, since newer methods typically provide a more detailed grain size distribution, rather than, necessarily, a more accurate measurement. Where the method of measurement is more significant is in relation to determination of mean grain size or other parameters, such as mode, which could be used in modelling.

5.2 Overview of Sediment Distribution

While a detailed investigation of the distribution of sediments is beyond the scope of this project, an overview of some of the main sediment distribution patterns and an examination of some the factors which influence them, is included here.

The Australian continent is characterised by low relief, deeply weathered, ancient land surfaces (Twidale, 1968, 1991; Twidale & Campbell, 1988;). As a result, terrigenous sediment yields are typically low. This, together with a geological history of slow subsidence of the passive margins, followed by the increasing development of clear shelf waters has resulted in conditions that are optimal for the development of carbonate sedimentation, in northern regions such as the Bonaparte, Sahul and Kimberley Shelves in the north (Glenn, 2004) and along the southern margin (eg Gostin *et al*.,1968).

The Australian landmass is today almost entirely encircled by some of the largest marine carbonate provinces in the world. These include the tropical Great Barrier Reef (Maxwell 1973), Torres Strait (Harris 1994), and Northwest Shelf (van Andel, 1965; Heyward *et al*., 1997) coralgal carbonate provinces in the north. These contrast with the cold temperate bryozoan-brachiopod and foraminiferal provinces in the southeast (Marshall & Davies 1976; Marshall 1980), the south (Bone & James, 1993);and southwest (Collins, 1988). In areas of particularly low terrigenous sediment supply, both the warm and cold water carbonate provinces may extend from the outer shelf right in to the shoreline (Gostin, et al., 1988; Harris, 1994). The two climatically-controlled shelf carbonate provinces pass into one another at mid-latitudes (~27^0 S) along both the eastern and western seaboards of Australia.

The extent of these provinces is evident from the map of carbonate content (Fig. 4.16). Over most of the continental shelf, carbonate content is high (>50%). Exceptions to this typically occur in areas adjacent to rivers, where terrigenous input is increased. The major regions in which this occurs are the eastern Gulf of Carpentaria, the Arafura, Sahul and Bonaparte Shelves and the southern Queensland coast.

Grain size distributions on continental shelves around Australia are influenced by the biogenic origins of much of the sediments. Biota typically contribute the bulk of gravel-sized particles to the sediment, although weathering of terrigenous rocks may also play a part in localised areas, for example Bass Strait (Passlow *et al*., 2004). Increased gravel content (>40%) in sediments associated with reefs is evident in the North-west, Central-western and North-eastern Marine Domains, as well as in the Northern Planning Area (Fig. 4.16). Many of these high gravel sediments are distinct enough to be reflected also in the map of Folk classification (Fig. 4.15).

Beyond these general patterns, grain size distributions on continental shelves are typically influenced by a range of factors, which include waves and tides. On the southern margin, exposure of the shelf to Southern Ocean storms and swells (James *et al*., 1994) has a profound influence on sediment production and off-shelf transport. This in turn impacts sedimentation on the upper slope (Passlow, 1997).

The extent of off-shelf sediment transport is evident in the distribution of mean grain size south of Tasmania (Fig. 4.14) and in the map of Folk classification (Fig. 4.15). This is in contrast to the few other areas where slope sediments are mapped and are typically dominated by muds (Figs. 4. 13, 4.14), reflecting the relative importance of sediment transport off shelf by suspension.

Sediment transport plays a strong role also in shaping the distribution of sediments along the NSW shelf (Eastern-central Marine Province). The sediment mobility regionalisation (Fig. 4. 25) shows a narrow band of wave only influence on the inner shelf. Grain size distributions show that sands dominate (Fig. 4.12, 4.14). A recent study of Quaternary cores from this margin shows that sediment distribution and, in particular, the development of the "sand river" can be related to a range of factors, in which waves, ocean currents and geomorphology all play a role (Roberts & Roy, 2004).

5.3 The Role of Sediment Data in Marine Bioregionalisation

5.3.1 Regionalisation Based on Sediment Data

A comparison of the sediment data with geomorphic units shows that at the scale of major geomorphic units, ie shelf, slope, rise and abyssal plain, there are clear-cut relationships, even despite the low number of sediment samples on the slope. Sediments on the shelf are typically coarser-grained. This is evident from the mean grain size (Fig. 5.2), but is reflected in the gravel, sand and mud content, as well as in the Folk classification.

At the level of geomorphic features, correlation with sediment properties is poor. In some areas, for example on the southern margin of Queensland (North-east Marine Domain), there is some correlation between mean grain size distribution and geomorphic features in the region of the Capricorn Channel (Fig. 5.3). The fine sands and silts in the Channel can be clearly distinguished from the medium sands on the plateaus to the north and south-west. Coarse sands are associated with the reefs to the north-east, however their distribution is less clearly constrained to the reefs and banks.

In comparison in other areas, such as Bass Strait in the South-east Marine Domain and the Gulf of Carpentaria in the Northern Marine Domain, there is less correlation with the geomorphology. In Bass Strait, the area of the central geomorphic basin only partially overlaps the region of finer-grained sediments (Fig. 5.4). In this area, the distribution of silts and fine sands are more clearly related to the energy regime (Fig. 4.24). A high level of off-shelf sediment transport is also evident in the South-east Marine Domain (Fig. 5.4). This is consistent with studies of slope sediments in the region (Boreen *et al*., 1993; Passlow, 1997).

In the Gulf of Carpentaria, the distinction between the central basin and outer shelf is obvious from mean grain size (Fig. 5.5), but there is a clear east-west difference in sediment mean grain size in the central basin, which is not reflected in the geomorphology.

The lack of correlation between sediment distribution and geomorphology reflects the fact that sediments are the result of a range of inputs, processes and controls, such as contributions by biota and terrigenous sources and the nature and scale of sediment transport, whether small-scale reworking, by waves or currents or large-scale, such as major slumping on the slope. Geomorphology may play only a minor role in the nature and distribution of sediments. Sediments over much of the continental shelf around Australia have a high relict content and are thus not in equilibrium with current processes (eg Jones & Davies, 1983; Boreen *et al*., 1993; James *et al*., 1999; Post *et al*., in press). Geomorphic features may themselves be relict, in that they relate to processes which no longer operate. The nature and relative input from terrigenous sources, in-situ biological production, particularly those with carbonate parts, sediment transport and reworking by waves or tides all have an impact on sediment properties. For example in Bass Strait, the degree of sediment mobilisation is high, resulting in winnowing of much of the mud content (Jones & Davies, 1983). Off-shelf sediment transport in the South-east Marine Domain (Fig. 5.4) highlights the degree to which the overlap between sediments and geomorphic features can be blurred by other processes.

A further factor is the difference in the scale of data coverage. Bathymetric data over much of the region is far more detailed than the coverage of sediment data. As a result, there is insufficient sediment data to distinguish finer-scale features. In deeper waters there is generally insufficient sediment data coverage for finer-scale features, such as canyons, to be resolved.

5.3.2 Regionalisation Based on Sediment Mobility

There are a number of factors which influence the nature and distribution of sediments on the continental shelf, including (past and present) shelf energy regime, climate, sea-level change, sediment supply, morphology, biology and chemistry. This section of the report focuses on the shelf energy regime of the Australian Region to obtain a national regionalisation based on the dominating physical processes at the seafloor.

Approximately 13% of the Australian GEOMAT region for which quantitative grain size data is available is not mobilised by swell waves or tidal currents. These results, however, do not take into account other oceanographic currents, such as wind and density driven currents, which may be able to mobilise sediments. Table 5.1 indicates that regions of “zero mobility” are characterised by the greatest depths (mean of 120 m), and coarser sediments (mean size of 0.48 mm). However, these regions also contain the lowest mud content (mean of 17.39%), and a high carbonate content (72.19%), which contradicts the concept of a graded shelf. A similar result was predicted by Porter-Smith *et al*. (in press). While these researchers concluded that the outer-shelf sediments are not in equilibrium with modern tide and wave hydrodynamic processes, the possibility that assumptions in the model may influence our results must be considered. For instance, non-cohesive sediments have an increased critical shear stress and higher mud content. Consequently, the results may be biased by the model predicting areas with high mud content to be mobilised, whereas if these sediments are cohesive, they may not be mobilised. In its current state, GEOMAT is unable to predict the mobilisation of cohesive sediments and is one aspect of the model which could be addressed in future developments.

The energy regime regionalisation indicates that areas where only swell waves mobilise sediment (~33% of the Australian GEOMAT region) are characterised by moderate water depths (mean ~39 m), low carbonate content (~58%), low mud content (~18%), and coarse sediments (mean grain size 0.53 mm). Sediments in “tides only” regions (~20% of the Australian GEOMAT region) are characterised by deep water depths (mean of 103 m), high carbonate content (~73.5%), highest mud content (~29%), and fine grained sediments (mean grain size 0.26 mm). This suggests that “waves only” regions are more efficient at winnowing and dispersing mud and finer grained sediment, and leaving behind a coarse lag deposit, than “tides-only” regions.

Regionalisation of the Australian GEOMAT region based on the physical energy regime and measurement of sediment mobility might provide an objective basis for predicting the spatial and temporal nature of benthic habitats. For example, Shephard (1983) and Poiner & Kennedy (1984) showed that the mobility of the substrate had an inverse relationship with the biodiversity and abundance of benthic species, with bedforms having the lowest abundance and diversity. Todd *et al*. (2000) have also suggested that on sediment-mantled continental shelves, benthic habitats are distinguished by sediment composition and grain size properties, together with the rate of sediment transport and the frequency of the resuspension of detritus during storm and current events.

Table 5.1. Areas of six different energy regime categories in relation to the observed mean grain size. The % <300 m is a percentage area of the Australian GEOMAT region for which calculations were carried out (i.e., excluding the south-south western portion of Australia’s shelf). This area totals 1866000 km^2.

Category	Area km^2	% <300 m	Mean Depth (m)	Mean Carbonate (%)	Mean Mud (%)	Mean Grain size (mm)
Waves only	624,280	33.5	39.37	58.83	18.49	0.53
Waves dominate	9,862	0.53	17.80	61.18	20.69	0.32
Mixed	75,223	4.0	29.04	65.35	17.83	0.35
Tides dominate	506,300	27.1	48.43	62.19	28.12	0.29
Tides only	378,090	20.3	103.35	73.57	29.52	0.26
Zero mobility	241,830	13.0	120.85	72.19	17.39	0.48

5.3.3 Limitations of the GEOMAT Model and Future Developments

Several simplifying assumptions are made in the GEOMAT model as it presently stands. These assumptions are made for two reasons: 1) to make the computations simpler, reducing the resources required to address the problem; and 2) because the data coverage is simply not sufficient for many variables required to make informative improvements to the model. For example, GEOMAT currently assumes all sediments are non-cohesive, constant density quartz spheroids. To improve on this assumption, quantities such as bulk density, measured sediment settling velocities and internal friction are required. These variables are virtually un-known for Australian marine sediments.

Another apparent significant limitation of the GEOMAT model is that the only hydrodynamic processes considered are surface gravity waves, including swell and locally-generated wind waves, and tides. The effects of density-driven ocean processes, such as the large scale intruding ocean currents (eg, the East Australian Current and the Leeuwin Current) and internal gravity waves, and locally generated wind-driven circulation, on sediment mobilisation are not considered. Intrusive ocean currents have previously been estimated to control sediment transport and dispersal over approximately 1 % of the Australian continental shelf (Harris, 1995), with the only location at which such currents are known to dominate sediment movement around Australia being the shelf offshore from Fraser Island where the East Australian Current intrudes. Although internal waves have been reported to have initiated sediment resuspension on the Californian continental shelf (Bogucki *et al*., 1997), few observations have been made as internal waves tend not to propagate close to the sea-floor, and consequently are not a dominant process in mobilising sediments.

Internal waves of extra large amplitude are well documented on the Australian north-west shelf (Holloway *et al.*, 1997). However, the influence of the large tides can be expected to remain the dominant process with regards to mobilising bed-sediments in this region. Hemer *et al.* (2004) carried out a modelling study to determine the ocean processes dominating sediment mobilisation on a localised scale in Torres Strait and the Gulf of Papua, considering all of tides, waves, density-driven ocean circulation, and wind-driven circulation. Sediment mobilisation as a result of tides and waves accounted for more than 90% of the resuspension events on the continental shelf in the study area. Although the ocean processes not presently part of the GEOMAT model (ie, density-driven circulation and wind-driven circulation) may be locally important, the available evidence indicates that waves and tides account for more than 90% of the resuspension of surface sediments on the Australian continental shelf.

Critical information for many management questions relating to sediment supply on the continental shelf is what potential these oceanographic processes have for mobilising sediments of *all* grain sizes on the continental shelf. Mean grain sizes observed on the continental shelf are in part a product of the fact wave and tide processes have already worked the sediments. A planned development for future versions of the GEOMAT model is to calculate the mobilisation for a full spectrum of grain sizes ranging from fines through to coarse sands, as-well as the single mean grain size, so that the model can predict the minimum grain size that is mobilised for some significant period of time. The benefit of this is the ability to determine the fate of sediments supplied to the continental shelf and relate this information to regionalisations based on dominating energy regimes.

5.3.4 Integration with Bioregionalisation

Geological data, particularly geomorphic units have been used extensively in bioregionalisations in Australia. Research has shown the links between benthic marine biota and substrates (eg Kostylev *et al*., 2001; Ferns & Hough, 2002).

Geological data have obvious benefits: geomorphic features are interpreted from bathymetric data with excellent coverage. This contrasts with the often patchy nature of biological data, particularly in deeper water. Even though there are significant gaps in sediment data, the coverage is still much greater than for biological data. What is not clear, however, is the degree to which geomorphic features and/or sediment properties can be used as surrogates for marine biota or communities. This is a relatively new field of research and to date little has been done in Australia. Some studies have focussed on a restricted range of sediment parameters or have had to deal with datasets which have not been collected concurrently (eg Passlow *et al*., 2002).

In areas such as the Gulf of Carpentaria, there is good evidence for correlation between some sediment properties and the distribution of infauna, including prawn species (Long & Poiner, 1994; Somers, 1994); but not for demersal fishes (Blaber *et al*., 1994). In the south-east region, fisheries data have shown a correlation between fish distributions and seabed type (Williams & Bax, 2001). The distinction between hard and soft substrate type was identified as important in faunal correlation (Williams & Bax, 2001); while the geology of hardgrounds determined their susceptibility to damage (Bax & Williams, 2001).

Research in Bass Strait carried out by Geoscience Australia and the Museum of Victoria (O'Hara & Passlow, 2002; Passlow *et al*., 2002) shows that while relationships between substrates and biota may be clear on the local scale; on a regional scale, such relationships do not necessarily hold. Research currently being carried out by Geoscience Australia and CSIRO Marine Research using biota and sediment samples from the Gulf of Carpentaria will help to elucidate the extent to which sediment properties can be used as surrogates for biota. Similarly, research, such as the project on Seabed Biodiversity on the continental shelf of the Great Barrier Reef World Heritage Area, currently being carried out through the Reef Co-operative Research Centre will enhance understanding of surrogates. Part of the work of this project is to develop transferable single-beam acoustic remote sensing methods for mapping seabed and assess the performance of acoustics as a surrogate for patterns in seabed species, assemblages and communities.

One of the issues in trying to relate sediment data to biota distribution has been use of historical sediment data. In areas where there is high variability in the environment, variations due to changes over time can mask any patterns in relation to biota (Bustamante, pers comm., 2004). Ideally, investigating the relationships between sediments and biota needs to be based on material collected concurrently. Once relationships have been established and the most relevant parameters identified, existing sediment data can be used to characterise regions with greater confidence.

Many of the sediment facies in Australian waters strongly reflect the biotas which grow in and on them. Both the cool-water carbonates of the south and tropical carbonates in the north have significant quantities of biogenic material. Research in the south-west of Australia has shown that the sediments produced are a reflection of a combination of oceanography, morphology and biota (James *et al*., 2001). Investigation of the biota preserved in sediments in Torres Strait by

Geoscience Australia (Post *et al*., in press) has shown that fossil content and, in particular, the distribution of benthic foraminifera in the sediments, can provide a detailed assessment of habitats, based on their correlation with environmental variables.

5.4 Strategic Directions

5.4.1 MARS as a National Fundamental Dataset and Development of a Public Access Website

Geoscience Australia will continue to support and develop MARS in line with custodianship guidelines for National Fundamental Datasets. Sediment samples from the coastal zone will also be included, with links to Geoscience Australia's OzEstuaries initiative. The MARS public access web site is scheduled for launch in February 2005.

5.4.2 New Data Collection

Areas of low sediment sample density have been identified during this project (see Section 5.1.1 above). This information can be used to inform planning of future research cruises in support of protection of biodiversity and the regional marine planning process. For example, in the South-west Marine Domain, the identification of data gaps will be invaluable in planning focus areas for study of sediments.

A quick audit by Geoscience Australia of sediment samples that have been collected but not analysed has indicated the potential for a significant increase in quantitative data coverage (about 45% of this project's marine domain area) if these samples are analysed using current techniques. The regions which would primarily benefit form this are the South-west and Western-central Marine Domains, although other domains would benefit from sample data in deeper waters, especially the South-east. These initial findings require confirmation by detailed audit. The samples are a valuable resource, as many have been collected in deeper-water areas where very little work has been done due to the costs and difficulty of obtaining samples.

This project has also highlighted the lack of quantitative sediment data in the South-west Marine Domain (6% coverage at 100 km sample spacing), the area that the National Oceans Office has identified for its next Marine Planning Area. Geoscience Australia's audit shows that sediment data coverage for the South-west Domain will benefit greatly (increased coverage of about 71% based on a 200 km sample spacing) should existing samples be analysed. Ideally, the South-west Marine Domain could be used as a pilot study in order to test the utility of analysing existing material.

Collaboration with researchers from Adelaide/Queens/Curtin Universities, who have carried out extensive studies of cool water carbonates in southern and south-western Australian waters, should also be considered for studies in the Western-central or South-west Marine Domains.

5.4.3 Continue Research into Sediments as Proxies

Geoscience Australia is continuing to investigate the utility of proxies through detailed research into sediment – biota links with current and proposed research programs, looking at environmental characteristics and including biogenic content of sediment samples.

Other existing data which could be collated to provide information useful in characterising the seafloor includes:

- video and still photographic data, which can be added to MARS
- collating and mapping hardgrounds, reefs and rocky outcrops
- sediment thickness
- acoustic facies mapping, already undertaken by Geoscience Australia for sections of the Great Australian Bight (Rollet *et al*. 2001), and by Whitmore & Belton, (1997) to the south of Tasmania.

5.4.4 Continue Research into Application of GEOMAT Sediment Modelling

The GEOMAT model is under development. The principal development presently is modelling the non-linear interaction between waves and tides on sediment mobility. Another future development is to give the model the ability to calculate the mobilisation for a full spectrum of grain sizes so that statistics on the length of time the different grain sizes are mobilised can be predicted. These and other developments would increase the explanatory power of the model and augment its application for bioregionalisations. However, the generation of additional sediment data from new and existing sediment samples is needed to improve the quality and consistency of the input data used in the modelling.

5.4.5 Continue Population of MARS with Historical Data

Geoscience Australia has accepted the role as the custodian of seabed sediment data for the Australian Maritime Jurisdiction, and will continue to populate MARS with its own data together with other sources as time and available resources permit. Time and financial assistance will be required for most universities to compile non-digital data. Equally crucial would be the timing of such work. Our communication with university staff showed that requests for data which were targeted at vacation time were far more successful. Organisations such as CSIRO Marine still hold valuable datasets that could not be accessed in the timeframe of this project.

One of the purposes of this project is to promote this custodianship role within the marine science community and among environmental managers and stakeholders. MARS will provide a central repository where they can either obtain or provide marine sediment data.

6 Conclusions

Following the development and population of the MARS database, sediment grain size, carbonate content and mobility have been mapped around the continental margin. This is the first continent-scale map, based solely on quantitative data. The exercise of identifying and collating sediment data has highlighted areas where little work has been done either to collect sediment samples or, in some cases, to analyse grain size and related properties from existing samples. Based on a coarse scale of resolution using sample spacing of less than 100 km, some 70% of the continental margin lacks quantitative data.

A comparison of sediments with geomorphic features shows that while there is a broad relationship between mean grain size and major geomorphic units, in particular the distinction between shelf and slope, at a finer scale, sediment properties reflect a range of factors. Sediment mobility is a significant factor and the production of an energy regime regionalisation adds to the knowledge available to bioregionalisation.

The MARS database will provide a basis for planning future research. The gaps in data highlight regions where little sampling has taken place. This project has also identified areas where samples exist but have not been quantitatively analysed. The potential for these samples to be analysed would provide a cost-effective means to add to knowledge of marine sediments, especially in the South-west Marine Domain.

In addition to continued acquisition of sediment data, continuing research into the links between geological properties and biota is important to better inform the use of geological proxies in bioregionalisation. Geological data have obvious benefits: even with significant gaps in quantitative sediment data, the coverage is still far greater than for biological data. Additional data, much of which is readily available, which could benefit this work, include video and still photographic data, mapping of hardgrounds, reefs and rocky outcrops, sediment thickness and acoustic response data.

The creation of the MARS database marks the transition to a new era of easy internet access to quantitative seafloor information.

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    - Northern Fisheries
    - Geological Survey
- NSW Department of Mineral Resources
    - Geological Survey
- Victorian Department of Sustainability and Environment
    - Marine Strategy
- University of Western Australia
- University of Newcastle

Published Data Sources:

- Alongi (1992)
- Blom and Alsopp (1988)
- James *et al*. (1999)
- Maxwell (1968)

Unpublished Data Sources:

- Bryce (1988)
- Clark (1985)
- Gray (1996)
- Lees (1987)
- Logan (1959)
- Parker (1997)
- Slater (1969)

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Appendix 1 – Project Staff

Dr Vicki Passlow	Project co-ordinator, report writing, sedimentology expertise, interaction with bioregionalisation team
John Rogis	Data Collation Manager, report writing
Alison Hancock	MARS Database Administrator, report writing
Dr Mark Hemer	GEOMAT Modelling, report writing
Dr Kriton Glenn	Sedimentology expertise, report writing
Murray Woods	Mapping and GIS output
John Ryan	Project Leader, Database Development Group
Ahsanul Habib	Database and Web Developer
Geoff Tuckerman	Web Developer
Jonathan Edwards	Database Population
Kristy Bewert	Database Population
Emma Punyer	Database Population
Amber Vine	Database Population
Danielle Thomson	Database Population
Edward Pask	Database Population

Appendix 2 – Details of Organisations Contacted and Identified Data Sources.

Commonwealth Agencies and Organisations

- ***Australian Institute of Marine Science*** – sediment data is collected as an adjunct to other studies, and is not a high corporate priority for collation. Datasets reside with individual scientists responsible for various projects and cruises. The quality and distribution of available data has not been determined by the organisation. The determination of sample grain size and carbonate content has not been a high priority for their research. They have not provided data to date.

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- ***CSIRO Marine Research*** - sediment data is collected as an adjunct to other studies. Data collected in the Northern Region has been made available to Geoscience Australia for MARS input. For other regions, sediment data has not been a high priority for collation by the organisation. These datasets reside with individual scientists responsible for various projects and research cruises, and have not been systematically compiled. In other cases sediment data was sourced outside the organisation e.g., NWS JEMS, for which data were obtained from Geoscience Australia. Unfortunately, some data may be difficult to locate as the researchers have retired or left the organisation.

Geoscience Australia has identified suitable datasets from the published literature and CSIRO cruise reports and has contacted individual CSIRO employees. Some additional data has been obtained for the Northwest Shelf.

- ***Australian Oceanographic Data Centre*** - the AODC holds about 50,000 to 60,000 mostly descriptive data points. Of this set, about 7,000 data points collected by Hydrographic Survey ships are considered publicly available, subject to resolution of National Security issues.

Following a number of discussions with AODC/Navy personnel, Geoscience Australia determined that this database was not suitable for inclusion in MARS for the National Bioregionalisation programme.

Northern Territory State Government

- ***Geological Survey*** – no data.
- ***Petroleum Environmental Group*** – no data.
- ***Fisheries*** - basic deck descriptions, not systematically recorded and of limited or no value for MARS input.
- ***Parks and Wildlife*** - agreement has been reached for the inclusion of the Beagle Gulf Benthic survey in MARS.
- ***Environment and Heritage*** – no suitable datasets.

Queensland State Government

- ***Geological Survey*** – have provided some digital data from the Gulf of Carpentaria. Other coastal data available from unpublished reports and published literature, no new surveys over last 10 years. Changes in staffing have limited the assistance that can be provided for data compilation.

- ***Northern Fisheries*** – a data access agreement is currently being negotiated. They have provided an extensive dataset for the eastern Queensland coast.

NSW State Government

- ***Geological Survey*** – extensive coastal dataset collected by Peter Roy (now retired), available in paper format only, kept in an office at Sydney University. Access to this data has been granted to Geoscience Australia, and numeric data points have been added to MARS.
- ***Department of Commerce*** (formerly Public Works) – most data is beach or nearshore coastal with copies for most datasets held in P Roy's collection.

Victorian State Government

- ***Department of Sustainability and Environment*** – their coastal dataset has been provided to Geoscience Australia for inclusion in MARS.

Western Australian State Government

- ***Geological Survey*** – no data.
- ***Petroleum Environmental Group*** – no data.
- ***Conservation and Land Management*** - may have some data from marine conservation reserve studies – located within State waters and not a priority for collation.

South Australian State Government

- ***Geological Survey*** – no data.
- ***Petroleum Environmental Group*** – no data.

Local Councils

- ***Gold Coast City Council*** – offshore surveys undertaken to find beach replenishment sands, initial contacts made but no data supplied to date.

Universities

- ***Northern Territory*** – no reply to Geoscience Australia's initial request.
- ***James Cook - Qld*** – continued support offered for MARS, but data provision restricted by lack of resources available for compilation. Unknown number of data points
- ***Qld Uni*** – no reply to Geoscience Australia's initial request.
- ***Newcastle University*** – support offered for MARS with unrestricted access to data points (mostly descriptive).
- ***University of NSW*** – no datasets suitable for MARS input.
- ***Sydney University*** – support offered for MARS – Geoscience Australia has compiled an extensive dataset from published reports and unpublished theses.
- ***Wollongong University*** – no reply to any of Geoscience Australia's approaches.

- ***Australian National University*** **-** support offered for MARS – data compiled from published sources.
- ***Curtin University – WA*** **-** support offered for MARS, but assistance restricted by lack of time and resources. No data provided as yet. Unknown number of data points.
- ***WA University*** - support offered for MARS, and assistance given in the compilation of thesis data.
- ***SA University*** – declined to support MARS. They have an extensive data set for the Great Australian Bight and Southwest WA, but have decided not to release it before their research is completed.
- ***Flinders University*** **-** no reply to Geoscience Australia's initial request.

Offshore Petroleum Explorers

- Approaches have been made to Woodside, OMV and Coogee Resources. No positive responses have been received to date.

Offshore Mineral Exploration

- Bauxite exploration in the Gulf of Carpentaria – reports have been obtained and data collated.
- Diamond exploration in the Bonaparte Gulf both digital data and reports have been obtained.
- Sand/aggregate exploration – offshore NSW identified.
- Marine phosphate exploration – Great Australian Bight and south-west Western Australia – reports have been obtained.

Consultants

- CEE Consultants – initial contact made, no further response.
- GHD Victoria – initial contact made, no further response.
- DAL Science and Engineering – initial contact made, no further response.

International Organisations

- ***US Geological Survey (USGS)*** – researcher contacted, unable to assist with data.

International Databases

- ***National Geophysical Data Centre (NGDC)*** – online database search completed.
- ***Ocean Drilling Programme (ODP)*** – online database search completed.
- ***Deep Sea Drilling Programme (DSDP)*** – online database search completed.
- ***Scripps Institute of Oceanography (SIO)*** – online database search completed.
- ***EU-SEASED*** – online database search completed. Information obtained on cruise and sample locations, but sample analysis data not available on website. European agencies will need to be contacted directly.
- ***Antarctic Research Facility – Florida State University*** – online database search completed.

- ***World Data Centre for marine geology and geophysics, Gelendzhik*** – appears to contain information on Russian Cruises – web site not functioning correctly.

Russian Cruises

Extensive work has been undertaken in the Southern and Indian Oceans in the 1950's-60's by Russian researchers in the vessels 'OB' and 'VITYAZ'. Options for obtaining this data are either via the World Data Centre detailed above, or from translations of cruise reports, whose availability has not been confirmed. The data should be comprehensive and high quality, but mostly located in the southern Ocean towards Antarctica.

Global Expeditions

Five have been identified as follows:

Identification	Vessel	Dates	Origin
Galathea Expedition	Galathea	1845-47	Danish
British Challenger Expedition	Challenger	1872-76	British
Carlsberg Foundation	Dana II	1928-30	Danish
Albatross Expedition	Albatross	1947-48	Swedish
Danish Deep Sea Round the World	Galathea II	1950-52	Danish

Two of these – the British Challenger and Danish Deep Sea Round the World - have been identified as collecting samples in Australian Waters. The remainder are yet to be assessed.

Research Theses

Honours, Masters and PhD dissertations held by various Universities contain valuable data that can be included in MARS, once ownership and IP issues have been addressed. Geoscience Australia has identified 25-30 that contain relevant information. In most cases, IP for the data rests with the Author, and they need to be found, contacted and data supply agreements negotiated. This is a time-consuming process, but is necessary due to the value and relevance of many of the datasets.

Literature Surveys

These have yielded additional data for previously completed cruises, and identified further potential data sources.

Appendix 3 – ArcGIS Mapping Parameters

Gravel, Sand, Mud, Carbonate and Mean Grainsize Maps:

- data imported to ArcGIS in csv format
- interpolate to raster using:
    - inverse distance weighted interpolator
    - cell size of 0.01 decimal degrees (dd) – about 1 kilometre
    - search radius of 12 points
    - maximum extrapolation distance of 0.45 dd – about 45 kilometres
- raster image clipped to Australian Economic Exclusive Zone limit and the National Mapping 1:250,000 coastline from the National GIS.
- additional clip areas were added where interpolator extrapolation produced artefacts that were not consistent with the surrounding data points.

Seabed sediment type – Folk Classification

- samples allocated to one of 15 Folk sediment type classifications based on gravel/sand/mud percentages prior to ArcGIS import
- data imported to ArcGIS in csv format
- interpolate to raster using:
    - Euclidian distance interpolation
    - cell size of 0.01 decimal degrees (dd) – about 1 kilometre
    - maximum extrapolation distance of 0.45 dd – about 45 kilometres
- raster image clipped to Australian Economic Exclusive Zone limit and the National Mapping 1:250,000 coastline from the National GIS.
- additional clip areas were added where interpolator extrapolation produced artefacts that were not consistent with the surrounding data points.

Wave and Tide Exceedance, Energy Regime Regionalisation

- data exported from MATLAB application (see Glossary) as ASCII grid files
- data converted to ESRI grid format in ArcToolbox using ASCII Import to Raster option
- raster image clipped to Australian Economic Exclusive Zone limit and the National Mapping 1:250,000 coastline from the National GIS.

Appendix 4 – GEOMAT Modelling Calculations

Method for computing wave-induced sediment threshold exceedance
The wave induced threshold of sediment movement for the observed grain size distribution around the continental margin of Australia has been estimated using Airy, first order wave theory (Komar & Miller, 1973).

Water depths were approximated from Geoscience Australia's bathymetry model. This bathymetric model was interpolated to a grid spacing of 0.01°.

The observed grain size distribution has been determined from grain size data available from the Geoscience Australia's MARS database, as described in Section 3.5.3. The mean grain size data was interpolated onto the same 0.01° grid as the bathymetry.

Geoscience Australia holds five years of wave model, WAM, output for the period March 1997 to February 2002, inclusive. The data are 6-hourly predictions of significant wave height, mean wave period, and mean wave direction, gridded at 0.1° spatial resolution. The high resolution wave model (0.1°) was run at the Australian Bureau of Meteorology. The wave model includes both swell waves generated outside of the model domain, and those locally-generated wind-waves generated inside the model domain as a result of storm and cyclone events.

The GEOMAT program interpolates the wave model outputs onto the bathymetry and mean grain size grids and determines 6-hourly estimates of the maximum near-bed wave orbital velocity. The number of times that this value exceeds the threshold value, at which speed non-cohesive sediment of mean grain size is mobilised (Clifton & Dingler, 1984), is then computed at each bathymetric grid point. These are converted to a percentage of time, and presented as a map of wave induced threshold exceedance on the Australian GEOMAT region.

Method for computing tide-induced sediment threshold exceedance
The mean grain size grid, with a spatial resolution of 0.01°, as used for the wave induced threshold exceedance, was used to calculate the threshold current speed, (the current speed at which non-cohesive sediments of mean grain size are initially mobilised) within the Australian GEOMAT region (Miller *et al*., 1977). Hourly-averaged, depth-averaged tidal currents were estimated using a hydrodynamic tidal model for the Australian continental shelf with a spatial resolution of 0.067° in both latitude and longitude. The tidal model was time-stepped through a spring-neap cycle (roughly two weeks) and hourly averages were output.

Within the GEOMAT package, the tidal model outputs are interpolated onto the 0.01° resolution bathymetry and mean grain size grids to obtain hourly estimates of the depth-averaged tidal current velocity. The number of times that the hourly current speed exceeds the threshold value is computed at each bathymetric grid point, and a percentage of time for which tidal currents exceed the sediment threshold exceedance is determined, and presented as the tidal-induced sediment threshold exceedance.

Appendix 5 – Statistics for Quantitative Data Coverage.

APPENDIX 5A QUANTITATIVE DATA COVERAGE SUMMARY - GRAVEL/SAND/MUD%

MARINE DOMAIN	On Shelf Data Point Coverage						SHELF AREA
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Shelf%	(km2)	Shelf%	(km2)	Shelf%	(km2)
Northern + Torres	226,210	41%	426,134	77%	545,285	99%	551,000
North-east	139,783	63%	189,769	85%	219,865	99%	223,000
Eastern-central	52,628	88%	57,498	96%	58,638	98%	60,000
South-east	118,407	54%	163,581	75%	192,805	88%	219,000
South-west	1,148	0%	2,568	1%	26,550	9%	307,000
Western-central	486	1%	983	2%	2,073	3%	63,000
North-west	93,560	31%	169,548	56%	224,631	74%	302,000
West-northern	132,690	53%	208,255	83%	243,975	98%	250,000
TOTALS	**764,912**	**39%**	**1,218,338**	**62%**	**1,513,821**	**77%**	**1,975,000**

MARINE DOMAIN	Off Shelf Data Point Coverage						OFF SHELF
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Off%	(km2)	Off%	(km2)	Off%	AREA (km2)
Northern + Torres	1,548	7%	2,266	11%	3,483	17%	21,000
North-east	19,504	2%	41,503	4%	102,358	10%	1,013,000
Eastern-central	22,279	4%	44,547	8%	88,615	15%	593,000
South-east	29,650	3%	80,064	8%	206,986	21%	975,000
South-west	2,007	0%	10,784	1%	34,630	5%	747,000
Western-central	107	0%	555	0%	2,506	1%	484,000
North-west	66,259	11%	118,199	19%	168,660	28%	610,000
West-northern	9,904	34%	13,030	44%	13,057	44%	29,500
TOTALS	**151,257**	**3%**	**310,949**	**7%**	**620,294**	**14%**	**4,472,500**

MARINE DOMAIN	Total Domain Data Point Coverage						DOMAIN
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Total%	(km2)	Total%	(km2)	Total%	AREA (km2)
Northern + Torres	227,757	40%	428,400	75%	548,768	96%	572,000
North-east	159,287	13%	231,272	19%	322,223	26%	1,236,000
Eastern-central	74,907	11%	102,045	16%	147,252	23%	653,000
South-east	148,056	12%	243,645	20%	399,791	33%	1,194,000
South-west	3,155	0%	13,352	1%	61,180	6%	1,054,000
Western-central	592	0%	1,539	0%	4,579	1%	547,000
North-west	159,819	18%	287,748	32%	393,291	43%	912,000
West-northern	142,595	51%	221,285	79%	257,031	92%	279,500
TOTALS	**916,168**	**14%**	**1,529,286**	**24%**	**2,134,115**	**33%**	**6,447,500**

APPENDIX 5B QUANTITATIVE DATA COVERAGE SUMMARY - CARBONATE%

On Shelf Data

MARINE DOMAIN	On Shelf Data Point Coverage						SHELF AREA (km2)
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Shelf%	(km2)	Shelf%	(km2)	Shelf%	
Northern + Torres	112,866	20%	185,458	34%	259,080	47%	551,000
North-east	142,510	64%	182,097	82%	208,976	94%	223,000
Eastern-central	53,048	88%	58,570	98%	59,892	100%	60,000
South-east	116,876	53%	163,046	74%	194,319	89%	219,000
South-west	1,149	0.4%	2,581	1%	20,728	7%	307,000
Western-central	12,598	20%	18,193	29%	24,184	38%	63,000
North-west	70,941	23%	151,609	50%	213,854	71%	302,000
West-northern	104,869	42%	186,581	75%	234,671	94%	250,000
TOTALS	**614,857**	**31%**	**948,135**	**48%**	**1,215,704**	**62%**	**1,975,000**

Off Shelf Data

MARINE DOMAIN	Off Shelf Data Point Coverage						OFF SHELF AREA (km2)
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Off%	(km2)	Off%	(km2)	Off%	
Northern + Torres	1,543	7%	2,239	11%	3,219	15%	21,000
North-east	27,542	3%	50,666	5%	113,413	11%	1,013,000
Eastern-central	23,165	4%	46,489	8%	86,849	15%	593,000
South-east	26,722	3%	74,505	8%	205,003	21%	975,000
South-west	94	0.01%	3,358	0.4%	28,952	4%	747,000
Western-central	121	0.03%	1,783	0.4%	6,490	1%	484,000
North-west	62,992	10%	115,556	19%	165,510	27%	610,000
West-northern	9,425	32%	12,993	44%	13,125	44%	29,500
TOTALS	**151,605**	**3%**	**307,590**	**7%**	**622,560**	**14%**	**4,472,500**

Total Domain Data

MARINE DOMAIN	Data Point Coverage						DOMAIN AREA (km2)
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Total%	(km2)	Total%	(km2)	Total%	
Northern + Torres	114,409	20%	187,697	33%	262,299	46%	572,000
North-east	170,053	14%	232,763	19%	322,389	26%	1,236,000
Eastern-central	76,213	12%	105,059	16%	146,741	22%	653,000
South-east	143,598	12%	237,551	20%	399,322	33%	1,194,000
South-west	1,243	0.1%	5,939	1%	49,680	5%	1,054,000
Western-central	12,719	2.3%	19,976	3.7%	30,674	6%	547,000
North-west	133,932	15%	267,165	29%	379,364	42%	912,000
West-northern	114,294	41%	199,574	71%	247,797	89%	279,500
TOTALS	**766,461**	**12%**	**1,255,725**	**19%**	**1,838,264**	**29%**	**6,447,500**

Glossary

ArcGIS – A GIS software suite developed by Environmental Systems Research Institute, Inc (ESRI).

GEOMAT – Geoscience Australia's GEological and Oceanographic Models for Australia's ocean Territory package that simulates the initiation of grain movement on the continental shelf under the influence of tidal currents and surface swell waves.

Georeferencing – The process of assigning a coordinate system that associates map or image data with a specific location on the earth, allowing this data to be viewed, queried, and analyzed with other geographic data.

GIS – Geographic Information System

Gravel – That component of a sediment sample where the particle size is greater than 2 millimetres, usually expressed as a weight percent.

MARS – Geoscience Australia's Marine Sediments Database

MATLAB – an intuitive language and a technical computing environment. It provides core mathematics and advanced graphical tools for data analysis, visualization, and algorithm and application development.

Mud – That component of a sediment sample where the particle size is less than 0.063 millimetres, usually expressed as a weight percent.

National Fundamental Marine Datasets - Datasets that are consistently required for marine planning no matter what region is under scrutiny. The goal is to provide a series of fundamental marine datasets under the auspices of the National Spatial Data Access and Pricing Policy. Ongoing custodianship of Fundamental datasets should be provided by appropriate organizations. Custodianship will involve maintaining and updating information in databases built to nationally agreed (ANZLIC) standards, listing dataset with appropriate meta-data libraries and providing public access to data at the marginal cost of transfer

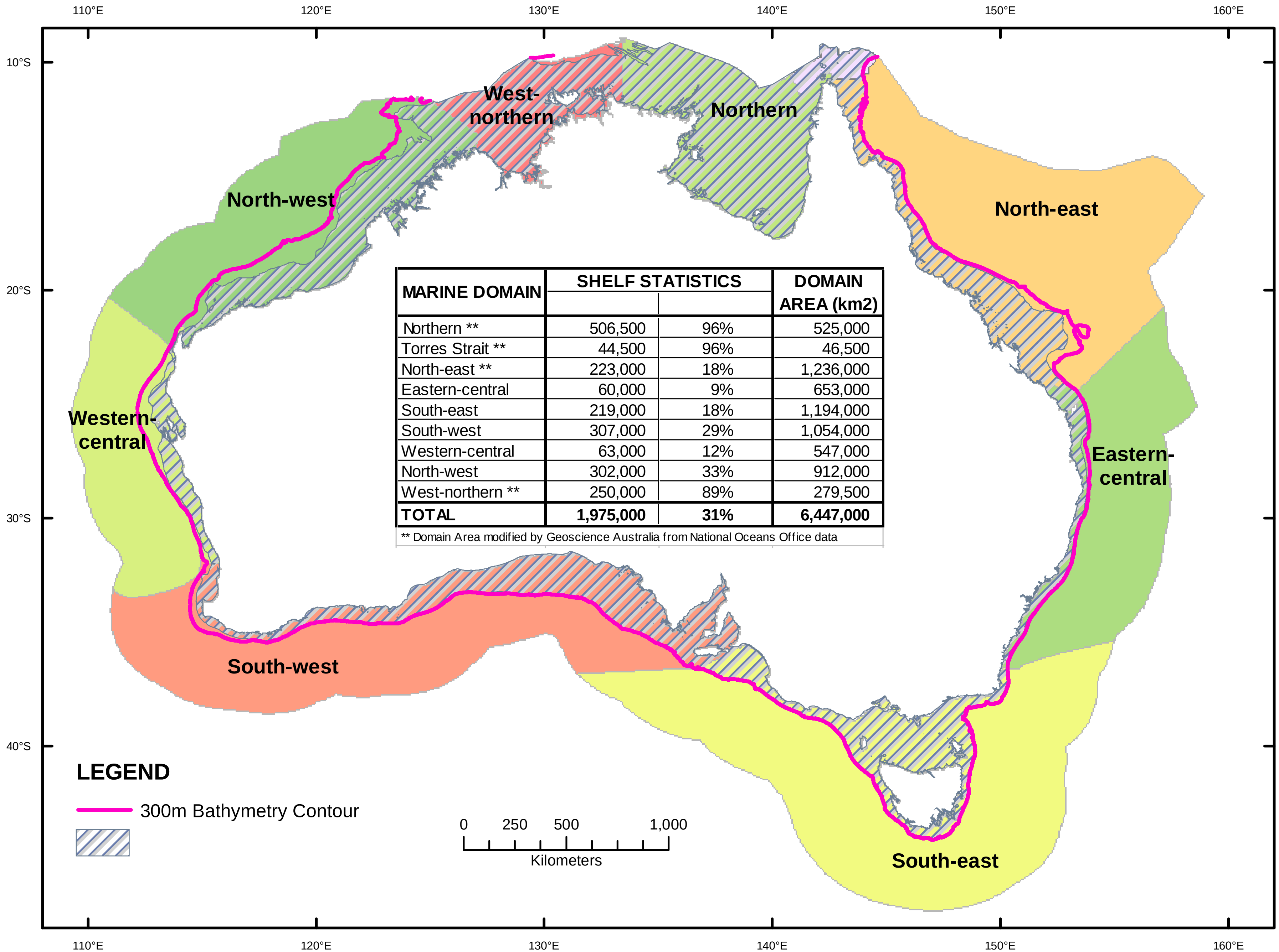
Sand – That component of a sediment sample where the particle size is less than 2 millimetres, but greater than 0.063 millimetres, usually expressed as a weight percent.

Shelf – The definition used for continental shelf is the geomorphic shelf, as defined by Harris *et al*., 2004. The shelf is divided into inner, mid and outer shelf areas. The inner shelf is defined as that area of the shelf closest to the coastline. Outer shelf is that area of the shelf adjacent to the shelf break. Mid shelf is the region between the inner and outer shelf.

Shelf break – identified as "the sudden change in seabed gradient (highlighted by closely spaced contours) that occurs at the boundary between the outer shelf and upper slope".

Slope – Slope seaward from the shelf edge to the upper edge of a continental rise or the point where there is a general reduction in slope. The upper slope is that part of the slope adjacent to the shelf break.

World coordinates – The features on a map that reference the actual locations of the objects they represent in the real world.



MARINE DOMAIN	SHELF STATISTICS		DOMAIN AREA (km2)
Northern **	506,500	96%	525,000
Torres Strait **	44,500	96%	46,500
North-east **	223,000	18%	1,236,000
Eastern-central	60,000	9%	653,000
South-east	219,000	18%	1,194,000
South-west	307,000	29%	1,054,000
Western-central	63,000	12%	547,000
North-west	302,000	33%	912,000
West-northern **	250,000	89%	279,500
TOTAL	**1,975,000**	**31%**	**6,447,000**

** Domain Area modified by Geoscience Australia from National Oceans Office data

Figure 3.1 - Distribution of Marine Domains and continental shelf around the Australian continental margin (modified after National Oceans Office 2004)

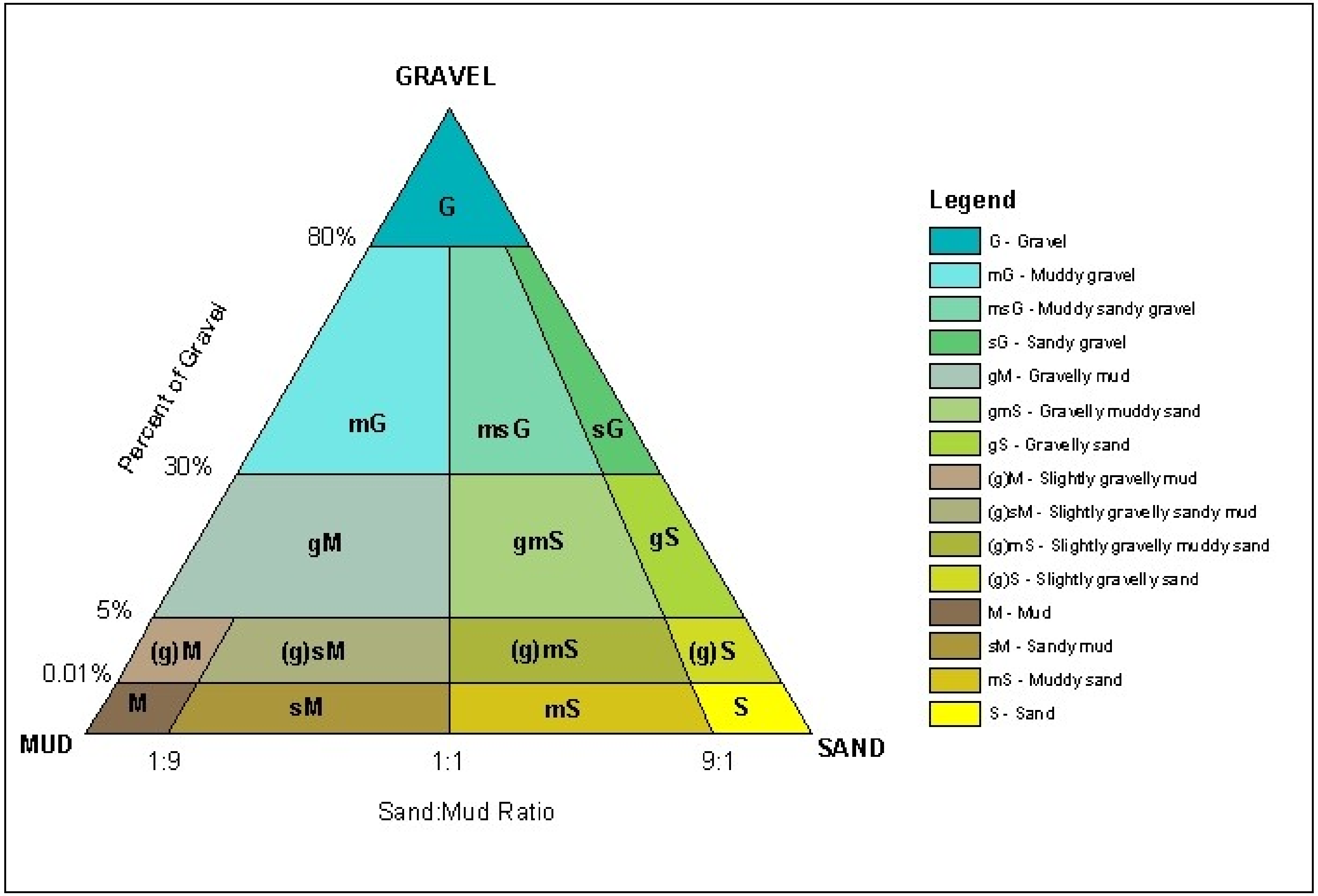
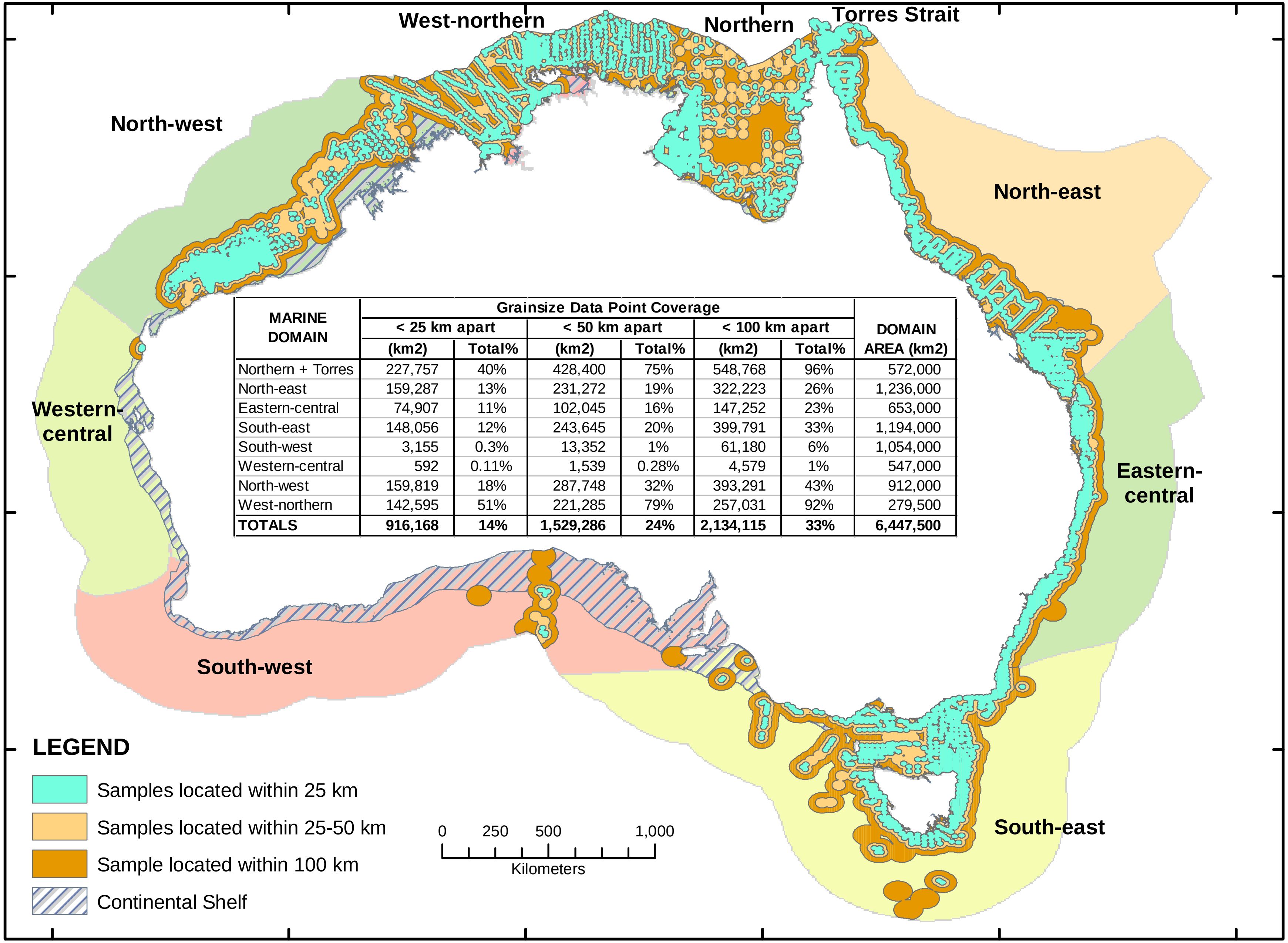
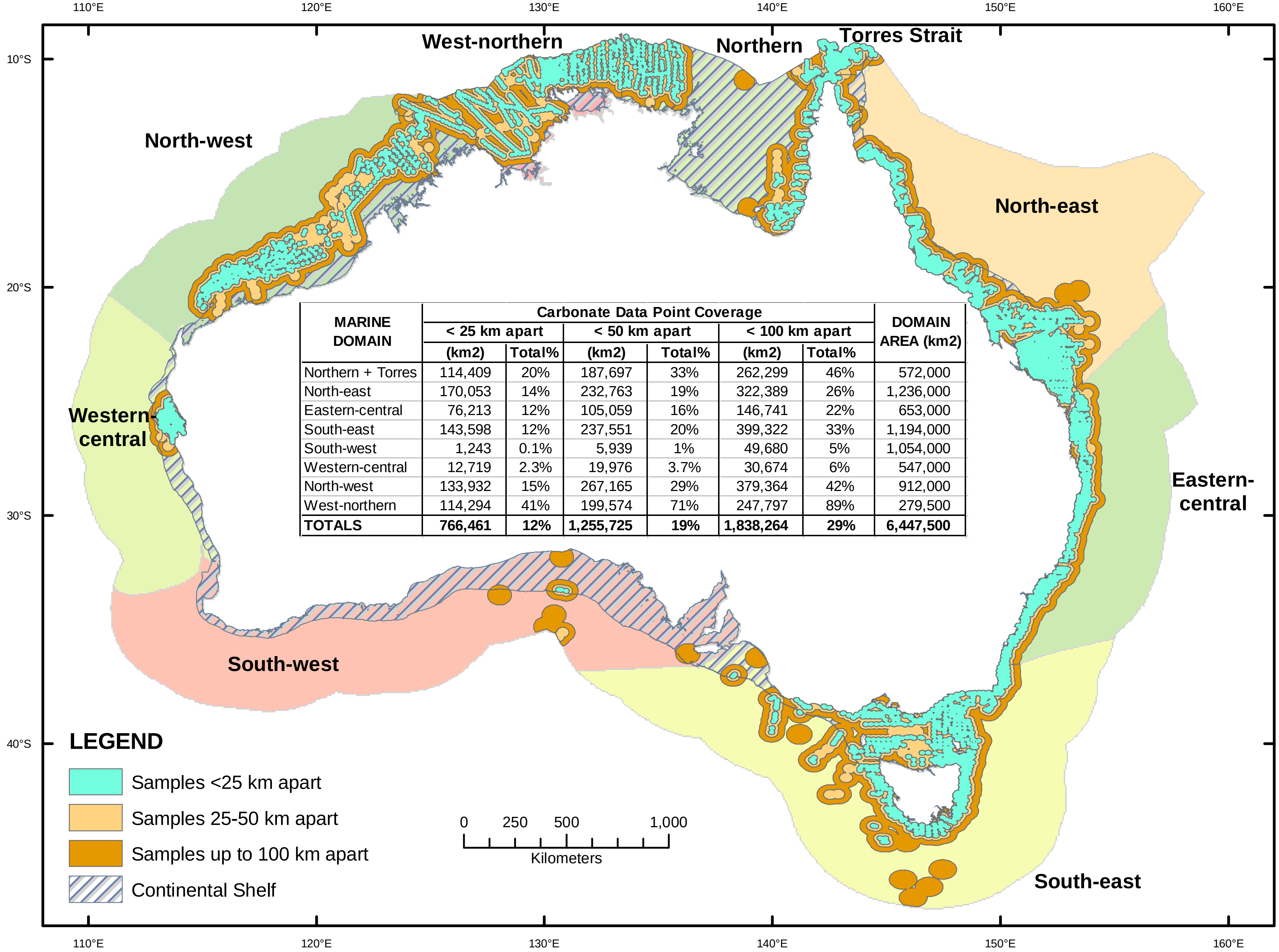


Figure 3.2. Triangular diagram showing sediment textural groups for Gravel/Sand/Mud constituents.



MARINE DOMAIN	Grainsize Data Point Coverage						DOMAIN AREA (km2)
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Total%	(km2)	Total%	(km2)	Total%	
Northern + Torres	227,757	40%	428,400	75%	548,768	96%	572,000
North-east	159,287	13%	231,272	19%	322,223	26%	1,236,000
Eastern-central	74,907	11%	102,045	16%	147,252	23%	653,000
South-east	148,056	12%	243,645	20%	399,791	33%	1,194,000
South-west	3,155	0.3%	13,352	1%	61,180	6%	1,054,000
Western-central	592	0.11%	1,539	0.28%	4,579	1%	547,000
North-west	159,819	18%	287,748	32%	393,291	43%	912,000
West-northern	142,595	51%	221,285	79%	257,031	92%	279,500
TOTALS	**916,168**	**14%**	**1,529,286**	**24%**	**2,134,115**	**33%**	**6,447,500**

Figure 4.1 - Grainsize% - Quantitative Data Coverage Summary



MARINE DOMAIN	Carbonate Data Point Coverage						DOMAIN AREA (km2)
	< 25 km apart		< 50 km apart		< 100 km apart		
	(km2)	Total%	(km2)	Total%	(km2)	Total%	
Northern + Torres	114,409	20%	187,697	33%	262,299	46%	572,000
North-east	170,053	14%	232,763	19%	322,389	26%	1,236,000
Eastern-central	76,213	12%	105,059	16%	146,741	22%	653,000
South-east	143,598	12%	237,551	20%	399,322	33%	1,194,000
South-west	1,243	0.1%	5,939	1%	49,680	5%	1,054,000
Western-central	12,719	2.3%	19,976	3.7%	30,674	6%	547,000
North-west	133,932	15%	267,165	29%	379,364	42%	912,000
West-northern	114,294	41%	199,574	71%	247,797	89%	279,500
TOTALS	**766,461**	**12%**	**1,255,725**	**19%**	**1,838,264**	**29%**	**6,447,500**

Figure 4.2 - Bulk Carbonate% - Quantitative Data Coverage Summary

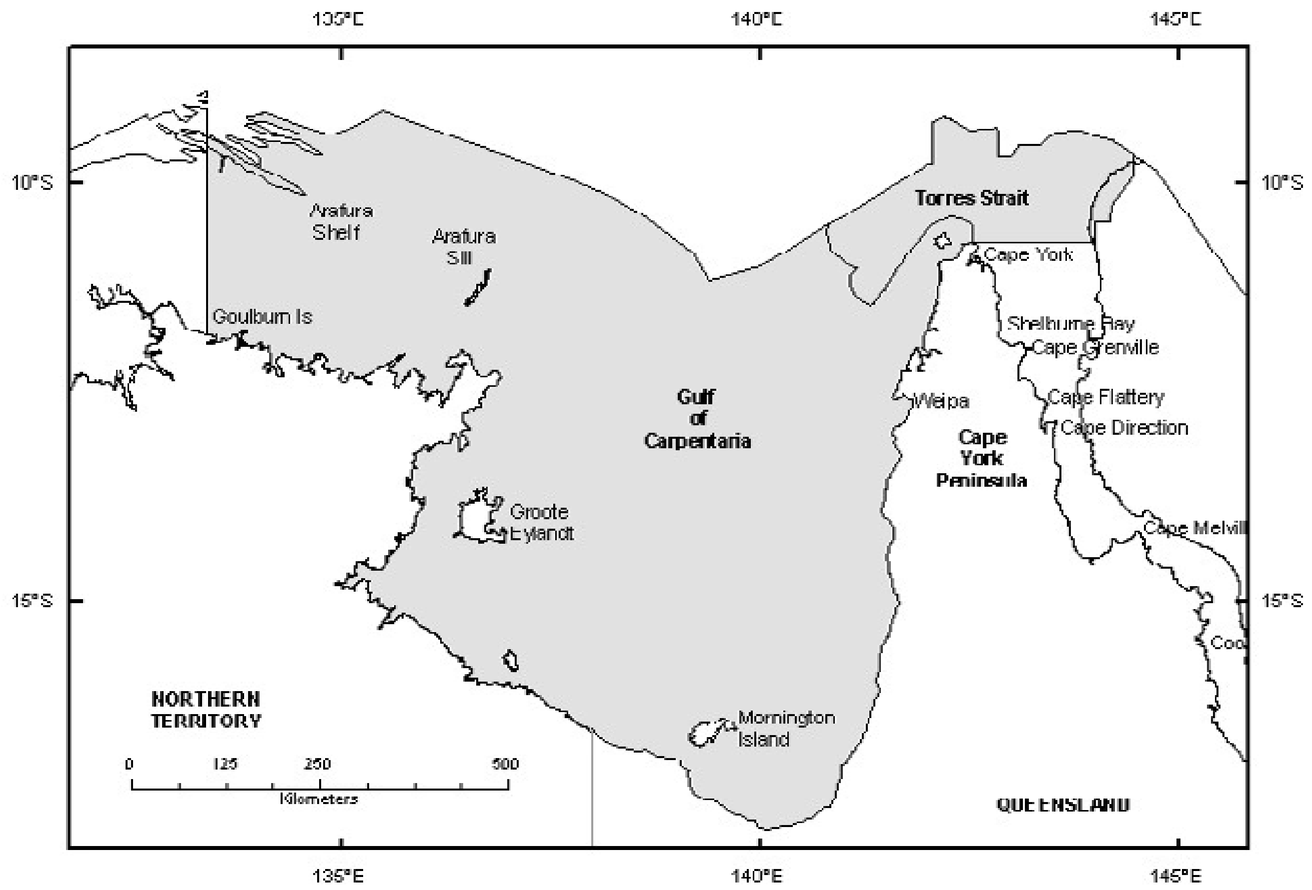


Figure 4.3. Northern Regional Management Planning Area – place names and geomorphic features

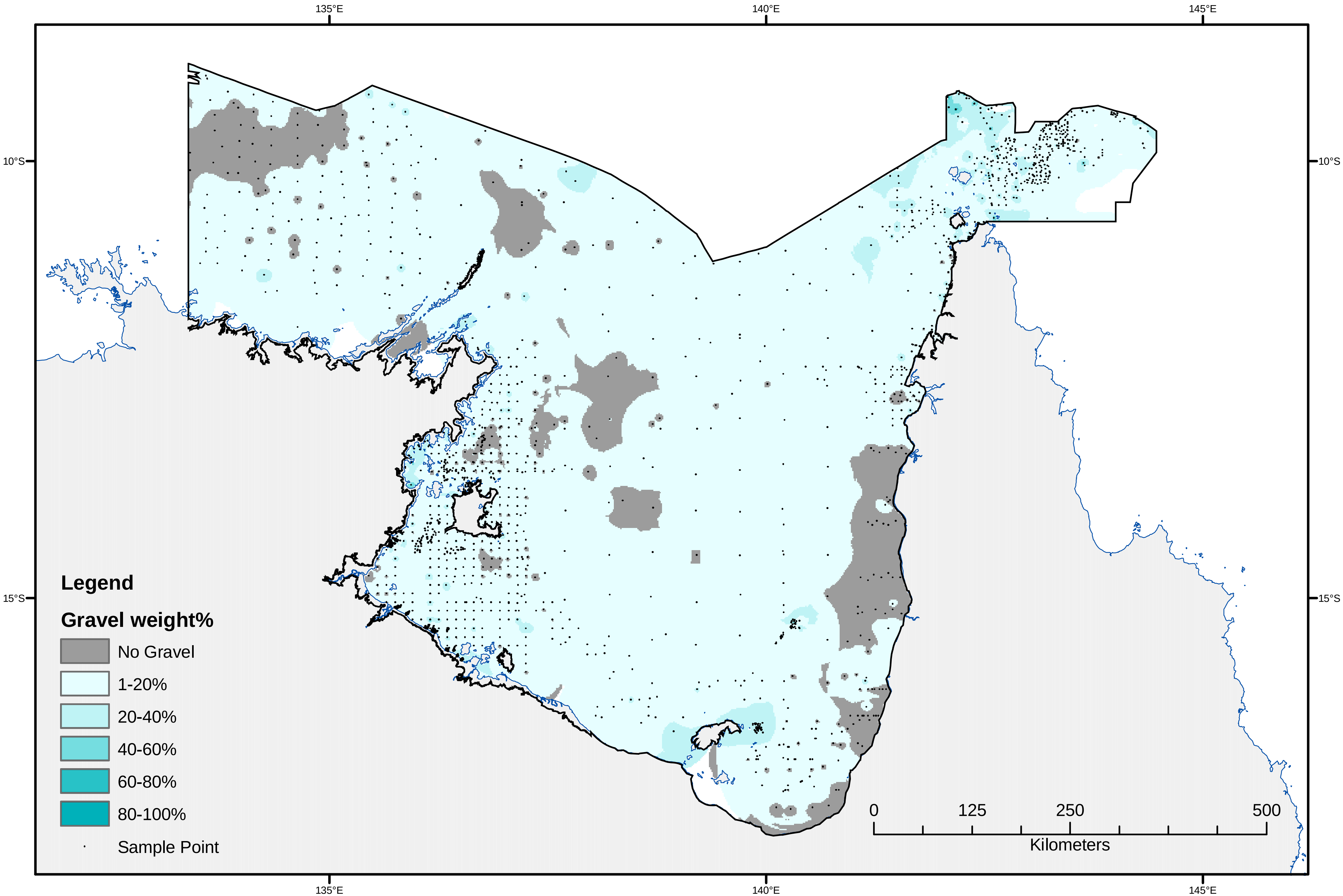


Figure 4.4. Measured gravel content - Northern Regional Management Planning Area

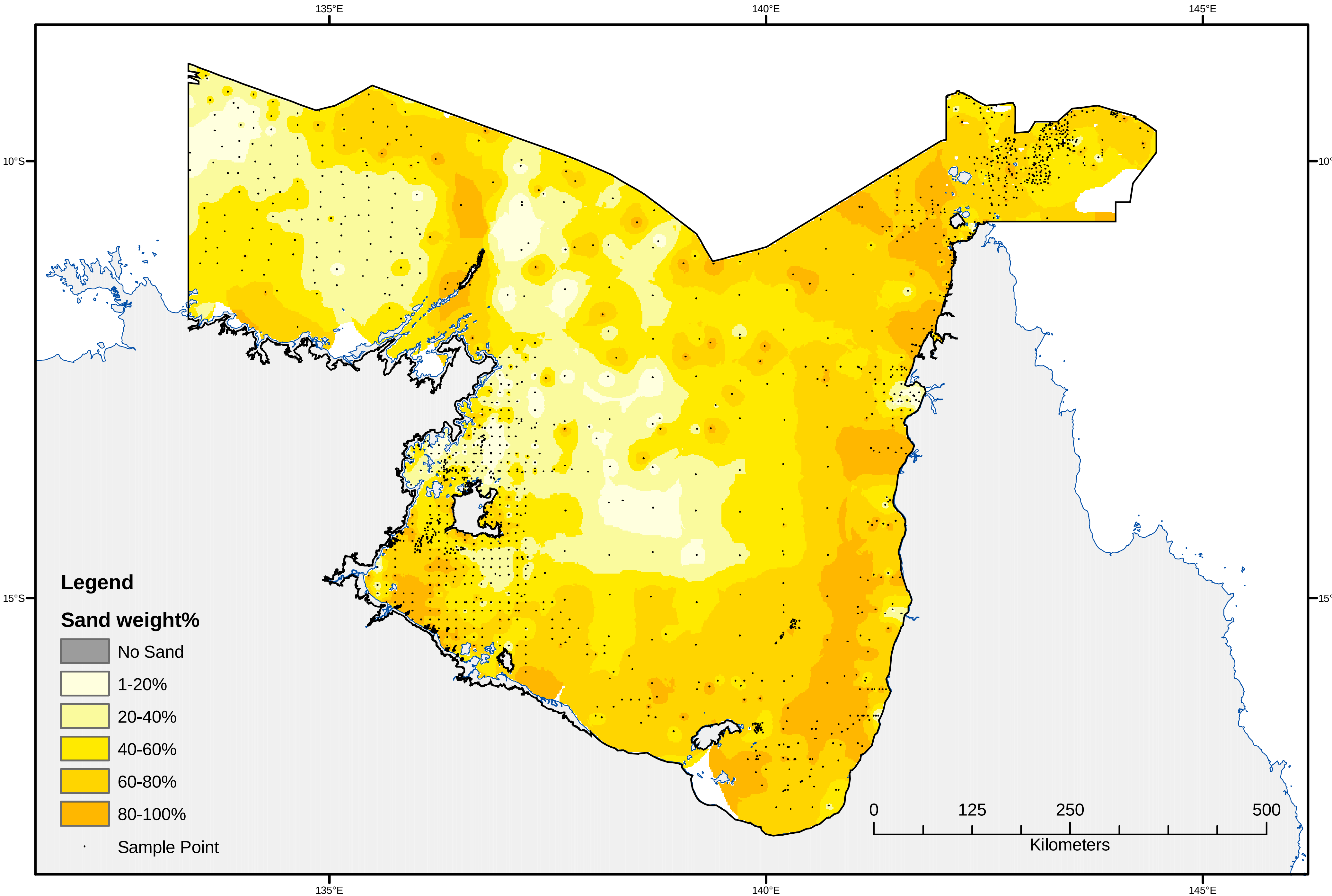


Figure 4.5. Measured sand content - Northern Regional Management Planning Area

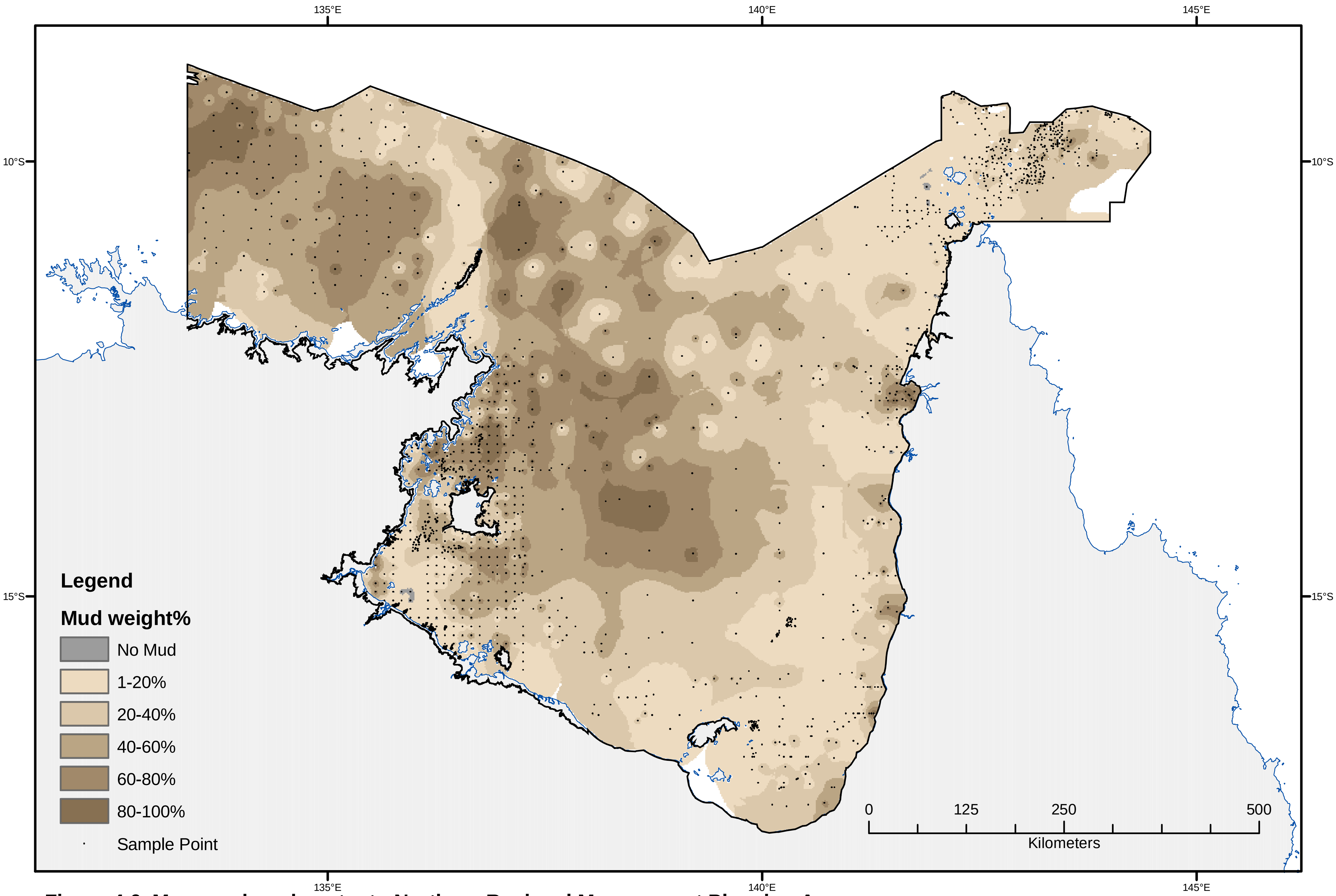


Figure 4.6. Measured mud content - Northern Regional Management Planning Area

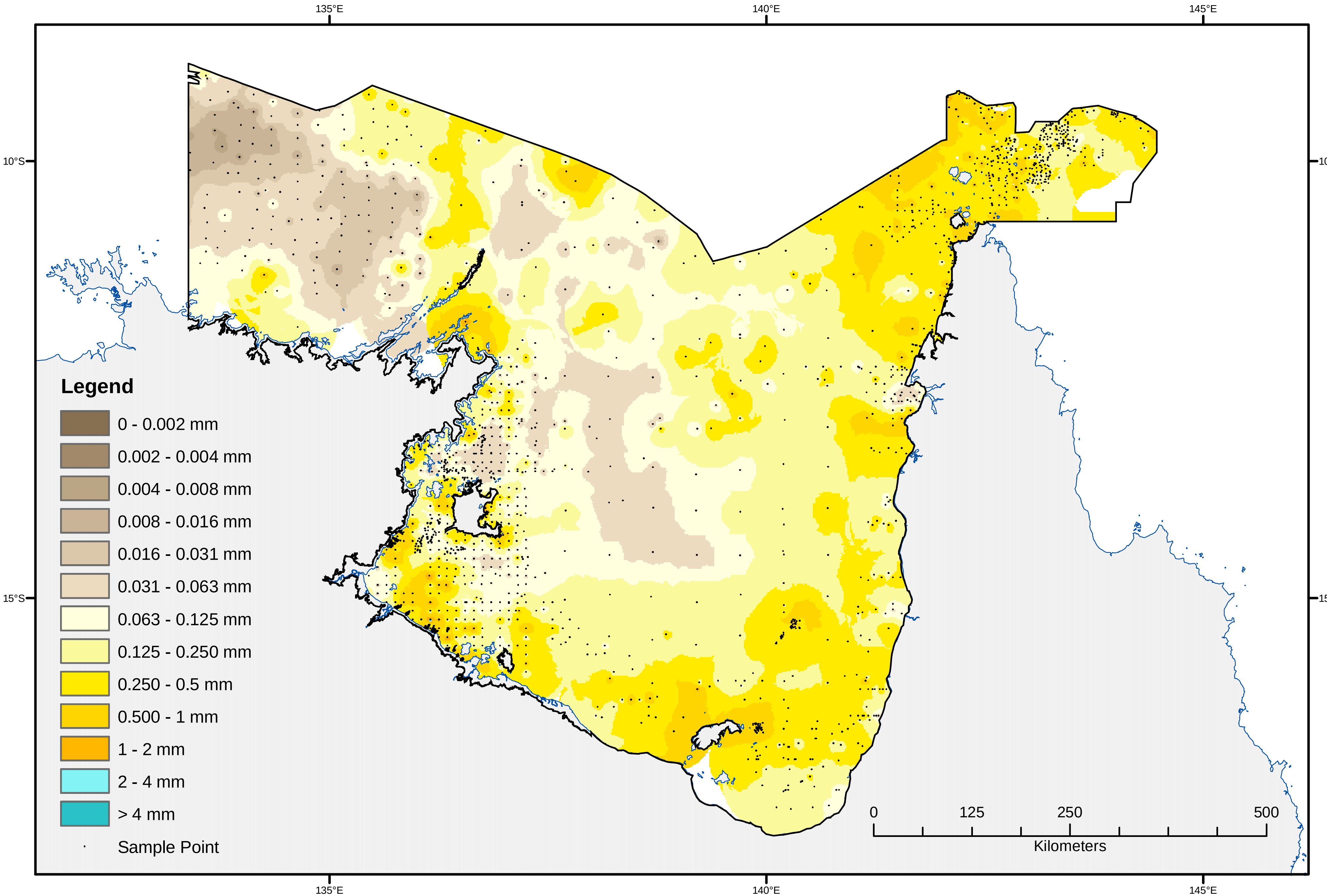


Figure 4.7. Mean grain size (mm) - Northern Regional Management Planning Area

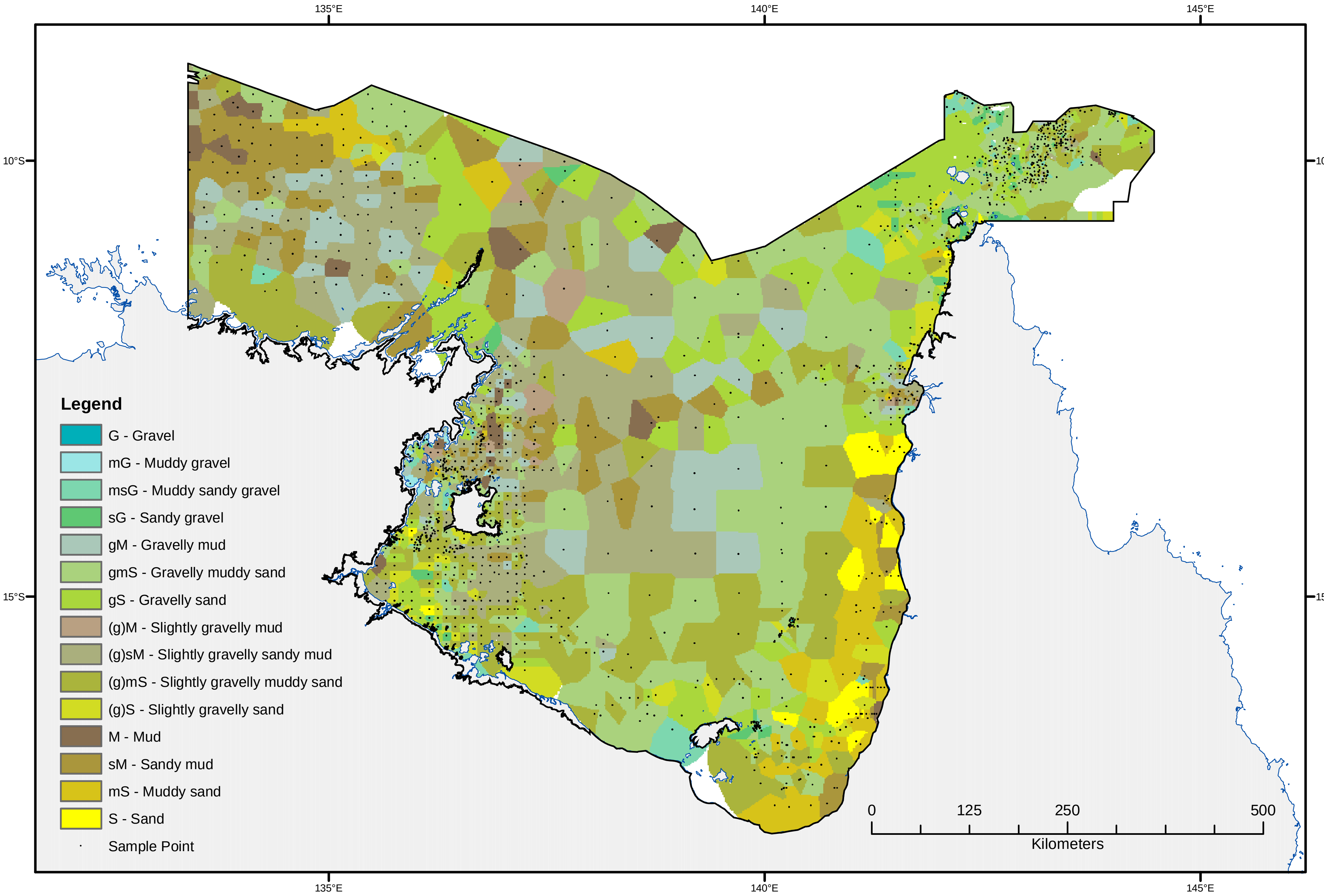


Figure 4.8. Sediment type classification after Folk (1954) - Northern Regional Management Planning Area

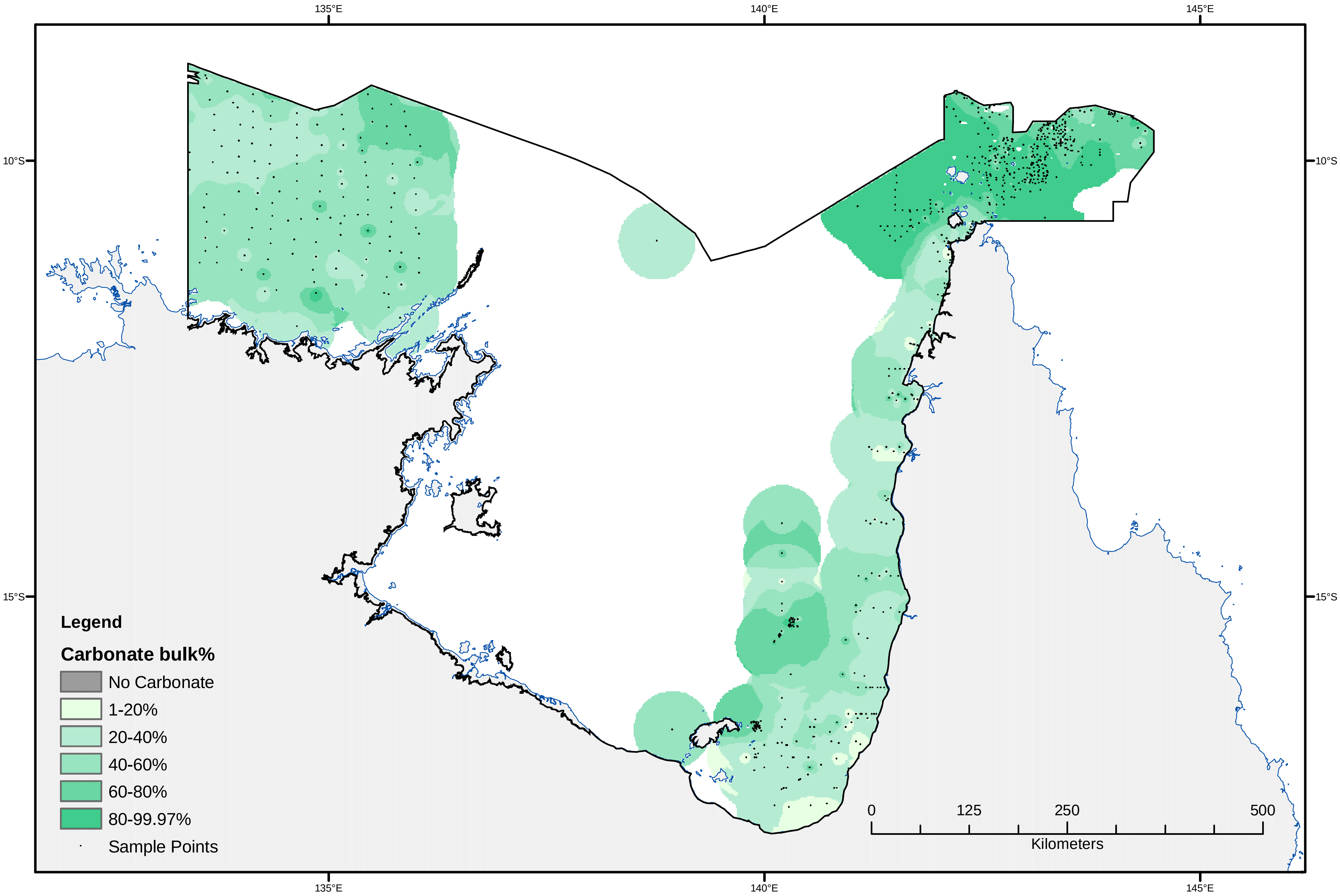


Figure 4.9. Bulk carbonate content - Northern Regional Management Planning Area

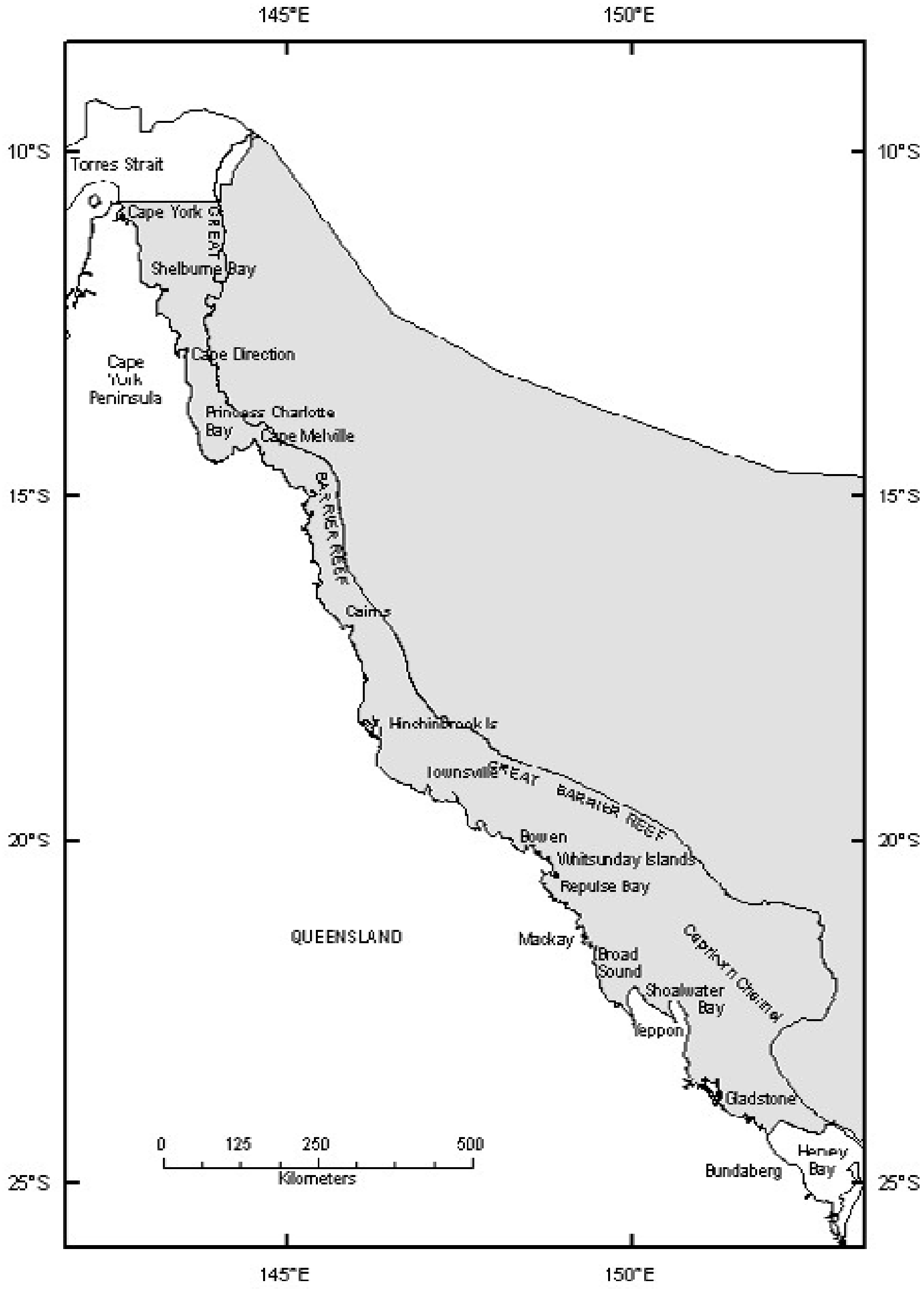


Figure 4.10. North-eastern Marine Domain – place names and geomorphic features

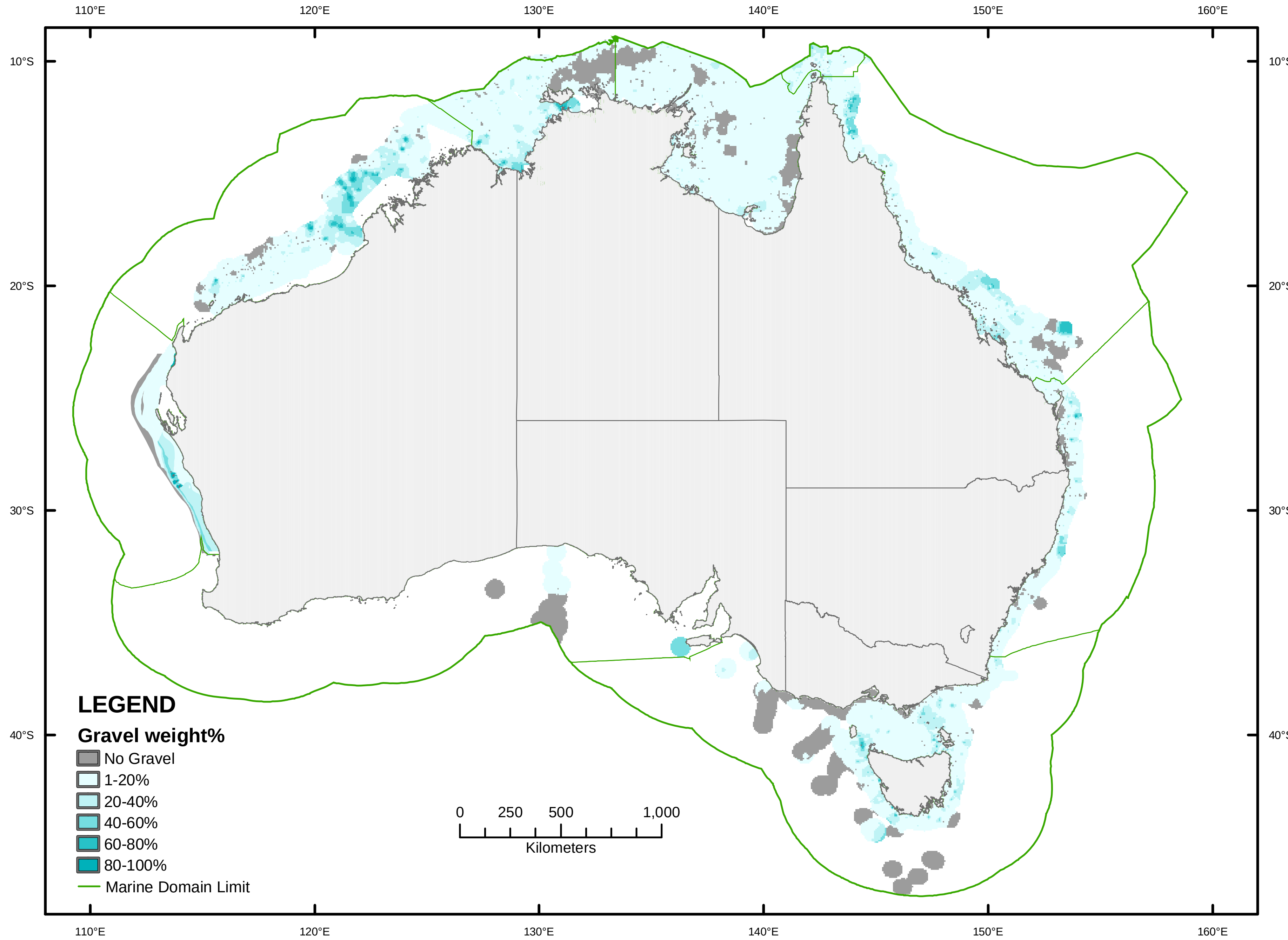


Figure 4.11 - Seabed sediment texture - measured gravel content

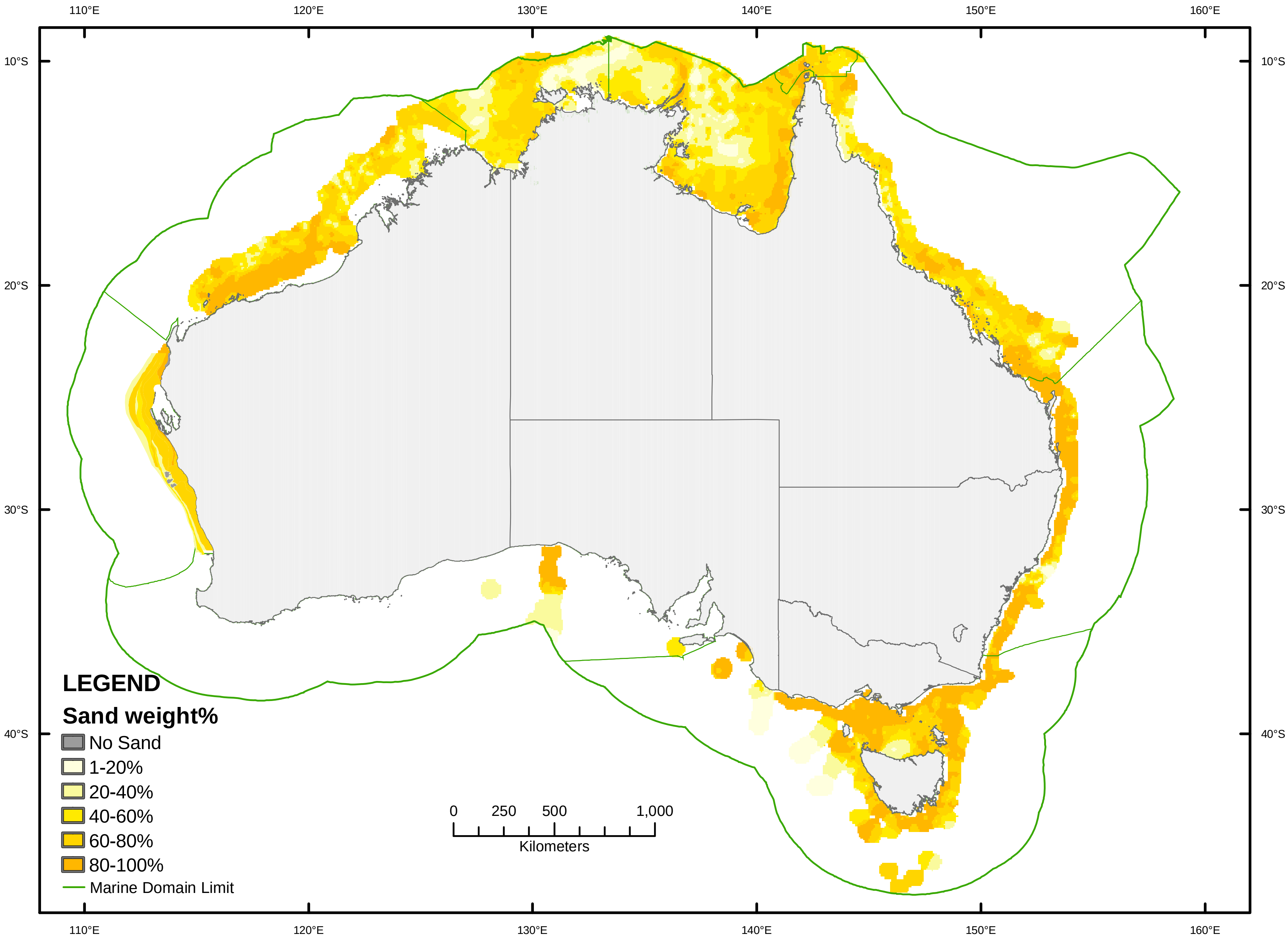


Figure 4.12 - Seabed sediment texture - measured sand content

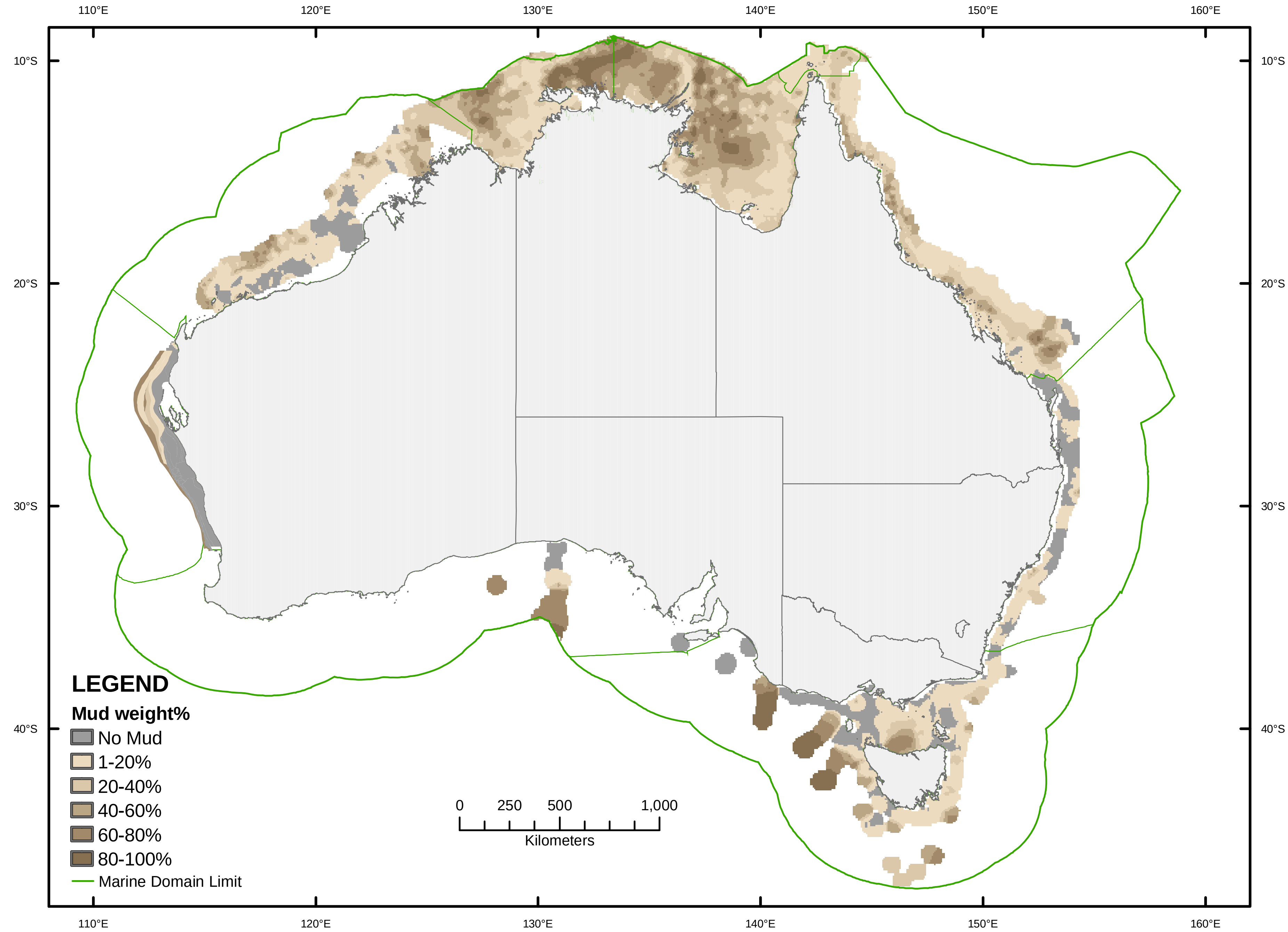


Figure 4.13 - Seabed sediment texture - measured mud content

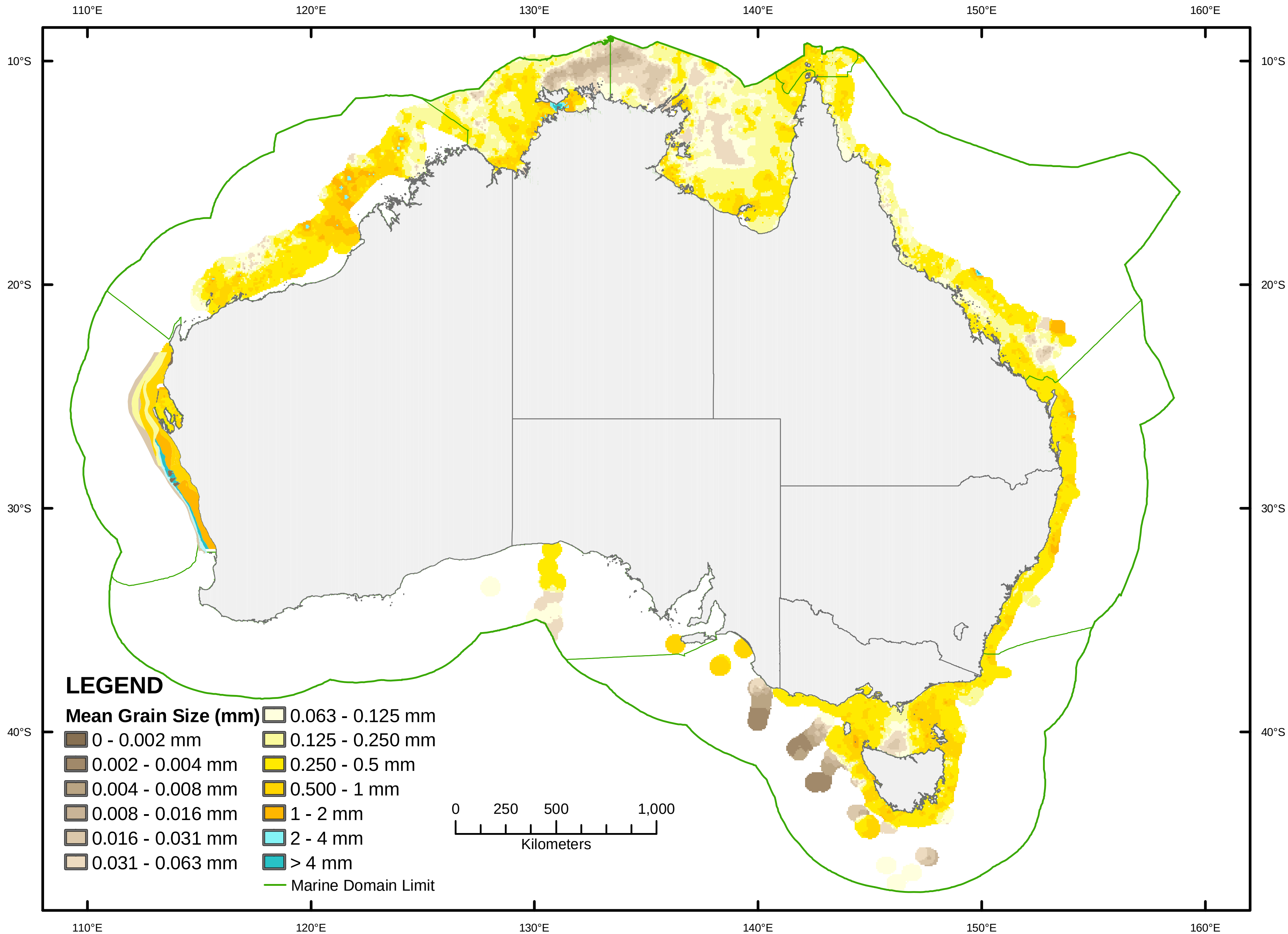


Figure 4.14 - Seabed sediment texture - measured mean grain size

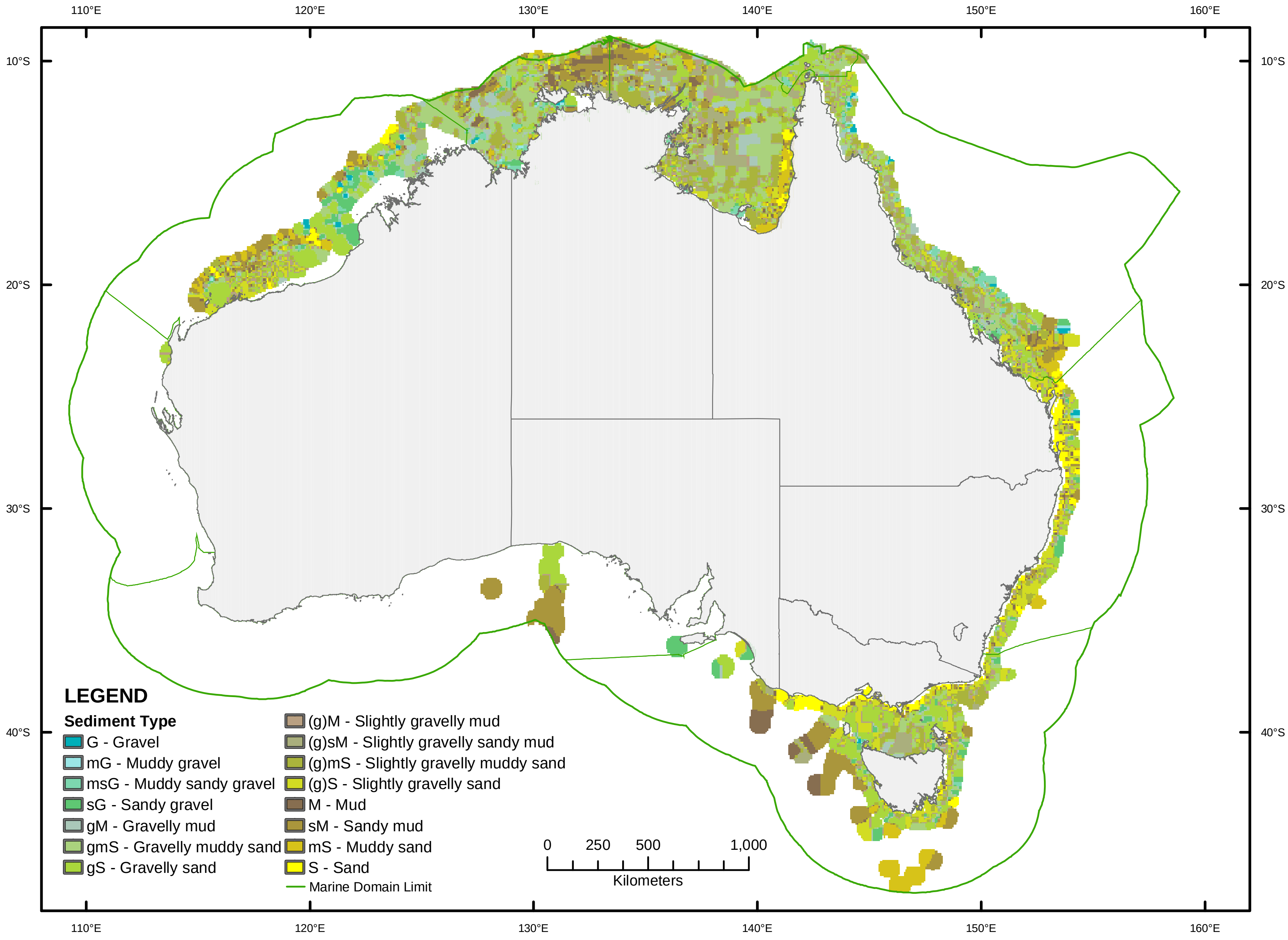


Figure 4.15 - Seabed sediment type - Folk Classification (after Folk, 1954)

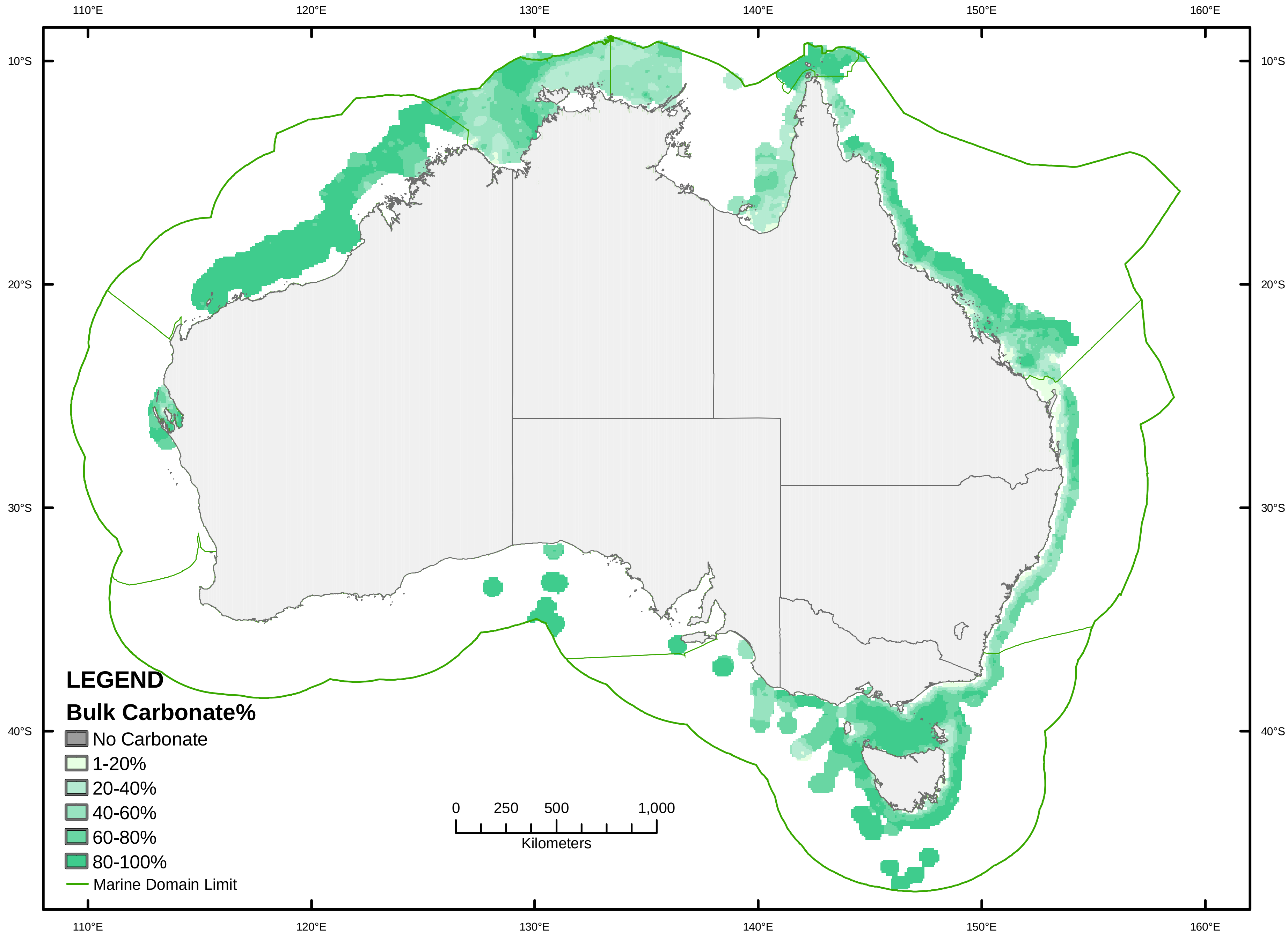


Figure 4.16 - Seabed sediment composition - measured bulk carbonate content

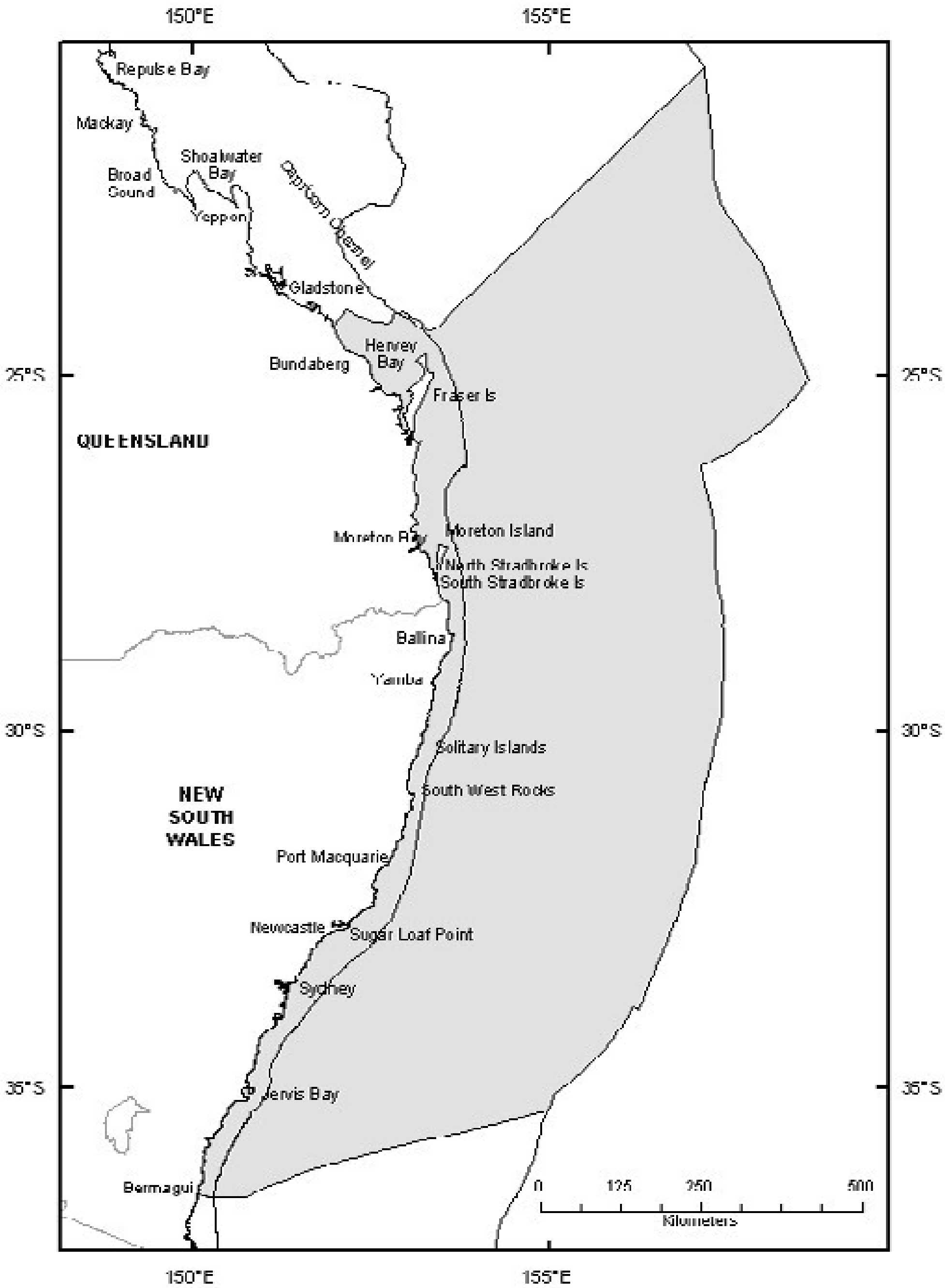


Figure 4.17. Eastern-central Marine Domain – place names and geomorphic features.

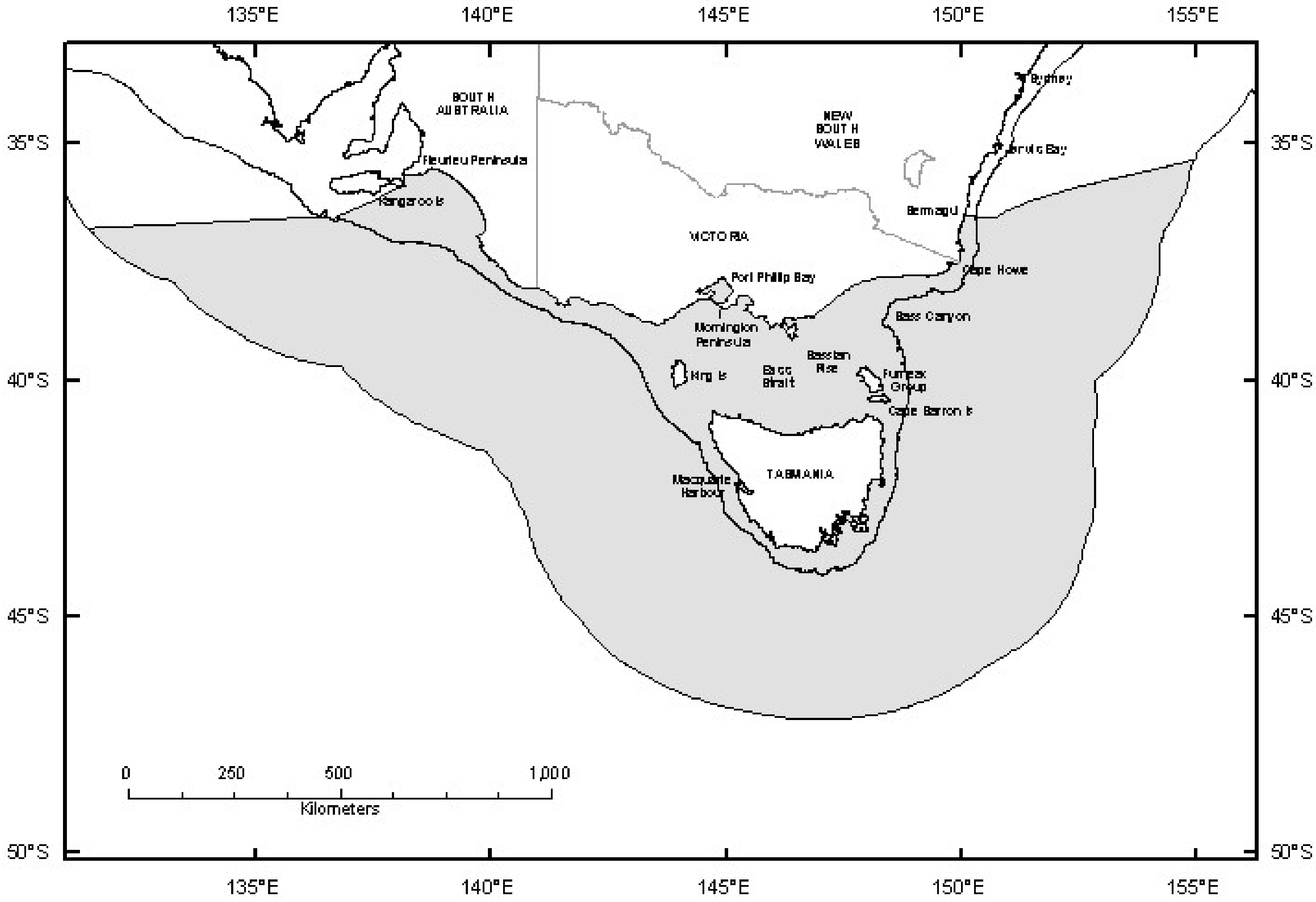


Figure 4.18. South-east Marine Domain – place names and geomorphic features

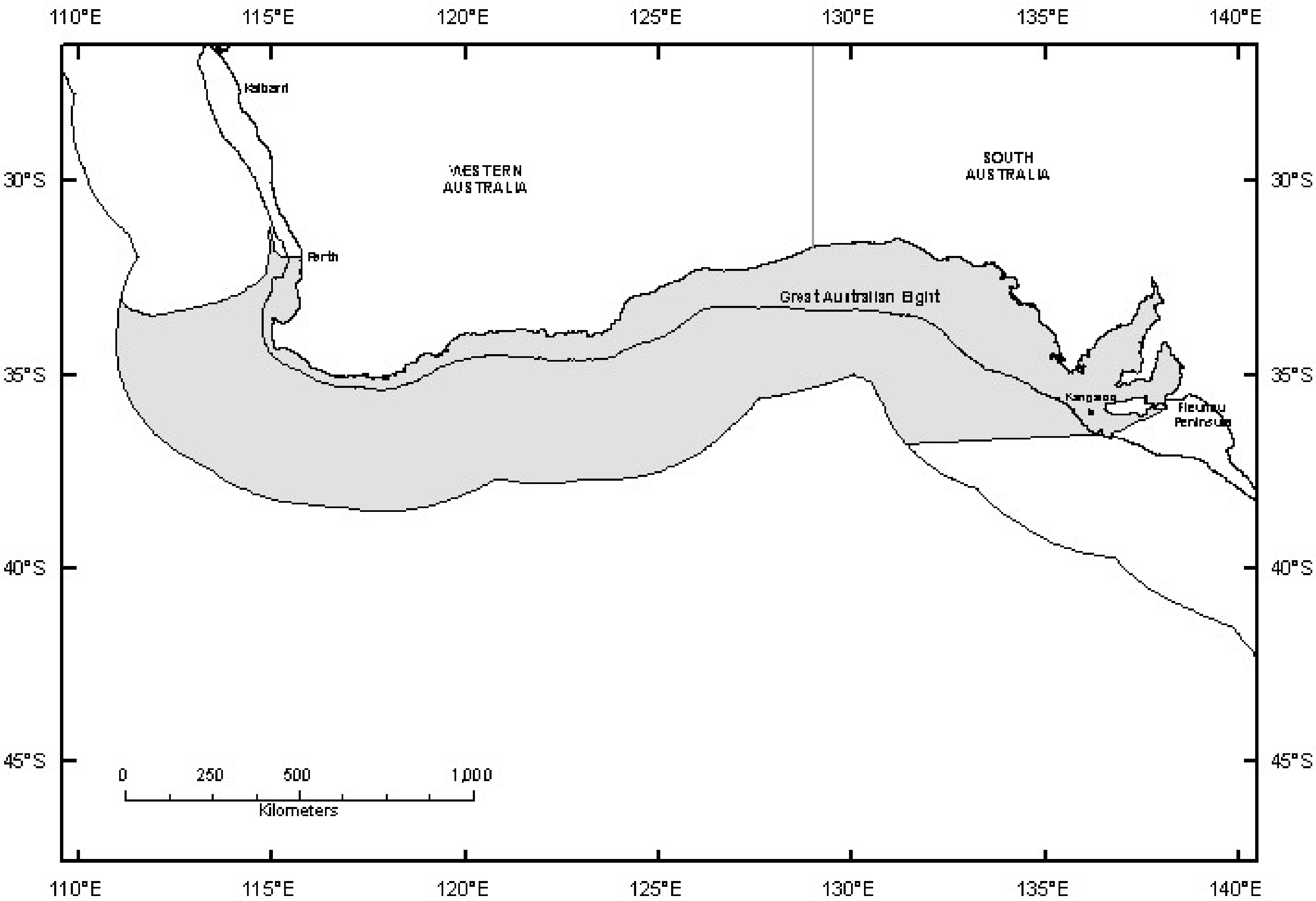


Figure 4.19. South-west Marine Domain - place names and geomorphic features.

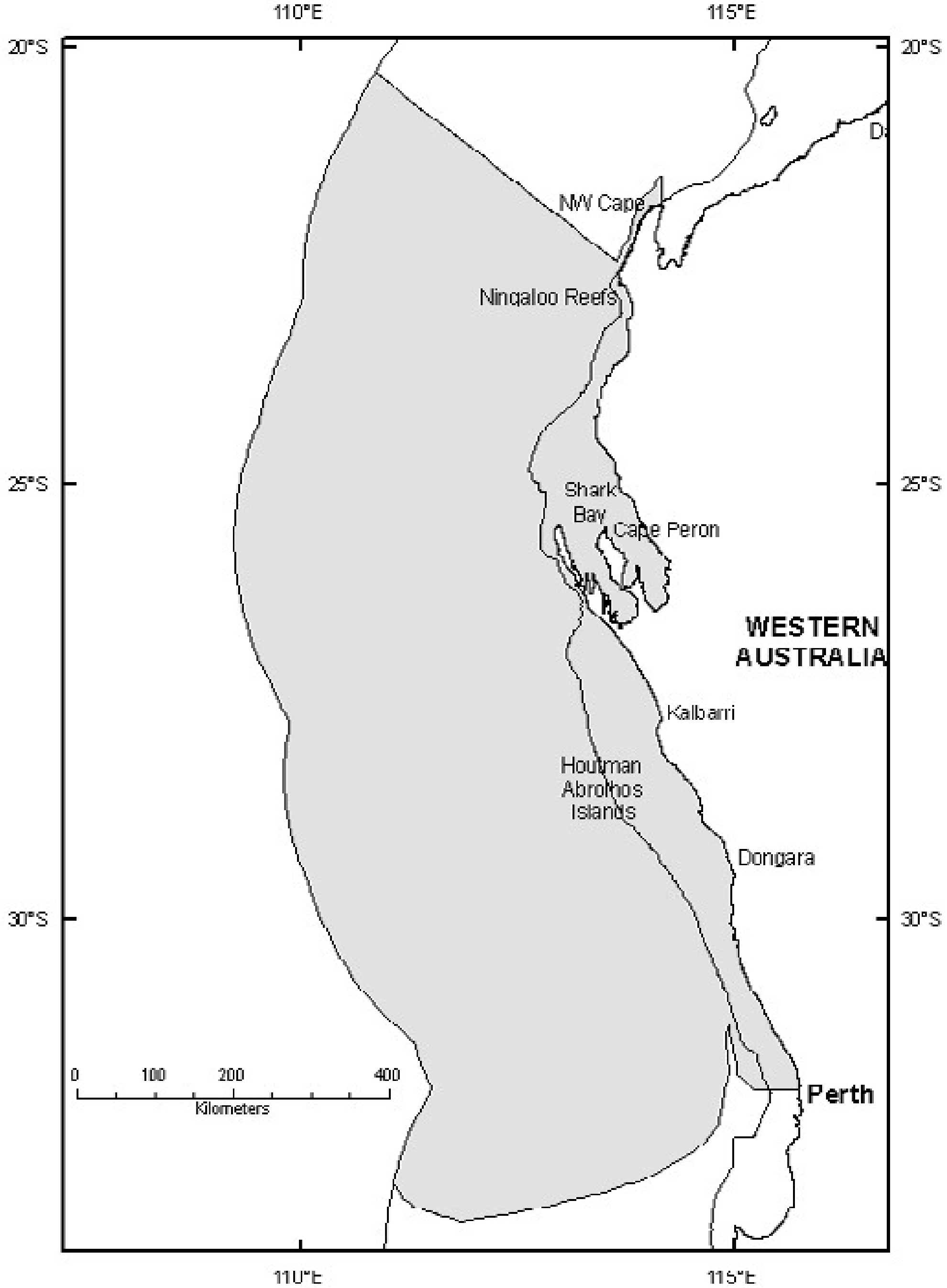


Figure 4.20. Western-central Marine Domain - place names and geomorphic features.

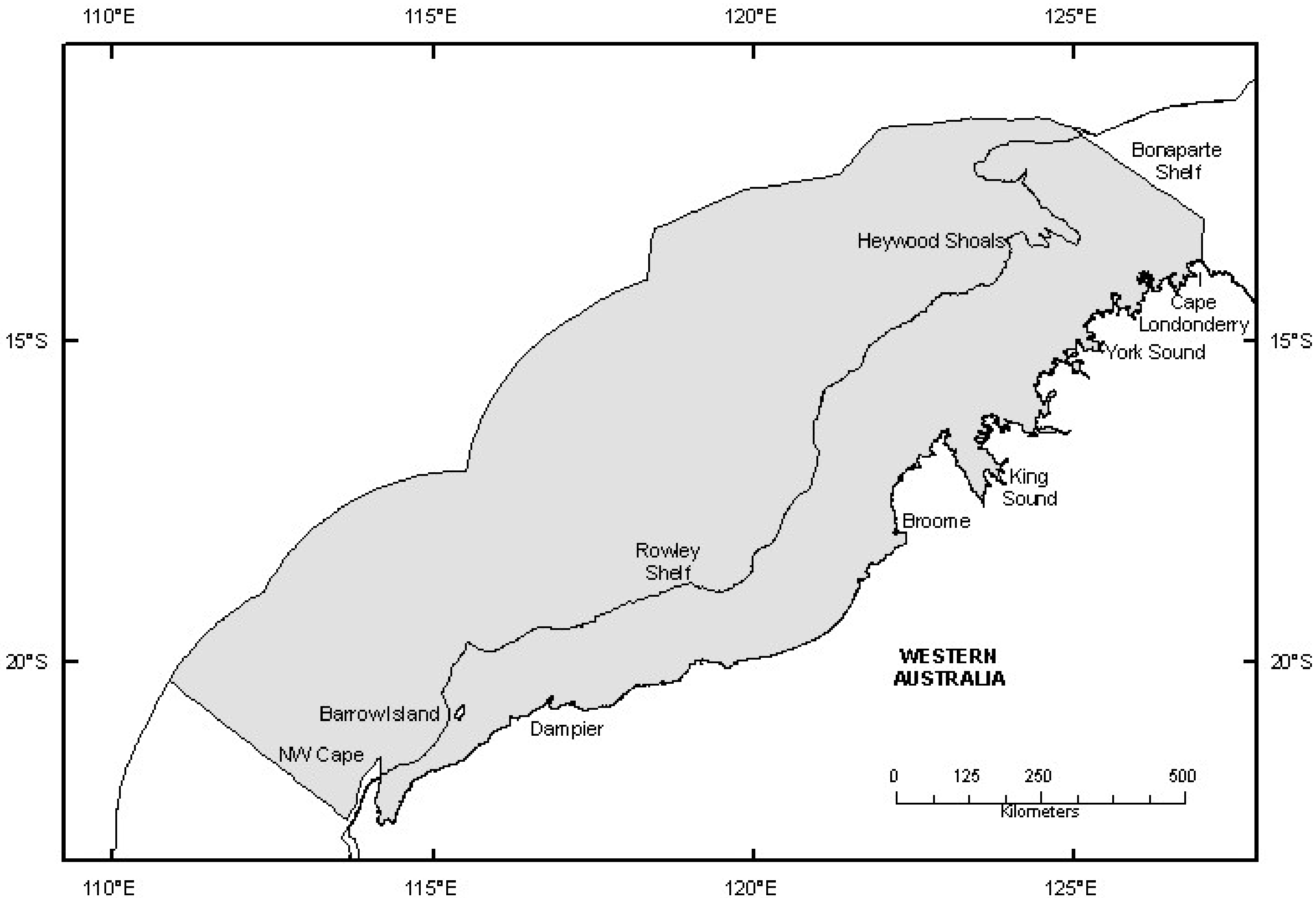


Figure 4.21. North-west Marine Domain - place names and geomorphic features.

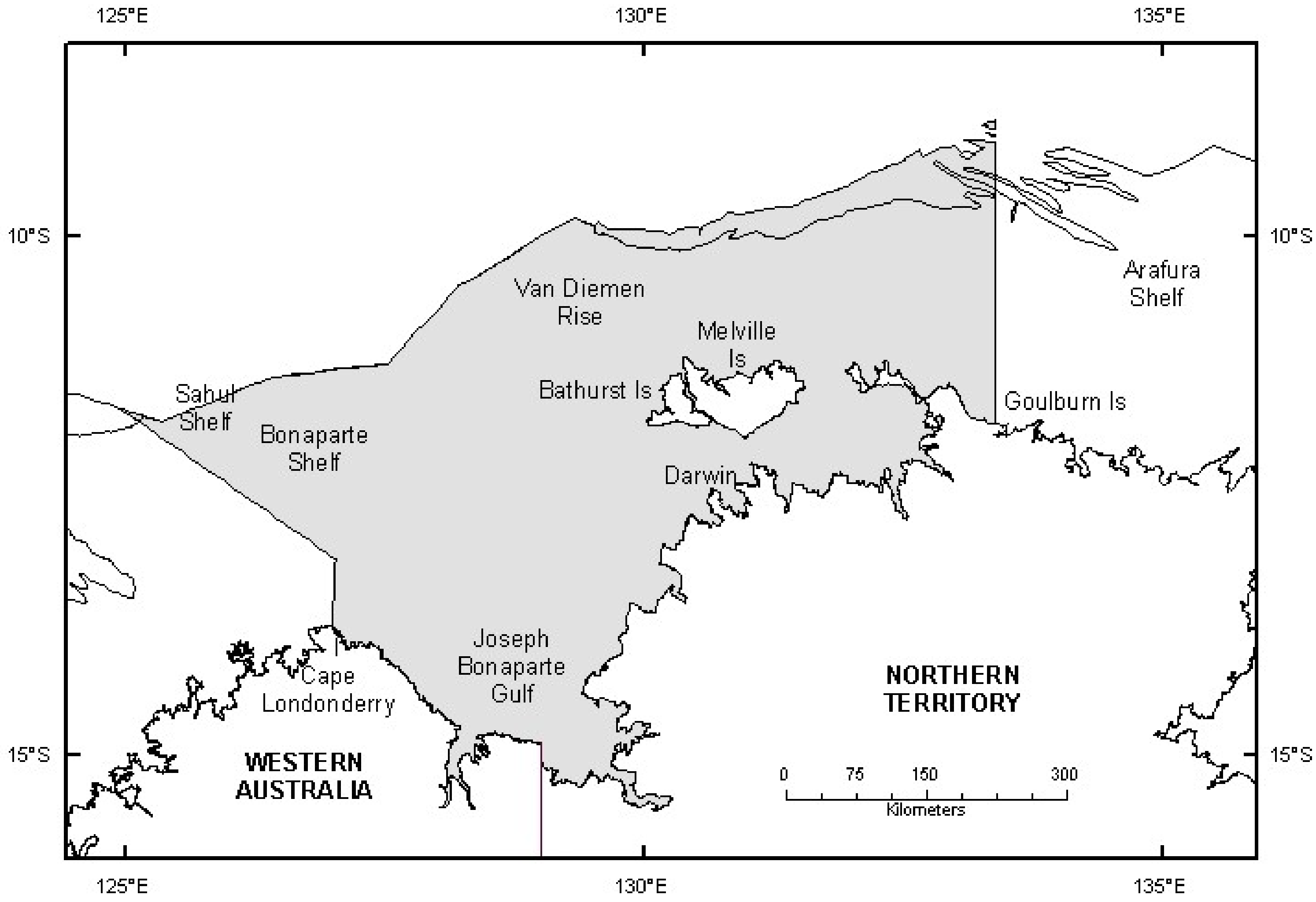


Figure 4.22. West-northern Marine Domain - place names and geomorphic features.

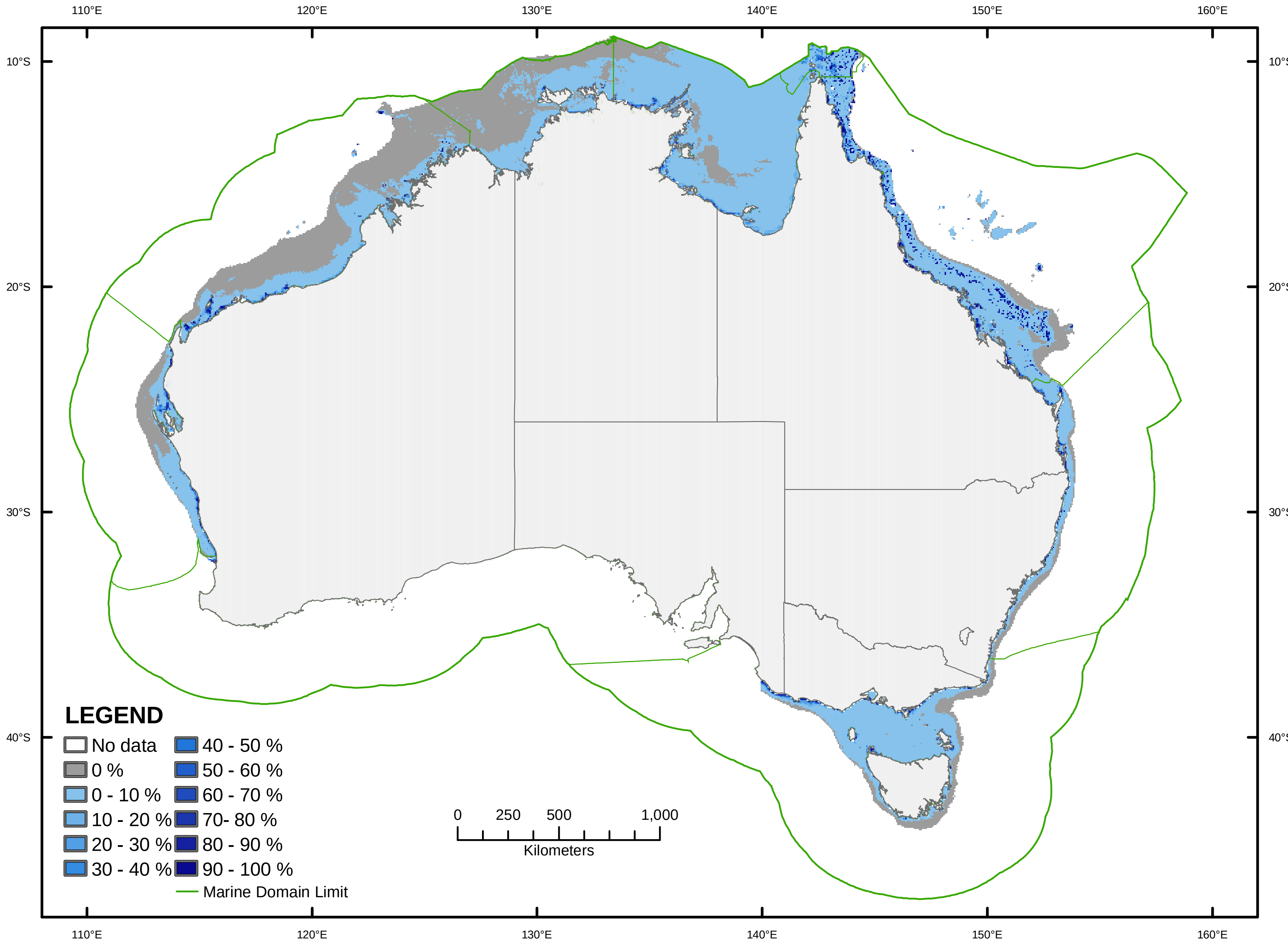


Figure 4.23 - Wave induced exceedence

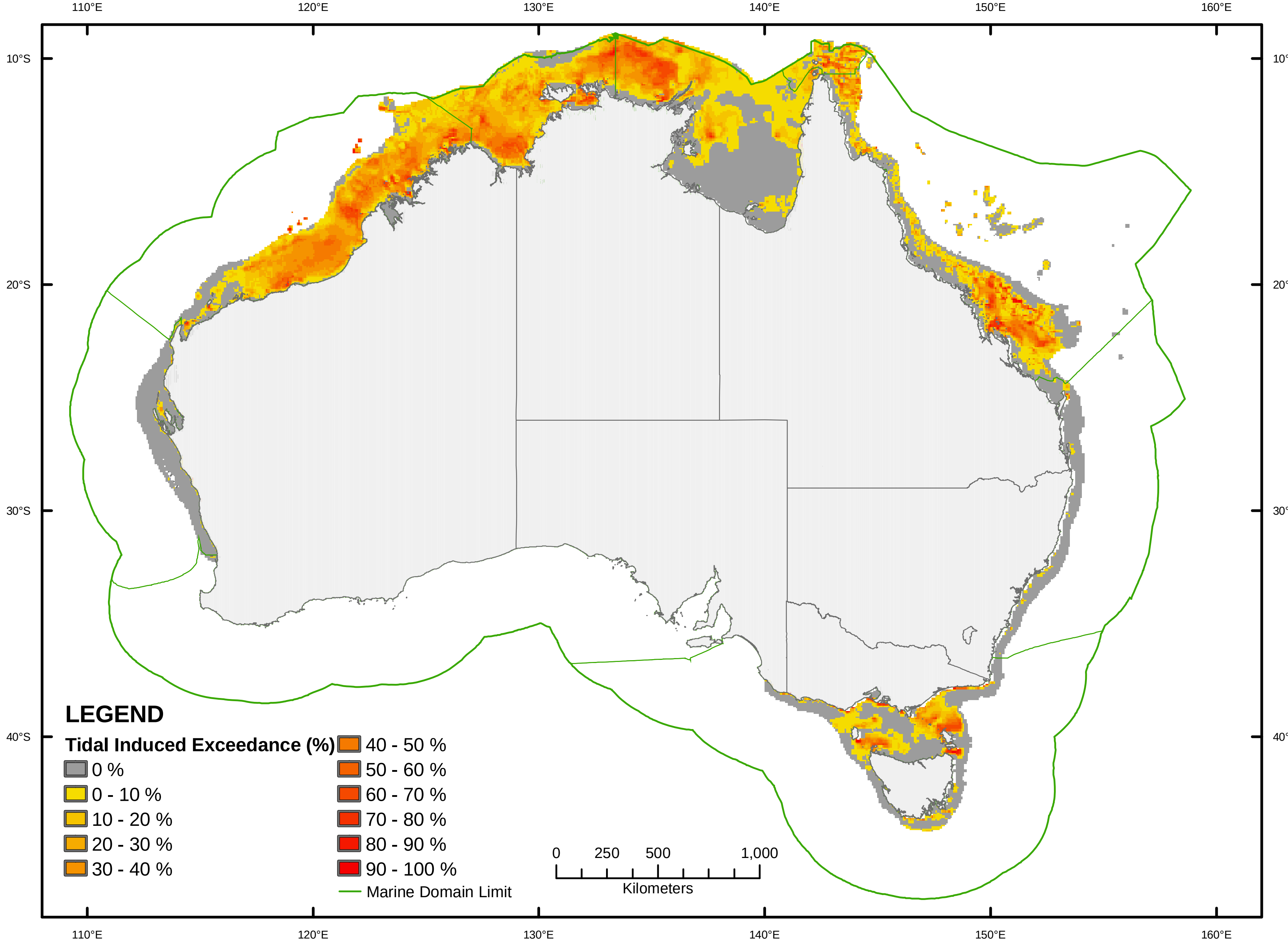


Figure 4.24 - Tidal induced exceedence

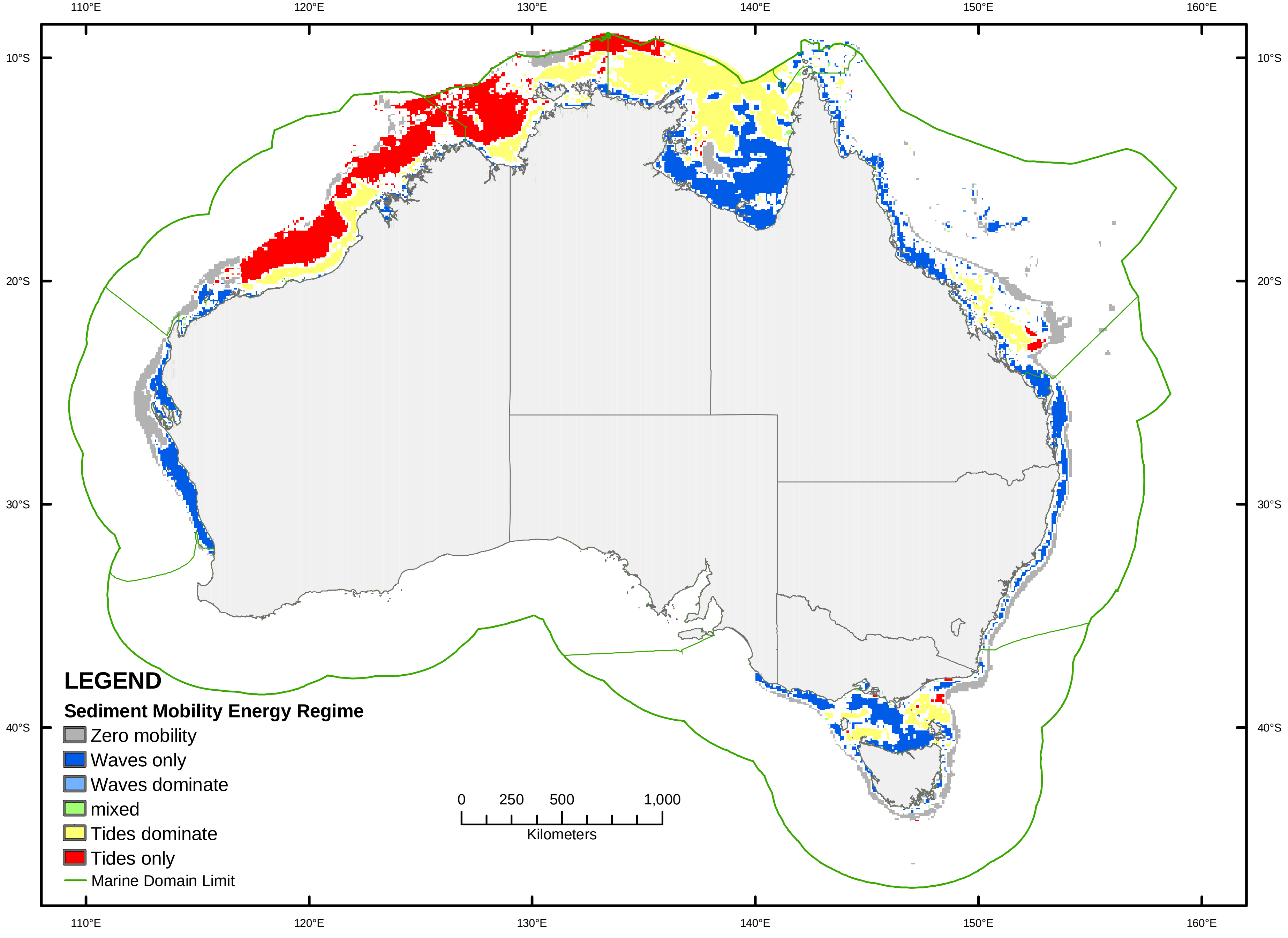


Figure 4.25 - Sediment mobility energy regimes

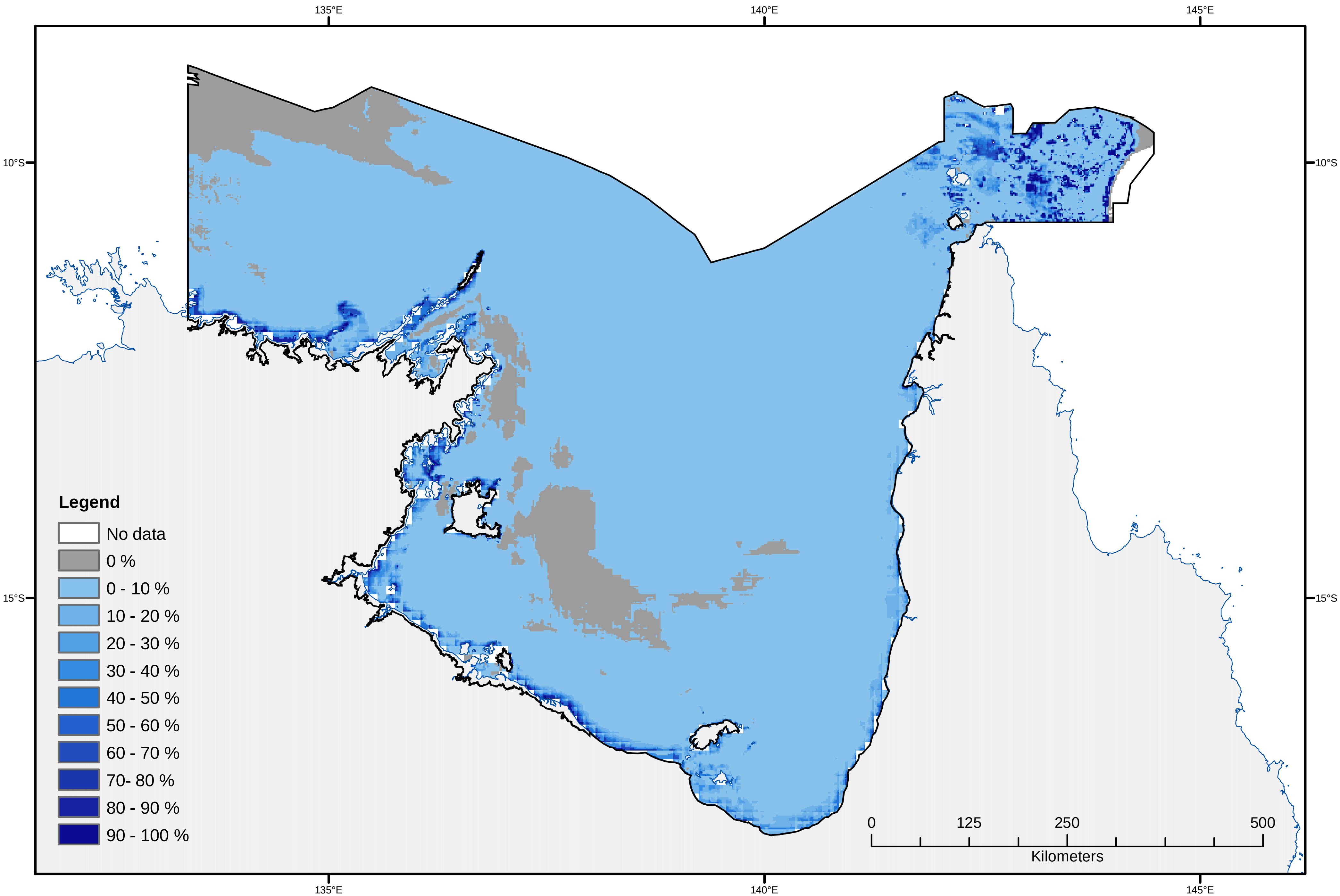


Figure 4.26. Wave induced exceedence - Northern Regional Management Planning Area

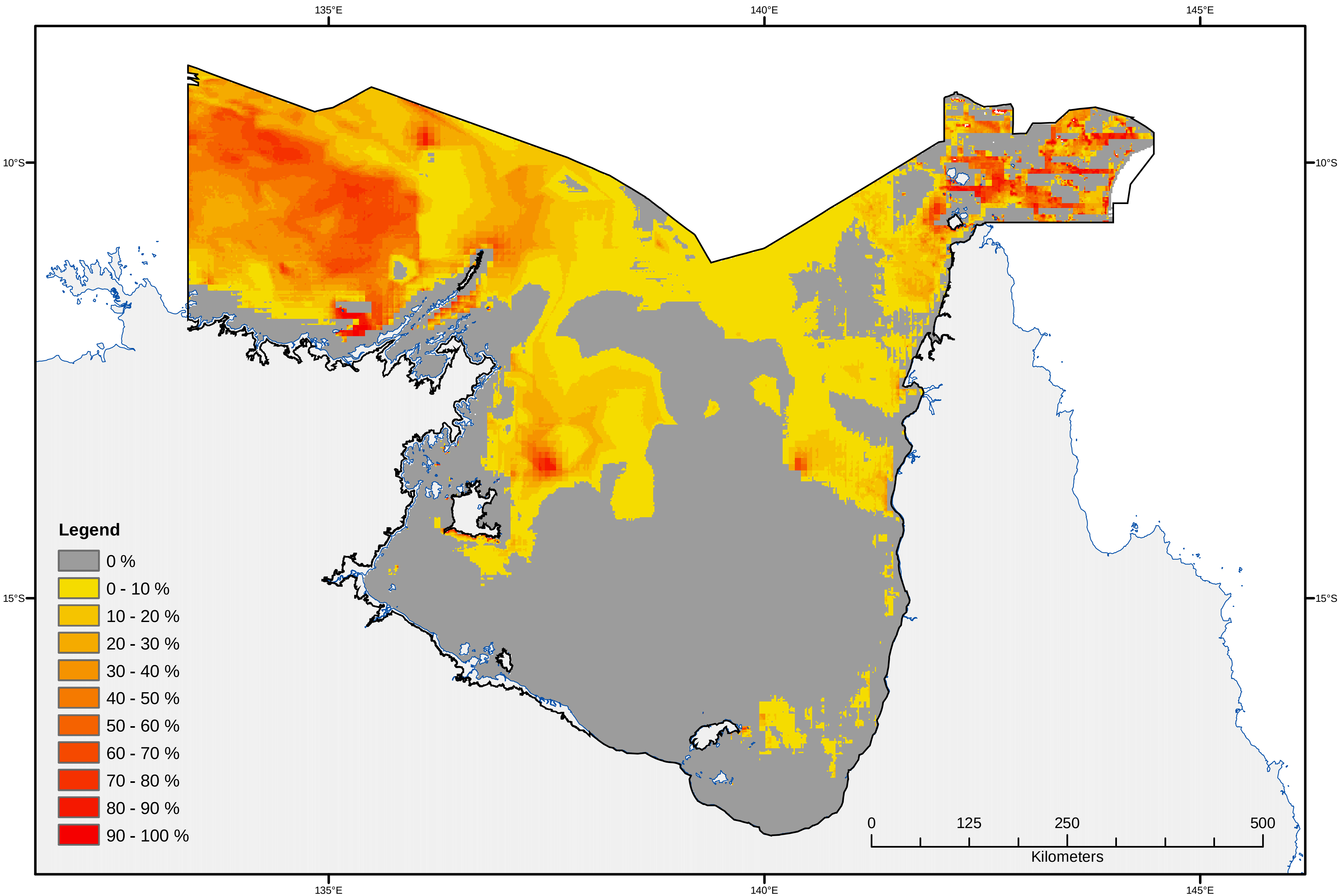


Figure 4.27. Tide induced exceedence - Northern Regional Management Planning Area

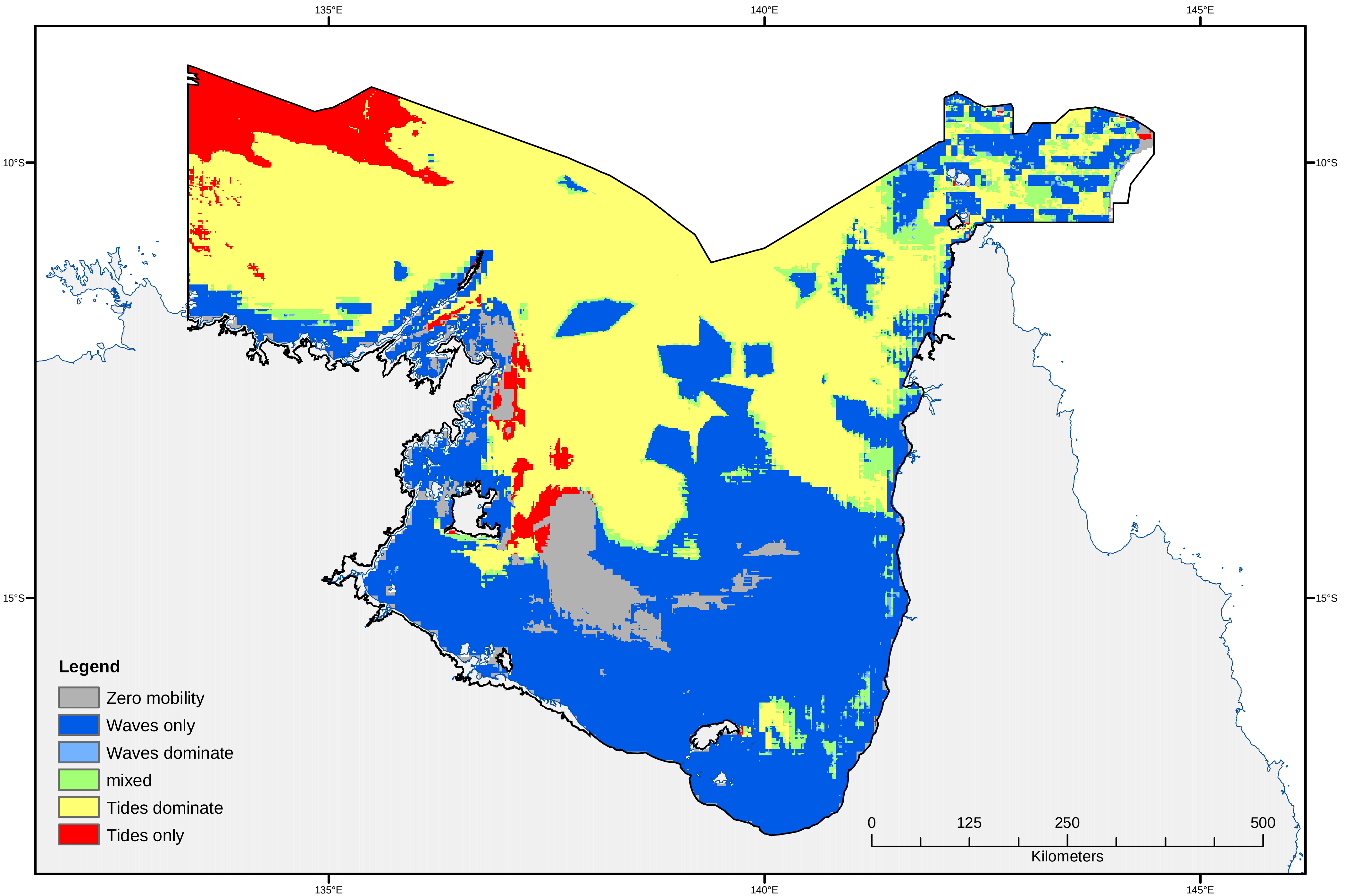
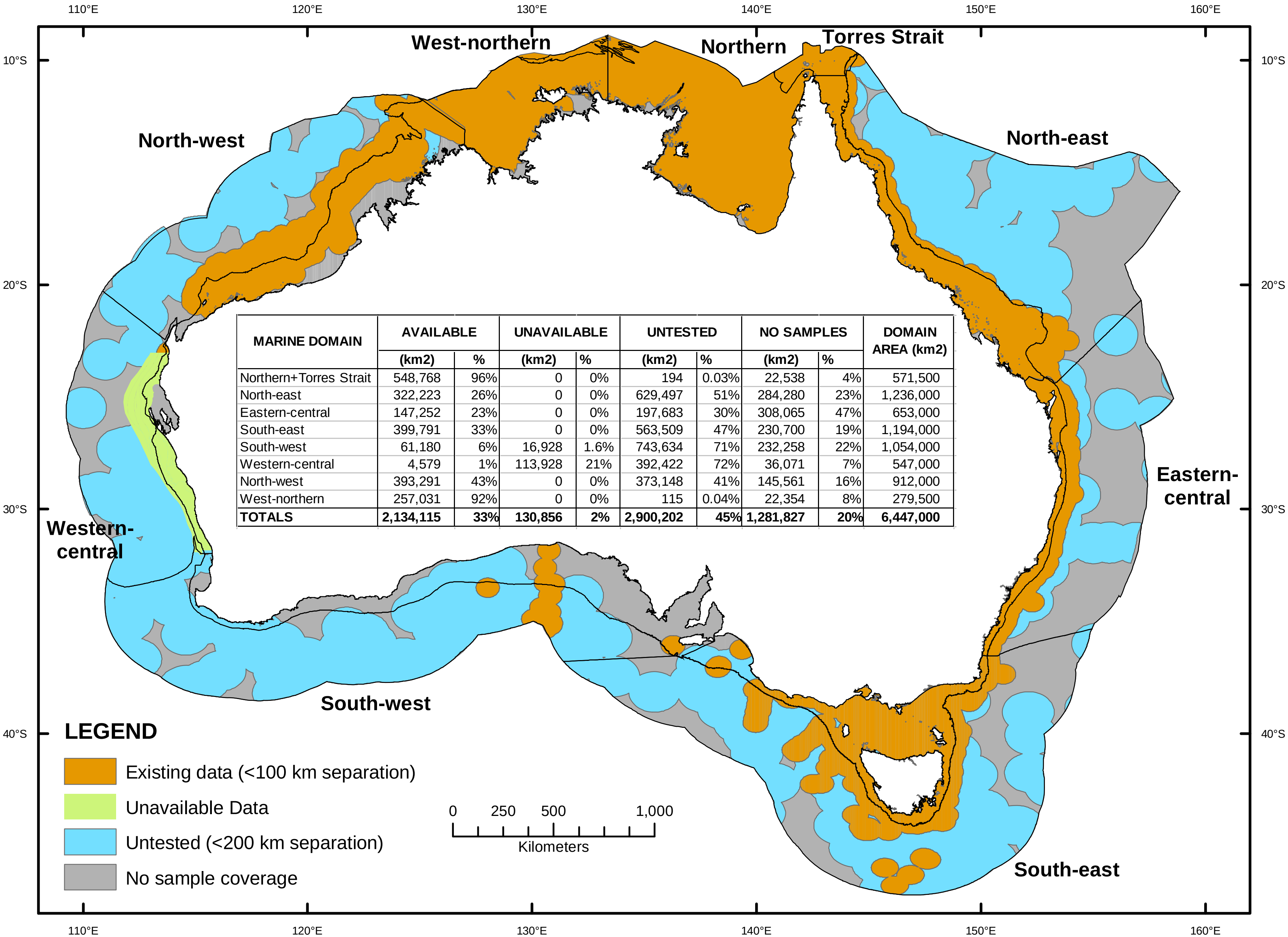


Figure 4.28. Sediment mobility energy regimes - Northern Regional Management Planning Area



MARINE DOMAIN	AVAILABLE (km2)	AVAILABLE %	UNAVAILABLE (km2)	UNAVAILABLE %	UNTESTED (km2)	UNTESTED %	NO SAMPLES (km2)	NO SAMPLES %	DOMAIN AREA (km2)
Northern+Torres Strait	548,768	96%	0	0%	194	0.03%	22,538	4%	571,500
North-east	322,223	26%	0	0%	629,497	51%	284,280	23%	1,236,000
Eastern-central	147,252	23%	0	0%	197,683	30%	308,065	47%	653,000
South-east	399,791	33%	0	0%	563,509	47%	230,700	19%	1,194,000
South-west	61,180	6%	16,928	1.6%	743,634	71%	232,258	22%	1,054,000
Western-central	4,579	1%	113,928	21%	392,422	72%	36,071	7%	547,000
North-west	393,291	43%	0	0%	373,148	41%	145,561	16%	912,000
West-northern	257,031	92%	0	0%	115	0.04%	22,354	8%	279,500
TOTALS	**2,134,115**	**33%**	**130,856**	**2%**	**2,900,202**	**45%**	**1,281,827**	**20%**	**6,447,000**

Figure 5.1 - Sample Coverage Summary for Large Marine Domains

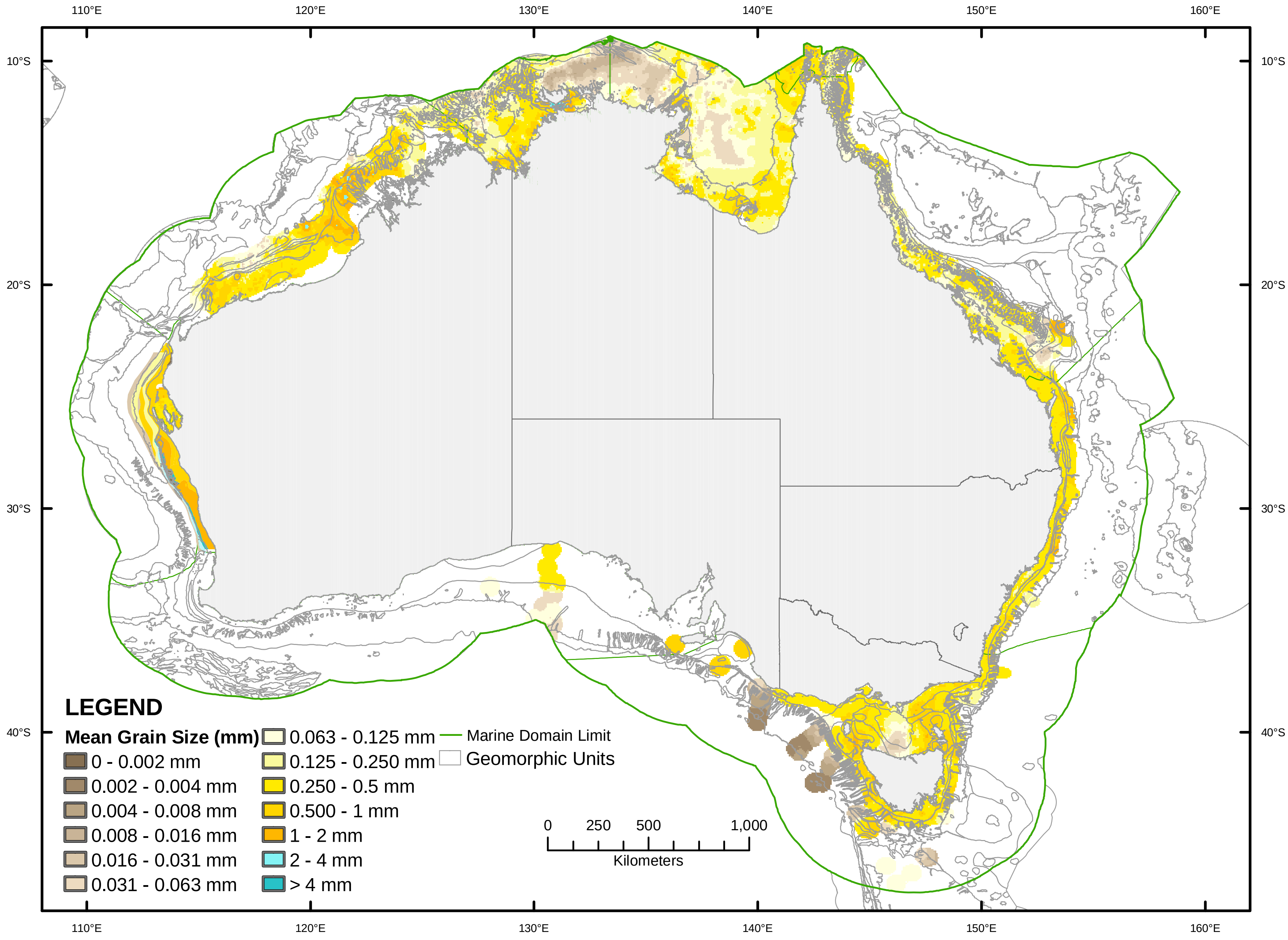


Figure 5.2 - Mean grain size overlain by geomorphic units of Harris et al, 2003

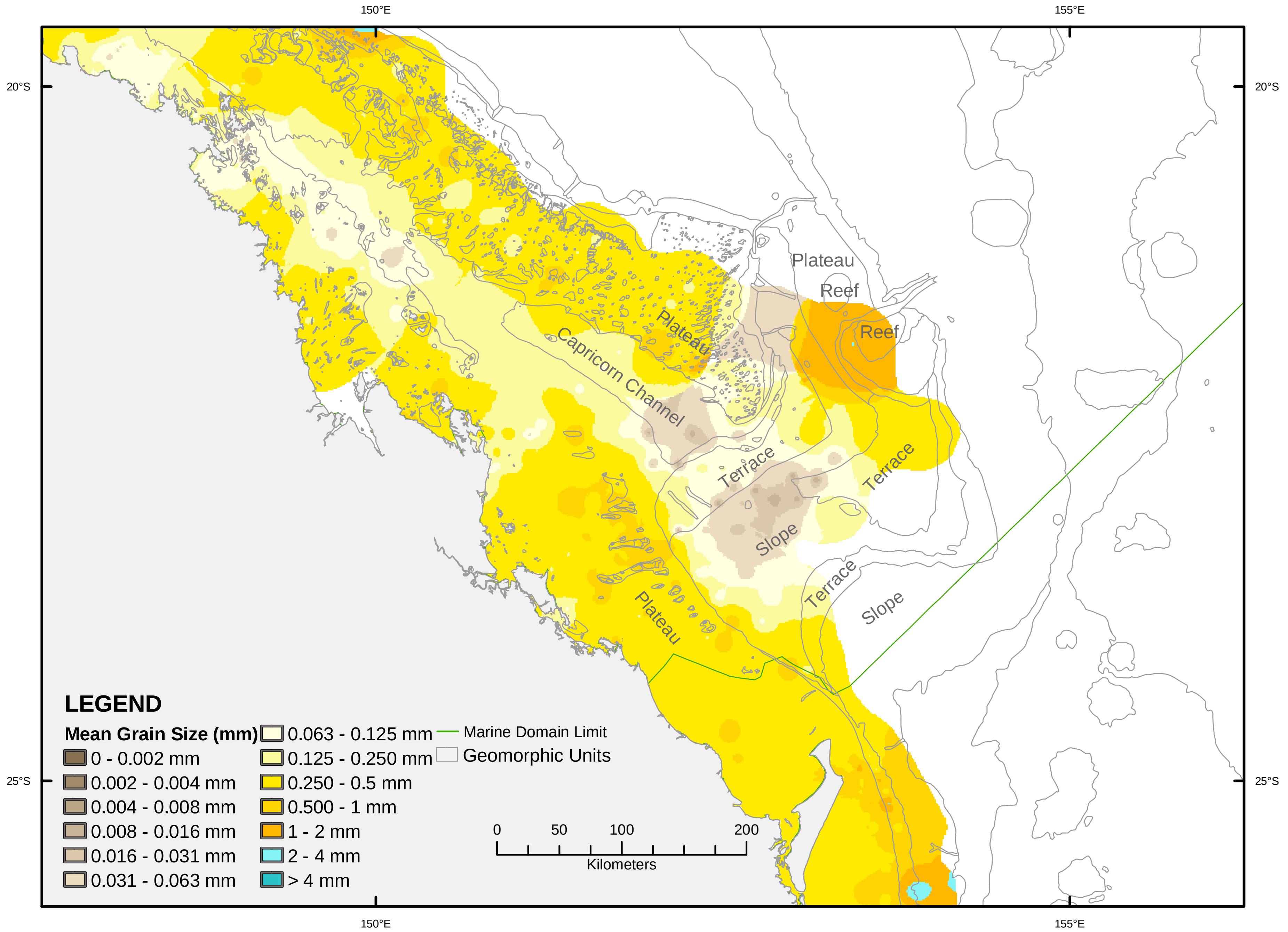


Figure 5.3 - Mean grain size and geomorphic units of Harris et al, 2003 - southern North-east Domain

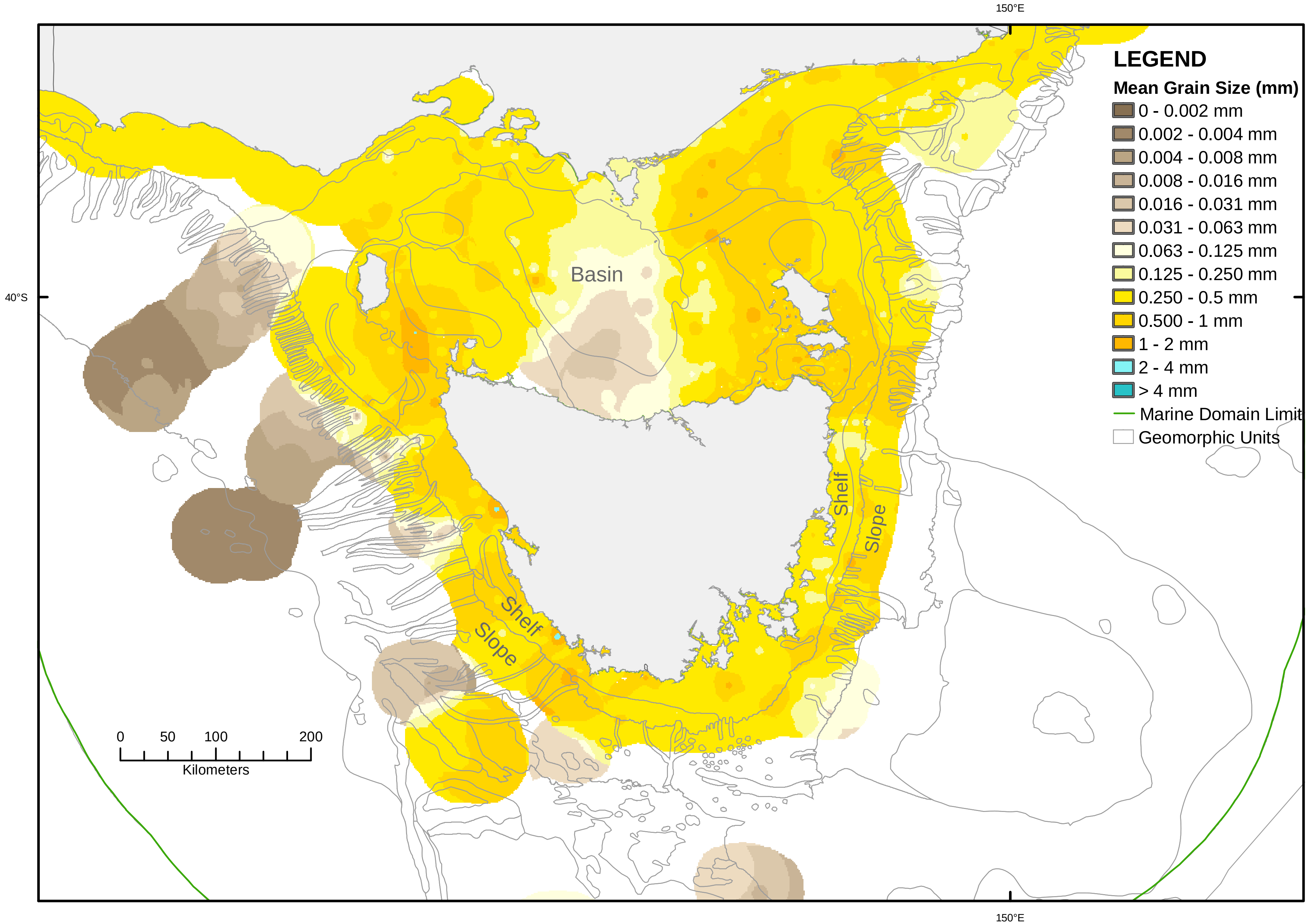


Figure 5.4 - Mean grain size overlain by geomorphic units of Harris et al, 2003 - Bass Strait region.

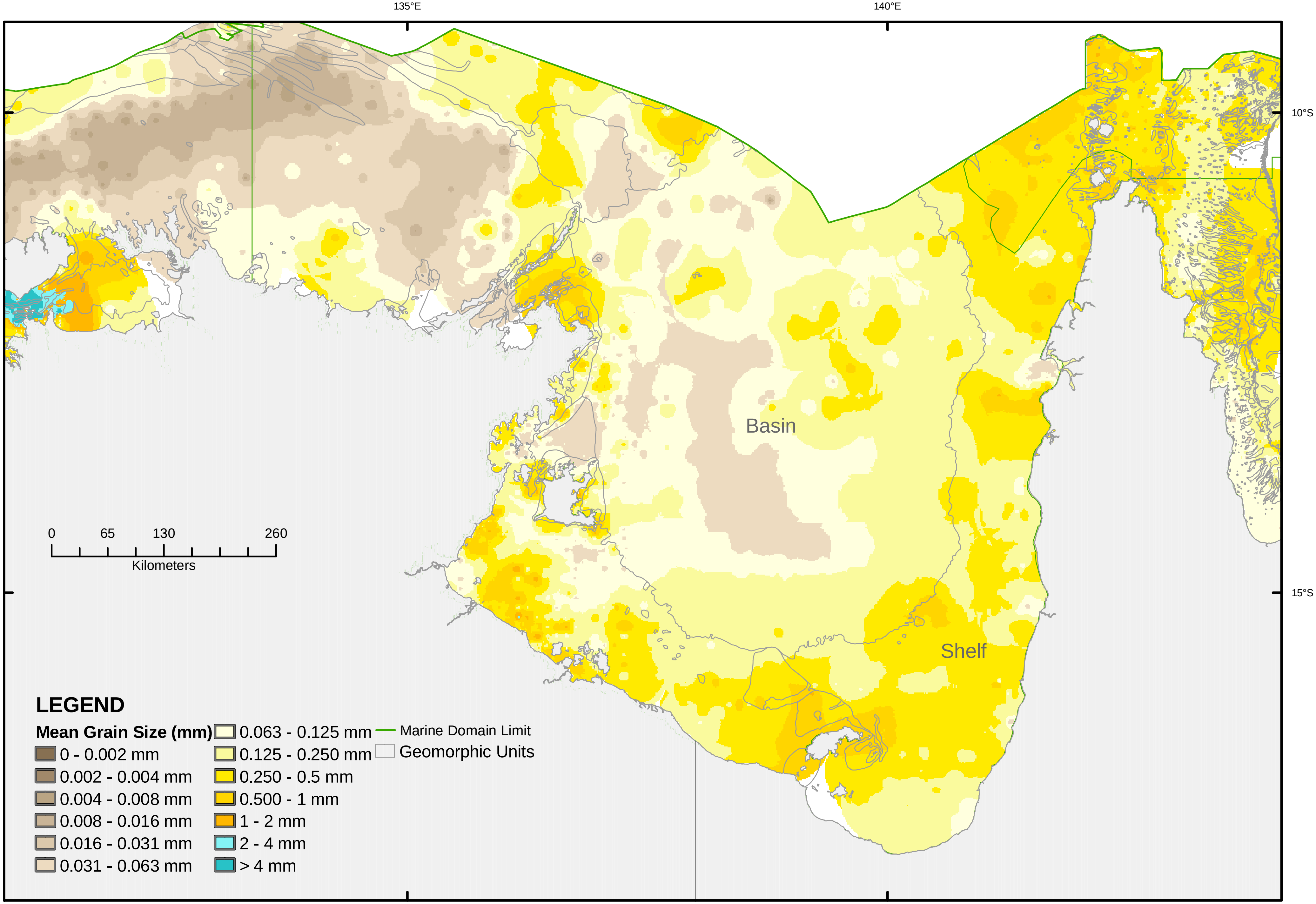


Figure 5.5 - Mean grain size and geomorphic units of Harris et al, 2003 - Northern Domain