Appendix 6: May 2008 EU-SOPAC Rapid Biological Marine Assessment Report

SOPAC

PACIFIC ISLANDS APPLIED GEOSCIENCE COMMISIION

Rapid Biological Marine Assessment of the Proposed RMI-EPA Sand and Aggregate Dredging Site Locations within Majuro Lagoon, Republic of the Marshall Islands

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Prepared for. Environmental Protection Agency Republic of the Marshall Islands

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1.0 EXECUTIVE SUMMARY

The Environmental Protection Agency (EPA) of the Republic of the Marshall Islands (RMI) is further developing environmental management regulations associated with the extraction of sand and gravel aggregate from the nation's lagoons, most of which are restricted to the nation's capital Majuro and the outer island population centres (e.g. Ebeye). These new regulations (currently pending) provide mechanisms to improve the management of current dredging operations, to make provisions for the use of alternative and improved technology and provide a framework to reduce environmental impacts. The adoption of lagoon-based suction dredge technology is an integral component of these regulations.

This report details information gained from a rapid marine biological assessment of a number of new RMI-EPA proposed dredging sites located within Majuro Lagoon and provides an account of the ecological implications if these sites were to be dredged. A total of 40 manta tows were undertaken on the reef flat, reef edge, reef slope and lagoon floor and 14 strip transect dives were undertaken parallel to the reef edge for the proposed new dredging sites. The total area covered by the manta tows during the assessment is estimated at 16 km^2. Detailed biological descriptions have been provided for each of the proposed dredging sites including a detailed account of the shallow water coastal ecosystems associated with these sites.

In summary, the marine biodiversity and hard coral health at the proposed dredging sites located on the southern side of Majuro Atoll varied considerably. Site AJT, Locations 1 and 2 recorded the highest diversity and hard coral percent live coverage. Sites RT, JT, DL and JB which have been heavily subjected to a wide range of anthropogenic impacts, including major dredging and land reclamation projects recorded generally lower and more varied results. However, all sites assessed include specific reef systems that recorded relatively abundant and diverse hard coral communities.

The marine biodiversity and hard coral health at the proposed dredging sites located on the northern side of the Majuro Lagoon have been subjected to considerably less anthropogenic impacts and maintain relatively healthy reef systems. The shallow water reef morphology of the northern lagoon sites revealed two distinct benthic habitats including exposed reef channels with associated deeper water sediment deposits, and lagoon bays located behind islets which have high hard coral coverage. The reef edge, reef slope and sub-tidal reef flats at the southern and northern sites showed the highest abundance of hard corals and percent coral coverage. The reef slope at all sites terminated at a water depth of between 8-12 meters into a relatively homogeneous sand-dominated lagoon basin that continues on a gentle slope to the lagoon proper at all sites assessed.

The ecological implications of extracting sand and aggregates from the RMI-EPA designated assessment sites are site specific. Each of the RMI-EPA designated assessment sites have locations that would be suitable for resource extraction. In general, the extraction of resources from waters deeper than 10-12 meters at all sites, if undertaken utilising the best management practices, is expected to have minimal impacts on the biological integrity of the shallow water reefs located at these sites. However, extreme care should be exercised if dredging is to be utilised at these sites in order to provide a high level of protection to the reef organisms associated with the reef edge and slope.

Dredging operations should not be undertaken at any site in the immediate vicinity of reef areas that recorded a high coral coverage and diversity during the assessment. Specifically, no dredging operations should occur in the vicinity of:

- Site AJT (Locations 1 and 2);
- the small patch reefs at each site associated with the southern assessment sites; and
- the reef systems associated with the inshore lagoon bays located behind the islands associated with the northern assessments sites.

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Abbreviations and Acronyms

CMI	College of the Marshall Islands
COTS	Crown of Thorns Starfish
EEZ	Exclusive Economic Zone
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
IUCN	The World Conservation Union
MICS	Marshall Island Conservation Society
MIMRA	Marshall Islands Marine Resource Authority
NEPA	National Environmental Protection Act
SOPAC	Pacific Islands Applied Geoscience Commission
SCUBA	Self Contained Underwater Breathing Apparatus
RMI	Republic of the Marshall Islands
SPREP	South Pacific Regional, Environmental Programme
UN	United Nations
US	United States of America
UTM	Universal Transverse Mercator

2.0 INTRODUCTION

2.1 Marshall Islands

The Republic of the Marshal Islands (RMI) is a young independent nation and became a member of the United Nations (UN) in 1981. It was a United Nations Trust Territory administered by the United States of America (US) until the two nations signed a Compact of Free Association in 1986. The trusteeship was officially terminated by the United Nations in 1990. The compact treaty established a special relationship with the US and provided for economic support to the RMI for 15 years. The funding provisions under the original compact terminated in 2005 and a new compact treaty for a further 15 years has been entered into with the United States. The economic stability of the RMI presently relies heavily on financial assistance available through the compact, foreign aid from the international community and revenues derived from international land leases (Kwajalein atoll and nuclear rehabilitation programs).

The US dollar is the currency used by the nation. The major economic activities within the nation are subsistence farming and fishing, agricultural production, commercial offshore fishing, wholesale, retail and Government services. The Government services dominate the economy. The minimum official wage for the private sector is US$1.50 per hour whilst US$2.00 an hour is the official Government wage (MIMRA, pers. comm.). Agriculture, fisheries and the tourism sectors are recognized as providing the long-term growth potential for the nation. Agricultural production and tuna fisheries (international and domestic) are the main commercial business within the islands. The international and domestic commercial tuna fishery provides annual revenues between US$1 to 3 million dollars (MIMRA, pers. comm.). The tourism sector is contributing small revenue earning to the nation, but recent business developments (e.g. direct charter flights from Japan) are aimed at developing this industry.

The Republic of the Marshall Islands is composed of twenty-nine atolls and five low elevated coral islands located in the north central Pacific Ocean (RMI Government, 2000). The majority of the islands are inhabited (Figure 1). The indigenous population is Micronesian with over half the population residing in the national capital of Majuro. The remaining population lives either on Ebeye Island on Kwajalein Atoll, a large US military installation or on the scattered atolls within the nation. The RMI has an exceptionally high regional population birth rate (3.89%) and a recent census (July, 2002) indicated the population within the nation was 73,630 of which half are younger than 15 years of age (RMI Government, 2003). The past decade has witnessed internal migration from the outer lying islands to the nation's capital and Ebeye (major center for employment) and an ever increasing outward emigration of the citizens to Hawai'i and the United States mainland in search of improved employment and education opportunities (SPREP, 2003).

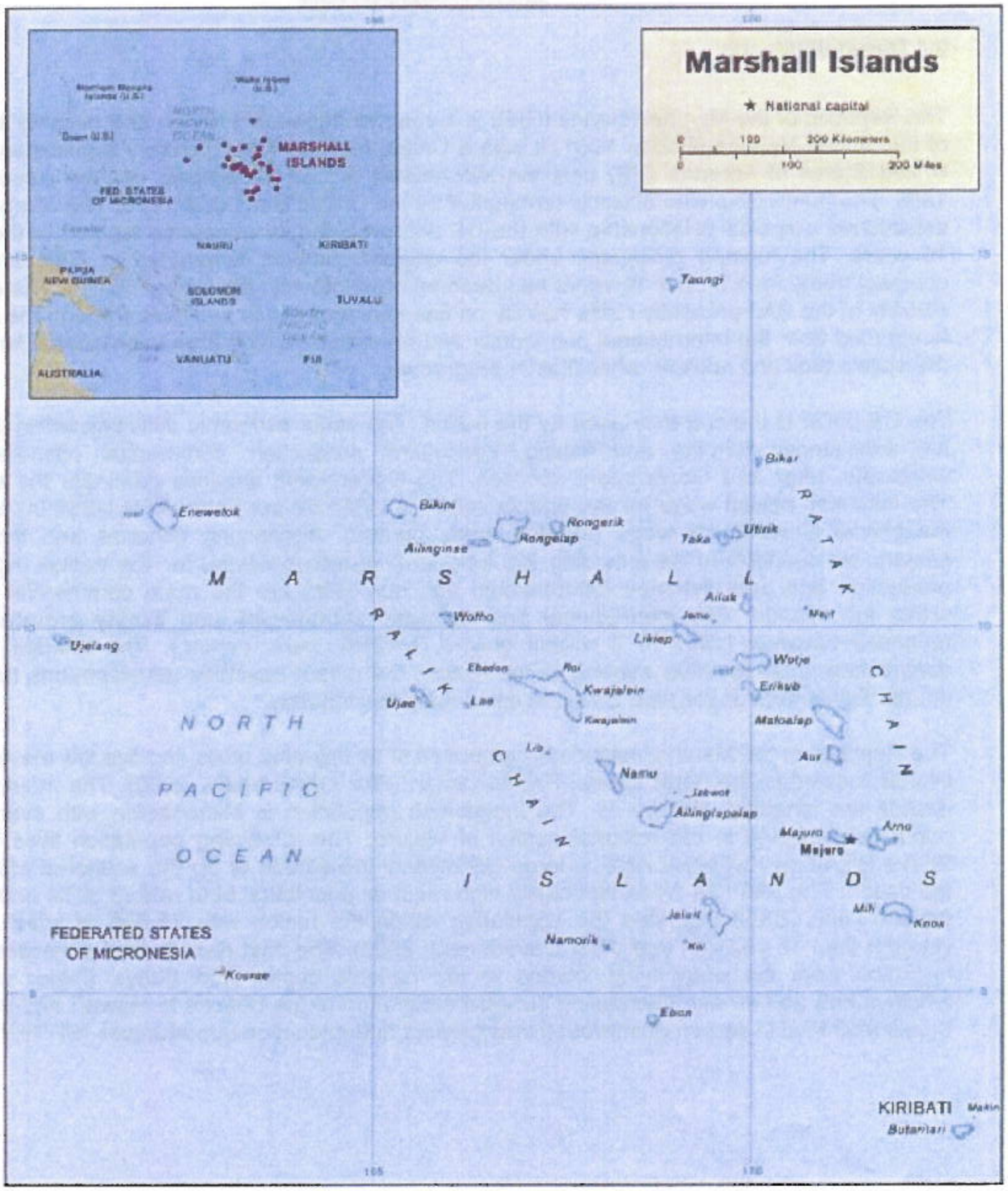

Figure 1. Locality map of the Marshall Islands and neighbouring nations.

Traditional, social and cultural institutions are very strong. Marshallese society is based on the extended family, which is responsible for the family welfare, especially in relation to customary family land. Ownership of land and marine areas varies between islands (RMI Government, 2000 and SPREP, 1999). However, the majority of land and marine areas within five nautical miles outside the reef are owned by the communities through traditional land ownership and managed in conjunction with atoll local governments (RMI Government, 2000). All marine zones within RMI atolls below the Mean High Water Mark (MHWM) falls under the jurisdiction of local councils and governments. RMI Law, Title 9, Public Lands and Resources, Chapter 1: Section 103. "Rights in areas below high water mark. (1) that portion of the law established during the Japanese administration of the area which is now the Republic that all marine areas below the ordinary high water mark belong to the government, is hereby confirmed as part of the law of the Republic". Land cannot be sold to non-citizens of the RMI. These land and marine ownership patterns greatly influence and complicate access usage of marine resources and therefore play a critical role in the collection of lagoon-based aggregates for the nation's development requirements.

2.1.1 Geography

The total landmass of the RMI is 181 square kilometres, with a declared EEZ covering 2.13 million square kilometres. The RMI comprises of 34 islands (coral atolls and low-lying coral islands) and the highest elevation is 8 meters. The atolls and islands within the archipelago consist of two roughly parallel island chains: the western "Ralik" ("sunset") and eastern "Ratak" ("sunrise") chains. The atolls extend approximately 1130 km north to south, from 14°43'N – 4°34'N and approximately 1290 km east to west, from 160°48'E – 172°10'E (RMI Government, 2000 & SPREP, 2003). The annual range of surface water temperatures is 27 – 30°C and the average tidal range is about 1 – 1.5 m. The nearest neighbours are Kiribati to the south, FSM (Federated States of Micronesia) to the west and Hawaii in the east.

The northeast trade winds belt heavily influences the tropical climate of the RMI. Trade winds prevail from December through April, periods of weaker winds and doldrums occur from May to November. Rainfall decreases as latitudes increase within the archipelagos with annual average rainfall between 60 – 360 centimetres. The nation has no permanent rivers. Groundwater seepage is the main mechanism by which dissolved contaminants and nutrients move from the terrestrial environment to the marine. In general there is no surface freshwater runoff from the atolls due to their low-lying, porous nature and small land areas, however runoff can occur in urban environments where hard surfaces predominate. The region is affected by storms and typhoons that are more severe as latitude increases and by periods of drought and excessive rainfall associated with the "El Nino" (ENSO) phenomena (RMI Government, 2000).

2.1.2 Marine Environment

Coral reefs and their associated ecosystems and biomes are the only shallow marine feature of the nation. All major types of coral reefs are found within the RMI, including barrier reefs, fringing reefs, large lagoons and submerged reefs associated with atolls that reveal high biodiversity and endemism (RMI Government, 2000).

Coastal resources, especially close to urban centres of Majuro and Ebeye, are over exploited. Inappropriate and unsustainable fishing practices are being employed. These practices have led to increased competition between resource users and have accelerated resource depletion, habitat alteration, degradation and in some cases destruction of the habitat (pers. comm. MIMRA). Coastal degradation due to poor land use management practices, sand mining and dredging operations (terrestrial and marine), land reclamation (ocean and lagoon areas) and pollution especially in the urban centres of Majuro and Ebeye is a growing concern for the nation (RMI Government, 2000 and SPREP, 2003).

2.1.3 Legislative Issues

The national constitution of the RMI is the basis for legal authority and decision making in the nation. In addition to the western-style democratic government, a traditional Marshallese governing system including a council of 12 paramount chiefs acts as an advisory body to the national government, especially on matters that affects customary land, law, traditional practices and land tenure (RMI Government, 2000).

Each inhabited island within the nation through its elected local councils holds jurisdiction over their own atoll including land, lagoon and water up to 5 nautical miles offshore from their reefs. These local governments are based on the national legislative system and have the powers to introduce laws and regulations pertinent to their atoll's affairs. In addition, the traditional hierarchal system of land owners plays a vital role in each atoll's management (RMI Government, 2000 and SPREP, 2003). The local island councils and traditional owners therefore, have jurisdiction over the majority of coastal areas and therefore are responsible for regulations and enforcement for all marine activities including sand and aggregate collection.

Marine and environmental regulations include those by the national congress, state legislatures and traditional authorities. Two national legislative acts empower two different government agencies through regulations with respect to the responsibility for the conservation and management of the marine resources of the nation. The Marshall Islands Marine Resources Act (1998) empowers the Marshall Islands Marine Resource Authority (MIMRA) with the responsibility for overall conservation and management of marine resources and the Marshall Islands National Environmental Protection Act (1984), known as NEPA, which includes a wide range of environmental legislation that allows the Environmental Protection Agency (EPA) to regulate and enforce these activities, one of which is sand and aggregate extraction (SPREP, 1999 and 2003). The environmental regulations under the NEPA (1984) have been reviewed with specific amendments for more sustainable dredging operations and the regulations are currently pending ratification.

2.2 Majuro Atoll

Majuro Atoll, located close to 171° 12'E and 7° 09'N, is where the capital of the Republic of the Marshall Islands is located, also named Majuro. The atoll one of the most developed and densely populated atolls in the Pacific with an estimated population of 30,000 (2006 US embassy web site). Majuro Atoll is elongate in shape, extending 40 km from east to west, and 9.7 km from the north to the south. The lagoon is approximately 180 km^2 and enclosed by an almost continuous reef flat which possesses several passages in the centre west side of the north rim, in which a 3.2 km wide and 9.1 – 18.3 m deep passage is located west of Calalin Island (Xue, 1997). The atoll consists of 64 islets covering approximately 6 km^2 with the majority located on the east, south and eastern half of the northern rims of the atoll (Figure 2). Causeways have been developed over the past 40 – 50 years that have connected the islands from Djarrit in the east to Laura in the southwest, with most natural sea water channels entering the lagoon closed off (Xue, 1997).

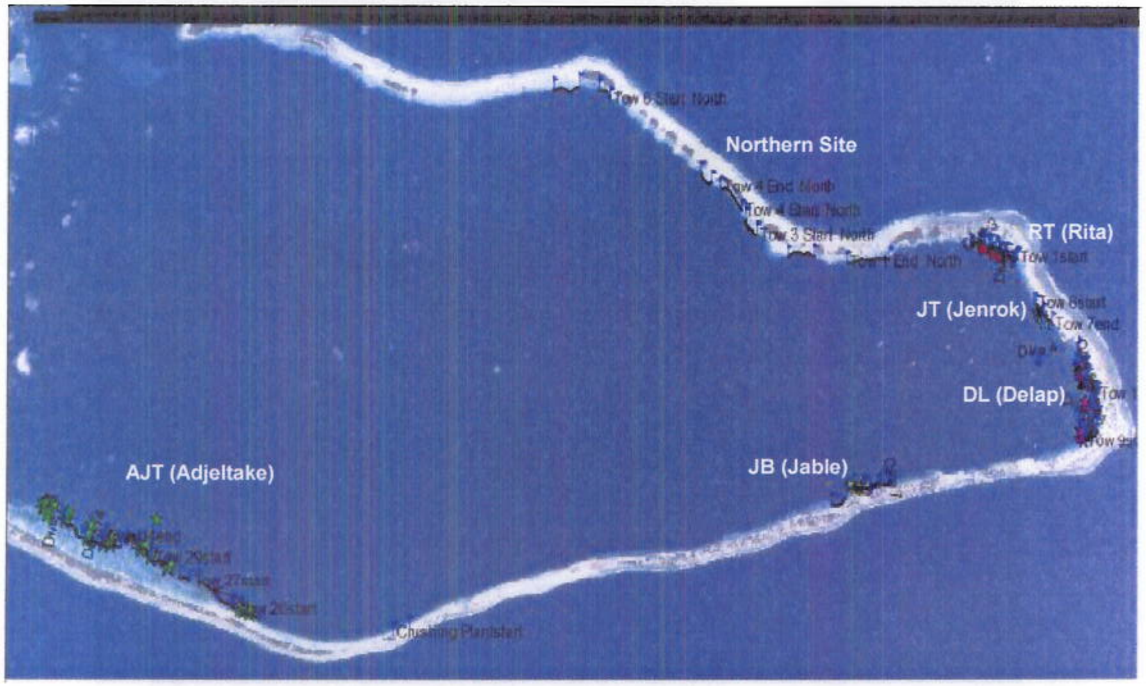

Figure 2. Site locality map of eastern Majuro Lagoon (see also Appendix 9).

2.3 Lagoon Mining and Dredging

Sand mining and aggregate dredging of the coastal foreshore and lagoon has been an integral and unregulated component of the development of Majuro for the past 100 years. Resources have been removed from the exposed sea ward reef flats, beaches and terrestrial areas on the islands and from the lagoon for a wide variety of purposes, most of which have been associated with the development of commercial infrastructure (e.g. causeways, roads, and buildings), land reclamation and residential development. Xue, (1997) provides a detailed summary on the major sand and aggregate commercial development activities of Majuro Lagoon over the past century.

Considerable land reclamation has been undertaken within Majuro Atoll for commercial and private use. Land has been reclaimed from the seaward side of the islands, lagoon beaches and intertidal reef flats of the lagoon. In the populated areas of Djarrit, Uliga and Dalap (DUD), which is situated in the eastern corner of the atoll, intensive lagoon reclamation has continued to occur. The reclamation process is undertaken by the land owners to add additional above water land to their properties. This land is usually acquired by erecting a temporary rock retaining wall (made from a wide range of material) and backfilled (Figure 3). Household garbage and commercial solid waste has in the past been used as a major source of land fill. Sand and gravel removed from the lagoon is generally used to cap the reclamation area before construction activities are undertaken. Reclamation activities in some areas have covered sections of the reef flat up to 50 meters from the original shoreline and much appears to have occurred in an ad hoc fashion.

Figure 3. Land reclamation site, Majuro Lagoon.

Three commercial methods of sand and aggregate extraction have been used in Majuro. The most common method is a dragline scraper operated by a crane from the shore line (Figure 4). The second method witnessed during the assessment utilises a hydraulic excavator from the shore line, which generally restricts the depth and range of its activities (Figure 5). Dragline scrapers utilise larger machinery and are capable of removing larger quantities of material than hydraulic excavators. Both methods extract resources from shallow water (maximum depth approximately 10 meters) and deposit the material directly onto the shoreline. The third method, which is rarely used is a nearshore suction dredge that extracts the material from shallow waters and deposits the material directly onto the shore via pipes attached to a suction head (Figure 6).

Small-scale sand and gravel extraction from beaches and nearshore environments for personal use has been undertaken throughout the atoll most of which is used for personal land improvements and construction. Most of these activities are undertaken by "manpower" utilising hand held tools.

All commercial and small-scale sand and aggregate removal is monitored and managed under the RMI-EPA regulations. Past adherence to these regulations has been mixed.

Figure 4. Shoreline based dragline scraper and crane system extracting sand and gravel from the Majuro Lagoon.

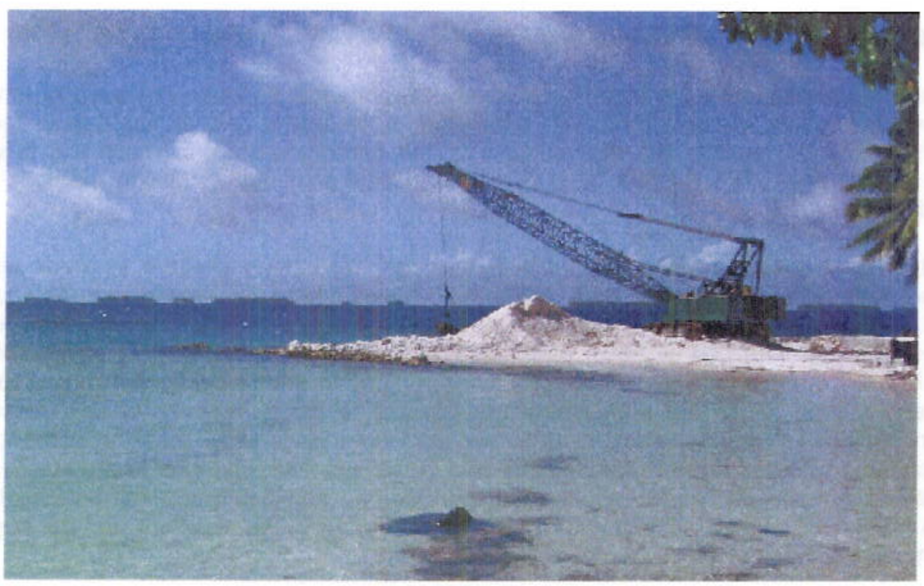

Figure 5. Shoreline based hydraulic excavator extracting sand and gravel from the Majuro Lagoon.

Figure 6. Suction dredge pump to extract sand and gravel from the lagoon bed.

2.3.1 Future Developments of the Sand and Aggregate Excavation in RMI

All sand and aggregate dredging operations cause environmental impacts. The severity of these environmental impacts is associated with a number of biological and anthropogenic factors. These environmental impacts are associated with the natural habitats in which the dredging operation takes place. The method of extraction and environmental mitigation methods were employed.

Past and present dredging sites within Majuro Lagoon have been situated in areas directly associated with land reclamation sites and have utilised shore line extraction methods, in particular, dragline scrapers and hydraulic excavators. The major marine environmental issues associated with the extraction of these resources can be delineated into primary and secondary impacts. Primary impacts include the direct physical alteration and/or destruction of substrates, habitats and marine life in the area where the material is being removed and/or deposited. Secondary impacts are related to sedimentation on adjacent marine areas resulting in changes in water circulation patterns due to physical changes in the sea bed, changes to the surrounding water quality by increased concentrations of suspended fine particles which can drift significant distances (sediment plumes), changes to the light penetrating to the sea floor and the physical smothering and damage of sensitive organisms (e.g. corals).

There have been several reports undertaken during the past decade associated with the need to locate new areas for the renewable extraction of sand and aggregate resources and to improve the environmental impacts associated with extraction methods for the continued development of Majuro Atoll (e.g. Smith, 1995, Xue, 1997 and Smith and Collen, 2004).

The negative environmental impacts that have resulted from past sand and aggregate dredging operations and the recommendations detailed by these reports has initiated the government of the RMI through the EPA to seek alternatives through regulative measures. The aim of these measures is to allow the continued supply of this crucial resource whilst providing advice and regulative measures to minimise environmental damage to the marine and coastal environment. Thus the RMI-EPA have drafted new regulations that manage and limit the number of extraction sites within the atoll, prevent or minimise shoreline alteration, restrict or phase out the use of equipment that inherently damages the coastal and foreshore environments (e.g. dragline scrapers and hydraulic excavators) and promote the use of the most economical and environmentally acceptable methods (e.g. suction dredge technology). It is the aim of the new EPA regulations that the industry will move towards the use of suction dredges in the next 3 – 5 years accessing resources from deeper waters away from the fragile reef communities located on the intertidal reef flats and slopes of the Majuro Lagoon.

The use of suction dredge technology still has the potential for environmental damage and care must be taken when deploying the equipment and associated structures. Correct preventative measures are required to contain the extracted resource when pumped onto land.

The recommended RMI-EPA regulation changes to the current shore based sand and gravel extraction processes will only be accepted and implemented by the commercial and private sectors if suitable alternative sand and gravel extraction sites can be provided and alternative extraction methods and equipment are economically profitable. Smith and Collen (2004) summarise the three important issues associated with the sustainable long term development of this industry which include;

- the government concern and requirement to ensure that both the dredging sites and extraction technology used satisfies the environmental regulations as guided by the Marshall Islands National Environmental Protection Act (1984);
- the private sector base line concern is the economic viability of the site locations and new technology; and
- the traditional land and resource owners fully understand the issues and provide the consent for the government agencies to be a responsible custodian in the development and management of these resources.

Smith, (1995), Xue, (1997) and Smith and Collen (2004) identified a number of new potential dredge sites within Majuro Lagoon based on sand and aggregate type, their size, resource renewability, and government, community and land owner concerns and issues. These sites have been acknowledged by the government of the RMI and have been highlighted to be assessed for the ecological implications of dredging. The list of sites highlighted in these reports makes up the specific sites assessed and documented in this report. The sites highlighted incorporate three different regions of the Majuro Lagoon including site RT, JT, DL, and JB located in the DUD areas of Majuro, the areas located at Site AJT Locations 1 and 2 which are located to the west of the airport and the lagoon areas located in the north of the atoll from Rita to Calalin Island.

3.0 BACKGROUND

3.1 Mission Objectives

The goal of the SOPAC (Pacific Islands Applied Geoscience Commission), European Union (EU) funded Project "Reducing Vulnerability in Pacific ACP States" is to address vulnerability through three key focal areas; 1) hazard mitigation and risk assessment; 2) coastal vulnerability and aggregates for construction; and 3) water resources supply and sanitation. The coastal vulnerability/aggregates for construction component has undertaken a variety of tasks characterising potential lagoon aggregate resources and bathymetric survey. It was recognised that in addition to the identification of potential resource areas that an assessment of the ecological implications of utilising these lagoon bed resources would both complement and better advice the EPA in its decision making processes.

As such, this consultancy was commissioned by SOPAC and had the overall objective to provide biological technical advisory services in conjunction with the SOPAC Coastal Processes Adviser (Dr Arthur Webb) to:

- Provide a baseline marine biological assessment of the RMI-EPA proposed shallow water marine dredge site locations within Majuro Lagoon.

The approach taken to achieve the objective was to:

- Undertake a rapid assessment of the marine biological components (fish, epi-faunal/infaunal invertebrates, seagrass, corals, algae, mangrove, etc.) and their considerable broader ecological function in each of the nearshore RMI-EPA proposed dredge site locations within Majuro Lagoon,
- Assess the impacts of the present dredging and proposed dredging activities on these biological components and develop monitoring guidelines and mitigation options, and
- Undertake informal discussions with key stakeholder groups and incorporate relevant comments into the report.

The overall outcomes of this consultancy were to provide:

- A report on the marine biological status of the RMI-EPA proposed dredge site locations within Majuro Lagoon including the measured and expected environmental impacts of dredging at these locations and provide recommendations and mitigation options in a form that is understandable to the key stakeholders; and to,
- Provide hands-on training and capacity building with in-country SOPAC work partners and key stakeholders.

The RMI-EPA originally proposed five lagoon dredge sites located on the southern side of the atoll to be assessed by the project. However, at the request of the RMI-EPA a number of additional proposed dredge sites associated with the northern fringing reef and islands between Rita and Calalin Island were included. These additional sites had been previously recommended (e.g. Smith and Collen, 2005) as potential aggregate resource areas, however these have not been exploited due to perceived conflicts of interests and use by other stakeholders, community groups and landowners. Nevertheless, these sites were included in this study to provide baseline biological information to allow the RMI-EPA to better evaluate the potential of these locations.

The overall goal of the consultancy was to provide biological baselines and background information to the RMI-EPA to manage the current and future sand and aggregate dredging sites within the Majuro Lagoon. It also provided baseline information to further guide the EPA's program to enhance the regulation of aggregate resource extraction and adoption of more environmentally sustainable technology (the RMI-EPA wish to see the widespread adoption of suction dredge technology in lagoon reef areas), such as;

- areas 10 – 20 meters in depth;
- those which have renewable sand and aggregate resources; and
- those with low benthic biological integrity and biodiversity (e.g. use sites that have been previously altered).

4.0 ASSESSMENT METHODOLOGY

A rapid marine biological assessment of five proposed Majuro Lagoon dredging sites indicated by the RMI-EPA (Rita RT; Jenrok JT; Delap DL; Jabel JB and Adjetaki AJT – see Figure 2) was undertaken from 1st – 12th May 2007. In addition, the consultant team evaluated seven inshore lagoon reef sites associated with the northern fringing reef between Rita and Calalin Island (termed the "northern sites" in this report).

The marine assessment was undertaken utilising international standard marine biological methods and was performed by the consultant and staff from the RMI-EPA and SOPAC. The assessment team included:

- Mr Stephen Lindsay — Project Consultant
- Mr Andrew Finlay — Environmental Advisor RMI-EPA
- Mr Peni Musunamasi — Senior Project Officer - SOPAC

Hands-on training and open discussions during the field activities were undertaken to develop the capacity of all staff in various aspects of marine biological assessment (biological survey, data collection, analysis, interpretation, and management protocols).

The assessment also included stakeholder discussions and during the course of the field work the team undertook discussions with; government agencies, EPA and MIMRA, the Marshall Island Conservation Society (MICS) and marine staff at the Collage of the Marshall Islands Marine Science Department (CMI).

The final component of the survey involved presentation of the preliminary findings of the study to the RMI-EPA. This detailed the biology and potential sensitivity of these locations to possible dredge impacts and including assessments at all five proposed dredging sites and the additional northern reef sites.

(Appendix 1 provides a daily work summary of the assessment team whilst in Majuro).

4.1 Marine Resource Assessment

The technologies utilised during the marine assessment were adopted from English et al (1997). These consisted of visual survey methods, manta tows and strip transects (SCUBA) and involved a systematic inventory of species present at each site. Through out this process EPA and SOPAC staff where involved in the survey, evaluation and identification of relevant indicator species (further details of methods are documented in Appendix 2).

A total of 33 manta tows and 14 strip transect dives were conducted during the study in the five RMI-EPA proposed dredge sites and 7 additional single manta tows were conducted along the lagoon reef flat and slope of the northern RMI-EPA proposed dredging sites. The total area covered by the manta tows during the assessment was estimated to be approximately 16 km^2 (*ca.*

10 km^2 for the five proposed dredging sites and 6 km^2 for the northern proposed dredging sites). Table 1 provides a guide to the area covered by the manta tow assessment for each site at each location.

A GPS was used to record the position at the start and end of each manta tow and strip transects and the track and distance travelled was also recorded by GPS. Total reef area surveyed was calculated by multiplying the distance travelled by the estimated width of each tow track (this GPS position data will be incorporated into SOPAC's broader GIS products being produced by the Reducing Vulnerability Project).

Table 1. Area covered by the manta tow assessment for each site at each location.

Six proposed dredging sites	Area covered km^2	Northern proposed dredging sites	Area covered km^2
Site RT	1.560	Area 1	1.620
Site JT	0.480	Area 2	1.400
Site DL	3.320	Area 3	0.720
Site JB	2.094	Enemonit Island	0.300
Site AJT		Area 4	0.420
Location 1	1.360	Eneko Island	0.150
Location 2	1.760	Area 5	1.080
Total	10.570	Total	5.69

Table 2. Corresponding manta tow and strip transect numbers for each assessment site during the survey.

6 Proposed dredging sites	**Manta tows**	**Strip transects (dives)**
Site RT	1, 2, 3, 4, 5	1, 2, 3
Site JT	6, 7, 8	4
Site DL	9, 10, 11, 12, 13, 14, 15, 16, 17	5, 6, 10, 11, 12
Site JB	18, 19, 20 ,21, 22, 23	7, 8
Site AJT		
Location 1	24, 25, 26	9
Location 2	27, 28, 29, 30, 31, 32, 33	13, 14

Manta tows were undertaken on the reef flat, reef edge, reef slope and lagoon floor to provide a comprehensive visual assessment of the marine benthic habitats associated with all of the RMI-EPA proposed dredging sites. Digital photos were taken during each manta tow highlighting specific benthic features (e.g. sediment, hard coral, and macro algae). The strip transect (dives) were only undertaken at the five proposed dredging site locations as detailed in Appendix 2. Each dive was video taped over its total length and digital photos were taken highlighting specific benthic features (e.g. sediment, hard coral, and macro algae). All raw data collected (manta tows and strip transects), video footage and digital photos have been provided and are held at RMI-EPA and with SOPAC (again these are expected to be incorporated into SOPAC's Project GIS products).

The water depth evaluated during the manta tow survey for all sites ranged from 1 – 12 meters whilst the depth range of water for the strip transect dives ranged from 4 – 24 meters. The linear distance for all manta tows range from 200 – 600 metres with the width assessed between 6 – 16 meters. All strip transect dives were 50 meters in length. All manta tows were not straight and therefore the distance travelled is not reflected by a straight line between GPS coordinates. All manta tows and strip transect (dives) have been assigned a number (Appendix 3, 4, 5, 6, 7, and 8) and is cross referenced with individual site maps.

All field data collected for the five proposed dredging sites is tabulated in Appendix 3, 4, and 5. Appendix 3 provides the latitude and longitude data in UTM's (Universal Transverse Mercator) for the start and end of each manta tow and strip transect dives including wind and sea conditions prevailing at the time of the assessment. Appendix 4 provides the data collected for water depth, manta tow/transect length, transect width, total number of turtles, mollusc (bivalves, gastropods), commercial sea cucumbers (also includes crown of thorn starfish COTS), marine algae (turf, macro, sea grass), selected commercial finfish located during all manta tows and strip transect dives for all sites assessed. Appendix 5 presents data collected on the percent live coral cover, litter, reef condition, dominant benthic forms, dominant hard coral genus and morphological forms for all manta tows and strip transect dives for all sites assessed.

All field data collected for the seven additional "northern site" proposed dredging site locations are tabulated in Appendix 6, 7, and 8. Appendix 6 provides the latitude and longitude data for the start and end of each manta tow including wind and sea conditions prevailing at the time of the assessment. Appendix 7 provides the data collected for water depth, manta tow length, transect width, total number of turtles, mollusc (bivalves, gastropods), commercial sea cucumbers (also includes crown of thorn starfish COTS), marine algae (turf, macro, sea grass), selected commercial finfish located during all manta tows for all sites assessed. Appendix 8 presents data collected on the percent live coral cover, litter, reef condition, dominant benthic forms, dominant hard coral genus and morphological forms for all manta tows for all sites assessed.

5.0 REEF EVALUATION AND SURVEY RESULTS

5.1 General Reef Synopsis

Majuro Atoll shows the typical morphology of a coral reef associated with a Pacific atoll from the sea ward side to the lagoon;

- outer reef drop off;
- lower and upper outer reef slope;
- reef crest;
- reef flat;
- island;
- beach rock;
- sand/coral rubble beach;
- shallow water intertidal reef flat;
- sub tidal reef flat;
- lagoon reef edge;
- lagoon reef slope; and
- lagoon proper.

The morphological reef areas assessed during this study included only those marine habitats associated with the inshore lagoon environments which include; shallow water intertidal reef flat, sub tidal reef flat, lagoon reef edge, lagoon reef slope, and the lagoon proper.

Majuro Lagoon is flushed twice daily when oceanic waters enter and leave through inter-tidal and sub-tidal passages. Tides are semi-diurnal and have a range of less than 1.5 meters within the Majuro Lagoon. The tides generate strong currents both within the lagoon and outside the reef with strong tidal generated currents associated with the northern and southern natural passes entering the lagoon with current speeds of 3 – 5 knots common. Circulation patterns and water residence times within the lagoon, particularly the eastern portion, have been altered over the past half century due to the construction of a number of causeways across former inter-tidal passages (to link populated islets), land reclamations activities (both seaward and lagoon sides) and via the excavation of deeper sub-tidal boat channels. It is likely that the extensive net work of causeways which have been constructed has had the net result of decreasing exchange with oceanic waters and contributes to changes in water quality within the eastern lagoon. In other similar locations such as Tarawa Lagoon (Kiribati), hydrodynamic studies (Damlamian, In press) show that causeways can greatly decrease lagoon water exchange or flushing and increase water residence times, and in combination with associated urban pressures such as groundwater contamination can lead to ecological change and environmental degradation within lagoon environments. During this study (and earlier studies by the author) surface water in the nearshore reef areas associated with the eastern end of Majuro Lagoon (e.g. DUD) has generally been observed to move in a westerly direction and is probably related to the predominant easterly trade wind conditions and wave set-up conditions on the eastern ocean reefs.

Smith (1995) indicated that the majority of beach sand (down to a depth 15 – 20 metres) within Majuro Lagoon is derived from foraminifera and these are deposited along the lagoon side beaches and sand deposition areas. The forams in general reside on the reef flats and are deposited into these areas by the daily movement of water across the reef flat into the lagoon through tidal flushing and storm events. The areas highlighted by Smith (1995), Xue (1997) and Smith and Collen (2004) along the northern side of the atoll showed deposition rates and all of the studies mentioned, indicate the long term viability of dredging operations maybe dependant on a continuing natural supply of new sediment (deposition). Similarly, these same studies raise concerns that deposition rates in the present dredge sites on the south-eastern lagoon rim are low and as such dredging in these locations should be seen as an extractive activity, i.e. not renewable resources.

5.1.1 Anthropogenic Impacts

Majuro Lagoon has had continued physical and biological anthropogenic alterations over the past 50 years. Much of the physical alterations are associated with the development of Majuro's residential and commercial areas (e.g. DUD) on the islands located along the southern side of the atoll rim (from DUD to Laura in the west). The northern islands of the atoll due to their isolation (not accessible by road) have been subjected to considerably less anthropogenic disturbances. The major anthropogenic threats to the marine environment within the Majuro Lagoon include:

- resource extraction (sand/rubble/coral rock - dredging);
- land reclamation and alterations (e.g. Hydrodynamic and physical);
- habitat destruction (e.g. dredging, anchors, trampling);
- habitat alteration (water craft channels);
- resource exploitation (over harvesting: e.g. sea cucumber);
- pollution (human waste, petrochemicals, rubbish);
- increased sedimentation; and
- increased terrestrial degradation.

Garbage both from residential (e.g. diapers, plastic bags, cans, washing machines) and commercial (rebar, lumber, concrete) sources was commonly found at all sites assessed, with large rubbish plies found at the assessment sites RT, JT and DL. Plastics and nuisance flotsam and jetsam was also prevalent on all shores neighbouring the assessment sites.

Figure 7. An example of residential garbage commonly found during the assessment (reef flat in front of Rita, Majuro Atoll).

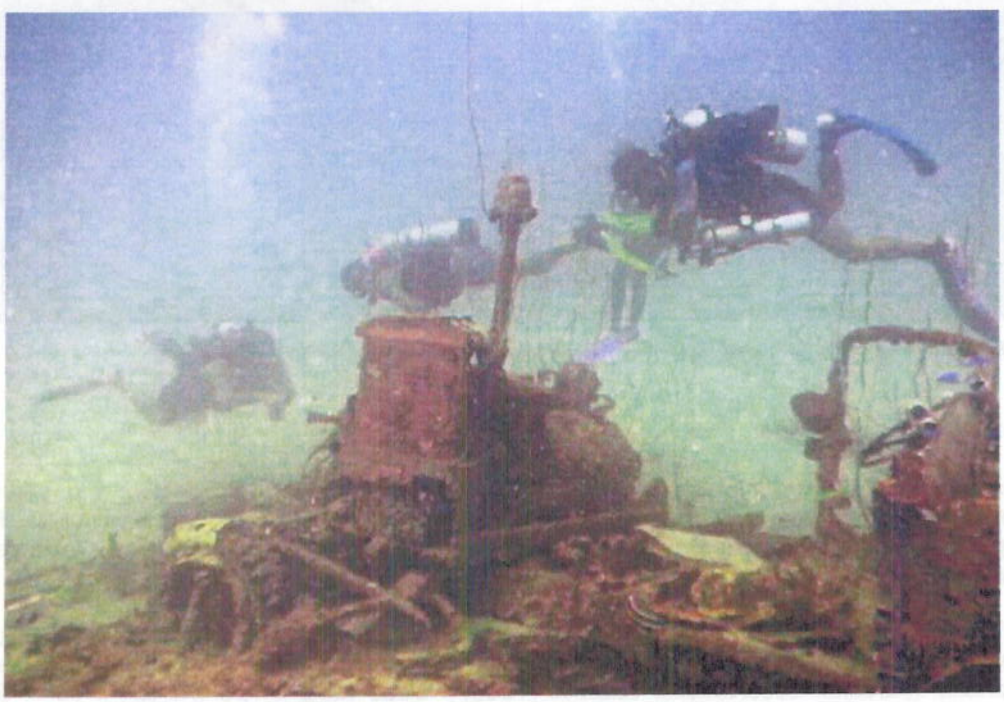

Figure 8. An example of commercial garbage commonly found during the assessment.

The lagoon areas associated with the five sites assessed and the northern reefs sites are not biologically pristine, however benthic coral reef communities show considerable resilience to these anthropogenic factors. In general, the biological integrity and marine biodiversity of the lagoon marine benthic habitats and associated organisms improves further away from the population centres of the atoll (from east to west – authors personal observations, 1992 – 2007). Physical damage was evident in the hard coral communities assessed (e.g. hard coral removal, reclamation activities, boat groundings, rubbish and anchors) and hard coral stress and mortality was witnessed and was likely associated with past and present dredge operations (e.g. opposite the islands garbage dump).

Figure 9. Coral reef subjected to high suspended sediment load associated with coastal mining.

5.1.2 Biological Impacts

There are a number of biological (e.g. predators, pathogens) and abiotic factors (e.g. sea water temperature) that have been reported to be detrimental and cause mortality in hard corals. These organisms and processes are a natural component of any reef system and are associated with the reef systems of Majuro Atoll.

Crown of thorns starfish – COTS (*Acanthaster planci*) outbreaks have been recorded over the past 4 – 5 years in the western half of the lagoon and were reported to have caused considerable mortality (personal observations, Jacobson, 2007). Dead table corals (*Acropora sp.* – 2 – 3 meters diameter) with COTS feeding scars were seen during the assessment at Site AJT, Location 2. Several small adult COTS specimens were located during the assessment (e.g. Site JT, Tow 6 and Site JB, Tow 22) however recent feeding scars seen on hard coral communities at these assessment sites were minimal. The number of COTS recorded during this assessment does not indicate these animals are a threat to reefs at these sites at the present time.

Figure 10. Coral damage due to Crown of thorns starfish, Site AJT, location 2.

During the assessment there was no evidence of coral bleaching (due to increased sea water temperature) nor was there any hard coral disease located.

The five proposed dredging location sites are not specifically utilised by the local tourism operators although an area near Site RT is a popular dive location due to the presence of several World War II vehicles on the seafloor. The northern reef sites assessed are utilised by both international and local tourists mostly for day excursions due to access to clean beaches and safe swimming/snorkelling areas. The majority of Majuro based marine dive tourism operators utilise the reefs associated with passes and outside reef locations which have considerable higher live coral cover.

5.1.3 Species Conservation Importance

Marine turtles were the only IUCN Red listed marine species located during the assessment. Nine juvenile green turtles (*Cheloina mydas*) were located during the assessment, three turtles were located at Site AJT, Location 1 and six specimens were located during the northern reef assessment sites foraging for food. No adult specimens were located nor were there any signs of nesting on the islands. Anecdotal information indicated that green turtles have been reported nesting along the northern islands of Majuro in the past, but recent nesting's have not been recorded (personal observations, Mr. V. Alfred, MRD).

There were no mangrove forests or significant sea grass beds located within or in close proximity to either the five main assessments sites or the northern sites.

It has however been reported that the endemic (not red listed) anemone fish *Amphiprion triscitus* has been identified on reefs of the eastern end of Majuro Lagoon (personal observations, Jacobson, 2007) although not confirmed by the assessment team. This fish is endemic to the RMI and care should be exercised if these animals are located close to a potential dredging location.

Subsistence food species (e.g. fin fish, molluscs) and commercial species (e.g. Maori wrasse, grouper) were rare or absent in all areas surveyed. The techniques utilised for the surveys were not specifically designed for fish surveys however when comparing data collected utilising similar techniques in Jaluit Atoll (SPREP, 2003) the data obtained during this assessment clearly indicated extremely low species abundance. This is particularly evident in the assessment sites associated with the residential areas of Majuro (e.g. DUD). The absence of giant clams, commercial species of sea cucumbers, reef sharks and large specimen of edible fish is a clear indication of over harvesting of these organisms.

5.2 Marine Environment of the Assessed Sites

Each of the five designated sites evaluated during this assessment and the seven sites assessed on the northern reefs of Majuro Lagoon are discussed separately (refer section 5.3 and 5.5), however there were a number of general environmental, morphological and biological attributes of each site that were similar and therefore are highlighted and discussed below.

5.2.1 Beach Rock and Sand/Rubble Beach

All sites evaluated had a distinctive region of exposed or hidden beach rock located on the upper shoreline. The beach rock is more predominate at Site AJT and on the small islands on the northern assessment sites. Much of the beach rock associated with the urban development areas (e.g. DUD) have been used as a base for the lagoon reclamation activities. Sand dominated the beaches at all sites whilst gravel beds (hard coral) were only associated with a small section of the northern islands that are adjacent to the intertidal channels and passes.

5.2.2 Inter Tidal Reef Flat

The beach rock descends to a shallow intertidal zone, which is comprised of and is dominated by fine sand and small to medium size rubble. This intertidal zone ranges in width between 10 – 60 meters with the shallow water areas exposed during low spring tides. All sites accessed had macro algal beds associated with these areas with the density and species varying between sites. The introduced algae *Acanthophora spicifera* (figure 11) was a dominate alga in this zone and was located in Sites DL, JB, AJT locations 1 and 2. In the deeper areas of the lower intertidal zone, small patches of hard coral were present at all sites and were dominated by small colonies (less than 1 metre) of *Porites lutea* (massive). Colonies located near past reclamation and dredging operations were damaged and in some cases dead. The intertidal area adjacent to DUD is the region where the majority of land reclamation activities and other disturbances have occurred and large volumes of garbage (domestic and industrial) was also witnessed especially at Sites RT, JT, and DL (refer figure 7 and 8).

Figure 11. Photo of the introduced macro algae Acanthophora spicifera at Site DL.

5.2.3 Sub Tidal Reef Flat

The sub tidal reef flat at all sites is dominated by sand and small to medium size rubble interspersed with living hard coral and algal beds. The shallow sub tidal zone ranges in width between 20 – 250 meters (widest at Site DL) with a water depth of 1 – 4 meters. The large massive coral (e.g. *Porites lutea*) was the dominate hard coral species located at all sites in this zone however as the water depth increased towards the lagoon's reef edge and slope, coral diversity and morphological form increases and becomes dominated by digitate (*Porites rus*), branching (*Porites cylindrical*) and tables (*Acropora sp.*) corals. Percent live coral cover in this zone in all sites assessed ranged between <5% through to 30%. Site AJT showed the highest percent live coral cover of all sites. Some live coral damage was witnessed at all sites and dead colonies were apparent in all sites, most of which is likely associated with sedimentation from past and current dredging operations (refer figure 9) and past crown of thorns (*Acanthaster planci*) predation at Site AJT (refer figure 10). Algal beds were located throughout this zone at all sites and in some areas dominated. The introduced algae *Acanthophora spicifera* (figure 11) was the most common alga in this zone and was located in Sites DL, JB, AJT. *Padina sp.*, *Dictyota sp.* and blue green algae (figure 12) were also abundant in this zone and small beds of *Halimeda sp* were located in several areas. Sites RT, JT, and DL are predominately made up of sand and rubble beds and all sites, except Site AJT have been subjected to dredging operations in the past. Large volume of domestic and commercial garbage was seen in this zone especially at Sites RT, JT, and DL.

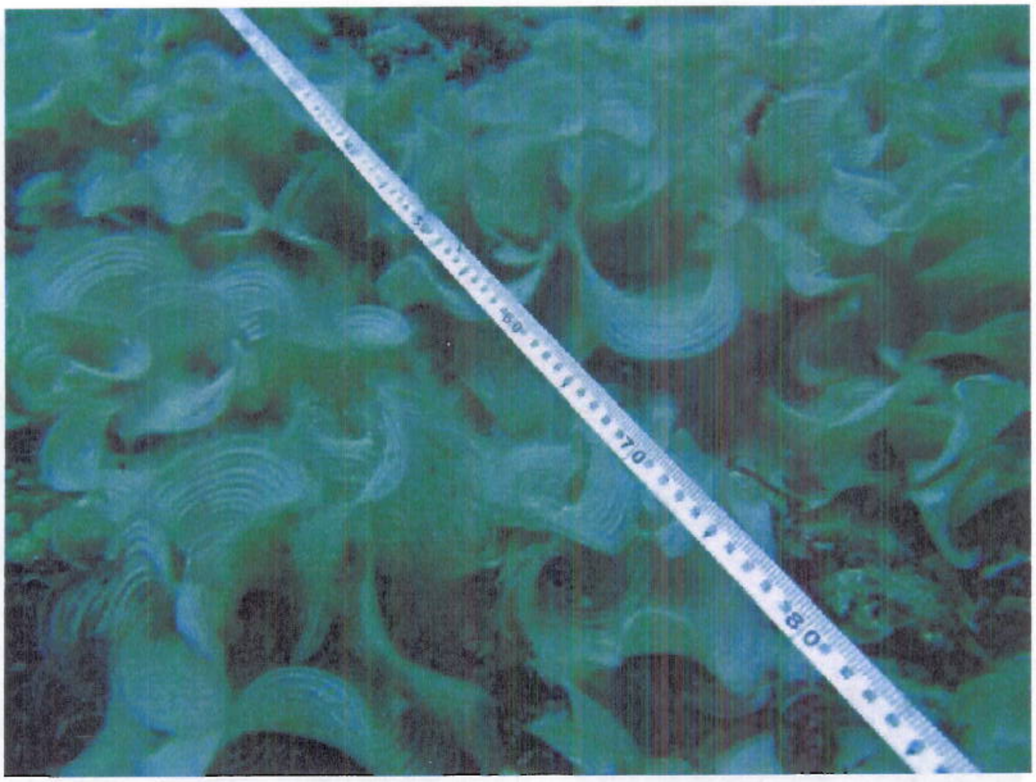

Figure 12. Photo of Padina sp beds associated with sub tidal reefs.

5.2.4 Reef Edge and Reef Slope

The reef edge and reef slope at all sites showed the highest percentage of live coral coverage and diversity. However, coral diversity at all of the five sites was low when compared to RMI lagoon reefs that have not been subjected to high levels of anthropogenic factors, e.g. Jaluit Atoll (SPREP, 2000). Coral cover ranged from less than 5 to 90 percent in this zone and was interspersed with areas of sand and small to medium coral rubble. The reef edge and reef slope zones are distinct at each site and cover an area of between 10 — 30 meters in total width and a water depth of between 4 – 12 meters at which point all sites were dominated by sand and a gentle slope towards the lagoon basin. In all areas assessed by the survey team the lower slopes towards the lagoon basin were almost exclusively dominated by sand and small rubble.

Total live percent coral coverage on the reef edges and slopes was highest at sites associated with reefs that were furthest away from the shore line and were subjected to stronger currents, less inshore derived sedimentation and less shoreline anthropogenic influences. Site AJT showed the highest diversity of hard and soft coral species however previous impacts caused by crown of thorns starfish (*A. planci*) were noticeable. Porites massive, digitate and branching forms dominated these reefs especially those at Sites RT, JT, and DL whilst a wide range of *Acropora sp* and other hard coral genus were also located in these reef areas. Coral recruitment was apparent in all sites, but more so on the reef edges and slopes. Site AJT showed the highest number and diversity of hard coral recruits which were dominated by a number of *Acropora* and *Pocilopora* species. The coral recruits varied in size indicating recruitment has occurred over the past several years. Dead adult coral colonies and recruits were recorded and is associated with past and current dredging operations at Sites JT, DL, JB and AJT Location 1.

Each site assessed has sections or areas of healthy and abundant hard coral reef community as well as areas devoid of hard coral and associated marine life. These areas that showed high coral coverage (refer table 3) need to be protected from disturbance, including dredging, as they contribute significantly to the lagoon's marine habitat and biodiversity. Such areas also likely play a critical part in recruitment of hard and soft corals within Majuro Lagoon. All sites had areas that possessed massive coral colonies (*Porites lutea*) that were larger than 2 metres in diameter. Sites DL and AJT Location 2 had *Porites* colonies larger than 4 metres in diameter.

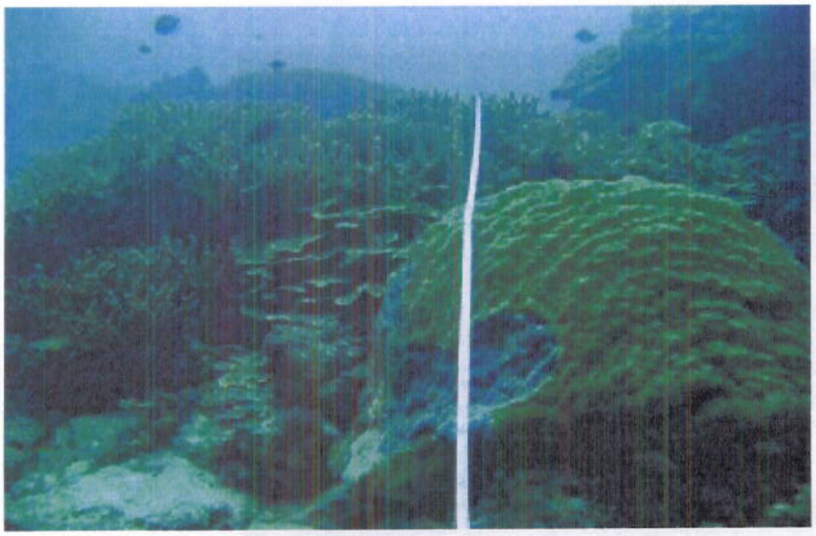

Figure 13. Large Porites lutea at Site AJT, Llocation 1.

Macro algae beds were also present throughout this zone and were more associated with sand and coral rubble beds located between the live coral patches. Several species dominated this zone including *Padina sp.* and *Dictyota sp. Halimeda sp.* also dominated on the reef slopes and blue green algae was common in areas where rubble dominated the substratum.

Figure 14. Halimeda sp. beds associated with the reef slope at Site AJT, Llocation 2.

Present dredging operations are mostly located inshore of the reef edge and slope (operations are shoreline based) and therefore direct physical damage of these reef areas is limited. However, several dredging operations (e.g. Site DL and Site AJT, Location 1) have encroached into the reef slopes and as a result the coral has been directly and negatively impacted both from physical disturbance and increased suspended sediment loads – it is important to note the sedimentation effects were consistently identified downstream of the operations.

Again, household and commercial garbage was a common feature on the reef edges and slopes at all sites and Sites RT, JT, and DL showed the highest levels of garbage.

Figure 15. Garbage located on the reef slope at Site DL.

Table 3 provides the site and tow number for reef edge and slope areas that have a high percent of coral coverage.

Table 3. Site and tow number for reef edge and slope areas that have a high percent of coral coverage.

Site	Tow Number	Percent Live Coral
RT	1	40
JT	6	60
DL	13	75
	14	75
	16	70
JB	20	55
AJT Location 1	24	80
	25	60
	26	90
AJT Location 2	28	60-80
	29	75
	30	80
	33	80

5.3 Assessment Results of the Five EPA Proposed Dredging Sites

A summary of the specific biological results for each site and an analysis of the potential ecological impacts, which may be a threat if dredging proceeds, are discussed below. These are the expected impacts associated with the use of suction dredge technology either positioned on a floating barged above the resource area and depositing material onto the barge or being pumped directly onshore.

5.3.1 Site RT

Five manta tows (1, 2, 3, 4 and 5), three strip transect dives (1, 2 and 3) and a visual assessment covered an approximate area of 1.56 km^2 at Site RT (Figure 16).

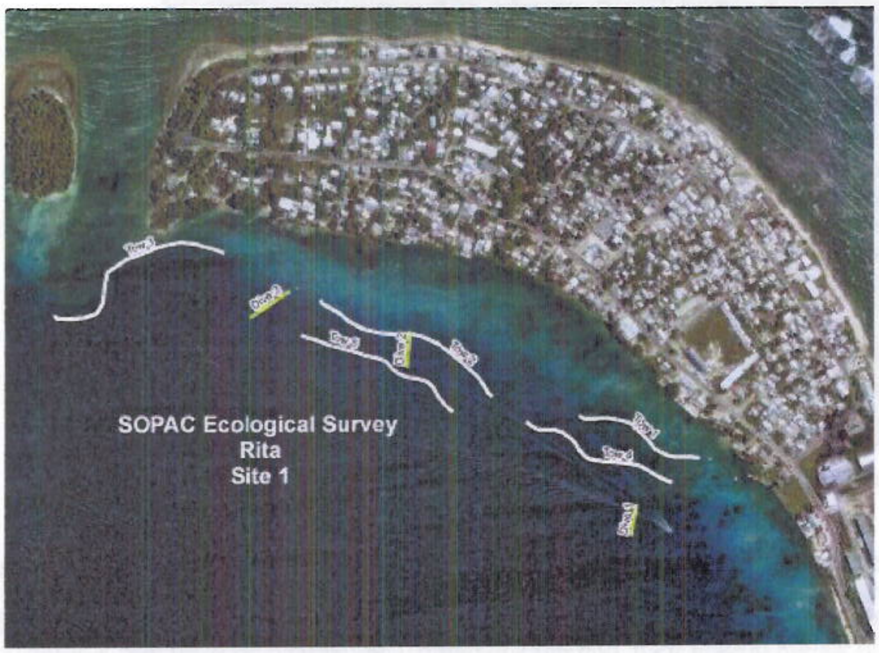

Figure 16. Shows the five manta tow and three dive locations evaluated during the assessment for Site RT (Rita).

Site RT is located directly opposite the community of Rita in the eastern corner of the lagoon. This area supports a dense urban population and considerable amount of reclamation has been undertaken on the lagoon side for residential and other purposes. The reef flat is relatively shallow, between 30 – 70 metres in width with the upper areas exposed during low spring tides. The reef flat has a gradual slope terminating at the reef edge which descends gradually towards the lagoon basin.

This site is dominated by sand and small coral rubble interspersed by small to medium sized colonies of *Porites lutea* and *Porites rus* with small patches of the soft coral (*Lobophyllia sp.*) and several small colonies of branching species of *Acropora sp.* The lagoon proper is dominated almost exclusively with sand down to 23 meters (maximum water depth assessed). The reef flat, slope and edge have a medium to high coverage of macro alga dominated by *Padina sp.*, *Dictyota sp.* and blue green algae whilst *Halimeda sp.* was located only on the reef edge and slope associated with the rubble and bommies. Domestic rubbish was high at all sites evaluated and included a wide range of items. The reef area has been subjected to continued anthropogenic issues associated with physical disturbances (e.g. land reclamation), rubbish and resource exploitation. Tow number 1 showed the only reef section that recorded a good percent of live coral cover (40%) along the reef edge. This area was dominated by the hard coral of the genus *Porites*, the soft coral *Sarcophyton* and *Lobophyllia* and small beds of the *Zooanthidea* (*Discosoma sp.*). Food fish and edible and/or commercial invertebrates were all but absent on this reef.

Figure 17. Photo of the seafloor at Site RT.

The biodiversity at this site is low and apart from the reef areas in manta tow 1, the habitat present is not unique to the Majuro nor the RMI. Therefore, from a biological perspective there would be limited negative environmental effects at this site if suction dredge mining for sand was to take place in waters greater than 10 meters in depth. Care should be exercised if dredging is to operate at this site to provide a high level of protection for the reef highlighted in manta tow 1 and the hard coral colonies on the reef flat. The implementation of an appropriate sediment management plan tailored to minimise sediment distribution for the use of a suction dredge should be mandatory. This reef area and associated adult hard coral colonies may play an important role in the long term recruitment of corals throughout the lagoon. Recruitment of hard coral species was sparse with only several small recruits located at this site. The replenishment of sand resources is expected to be limited due to the issues highlighted in previous SOPAC reports (Smith 1995, Xue 1997, Smith and Collen 2004)

5.3.2 Site JT

Three manta tows (6, 7 and 8) and one strip transect dive (4) covering an estimated area of 0.48 km^2 (Figure 18) were undertaken at Site JT. The biodiversity at this site was low and apart from the reef areas associated with manta tow 6 was not a unique habitat in Majuro Lagoon. Therefore biologically there would be limited negative environmental effects to the reefs associated with this site if suction dredge mining for sand was to take place in waters greater than 10 meters depth.

Care should be exercised if dredging is to operate at this site to provide a high level of protection for the reef highlighted in tow 6 on the reef flat. The implementation of an appropriate sediment management plan tailored to minimise sediment distribution for the use of a suction dredge should be mandatory. This reef area and associated adult hard coral colonies may play an important role in the long term recruitment of corals throughout the lagoon. Recruitment of corals for all hard coral species was sparse with only small numbers recorded at this site (tow number 6). The replenishment of sand resources is expected to be limited due to the issues highlighted in previous SOPAC reports (Smith 1995, Xue 1997, Smith and Collen 2004).

Figure 18. Shows the 3 manta tows and single dive location evaluated during the assessment for Site JT.

Site JT is located directly opposite the community of Uliga in the eastern corner of the lagoon. This densely populated urban area is the site of extensive reclamation and residential and commercial development. The reef flat is relatively shallow and short (approximately 40 metres maximum in width) with the upper regions exposed during low spring tides. The reef flat has been dredged previously to provide a source of fill material for reclamation and to widen and deepen navigation channels to several commercial facilities (e.g. Robert Reimers Enterprises dock). Domestic and commercial rubbish was a common feature of all sites evaluated and included a wide range of material from small plastics to ship wrecks (Figure 8).

The reef flat has a gradual slope terminating at the reef edge which then descends relatively steeply to the lagoon basin. The deeper lagoon slopes was dominated almost exclusively by sand and macro algae (down to 23 meters). The steepness of the reef edge and slope appears to be an artefact of past shore line dredging operations. The reef flat in general is dominated by sand and small coral rubble interspersed by low numbers of small to medium size colonies of *Porites lutea* and *Porites rus* with small patches of *Acropora sp.* However there is an area of approximately 30 m^2 (tow number 6) that showed a high level of hard coral cover (60%) and reasonably diverse assemblages of hard coral species. This area was dominated by the hard corals of the genus Porites, Acropora, Fungia and Pavona and also contained beds of the Zooanthidea (*Discosoma sp.*), soft corals (e.g. *Lobophyllia sp.*) and sponges. This reef terminated at the reef slope in a water depth of 4 – 6 meters and the descent to the lagoon basin was dominated by sand. Food fish and edible and/or commercial invertebrates were all but absent on this reef.

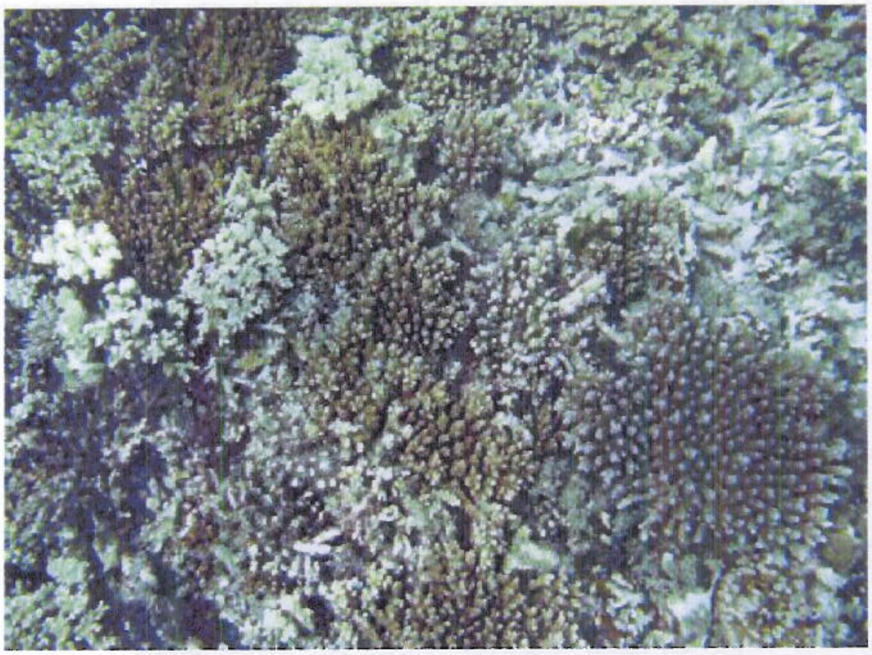

Figure 19. Photo of reef located at manta tow number 6, Site JT.

The reef flat, slope and edge have a medium to high coverage of macro alga dominated by *Padina sp.*, *Dictyota sp.* and blue green alga in the shallow areas whilst large beds of *Halimeda sp.* and to a lesser degree *Caulerpa taxifola* were located on the reef slope. The reef slope almost devoid of benthic life showed a high presence of the sand anemone (*Actinodendron sp.*) associated with tow numbers 8.

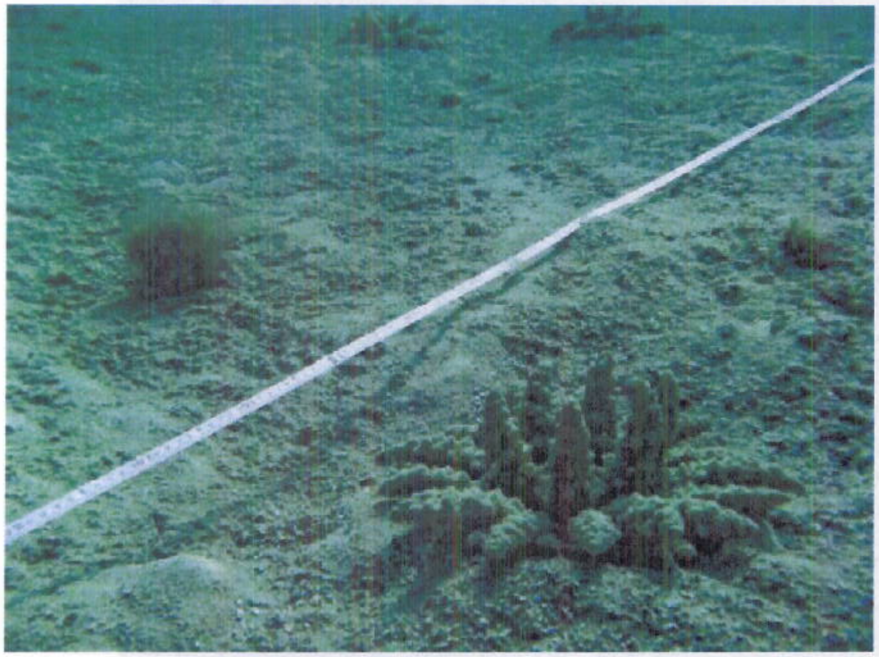

Figure 20. Actinodendron sp. located at Site JT, manta tow number 8.

5.3.3 Site DL

Nine manta tows (9, 10, 11, 12, 13, 14, 15, 16 and 17) and six strip transect dives (4,5, 6, 10, 11 and 12) covering an approximate area of 3.32 km^2 (Figure 21) were completed at Site DL. Again, biodiversity at Site DL was low and apart from the reef associated with manta tow 13, 14 and 16 is not unique to Majuro Lagoon. Therefore biologically there would be limited negative environmental effects to the reefs associated with this site if suction dredge mining for sand was to take place in waters greater than 10 meters depth. Care should be exercised if dredging is to operate at this site to provide a high level of protection for the reef highlighted in tow 13 and 14. These reefs should not be protected. Furthermore, the large *Porites* bommies found throughout this site should be protected. The implementation of an appropriate sediment management plan tailored to minimise sediment distribution for the use of a suction dredge should be mandatory. These reef areas and adult colonies may play an important role in the long term recruitment of corals throughout the lagoon. Recruitment of corals for all hard species was noticeable in areas associated with reasonable coral cover (e.g. Tows 13 and 14). The replenishment of sand resources is expected to be limited due to the issues highlighted in previous SOPAC reports (Smith 1995, Xue 1997, Smith and Collen 2004).

Figure 21. Shows the 9 manta tows and 6 dive locations evaluated during the assessment for Site DL.

Site DL is located directly opposite the community of Uliga and Delap in the south-eastern corner of the lagoon. This densely populated area with extensive lagoon side reclamation is almost exclusively used for residential and commercial development. The neighbouring reef flats are relatively shallow and range in width from approximately 50 – 300 metres in Uliga and Delap, respectively. The shallowest areas shoal at low spring tides. Generally the reef flat has a gradual slope which transitions at a poorly distinguished reef edge and slope before descending towards the lagoon basin. The reef edge and slope are however distinctive at two locations and are associated with a reef promontory (tow number 13) and an offshore reef (tow number 14). Both sites are in close proximity to each other and possessed high coral cover (Figure 22).

Figure 22. Photo of reef located at manta tow number 14, Site DL.

Various areas of the reef flat have been previously and are currently dredged to provide material for reclamation activities and to widen and deepen water access to several commercial facilities fill (e.g. Mr Dominic's dredging site). Considerable sedimentation has occurred on reefs downstream of the present dredging operation, which has resulted in hard coral mortality. Improvements in the deployment, location and use of sediment curtains to prevent sedimentation and smothering are urgently required during all dredging activities. Domestic and commercial rubbish dumping was prevalent throughout the Site and included a wide range of items.

Figure 23. Photo of the present shore based dredging operation at Site DL.

The reef flat in general is dominated by sand and smaller coral rubble and was interspersed by scattered, small to medium sized colonies of *Porites lutea* and *Porites rus* with small patches of *Acropora sp*. The large reef flat areas adjacent to the weather station possess large colonies of massive Porites which range in size from 3 – 5 metres in diameter. These colonies are very old. Dead colonies of a branching *Acropora sp* were located within the deeper sections of the reef flat (no live colonies were witnessed during survey at this site). The reef flat extends to a gentle descending reef slope that is dominated almost exclusively by sand and patches of the macro algae *Halimeda sp*. The reef flat, slope and edge have a medium to high coverage of macro alga dominated by *Padina sp*., *Dictyota sp*. and blue green algae in the shallower areas. The introduced macro algae *Acanthophora spicifera* was abundant on the reef flat in shallow areas (high densities at tow numbers 11, 12 and 17).

Within this site two reef areas (tow number 13 and 14) showed high levels of hard coral cover (75%) and possess a reasonably high diversity of coral species. Both reefs are a considerable distance off shore and posses a distinctive reef edge and slope. Coral coverage at both reefs terminated at approximately 8 –10 meters and transitioned into sandy substratum with patches of the macro algae *Padina sp*. towards the lagoon basin. The reefs were dominated by hard corals of the genus *Porites, Acropora, Fungia, Pocillopora* and *Pavona* and possessed considerable beds of the *Zooanthidea* (*Discosoma sp*.), soft corals (*Lobophyllia sp*. and *Sarcophyton sp*.) and sponges. Similarly, tow number 16 showed a high coral coverage associated with large coral bommies which were dominated by the hard coral genus *Porites sp*. and the soft corals *Lobophyllia sp* and *Sarcophyton sp*. Sand and small coral rubble dominated the sea floor between bommies. Food fish and edible and/or commercial invertebrates were all but absent on these reefs.

5.3.4 Site JB

Six manta tows (18, 19, 20, 21, 22 and 17) and two strip transect dives (7 and 8) covering an approximate area of 2.09 km^2 (Figure 24) were undertaken at Site JB. The biodiversity at Site JB was low to medium and was not considered unique in Majuro Lagoon, i.e. the species identified were commonly found in other areas of Majuro Lagoon. As such, from a biological perspective there would be limited negative environmental effects to the reefs of site JB if suction dredge mining for sand was to take place in waters greater than 10 meters depth. Care should be exercised if dredging is to operate at this site to provide a high level of protection of corals located on the reef edge and slope and the large *Porites* bommies found throughout this site should be protected. The implementation of an appropriate sediment management plan tailored to minimise sediment distribution from the use of a suction dredge should be mandatory. These reef areas and adult colonies may play an important role in the long-term recruitment of corals throughout the lagoon. Recruitment of corals for all hard species was relatively sparse and was located on the reef slope and edge in areas associated with reasonable coral cover (e.g. Tows 18 – 21). Reef areas, especially associated with the reef edge and slope have been and remain impacted by present land based dredging operations, with high levels of sedimentation occurring. The replenishment of sand resources is expected to be limited due to the issues highlighted in previous SOPAC reports (Smith 1995, Xue 1997, Smith and Collen 2004).

Figure 24. Shows the 6 manta tows and 2 dive locations evaluated during the assessment for Site JB.

Site JB is located directly opposite the community of Jable situated in the southern side of the lagoon between Majuro airport and Majuro Bridge. This area supports fairly dense population and reclamation is again common on the lagoon side. This site is directly opposite the Majuro solid waste dump facility. The reef flat is relatively shallow and ranges in width from approximately 20 – 40 metres with the upper regions exposed during low spring tides. The reef flat in general has a gradual slope, which terminates at a distinct reef edge and from here descends towards the lagoon basin. The reef slope starts at around the 4 – 5 meters water depth and terminates between 8 –10 meters.

Sections of the reef flat have been previously and are currently dredged to provide a source of material for capping the public dump, land reclamation activities and to widen and deepen access channels (Figure 25). Considerable sedimentation has occurred on reefs downstream of the current dredging operation, which has resulted in hard coral mortality. Improvements in the deployment and use of sediment curtains are urgently required. Domestic and commercial rubbish was less frequently seen on this site. It is important to note that no chemical analysis to determine possible impacts of the Majuro dump was undertaken however it very likely that leachates from the dump would drain into neighbouring lagoon and ocean side waters.

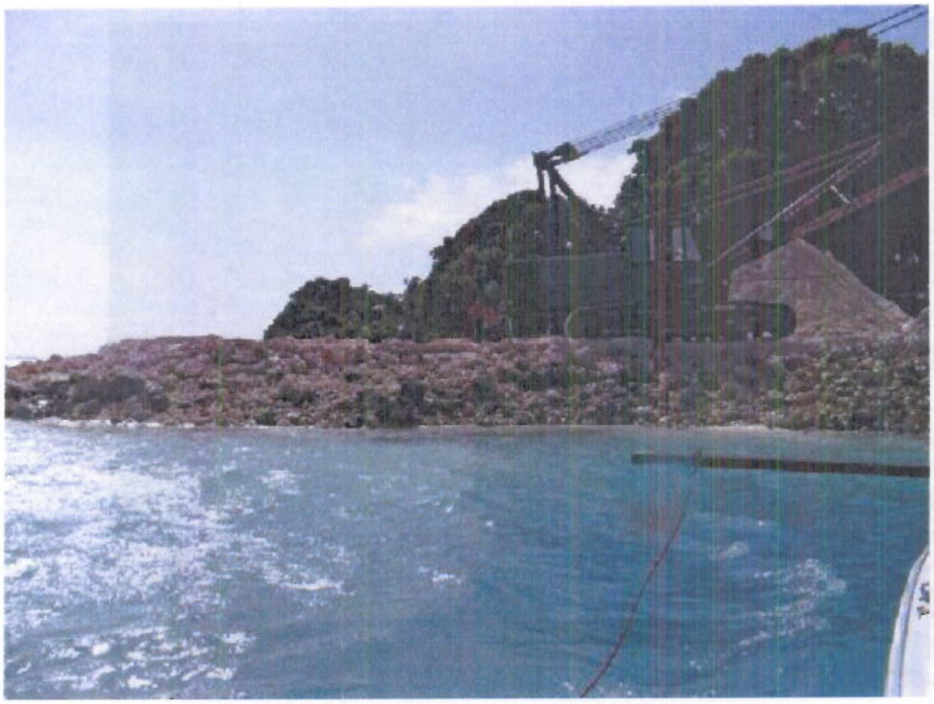

Figure 25. Photo of the shore line hydraulic dredging operation at Site JB.

The reef flat is dominated by sand and small coral rubble interspersed occasionally with small to medium sized colonies of *Porites lutea*. On the shallower reef flat, slope and edge there was a medium to high coverage of macro alga (*Padina sp.*, *Dictyota sp.* and blue green algae). *Padina sp.* and blue green algae dominated the reef slope towards the lagoon basin. The introduced macro algae *Acanthophora spicifera* was also recorded on the reef flat.

The reef edge and reef slope were characterised by patches of sand and rubble with a high macro algae and live coral cover. The reef slope and lagoon floor possess large healthy colonies of massive *Porites*, which range in size from 3 – 4 metres in diameter. These colonies are very old and are found at a maximum water depth of 10 meters.

The reef edge and slope recorded an average of 30 percent coral cover for tow number 18, 19, 20 and 21. Coral coverage terminated at approximately 8 – 10 meters where sand associated with the lagoon basin dominates with patches of *Padina sp.* The reef areas were dominated by hard corals of the genus *Porites*, *Acropora, Fungia, Pocillopora and Pavona,* soft corals (*Lobophyllia sp.*) and small colonies of *Millipora sp.* Tow numbers 22 and 23 possessed low coral cover and were dominated by sand and macro algae. These sites were located behind the reef edge and slope and subsequently likely received a constant deposition of sediments washing over the reefs from the east. Nevertheless healthy massive *Porites lutea* colonies were located in this zone. Food fish and edible and/or commercial invertebrates were all but absent on these reefs.

Figure 26. Photo of the reef edge located at tow number 19, Site JB.

5.3.5 Site AJT Location 1

Three manta tows (24, 25, 26 and 27) and one strip transect dive (9) covering an estimated area of 1.36 km^2 (Figure 27) were undertaken at Site AJT. The biodiversity at this site is medium to high and although not unique to the lagoon contains a healthy functioning reef. From a biological perspective there would be limited negative effects to the reefs in this site if responsible suction dredge mining for sand was to take place in waters greater than 12 meters depth. Care should be exercise if dredging is to operate at this site to provide a high level of protection to corals located on the reef edge and slope, the large *Porites* bommies and large table corals (*Acropora sp.*) found commonly at this site should be protected. The implementation of an appropriate sediment management plan tailored to minimise sediment distribution from the use of a suction dredge should be mandatory. These reef areas and adult colonies would play an important role in the long-term recruitment of corals throughout the lagoon. Reef areas, especially associated with the reef edge and slope, have not been subject to high levels of anthropogenic impacts and subsequently are in good health. However, some sedimentation from recent dredging operations has had a negative impact on corals in close proximity to these activities. The replenishment of sand resources is expected to be limited due to the issues highlighted in previous SOPAC reports (Smith 1995, Xue 1997, Smith and Collen 2004).

Figure 27. Shows the 4 manta tows and 1 dive location evaluated during the assessment for Site AJT, location 1.

Site AJT location 1, (on the southern rim of the lagoon west of the airport) is less impacted than the eastern urban areas since population pressures are lower and development such as reclamation is less frequent. The reef flat is relatively shallow and ranges in width from approximately 30 – 60 metres with the upper regions exposed during low spring tides. The reef flat has a gradual slope terminating at the reef edge and steeper slope, which descends towards the lagoon basin. The reef slope starts at around the 4 – 5 meters water depth and terminates between 8 – 10 meters.

Certain areas of the reef flat have evidence of past dredging impacts and are presently subject to dredging to provide a source of material for land reclamation and to widen and deepen access channels. Considerable sedimentation has occurred on reefs downstream of the dredging operation (Figure 28), which has resulted in hard coral mortality. Improvement and correct deployment of sedimentation curtains are urgently required. The presence of domestic and commercial rubbish was low at Site AJT.

Figure 28. Photo of the present dredging operation at Site AJT, location 1.

The reef flat at Site AJT is mostly dominated by sand and small coral rubble sparsely interspersed by small to medium size colonies of *Porites lutea* and *Porites rus* and a few small isolated patches of branching *Acropora sp.* and soft corals *(Sarcophyton sp.)*. The reef flat, slope and edge have a medium to high coverage of macro alga dominated by *Padina sp.* (some sites with > 25% coverage), which was associated with coral rubble and scattered live hard coral patches. Blue green algae, *Asparagopsis sp.* and the introduced macro algae *Acanthophora spicifera* were also present.

The reef edge and reef slope are characterised by patches of sand and rubble and live coral cover with areas of the macro algae *Padina sp* and *Halimeda sp*. The reef slope and lagoon floor had large healthy massive colonies of *Porites*, which ranged in size from 3 – 4 metres in diameter (refer figure 13). These colonies are very old and are found at a maximum water depth of 10 meters.

The reef edge and slope recorded a high percent (>60%) live coral coverage for all areas assessed (tow number 24, 25 and 26). Coral coverage terminated at approximately 8 – 10 meters where it transitioned into sandy substratum with patches of *Padina sp.*, towards the lagoon basin. The reef areas showed a high diversity of hard and soft coral species (Figure 29) but was dominated by the hard corals of the genus *Porites* (4 species), *Acropora* (5 species), *Fungia, Pocillopora* and *Pavona*, soft corals (*Lobophyllia sp.*) and small colonies of *Millipora sp.* Large *Acropora sp.* tables were present (1–2 metres in diameter) and reasonable levels of coral recruitment were witnessed, especially those of the genus *Acropora.* Food fish and edible and/or commercial invertebrates were present at this site but only in low numbers.

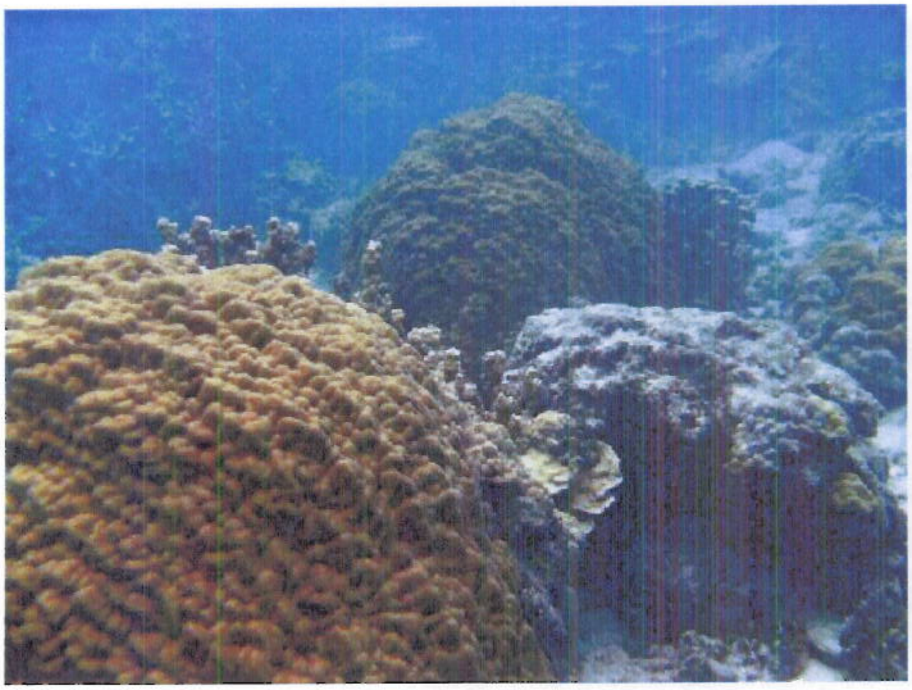

Figure 29. Photo of the reef edge located at tow number 24, Site AJT, Location 1.

5.3.6 Site AJT, Location 2

Site AJT, Location 2, included 7 manta tows (28, 29, 30, 31, 32 and 33) and two strip transect dives (13 and 14) covering an approximate area of 1.76 km^2 (Figure 30). The biodiversity at this site is medium to high and although not unique to the lagoon provides a healthy functioning reef habitat. Whilst direct damage to corals should be avoided responsible suction dredging would have limited negative effects to the reefs so long as extraction took place in waters greater than 12 meters depth. Care should be exercised if dredging is to operate at this site to provide a high level of protection of coral located on the reef edge and slope and the large *Porites* bommies and large table corals (*Acropora sp.*) found throughout this site should be protected. The implementation of an appropriate sediment management plan tailored to minimise sediment dispersion associated with the use of a suction dredge should be mandatory. These reef areas and adult colonies would play an important role in the long-term recruitment of corals throughout the lagoon as well as being an intrinsically important habitat. Reef areas, especially associated with the reef edge and slope have not been subjected to high levels of disturbance and show a level of integrity not present at the other sites. The replenishment of sand resources is again expected to be limited due to the issues highlighted in previous SOPAC reports (Smith 1995, Xue 1997, Smith and Collen 2004).

Figure 30. Shows the six manta tows and two dive locations evaluated during the assessment at Site AJT, Location 2.

Site AJT, Location 2 is located roughly half way along the south-eastern rim of Majuro, it is more rural in land use type and disturbances such as reclamation are less frequent. The reef flat is relatively shallow and ranges in width from approximately 30 – 80 metres with the upper areas exposed during low spring tides. The reef flat has a gradual slope terminating at the reef edge which then slopes down and descends towards the lagoon basin. The reef slope starts at around the 3 – 4 meters water depth and terminates between 8 – 10 meters.

Certain areas of this reef flat have been previously dredged to provide a source of material for reclamation and to widen and deepen access channels there was far less evidence of domestic and/or commercial rubbish at this Site.

The reef flat in general is dominated by sand and small coral rubble interspersed by low numbers of small to medium size colonies of *Porites* and in some cases small isolated patches of branching *Acropora sp.* The reef flat, slope and edge have a medium to high coverage (>15%) of macro algae dominated by *Halimeda sp.* and to a lesser degree blue green algae, *Asparagopsis sp.* and the introduced macro algae *Acanthophora spicifera.* The *Halimeda sp.* patches were associated with live coral cover on the reef edge and slope. The reef slope and lagoon floor possess large healthy colonies of massive *Porites* which range in size from 3 – 4 metres in diameter. These colonies are very old and are found at a maximum water depth of 10 meters.

The reef edge and slope recorded a high percent live coral coverage for tow numbers (27, 28, 29, 30 and 33) ranging from 40% to 80% live coral cover whist tow numbers 31 and 32 showed 30% and <5% respectively. Coral coverage terminated at the reef slope at approximately 8 – 10 meters were sandy substratum associated with the lagoon basin dominates with patches of *Halimeda sp.* The reef areas showed a high diversity of hard and soft coral species which were dominated by the hard coral genus *Porites* (4 species), *Acropora* (5 species), *Fungia, Heliopora, Pocillopora and Pavona,* soft corals (*Lobophyllia sp.*) and small colonies of *Millipora sp.* Large

Acropora sp. tables were present (1 – 2 metres in diameter) throughout the reef edge and slope area. Approximately, 30% of the *Acropora sp.* tables were dead and was most likely due to previous COTS outbreaks (refer figure 11). Hard coral recruitment was recorded at all sites that showed a high coral coverage with most of the new recruits belonging to the species *Acropora* and *Pocillopora*. Tow numbers 31 and 32 had low coral cover and were dominated by sand, rubble and macro algae. These sites were located behind reef promontories where it appeared that reef derived sediments were frequently deposited preventing coral establishment and growth. Nevertheless a number of healthy massive *Porite* colonies were located in this zone. Food fish and edible and/or commercial invertebrates were more abundant at this site but not in great numbers.

5.4 Summary of the Five Proposed Sites

The marine biodiversity and hard coral health at the five RMI-EPA proposed dredge sites varied considerably with Site AJT, Locations 1 and 2 recording the highest diversity and hard coral percent live coverage. All sites have been artificially altered over the past 50 years due to progressive urbanisation and development on the atoll. Sites RT, JT, DL and JB have been heavily impacted by a wide range of anthropogenic impacts, including major dredging and land reclamation projects. However each of the five site locations have viable patch reef systems that recorded relatively abundant, healthy and diverse hard coral communities. These reef patches (highlighted in section 5.3) should be preserved and managed (refer section 6.0) to prevent any further degradation of this important habitat. Most of the present environmental impacts associated with these sites are anthropogenic in nature (e.g. land based dredging, water quality and water exchange changes). The remaining healthy reef patches provide important habitat and would likely act to supply recruits and maintain populations of a variety of marine species. These living reefs also provide shore line protection by reducing wave energy and providing a constant supply of calcium carbonate material to build beaches.

The hard coral genus *Porites, Acropora* and *Pocilopora* dominated the hard coral species located at all sites whilst macro algae (*Padina, Halimeda, Dictyota* and blue green algae) dominated the sand and rubble regions at all sites. In summary, the five RMI-EPA proposed dredging sites include;

- The reef edge and slope located in water depths between 3 – 12 meters for all five sites showed the highest percent coverage (40-80%) and diversity of hard and soft coral species with Site AJT (Location 1 and 2) possessing the highest percent coverage (50 – 85%) and greatest diversity of corals. The hard coral genus of *Porites, Acropora, Fungia, Pocillopora* and *Pavona* and the soft corals (*Lobophyllia sp.*) dominated all sites. Sites RT, JT, DL and JB recorded only small patches of hard corals on the reef slope and edge with macro algae beds associated with lower sand and rubble areas.

- The inter tidal and sub tidal reef flats for all sites were dominated by sand and small rubble interspersed with a low occurrence of hard corals (mostly *Porites lutea*) and were dominated by beds of macro algae of the genus *Padina, Halimeda, Dictyota* and blue green algae. The introduced macro algae *Acanthophora spicifera* was located at all sites within this zone. Considerable habitat alteration and land reclamation activities have been undertaken over the past half a century to these reef areas.

- The lagoon floor (10 – 24 meters water depth) was composed predominately of sand interspersed with patches of small to medium size rubble which was frequently colonised by macro algae (*Halimeda* and *Padina*). Hard corals were all but absent from these deeper areas.

The ecological implications of extracting sand and aggregates from the five RMI-EPA designated assessment sites are site specific. In general, the extraction of these resources from waters deeper than 10 – 12 meters at all sites if undertaken utilising the best management practises is expected to have minimal impacts on the biological integrity of the shallow water reefs located at these sites. Each of the RMI-EPA designated assessment sites have locations that would be suitable for sand and aggregate resource extraction, however extreme care should be exercised if dredging is to operate at these sites to provide a high level of protection to the adjacent reef and organisms associated with the reef edge and slope. Dredging operations should not be undertaken at any site in the immediate vicinity of living reef areas especially those which recorded a high coral coverage and diversity (e.g. Site AJT (Location 1 and 2).

If dredging technology which minimises environmental damage (siltation) is used, deeper (>10 – 12 meters) lagoon bed dredging appears to be a viable and a more environmentally acceptable alternative to shallow water dredging. Special attention must be paid to the utilisation of environmentally sound sediment dispersal mitigation methods of both techniques and technology. Each of the RMI-EPA designated assessment sites has specific areas that would be suitable for resource extraction by suction dredging and with the use of such improved technology in these specific locations, it is expected to reduce the present direct and indirect environmental impacts associated with shoreline based shallow water dredging (refer section 7.0). The implementation of an appropriate sediment management plan tailored to minimise sediment distribution should be mandatory as discussed in section 6.0.

Current land based dredging operations have degraded the biological integrity and biodiversity of the nearby reefs at each dredge site and the surrounding marine habitats especially the shallow areas downstream of the dredging operation have been particularly impacted. Minimal mitigation methods are presently in use and those that were witnessed were not deployed correctly nor maintained (e.g. silt screens fouled with algae, surface floats deployed without silt screens, gaps and poor coverage, etc). It is critical that sound mitigation methods are implemented where ever dredging is undertaken and meaningful environmental management and monitoring protocols are observed.

5.5 Assessment Results of the Northern Reef Sites

A summary of the results for each site assessed and the potential ecological impacts associated with dredging at these sites is discussed below. The dredging impacts are those expected from the use of a suction dredge positioned on a floating barge above the resource area (where sand is pumped onto the barge). Possible impacts of shore base dredging; i.e. dragline scraper operated by a crane or hydraulic excavator, are not discussed. Detailed information associated with each manta tow undertaken at each of the RMI-EPA proposed assessment sites for the northern reefs are presented in Appendix 7, 8 and 9. Seven manta tows in total covering an estimated area of 5.69 km^2 were completed during the assessment (Figure 31).

Figure 31. Shows the 7 manta tow locations evaluated during the assessment – northern reef sites.

The northern assessment sites are adjacent to a string of small islets located on the northern rim. These areas were earlier identified by Smith (1995) and Smith and Collen (2004) as having good potential as a renewable aggregate resource area not only because their sediments are of better quality but also because the numerous intertidal channels between the islets, supply a constant supply of fresh calcium carbonate debris from the productive northern ocean-side and intertidal reefs.

The shallow water reef morphology of the northern resource sites are distinct depositional fans bulging into the lagoon (in-filling) and are associated with the intertidal reef channels (200 – 1500m wide). Protected by and located behind the islets are quieter lagoon embayments. The morphology seen at these sites during the assessment follows the general atoll pattern as described in section 5.2. The percent coral coverage and species biodiversity varied considerably throughout the area assessed but patterns consistent with the two distinct morphological features were evident (depositional fans and protected bays).

The exposed intertidal reef channels are characterised by the movement of large volumes of water during tidal exchange and due to their high velocities carry sand and to a much lesser extent rubble towards the lagoon. The channel floor was almost exclusively dominated by sand and rubble in the inter and sub tidal zones with a non distinguished reef edge and slope terminating on the lagoon side in a completely sand dominated substratum (starting at 3 – 6 meters of water). The deposition of this material has created the large expanse of sub tidal lagoon sand banks in front of the channels.

Live coral coverage and biodiversity was low at all sites in these channel areas with most live coral being located on the shallow reef flat and reef edge. The depositional areas associated with the channels were completely devoid of hard corals and in most cases dominated by sand from depths of 3 – 6 meters through to the deeper lagoon basin. Macro algae was common on the shallow rubble beds (*Dictyota sp. Padina sp.* and blue green algae) and blue green algae and to a lesser degree *Halimeda sp.* dominated the slopes and shallow sections of the lagoon basin. It appears that the continuous movement of sand and rubble carried by tidal flow through the channels does not provide an environment suitable for coral growth and it is known from Smith and Collen's (2004) work that replenishment of sand in these areas is high and continuous.

In contrast, the lagoon side inter and sub tidal reef flats and bays which are located behind the islets recorded a high coverage (40-90%) and diversity of hard corals which terminated at a non distinct reef edge and slope (3-6 meters) and transitioned onto sand dominated deeper lagoon floor. Isolated bommies of *Porites* were also located throughout these deeper sandy sites in water depth of between 6 – 12 metres. The hard coral biodiversity and morphological forms were slightly higher than at the RMI-EPA proposed five southern rim Sites however species assemblages were generally quite similar. These reefs were dominated by the hard corals of the genus (Figure 32) *Porites, Acropora, Fungia, Pocillopora, Goniopora* and *Pavona*, soft corals (*Lobophyllia* and *Sarcophyton*), colonies of *Millipora* and *Heliopora* and beds of zooanthids (*Discosoma sp.*). Hard coral recruitment was recorded at all sites that showed a high coral coverage (those sites/bays behind the islands) with most of the new recruits recorded belonging to species of *Acropora, Pocillopora* and *Fungia*.

Figure 32. Coral diversity on the sub tidal reef flat associated with Eneko Island.

There were far fewer signs of human disturbance at these northern sites and certainly far less than that at the RMI-EPA proposed southern dredge sites however, garbage (domestic and industrial) mostly carried by wind and tides was seen at all sites. In addition, hard coral damage from anchor usage (crushed corals), fishing (lines on the bottom of the sea floor) and in one location a ship grounding (Figure 33) was recorded. The ship grounding site at Enemonit Island has caused considerable localised damage to the hard coral reef.

Figure 33. Coral (Porites lutea) damage due to ship grounding, Enemonit Island, northern assessment site.

The marine biodiversity associated with the bays and reefs behind the islets high in comparison to other areas of Majuro Lagoon and although not unique is a healthy functioning reef and should be protected and preserved. It is also likely that these reef areas and adult colonies would play an important role in the long term recruitment of corals throughout the lagoon. The ecological implications of extracting sand and aggregates near these reefs (in deeper 10 – 20m, sandy areas lagoon-wards from the reef) could potentially impact these healthy corals. Any disturbance such as dredging should be avoided or if undertaken, extreme care, close management and monitoring must be undertaken to ensure there are no negative effects. Several of these islands (e.g. Enemonit and Eneko) are popular tourist destinations for both local and international visitors and thus support a small but functioning tourist industry. Dredging operation in the vicinity of the tourist destinations would be expected to affect the long term economic viability of this activity.

However, ecological implications of extracting sand and aggregates from the large sand deposits associated with the intertidal channels is expected to have minor, if any, lasting negative impacts. So long as dredging was undertaken only on these depositional fans in waters deeper than 10 – 12 meters negative impacts are not expected especially since this is a fairly high energy area and sediment fines would be less common. Nevertheless, care should still be exercised and a high level of management and monitoring to ensure hard coral communities associated with the island lagoon bays are not indirectly impacted. The implementation of an appropriate sediment management plan tailored to minimise sediment distribution for use with a suction dredge operation should be mandatory. Unlike the southern rim sites, replenishment of sand resources on the depositional fans is expected to be continuous as highlighted in previous SOPAC reports (Smith 1995, Xue 1997, Smith and Collen 2004).

6.0 MONITORING

The new proposed NEPA (National Environmental Protection Act) amendments to the RMI national regulations clearly articulate the need for more diligent management and monitoring of the nation's dredging operations and highlights the need to provide protocols that can identify and address the issues associated with sand and gravel removal from marine and coastal environments. These regulations if adhered too will provide a mechanism to reduce negative environmental impacts associated with these operations whilst providing a cost effective platform that regulates the removal of the resources within the nation.

Increased public awareness of the proposed changes and tighter control through management, monitoring and enforcement will be required to implement these regulations. This includes:

- increased understanding, adherence and conformity to these regulations;
- use of approved technology (i.e. suction dredging);
- use of approved sites locations;
- use of approved environmental mitigation measures (e.g. sediment traps); and
- use of biological monitoring programs.

The sand and aggregate resources within Majuro Lagoon are finite (refer Smith and Collen 2004) and especially on the southern and eastern lagoon rim dredging will be extractive i.e. not a renewable resource. Only those sites on the northern rim (depositional fans) are likely to have replenishment rates, which could off set extraction.

From a biological perspective, all proposed sand and gravel dredging sites should have a site specific long term monitoring program established. This would be initiated by the proponent who would submit a report, which clearly articulates planned activities (location, technology, mitigation methods, extraction rates, use of extracted material, storage sites, etc.). This in turn would be reviewed by the RMI-EPA to determine if an Environmental Impact Assessment (EIA) or Environmental Impact Statement (EIS) is required. It is envisaged that all dredging operations would need either an EIS or full EIA to ensure impact mitigation and operations are appropriate and should include (as stated in the RMI-EPA regulations and pending amendments);

- a pre dredging biological assessment (EIA);
- an assessment(s) designated time intervals (e.g. every 6 months) whilst the dredging operation is taking place (biological and environmental); and
- a post dredging assessment (biological and environmental).

EIA assessments need to be undertaken by qualified environmental scientists to provide a clear understanding of the ecological status and function of the proposed site and possible impacts of extractive activities. The reports should include information pertaining to the target and adjacent marine environments, potential environmental and biological impacts and identify management and mitigation protocols. The current and pending RMI-EPA regulations clearly identify the requirements of an EIA and biological assessment methods that are suitable for these environments. All scientific methods used to undertake these biological and environmental assessments need to be standardised and repeatable (refer Appendix 2 for protocols used during this report).

Information pertaining to the water circulation patterns and the subsequent movement of suspended sediments derived from dredging operations are not well understood for the lagoon of Majuro and therefore it is suggested that the RMI-EPA approach SOPAC or other institutions/donor agencies to undertake scientific studies to identify the general circulation patterns within the atoll. This information will be invaluable to assist in the long term management of dredging operations and reduce the environmental impacts associated with suspended sediments.

7.0 CONCERNS AND CONSTRAINTS

Coral reefs are very sensitive to external disturbances, both natural (e.g. typhoons) and anthropogenic (e.g. dredging). However levels of susceptibility between reef organisms vary. Impacts associated with coastal dredging on coral reefs is complex, both in biological and physical terms and are far from fully understood. Local physical conditions of water movement and energy are unique, change regularly (e.g. seasonally) and therefore all environmental management programs need to be tailored to meet these localised conditions.

All dredging operations in coastal marine areas cause environmental disturbance and have the potential to degrade the environmental integrity of both the target area and nearby surrounding reef systems. The intensity and duration of the impacts is site and operation specific and generally decreases once the dredging operation is terminated. These impacts can be significantly reduced through careful on site planning, management and monitoring. The current and proposed RMI-EPA regulations pertaining to sand and gravel extraction provides a mechanism to allow dredging operations to continue whilst providing a framework in which environmental impacts can be reduced and managed. The RMI-EPA recommendations to limit all sand and gravel extraction operations to the use of underwater suction dredges below 10 – 12 meters of water depth is fully supported and will greatly assist in decreasing environmental impacts to the coral reefs in Majuro Lagoon.

Dredging operations utilising dragline scrapers (Figure 4) and hydraulic excavators (Figure 5) are inherently destructive to coastal areas and coral reefs. The use of the locally available antiquated technology should be phased out as detailed in the pending NEPA regulations and it is hoped that this will assist in decreasing the detrimental impacts on the coastal shores and coral reefs of Majuro. This technology has been discussed in section 2.3 of this report and therefore is not repeated here.

The RMI-EPA proposed dredging sites (southern and eastern rim) evaluated during this study have all been affected by a range of anthropogenic impacts and generally are in a degraded environmental state. It is important to note that coastal and near shore dredging operations have played a significant part in this degradation. Nonetheless, functioning coral reefs were present in the southern and eastern rim areas and where possible should be protected to prevent further degradation.

There are two major environmental impacts associated with suction dredging which include;

1) the direct physical damage caused by the removal of the resource – physical destruction of habitat and organisms.

2) The indirect damage caused by the dredging operation, including;
   - increased sedimentation loads;
   - turbidity;
   - other changes in water quality;
   - disturbance of the substratum may cause hydrodynamic changes; and
   - noise and unsightliness, plus other intangibles.

A robust management plan and environmental monitoring program is essential to managing these impacts and ensuring the viability of such operations.

7.1 Direct Impacts

A well managed suction dredge operation has the potential to produce far less impacts compared to the present technology and practises being used in Majuro. Suction pumps lift sand and/or gravel resources directly off the sea floor in the designated resource area and pumps a slurry (ca.

40% solid, 60% liquid) via sealed pipes to either a discharge area on shore (impoundment) or onto a floating barge. One of the major challenges of this method is the safe release of the liquid component of the slurry as this is high in suspended sediments and if not managed carefully can travel significant distances to settle on sensitive habitats such as living reef. Shore based impoundment areas are an effective method of allowing suspended material to settle before release of clarified headwaters. Alternatively, where a barge is used to accept the pumped slurry (then transported to shore) the liquid component must be returned immediately. There are methods to reduce the impacts of this such as a return hose which releases at the seafloor (preventing transport by surface currents) and there are also systems which return the liquid directly to the suction head, recycling a significant component of the sediment laden water.

All organisms that reside on or in the sediment that are not mobile (i.e. burrowing organisms) will be removed and destroyed by dredging. Larger slow moving benthic organisms (e.g. sea cucumbers, star fish) could also be disturbed by dredging but more mobile species (e.g. fin fish) are expected to leave the area during operations. Many burrowing organisms are quite robust and could be expected to recolonise the dredge zone when operations cease however, changes in depth and water movement as well as sediment chemistry and composition may alter the composition.

Direct physical damage and death may occur to benthic organisms (e.g. corals) during the deployment, operation and retrieval of suction dredge and discharge pipes especially if a "pump to shore" system is used. The transfer pipes are heavy and if laid across the surface of living reefs will cause significant physical damage as they "work" due to pumping, wind, waves and tidal motion. Similarly, the use of a floating barge will require anchorage and again attention will be needed to prevent the pipes from damaging sensitive areas.

7.2 Secondary Impacts

The secondary impacts are mostly associated with release of suspended sediment laden water from the barge or impoundment area. The suspended sediments expected from dredging from the RMI-EPA proposed sites would consist of fine sand particles derived from the skeleton of forams or broken coral and other marine organisms. This varies in size and density depending on the composition and location of extraction. Suspended sediment impacts can be significantly reduced with appropriate technology and management as discussed earlier. Accidental spillage of return water is a common problem but again is entirely preventable if the dredge pipes and connections are adequately maintained and shore based impoundments and settlements bunds are correctly constructed.

A well maintained and operated suction dredge operated in the correct location is expected to have acceptable levels of environmental disturbance and should not result in large volumes of suspended sediment entering the environment. Unlike the present dragline scrapers and hydraulic excavators which do not have adequate mitigating strategies and are using resources from sensitive and unsustainable locations.

Many organisms have physiological and/or behavioural methods of dealing with suspended sediments. For example, avoidance (e.g. fish swim away) and production of mucus to remove the sediment (e.g. hard and soft corals). However, above certain species specific thresholds sedimentation can cause adverse effect and ultimately can cause death and broader ecosystem alterations. Hard corals are particularly vulnerable to both sedimentation and light attenuation or increased turbidity (deprivation of sunlight) can have adverse effects. Otherwise, abrasion, clogging of organs (e.g. gills, feedings) and smothering are other impacts and it should be noted are common problems on the south-eastern rim of Majuro Lagoon. High levels of sedimentation can also occur during natural events such as typhoons, however natural events tend to be sporadic with long periods between events. In comparison, dredging operations that do produce high levels of sediments are usually continuous for weeks to months and do not provide an opportunity for the organisms to recover.

Similarly, the majority of coral reef benthic invertebrates and macro algae are negatively affected by increased sedimentation levels, which can cause decline, death and alterations in species distribution and composition and therefore broader ecological change.

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9.0 APPENDICES

Appendix 1. Summary of the Assessment Teams Daily Activities whilst in Majuro.

Date	Day	Location	Work Summary
30-04-07	1. Monday	Travel – International Cairns – Guam-Majuro	Consultant (S. Lindsay) and SOPAC representative (Musunamasi) arrive.
01-05-07	2. Tuesday	Majuro	Met with EPA advisor Mr. Andrew Finlay to discuss the program and finalise the field work logistical requirements.
02-05-07	3. Wednesday	Majuro	Started field work. 8 manta tows were completed (5 tow in Site RT and 3 tows in Site JT) and 3 dives transects in site RT. Data entered into computer in the evening.
03-05-07	4. Thursday	Majuro	Field work continued. 9 manta tows were completed at Site DL, 1 and 2 dives transects were completed at Site JT and Site DL respectively. Data entered into computer in the evening.
04-05-07	5. Friday	Majuro	Field work continued. 6 manta tows and 2 dive transects were completed at Site JB. Data entered into computer in the evening.
05-05-07	6. Saturday	Majuro	Field work continued. 3 dives were under taken at site DL. Data entered into computer in the evening.
06-05-07	7. Sunday	Majuro	The morning spent reading reports associated with the consultancy from EPA, finalizing data sheets and late afternoon discussions with field team to finalise the logistical requirements for the rest of the week.
07-05-07	8. Monday	Majuro	Field work continued. 3 manta tows and 1 dive transects were completed at Site JB and 1 tow undertaken at site AJT, location 2. Data entered into computer in the evening.
08-05-07	9. Tuesday	Majuro	Field work continued. 6 manta tows and 2 dive transects were completed at Site AJT, location 2. Data entered into computer in the evening.
09-05-07	10. Wednesday	Majuro	Field work continued. 7 manta tows were completed at the northern reef sites. Data entered into computer in the evening.
10-05-07	11. Thursday	Majuro	Morning spent obtaining GPS points for current dredge sites operating within the south section of Majuro Lagoon. Afternoon talking with biologists at the College of Micronesia and Marshall Islands Marine Resource Authority.
11-05-07	12. Friday	Majuro	Meeting with EPA manager and staff undertook presentation, reviewed data information and entered GPS data onto maps for SOPAC. Final discussion with assessment team.
12-05-07	13. Saturday	International travel Guam	Majuro to Guam. Day travelling.
13-05-07	14. Sunday	International travel	Day spent working on logistical reporting information. Evening flight Guam to Cairns

Appendix 2. Resource Assessment and Monitoring Methodology

The resource assessment methodologies documented below were undertaken during the marine survey evaluation of the six proposed dredging sites and the additional dredging locations on the northern reefs of Majuro atoll between Rita and Calalin Island.

Manta Tows

Manta tows are used to provide information on broad changes and species population abundances in benthic communities on coral reefs. This method allows visual assessments of large areas of reef within short periods of time. This method is considerable useful in areas of clear water and in relatively shallow water.

The manta tow technique used for the marine assessment of the proposed dredge sites within Majuro Lagoon involved the securing of a piece of wood across the front of a boat so that approximately 1 meter of wood hung over each side of the boat. Ropes with hand loop were attached to each end of the wood so that observers can be towed through the water. Each observer used the centre of the boat hull as a guide and actual counts were made on each species as the boat moved over the reef. The width that each observer recorded was dependent on local water clarity, water depth and species abundance.

A GPS point (latitude and longitude) was marked at the start and end of each manta tow and the distance travelled was recorded directly from the GPS unit (km). The distance travelled multiplied by the width of the tow evaluated for both members of the survey team provided data to determine total reef area surveyed.

The following data were collected for each manta tow undertaken for the marine assessment. Site location, tow number, total percent live coral cover, reef aesthetics, dominant benthic organisms and form, dominate hard coral genus and associated morphological form, dominate turf and macro algae, sea grass, substrate type, litter, tow length, tow width, water depth, sea and wind condition. In addition, total individual numbers were recorded for the following indicator species: turtles, marine mollusc (gastropods, bivalves), sea cucumbers, crown of thorns starfish – COTS (*Acanthaster planci*) and marine finfish.

All data collected in the field were transcribed onto data form sheets and entered directly into a computer database (Appendix 3, 4, 5, 6, 7, 8) for later analysis. All assessment team members were actively involved with all aspects of field collection and data recording.

The advantages of this method of survey are (adopted from English et al. 1997):

- large areas of reef can be surveyed in a relatively short period of time. This reduces the possibility of not documenting population changes in space and time (e.g.: dynamite fishing or storm damage);
- it is relative simple to perform after some initial training;
- it does not require expensive equipment (e.g. SCUBA) nor specialised qualifications;
- it can be performed in remote locations with minimal support;
- the observers can cover great distances with minimal fatigue; and
- it is rapid, non destructive and inexpensive.

The disadvantages are (adopted from English et al. 1997):

- if the organisms are cryptic they may be over looked;
- if the organism is fast moving (e.g.: some fish) then they may be overlooked;
- the observer may have too much information to remember and provide inaccuracy in data; and
- the survey may be conducted over inappropriate sections of the reef because the tow path is controlled by the driver who views the reef from above.

Strip Transects

Strip transect lines are used to provide information on broad changes and species population abundances in benthic communities and also provides an accurate account of the benthic substrate associated with coral reefs. This method allows visual assessment of the reef, but is limited in area coverage and is time consuming. Strip transects utilising SCUBA were used to collect data on the sub tidal reef associated with proposed dredging sites.

A 50-meter measuring tape was laid on the reef slope starting at the 5 meters depth contour (secured by a lead weight) and was laid out perpendicular to the reef edge by one member of the assessment team whilst the second member video taped the entire length of the transect recording all biological life and substrate type and returning with a digital still camera photographic the substrate and biological organism on the return.

A GPS point (latitude and longitude) was marked at the start and end of each strip transect from the surface and the distance of transect was read from the tape measure (all transects were 50 meters).

The following data were collected for each transect undertaken for the marine assessment. Site location, dive number, total percent live coral cover, reef aesthetics, dominant benthic organisms and form, dominate hard coral genus and associated morphological form, dominate turf and macro algae, sea grass, substrate type, litter, tow length, tow width, water depth, sea and wind condition. In addition, total individual numbers were recorded for the following indicator species: turtles, marine mollusc (gastropods, bivalves), sea cucumbers, crown of thorns starfish – COTS (Acanthaster planci) and marine finfish.

All data collected in the field were transcribed onto data form sheets and entered directly into a computer database (Appendix 3, 4 and 5) for later analysis. All assessment team members were actively involved with all aspects of field collection and data recording.

The advantages of this method are (adopted from English et al. 1997):

- it provides quantitative and qualitative data on fast moving and cryptic reef organisms (e.g.: Spider Shells);
- is a reliable and efficient sampling method for obtaining quantitative percentage sessile benthic invertebrates and marine plants;
- can provide detailed information on spatial pattern;
- if replicated over time, it can provide information on temporal change; and
- it is relatively simple to undertake.

The disadvantages are (adopted from English et al. 1997):

- requires the placement of a measuring rope on the reef that may cause reef damage;
- results may differ between observes without careful training and comparison activities;
- is time consuming; and
- organisms may be attracted or actively swim away from the observers affecting data collections.

Appendix 3. Marine Resource Data for the Six Proposed Dredging Sites.

Location Site Date:	Tow Or Dive No.	Latitude/Longitude UTM Start of transect	Latitude/Longitude UTM Finish of transect	Wind Condition Knots	Sea Conditions
SITE RT					
2/5/07	Tow 1	59N 0540120 0780007	59N 0539936 0787072	12-15	Calm, Protected by islands
2/5/07	Tow 2	59N 0539800 0787100	59N 0539540 0787252	12-15	Calm, Protected by islands
2/5/07	Tow 3	59N 0539390 0787324	59N 0539130 0787229	12-15	Calm, Protected by islands
2/5/07	Tow 4	59N 0540079 0786965	59N 0539853 0787060	12-15	Calm, Protected by islands
2/5/07	Tow 5	59N 0539741 0787077	59N 0539509 0787198	12-15	Calm, Protected by islands
2/5/07	Dive 1	59N 0539491 0787266	59N 0539432 0787226	12-15	Calm, Protected by islands
2/5/07	Dive 2	59N 0539673 0787204	59N 0539669 0787150	12-15	Calm, Protected by islands
2/5/07	Dive 3	59N 0540025 0786934	59N 0540014 0786885	12-15	Calm, Protected by islands
SITE JT					
2/5/07	Tow 6	59N 0540498 0786153	59N 0540655 0785954	12-15	Calm, Protected by islands
2/5/07	Tow 7	59N 0540652 0785950	59N 0540863 0785766	12-15	Calm, Protected by islands
2/5/07	Tow 8	59N 0540510 0786107	59N 0540619 0785860	12-15	Calm, Protected by islands
3/5/07	Dive 4	59N 0540600 0785044	59N 0540564 0785040	8-10	Calm, Protected by islands
SITE DL					
3/5/07	Tow 9	59N 0541532 0783600	59N 0541804 0783838	8-10	Calm, Protected by islands
3/5/07	Tow 10	59N 0541840 0784061	59N 0541819 0784417	8-10	Calm, Protected by islands
3/5/07	Tow 11	59N 0541822 0784495	59N 0541615 0784812	8-10	Calm, Protected by islands
3/5/07	Tow 12	59N 0541591 0784968	59N 0541412 0785302	8-10	Calm, Protected by islands
3/5/07	Tow 13	59N 0541553 0784957	59N 0541467 0784976	8-10	Calm, Protected by islands
3/5/07	Tow 14	59N 0541549 0784657	59N 0541525 0784663	8-10	Calm, Protected by islands
3/5/07	Tow 15	59N 0541550 0783624	59N 0541745 0783913	8-10	Calm, Protected by islands
3/5/07	Tow 16	59N 0541649 0783907	59N 0541714 0784246	8-10	Calm, Protected by islands
3/5/07	Tow 17	59N 0541772 0784446	59N 0541611 0784757	8-10	Calm, Protected by islands
3/5/07	Dive 5	59N 0541370 0784971	59N 0541352 0785032	8-10	Calm, Protected by islands
3/5/07	Dive 6	59N 0541627 0784762	59N 0541588 0784722	8-10	Calm, Protected by islands

Location Site Date:	Tow Or Dive No.	Latitude/Longitude UTM Start of transect	Latitude/Longitude UTM Finish of transect	Wind Condition Knots	Sea Conditions
SITE DL Cont.					
5/507	Dive 12	59N 0541592 0783739	59N 0541569 0783756	10-12	Calm, Protected by islands
Site JB					
4/5/07	Tow 18	59N 0537471 0782807	59N 0537198 0782756	8-10	0.5-0.75 meter wave
4/5/07	Tow 19	59N 0537156 0787756	59N 0536901 0782693	8-10	0.5-0.75 meter wave
4/5/07	Tow 20	59N 0536901 0782693	59N 0536557 0782682	8-10	0.5-0.75 meter wave
4/5/07	Tow 21	59N 0536539 0782571	59N 0536237 0782422	8-10	0.5-0.75 meter wave
4/5/07	Tow 22	59N 0537261 0782808	59N 0536961 0782725	8-10	0.5-0.75 meter wave
4/5/07	Tow 23	59N 0536916 0782725	59N 0536656 0782766	8-10	0.5-0.75 meter wave
4/5/07	Dive 7	59N 0537298 0782804	59N 0537290 0782850	8-10	0.5-0.75 meter wave
4/5/07	Dive 8	59N 0536904 0782714	59N 0536902 0782746	8-10	0.5-0.75 meter wave
Site AJT	L 1				
7/5/07	Tow 24	59N 0524284 0780249	59N 0523880 0780436	10 -15	1.0 - 1.5 meter wave
7/5/07	Tow 25	59N 0523749 0780485	59N 0523424 0780642	10 -15	1.0 - 1.5 meter wave
7/5/07	Tow 26	59N 0523319 0780786	59N 0523002 0780959	10 -15	1.0 - 1.5 meter wave
7/5/07	Dive 9	59N 0523702 0780502	59N 0523705 0780522	10 -15	1.0 - 1.5 meter wave
Site AJT	L2				
7/5/07	Tow 27	59N 0522831 0780987	59N 0522566 0781072	10 -15	1.0 - 1.5 meter wave
8/5/07	Tow 28	59N 0522321 0781266	59N 0521973 0781389	10 -15	0.75 - 1.5 meter wave, rain
8/5/07	Tow 29	59N 0521994 0781393	59N 0521725 0781555	10 -15	0.75 - 1.5 meter wave, rain
8/5/07	Tow 30	59N 0521701 0781687	59N 0521451 0781700	10 -15	0.75 - 1.5 meter wave, rain
8/5/07	Tow 31	59N 0521357 0781645	59N 0520991 0781626	10 -15	0.75 - 1.5 meter wave, rain
8/5/07	Tow 32	59N 0520968 0781663	59N 0520621 0781727	10 -15	0.75 - 1.5 meter wave
8/5/07	Tow 33	59N 0520518 0781792	59N 0520171 0782050	10 -15	0.75 - 1.5 meter wave
8/5/07	Dive 13	59N 0520120 0782071	59N 0520124 0782111	10 -15	0.75 - 1.5 meter wave
8/5/07	Dive 14	59N 0520997 0781739	59N 0521019 0781806	10 -15	0.75 - 1.5 meter wave

Appendix 4. Marine Resource Data for the Six Proposed Dredging Sites.

Location Site Date:	Transect Or Dive No.	H_2O Depth (m)	Transect Length (m)	Transect Width (m)	Turtles	Mollusc Clams, Oysters,	Sea Cucumber	Turf Algae/ Macro Algae/ Sea Grass	Finfish
SITE RT									
2/5/07	Tow 1	2-10	300	10	0	0	4A, 5C	A, C	3A, 3C
2/5/07	Tow 2	1-2	300	10	0	0	4C, 3D	C, F	0
2/5/07	Tow 3	2-12	300	10	0	0	1C	C, F, B on slope	0
2/5/07	Tow 4	8-12	300	12	0	0	10A	A, C, F on bommies	1C
2/5/07	Tow 5	6-12	300	10	0	0	7A, 5C	A, C, F on bommies	0
2/5/07	Dive 1	5-12	50	2	0	0	4A	B on base of bommies	0
2/5/07	Dive 2	5-12	50	2	0	0	0	C, A	0
2/5/07	Dive 3	5-17	50	2	0	1 *Lambis sp.*	0	A, F	0
SITE JT									
2/5/07	Tow 6	1-4	300	8	0	0	10C	A, C, F	0
2/5/07	Tow 7	2-9	300	8	0	0	3C, 2F 2 *Diadema sp*	C & B mats	1C
2/5/07	Tow 8	4-12	300	10	0	0	11A, 1B, 31C,	C, B	1C
3/5/07	Dive 4	5-21	50	2	0	0	10B	B, E, F	0
SITE DL									
3/5/07	Tow 9	1-4	400	10	0	1 *Atrina sp*	14C	A, C	1D
3/5/07	Tow 10	1-4	400	10	0		2C	A, B, C	0
3/5/07	Tow 11	1-3	400	6	0	1 *Atrina sp,* 1 *Pinctada margaritifera*	4C	A, B, C, D	0
3/5/07	Tow 12	1-2	400	8	0	1 *Atrina sp*	2C	A, B, C, D on bommies	0
3/5/07	Tow 13	4-12	400	10	0	1 *Atrina sp*	4A, 1B, 14C	A, B on bommies	2C
3/5/07	Tow 14	2-10	400	8	0	0	3C	A on bommies	1C
3/5/07	Tow 15	3-7	400	11	0	1 *Atrina sp*	4C	A, C on bommies	0

Location Site Date:	Transect Or Dive No.	H_2O Depth (m)	Transect Length (m)	Transect Width (m)	Turtles	Mollusc Clams, Oysters,	Sea Cucumber	Turf Algae/ Macro Algae/ Sea Grass	Finfish
SITE DL Cont.									
3/5/07	Tow 16	3-8	400	10	0	0	3A, 3C (Spawning male)	A, B, C on bommies	2C
3/5/07	Tow 17	2-8	400	10	0	1 *Atrina sp*	1A, 5C	B, F on bommies	0
3/5/07	Dive 5	4-16	50	2	0	0	1E	0	0
3/5/07	Dive 6	4-19	50	2	0	0	0	A, B, D, G	0
5/5/07	Dive 10	6-19	50	2	0	0	1A, 1C	B, A, C	0
5/5/07	Dive 11	8-24	50	2	0	0	0	C, B	0
5/507	Dive 12	11-13	50	2	0	0	0	C, Minor F	0
Site JB									
4/5/07	Tow 18	1-3	300	8	0	0	2C, 7H	A dominant, F, B (small patches)	0
4/5/07	Tow 19	1-3	200	6	0	0	2C	A and F on rubble, B (small patches)	1C
4/5/07	Tow 20	1-5	400	10	0	0	2B, 22C, 5G	C on rubble, F on sand, H, I (small patches)	1E
4/5/07	Tow 21	1-6	400	9	0	0	2A, 9C	C and F on rubble, some A	3C, 1D, 1E
4/5/07	Tow 22	5-15	380	13	0	0	11A, 3G	F on sand/rubble	0
4/5/07	Tow 23	5-15	300	16	0	0	9A, 2C	F on sand/rubble	1B
4/5/07	Dive 7	5-18	50	2	0	0	4G	F dominate with small A, B, C and red unidentified.	0
4/5/07	Dive 8	5-23	50	2	0	0 dead helmet shell *Cassis sp.*	8A	F dominate	0

Location Site Date:	Transect Or Dive No.	H_2O Depth (m)	Transect Length (m)	Transect Width (m)	Turtles	Mollusc Clams, Oysters,	Sea Cucumber	Turf Algae/ Macro Algae/ Sea Grass	Finfish
Site AJT	L1								
7/5/07	Tow 24	4-12	400	12	2A	0	1C	B, D and J dominate on reef (25% cover). F on rubble/sand.	4C
7/5/07	Tow 25	4-12	400	12	1A	0	11C, 1E	B & J dominate on reef (10% cover). D on rubble/sand.	2D
7/5/07	Tow 26	2-12	400	10	0	0	6C	B on reef (5%) F on rubble/sand	0
7/5/07	Dive 9	5-24	50	2	0	0	0	B on coral, small patches of A, I and F on coral rubble.	0
Site AJT	L2								
7/5/07	Tow 27	3-8	400	10	0	0	6C, 6H	B & J dominate on reef (35% cover). F on rubble/sand.	0
8/5/07	Tow 28	2-8	400	10	0	0	7C	B & F dominate on reef, A small patches.	1D
8/5/07	Tow 29	1-8	400	12	0	0	9C	B dominate on reef, A small patches and F sand.	0
8/5/07	Tow 30	2-12	400	12	0	0	1B, 4C,	B dominate on reef, A patches and F sand.	2E, 1F
8/5/07	Tow 31	3-6	400	8	0	0	3C, 1E, 1H	F dominate sand/rubble. B small patches	0

Location Site Date:	Transect Or Dive No.	H_2O Depth (m)	Transect Length (m)	Transect Width (m)	Turtles	Mollusc Clams, Oysters,	Sea Cucumber	Turf Algae/ Macro Algae/ Sea Grass	Finfish
Site AJT	L2								
8/5/07	Tow 32	2-5	400	8	0	0	3C	F dominate sand/rubble. B small patches	0
8/5/07	Tow 33	2-8	600	8	0	0	0	B dominate on reef, A small patches and F sand.	1F (juvenile)
8/5/07	Dive 13	4-8	50	2	0	0	1C	F on sand, some B	0
8/5/07	Dive 14	7-11	50	2	0	0	0	B patches on bommies, F on sand,	0

Appendix 5. Marine Resource Data for the Six Proposed Dredging Sites.

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
SITE RT						
2/5/07	Tow 1	40	High	Good	Sand/rubble, Bommies, Macro algae on rubble/sand	Porites massive (*P. lutea*) Porites digitate (*P. rus*), *Sarcophyton sp*
2/5/07	Tow 2	> 5	High	Fair	Sand/rubble, some bommies	Porites massive (*P. lutea*) Porites digitate (*P. rus*), *Lobopyllia sp, Acropora sp.*
2/5/07	Tow 3	>5	High	Poor	Sand/rubble, algal mats, high rubbish on slope in channel	Porites massive (*P. lutea*) branching *Pocilopora sp.*
2/5/07	Tow 4	70 bommies 0 sand	High	Fair	Sand/rubble, Bommies	Porites massive (*P. lutea*) Porites digitate (*P. rus*), *Acropora sp.* tables (small)
2/5/07	Tow 5	70 bommies 0 sand	High	Fair	Sand/rubble, Bommies	Porites massive (*P. lutea*) Porites digitate (*P. rus*),
2/5/07	Dive 1	60 bommies 0 sand	Low	Fair	Sand/rubble, Bommies	Porites massive (*P. lutea*)
2/5/07	Dive 2	60 bommies 0 sand	Low	Fair	Sand/rubble, Bommies	Porites massive (*P. lutea*)
2/5/07	Dive 3	75 bommies 0 sand	Low	Fair	Sand/rubble, Bommies	Porites massive (*P. lutea*) Porites digitate (*P. rus*), Zooanthidea (*Discosoma sp.*).
SITE JT						
2/5/07	Tow 6	60 bommies 5 sand	High	Good	High coral diversity beginning decreasing into sand/rubble in areas previously dredged sites. Macro algae beds. 1 x *Acanthaster planci*	Porites and Acropora digitate and branching. (*Porites rus, Porites* lutea, *P antennuata*) *Acropora sp. Fungia sp., Pavona cactus*, Zooanthidea (*Discosoma sp.*) Sponges (e.g. blue *Cribrochalina sp.*)

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
SITE JT						
2/5/07	Tow 7	> 5	High	Poor	Dredged sites dominated with algal beds and mats of *Padina sp.* and blue green algae	Porites massive (*P. lutea*) few
2/5/07	Tow 8	> 5	High	Poor	Sand/rubble, some macro algal beds on slope. 24 Anemone located (Actinodendron sp.) 4 – 10 m depth	Porites massive (*P. lutea*) Porites digitate (*P. rus*) and some Acropora branching. Sponges (e.g. blue *Cribrochalina sp.*)
3/5/07	Dive 4	Sand only	Minimal	Poor	Sand dominate some small rubble *Halimeda sp.* Patches	None located
SITE DL						
3/5/07	Tow 9	15	Minimal	Poor	Sand Rubble with macro algae associated with rubble (15%).	Porites massive (*P. lutea*) Porites digitate (*P. rus*), Porites branching (*P. cylindrical*). *Pocillopora damicornis*, small bed of *Millipora sp. Acropora sp.* and *Lobophyllia sp.* (massive).
3/5/07	Tow 10	>5	Low	Poor Current dredging activities	Sand associated with dredging activities, sand/rubble with algal associated. Anemone located (Actinodendron sp.)	Porites massive (*P. lutea*) Porites digitate (*P. rus*) dominate.
3/5/07	Tow 11	>5	Low	Poor	Sand Rubble with macro algae associated with rubble (40%)	Few small Porites massive (*P. lutea*) and Anemone (Actinodendron sp.).
3/5/07	Tow 12	>5	Low	Poor	Sand Rubble with macro algae associated with rubble (10%)	Few small Porites massive (*P. lutea*) and *Lobophyllia sp.* Anemone (*Actinodendron* sp.).

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
SITE DL Cont.						
3/5/07	Tow 13	75	Low	Good	High coral diversity 3 – 12 meter then sand/rubble lower slope. Good Site	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with Acropora branching and tables, soft corals, *Fungia sp., Pavona cactus, Lobophyllia sp, Pocillopora damicornis,* Sponges (e.g. blue *Cribrochalina sp.*)
3/5/07	Tow 14	75	Low	Good	High coral diversity 3 – 12 meter then sand/rubble lower slope. Good Site *Pocillopora damicornis.* Sponge (*Cribrochalina sp.*)	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with Acropora branching and tables, soft corals, *Fungia sp., Pavona cactus, Lobophyllia sp,*
3/5/07	Tow 15	>5	Low	Poor	Sand Rubble with macro algae associated with rubble (5%). Some large massive bommies	Few Porites massive (*Porites rus, P. lutea*), and massive *Lobophyllia sp.* Dead patch of large branching *Acropora sp. Pocillopora damicornis Fungia sp. Sarcophyton sp.*
3/5/07	Tow 16	70 Bommies	Low	Poor	Very large (*Porites sp.*) massive bommies in good health. Sand/ Rubble with macro algae associated with rubble (5%)	Porites massive (*Porites rus, P. lutea*), massive *Lobophyllia sp. Sarcophyton sp., Pocillopora damicornis.* Sponges (e.g. *Cribrochalina sp.*)

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
SITE DL Cont.						
3/5/07	Tow 17	>5	Low	Poor	Sand Rubble with macro algae associated with rubble (10%) few bommies anthropogenic damage.	Porites massive (*P. lutea*), massive *Lobophyllia sp.*
3/5/07	Dive 5	40% 5-12 m 12 + m sand	Minimal	Poor	Massive digitate down to 12 m sand deeper	Porites massive (*P. lutea*) Porites digitate (*P. rus*) dominant some *Lobophyllia sp*, *Pavona cactus* and *Astrepora sp*
3/5/07	Dive 6	Sand Only	Minimal	Poor	Sand dominate some small rubble *Halimeda sp.* patches	Sand, one very small *Pocillopora damicornis*
5/5/07	Dive 10	>1	Minimal	Poor	Sand, Halimeda *sp.* dominate some small *Dictyota sp.* and *Padina sp.*	Sand, several small massive *Porites lutea* (15m)
5/5/07	Dive 11	>5	Low	Poor	Rubble/small boulders on slope sand deeper, *Padina sp* beds (8 – 16m) dominate, some *Halimeda sp.*	Rubble small boulders dominate slope sand deeper with one medium massive *Porites rus* (15m)
5/507	Dive 12	>1	Minimal	Poor	Sand dominates one patch (5m x 5m) soft coral with minor blue green filamentous algae.	Sand, one patch of Sinularia (13m) one specimen of each small massive *Porites rus* and *Sarcophyton sp.*
Site JB						
4/5/07	Tow 18	30	Low	Poor – Fair	Large – medium (*Porites sp.*) massive bommies in good health. Sand/ Rubble with macro algae associated with rubble (5%)	Porites (massive, digitate and branching – dominate) *Porites rus, P. lutea*, P. *cylindrical, P antennuata), Sarcophyton sp., Pocillopora damicornis* and *P. danae, Pavona cactus* and small colonies of *Millipora sp.*

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Site JB Cont.						
4/5/07	Tow 19	30	Low	Poor – Fair	Large – medium (*Porites sp.*) massive bommies in good health. Sand/ Rubble with macro algae associated with rubble (5%). Rubble disappears close to inshore dredge site.	Porites (massive, digitate small branching – dominate) *Porites rus, P. lutea*, P. *cylindrical, P antennuata), Sarcophyton sp., Pocillopora damicornis* and small *Acropora sp.*
4/5/07	Tow 20	55 increase towards point	Low	Fair – Good	Large – medium (*Porites sp.*) massive bommies in good health. Macro algae associated with sand/rubble. Sand dominates substrate closer to point, good coral cover 2 – 5 meters then bommies between sand on deeper shelf (10m) then sand.	Porites (massive, digitate dominate some branching) *Porites rus, P. lutea*, P. *cylindrical, P antennuata), Sarcophyton sp., Pocillopora damicornis, Pavona cactus*, some *Lobophyllia sp*, small colonies of *Millipora sp.*
4/5/07	Tow 21	30	Low	Fair	Medium to small (*Porites sp.*) massive bommies in good health. Macro algae associated with sand/rubble.	Porites (massive, digitate dominate some branching) *Porites rus, P. lutea*, P. *cylindrical, P antennuata), Sarcophyton sp., Pocillopora damicornis*, some *Lobophyllia sp*, small colonies of *Millipora sp*
4/5/07	Tow 22	>5	Low	Poor	Few large – medium size (*Porites sp.*) massive bommies in average health on slope. Macro algae (blue green) associated with sand/rubble. Sand dominates (8m).	Porites (massive, digitate dominate minor branching) *Porites rus, P. lutea)*. Mostly sand rubble on slope with blue green algae cover. 1 x *Acanthaster planci*

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Site JB Cont.						
4/5/07	Tow 23	>5	Low	Poor	Few large – medium size (*Porites sp.*) massive bommies in average health on slope. Large *Lobophyllia sp* damaged on slope. Macro algae associated with sand/rubble.	Porites (massive, digitate dominate minor branching) *Porites rus, P. lutea).* Mostly sand rubble on slope with blue green algae cover.
4/5/07	Dive 7	Sand Only	Low	Poor	Sand rubble beds with small rubble, with macro algae.	None located
4/5/07	Dive 8	5	Low	Poor	Small/rubble on slope between 4 – 8 meters then larger rubble to 10 meters then sand dominates substrate. Anthropogenic disturbance apparent.	Some small massive and encrusting Porites sp. deeper.
Site AJT	L1					
7/5/07	Tow 24	80% (15% at end in sand)	Minimal	Good	High coral diversity 5 – 12 meter on slope then sand/rubble lower slope with minimal coral cover only on isolated bommies (*Porites lutea* or *Lobophyllia sp)* Macro algae on reef in high density patches. Good Site	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with Acropora branching and large tables, soft corals (*Sarcophyton sp*). , large massive *Lobophyllia sp, Pocillopora damicornis,*
7/5/07	Tow 25	60%	Minimal	Good	High coral diversity 5 – 12 meter on slope then sand/rubble lower slope with minimal coral cover only on isolated bommies (*Porites lutea* or *Lobophyllia sp)* Macro algae on reef in high density patches and reef slope sections of rubble/sand beds. Good Site	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with Acropora branching and large tables, soft corals (*Sarcophyton sp*). , *Fungia sp.*, large massive *Lobophyllia sp.* (some damaged by anchors.)

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Site AJT L1 Cont.						
7/5/07	Tow 26	90% (45% around point)	Minimal	Good	High coral diversity 5 – 12 meter on slope then sand/rubble lower slope with minimal coral cover only on isolated bommies (*Porites lutea* or *Lobophyllia sp)* Macro algae on reef in high density patches. Coral cover decreased after going around point (southerly direction). Good Site	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea*, P. *cylindrical, P. antennuata)* associated with Acropora branching and large tables, soft corals (*Sarcophyton sp*). , large massive *Lobophyllia sp.* some damaged by anchors.
7/5/07	Dive 9	20%	Minimal	Good	Hard coral cover from 5 – 10 meter on slope then sand and some rubble lower slope with isolated bommies (*Porites lutea* or *Lobophyllia sp).* Macro algae on reef in high density patches, reef slope sand/rubble bed (blue greens).	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea*, P. *cylindrical)* associated with Acropora branching and large tables, soft corals (*Sarcophyton sp*). large massive *Lobophyllia sp.*
Site AJT	L2					
7/5/07	Tow 27	40%	Minimal	Good	Good coral cover and diversity 5 – 8 meter on gentle slope then sand/rubble lower slope with minimal coral cover only on isolated bommies (*Porites lutea* or *Lobophyllia sp)* Macro algae on reef in high density patches and reef slope sections of rubble/sand beds.	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea*, P. *cylindrical, P. antennuata)* associated with Acropora branching and large tables, soft corals (*Sarcophyton sp*). , small – medium massive *Lobophyllia sp.* (some damaged by anchors.)

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Site AJT L2 Cont.						
8/5/07	Tow 28	60 -80% reef sand deeper	Minimal	Good Sand area with some coral bommies	Good coral cover and diversity. 3 – 10 meter on reef corner steep slope then sand/rubble lower slope with minimal coral cover only on isolated bommies (*Porites lutea* or *Lobophyllia sp)* Macro algae on reef in reasonable density patches and blue green on reef slope sections of rubble/sand beds.	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with Acropora branching and large tables on reef – 50% large tables dead, soft corals (*Sarcophyton sp*). , small – medium massive *Lobophyllia sp.* (some damaged by anchors.)
8/5/07	Tow 29	75% reef sand deeper	Minimal	Good	Good coral cover and diversity 3 – 8 meter on gentle slope then sand minimal rubble gentle slope with almost no coral cover very isolated bommies (*Porites lutea* or *Lobophyllia sp)* Macro algae on reef in reasonable density patches and blue green on reef slope sections of sand/rubble beds.	Porites and Acropora even dominate forms. Porites (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with Acropora branching and large tables on reef – 50% large tables dead, soft corals (*Sarcophyton sp*). , small – medium massive *Lobophyllia sp.* (some damaged by anchors.) Small patches of *Heliopora coerulea* and *Pocillopora danae.*

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Site AJT L2 Cont.						
8/5/07	Tow 30	80% reef corner sand deeper	Minimal	Good	Good coral cover and diversity. 3 – 12 meter on reef corner steep slope then sand/rubble lower slope with a number of large coral cover bommies (*Porites lutea* or *Lobophyllia sp)* on reef flat. Macro algae on reef in reasonable density patches and blue green on reef slope sections of sand.	Porites and Acropora even dominate forms. Porites (massive, digitate and branching) *Porites rus, P. lutea*, P. *cylindrical, P. antennuata)* associated with Acropora branching and large tables on reef – 30% large tables dead, soft corals (*Sarcophyton sp*). , small – medium massive *Lobophyllia sp.* (some damaged by anchors.) Patches of *Pocillopora danae.*
8/5/07	Tow 31	30% on reef edge >5% on reef slope	Minimal	Fair Sedimentation issues	Reasonable coral cover on reef edge with large - medium size (*Porites sp.*) colonies and Acropora small branching and tables. High sedimentation on reef and considerable colony death in reef. Macro algae associated with sand slope. Extensive sand slope 6 – 14 meters deep and about 60 meters wide.	Porites (massive, digitate branching) *Porites rus, P. lutea*, P. *cylindrical).Acropora sp.* (3 species) branching and tables with considerable death of large tables. Soft corals (*Sarcophyton sp*) and *Pocillopora danae* colonies. Sand (fine) dominated slope with almost no live coral or rubble.

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Site AJT L2 Cont.						
8/5/07	Tow 32	>5% on reef slope	Minimal	Poor Sedimentation issues	Low coral cover on reef edge with large – medium size (*Porites sp.*) colonies and Acropora small branching and tables. High sedimentation on reef and considerable colony death on reef. Macro algae associated with sand slope and on dead reef. Extensive sand slope 6 – 14 meters deep and about 50 meters wide.	Porites and Acropora even dominate forms. Porites (massive, digitate branching) *Porites rus*, *P. lutea*, P. *cylindrical).Acropora sp.* branching and tables with considerable death of large tables. Soft corals (*Sarcophyton sp*) and *Pocillopora danae* colonies. Sand (fine) dominated slope with almost no live coral or rubble.
8/5/07	Tow 33	80% reef slope 40 % 0verall before sand deeper	Minimal	Good	Good coral cover and diversity. 3 – 10 meter on reef edge and slope then sand/rubble lower slope with a number of large coral cover bommies (*Porites lutea* or *Lobophyllia sp)* on reef flat. Macro algae on reef in reasonable density patches and blue green on reef slope sections of sand.	Acropora dominate forms, Acropora branching and large tables on reef, 30% large tables dead. Porites (massive, digitate and branching) *Porites rus*, *P. lutea*, P. *cylindrical)* – soft corals (*Sarcophyton sp*). small – medium massive *Lobophyllia sp.* (some damaged by anchors.) Patches of *Pocillopora danae.*

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Site AJT L2 Cont.						
8/5/07	Dive 13	>5% on reef slope	Minimal	Poor Sedimentation issues	Low coral cover on reef edge with large – medium size (*Porites sp.*) colonies and Acropora small branching and tables. High sedimentation on reef and considerable colony death on reef. Macro algae associated with sand slope and on dead reef. Extensive sand slope 6 – 14 meters deep and about 50 meters wide.	Porites and Acropora even dominate forms. Porites (massive, digitate branching) *Porites rus, P. lutea,* P. *cylindrical).Acropora sp.* branching and tables with considerable death of large tables. One large *Favites sp.* colony, Soft corals (*Sarcophyton sp*) and *Pocillopora danae* colonies. Sand (fine) dominated slope with almost no live coral or rubble.
8/5/07	Dive 14	>5% on reef slope	Minimal	Poor Sedimentation issues	Low coral cover only associated with bommies between sand bottom. Medium size (*Porites sp.*) colonies and Acropora small branching and tables. High sedimentation on reef and considerable colony death on reef. Macro algae associated with bommies. Extensive sand slope 6 – 7 meters deep and about 60 meters wide.	Porites and Acropora even dominate forms. Porites (massive, digitate branching) *Porites rus, P. lutea,* P. *cylindrical).Acropora sp.* branching and tables some death on large tables. Soft corals (*Sarcophyton sp. and Sinularia sp.*) and *Pocillopora danae* colonies. Sand (fine) dominated sea floor with no live coral or rubble.

References:

Beche-de-mer:	Fish:	Marine Plants:	Turtles:
A = Thelenota anax B = *Thelenota ananas.* C = *Bohadschia argus.* *D = Bohadschia vitiensis* E = *Actinopyga miliaris* F = *Euapta godeffroyi* *G = Holothuria edulis* *H = Holothuria atra*	A = *Epinephelus polyphekadion* B = *E. maculatus* C = Coral Trout (*Plectropomus laevis, P. oligacanthus, P. areolatus)* D = Coronation Trout (*Variola louti*). E = Peacock (*Cephalopholus argus*). F = Humphead (Napoleon) Wrasse (*Cheilinus undulatus*).	A = *Dictyota sp.* B = *Halimeda sp.* C = *Padina sp.* D = *Acanthophora spicifera.* E = *Caulerpa taxifola* F = Blue green filamentous algae G = *Ulva sp.* H = *Actinotrichia fragilis* I = *Tydemania expeditionis* J = *Asparagopsis sp.*	A = Green Turtle (*Chelonia mydas*)

Appendix 6. Marine Resource Data for the North-eastern Proposed Dredging Sites.

Location Site Date:	Tow Or Dive No.	Latitude/Longitude UTM Start of transect	Latitude/Longitude UTM Finish of transect	Wind Condition Knots	Sea Conditions
Area 1					
9/5/07	Tow 1	59N 0537432 0787000	59N 0536530 0786940	5	Calm, Protected by islands
Area 2					
9/5/07	Tow 2	59N 0535846 0787060	59N 0535290 0787038	5	Calm, Protected by islands
Area 3					
9/5/07	Tow 3	59N 0534641 0787447	59N 0534416 0787711	5	Calm, Protected by islands
Enemonit Island					
9/5/07	Tow 4	59N 0534352 0787876	59N 0533906 0788304	5	Calm, Protected by islands
Area 4					
9/5/07	Tow 5	59N 0533716 0788398	59N 0533486 0788566	5	Calm, Protected by islands
Eneko Island					
9/5/07	Tow 6	59N 0531546 0789961	59N 0531321 0790136	5	Calm, Protected by islands
Area 5					
9/5/07	Tow 7	59N 0530912 0790192	59N 0530355 0790130	5	Calm, Protected by islands

Appendix 7. Marine Resource Data for the North-eastern Proposed Dredging Sites.

Location Site Date:	Transect Or Dive No.	H_2O Depth (m)	Transect Length (m)	Transect Width (m)	Turtle	Mollusc Clams, Oysters,	Sea Cucumber	Turf Algae/ Macro Algae/ Sea Grass	Finfish
Area 1									
9/5/07	Tow 1	2-14	900	18	0	0	38A, 17B, 15C 1COTS	B, A and C on rubble shallow reef, D on rubble on slope	2A
Area 2									
9/5/07	Tow 2	3-15	700	20	0	Cultured Td,Tg. Natural Tm, Ts, Hh. Broodstock	190A	D dominate reef flat early slope rubble with less E, A, B and F patches on rubble,	0
Area 3									
9/5/07	Tow 3	3-10	400	18	0	1 *Cassis sp.* (helmet shell)	1C	F dominate ion shallow rubble with D, C and small patches of B	0
Enemonit Island									
9/5/07	Tow 4	1-2	500	6	0	6 *Cassis sp.* (helmet shell)	1C	A dominate on coral, small patches of B and C	1A
Area 4									
9/5/07	Tow 5	2-12	350	12	0	0	4A, 1B	F dominate on rubble small patches of B	0

Location Site Date:	Transect Or Dive No.	H_2O Depth (m)	Transect Length (m)	Transect Width (m)	Turtle	Mollusc Clams, Oysters,	Sea Cucumber	Turf Algae/ Macro Algae/ Sea Grass	Finfish
Eneko Island									
9/5/07	Tow 6	2-3	300	8	0	0	6A	F dominate on rubble small patches of A, B, C	0
Area 5									
9/5/07	Tow 7	3-15	600	18	6 Green Turtle (*Chelonia mydas*)	1 *Lambis truncata.*	0	F dominate on rubble patches of B (6-12m) towards end of tow.	1A

Appendix 8. Marine Resource Data for the North-eastern Proposed Dredging Sites.

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Area 1						
9/5/07	Tow 1	80% on reef flat >5% on slope	Minimal	Good	Good coral cover and high diversity. 3-5 meter on reef flat then slope dominated by sand with sum rubble then sand for deep slope. Macro algae and blue green on rubble and sand associated with reef slope. No hard coral deeper that 6 meters dominated by fine foram sand.	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with small colonies of Acropora branching and small tables. Small patches *Pocillopora danae.*
Area 2						
9/5/07	Tow 2	>5% on reef flat 0 reef slope	Minimal	Poor	Reef flat dominated by sand/rubble with macro algae onto reef slope dominated by fine foram sand.	Small number of Porites small medium massive, digitate and branching colonies (*Porites rus, P. lutea,* P. *cylindrical)* associated with colonies of Acropora branching, some patches dead.
Area 3						
9/5/07	Tow 3	>5% on reef flat 0 reef slope	Minimal	Poor	Reef flat dominated by sand/rubble with macro algae onto reef slope dominated by fine foram sand.	Small number of Porites small medium massive, digitate colonies (Porites *rus, P. lutea,)* associated with colonies of Acropora branching and plates.

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Enemonit Island						
9/5/07	Tow 4	70% on reef flat >5% on slope	Minimal	Good	Good coral cover and high diversity. 2-4 meter on reef flat then slope dominated by sand (some rubble) with medium to large Porites massive and digitate bommies then sand dominate slope. Macro algae and blue green on rubble and sand associated with reef slope. No hard coral deeper that 8 meters dominated by fine foram sand.	Porites dominate (massive, digitate and branching) *Porites rus, P. lutea,* P. *cylindrical, P. antennuata)* associated with small to medium size colonies of Acropora branching and tables. Patches *Pocillopora danae,* Heliopora *coerulea,* soft corals *(Sarcophyton sp), mushroom corals (Fungia sp.), Millepora sp.*, patches of *Goniopora sp.* and large beds of zooanthids (Discosoma sp.)
Area 4						
9/5/07	Tow 5	>1%	Minimal	Poor	Reef flat dominated by sand/rubble with macro algae onto reef slope dominated by fine foram sand.	Small number of Porites small and large massive, digitate colonies (Porites *rus, P. lutea,)* associated with few small colonies of Acropora branching.

Location Site Date:	Transect Or Dive No.	% Live Coral Cover	Debris Litter	Reef Condition	Dominate Benthic Forms	Dominant Hard Coral Morphological Form and Genus
Eneko Island						
9/5/07	Tow 6	30% on tow 60% on reef flat	Minimal	Good	Reasonable coral cover on reef flat (2-4 meter) then slope dominated by sand (some rubble). Macro algae and blue green on rubble and sand associated with reef slope. No hard coral deeper that 5 meters dominated by fine foram sand.	Porites dominate (massive, digitate and branching) *Porites rus*, *P. lutea*, P. *cylindrical,)* associated with small size colonies of Acropora branching and tables. Patches of Heliopora *coerulea* attached to bommies.
Area 5						
9/5/07	Tow 7	>1%	Minimal	Poor	Reef flat dominated by sand/rubble with macro algae onto reef slope dominated by fine foram sand.	Small number of Porites small massive colonies (*P. lutea,)*. Sand dominated reef

References:

Beche-de-mer:	Fish:	Marine Plants:	Turtles:
A = Thelenota anax B = *Thelenota ananas.* C = *Bohadschia argus.*	A = *Epinephelus maculatus*	A = *Dictyota sp.* B = *Halimeda sp.* C = *Padina sp.* D = Blue green filamentous algae E = *Actinotrichia fragilis* F = *Asparagopsis sp.*	A = Green Turtle (*Chelonia mydas*)

Appendix 9. Site locality map of eastern Majuro Lagoon.