WESTERN MINING CORPORATION LIMITED

PETROLEUM DIVISION (AUSTRALASIA)

TP/7 and TL/2

FIVE YEAR OFFSHORE DRILLING PROGRAMME

CONSULTATIVE ENVIRONMENTAL REVIEW

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SUMMARY

In 1986 Western Mining Corporation Limited, on behalf of the TP/7 permit and TL/2 licence holders, submitted a revised Offshore Oil Production Environmental Review and Management Programme (ERMP). This programme covered the development and recovery of an estimated 1,700,000 kl of crude oil from the South Pepper, North Herald and Chervil oil fields and involved the construction and installation of platforms and pipelines offshore and process and storage facilities on Airlie Island.

Subsequent to that programme being submitted production has commenced and some 1,500,000 kl of oil has been produced.

Environmental aspects of the project remain as presented in the original ERMP. However further exploration and appraisal drilling and is required to prove up additional reserves and to provide a continuous supply of oil for facilities to be utilised to the maximum benefit. Drilling is warranted to assess the possibilities of additional reserves that would ensure maximum benefit from the existing facilities.

A five year drilling programme is proposed by Western Mining to achieve this aim. Whilst not all well locations are yet defined, the permit area is small enough and uniform enough to allow the preparation of an overall environmental review. This document forms that review and has been compiled to summarise environmental impacts and give details of the proposed management of these impacts.

SECTION 1

INTRODUCTION

1.1 Project Background

Western Mining Corporation, as operator for the permit holders, has developed the South Pepper, North Herald and Chervil oilfields in permit area TP/7 and TL/2 off Onslow, Western Australia. The project includes producing wells at four locations, separating facilities and a storage and loading terminal on Airlie Island.

The original permit area, WA-149-P, was granted to the Joint Venture on the 1st March 1981. The Offshore Production Notice of Intent was filed in December 1984 and the Environmental Review and Management Plan (ERMP) was submitted in January 1985. A subsequent downgrading of resources led to a reduced scope of development and a second revised ERMP, dated November 1986, was submitted. Approval to proceed was granted and oil production from the South Pepper/North Herald fields commenced in December 1987. With the initial investment made and a positive re-assessment of the field available, it was decided in 1989 to exploit the Chervil Oilfield. In April 1989 a Notice of Intent was issued and approval gained. Production of Chervil began in September 1989.

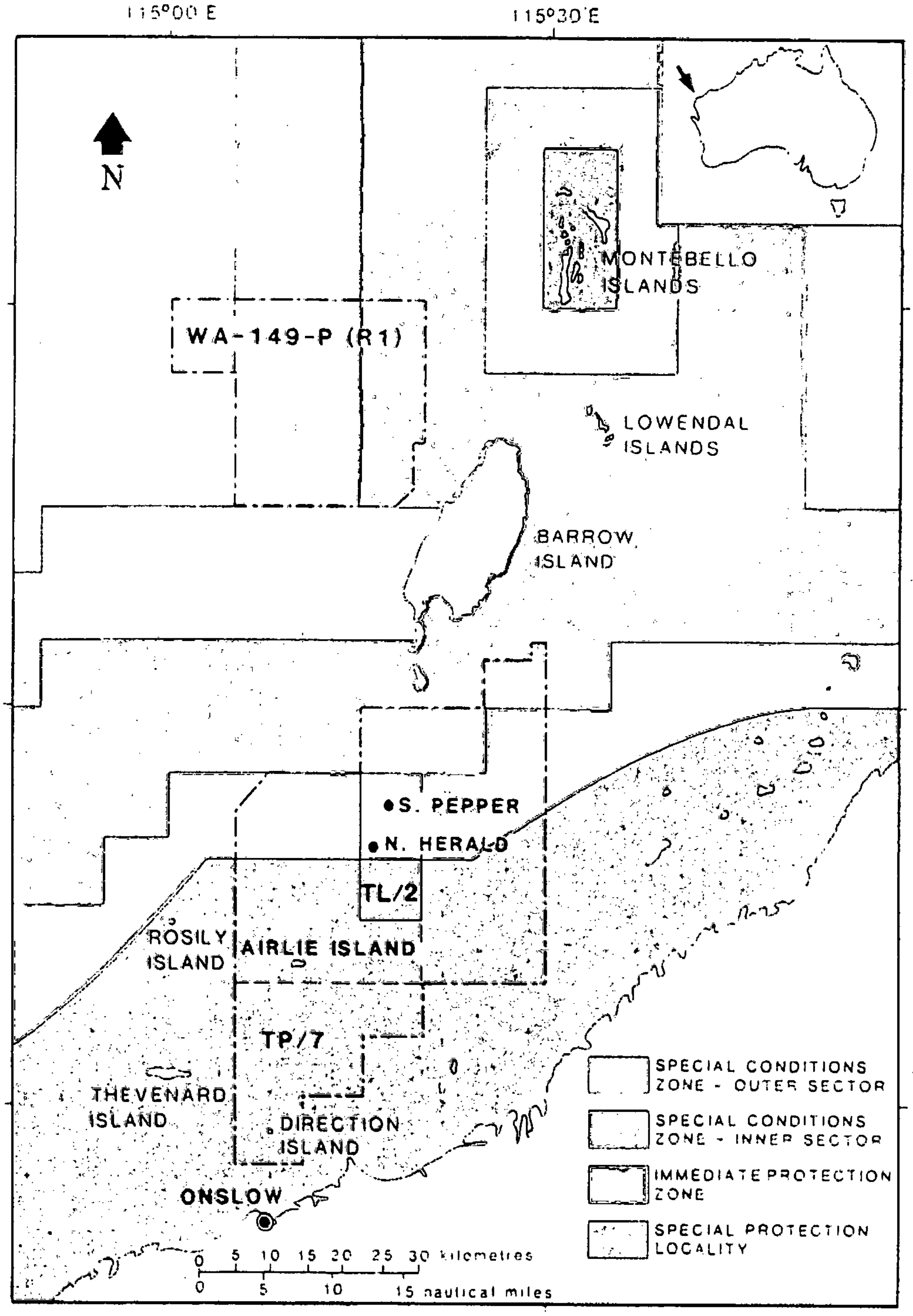
Since the original discoveries, Western Mining has drilled a number of exploratory wells. It is now developing a 5 year drilling programme to fully evaluate the oil prospects of the lease. This document describes the proposed programme, assesses the likely environmental impacts and defines a management programme to contain and minimise any adverse effects which could occur.

1.2 Location of Exploration Area

The combined Area (TP/7 & TL/2) covers an area of approximately 1800 square kilometres and is located due North of Onslow between latitudes 21° 35' S and 20° 55' S and longitudes 115° 5' E and 115° 30' E. The southern portion is approximately 5 km from Onslow. See Figure 1.

The entire permit area is located in the environmentally significant area of the Rowley Shelf. The southern half is within a special protection locality as defined by the Environmental Protection Authority (EPA), the northern half spans the immediate protection zone.

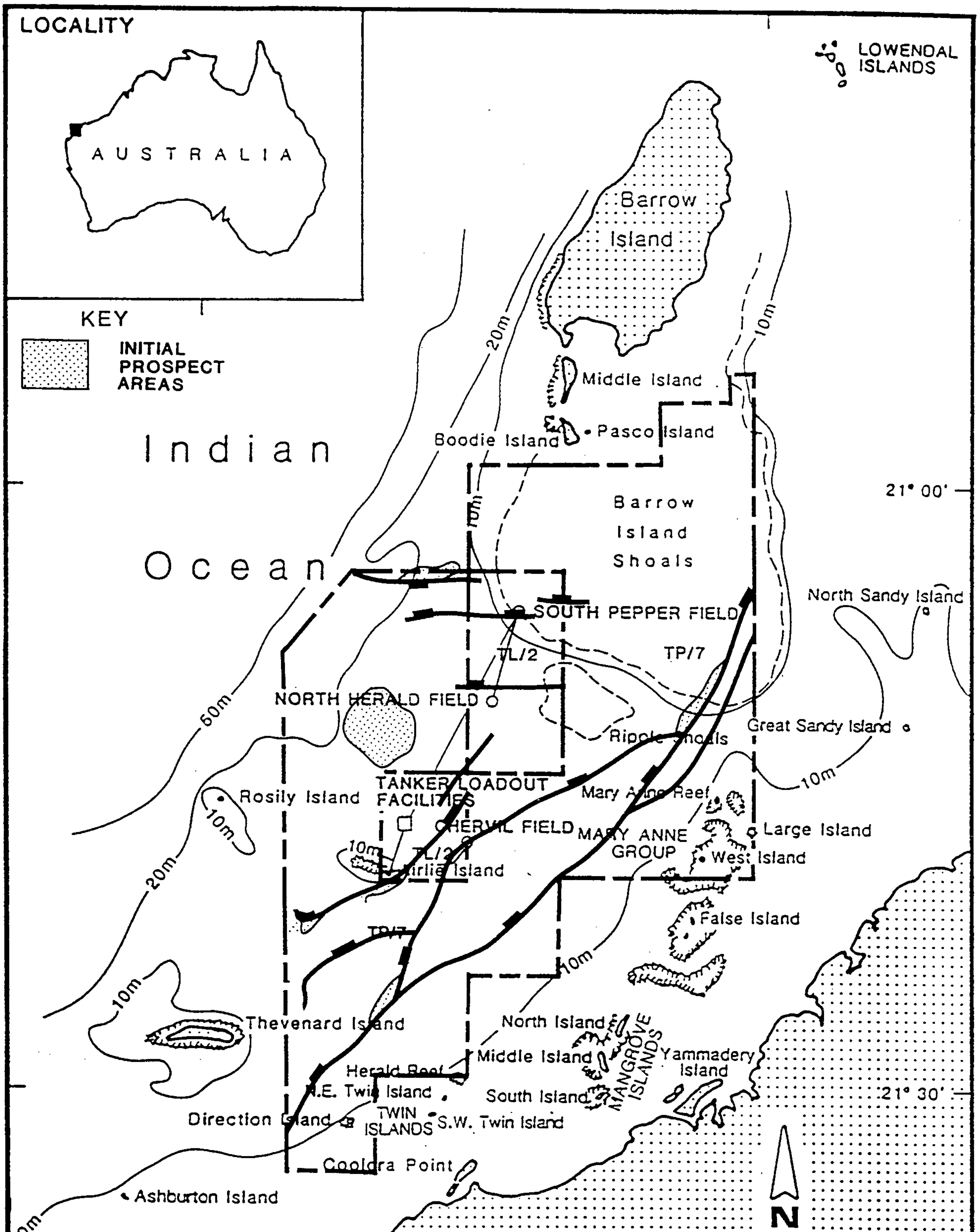
Future exploration and development drilling is planned to occur at selected locations within the permit area as indicated in Figure 2.



WMC

LOCATION OF TP/7, TL/2 AND ENVIRONMENTALLY SENSITIVE AREAS

FIG. 1



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LOCATION MAP & INITIAL PROSPECT LOCATIONS

FIG. 2

1.3 Legislative Requirements

Exploration and development of offshore petroleum resources in Western Australia is undertaken subject to a number of Government Acts. Relevant Commonwealth Acts are:

* Petroleum (Submerged Lands) Act 1967.
* Environmental Protection (Sea Dumping) Act, 1981
* Protection of the Sea (Civil Liability) Act, 1981
* Protection of the Sea (Discharge of Oil from Ships) Act, 1981
* Protection of the Sea (Powers of Intervention) Act, 1981

Relevant Western Australian Government Acts include:

* Fisheries Act, 1905
* Prevention of Pollution of Water by Oil Act, 1960
* Western Australian Marine/Sea Dumping Act, 1981
* Petroleum Act, 1981
* Petroleum (Submerged Lands) Act, 1982 (Revised 1990)
* Environmental Protection Act, 1986

The Commonwealth and the States have agreed to certain arrangements with respect to the regulation and control of offshore petroleum exploration and production. A Joint Authority has been established in each State to give effect to the arrangements, consisting of a Commonwealth Minister and a Minister of the relevant state. The W.A. Act nominates the W.A. Minister for Mines as its member of the Joint Authority. Applications are made to this Minister and day to day administration remains with the State.

The Acts cover exploring for and recovery of petroleum, construction and operation of pipelines and other relevant matters. These operations are specifically guided by requirements set out in "Direction No 1 - Petroleum (Submerged Lands) Act 1967" (Commonwealth) which integrates all activities. Exploration requires an exploration permit, recovery a production licence and pipelines require special licences.

The extensive seismic and drilling exploration activities which have occurred in the Permit area since 1981 have been conducted by the Permit Holders to the approval of the Department of Mines within the framework of the requirement above.

1.4 The Participants

The area covered by this CER is as shown on Figure 1. Two areas are included, these being permit TP/7 and production licence TL/2. TL/2 is contained within the boundaries of TP/7.

The joint venturers and their respective interests in each area are as follows:

TP/7

Western Mining Corporation Limited (Operator)	49.896%
Ampol Exploration Limited	12.474%
Muswellbrook Petroleum Limited	8.525%
OGE Limited	6.237%
Bridge Oil Ltd	18.711%
Pan Pacific Petroleum NL	4.157%
	100%

TL/2

Western Mining Corporation Limited (Operator)	40.000%
Pacific Oil & Gas Limited	19.833%
Bridge Oil Ltd	15.000%
Ampolex (PPL) Pty Limited	10.000%
Muswellbrook Petroleum Limited	6.834%
OGE Limited	5.000%
Pan Pacific Petroleum NL	3.333%
	100%

1.5 This Document

This document is a Consultative Environmental Review produced for the proposed 5 year drilling programme by WMC in response to the EPA request of 5th September 1990. It outlines the need for the proposal, summarises environmental impacts and outlines a management plan for amelioration of the possible impacts and has been prepared using material from specialist reports previously commissioned by WMC. It also includes a revised Oil Spill Contingency Plan to facilitate an efficient and effective response to such an eventuality.

SECTION 2
PROJECT BENEFITS AND NEED

2.1 Need for the Proposal

The importance to Australia of oil exploration and oilfield development is becoming increasingly obvious as the production of the Bass Strait Fields continues to decline. In 1989, Australia imported 30,700 kls of crude per day while exporting only 13,400 kl per day. Although we export refined products in an excess of 33,000 kl per day over imports, our current 85% self sufficiency is steadily declining. Australian production in the March 1990 quarter was over 950,000 kl per day, but is forecast to fall to 715,000 kl per day in 1992. (Australian Business, 22nd August 1990). The negative impact of this import bill on the balance of payments is obvious and the trend can only be reversed by continuing discoveries.

The Commonwealth Government recognises the importance of exploration and the Federal Minister for Resources, Mr Griffiths, has called for more effort to realize Australia's Oil reserves. (The Australian, 16th August 1990).

A long term exploration programme, as outlined in this document, is an essential step in the discovery process and has the potential to provide substantial benefits to the country and the state.

2.2 Capital Expenditure, Employment and Revenue

The total capital cost of the proposed exploration and appraisal drilling programme, over the five year period is estimated to be in the order $90,000,000 the majority of which will be spent on Australian and in particular Western Australian resources. This represents a significant boost to the State's economy in a period of economic recession. The capital expenditure, employment and royalty benefits that would occur from a discovery are, of course, much greater than this.

The drilling programme will employ an estimated 50 people per year over the life of the programme (full time annual equivalent). These individuals will be employed both in Perth and the North West. The exploration programme will require a broad range of expertise and specialist back-up, which it is important to maintain in the State. It is difficult to estimate flow-on effects, but a full time employment factor of 25% is probable.

2.3 The Effect on the Joint Venture and The State If The Drilling Programme Did Not Proceed At This Time

The issue of the original WA-149-P and subsequent TP/7 and TL/2 permits to the Joint Venture was conditional upon the partners exploring the area for hydrocarbons. If the Joint Venture is denied the opportunity to proceed with this exploration programme, further exploration by both this proponent and others in the industry would be severely discouraged.

Exploration expenditure to date on this permit has been approximately $120,000,000. A further $60,000,000 has been spent on developing the existing oil field, representing a total expenditure to date of $170,000,000. A further $30,000,000 is contemplated. These substantial figures have been committed in the belief that the proponent will be granted relative freedom to continue exploration in the permit area.

A no go option would mean the loss of significant capital expenditure in the State and removal of the anticipated employment opportunities in 1991 and onwards.

SECTION 3

DESCRIPTION OF PROPOSAL

3.1 Concept

Western Mining Corporation on behalf of its joint venture partners, proposes to undertake an exploration drilling programme to fully evaluate the prospectivity of areas TP/7 & TL/2. Because the permit area tides move predominately are in an east west direction, the environmental impacts of an oil spill from any location are similar and it is feasible to cover these in one CER. This also gives the company the freedom to position wildcat wells at the latest possible date and so assists geophysicists and geologists in their evaluations and the company in its planning.

Western Mining Corporation has prepared a 5 year program because it believes that such an approach provides a better framework in which to plan the work and allocate revenue. Obtaining approval for a five year program reduces the load on regulatory authorities and in particular on the EPA, by eliminating the need to re-assess what is essentially the same programme every 12 months. The current proposal calls for the drilling of 6 initial wells, one in each of the prospective areas shown in Figure 2. Further drilling will be required at one or more of these prospects (and elsewhere in the permit) and approval of this CER will allow that to occur at short notice. The relevant Government departments will be given full details of each proposed well before drilling commences.

3.2 Existing Field and Facility Details

The Joint Venture currently produces oil from three oilfields in the area; South Pepper, North Herald and Chervil. To achieve this it has constructed a terminal on Airlie Island, monopods at North Herald and Chervil and utilizes a jack-up drill rig with conductor support frame at South Pepper. It also produces fluids from a subsea wellhead at South Pepper No 4.

3.2.1 Existing Field Details

The three oilfields currently operated by the Joint Venture are:

1. **South Pepper** This field is centred about latitude 21° 07' 30" South, longitude 115° 16' 30" East in shallow waters (approximately 17m) about 65km North-East of Onslow. Production depths are around 1,200m below seabed.

2. North Herald	This field is centred about latitude 21° 10' 34" South, longitude 115° 16' 02" East in shallow waters (approximately 17m) some 6km SSW of South Pepper.
3. Chervil	This field is centred about latitude, 21° 18' 23" South, Longitude 115° 13' 47" in shallow water (about 13m) some 13km ENE of Airlie Island.

3.2.2 Production Facilities

Fluids from the South Pepper and North Herald Fields are processed at a semi-permanent platform facility at South Pepper. This involves a jack-up drilling rig (the "Vicksburg") which has appropriate processing equipment mounted on the deck. A conductor support jacket is installed which supports the wellheads. Fluids from each well are combined and separated on the Vicksburg. Gas is flared and treated waste disposed of. Crude oil is then pumped to the Airlie oil terminal, some 25km distant.

Production and support staff have always been accommodated on the Vicksburg although since the Chervil Field came on line, 2 operators have been stationed on Airlie Island. The rig and island are serviced by helicopter from Onslow.

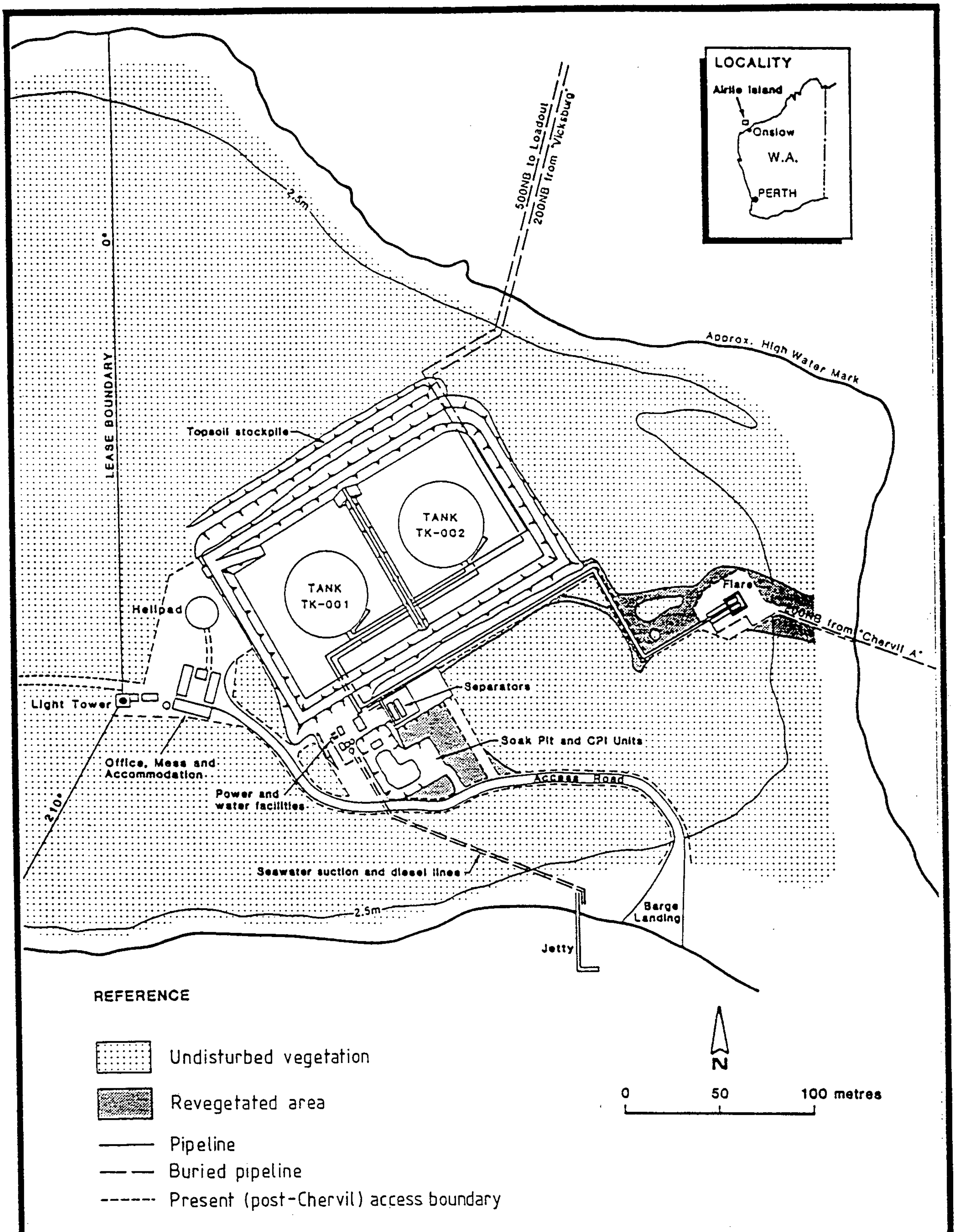
3.2.3 Airlie Island Facilities

The eastern quarter of Airlie Island is utilised for the oil terminal and process facilities for the Chervil oil field.

Facilities located on the Island include:

- An oil storage system with 47,200m^3 capacity
- Process facilities for the Chervil Oil Field
- Accommodation for up to ten persons.

The terminal layout is shown in Figure 3. Facilities have been arranged in a compact layout commensurate with safety, which minimises ecological disturbance to the island and retains vegetation niches within the disturbed area, which will assist rehabilitation after completion of the project.



AIRLIE ISLAND FACILITIES

FIG. 3

Two (2) storage tanks 15.5m high x 43.2m diameter receive all produced oil from the fields. The tanks are bunded for containment of spills with local sand being redistributed to form the bund wells. A sealing membrane of 0.2mm high density polythene is used for sealing purposes. This is assisted by a 40mm "shotcrete" layer on the bund walls and a bentonite clay layer on the floor. The outer bund walls are stabilised by a bitumen emulsion spray to minimise wind and rain erosion.

The storage tanks are floating roof type with mechanical shoe seals for maintenance simplicity. Corrosion treatment of the roof, wind girders, external walls and internal tank floor has been undertaken.

Water is drained from the tank to the Corrugated Plate Interoption (CPI.) whilst rainwater from within the bunded area is discharged after being processed through the CPI which brings the oil in water content down to below 35ppm.

3.2.4 Production Loadout Facility

The loadout mooring and turning basins are located 3km north of the Airlie Island terminal and are approached from the North West.

Tankers which are not permitted to discharge ballast water containing oil contaminants for clean up and disposal at Airlie Island, are secured in the mooring/turning basin to a conventional mooring system.

The 20" nominal diameter steel product pipeline from the storage tanks on Airlie Island terminates with a flexible hose and valve. This hose is lifted from the seabed via a line connected to a surface buoy and coupled to the tanker loading manifold.

This system has been successfully employed at Airlie Island for 50 tanker loadings over the last three (3) years.

The loadout line is retained full of oil on the seabed, but is sealed and under negative pressure relative to sea water pressure when not in use. Pumping only commences when the hose connections have been secured, the valves opened, and checking procedures designed to ensure that the ship is ready to receive oil have been completed. Portable radios are employed to maintain ship to shore communications.

Pumping rates are controlled to ensure that safe working pressures are maintained in the lines. In the event of an emergency, closure is effected at the pump delivery valve and the ship manifold valve.

3.3 Drilling Operations Details

3.3.1 Operations Logistics

During the proposed drilling program support for the drilling rig will be identical to the arrangements currently used for the production facility. Crew changes will be made by charter aircraft from Perth to Onslow where a helicopter will ferry crew to and from the rig. Separate support vessels to that used for the Vicksburg operation will be employed for the drilling program.

These vessels will assist in towing the rig to location and will transport fuel, drilling fluid components, casing, cement, food and all other requirements during the work. A boat is kept in the vicinity of the rig in case of emergency and would be used to deploy the oil spill containment boom if this was necessary.

3.3.2 Drilling Procedures

Detailed drilling procedures cannot be given because of the range of well depths being considered, however a typical vertical exploration well Drilling Programme for TP/7 is in Appendix B. Anticipated target depths vary between 900m and 2500m. For the deeper hole limit, drilling will proceed as follows:

Firstly a 26" hole is drilled to a depth of approximately 140m. This initial hole uses seawater for lubrication and disposes of drill cuttings directly. The 20" casing is cemented into position and the umbilical attached to allow mud recirculation. A 19 1/8" hole is then drilled and 13" casing installed to its design depth. For a 2500m hole, this would be a depth of some 300m. Upon cementing of the 13 3/8" casing, the Blow Out Preventer (BOP) is installed and the casing tested. A 12¼" hole is drilled from the 300m depth to 1200m and 9 5/8" casing is set. The final hole is a 8½" and a 7" casing is used. After constructing each string, the arrangement is pressure tested before continuing drilling. Formation pressures within the drill string are continuously monitored, as is the volume of returned drilling fluid. Once a flowing formation is intercepted, the BOP is used to control the flow and the mud weight is increased proportionately to provide primary well control.

Strict procedures are used for abandonment. Permeable zones are isolated with cement plugs and a surface plug is set in the 30" string. Dry wells will have all surface casing removed to a depth of at least 5m below the surface.

A producing well is plugged at the bottom of the production casing and is capped above the seabed, ready for later retrieval.

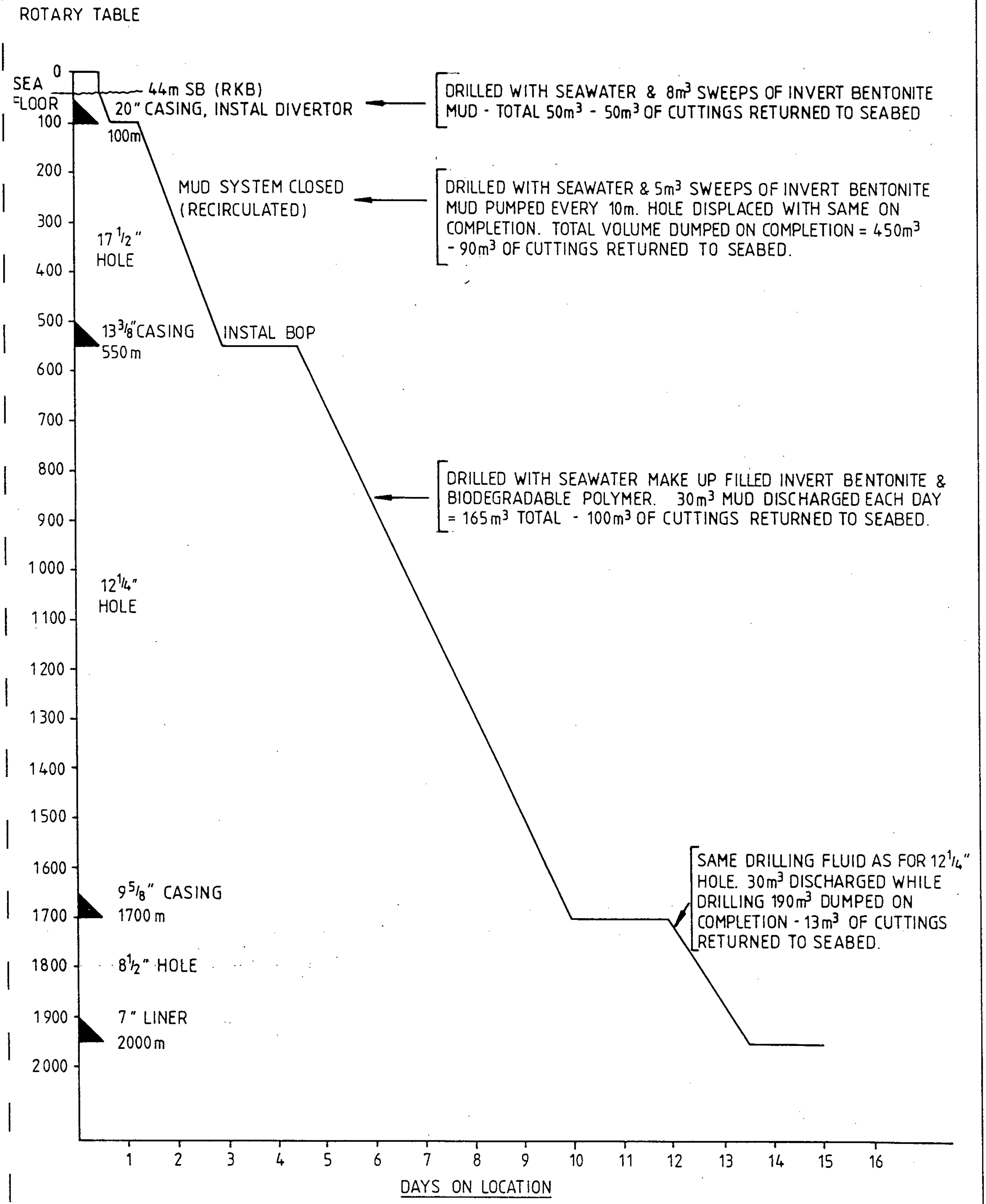
3.3.3 Operational Discharges

Operational Discharges comprise drill cuttings, drilling fluid, treated sewage and engine cooling water. Drill cuttings are the result of material removed from the hole and are inert mineral particles varying in size from a silt to a gravel. Often larger, thin angular cuttings result. Drill fluid is a mixture of various components such as bentonite (clay) with seawater. It is required for bit cooling and lubrication and is used to remove cuttings from the hole. It is also used to control formation pressures and maintain well control.

Drilled cuttings are separated from the drilling fluid by processing through the solids removal equipment on the rig. The cuttings are then discharged overboard while the drilling fluid is conditioned prior to being circulated back to the well. At the time of abandoning a well, the wellbore is left full of drilling fluid while any surplus drilling fluid is discharged to the ocean prior to moving the rig. A typical cuttings and mud discharge program for a well in TL/2 and TP/7 is shown in figure 4.

Typically some 250m^3 of cuttings would be discharged from the rig during drilling of a 2500m hole.

Sewage is treated through an on board plant and is discharged at the rate of 60 to 90m^3 per day. Deck drains will be a sealed system which discharges to a closed tank. Waste oil is pumped to a holding tank to be disposed of ashore in an approved manner. Wastes are burnt or removed from the rig. No other significant discharges will occur.



TYPICAL CUTTINGS AND MUD DISCHARGE SCHEDULE FOR 2500m WELL

FIG. 4

SECTION 4

EXISTING ENVIRONMENT

4.1 Introduction

4.1.1 Specialist Studies

Prior to the present project there was relatively little specific information about the environment in the region of the Permit area. Accordingly, the proponent commissioned various specialist studies as follows:

Oceanography and Oil Spill Trajectory Modelling	R.K. Steedman and Associates 1984
Geomorphology	Le Provost, Semeniuk and Chalmers, 1984a.
Geotechnical Investigations	Dames and Moore, 1985a, 1985b
Marine Ecology	T.D. Meagher and Associates, 1984
Mangroves	Le Provost, Semeniuk and Chalmers, 1984b.
Terrestrial Vegetation and Flora	M.E. Trudgen, 1984
Vertebrate Fauna	A. and S.R. Tingay, 1984.
Wedge-tailed Shearwater	A. and S.R. Tingay, 1985.

In addition, consultants were engaged to provide ongoing monitoring studies of marine and terrestrial flora and fauna. This information has been presented in the relevant annual reports since 1987.

The listed studies contain considerable data on the coastal and adjacent marine environment from Tubridgi Point to Cape Preston. This region extends some distance beyond the boundaries of TP/7 as it is recognised that evaluation of the proposal requires consideration of the regional ecosystem.

In this section, information from the specialist reports is summarised to present a general description of the region. Emphasis has been placed on those aspects which are considered to be of most relevance to environmental evaluation, management and monitoring.

4.1.2 Environmental Zones

TP/7 includes part of an Environmentally Sensitive Locality (ESL) which extends from Tubridgi Point on the North West Cape to a point on the mainland coast at 116° 00' E (Hancock et al., 1979). ESL's have been defined by the EPA around the coast of Western Australia to assist in the environmental management of offshore oil operations. They are areas with significant marine resources where extra environmental protection measures are recommended for oil exploration and production.

For this particular ESL, the significant marine resources are seabird nesting islands, mangrove and tidal flats, coral reefs, fish nurseries, dugongs, commercial and recreational fisheries and tourism. The area is also a source of nutrients for regional ecosystem processes.

In order to afford extra protection to ESLs, two categories of buffer zone have been designated, an inner nominal 8km Immediate Protection Zone (IPZ) and an outer nominal 50km Special Conditions Zone (SCZ). The SCZ may be divided into inner (0 - 30km) and outer (30 - 50km) buffers. As with the ESL, Government agencies and particularly the Environment Protection Authority have guidelines for offshore oil operations in IPZ's and SCZ's (Hancock et al., 1979).

4.2 The Physical Environment

4.2.1 Climate

Onslow is in the arid summer rainfall sub-tropical zone (Department of Science and Technology, 1983). The summers are very hot and winter moderate. On average, 217 days each year have a maximum temperature above 30°C and 25 of these are above 40°C. Nevertheless, cold temperatures can occur in winter, the lowest minimum ever recorded being 2.9°C in June.

Annual rainfall (average 261mm) is significantly influenced by the passage of cyclones which predominantly occur from January to March. Associated rainfall may be very heavy over relatively short time intervals, the highest one day recording at Onslow being 356mm.

Wind patterns are of particular importance for the prediction of the behaviour of marine oil spills. Comprehensive information is given in Steedman and Associates (1984). Estimated seasonal and annual wind speeds and direction roses are shown on Figure 5 for the South Pepper area. From June to August the dominant wind direction is Easterly with speeds generally ranging from 2 to 8m/sec. From November to March the winds are almost constantly from the South-West with speeds generally from 4 to 8m/sec.

Other months are transitional periods when winds may be variable. Land and sea breezes occur as daily cycles but these may be masked by the synoptic scale airflow.

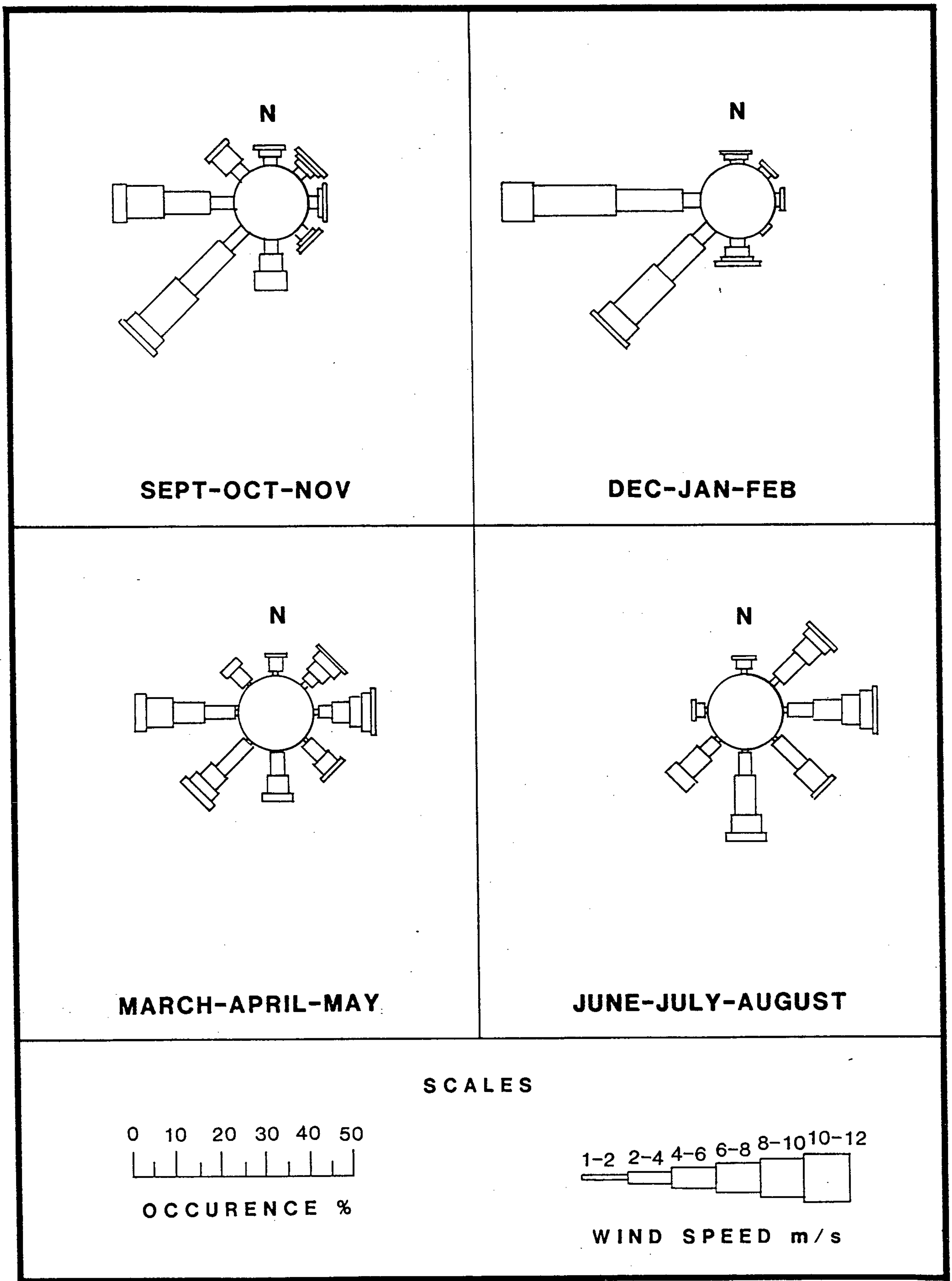
Tropical cyclones usually form in the Timor Sea area between November and April and then travel initially in a general South-Westerly direction. As a storm develops it can alter its course to travel in a South or South-Easterly direction in the area of interest.

During the period 1909 to 1980 an average of 2.7 tropical cyclones per year passed within 300 nautical miles of the South Pepper Field. The highest recorded coastal wind speed in an Australian tropical cyclone of 246 km/hr occurred at Onslow during the passage of cyclone Trixie in 1975 (Southern, 1979). Cyclone "Orson", which passed over the North Rankin "A" platform on 23rd April 1989 caused wind speeds of in excess 250k/hr but no records are available of winds speeds caused by "Orson" at the coast.

Pressure gradient storms may occur between May and September and result in Easterly gales with wind speeds up to 39m/sec. Other storm conditions, such as thunder squalls and water spouts, occur in the area between November and April.

4.2.2 Geomorphology

The major geomorphological feature of the permit area is the Rowley Shelf (Le Provost, Semeniuk and Chalmer, 1984a). The shelf comprises extensive cemented calcareous sediments (limestone) which form a shallow gently inclined seabed extending from the coast to some 20km offshore where water depths reach 20m. Sands derived from erosion of the limestone and detritus of biota such as shells, blanket the submarine shelf in varying amounts.



WIND SPEED & DIRECTION FOR PERMIT AREAS

FIG.5

The numerous barrier and oceanic islands, reefs and cays in the region are upstanding components of the Rowley Shelf, while Barrow Island and its associated islands comprise a North-trending extension. The islands and reefs may be surrounded by aprons or spits of reworked sand. Beaches occur on sheltered islands but most have rocky shores covered in places by isolated deposits of sand and mud.

4.2.3 Oceanography

The bathymetry of the region is a complex of relatively shallow water created by the Rowley Shelf. All components of the project are located in water generally less than 20m deep.

Modelling undertaken by Steedman and Associates (1984) indicates that the surface water movements in the inshore area are dominated by tidal currents modified by wind stress rather than by oceanic current effects. While tidally induced currents are substantial in the area, there are many localities of significant overfall where opposing flows meet, causing locally confused surface water movement. The result of computer model simulation of spring tides is shown on Figure 6.

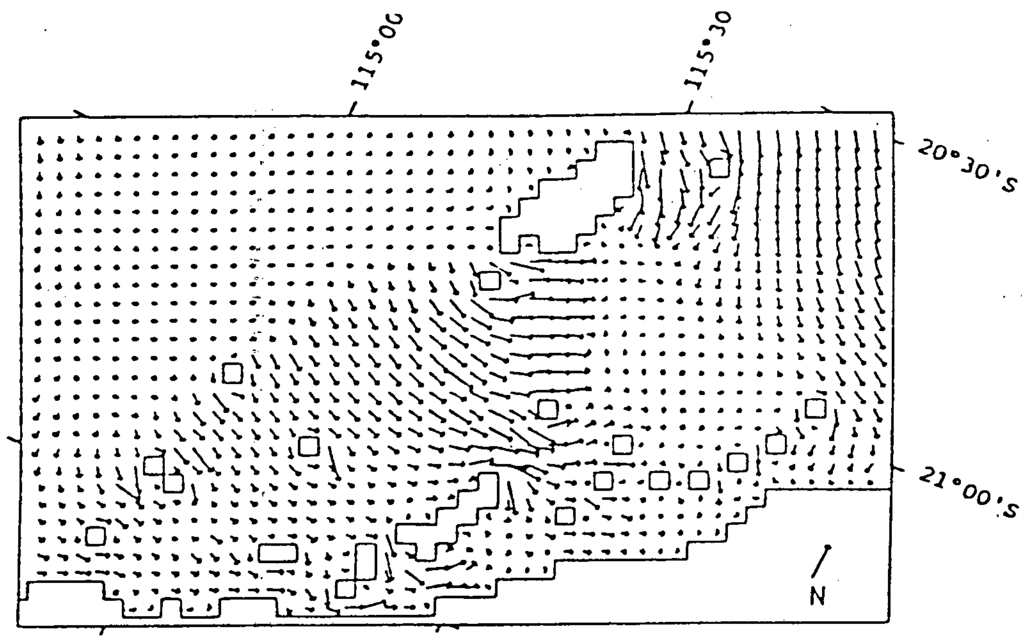
Tides are semi-diurnal (twice daily high water) and the tidal range progressively increases Northwards along the coast. The mean spring tidal range is 1.8m at Onslow and 2.5m at Barrow Island.

The strength and direction of tidal currents in the inshore area is locally modified by seafloor topography. The nearshore area includes numerous small islands and extensive shoals interspersed by deeper channels. The navigation charts indicate that in some areas around the islets and shoals, currents of 2 to 4 knots (3.7 - 7.4 kph) occur during spring tides. In the more open expanses of this area, currents generally flow at less than 1 knot (1.9 kph).

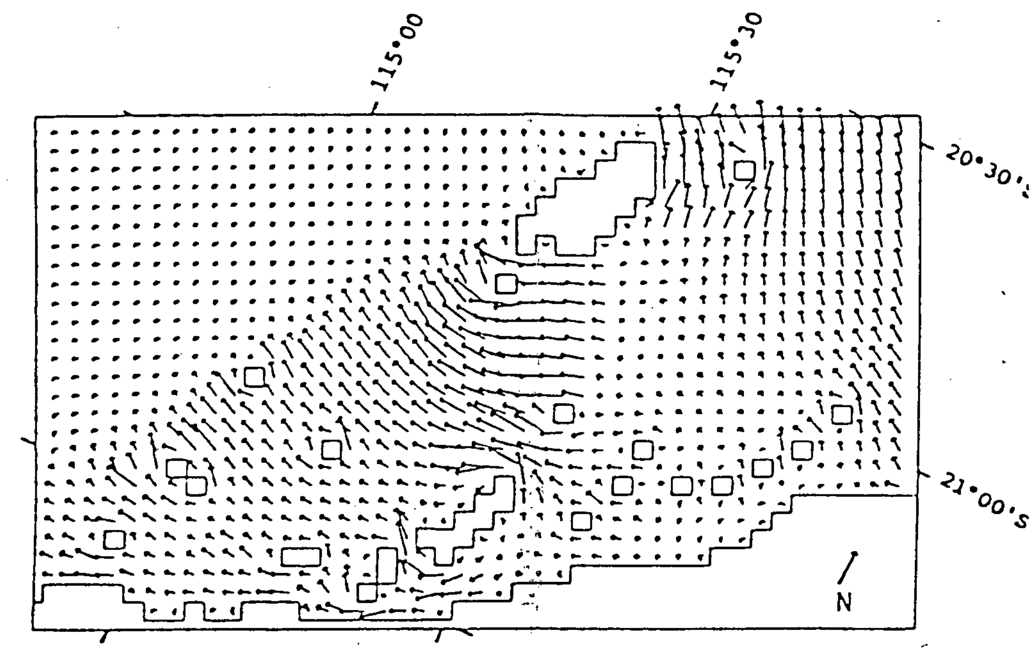
4.3 The Marine Biological Environment

4.3.2 Introduction

The emphasis in the marine studies undertaken in the permit areas was to identify and map major components of the marine ecosystem rather than to compile exhaustive lists of the biota (T.D. Meagher and Associates, 1984). This approach accords with that of the Dampier Archipelago Marine Study (Chittleborough, 1983).



(a) 0900 hours May 24, 1982.



(c) 1500 hours May 24, 1982.

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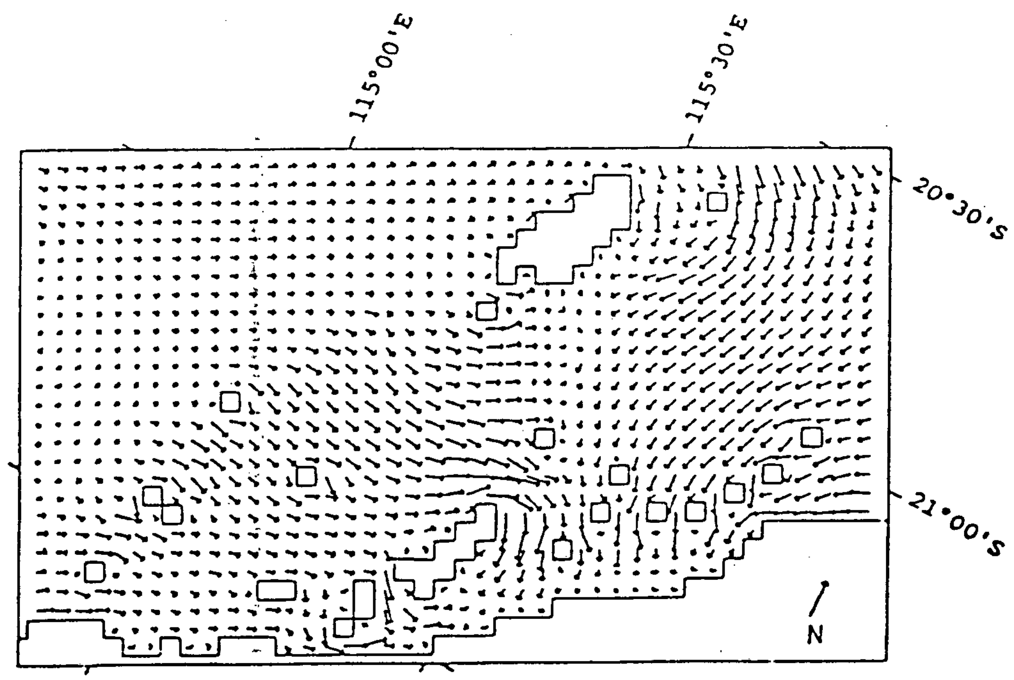
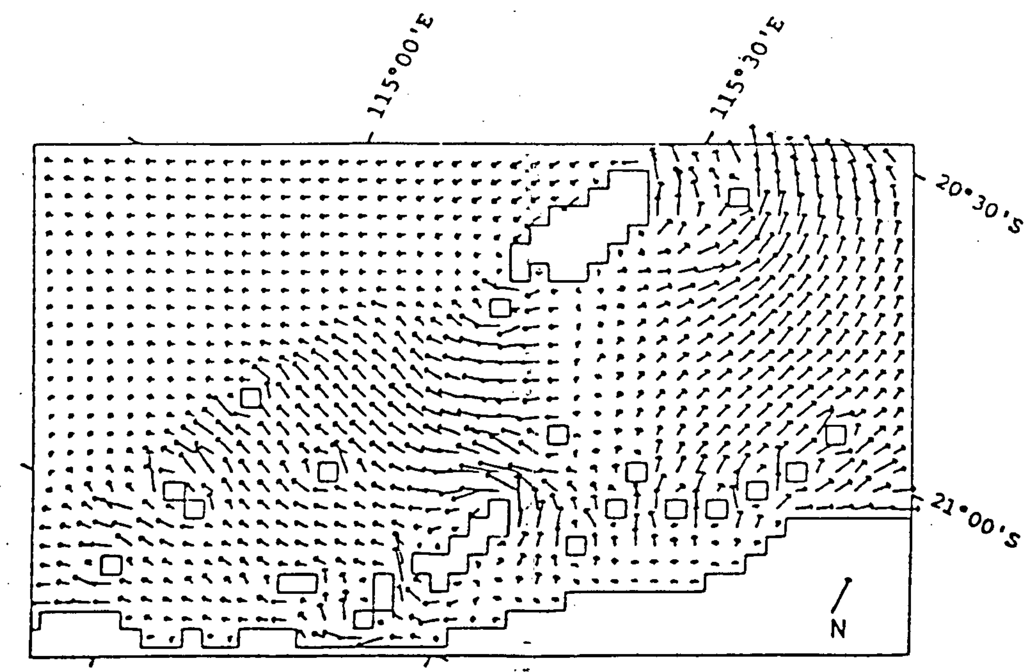


(b) 1200 hours May 24, 1982.



(d) 1800 hours May 24, 1982.

VECTOR PLOT OF THE DEPTH AVERAGED TIDALLY FORCED CURRENTS PREDICTED BY CIRCULATION MODEL - TAKEN FROM BROWN, 1984

FIG. 6

The marine biota of the North-West has been documented in various other publications (e.g. Woodside Petroleum Development Pty Ltd, 1979) and the Western Australian Museum has extensive collections from the region.

The major components were identified either by physical characteristics (e.g. limestone pavement) or by biological community (e.g. mangals). They were mapped by interpretation of satellite imagery and aerial photographs in combination with field validation. Twenty major components were identified, 11 subtidal and 9 intertidal. Important components in terms of project evaluation are discussed below (Sections 4.3.2 to 4.3.5) and their locations are shown on Figure 7.

In addition, certain faunal elements were considered to be of particular significance and information on these is reviewed (Sections 4.3.6 to 4.3.11).

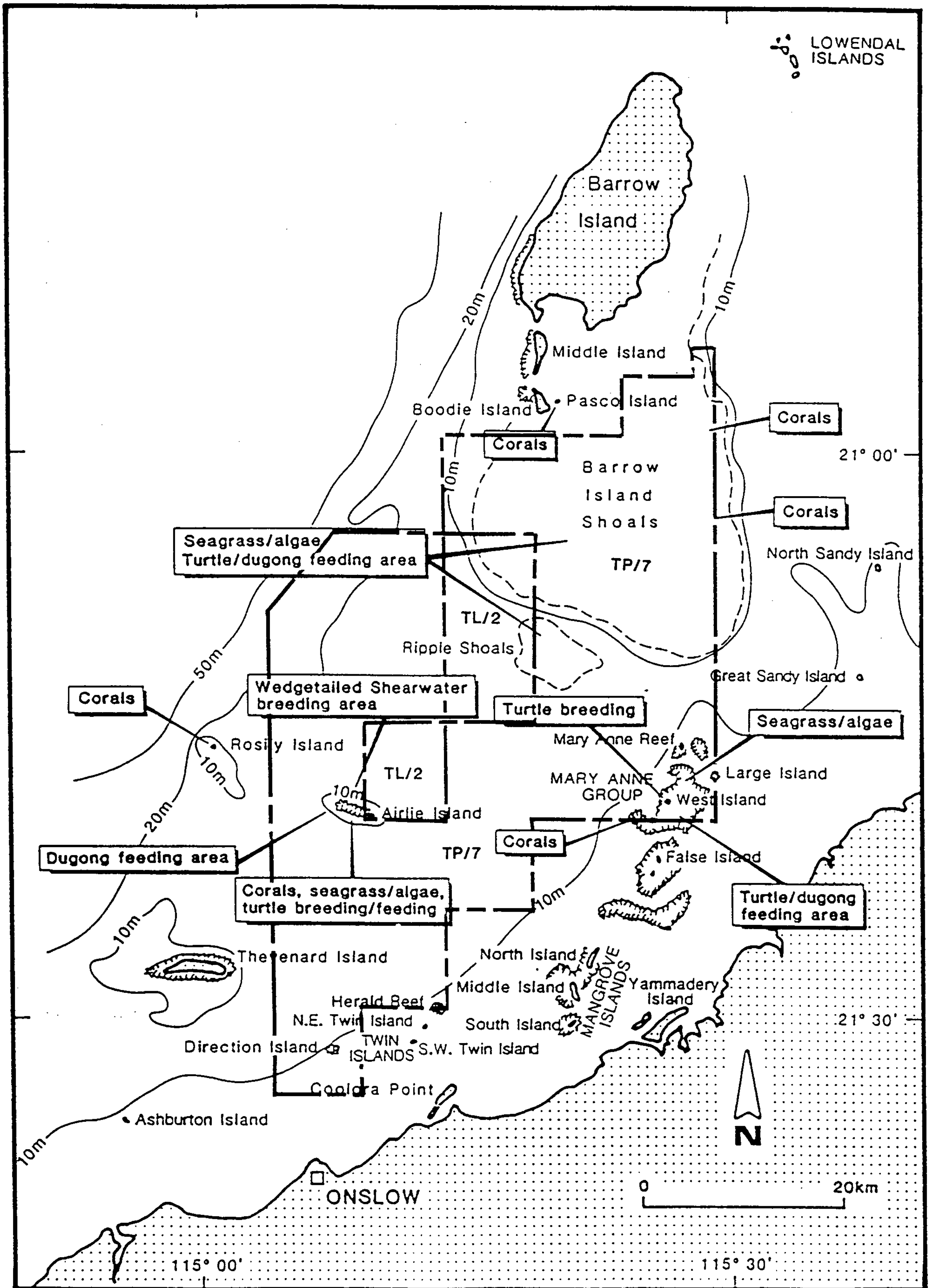
In 1989 WMC commissioned a report on Marine Habitat Distribution in the lease area. The completed report is attached to this C.E.R. as Appendix E.

4.3.2 Macro-Algal and Seagrass Beds

Algal associations appear to be the important primary producers on the Pilbara coast. Blue-green algal mats often occur on intertidal flats near mangrove in this region. Seagrass beds which may be locally extensive, are also likely to be important and have particular significance for Tiger Prawns, Green Turtles and Dugongs.

Macro-algal and seagrass communities occur extensively at four locations in or near the Permit area:

* On Taunton Reef
* On limestone pavement thinly covered with sand near Mary Anne and West Islands.
* On sand flats near Ripple Shoals and Barrow Island Shoals.
* On fine-medium grained sand between Pascoe and Barrow Islands and in Bandicoot Bay, Barrow Island.



HABITATS AT RISK

FIG. 7

Intertidal algal turf was located on reef flats on the Western side of North Mangrove Island. It is probable that such mats occur in similar intertidal zones near mangrove associations throughout the region.

4.3.3 Corals

Corals represent fixed consumers within the marine ecosystem. As they cannot move to exploit food sources, they tend to occur in areas of strong currents where water movements constantly transport nutrients and food supplies. Relatively shallow and clear water is also essential to their development and survival. The reefs themselves create a habitat for a large number of types and populations of other organisms and even dead coral can be important in this respect.

Taunton Reef, which is close to the Chervil Field, supports soft coral communities above depths of 13m. Other communities with close to 100% cover occur extensively in water less than 4m deep between Shark Point on Barrow Island and the Barrow Island Shoals. Coral reefs are also associated with many islands and scattered corals occur generally on the seabed throughout the region.

4.3.4 Intertidal Rock Communities

Intertidal platforms of limestone fringe most of the islands in the region. They are a prominant feature around Airlie Island. Typically, wave erosion has created a moderately broken terrain which traps pools of water at low tide. This provides a habitat for a variety of organisms, including molluscs, crustacea, bristle-worms and fish.

Rock oysters form a relatively distinct community within this habitat in exposed situations. Large populations exist near the west and north coasts of Airlie Island. Oysters ingest water for respiration and for food in the form of suspended particulate matter. This behaviour and their exposure to surface water during tidal fluctuations causes oysters to bioaccumulate marine pollutants. As a result, they are often used as environmental indicators.

The rock oyster communities in the region do not support any local fishing industry, but many are no doubt taken by recreational fishermen.

4.3.5 Mangals

The term mangal is used to describe the total biological community supported by mangrove vegetation associations. These communities typically have high biological productivity and conservation significance. Six mangrove associations occur in the region, featuring various combinations of six mangrove species.

These are most exclusively along the mainland coast but distinctive associations also occur on oceanic islands relatively close to this coast and especially the Mangrove Islands (Figure 7). The pattern of occurrence is complex. For example, on the Mangrove Islands Rhizophora-Avicennia-Bruigera associations occur on limestone pavement. On the mainland a Rhizophora stylosa-Avicennia marina association occurs on muddy tidal flats whereas A. marina-Aegialitis annulata association occurs on limestone pavement.

The associations are distinctive because of a unique interaction of geomorphology, sediments, hydrology, oceanic and climatic factors. However, they are not equivalent in terms of productivity or uniqueness and their overall significance was assessed by comparison with others in similar basin settings elsewhere. In these respects, the associations on the Mangrove Islands stand out as being of high conservation value.

The assemblages of the barrier islands and embayments are regionally more widespread and therefore are not so unique. Nonetheless, in terms of productivity and diversity, some dense stands of this system are locally significant as are similar elements of the deltaic system. Narrow fringing mangroves are of lesser importance.

4.3.6 Prawns

Prawns are the target species of a significant component of the local fishing industry. As such they are of fundamental importance to the regional economy.

Tiger and Western King Prawns are the predominant components of the catch. The life cycle of both species has been summarised by Penn and Stalker (1979). In the Shark Bay area, spawning of both species occurs in water more than 18m deep. The planktonic larvae remain at sea but by early post-larval stages both species drift to shallow nearshore waters.

Juvenile Tiger Prawns occupy seagrass beds, especially actively growing Posidonia sp. in shallow subtidal waters. King Prawn juveniles develop on fine silty sand flats with small clumps of algae that occur from just below the low watermark to depths of about 1m. In Shark Bay these nursery area are immediately off the mainland coast.

After about three months both species migrate out to deeper water. As adults the Tiger Prawns prefer areas with sediments of high mud content, whereas Western King Prawn adults occupy coarser substrate.

Adults of both species burrow into the sediments, the Tiger Prawns emerge at night regardless of water temperature, but King Prawns may remain inactive (buried) in cold conditions. This difference in behaviour is a major factor in determining the ratio of these two species in the catch.

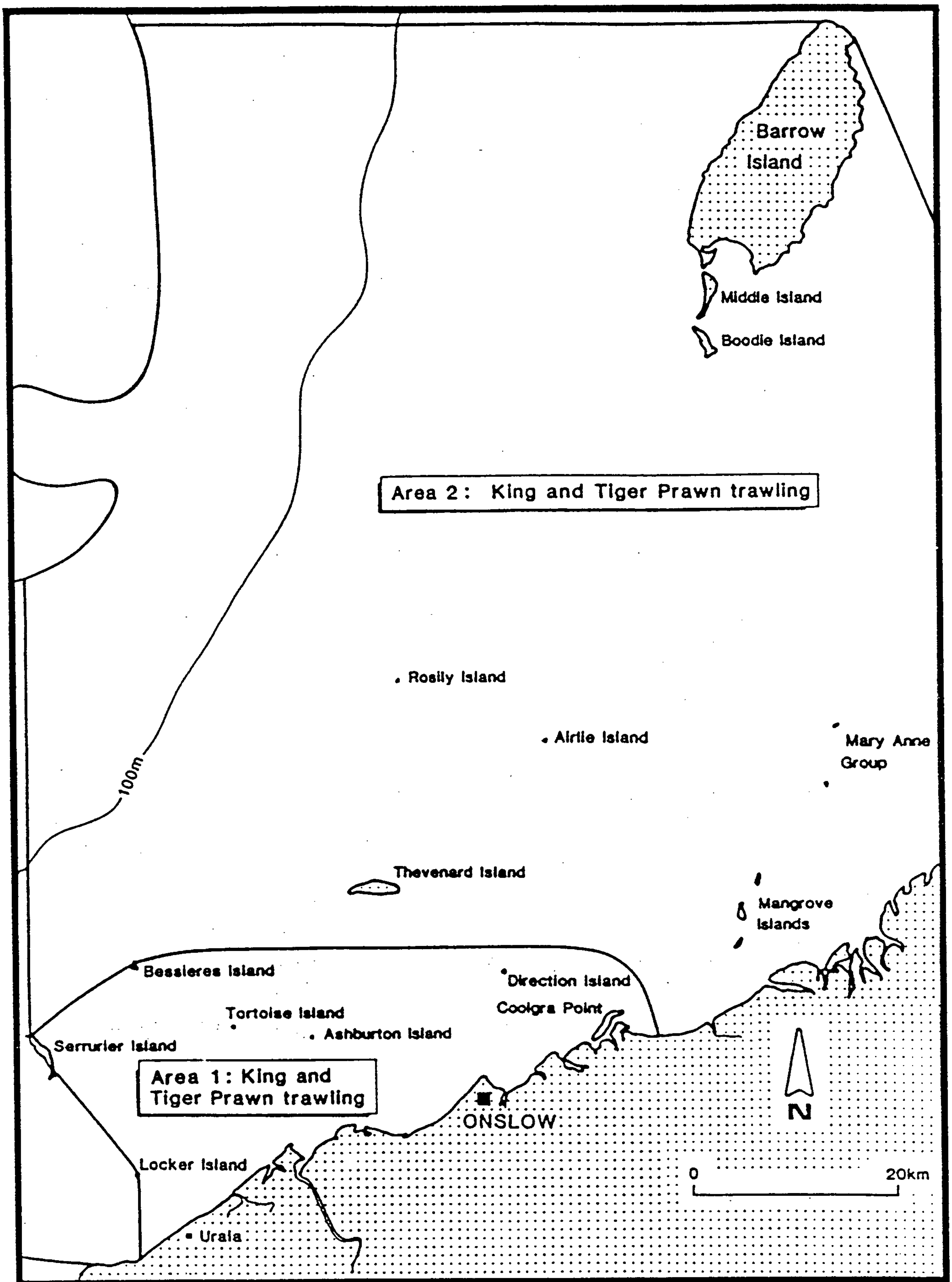
The life cycles of these prawns has not been studied in the Onslow area. The Shark Bay stocks are known to be relatively autonomous and it is reasonable to predict that Onslow populations are localised perhaps as an extension of Exmouth Gulf stocks (Hancock, 1974). Similarly it can be assumed that nursery areas predominate just offshore from the mainland coast where the rivers have deposited fluviatile sediments to create mud flats (Western King Prawns) and seagrass beds are thought to occur (Tiger Prawns). Seagrass beds are also extensive near Barrow Island and Ripple and Barrow Island Shoals. Sediments suitable for adults occur in many parts of the region in deeper water.

Prawning areas based on Onslow are shown in Figure 8. The number of locally based trawlers varies from three to five, but these are supplemented in the main season (March-September) by boats based elsewhere. Up to 40 trawlers may be operating in the region at any one time, and 200 different boats may visit in a season.

The Onslow based trawlers apparently prefer to operate relatively close to the mainland coast and do not fish near the proposed drilling area as a general rule.

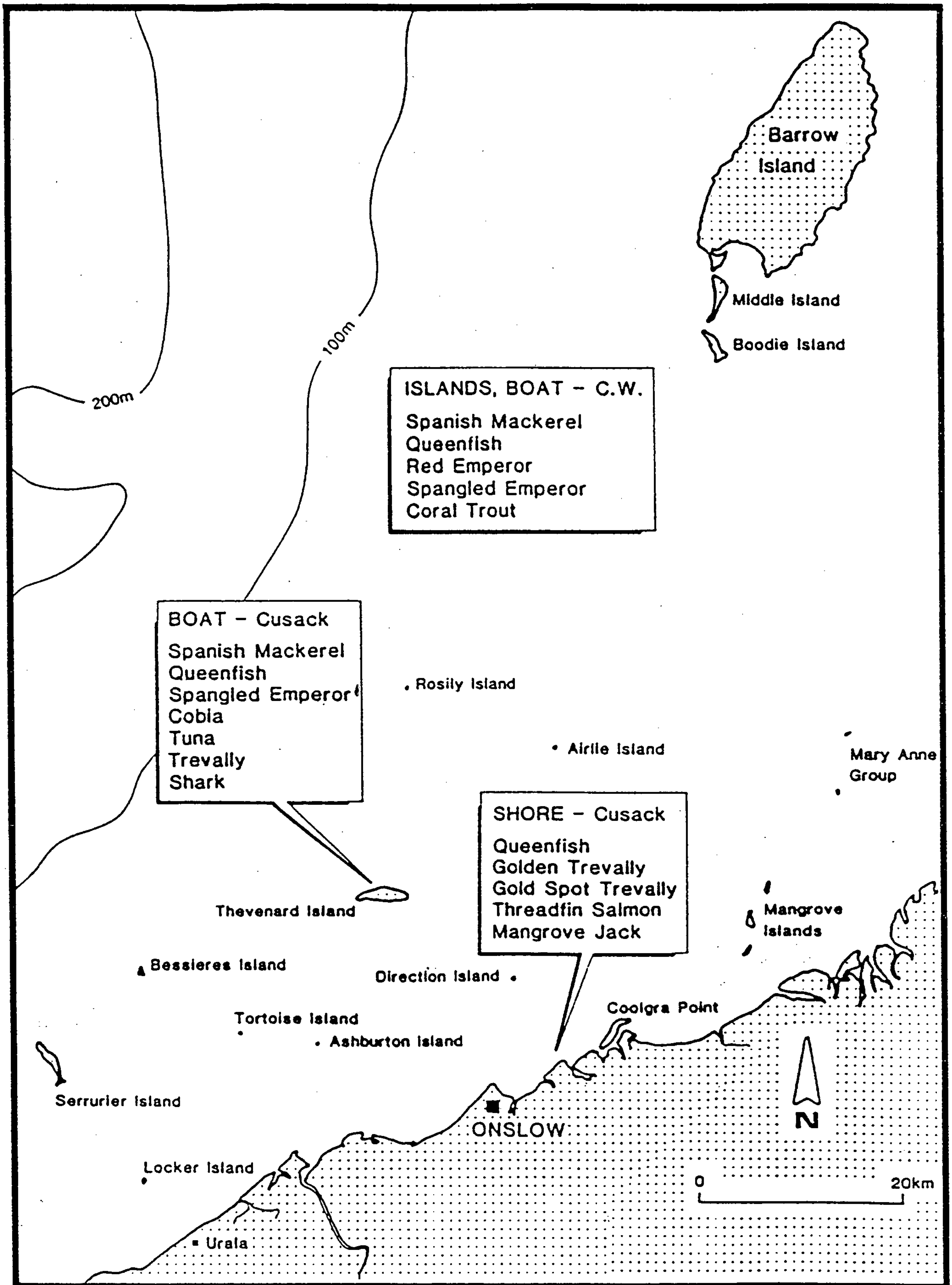
4.3.7 Fish

There is a small, but locally significant, commercial fishery operating from Onslow (Figure 9). Approximately 6 boats fish for a variety of species that include Tuna, Spanish Mackerel, Parrot Fish, Trevally, Shark, Pink Schnapper, Blue-spangled Emperor, Mulloway and Cod.



PRAWN FISHING AREAS OFF ONSLOW

FIG. 8



WET LINE SPECIES OF FISH, ONSLOW AREA

FIG. 9

The fishing fleet operates in relatively deep waters along the Eastern and Western margins of the shelf that extends Southwards from Barrow Island. Mary Anne Passage and the region surrounding North Sandy Island, are also exploited. These areas are all distant from proposed development sites. The fish are processed in Onslow and sold to the North West mining towns and outlets in Perth. In 1981/82, 91 tonnes of fish were caught from Onslow (Australian Bureau of Statistics, 1983).

The potential of the area for game fishing is rapidly gaining importance. The game fishing season from Exmouth extends from late October through to early February, with peak activity in December and January. The main species sought include Barracuda, Wahoo, Queenfish, Sea Kingfish, Tuna, Marlin, Sailfish, Swordfish, Threadfins and Spanish Mackerel.

Shorefishing is also a popular recreational activity for residents and visitors to Onslow. Fish species sought include Kingfish, Trevally, North West Schnapper, Sea Perch, Cod, Bream, Parrot Fish, Flathead, Flounder, Whiting, Pike, Giant Herring, Catfish and Wrasse.

4.3.8 Turtles

Four species of turtles are known from the region; the Loggerhead (Caretta caretta), Flatback (Chelonia depressa), Green (Chelonia mydas) and Hawksbill (Eretmochelys imbricate). All four species are essentially tropical in their distribution and are found around the Northern coast from Western Australia to Queensland (Cogger, 1975). The Flatback Turtle is seldom found South of the Kimberley and has only been recorded in the study region (Smith, 1976). The Hawksbill is common at times around Barrow Island (Butler, 1970) and has been recorded at Great Sandy Island (WA Department of Fisheries and Wildlife files). The Loggerhead is apparently common but inhabits deeper water and is seldom recorded (T.D. Meagher and Associates, 1982). The Green Turtle is abundant throughout the region in all seasons (Butler, 1970).

The Loggerhead, Flatback and Hawksbill Turtles are carnivorous species. The former feeds in deep water while the two latter forage for crustacea, shellfish, sponges etc, often around coral reefs. The Green Turtle is carnivorous when young but apparently almost entirely herbivorous when adults when if feeds on algae and seagrass.

The Hawksbill and Loggerhead Turtles are thought to nest in summer but little is known of their biology. No positive records of nesting in the study area have been made for these species.

Green Turtles start nesting in the region during August at the earliest and continue to late March with the last young appearing by the end of May (Butler, pers. comm). There are reports that most nesting by this species may coincide with maximum tides (A. and S.R. Tingay, 1984/85).

4.3.9 Cetaceans

At least seven species of cetaceans (whales, dolphins etc) occur in the region. Six have been recorded as beached specimens on Barrow Island or off its coast (Butler, 1970 and 1975) and the Humpback Whale migrates through the region in winter and spring (Chittleborough, 1953 and 1965). The status of these species in the region is unknown but the latter may be common at certain times.

Humpback Whales (Megaptera novaeangliae) feed on plankton while in Antarctic waters during summer (Chittleborough, 1965). In winter one population of the species (Group IV) migrates North along the West coast of Australia. Most reach the coast in June, pass latitude 28°S late in June or July and reach at least latitude 20°S (Port Hedland area). By October they have begun the return journey Southwards. During this winter migration, Humpback Whales stay in relatively shallow waters (e.g. Shark Bay) and females give birth mostly in August. Adults do not appear to eat during the long migration but rather subsist on fat reserves accumulated in the plankton-rich seas of Antarctica.

4.3.10 Dugongs

Dugongs (Dugong dugon) are known from the study area. Resource maps of the WA Department of Fisheries and Wildlife indicate that there are "reasonable concentrations" at times near Little Rocky Island and between Weld Island and the coast. Individuals have also been observed off the West coast of Barrow Island (Butler, 1975). Several individuals were sighted by operators on the Vicksburg and on Airlie Island in 1989.

The Dugong typically inhabits sheltered shallow, nutrient rich waters. It is entirely herbivorous and feeds almost exclusively on seagrasses or marine algae if the former are scarce. Movements are largely determined by tide, weather and season. As tides rise they move into shallow water and then return to deeper water at low tide. Movements up to 25km in one day are common and can form large herds. Young are born between September and April with most births occurring in shallow water protected by sandbars. Females are typically pregnant every 3 - 6 years, and usually have only one young, so recruitment is a slow process.

4.3.11 Seabirds

Seabirds exploit both marine and terrestrial components of the local ecosystem, and various species nest on many of the islands within the study area. Records of nesting colonies are available in the files of the WA Department of Fisheries and Wildlife and in Abbott (1979). Several other colonies were located during specialist studies for the ERMP.

The Wedge-tailed Shearwater (Puffinus pacifius) if of particular interest for development as a nesting population occurs on the Terminal Site Airlie Island.

During studies for the ERMP, all nesting colonies in the region between Tubridgi Point and Cape Preston were located and objective estimates were made of their size in terms of burrows (A. and S. Tingay, 1984, 1985). In some instances the total number of burrows was actually counted, but in other cases estimates were made on the basis of large samples.

Fifteen islands in this region support colonies ranging in size from 90 burrows on Mardie Island to an estimated 6,000 on Serrurier Island. The total regional population is estimated at approximately 29,6000 burrows. Other colonies occur nearby but beyond the defined study region. That on North-east Regnard Island is large (A. and S.R. Tingay, 1985) as are the colonies on North and South Muiron Islands. (Astron Engineering, 1990)

TABLE 4.1

SIZE OF NESTING COLONIES OF THE
WEDGE TAILED SHEARWATER ON ISLANDS OF THE ROWLEY SHELF

Island	No of Burrows counted	Estimated No of Burrows
Airlie	2720	2720
Anchor	1951	4000
East	1147	1147
Flat	1359	1500
Great Sandy	324	324
Locker	2996	5000
Mardie	90	90
North Sandy	143	143
Pup	499	499
Round[1]	908	4000
Round[2]	224	224
Serrurier	2068	6000
Solitary	1933	1933
Steamboat	1706	2000
TOTAL	18068	29580

Key 1: Round Island in Passage Group between Scholl and Long Islands
Key 2: Round Island to West of Serrurier Island

4.4 The Terrestrial Biological Environment

The terrestrial component of the regional ecosystem consists of numerous islands. Most of these are relatively small in area and have depauperate wildlife communities. Nevertheless they have considerable scientific and conservation significance, especially as seabird nesting sites. Some also support populations of small mammals. Information on this wildlife is presented in Trudgen (1984) and A. and S.R. Tingay (1984 and 1985). Comprehensive information on Airlie Island is now available in the relevant annual reports (Astron Engineers, 1988; 1989).

4.5 The Social Environment

4.5.1 Onslow

Onslow is used as the base of operations for the Joint Venturers Production facility and will also be used as a drilling base. Crew changes will be made through Onslow airport and Beadon Creek will be utilised for offloading certain items of equipment.

Onslow is a small, remote community with a permanent population of 524 and a visiting population during the 1986 census (June 30) of 226 (Australian Bureau of Statistics, 1986). Unemployment is high, and the town is largely dependent on government salaries and pensions, with 50% of the adult population (15 and over) on a government salary or receiving social security payments (Woods, 1990).

The town has recently received some importance as a supply base for the oil industry and tourism has increased since the only access road was bitumised. The Department of Land Administration is currently developing land for residential sale and an application has recently been submitted to construct a Solar Saltfield. The town nevertheless relies heavily on Government assistance.

4.5.2 The Oil Industry

Three offshore companies currently use Onslow as a base of operations. In addition to WMC, Hadson Energy and WAPET utilise the facilities at Beadon Creek to load out supplies and equipment for their offshore production developments. Doral Resources has also recently established a base in the town for work on its Tubridgi Pipeline.

These companies have each brought a measure of prosperity to Onslow through employment of local people and utilisation of the commercial infrastructure. Both WAPET and Hadson Energy (previously Bond Energy) have built wharf facilities at Beadon Creek. Most companies utilise the airport for crew changes, and while they have little direct investment in the town, have a continuing need for its facilities. Apart from the producing oilfield requirements, there is often seismic work, offshore exploration or onshore drilling going on in the vicinity. Thus the oil industry is of commercial benefit to the region.

4.5.3 Tourism

Tourism has long been important to Onslow, and although the natural features of the immediate mainland region have not attracted attention, the offshore islands and peaceful coastal locality of the town continues to draw visitors. Anecdotal evidence indicates that tourism has increased since the main access road was sealed in 1986, but accommodation and services are limited. There is space for about 110 caravans in the local park and accommodation for approximately 100 people in two developments. Tourism is based on the areas fishing, island and beach resources.

4.5.4 Commercial Fishing

There is a small commercial fishing industry based in Onslow which fishes for prawns in the period April to November each year. The fishing grounds are at the mouth of the Ashburton River and they support 6 trawlers. The Onslow prawn fishery, is controlled as a restricted entry development fishery, based on historical residency of the Onslow township.

In addition to the prawn fisheries, there is a coast shoreline net fishery and a line and trap fishery which gather a variety of species including tuna, trevally, blue spangled emperor, Spanish Mackerel and Shark. The net fishing comprises 3 boats and the line and trap fishery is made up of anything between 10 and 40 units.

SECTION 5

ENVIRONMENTAL IMPACTS

5.1 Introduction

The potential effect of the present proposal on the existing environment has two elements:

* The direct effects of well drilling, cuttings disposal etc.

* The consequences of any accidental oil spill.

The effect of normal drilling operations is well documented and will be discussed in this section.

Contingency planning and treatment strategies have been designed to ensure that the possibility of an accidental oil spill is remote. A plan has been devised which will minimise environmental impact should a spill occur. This plan is included as an appendice to this CER.

5.2 The Effect of Drilling Operations on the Marine Environment

5.2.1 <u>Drilling Discharges</u>

There are two primary discharges which need to be considered; these are the drill cuttings and the drill fluid.

Drill cuttings are inert clay particles removed by the drill bit. They vary in size from a coarse sand to a large gravel. Being relatively heavy, they are gravity driven and tend to accumulate in the vicinity of the well on the seafloor. The primary biological effect of the cuttings is smothering of seafloor communities directly beneath the disposal point.

Drill fluid is a mixture of seawater (usually in excess of 90%) and components which provide viscosity control (clay), pH control (caustic soda) and other functions. (For example soda ash is used to precipitate calcium, lime is used as a flocculant).

There has been considerable research into the environmental effects of drilling fluid. Results vary with the type of mud and biota under investigation and general conclusions about toxicity and other effects are not possible (Menzie, 1983).

Bioassays of acute toxicity are common in the literature and a wide range of marine organisms has been tested. These include phytoplankton, copepods (planktonic crustacea), isopods and amphipods (other small type of crustacea), decapods (larger crustacea such as prawns and crayfish), gastropods (sea snails, slugs and limpets, whelks etc. mostly with spiral shells), bivalves (twin shelled animals), echinoderms (spiny animals such as sea urchins and starfish), polychaetes (marine bristle worms) and fish.

General findings are that the acute lethal toxicity of drilling muds on marine organisms is very low. Some groups such as phytoplankton and copepods or planktonic crustacea are more sensitive than others. Larval stages and moulting animals are also more sensitive than adults and intermoults.

Sub-lethal effects of drilling muds such as behavioral changes are more difficult to assess. Disturbance to corals, reduced recruitment of colonising benthic invertebrates and modification of juvenile crayfish behaviour have been noted in field or laboratory trials.

Drilling fluids generally dilute rapidly from the vicinity of the discharge point. The Rowley Shelf is characterised by strong tidal currents and these assist in fluid dispersal. Therefore no significant effects due to the drilling fluid are anticipated.

5.2.2 Other Discharges

Small spillages of drilling fluids, lubricating and emulsified oils and greases occur during drilling. Accidental minor spillage of this type does not constitute a significant environmental hazard. Operational procedures are designed to limit spills to a minimum.

Other discharges include engine cooling water, treated sewage, flared gas and food scraps. Drinking water is produced by a flash distillation process which has a minimal backwashing requirement.

None of these discharges are of significant concern to the environment.

5.3 The Effects of a Possible Oil Spill

5.3.1 General

The primary environmental hazard associated with offshore oil exploration, is the potential for oil pollution. The extent of risk, the sources of potential spills, area of impact and the potential effects of oil pollution on the regional ecosystem are examined below.

5.3.2 Oil Spill Characteristics

As assessment of the behaviour of oil spills at sea from oil in this region has been made (Kagi, 1985 and Kagi et al, 1988).

When crude oil is spilled at sea, a number of weathering processes act to disperse and modify it. These processes are inter-related in a complex manner and their respective weathering rates are greatly affected by prevailing weather conditions. They can be summarised as follows:

* Loss to the atmosphere by evaporation and aerosol formation.

* Spreading and drifting

* Dispersal into the water column by solution, emulsification, absorption into particles.

* Alteration by photo-oxidation and microbial attack.

* Incorporation into sediments and biota.

All of the crude oils which are expected to be found in this programme are relatively light and the offshore waters are warm (20 - 30°C). Accordingly, evaporation is a most important factor affecting the behaviour and fate of an oil spill in this region. Evaporation rates depend on a number of factors, particularly wind speed and sea state, undergoing increases of between one and two orders of magnitude as conditions range from rough to very rough.

Based on studies of oil spills under wind speeds of 20 - 25km in the Bahamas, all of the material lighter than the alkane n-C13 (80% of the total content of South Pepper, North Herald and Chervil oils), would have evaporated after 6 hours and material up to C15 would be very depleted.

In the context of this drilling programme, therefore, in all circumstances except those where there was a large and rapid release (more than say 100 tonnes) in very still conditions, the oil could be expected to spread out and evaporate rapidly and leave a residue of up to 10% of the released material. This residue would have characteristics similar to diesel fuel and would be rapidly dispersed.

In regard to the spreading characteristics, reference is made to experience with other light crude oils. An untreated spill of 120 tonnes of Iranian light crude, even in the colder waters of the North Atlantic under light weather conditions is reported to have effectively disappeared after 4 days, its maximum measured radius being 1.2km. A spill of this magnitude is not expected during the drilling programme.

It is also noted by Kagi (1985) that under conditions prevailing in the project area, evaporation of the toxic aromatic components such as alkyl benzenes and alkyl naphalenes, would occur rapidly.

5.3.3 Area of Impact

Oil spill trajectory predictions have been prepared for simulated oil releases at the South Pepper and North Herald fields and the tanker loading facility (Steedman, 1984). In each simulation, parcels of oil are "released" into the model at 30 minute intervals over four time periods (6 hrs, 12 hrs, 24 hrs and 48 hrs). The trajectory of the centre of each parcel is traced. Because of the installation of facilities designed to shut off the oil supply in the event of non-standard operating conditions being experienced, a significant oil release, if it did occur, is far more likely to be a short term event. Thus the real extent of the oil releases produced by modelling is most unlikely to be experienced in practice. The model is of principal interest in providing an estimate of the distance travelled from the centre of the source to the outer edge in the time frame considered. Separate account has also been taken of lateral spreading of an oil release on the water surface and losses due to evaporation and chemical transformation.

The driving forces on the oil parcels, i.e. wind and tidal currents, have been based on recorded field conditions considered likely to be adverse to the containment of the slick.

Of particular interest to this study is the extent of travel towards the islands 20km to the East near the mainland within a 48 hr time scale and under adverse conditions of strong Westerly winds and spring tides. The model results show that the oil release is contained well within the offshore waters (Figure 10). Substantial oil combat resources would be on site within the 48 hr time scale (Appendix A).

5.3.4 Environmental Impact of Oil Pollution

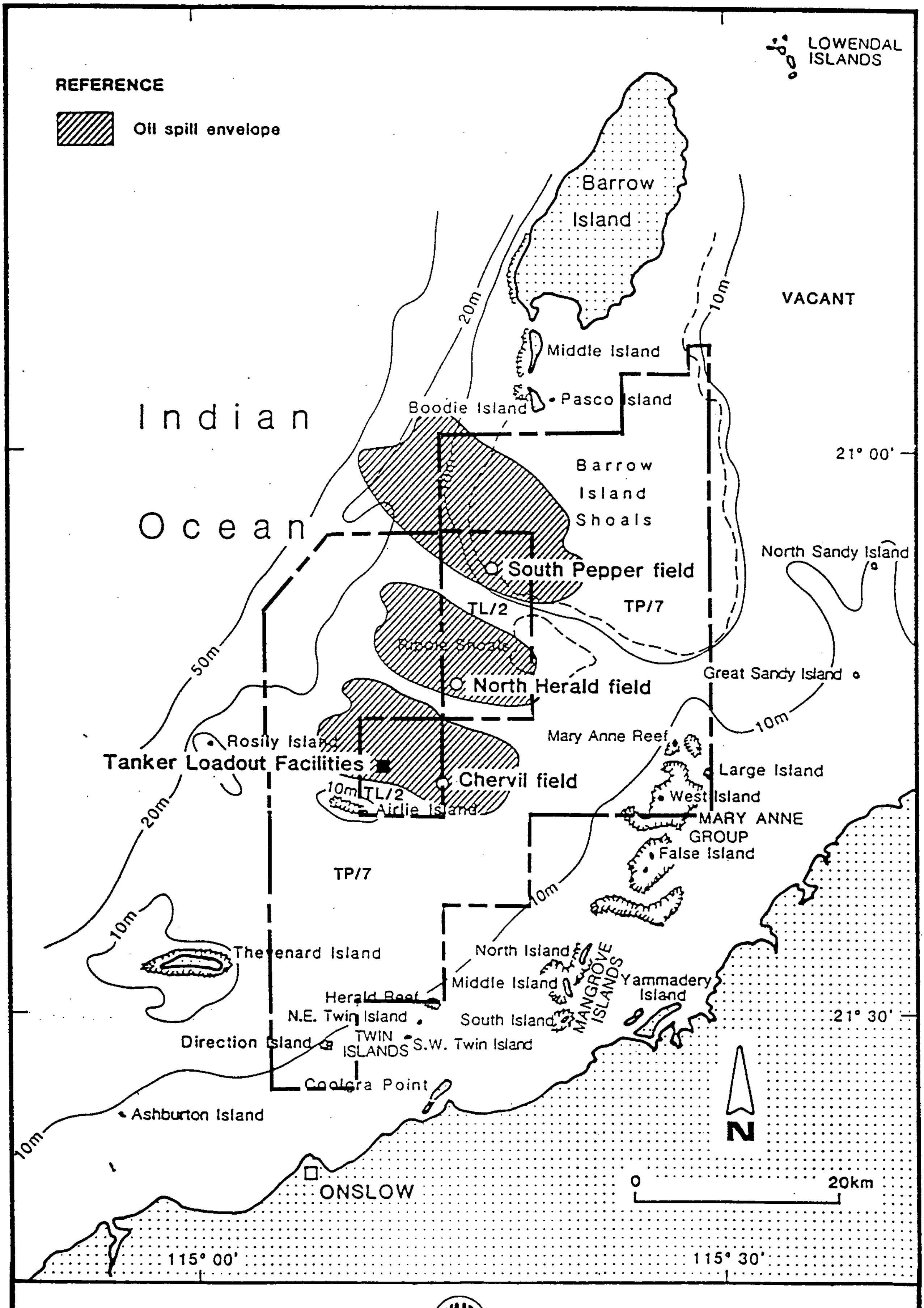
The oil spill modelling and crude oil characteristics described above indicates that any major spill in the project area is most likely to remain at sea in relatively deep water where it will evaporate quickly. Shallow areas near the Mangrove Islands and Barrow Island are clear of the zone. Subtidal areas near a spill would not be exposed unless the oil was broken up and dispersed through the water column.

While at sea a slick poses a threat mainly to organisms that use surface waters. These include plankton, some fish, turtles and seabirds. Pollution of such surface organisms, particularly plankton, may eventually affect other components of the marine ecosystem through food webs. As the slick approaches shallow water the range of organisms at risk increases and in addition there is the potential of damage to or destruction of intertidal communities.

However, the response of organisms to oil pollution is highly variable. Results of an extensive literature review on this subject are given in a supporting report (T.D. Meagher and Associates, 1984) and are summarised in an appendix to this CER (Appendix C).

5.3.5 Conclusions

The low probability of accident, effect of evaporation and the remoteness of operations from most shallow sub-tidal and intertidal habitats in the region indicate that the drilling programme will not present a risk of significant oil pollution to the regional ecosystem. Nevertheless any spill in the southern part of the permit may place at risk certain communities fringing Thevenard and Airlie Islands, and if dispersed through the water column, Taunton Reef. The possibility, although remote, of remnants or an oil spill reaching the shores of Middle and Boodie Islands to the North and the Mangrove Islands to the East needs to be taken into account. This has been done through the provision of organised oil spill combat facilities, described in the Appendix A.



48 hr OIL SPILL DISPERSION

FIG. 10

Information cited in this section and Appendix C indicates a surprising resilience of some marine organisms to hydrocarbon contamination. On the Rowley Shelf the marine ecosystem itself has also evolved resilience to major environmental disturbance in the form of frequent cyclones. These would cause damage to organisms and habitats from severe wave action and high levels of turbidity. Recovery from such disturbances is of particular interest in the present context and will be specifically studied should any cyclones pass through the area during the life of the project (Section 7).

5.4 The Effect of Drilling on the Social Environment

5.4.1 Onslow

The effect of drilling activity on the township of Onslow is beneficial due to the necessity to crew change out of Onslow. This will require stationing of a large helicopter at the airport, with associated support staff living in town. Although personnel will be stationed on the drilling rig, there is the likelihood of some increased business for the town through purchase of some supplies etc. The standby vessel MV Marella, regularly makes trips to Onslow as the town is used as a land base for the oil fields. Local fuel and transport business benefit from this. In addition, accommodation on the mainland is often required for management and other groups making short-term visits to the area for the project.

5.4.2 Trawling and Fishing

The preferred fishing and trawling areas in the vicinity do not occur in TL/2 or TP/7 so no substantial conflict of interest will arise as a result of the drilling programme.

5.4.3 Shipping

None of the proposed leads occurs in the shipping lane so interference with shipping will be minimal.

5.4.4 Tourism and Recreation

There is little recreational fishing in the Onslow area. There will be a 500m exclusion area around the rig, but this is not regarded as a significant disruption to tourism.

SECTION 6

ENVIRONMENTAL MANAGEMENT

6.1 Introduction

In general, exploration and development of offshore petroleum resources in Western Australia are undertaken subject to the various Government Acts listed in Section 1.3. The exploration proposed in this project is presently proceeding in accordance with these regulations and in addition to guidelines set down by the Australian Petroleum Exploration Association's Code of Environmental Practice, Offshore.

The intent of this Environmental Management Plan is to ensure that all environmental impacts, both planned and accidental are minimised and controlled.

6.2 Engineering Design and Operational Safeguards

The maintenance of well and rig structural integrity during extreme events likely to be experienced within the drilling programme is of the utmost importance. The proponents have previously initiated extensive site-specific studies of the meterological, oceanographic, bathymetric and geotechnical criteria required to be taken into account in ensuring the safety of all phases of the work.

6.3 Operations

6.3.1 Cuttings and Drill Fluid Disposal

During any drilling operation, the drilling fluid and well cuttings are brought to the surface where they are passed through a shaker and centrifuge to remove cuttings from the fluid. The cuttings are disposed of continuously into the sea and the fluid is re-used down the well. Fluid is not normally discharged unless there is a need to modify its properties. Such a discharge is a short term localised event, but will nevertheless be done when currents are strong to ensure that turbidity is minimised. As indicated in Section 5.2.1, drilling fluid is non-toxic in the concentrations that will occur in the receiving environment.

Cuttings are inert and will tend to stay at the well location, unless dispersed by strong currents.

All currently proposed wells sites are surrounded by sandy or limestone seabed with relatively depauperate biotic communities. As a consequence no large disturbance of ecosystem components or processes is predicted. It is recognised that some tidal dispersion may occur and if a well is located near a reef or other sensitive community, drilling solids will be pumped directly to the seafloor via a flexible pipeline. Drilling locations will be chosen to maximise the distance from sensitive locations within TP/7 and TL/2.

6.3.2 Operational Discharges

Operational discharges include engine cooling water, treated sewage, flared gas and food scraps. These are regular disposal events which are of minor environmental impact. Nevertheless, the company's environment and safety engineer will monitor all routine discharges.

6.4 Oil Spills

6.4.1 Treatment Strategies and Techniques

A large variety of methods is available for the control and treatment of oil spills. The appropriateness of each method depends on the probable origin or the spill, geographical location, site, size, weather, sea conditions and other variables. Treatments require evaluation to determine whether they may cause environmental impact in addition to or in excess of the spilt oil.

Table 6.1 give a range of strategies and appropriate techniques which may be employed separately or in combination to treat floating or beached oil slicks.

The main techniques considered in offshore contingency plans in Western Australia have been the use of booms or similar containment or deflection devices, dispersion with chemical treatments and absorption with fibre mats, sand and/or hay for beached oil.

TABLE 6.1

EXAMPLES OF TECHNIQUES ASSOCIATED WITH VARIOUS OIL SPILL TREATMENT STRATEGIES

Strategy	Techniques
Contain or divert oil	Curtain or fence type boom Booms incorporating pick-up Absorbent booms
Physical removal picked up	Skimmers Absorbents distributed then Mechanical pick up
Move oil into different part or form of environment	Loose absorbent not recovered Sink to sediment Disperse into the water column
Rely on natural degradation	Natural biodegradation by microbes and photochemical oxidation
Destroy the oil by burning	Burn, with or without combustion aids

Many chemicals are available to disperse and clean up oil spills. These dispersants may be used in relatively more difficult weather and ocean conditions than booms and can be deployed rapidly by specially adapted light aircraft and helicopters. Helicopters in particular give a high degree of accessibility and efficiency.

Dispersants have attracted frequent criticism because of potential environmental risks associated with their use. Some products have been found to be more toxic to biota than were the oil they were designed to treat. As a consequence, use in Western Australia is limited to approved products. Dispersants also distribute the oil at depth through the water column and can facilitate penetration into sediments, especially in shallow sub-tidal and intertidal areas. These features increase the range and number of organisms that are exposed to the oil and therefore the potential ecological consequences of the spill than if it remained afloat. The period required for biodegradation can also be prolonged by dispersants particularly when deep penetration of sediments is promoted.

Despite these problems, dispersants may be appropriate in relatively deep water contexts and for cleaning sandy beaches in advance of a rising tide or before the spill strands (Ministry for Conservation, 1979). Application in the latter case requires great care to ensure that the structure of the beach is not affected and that ecological damage is minimised. Such treatment is only advised if the beach has a high recreational value.

There are some reports that the proper use of chemical dispersants to remove oil from shorelines may have relatively little impact especially in comparison with mechanical clean-up (Canevari, 1979). Siva (1979) suggests that given the damage caused by clean-up techniques in general that beaches and tidal flats are best left to recover by natural means. Victorian authorities agree that soft sediment environments cannot be cleaned by any available technology (Ministry for Conservation, 1979).

The strategy of not treating an oil spill and relying on natural biodegradation is appropriate if:

* the spill is unlikely to threaten a sensitive area, or

* alternative treatments may be more damaging than the oil (i.e. dispersants and clean up in intertidal and other sensitive habitats).

Natural biodegradation is especially indicated in the case of light crude oil with a high evaporation rate such as from the present fields.

6.4.2 Oil Spill Management Requirements

The Southern part of TP/7 is within an Environmentally Sensitive Locality (ESL) while the Northern part is within the adjacent Immediate Protection Zone (IPZ) and Special Conditions Zone (SCZ). Special management requirements apply to oil production operations within these zonings (Hancock et al., 1979):

* An approved contingency plan for dealing with accidental oil pills must be prepared.

* Adequate mechanical diversion equipment (booms) must be provided at the nearest regional centre to cope with an oil spill for the first 24 hours.

These requirements have already been fulfilled by the operator.

6.4.3 Contingency Plan

The contingency plan for the proposed drilling programme is described in Appendix A. This specifies the clean-up equipment that will be available and action priorities. Procedures that will be adopted during cyclone conditions are specified in Appendix B.

6.5.4 Management Strategy

In addition to the contingency plan a management strategy has been implemented. This is designed to maximise protection of environmentally important resources in the region by specifying treatments appropriate to the various contexts in which a spill could occur. It is based on recommendation of the Victorian Ministry of Conservation (1979) and conforms with ESL and IPZ and SCZ requirements.

Containment with booms and physical removal of oil will be attempted if at all possible. Effective deployment of booms is likely to be hampered in rough weather and near islands and shoals where navigation is hazardous and currents strong.

If containment is not possible, further treatment will depend on the direction in which the oil slick is travelling and on the proximity of important environmental resources.

If the oil is moving out to sea into deeper waters and no coastlines are at risk, the slick will be monitored but left to biodegrade naturally. Dispersants may be used, particularly in relatively deep water outside ESL and IPZ areas, if there is a risk of tidal flow eventually moving the slick back towards shorelines. The location of coral reefs, algae and seagrass beds will be taken into consideration and avoided in any use of dispersants.

If the oil is moving towards intertidal habitats, booms will be used in an attempt to prevent beaching and to shepherd the slick out to deeper water for treatment with dispersants. If it is possible to prevent the oil from beaching, booms will be deployed to protect vulnerable habitats if at all possible. Otherwise, the oil will be allowed to beach.

Once the oil has stranded it will be left to biodegrade naturally without treatment. Decomposition of the oil and recovery of the biota will be monitored. Stranded oil rarely floats off again and successive tides usually move it higher up the shore. Once beached, there is little risk of further contamination to seabirds or other birds using intertidal habitats for feeding. Contaminated rocky shores may initially be a hazard to birds used to roosting there, but it is likely such areas would be avoided.

Natural degradation, though a slow process, is the most appropriate strategy from a biological viewpoint. Attempts to clean habitats such as mangroves, beaches and mud flats have caused greater environmental damage than the oil pollution itself (Ministry for Conservation, 1979). Covering stranded oil with sand only inhibits biodegradation.

If natural degradation of stranded oil is considered unacceptable on environmental or recreational grounds, careful application of dilute dispersants will be undertaken on advice from State authorities. Pollution of beaches used by turtles for nesting may warrant such treatment. Again, recovery following treatment would be closely monitored.

Overall, the plan for oil spill treatment involves different strategies in different contexts. It requires the capacity to deploy booms to protect special habitats if necessary and the availability of dispersants and deployment capacity in particular circumstances.

6.5 Cyclones

The permit area is located within a region of regular cyclone activity. Drilling between the months of October and April could well require evacuation for a tropical cyclone. Procedures have been written to cover such an eventuality and are included in Appendix B.

6.6 Education

All personnel involved in the drilling programme will be given an environmental and safety indoctrination by the company's qualified officers. The indoctrination will be given to all site personnel and selected management staff in Perth. A brief pamphlet will be produced specifically for the purpose and will be distributed during the face-to-face indoctrination.

SECTION 7

MONITORING STUDIES

7.1 Introduction

In addition to the management and safeguards described in Section 6 Western Mining Corporation Limited as operator of the permits undertakes a programme of scientific studies carried out by consultants and co-ordianted by WMC designed to monitor environmental quality throughout the life span of the production and drilling phases of the project. These enable a continuous audit of project impact and adjustment of environmental management if required. Some of the information collected is relevant to the management of Nature Reserves in the region and also to management of offshore operations in general.

If an oil spill should occur, the studies will provide data on environmental conditions prior to the accident, on environmental impact and on recovery.

The locations for study have been selected as representative examples of relatively important ecosystem components of the region. Sub-tidal, intertidal and supratidal (terrestrial) studies have been included. For a full description of the methods utilised, reference should be made to the First and Second Annual Reports prepared by Consultants. (Le Provost Semenuik and Chalmer, 1989; 1990: Astron Engineering, 1988; 1989). The general approach has been to design studies that are scientifically rigorous but which offer relative ease of data collection. As with any scientific research, the aims and methods of the studies are regularly reviewed on the basis of incoming data and are modified as a consequence.

7.2 Objectives and Scope

The primary objectives of the marine biological monitoring survey are:

(i) to confirm the ERMP prediction that significant marine resources in the vicinity of the development have not been significantly adversely affected by oil spills during the life of the project;

(ii) in the unlikely event of a major oil spill occurring, to determine the nature and extent of effects of that spill on ecologically important elements of the biota.

The scope of work required to meet the above objectives include:

(i) monitoring of shallow water (less than 5m deep) coral reef and seagrass/algae assemblages by divers;

(ii) monitoring of rocky shoreline population dynamics at fixed locations in the vicinity of Airlie Island;

(iii) monitoring of rocky shoreline fauna for petroleum hydrocarbons;

The monitoring sites are shown in Figures 11, 12 and 13.

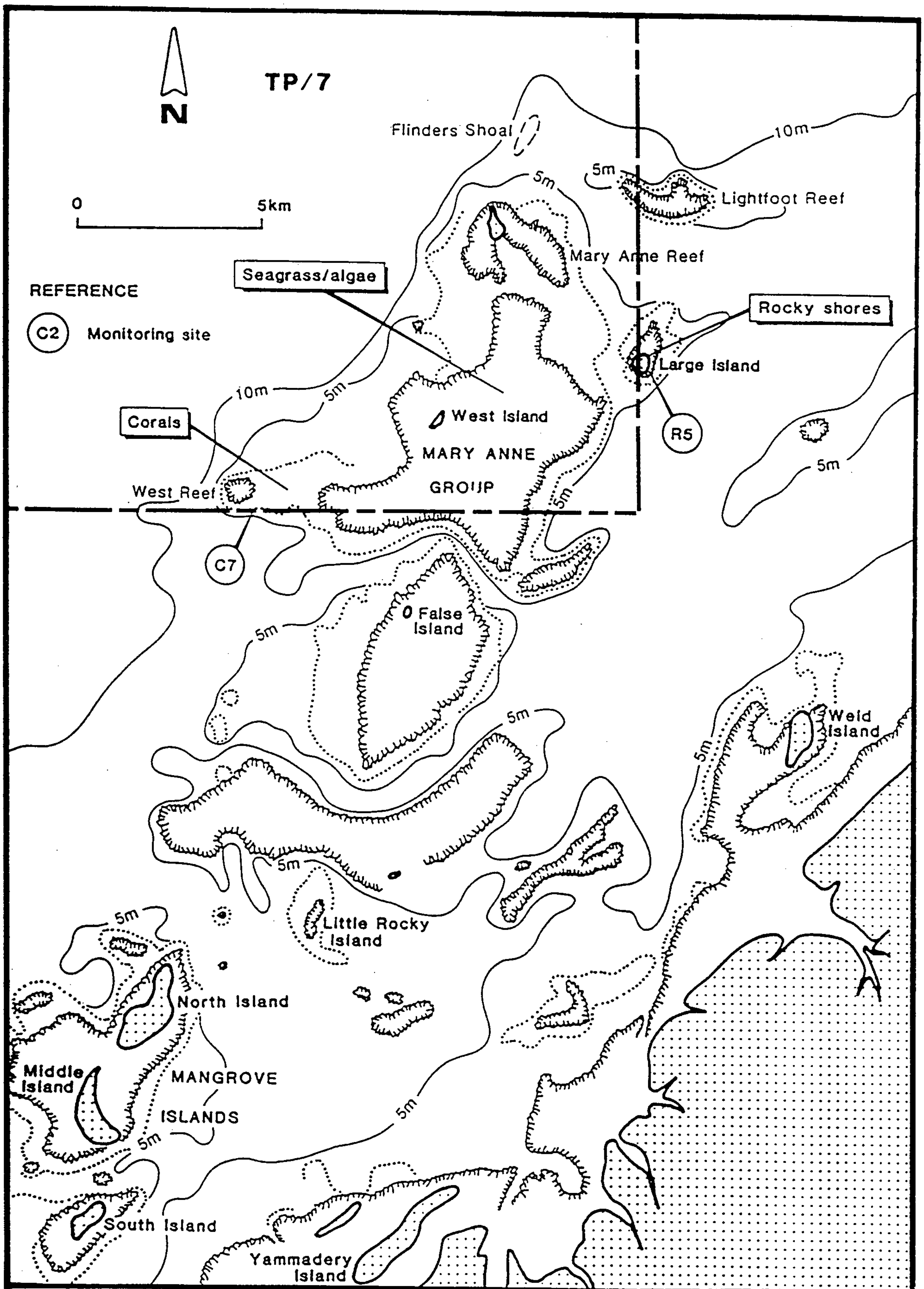
The broad spread of monitoring area utilised by WMC consultants means that baseline data is now available for all significant biological communities in the vicinity of TP/7 and TL/2. (Thevenard Island is not represented in WMC monitoring sites, but is the base for West Australian Petroleum's Saladin Development and is therefore monitored by WAPET. This allows for an exceptionally complete and detailed study of the impacts of drilling if one is required.)

7.3 Methods

7.3.1 Coral Monitoring

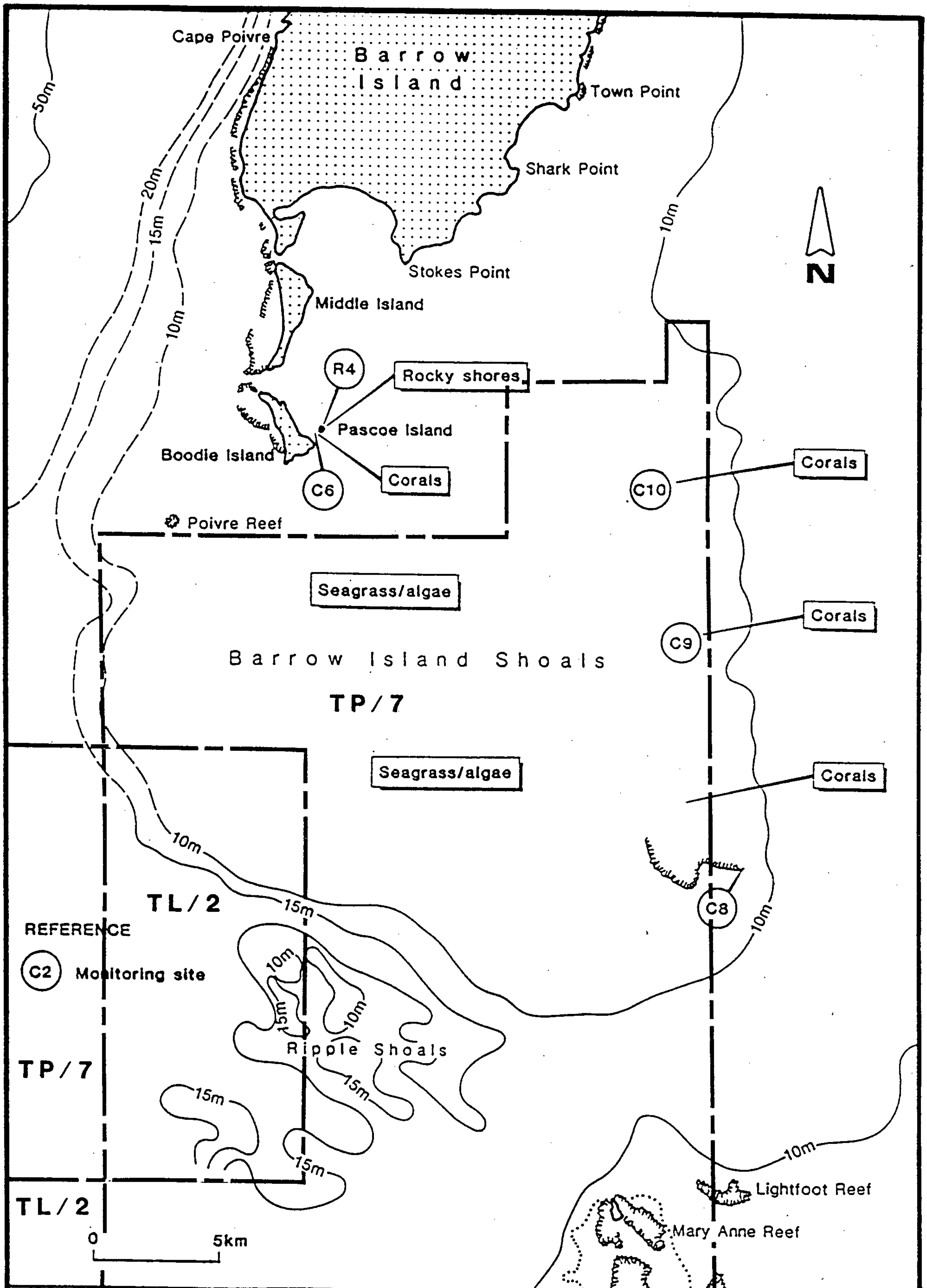
Corals are being monitored at three sites around Airlie Island, one site each at Taunton Reef and Rosily, Pascoe and West Islands, and at three sites on Barrow Island Shoals. Oil from a spill is most likely to affect corals that are exposed at low tide. Consequently, corals which could be readily inspected and were either exposed at low tide or located in very shallow water were selected for monitoring. In practice, the sites range in depth from 0-2m depth at low tide and were generally located on coral bommies up to 10-20m in diameter. Practical considerations also meant that the sites were selected such that they were readily re-locatable and are unlikely to be subject to heavy swell during monitoring surveys.

Most monitoring sites are located on small, isolated coral bommies. At each of the coral monitoring sites, C1-C10 (Figs 11, 12 and 13), a short transect (5m x 1) has been established in an area where coral abundance is highest. The end of each transect is marked by weights. Each $1m^2$ quadrat is photographed annually and the locations of the coral mapped. The coral maps are later used to determine the total number of living corals in each transect at the time of the survey.



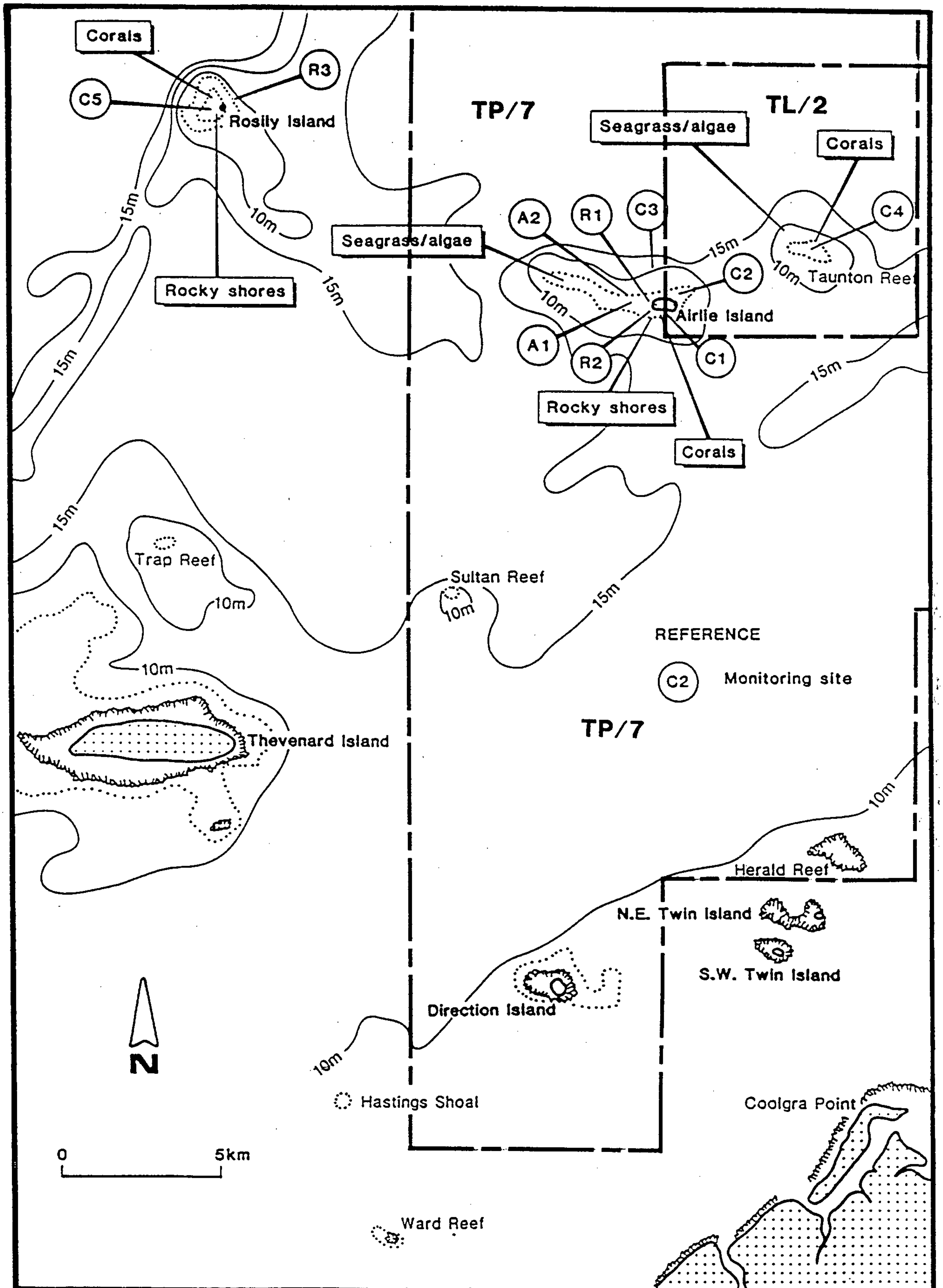
HABITATS & MONITORING SITES
MARY ANNE GROUP

FIG. 11



HABITATS & MONITORING SITES
BARROW ISLAND SHOALS

FIG.12



HABITATS AND MONITORING SITES
AIRLIE ISLAND SHOALS

FIG.13

During the surveys subsequent to the initial one, the coral maps are used to determine:

(i) the total number of living corals at the time of that survey;

(ii) the number of corals which have died since the previous survey;

(iii) the number of new coral colonies not previously recorded in the transect, referred to here as recruits. In this context the term recruitment includes juvenile corals settling from the plankton, corals established adjacent to the transect which have grown into the monitoring transect and, more rarely, coral colonies which have divided or broken into two or more independent colonies;

(iv) the percent of substrate covered by coral in each transect.

7.3.2 Rocky Shore Fauna Monitoring - Population Dynamics

The abundance of rocky shore fauna is being monitored at two sites at Airlie Island and at one site at each of Rosily, Pascoe and Large Islands. The sites are located at the mid-intertidal levels of the rocky shores where oysters, barnacles and associated fauna are present. These intertidal fauna will be subjected to spilt oil and the effect on the biota can be documented and the extent and passage of the oil spill determined.

At each rocky shore monitoring site, R1-R2 (Figs 13), five replicate quadrats, each $0.25m^2$, are located in the mid-tidal zone where rock oysters are most abundant. Each quadrat is marked permanently so that it can be readily relocated. At each inspection, the quadrat is photographed and the visible fauna in it counted. In addition, other species present in the vicinity of the quadrats have been recorded.

7.3.3 Seagrass/Algae Monitoring Sites

The algae and seagrasses are major primary producers in the lower intertidal and shallow subtidal water which surround the islands and reefs in the region of the oilfield development. The seagrasses are also an important food source for the protected dugong and turtle populations which inhabit these waters.

Because of its largely shallow water distribution the seagrass/algal community is potentially at risk in the event of an oil spill. While it is believed that recolonisation would occur relatively quickly following an oil spill, monitoring at selected sites has been initiated to gain data on community dynamics in order to measure recovery should a spill occur.

Permanent monitoring sites have been established at Airlie Island (June 1988) and more recently at Taunton Reef (July 1989) (Fig 13) for this purpose.

At each of the monitoring sites, at Airlie Island (A1 and A2) and Taunton Reef (A3) (Fig 13), five replicate quadrats, each 1.0m², have been established along a short transect line, permanently marked for relocation.

During the regular monitoring surveys each of the five 1m² quadrats in each transect is photographed and the following information collected:

(i) substrate type and distribution;

(ii) species present in each quadrat

(iii) the percentage of the substrate covered by each species within each quadrat since July 1989.

Data on the substrate of each quadrat is also maintained as changes in the substrate over time affect the diversity and abundance of the seagrasses and attached algae which a particular site can support.

Percentage cover estimates have been introduced to provide a measure of the relative abundance of each species over time. Due to variability in growth forms it is not possible to make inter-species comparisons using this technique, however being non-destructive it does not bias future monitoring results.

7.3.4 Rocky Shore Fauna Monitoring - Hydrocarbon Analysis of Oysters

Samples of oyster tissue were initially collected in December 1987 from two sites at Airlie Island, R1 and R2, prior to the commissioning of the South Pepper/North Herald oilfield, but during construction activities on Airlie Island. Logistical difficulties precluded the collection of samples from rocky shore sites at Rosily Island, Pascoe Island and Large Island at that time. Samples collected from the Airlie Island sites (R1 and R2) are considered to be representative of baseline data.

Samples are collected annually from rocky shore sites on Airlie Island (R1 and R2), Rosily Island (R3), Pascoe Island (R4) and Large Island (R5) to enable monitoring of past production hydrocarbon pollution.

Approximately 50 oysters are collected from rocky shore Sites R1 - R5 generally mid-year. The oysters are immediately chilled on ice and shipped to Perth where they were stored at -10°C.

Exhaustive, wet chemical extraction and clean-up procedures are employed resulting in minimal loss of polycyclic aromatic hydrocarbons (PAH) and saturated hydrocarbons. Each sample is spiked with internal standards prior to extraction. These internal standards are biphenyl (PAH fraction) and 1-cyclohexyldecane (saturate fraction). The samples are then analysed by gas chromatography (GC).

7.4 Results To Date

Because so little monitoring work had been done in the area prior to the Joint Venturers interest, baseline data for all monitoring is essentially reliant on only one year's results (1987). This makes later appraisals difficult as typical regional variations are unknown.

Although coral numbers have declined since project inception, this is believed to be partly a large scale phenomena (bleaching) and partly a natural fluctuation. Rocky shore fauna have either increased or remained stable since 1987, as have macrophyte populations. Very low levels of hydrocarbons have been detected in oysters gathered at Airlie Island, but all other sites were free from evidence of hydrocarbon contamination.

7.5 Monitoring Specific to Drilling Programme

The broad nature of the project marine monitoring indicates that further work related to drilling activity may be small in scale and localised in extent.

It is proposed that upon final location of the drill site, a survey of the seafloor and nearby communities at risk from a large spill be undertaken. The results of this survey will be forwarded to the EPA with the final drilling programme and well details. Should any particularly sensitive areas be found, a new monitoring site would be established and a post-drilling survey made to confirm the predictions of this CER.

SECTION 8

CONCLUSIONS

It has been proposed by the Joint Venture with WMC as operator, to drill a number of wells in the permit area TP/7 and production licence TL/2 over a 5 year period beginning April 1991.

The company has already demonstrated its commitment to environmental issues through detailed marine and terrestrial monitoring programmes and through numerous research papers it has sponsored into the flora and fauna resources of the vicinity. It intends to maintain its excellent record through a continued education programme, and further monitoring, where required.

The major environmental impacts of this drilling programme are due to inert minerals and low toxicity chemicals, both of which are in volumes which are small in comparison to the environmental inputs and changes wrought by cyclones, local river systems and other natural occurrences. The risk of a major oil spill from the work is low and detailed plans have been prepared to combat such an event should it occur.

EPA, CALM and The Department of Mines will be kept fully informed of the environmental impact of the drilling program through the inclusion of a separate section in the existing annual report that is produced as part of the condition for existing production facilities.

Exact details of well locations, seafloor communities and adjacent marine resources will be forwarded to the EPA prior to the drilling of each well. In the mean time the Joint Venture with Western Mining Corporation as operator request blanket permission to proceed with its 5 year exploration drilling programme.

REFERENCES

ABBOTT, I. 1979.
"The Distribution and Abundance of Seabirds at Sea and on Islands near the Mid and North-Western Coast of Australia."
Corella, 3, 93-102.

ASTRON ENGINEERING 1990 a

Chelonia Seismic Survey:
Muiron Islands Post - Survey Environmental Report
Unpublished Report Prepared for Lasmo Oil Australia

ASTRON ENGINEERING 1990 b

TP/7 Development of South Pepper, North Herald and Chervil Fields.
Airlie Island Terminal Third Annual Report

ARSCOTT R.L., 1989
"New Directions in Environmental Protection in Oil and Gas Operators"
J. Petrol Tech., April 1989

AUSTRALIAN BUREAU OF STATISTICS. 1983
"Fisheries, Western Australia, 1981 - 1982."
Catalogues No. 7601.5.

AUSTRALIAN BUREAU OF STATISTICS. 1986
Census Data.

AUSTRALIAN BUREAU OF STATISTICS. 1988
WA Year Book. 1988

AUSTRALIAN GOVERNMENT & GOVERNMENT OF THE STATE OF QUEENSLAND,1974.
"Royal Commission into Exploratory and Production Drilling for Petroleum in the Area of the Great Barrier Reef." 2 Volumes.

BIRKELAND, C.E., REIMER, A.A. AND YOUNG, J.R., 1976
"Effects of Oil on Tropical Shore Natural Communities in Panama."
EPA Report 14-12-874, US Environmental Protection Agency; as cited in Reimer, A.A. Marine Pollution Bulletin, 6, 39.

BIRKELAND, C.E., REIMER, A.A. AND YOUNG, J.R. 1976
"Survey of Marine Communities in Panama and Experiments with Oil."
EPA Report 600/3-76-028, US Environmental Protection Agency.

BRANDSMA M.G. AND T.C. SAUER, 1983
"Mud Discharge Model. Report and User's Guide Model Version 1.0
Exxon Production Research Company, Houston, Texas

BLAKERS, M., DAVIES, S.J.J.F., REILLY, P.N. 1984
"The Atlas of Australian Birds"
Melbourne University Press

BUREAU OF METEOROLOGY, 1984
"Summary of Tropical Cyclones Affecting Northern Western Australia for 1950 - 1983 Period Which Caused Wind Speeds of 50 knots of Greater"

BUTLER, W.H. 1970
"A summary of the Vertebrate Fauna of Barrow Island, W.A."
Western Australian Naturalist, 13, 149-160

BUTLER, W.H. 1975
"Additions to the Fauna of Barrow Island, W.A."
Western Australian Naturalist, 13, 78-80.

CANEVARI, G.P. 1979
"The Restoration of Oiled Shorelines by the Proper Use of the Chemical Dispersants".
Exxon Research and Engineering Co.

CHITTLEBOROUGH, R.G. 1953
"Aerial Observation on the Humpback Whale, Megaptera nodosa (Bonaterre), with Notes on Other Species."
Australian Journal of Marine and Freshwater Research, 4, 219 - 266

CHITTLEBOROUGH, R.G. 1965
"Dynamics of Two Populations of the Humpback Whale, Megaptera novaeangliae, (Borrowski)."
Australian Journal of Marine and Freshwater Research, 16, 13 - 128.

CHITTLEBOROUGH, R.G. JULY 1983.
"The Dampier Archipelago Marine Study. A Progress Report."
Department of Conservation and Environment. Bulletin 141.

COGGER, H.G. 1975
"Reptiles and Amphibians of Australia".
A.H. and A. Reed.

COLES, S.L. AND MARAGOS, J. 1972
Marine Pollution Bulletin, Volume 3, p21.
Referred to in Johannes, R.E., Maragos, J., and Coles, S.L. (1972).

CONNELL, D.W. AND MILLER, G.J. 1981.
"Petroleum Hydrocarbons in Aquatic Ecosystems - Behaviour and Effects of Sub-Lethal Concentrations". Part 2.
Critical Reviews in Environmental Control, pp105 - 162.

DEPARTMENT OF CONSERVATION AND ENVIRONMENT, W.A. 1981.
"Water Quality Criteria for Marine and Estuarine Waters of Western Australia".
Bulletin No. 103

DEPARTMENT OF CONSERVATION AND ENVIRONMENT, W.A. 1982
"Status of Recommendations by the Environment Protection Authority for Conservation Reserves in Western Australia."
Bulletin No. 131

BUREAU OF METEOROLOGY
"Climate of Australia"
Department of Science and Technology. 1983

DEPARTMENT OF REGIONAL DEVELOPMENT AND THE NORTHWEST/SHIRE OF WEST PILBARA 1985
"Establishing Priorities for Onslow" Perth

DET NORSKE VERITAS, 1985.
"Oil Spill Risk Analysis, WA-149-P Production Phase"
Report for Wesminco Oil Pty Ltd

DIAZ-PIFERRER, M. 1962
"The Effects of an Oil Spill on the Shore of Guanica, Puerto Rica"
In association with Island Marine Laboratories, 4th Meeting, Curacao, November 1962.

DUNLOP, J.N. AND STORR, G.M. 1981
"Carnac Island, Western Australia"
Corella 5(3), 71 - 74.

ELGERSHUIZEN, J.H.P.W. AND DE KRUIJF, H.A.M. 1976
"Toxicity of Crude Oils and a Dispersant to the Stony Cora, Madracis mirabillis"
Marine Pollution Bulletin, Vol 7. No. 22

ENVIRONMENTAL PROTECTION AUTHORITY, 1975
"Conservation Reserves for Western Australia, Systems 4, 8, 9, 10, 11, 12"

FOWLER, S.W. 1982
"Biological Transfer and Transport Processes"
In: Pollutant Transfer and Transport in the Sea. Ed. G. Kullenburg, p 1 -53

GEOMEX SURVEYS, 1983a.
"Report on Site Survey on Location South Pepper I, Block WA-149-P, Western Australia."
2 Volumes

GEOMEX SURVEYS 1983b.
"Report on Rig Site Survey Locations Chervil I and Chervil II, Block WA-149-P, North-West Shelf, Australia."

GOVERNMENT OF NEWFOUNDLAND, APRIL 1978.
"A Preliminary Physical and Biological Environmental Baseline Study and Environmental Impact Analysis of Blowouts for Shelf Zone of South-Eastern and Southern Newfoundland Waters."

GRANT E.M. 1970
"Notes on an Experiment on the Effect of Crude Oil upon Live Corals"
Fisheries Notes, Vol 1, Department of Primary Industries, Brisbane

HANCOCK, D.A. 1974
"The Basis for Management of Western Australian Prawn Fisheries"
Department of Conservation and Environment, Bulletin No. 71

HANCOCK, D.A., JONES, H.E. AND FIELD, R.A. 1979
"Oil Spills and the Western Australian Marine Environment"
Department of Conservation and Environment. Bulletin No 71

HANRAHAN, D.C. 1983
"A Practical Method for Predicting Dispersion at an Ocean Outfall"
6th Australian Conference on Coastal and Ocean Engineering.

HARRISION W., M.A. WINNIK, P.T. KWONG AND D. MACKAY, 1975
"Crude Oil Spills: Disappearance of Aromatic and Aliphatic Components from Small Sea-Surface Slicks"
Environmental Science and Technology, 9(3), 231 - 234

JOHANNES, R.E. 1972
"Coral Reefs and Pollution"
In: 'Marine Pollution and Sea Life'. Ruivo, M. (ed)
Fishing Trading News (Books) Surrey, pp36

JONES H.E., 1986
Marine Resources Map at Western Australia.
Part 1: "The Resources".
Part 2: "The Influence of Oil on Marine Resources and Associated Activities with an Emphasis on those found in Western Australia."
Report No. 74, Department of Fisheries, Perth.

KAGI, R.I. 1985
"A Preliminary Report on the Behaviour Predicted for Spills of Oils from Chervil No 1, North Herald No 1 and South Pepper No 1 in the Barrow Island Region of Western Australia." Report for Wesminco Oil Pty Ltd.

KAGI R.I.; FISHER S.I.; ALEXANDER R., 1988
"Behaviour of Petroleum in Northern Australian Waters" in Purcell R.G. and R.R. (Eds) Proceedings North West Shelf Symposium, Perth

KERHOFF, M. 1974
"Oil Pollution of the Shellfish Areas in the Oosterschelde Estuary: December 1973. International Council for the Exploration of the Seas, Fisheries Improvement Committee, Copenhagen.

KOONS, C.B., MCAULIFFE, C.D. AND WEISS, F.T. 1975.
"Environmental Aspects of Production Waters from Oil and Gas Extraction Operations in Offshore and Coastal Operations."
Report to Sheen Technical Sub-committee, Offshore Operators' Committee, New Orleans, Los Angeles.

LEE, R.F. 1977
"Accumulation and Turnover of Petroleum Hydrocarbons in Marine Organisms."
In: 'Fate and Effect of Petroleum Hydrocarbons in Marine Organisms and Ecosystems'. Wolfe, D.A., (ed). Pergamon Press, Oxford, Chapter 6

LEE, R.D., RYAN, C. AND NEUHAUSER, M.L. 1976
"Fate of Petroleum Hydrocarbons Taken Up From Food and Water by the Blue Crab Callinectes sapidus"
Marine Biol. 37, p363

MACKAY D. AND R.S. MATSUGU, 1973
"Evaporation of Liquid Hydrocarbon Spills on Land and Water"
Canadian Journal of Chemical Engineering, 51 (5), 434 - 439

LE PROVOST, SEMENIUK AND CHALMERS, 1984A
"The Geomorphology of the Onslow-Barrow Island-Fortescue River Region"
Report prepared for Wesminco Oil Pty Ltd

LE PROVOST, SEMENIUK AND CHALMERS, 1984b.
"Mangrove Environments of the Onslow-Barrow Islands-Fortescue River Area".
Report prepared for Wesminco Oil Pty Ltd

MEAGHER, T.D. AND ASSOCIATED. 1984
"An Analysis of the Dispersion and Dilution of the Treated Water Discharge from Airlie Island."
Report prepared for Wesminco Oil Pty Ltd

MENZIE, C.A. 1983
"Environmental Concerns About Offshore Drilling - Muddy Issues."
Oceanus 26, 33 - 38

MESA AUSTRALIA LTD. AND MEAGHER, T.D. AND ASSOCIATES 1982
"Notice of Intent Stage I."

MINISTRY FOR CONSERVATION, VICTORIA. 1979
"Guidelines for the Control of Oil Spills Project T04."
Project Report

NEFF, J.M., COD, B.A., DIXIT, D. AND ANDERSON, J.W. 1976
"Accumulation and Release of Petroleum-derived Aromatic Hydrocarbons by Four Species of Marine Animals."
Marine Biology Vol. 38, p279

NEFF J.M. 1987
Biological effects of drilling fluids, drill cuttings and produced waters. In: D.F. Boesch and N.N. Rabalais (Eds). Long-term environmental effects of offshore oil and gas developments. Elsevier Applied Science, New York.

NELSON-SMITH, A. 1972
"Oil Pollution and Marine Ecology." London

NITTA, T. 1972
"Marine Pollution in Japan"
In: 'Marine Pollution and Sea Life'.
London: Fishing news (Books) Ltd.

NORTH, W.J., NEUSHUL, N. and GLENDENNING, K.A. 1964
"Successive Biological Changes Observed in a Marine Cove Exposed to a Large Spillage of Mineral Oil."
In: Symposium Pollution Marine Micro-Org. Prod. Petrol., Monaco, 1964

NUNN, R.M. 1978
"Commonwealth and State Procedures for the Environmental Assessment of Mining and Petroleum Proposals in Western Australia."
Australian Mining and Petroleum Law Journal Vol. 1(2), pp 570 - 597

PENN, J., STALKER, R. 1979
"Shark Bay Prawn Fishery 1970-76"
Report No 38. Department of Fisheries and Wildlife

PETERS, E.C., MEYERS, P.A., YEVICH, P.V. AND BLAKE, N.J. 1981
"Bio-accumulation and Histopathological Effects of Oil on a Stony Coral."
Marine Pollution Bulletin, Vol 12(10), pp 333-339

REIMER, A.A. 1975
"Effects of Crude Oil on Corals"
Marine Pollution Bulletin, Vol 6, (39)

RENSONI, A. 1975
"Toxicity of Three Oils to Bivalve Gametes and Larvae"
Marine Pollution Bulletin, Vol. 6, p 125

SAGE, B., 1979
"Flare Up over North Sea Birds"
New Scientist, Feb., 464-466

SERVENTY, D.L., SERVENTY, V. AND WARHAM, J. 1971
"The Handbook of Australian Seabirds"
A.H. and A.W. Reed, Sydney

SIVA, J.L. 1979
"Ecological Impacts of Oil Spill Cleanup: Are They Significant?"
1979 Oil Spill Conference. American Petroleum Institute

SMITH, L.A. 1976
"The Reptiles of Barrow Island"
Western Australian Naturalist, Vol 13, pp125-136

SOUTHERN, R.L. 1979
"The Atmosphere"
In: B.J. O'Brien (ed). Environment and Science. University of W.A. Press, pp183-226

STEEDMAN, R.K. AND ASSOCIATED. 1984
"Prediction of Oil Spill Trajectories for South Pepper and North Herald Locations"
Report for Wesminco Oil Pty Ltd

TINGAY, A. and S.R. 1984
"South Pepper - North Herald Oil Field Project Vertebrate Fauna"
Report for Wesminco Pty Ltd

TINGAY, A and S.R. 1985
"Wedge-tailed Shearwater (Puffinus pacificus) Nesting Colonies in the Onslow Region of Western Australia."
Report for Wesminco Oil Pty Ltd

TRUDGEN, M.E. 1984
"South Pepper - North Herald Oil Field Project - Vegetation and Flora"

WESMINCO OIL PTY LTD 1983
"South Pepper Joint Venture Notice of Intent"

WESMINCO OIL PTY LTD 1984.
"WA-149-P Offshore Oil Production Notice of Intent"

WILDER, D.G. 1970
"The Tainting of Lobster Meat by Bunker Sea Oil Alone or in Combination With The Dispersant Corexit."
Journal of the Fisheries Research Board of Canada

WOODSIDE PETROLEUM DEVELOPMENT PTY LTD 1979
"North West Shelf Development Project, Draft Environment Impact Statement and Environmental Review and Management Programme"

WOODS, S. 1990
Social Impact Assessment for Proposed Solar Salt Project
Onslow, West Australia.
Unpublished Report to Gulf Holdings Pty Ltd.

ASTRON ENGINEERING (1987)
WA-149-P Development of South Pepper North Herald Fields, Airlie Island Terminal Initial Environmental Report.

ASTRON ENGINEERING (1988)
Development of South Pepper and North Herald Fields, Airlie Island Terminal. First Annual Environmental Report.

ASTRON ENGINEERING (1989)
Development of South Pepper/North Herald and Chervil Fields, Airlie Island Terminal Second Annual Environmental Report.

ASTRON ENGINEERING (1990a)
Chelonia Seismic Survey:
Muiron Islands Post - Survey Environmental Report
Unpublished Report Prepared for Lasmo Oil Australia

ASTRON ENGINEERING (1990b)
TP/7 Development of South Pepper, Norther Herald and Chervil Fields.
Airlie Island Terminal Third Annual Report

LE PROVOST, SEMENIUK & CHALMER (1989)
South Pepper/North Herald Oilfield Marine Monitoring Programme Baseline Survey and First Annual Report.

LE PROVOST, SEMENIUK & CHALMER (1990)
South Pepper/North Herald Oilfield Marine Monitoring Programme Baseline Survey and Second Annual Report.

APPENDIX A

OIL SPILL CONTINGENCY PLANNING

A1 Introduction

The planning considerations described below will be the subject of regular updating, as project logistics are refined and new data becomes available, particularly data from other oil producers with responsibilities in this region. The detailed Oil Spill Contingency Plan Manual will then be prepared prior to the commencement of each well.

A2 Objectives and Priorities of Oil Spill Planning

If by accident or an unforseen combination of events, a spill does occur, the oil spill contingency plan objectives, in order of priorities, are:

(1) Following procedures to protect human life and equipment and in particular, those procedures reducing the risk of fire or explosion.

(2) Cutting off the supply of oil to the spillage.

(3) Identification and notification of the extent of spillage and weather/current conditions in the area so that the appropriate management actions can be implemented.

(4) Implementation of actions for oil spill tracking, containment, collection, treatment and clean up as appropriate.

(5) Preparation of a report to be forwarded to the WA Department of Mines, EPA and CALM describing the spill, damage arising, the cause and remedial action.

(6) Monitoring shoreline and intertidal zones if impacted by an oil spill, for environmental effects.

A3 Characteristics of Oils

It is expected that at each site their will be:

(i) Produced light crude oil during testing phase - if applicable

(ii) Diesel fuel transported from Onslow and employed for power generation and plant operation.

The characteristics of the produced light crude oil have been subjected to a preliminary study (Kagi, 1985).

Crude Oil

Crude oils produced from each of the three fields in the location have typical API gravities ranging between 44 and 45 and are very light oils. Sea water temperatures are generally in the 20° - 30° C range with higher temperatures again being experienced in shallow embayments. These light oils are very volatile and evaporation will be the dominant source of loss if a spill occurs. After 6 hours, approximately 80-90% of the oil will be lost in this manner including the majority of the toxic aromatic components, and the residue will be rapidly dispersed. The residue can be assumed to have properties similar to the diesel fuel, a description of which follows.

Diesel Fuel

A typical diesel (e.g. No. 2 fuel as supplied by BP Australia) has a density of between 0.82 - 0.86 at 15°C and is a light-end petroleum product which rapidly spreads out to thin film and evaporates after spillage. Based on average weather conditions for a marine environment in this region, an estimate of the weathering charatering of typical oil produced in the lease is as shown in Figure A1 and Table A1.

TABLE A1

RELATIONSHIP BETWEEN TIME AND EVAPORATION FOR DIESEL SPILL

Time	Approximate % of Oil Remaining
1	90
6	60
12	45
24	35
48	25

Of the remaining fuel oil, after 48 hours less than 2% is composed of the higher and potentially more toxic components (C11 - C15 range).

A4 Oil Spill Trajectories

The Oil Spill Contingency Plan Manual incorporates typical trajectory estimates and the associated tidal and wind driven current data for 6, 12, 24 and 48 hour intervals after spillage. These will be referred to by the responsible officers on site and in the Perth Office, when tracking the observed trajectory of a spill. Any significant variations will be noted and referred to in the deployment of combat equipment on site.

A5 Notification and Communications

The hierarchy of industry arrangements established to deal with oil spills is as follows:

(i) Deployment of equipment and staff belonging to the operator (Western Mining Corporation Ltd).

(ii) Deployment of equipment and staff available from other parts of Australia, which can be called upon under the Australian oil industry's Marine Oil Spill Action Plan (MOSAP).

(iv) Additional assistance for a major oil spill situation available under the State and National Plan to Control Pollution of the Sea by Oil (NATPLAN). Under NATPLAN equipment could be mobilised from the Eastern States if required.

MOSAP's role is to maintain an organisation capable of assisting a member company such as Western Mining Corporation Limited - Petroleum Division in combating an oil spill of a size which is beyond the member's ability to handle adequately. MOSAP's Regional Industrial Controller (RIC) is located in Dampier. The RIC maintains liaison with State authorities, State branches of Commonwealth authorities and particularly with the W.A. State Combat Committee which is the W.A. arm of NATPLAN. Liaison with NATPLAN is carried out through the RIC and his superior, the MOSAP Overall Industry Co-co-ordinator.

The W.A Department of Mines, in issuing guidelines to offshore operators, has described notification procedures for two categories of oil spills, one being within an operator's capacity to manage and one where external assistance may be required. With minor variations, they are appropriate to the drilling and production phases of this project and are shown diagrammatically in Figures A1 and A2.

An Oil Spill Contingency Plan Manual is issued to all key staff. It includes names (by organisation and position), home and office phone numbers and address and radio contact channels for the following personnel:

Operations Superintendent
Senior Production Supervisor
Maintenance Supervisor
Senior Drilling Engineer
Environment and Safety Engineer
Perth Office General Manager and Deputy
MOSAP RIC (Dampier)
Personnel nominated by respective government departments listed on Figures A2 and A3
State Combat Committee Representative
Helicopter Charter Company (Perth/Karratha)
Light Plane Charter Company (Perth/Karratha)
Workboat Master/Barge Master
West Pilbara Shire Clerk and Deputy
WAPET General Manager (Perth)
WAPET (Barrow Island Superintendent)
WAPET (Thevenard Island Superintendent)
Boat Charter (Onslow/Dampier)
Diving Services (Dampier)

During the drilling programme there will be radio and telephone communication between the drilling rig and Perth Office, between each rig and the workboat and between these and Airlie Island.

Perth Office will initiate communications with government departments and outside agencies.

FIGURE A1

WESTERN MINING CORPORATION LIMITED

PETROLEUM DIVISION (AUSTRALASIA)

OIL SPILL CONTINGENCY PLAN

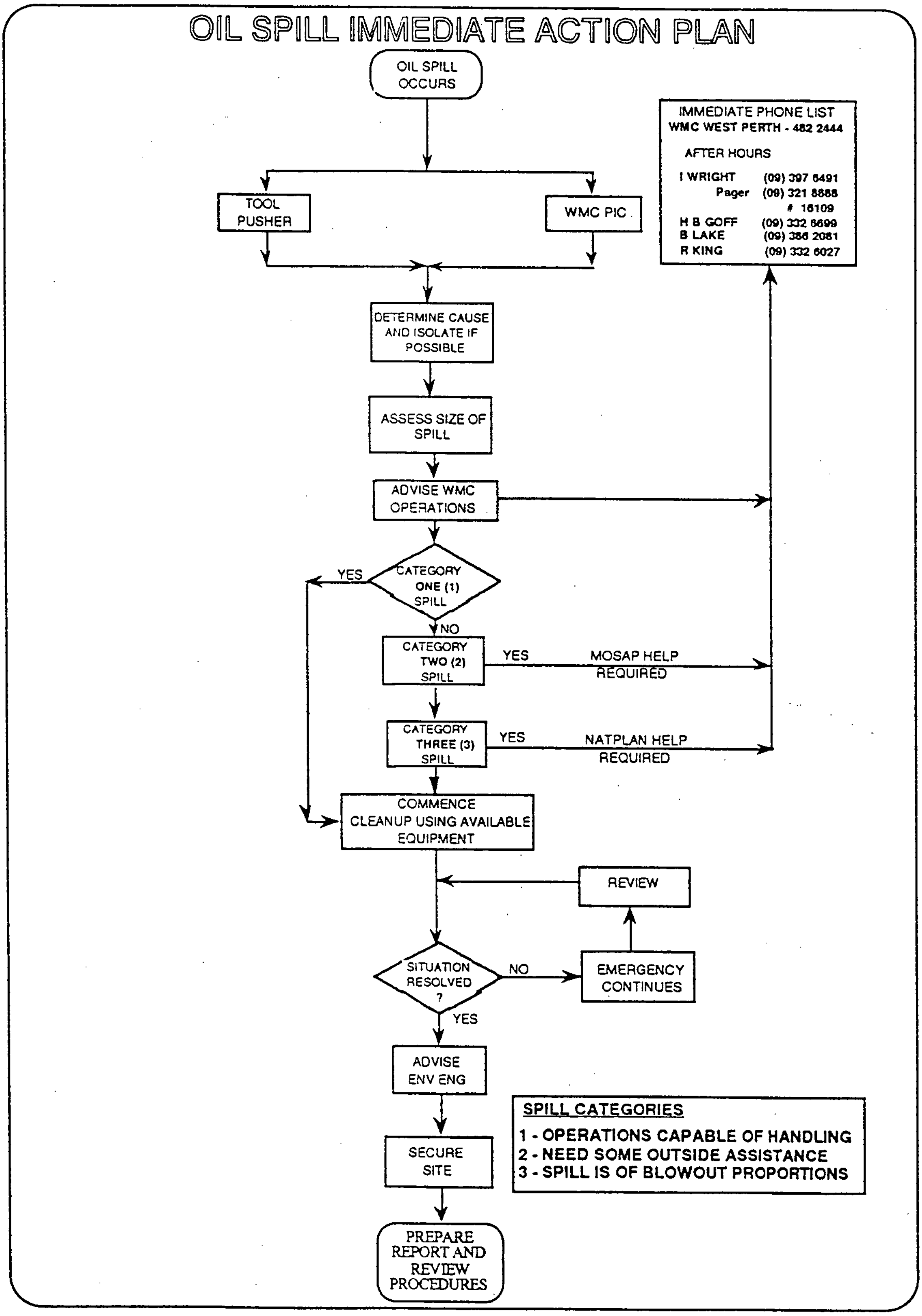
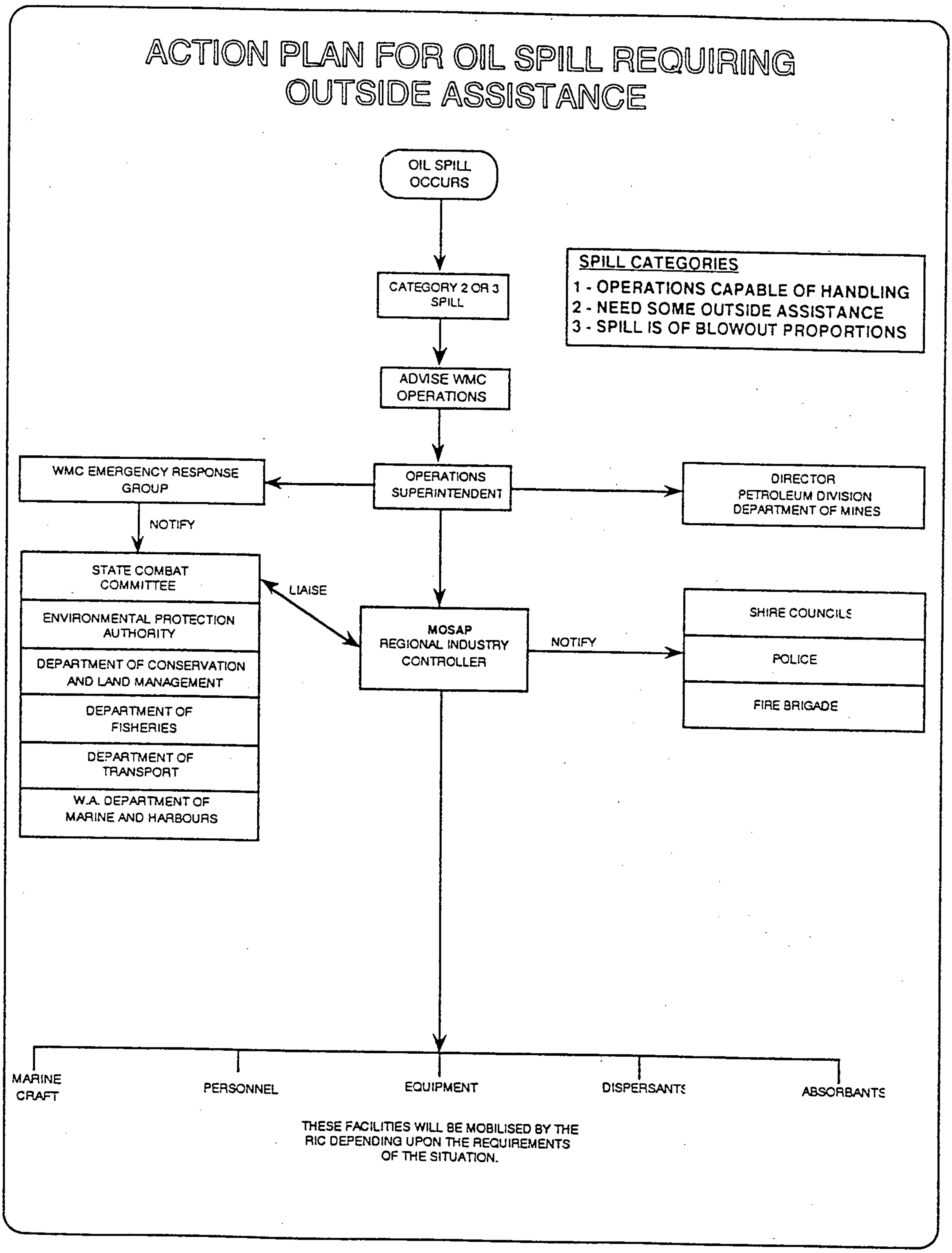


FIGURE A2

WESTERN MINING CORPORATION LIMITED
PETROLEUM DIVISION (AUSTRALASIA)
OIL SPILL CONTINGENCY PLAN



A6 Containment, Recovery and Clean up Resources

A6.1 Equipment

Equipment for containment and recovery of an oil spill includes the operator's resources on site, regional resources, resources in WA and interstate (national) resources.

The type of equipment utilised to handle floating and beached oil spills are briefly described below:

(i) Oil Slick at Sea

Floating booms are used to either;

(a) trap the oil slick, allowing it to be recovered by floating skimmers, or

(b) deflect the slick away from sensitive local areas either back to the sea or onto identified collection beaches.

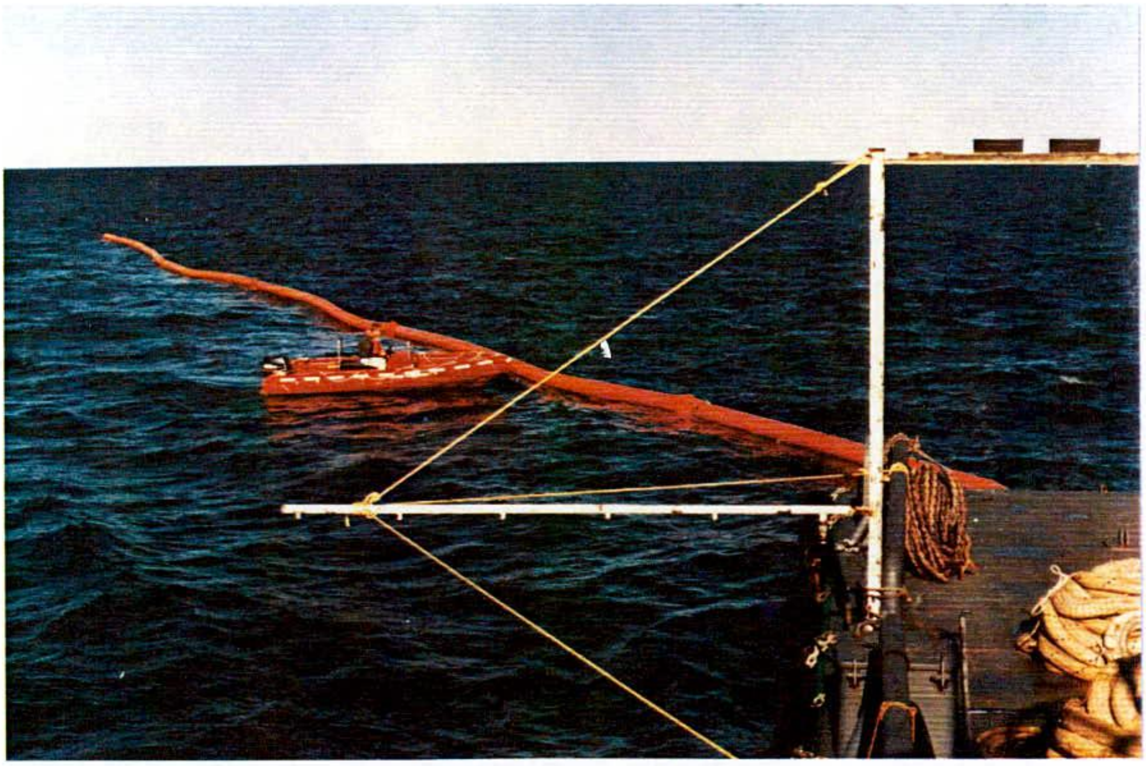


Plate A1 Oil Boom Deployment

These booms are 100 - 600m long often drum mounted with total weight which can be in excess of 5 tonnes. They are run out and towed to the slick and are generally effective in choppy seas upto 1 - 1.5m wave height and currents up to 1 knot, or 2.5 knots in the case of a deflection mode.

(ii) Beached Oil Slick

If a spill beaches it can, under favourable circumstances, be recovered in part by the use of absorbent mats, vacuum collection equipment or by direct mechanical surface skimming (e.g. light grader and front end loader). In muddy areas these methods are usually inappropriate and in rocky areas grading is impractical. With the light oils associated with this project and given the rapid spreading and resulting thin film thickness, the use of absorbent mats or vacuum devices is not practical. Sea water pump sluicing can be utilised on rocky surfaces on a falling tide to clear the retained oil film.

It can be seen from the description of the light crude oil and diesoline that the most effective means of disposal, except for larger single spills of the order of 100 tonnes or more, will be by evaporation. Nevertheless the operators will have a substantial suite of containment and collection equipment available if required.

Equipment is available outside the immediate Western Mining Corporation Ltd resources for mobilisation and application to deal with oil spills. This equipment resource is augmented by specially selected equipment held on Airlie Island. Simplicity of operation and the ability to be rapidly deployed in shallow waters are factors considered paramount to this site specific equipment.

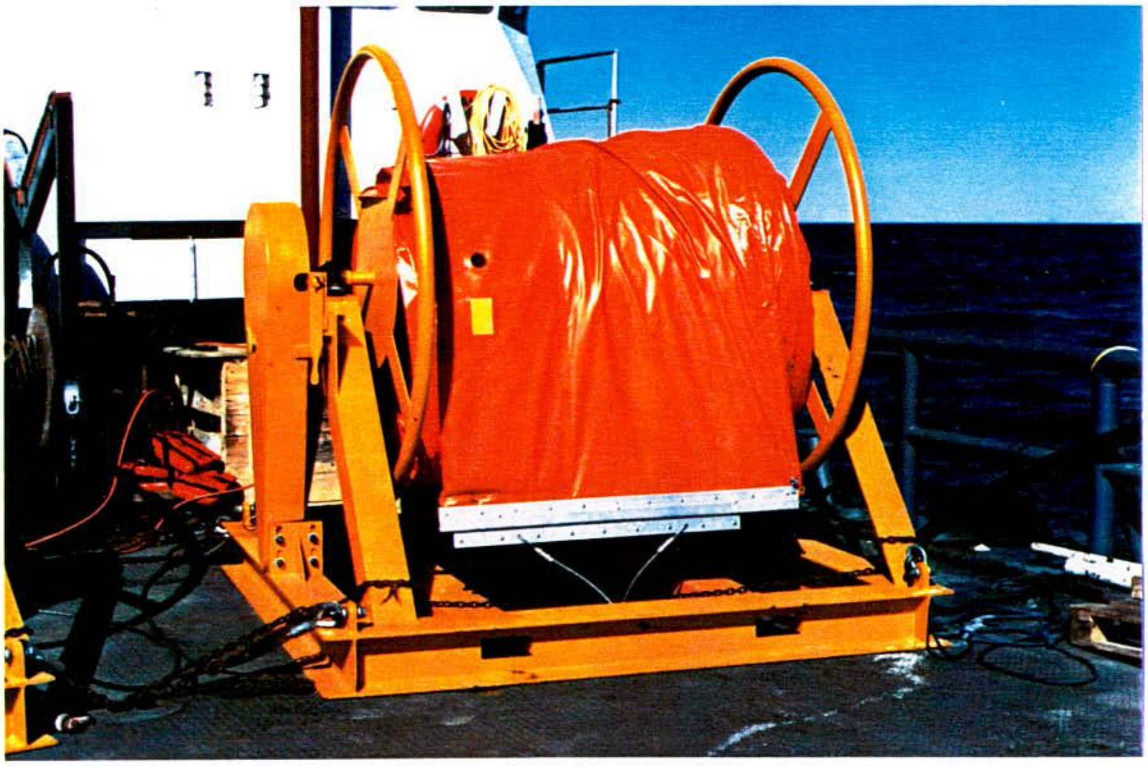


Plate A2 Oil Boom Ready For Deployment

The equipment on Airlie Island will be used at short notice to contain or deflect oil spills clear of the island shorelines. It can be rapidly deployed for similar tasks in shallow waters at Middle and Boodie Islands (or islands near the mainland in the highly unlikely event of significant oil slick reaching these areas).

A shallow draft barge will be available for operating the booms, with other charter launch resources available from Onslow.

A6.2 Chemical Dispersants

Dispersants will not be used unless directed by the State Combat Committee and the Environmental Protection Authority. Dispersants approved by the State Combat Committee (Corexit 9527 or Bp1100) have passed the toxicity and efficiency tests of either the UK Government or the US Environmental Protection Agency. Available stocks of these are listed by the Department of Mines. Fifty 200 litre drums of Corexit 9527 are palletised and available for despatch to site from Port Hedland.

In addition, the vessel will have on board approximately 1000 litres of Corexit 9627 or BP1100 together with pump and spray equipment. A similar reserve of dispersant is held on Airlie Island.

A6.3 Manpower

During the drilling program reliance will be placed on trained WMC personnel for the specialist operations involved in boom deployment and operation, including oil recovery. The can be supplemented if necessary by the onsite workboat crews and charter boat crews from Onslow, and if required under emergency conditions, from Dampier and Barrow Island.

A7 OIL SPILL ACTION PLAN - PRODUCTION PHASE

A7.1 Management, Resources and Communications

As an introduction to the sequence of actions associated with combating an oil spill, a brief reiteration is given of the project management, resources and communication facilities which are already in place.

Site operations are directed by the Operations Superintendent who reports to the General Manager Perth Office. Operators are instructed and trained in safety procedures. The Oil Spill Procedure Manual is issued to site and Perth Office personnel.

Oil spill equipment and dispersants located on site comprise a 300m long light oil containment boom with anchors and buoys, 1,000 litres of approved dispersant in drums and a mobile sluice pump for washdown purposes. The Marella is equipped to handle and operate this gear and spraying the dispersant. Three staff trained in handling the equipment are also on site, four others are available for immediate mobilisation to site, from Perth.

In addition, equipment and manpower available through MOSAP can be requested or mobilised in readiness for use.

A helicopter is available at approximately 1 hours notice.

Contingency arrangements for additional boat hire from Onslow can be implemented.

Boat to shore and shore to mainland radio communication is in place. Charts showing typical forecast oil spill trajectories under various wind and tide patterns are on site for combat reference purposes.

A range of conditions and corresponding responses are discussed below.

Response - Scenario 1:

Assume a small spill of 20m³ comprising either light crude oil or diesel, with the source effectively sealed.

(1) Monitor the slick movement and have the barge and boom on standby. If the slick is likely to beach within 6 hours seek instructions from the Operations Superintendent in Perth and Environmental and Safety Engineer who will contact the Environmental Protection Authority and the State Combat Committee) on the application of dispersant. if the instruction is negative, continue surveillance and/or collection/dispersal action until negligible oil traces remain. Dispose of any collected oil/water mix either at the West Pilbara Shire nominated disposal site or return to the oil/water separator processing at Airlie Island.

Advise Operations Superintendent Perth of task completion, refer to detailed logs to prepare report. Initiate with General Manager measures to avoid recurrence.

(2) If the spill is likely to reach Airlie Island shores overnight, mobilise portable lighting system from Onslow, flood lighting from boats to be used to assist in offshore containment and deflection operations. Arrange for regular shoreline patrols (these will also discourage use of shoreline water interface by turtles and birds at this time).

If the remnant slicks do reach the shore, apply water jets over contaminated rocky shores on a falling tide. Attempt to secure and clean up any birds or turtles which may have been in contact with oil (procedures for this activity are detailed in the Manual).

Arrange for the Environmental and Safety Engineer to inspect the clean up, and set up post spill monitoring of the impacted area. Complete the oil spill report and forward through the General Manager Perth to the Department of Mines and Environmental Protection Authority.

Response - Scenario 2:

Assume 1,000m³ release of light crude oil.

The following variations to Response - Scenario 1 would apply:

(1) Operations Superintendent to notify MOSAP to be on standby to receive a request to mobilise supplementary equipment and manpower.

The tracking and containment/collection and dispersion procedures to be in operation are as described in Response - Scenario 1, employing the Airlie Island based resources. Impingement of the slick area could occur only after the passage of at least 2-3 days and with consistent winds and tidal conditions favouring a landfall. By this time very substantial reductions in film thickness and volume would have occurred by natural processes.

If the conclusion is reached during tracking of the oil slick that a portion of the slick could impinge on, for example, Middle Island, then the barriers mobilised from Perth/Fremantle under MOSAP, to be deployed in a combination of containment and deflection modes to protect the more significant areas.

These actions to be taken under the field direction of the Production Supervisor reporting to the Operations Superintendent Perth who in turn would be responsible for co-ordinating the flow of data to and the advice and instructions received from the MOSAP RIC, the State Combat Committee and the nominated government departments.

Shoreline clean up action, where appropriate, to be implemented as described under Response - Scenario 1 for rocky shorelines.

Under Response - Scenario 2 the Deputy Superintendent or his appointee to be installed at Onslow to supervise, under the Superintendent's direction, the receival and deployment of resources sent to the site.

Response - Scenario 3

Assume a continuing major flow of oil and difficulties being experienced with shut down.

Response - Scenario 2 to be followed in respect to deployment equipment, except that priority to be given through the State Combat Committee and MOSAP to the urgent deployment of all available State resources, with supplementary national resources on standby.

Equal emphasis to be given through the Operations Superintendent Perth Office to the assembly of specialists to achieve shut down as soon as practicable commensurate with safety requirements.

A8 OIL SPILL ACTION PLAN - DRILLING PROGRAM

A8.1 Management, Resources and Communications

The Drilling Supervisor on site will report to the Senior Drilling Engineer in Perth Office. Drilling rig operators will be trained in the safety and shut down procedures to be followed in the event of an oil spill. An Oil Spill Procedure Manual will be in place on the rig and in Perth Office.

Oil spill containment and collection equipment will, in the first instance, be that available from the Production Facilities in the license operated by WMC other operators in the area. Trained operating staff can be mobilised from Perth. A workboat capable of handling the equipment will be routinely on site during the drilling phase. This will also carry the dispersant and spray equipment.

Additional equipment and manpower available through MOSAP will be put on standby and called upon as required.

Contingency arrangements for additional boat hire from Onslow will be implemented. A helicopter will be available at approximately 1 hour's notice.

Drilling rig to mainland and workboat to rig radio communication will be in place.

Charts showing typical forecast oil spill trajectories under various wind and tide patterns will be on site for combat reference purposes, in addition to current weather forecast and tide data.

A8.2 Action on Advice that Spill has Occurred

Initial Response:

(1) The Drilling Supervisor will first ensure that shut down and associated safety procedures are followed to reduce the risk of fire or explosion.

(2) He will then report to the Drilling Engineer Perth Office on location, the cause (if known) and time of occurrence, whether the source is shut off, safety procedures followed, the type of oil (e.g. diesel or crude light oil), the volume estimate or the dimension of slick or both, the direction of travel of the slick, the wind/sea state, tide and visibility conditions. He will make reference to the current weather forecast and tide table. He will then confirm with the Drilling Engineer the mobilisation of a helicopter for slick tracing purposes, and a diver if subsea inspection is required.

(3) The Drilling Engineer will assess with the Drilling Supervisor whether the spill is minor or major, and if major, whether it is within WMC containment capability.

(4) The Drilling Engineer will then contact personnel as listed in Figure A1.

As in the case for production the subsequent action from hereon will depend upon the size if the spill, its source and the prevailing and forecast weather conditions.

Response - Scenario 1:

Assume a small spill of 20m^3 with the source effectively sealed.

(1) The Drilling Supervisor to seek instruction on the use of on-board dispersant from the Drilling Engineer (who will contact the Department of Environmental Protection Authority and the State Combat Committee). Tracking of the slick to continue by workboat and helicopter.

(2) If the slick is likely to beach at Airlie Island, patrols to be set up along the shore to discourage birds and turtles utilising the shore/water interface. Sluice pump equipment to be landed to wash down rocky areas which have been contacted. Attempts to be made to secure and clean up birds or turtles coming in contact with the slick as it beaches. The environmental specialist to be called in to commence preparations for monitoring the area which has been in contact with the slick.

(3) If the slick remains at sea, the dispersion and evaporation of the slick to be monitored until it is no longer significant.

(4) A report to be prepared on the event by the Operations Superintendent for forwarding to the Department of Mines and Environmental Protection Authority. This will incorporate measures taken to avoid a recurrence of the incident.

Response - Scenario 2:

Assume a 100m³ release of oil from a wellhead source.

The following variations to Response - Scenario 1 would apply:

(1) Operations Superintendent Perth to notify MOSAP RIC

(2) MOSAP to be on standby to receive a request to mobilise supplementary equipment and manpower from WA resources.

(3) if the wind and tidal data, together with tracking, confirm that a landfall is possible within a 12 hour period from the spill occurrence and a negative response to dispersant use is received, mobilize the boom and commence containment/collection operations as described in Response - Scenario 1.

Otherwise procedures will follow those described in response - Scenario 2.

Response - Scenario 3 to be similar to that described above for the Production Phase.

APPENDIX B

CYCLONE PROCEDURES

DRILLING

Note: These procedures are typical of those taken in previous drilling operations conducted at South Pepper and North Herald oilfields.

B1 DRILLING

These procedures are to be used in conjunction with Procedures for the Drilling Rig Operation.

Notification of tropical depressions which have the potential to develop into a cyclone will be passed to the rig from Perth Office. Western Mining Corporation is a member company of the established Tropical Cyclone Industrial Liaison Committee and therefore has ready access to weather advisory service through that body

It is essential that close liaison is maintained between the rig, vessels, helicopter base and Perth Office at every stage of the procedures, bearing in mind that safety of life is the primary consideration.

Upon receipt of notification from Perth Office the procedure to be followed is divided into three stages defined as:

First Stage Alert	-	Warning that a cyclone could threaten operations
Second Stage Alert	-	Notice to shut-down operations with all convenient speed.
Third Stage Alert	-	Evacuation

B1.1 First Stage Alert

(1) Rig keeps 24 hour radio watch.

(2) Lay down any surplus drill pipe in derrick

(3) Stow below decks or secure any loose equipment not immediately required.

(4) Check Emergency generator, fuel supply and batteries

(5) Check navigation and obstruction lighting and foghorn.

(6) Check of wellhead and Blow Out Preventer stack bolts

(7) Check all lines connecting rig to Blow Out Preventer stack bolts prepare plan for disconnecting same if necessary.

(8) Arrange evacuation of non-essential personnel and check off names as they depart.

(9) Clean tubulars from skid rails and keep clear to allow for emergency skidding

(10) Commence accurate assessment of the variable load on board and measure position of the centre of gravity of each item. Prepare the calculation for added ballast which will be required to give maximum allowable weight on the platform.

(11) Prepare calculation to ascertain distribution of ballast and variables such that the centre of gravity of the platform is exactly over the centroid of the legs.

(12) Commence hourly recordings of sea height, wind speed and direction, barometric pressure, humidity and temperature. Report this information to Perth Office which will also serve as radio check.

(13) Perth office to advise evacuation transport not to commence large maintenance operations in order to keep in readiness for take off.

B1.2 Second Stage Alert (Notice to shut down with all convenient speed)

In the event that the depression develops into a confirmed cyclone, and when estimated to be 36 hours away, the rig will be on SECOND STAGE ALERT.

N.B. The speed of cyclone varies from 8 to 40 knots.

(1) Alert the person in charge of the operating unit, both company and contract, including shore based personnel.

(2) Follow procedure A, B, C, D or E below according to the operation.

A. <u>Pipe In Hole - Hydrocarbon-Bearing Section Open</u>

If drill pipe is in the hole and drilling operations are being carried out when the decision to secure is made, the following procedure shall be carried out:

(a) Circulate hole clean.

(b) "Pull out of hole" and lay down excess pipe. Pull remainder in stands.

(c) "Run in hole" open ended with 10 stands below all drill collars and remainder of pipe.

(d) Set minimum of 30m cement plug across casing shoe, pull clear of plug, install inside blow out preventer one joint below test plug.

(e) Hang off pipe on test plug, back out landing joint.

(f) Close and lock blind rams, secure lines, hoses etc.

B. <u>Pipe in Hole - No Hydrocarbon-Bearing Section Penetrated</u>

If drill pipe is in the hole when decision to secure is made and no objective section has been penetrated the following procedure should be carried out:

(a) "Pull out of hole" and laying down excess drill pipe until bit is at least 30m inside casing.

(b) Install Gray inside blow out preventer one joint below test plug.

(c) Hang off drill pipe on test plug. Back out and lay down landing joint.

(d) Close and lock blind rams, secure lines, hoses etc.

C. <u>Pipe Out of Hole - Hydrocarbon-Bearing Section Open</u>

If drill pipe is out of the hole when the decision is made to secure and an objective section has been penetrated, the following procedure shall be carried out:

(a) "Run in Hole" open ended with 10 stands D.P. below all drill collars to T.D. and pull out laying down excess pipe until casing show reached.

(b) Set minimum 30m cement plug across shoe, pull clear of plug, install inside blow out preventer one joint below test plug.

(c) Hang off drill pipe on test plug, back out landing joint, close and lock blind rams, secure lines, hoses etc.

D. <u>Pipe Out of Hole - No Hydrocarbon-Bearing Section Penetrated</u>

(a) "Run in Hole" with proposed hook-up for continuation of operations to total depth, and pull out laying down excess pipe until pipe 30m inside shoe.

(b) Install Gray inside blow out preventer one joint below test plug.

(c) hang off drill pipe on test plug. Back out landing joint, close and lock blind rams, secure lines, hoses etc.

E. <u>Running Casing</u>

The decision as to how to secure if casing is being run will depend entirely on the time element and position of casing in the hole. This decision will be taken by the Company Representative on site in conjunction with the Senior Toolpusher. The Drilling Superintendent or Senior Drilling Engineer will be consulted if time and circumstances permit.

(3) Secure barge according to fuel move check list.

(4) Disconnect all lines from blow out preventer stack according to plan already prepared.

(5) Move variable loads to minimise free surface effects and centralise centres of gravity insofar as this is practical.

(6) If barge is at non cyclone season air gap, withdraw the drive pipe support and elevate to the air gap which would be required during the cyclone season for the location concerned. It will then be necessary to secure the blow out preventer stack with wire lines and turnbuckles.

(7) Send all remaining floating equipment not necessary for evacuation to safe harbour.

(8) Have boats, helicopters, etc. ready to evacuate personnel, ie. unload and standby.

(9) Secure all remaining equipment as if for tow.

(10) Fit weather proofing on windows, etc.

(11) Remove spider deck and stow.

(12) Close vents to store rooms and batten unused watertight doors in store rooms and lock to prevent unauthorised entry.

(13) Ensure the rig it at cyclone air gap as per Noble Denton Certificate of Approval.

(14) Take on board maximum variable load and position as previously calculated to ensure Centre of Gravity over the Centroid of the legs. On completion, close all preload tank manhole lids.

(15) Skid derrick forward to stowed position, secure substructure, upper skid unit, and derrick as for towage, i.e. using turnbuckles for substructure and upper skid unit, and apply tension to travelling block.

(16) Advise Perth Office and Helicopter Base the number of personnel to go ashore and ensure sufficient helicopters are available.

B1.3 Third Stage Alert (Evacuation)

If the cyclone appears to be moving towards the rig and gets approximately 24 hours away a THIRD STAGE ALERT will be declared.

(1) Start emergency generator, and ensure platform warning lights are functioning plus as many deck and derrick lights as possible.

(2) Elevate and secure raw water tower.

(3) Shut down and secure all other machinery.

(4) Check nobody left below, then close and secure all water tight doors.

(5) Close all ventilators, hatches and all deck openings.

(6) Senior toolpusher will check off all personnel as they are evacuated.

(7) Before the toolpusher leaves and he is sure the rig is evacuated, he should dismiss all remaining boats to proceed for shelter.

(8) Notify the base radio operator of safe arrival, so that he can account for all vessels, aircraft and personnel.

(9) personnel will then be evacuated to nearest habitable centre except the following, who will be housed in nearby onshore accommodation:-

Senior Toolpusher
Toolpusher
Driller
Mechanic
Electrician
Barge Engineer

The individuals concerned will be notified by the Senior Toolpusher.

APPENDIX C

The Response of Marine Organisms to Oil Pollution

1. Introduction

As part of the scientific research and literature surveys instigated by Western Mining Corporation, for its involvement in permit areas WA-149-P and TP/7, a report on the response of organisms to oil pollution was commissioned (T.D. Meagher and Associates, 1984). This report is summarised below, for inclusion in the 5 year drilling programme CER.

2. Plankton

Phytoplankton is generally the most important primary producer of marine ecosystems. However there is evidence to suggest that in the shallow coastal waters off the Pilbara coast phytoplankton is relatively unimportant although blooms of Trichodesmium sp have been recorded in summer (Chittleborough, 1983). As a consequence of these observations sampling of phytoplankton is not considered to be a priority.

Laboratory studies have shown that the various quantities of oil can inhibit activity and sometimes kill various species of phytoplankton. However, there is also some evidence that oil can enhance the activity and growth of some species and that others are unaffected (Government of Newfoundland 1978).

Zooplankton includes the early larval stages of commercial crustaceans, the eggs and larvae of fish and other organisms. There is evidence that zooplankton can rapidly absorb hydrocarbons form water but ingestion is a more important transfer process (Fowler, 1982). Ichthyoplankton (fish eggs and larvae) are possibly more vulnerable.

Hydrocarbons are persistent in zooplankton and may be transferred from this primary consumer level to higher tropic levels of the ecosystem. There is however no evidence that hydrocarbons biomagnify (i.e. accumulate at increased levels) in marine food webs.

As with phytoplankton, the patchy distribution and mobility of zooplankton in the proposal area is likely to prevent any major consequence from oil pollution. Large scale mortality of zooplankton as a result of oil pollution has never been observed in field studies (Government of Newfoundland, 1978).

3. Macro-algae and Seagrass

Oil contact with algae may occur on intertidal reef flats. North et al. (1964) demonstrated that hydrocarbon pollution may severely inhibit photosynthesis in macro-algae. However, some lower forms of algae, particularly the blue-green groups, may benefit from oil pollution and blooms may occur (Diaz-Pifferrer, 1962). This does not mean that the local ecosystem as a whole will necessarily benefit.

Macro-algae can recover from pollution because growth points may be on the lower unaffected parts of the plants (Nelson-Smith, 1972). Species with mucilage coating may also be cleaned by tidal washing.

There is some evidence that seagrasses are less resilient than algae (Nelson-Smith, 1972) but research data is very limited.

In the permit region macro-algae and seagrasses are largely protected from oil pollution by being sub-tidal and distant from the risk zone.

4. Corals

Well developed coral reefs are major components of tropical and subtropical marine ecosystems. As such potential pollution of these benthic invertebrate communities is of particular concern.

Reimer (1975) concluded that oil may not cause immediate mortality or any visible damage to certain coral species, but it undoubtedly has some physiological effects that shorten survival and affect normal behaviour. This conclusion is substantiated by a range of studies reported in the literature.

Grant (1970) conducted experiments on species of hermatypic corals in which the coral was kept in aquaria for seven days with a layer of crude oil floating on the surface. In one experiment, direct contact between the oil and the coral was permitted. At the conclusion of the experiment, the corals were alive and apparently unaffected. Similarly Coles and Maragos (1972) floated five types of oils over groups of Hawaiian corals for 2.5 hours and following twenty-five days of observations, no visible damage was noted.

Peters et al. (1981) cite examples which illustrate that while oil floating over corals may not cause visible damage. Hydrocarbons, through coating or ingestion, could impair the colonies growth rates, damage reproductive systems, reduce the viability of the coral larvae, and ultimately cause death.

Johannes (1972) exposed the upper half of the twenty-two species of corals to crude oil for 1.5 hours. Oil adhered to portions of surfaces of most species, and tissue death ensued in these areas, but not where the oil did not adhere. Birkeland et al. (1975, 1976) observed that corals exposed directly to diesel fuel showed responses, depending upon species and experimental conditions, that ranged from a decrease in growth rate, to eventual death after several days to several weeks.

Overall, the lethal and sub-lethal effects of crude petroleum oil on corals remain undefined. Observations suggest, however, that oil immersed, solubilised and dispersed in water has a much greater effect than oil floating on the surface (Eligershuizen and de Kruijf, 1976). Corals coming into direct contact with oil would also suffer deleterious effects.

Field investigations conducted for the present study indicate that corals in the region of TP/7 remain submerged during low tides. Therefore they are unlikely to come into direct contact with spilled oil, especially low specific gravity oils such as may be expected from discoveries in TP/7.

5. Intertidal Rock Communities

Algae and immobile benthic animals which colonise intertidal rock habitats are vulnerable to oil spills. Filter feeders such as molluscs are especially liable to ingest oil with lethal and various sub-lethal effects. The latter include alteration in respiration rates, decrease in filter feeding activity, reduced growth rates and carbon fluxes, inhibition of biomass formation, biochemical effects, increased vulnerability to predation, mechanical destruction by waves due to inability to maintain a hold on substrate, and reproductive failure (Renzoni, 1975; Connel and Miller, 1981).

6. Mangals

Mangrove trees and hence mangal communities are vulnerable to oil slicks as stranded oil may clog aerial roots and cause death of trees. No mangroves occur within the 48 hour risk zone but important associations occur on the Mangrove Islands to the South-East of the Chervil field.

7. Crustacea

The impact of oil on crustaceans varies with oil type, oil quantity, weathered state, extent of exposure and the individual organism's feeding strategy.
There is evidence that crustaceans are able to metabolise and eliminate petroleum hydrocarbons except in situations of chronic pollution (Neff et al. 1976; Lee, 1977; Lee et al. 1976, Fowler, 1982).

Lee et al. (1976) have shown that crabs which accumulate hydrocarbons from either water or food, rapidly lose these compounds, mainly through defecation. Wilder (1970) concluded that even consumption of oil by lobsters did not necessarily lead to tainting of flesh.

8. Fish

The major impact of spilled oil on fish is likely to involve non-pelagic species due to accumulation of oil in sheltered low-energy waters, and to be most detrimental to larvae and juveniles which tend to concentrate near the surface.

Probably the most important potential impact is not toxic or sub-lethal effects but tainting. Estimates of the minimum concentration of oil in seawater capable of producing taint range from 1 ppm (Nita, 1972) to 300 ppm (Kerhoff, 1974) but these generalisations do not take into account the type of oil, degree of weathering or length of exposure. Tainting will persist if fish are continuously exposed to chronic sources of pollution. In the present case, the risk of such contamination are regarded as small.

9. Turtles

There appear to be no records of mortality among turtles due to oil spills. It is unlikely that feeding areas in and near the permit are would be contaminated by a major oil spill due to their distance and sub-tidal location in relation to the risk zone.

The proximity of the production sites to some beaches used by nesting Green Turtles may present a risk.

Ingestion of oil and eye contamination among beaching adults and departing hatchlings (breeding season lasting from August to May) are likely if oil accumulates on or near a nesting beach. The effects are likely to be most severe on hatchlings.

The number of such sites that may be effected is small as most breeding islands in the region are outside the permit area. The nesting turtle population on Airlie Island is small and mostly confined to the Western end of the island.
Apart from Airlie Island the closest populations are on Boodie Island 18km North of South Pepper "A" and Thevenard Island 20km South-West of Airlie Island.

10. Cetaceans and Dugongs

Although there are no published accounts of mortality of cetaceans or dugongs as a direct result of oil spills, it is possible that sub-lethal effects on physiology and behaviour may result from ingestion or oil and/or contaminated food.

Bottle-nosed dolphins may be a risk through food contamination as they feed on general marine life, particularly fish. Humpback Whales are not known to feed while in Australian waters, and Dugongs feed on algae and seagrass beds which are sub-tidal and located outside the oil spill risk zone.

11. Seabirds

About thirty species of birds recorded in the region derive their food from marine habitats including mangroves. All could potentially be affected by oil spills in various ways:

* Disruption of food chains
* Loss of feeding/nesting habitats
* Direct fouling of plumage and subsequent ingestion of oil causing death.

Studies of major overseas oil spills indicate that birds which dive into, settle or swim on the sea are the most vulnerable groups (Australian Government, 1974). This includes shearwaters, pelicans, cormorants, terns and gulls. Some of these species have very low reproductive rates of one or two young per adult pair per year. Recovery rates for such species may be slow especially if large numbers of birds were oiled. Resident populations are more vulnerable than transient migrants and nomads.

No information is available on the local feeding areas of pelagic seabirds in the region and the extent of risk from oil pollution cannot be assessed. Most nesting colonies are outside the predicted oil risk zone or are above high tide level and are safe from direct pollution. However, in the unlikely event of a significant oil spill, adults may be fouled while fishing at sea with consequential impact on breeding.

AUSTRALIAN GOVERNMENT & GOVERNMENT OF THE STATE OF QUEENSLAND,1974.
"Royal Commission into Exploratory and Production Drilling for Petroleum in the Area of the Great Barrier Reef." 2 Volumes.

BIRKELAND, C.E., REIMER, A.A. AND YOUNG, J.R., 1976
"Effects of Oil on Tropical Shore Natural Communities in Panama."
EPA Report 14-12-874, US Environmental Protection Agency; as cited in Reimer, A.A. Marine Pollution Bulletin, 6, 39.

BIRKELAND, C.E., REIMER, A.A. AND YOUNG, J.R. 1976
"Survey of Marine Communities in Panama and Experiments with Oil."
EPA Report 600/3-76-028, US Environmental Protection Agency.

CHITTLEBOROUGH, R.G. JULY 1983.
"The Dampier Archipelago Marine Study. A Progress Report."
Department of Conservation and Environment. Bulletin 141.

COLES, S.L. AND MARAGOS, J. 1972
Marine Pollution Bulletin, Volume 3, p21.
Referred to in Johannes, R.E., Maragos, J., and Coles, S.L. (1972).

CONNELL, D.W. AND MILLER, G.J. 1981.
"Petroleum Hydrocarbons in Aquatic Ecosystems - Behaviour and Effects of Sub-Lethal Concentrations". Part 2.
Critical Reviews in Environmental Control, pp105 - 162.

DIAZ-PIFERRER, M. 1962
"The Effects of an Oil Spill on the Shore of Guanica, Puerto Rica"
In association with Island Marine Laboratories, 4th Meeting, Curacao, November 1962.

ELGERSHUIZEN, J.H.P.W. AND DE KRUIJF, H.A.M. 1976
"Toxicity of Crude Oils and a Dispersant to the Stony Cora, Madracis mirabillis"
Marine Pollution Bulletin, Vol 7. No. 22

FOWLER, S.W. 1982
"Biological Transfer and Transport Processes"
In: Pollutant Transfer and Transport in the Sea. Ed. G. Kullenburg, p 1 -53

GOVERNMENT OF NEWFOUNDLAND, APRIL 1978.
"A Preliminary Physical and Biological Environmental Baseline Study and Environmental Impact Analysis of Blowouts for Shelf Zone of South-Eastern and Southern Newfoundland Waters."

GRANT E.M. 1970
"Notes on an Experiment on the Effect of Crude Oil upon Live Corals"
Fisheries Notes, Vol 1, Department of Primary Industries, Brisbane

JOHANNES, R.E. 1972
"Coral Reefs and Pollution"
In: 'Marine Pollution and Sea Life'. Ruivo, M. (ed)
Fishing Trading News (Books) Surrey, pp36

KERHOFF, M. 1974
"Oil Pollution of the Shellfish Areas in the Oosterschelde Estuary: December 1973.
International Council for the Exploration of the Seas, Fisheries Improvement Committee, Copenhagen.

LEE, R.D., RYAN, C. AND NEUHAUSER, M.L. 1976
"Fate of Petroleum Hydrocarbons Taken Up From Food and Water by the Blue Crab Callinectes sapidus"
Marine Biol. 37, p363

MEAGHER, T.D. AND ASSOCIATED. 1984
"An Analysis of the Dispersion and Dilution of the Treated Water Discharge from Airlie Island."
Report prepared for Wesminco Oil Pty Ltd

NEFF, J.M., COD, B.A., DIXIT, D. AND ANDERSON, J.W. 1976
"Accumulation and Release of Petroleum-derived Aromatic Hydrocarbons by Four Species of Marine Animals."
Marine Biology Vol. 38, p279

NELSON-SMITH, A. 1972
"Oil Pollution and Marine Ecology." London

NORTH, W.J., NEUSHUL, N. and CLENDENNING, K.A. 1964
"Successive Biological Changes Observed in a Marine Cove Exposed to a Large Spillage of Mineral Oil."
In: Symposium Pollution Marine Micro-Org. Prod. Petrol., Monaco, 1964

PETERS, E.C., MEYERS, P.A., YEVICH, P.V. AND BLAKE, N.J. 1981
"Bio-accumulation and Histopathological Effects of Oil on a Stony Coral."
Marine Pollution Bulletin, Vol 12(10), pp 333-339

REIMER, A.A. 1975
"Effects of Crude Oil on Corals"
Marine Pollution Bulletin, Vol 6, (39)

RENSONI, A. 1975
"Toxicity of Three Oils to Bivalve Gametes and Larvae"
Marine Pollution Bulletin, Vol. 6, p 125

WILDER, D.G. 1970
"The Tainting of Lobster Meat by Bunker Sea Oil Alone or in Combination With The Dispersant Corexit."
Journal of the Fisheries Research Board of Canada

APPENDIX D

TL/2 & TP/7 TYPICAL VERTICAL EXPLORATION WELL DRILLING PROGRAMME

CONTENTS

1.0 GENERAL

2.0 HOLE SIZE AND CASING PROGRAMME

3.0 BOP EQUIPMENT, ANTICIPATED FORMATION PRESSURES AND INTEGRITY TESTS

4.0 CEMENTING PROGRAMME

5.0 MUD PROGRAMME

6.0 LOGGING, CORING & EVALUATION PROGRAMME

7.0 DETAILED DRILLING PROGRAMME

1.0 GENERAL

1.1 Well Name: Vertical Exploration Wells. Majoram, Lavender & West Pepper.

1.2 Surface Location: As advised.

1.3 Permit: TP/7 & TL/2

1.4 Elevation:

Rotary Table to M S L 33m *
Water Depth approx. 15m

<u>Notes:</u>
(a) * assumes a 16m air gap
(b) all depth in this programme refer to RT

1.5 Rig:

Name: TBA
Type: Self Elevating Jack Up
Contractor: TBA

1.6 Proposed TD:

Measured Depth
Majoram: 1133
Lavender: 1243
West Pepper: 1433

2.0 HOLE SIZE AND CASING PROGRAMME

2.1 Casing Programme

HOLE SIZE (in)	CASING SIZE (in)	SETTING DEPTH (m) MD	WEIGHT (lb/ft)	CASING GRADE	COUPLING	BURST LIMIT kPa (psi)	COLLAPSE LIMIT kPa (psi)	TENSION LIMIT tonnes	(Kip)
26	20	80	94	X56	JV-LW	13800 (2000)	3588 (520)	671	(1480)
17½	13 3/8	360	68	K55	Buttress	23805 (3450)	13455 (1950)	485	(1069)
12¼	9 5/8	TD	47	N80	Buttress	47403 (6870)	32775 (4750)	493	(1086)

Notes:
- Total depth of the well will be 1280m MD
- It is not proposed to set casing beneath 13 3/8" shoe. Following electric logs the well will be abandoned or plugged back and deviated.

12¼" hole based on TD at 1280m.

2.2 Casing Design Safety Factors

CASING SIZE (in)	SETTING DEPTH (m) TVD	MUD WT (ppg) SG	SAFETY FACTORS Burst	Collapse	Tension
20	80	(S/W) 1.02	-	-	-
$13^3/8$	360	(8.7) 1.05	5.68	1.92	8.66
$9^5/_8$	TD	(9.2) 1.11	4.92	2.40	4.40

Note: i) Mud weights are the maximum anticipated mud weights in which the casing will be set.
12¼" hole based on 1280m TD.

3.0 BOP EQUIPMENT, ANTICIPATED FORMATION PRESSURES & INTEGRITY TESTS (FIT)

3.1 BOP Equipment

HOLE SIZE (in)	DEPTH (m) (TVD)	CASING SIZE (in)	BOP EQUIPMENT	
26	80	20		
17½	360	$13^3/8$	Type:	Annular
			Quantity:	1
			Make:	TBA
			Model:	
			Size:	21¼
			WP:	2000 psi
12¼	TD	-	Type:	Annular Ram
			Quantity:	1 3
			Size:	$13^5/8$" $13^5/8$"
			WP:	5000psi 10000psi

3.2 Anticipated Formation Pressures

HOLE SIZE (in)	DEPTH (TVDm)	BOTTOM HOLE PRESSURE (psi) kPa	MAX SURFACE PRESSURE (psi) kPa
26	80	(120) 820	N/A
17½	360	(550) 3810	(150) 1035
12¼	TD	(2030) 14000	(607) 4188 (Based on 1280m TVD)

Note: Surface pressure calculations based on WA Petroleum Act "DIRECTIONS AS TO DRILLING OPERATIONS". Schedule 1 Item 8.

3.3 Formation Integrity Tests

3.3.1 Procedure

On drilling out the 13⅜" casing shoe a formation integrity test will be performed according to the following procedures.

(i) Drill out shoe
(ii) Drill 2m of new hole
(iii) Clean hole, condition mud and ensure uniform mud weight
(iv) Pull back into casing shoe
(v) Close BOPs and pressure up in stages recording barrels of fluid pumped and pressures reached. Record pressure at which formation first starts to take fluid and calculate equivalent mud weight.

3.3.2 Required Equivalent Mud Weights

HOLE SIZE (in)	E M W SG	(ppg)
12¼	1.50	(12.5)

4.0 CEMENTING PROGRAMME

4.1 20" Casing

Set at 80m. Cement back to seabed with neat class G cement plus 2% calcium chloride.

Slurry Details:	Cement:	Class G
	Mixwater:	5.10 gal seawater per sack
	Additives:	2% Calcium Chloride (BWOC)
	Slurry Weight:	15.8 ppg (SG 1.9)
	Yield:	1.15 cu ft per sack
	Excess:	200%

4.2 13⅜" Casing

Set shoe at approximately 360m and cement as follows:

4.2.1 Lead Slurry

Cement from 200m to 50m with Class G cement with 4.0% prehydrated bentonite.

Slurry Details:	Cement:	Class G
	Mixwater:	12.53 gal freshwater per sack
	Additives:	4% prehydrated Bentonite (BWOC)
	Slurry Weight:	12.4 ppg (SG 1.49)
	Yield:	2.18 cu ft per sack
	Excess:	30% over calliper volume

4.2.2 Tail Slurry

Cement from casing shoe back to 200m with neat Class G cement.

Slurry Details:	Cement:	Class G
	Mixwater:	5 gal seawater per sack
	Additives:	Nil
	Slurry Weight:	15.8 ppg (SG 1.9)
	Yield:	1.15 cu ft per sack
	Excess:	30% over calliper volume

4.2.3 $9^5/_8$" Casing

If required the shoe is likely to be set at TD. Slurry design to be advised at that time.

5.0 MUD PROGRAMME

5.1 26" Hole

Drill with seawater and slugs of viscous mud spotted as necessary to keep the hole clean. Prior to running casing flush the hole by pumping a 100 bbls slug of viscous mud and circulating out. Following this operation fill the hole with 1.08 SG (9.0 ppg) viscous mud.

5.2 17½" Hole

Drill with seawater and slugs of viscous mud spotted as necessary to keep the hole clean. Prior to running casing flush the hole by pumping a 100 bbls slug of viscous mud and circulating out. Following this operation fill the hole with 1.08 SG (9.0 ppg) viscous mud.

5.3 12¼" Hole

Drill this section with a seawater polymer mud. As this hole will penetrate major objectives of the well, maintain a low-solids, low water loss system. Properties required are as follows:

Mud Weight:	SG 1.08 - 1.12 (9.0 - 9.3 ppg)
Viscosity:	38 - 45
PV:	12 - 15 cps
YP:	15 - 25 lbs/100 sq ft
Gels:	Minimum
W L (APD):	Less than 10 cc/30 min
Solids:	Minimum

Note: i) NaCl to be used as weighting and inhibiting material.

ii) To minimise formation damage, overbalance is to be restricted to 700 kPa (100 psi). Mud weight should not exceed SG 1.12 (9.3 ppg).

iii) Drilling to the top Barrow Group sands must be accomplished with low solids mud. Effective solids control will be achieved mechanically, with dilution, and if necessary by displacing the mud in hole with a clean fluid.

iv) No Barite to be used in the 12 1/4" hole section (except in the case of well control).

v) Occasional viscous slugs may be required to be pumped to aid cutting removal from the hole.

vi) Bentonite may be added to aid fluid loss and lubricity if deemed necessary.

6.0 LOGGING, CORING AND EVALUATION PROGRAMME

6.1 Mud Logging

Mud logging services will be operational from the time of spudding but sample collection will not commence until after setting the 20" casing, if hole conditions permit.

6.2 Electric Logging

HOLE SIZE (in)	LOGS TO BE RUN
20	-
17½	MWD only
12¼	MWD, DIL-SONIC-GR, LDL-CNL, RFT

Note: i) Electric logs will only be run in 12¼" hole if significant hydrocarbons are encountered.

ii) RFT may be run if hydrocarbons are encountered.

6.3 MWD

MWD will possibly be the only evaluation tool run unless significant hydrocarbons are encountered, and will be run from the 13 3/8" shoe to TD (GR-Resistivity-Directional).

6.4 Coring

Cores may be cut depending on shows and lithology intersected.

6.5 Cased Hole Testing

The well will be drilled to evaluate the reservoir, GOC and OWC. No tests will be run. Tests will be run in the event of an oil column being intersected.

7.0 DETAILED DRILLING PROCEDURE

7.1 26" Hole

7.1.1 <u>Drilling</u>

Make up a 26" drilling assembly and drill 26" hole to approximately 80m. Take Totco survey at TD. Drill hole so that MLS hanger will be set approximately 1m above the seabed. Condition hole.

Make up 26" drilling assembly as follows:

26" Bit
3 x 9½" Drill Collars
X - 0
Dri8"Collars

7.1.2 <u>Run 20" casing as follows</u>:

i) Shoe Joint
ii) Intermediate Joints
iii) Landing joint complete with MLS hanger and running tool
iv) 20" casing to surface

7.1.3 <u>Cementing</u>

As per programme using inner string cementing adaptor. WOC until surface samples are hard. Hang off conductor on BOP hoists.

7.1.4 <u>Install 20" diverter and test</u>

7.2 17½" Hole

7.2.1 Make up 17½" slick BHA, RIH. Drill out cement shoe and rathole with seawater. Drill approximately 20m of new hole. POOH.

7.2.2 Make up 17½" Drilling Assembly as follows:

17½" Bit
Bit Sub
1 x 9½" Drill Collar
Stabiliser
2 x 9½ Drill Collar
X - O
6 x 8" Drill Collar
X - O
12 x 5" HWDP
DP

Drill out cement and shoe and drill ahead to approximately 360m. Single shot surveys to be taken on wiper trips as required and at section TD. POOH.

7.2.3 Condition hole to run casing. Run 13 3/8" casing as follows:

i) 13³/8" Float shoe.
ii) 1 joints 13³/8" X 68lb/ft x K55 casing.
iii) 13³/8" Float collar.
iv) 13 3/8" x 68lb/ft x K55 casing to MLS.
v) 20" x 13³/8" MLS casing hanger and running tool.
vi) 13³/8" x 68 lb/ft x K55 landing string to surface.

Run centralisers as follows:

1 x 3m above shoe
1 x on collar of shoe joint
1 x 3m above float collar
1 x on each of joints 4 and 5
(Total five (5) centralisers)

Note: Bottom three casing connections to be THREADLOCKED.

7.2.4 Condition mud as necessary (minimum one casing volume). Cement as per programme. Displace cement with seawater. Bump plug and pressure to 17500 kPa (2500 psi) and test casing. Check for backflow.

7.2.5 Nipple down diverter. Set slips. Cut casing. Install 13 3/8" casing spool. Nipple up BOP. Testing BOP to 21000 kPa (3000 psi) and casing spool to 10500 kPa (1500 psi). Install wear bushing.

7.3 12¼" Hole

7.3.1 Make up 12¼" slick BHA, RIH. Drill out cement, shoe and rathole with seawater. Displace hole to mud. Conduct leak-off test as per programme.
Drill approximately 40m new hole. POOH.

7.3.2 Make up 12¼" BHA as follows:

12¼" Bit
Bit Sub
Short Drill Collar
Stabiliser
2 x 8" Drill Collar
Stabiliser
12 x 8" Drill Collar
Drilling Jar
3 x 8" Drill Collars
X-0
12 x 5" HWDP
DP

Drill to TD. Cut cores in the objective intervals as directed by the well site geologist. Condition hole for logging.

7.3.3 Logging

Run Electric Logs as per programme.

If significant hydrocarbons are encountered it is likely the well will be plugged back and deviated or plugged back and abandoned with a deviated offset well then being drilled.

Should there be no shows then the well will be plugged and abandoned. The rig will then be jacked down and moved off location in accordance with WMC and the Contractors operating and safety procedures.

APPENDIX E

MARINE HABITAT DISTRIBUTION AND COMPOSITION OF SHALLOW MARINE COMMUNITIES FROM TWIN ISLANDS TO BARROW SHOALS

Report to: Western Mining Corporation Limited,
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MARINE HABITAT DISTRIBUTION AND COMPOSITION OF SHALLOW MARINE COMMUNITIES FROM TWIN ISLANDS TO BARROW SHOALS

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MARINE HABITAT DISTRIBUTION AND COMPOSITION OF SHALLOW MARINE COMMUNITIES FROM TWIN ISLANDS TO BARROW SHOAL

1 INTRODUCTION

The baseline survey for the South Herald - North Pepper Oilfield development was first conducted in December 1987 (LSC, 1989). The baseline survey centred on Airlie Island for which adequate water penetrating aerial photography was available. For habitats further afield (i.e. Barrow Shoal and the islands of the Mary Anne Group) the lack of suitable photography and bathymetric information meant that only a generalised map of habitat distribution of these areas could be produced at that time. From this work, areas sensitive to oil spills were identified and maps of their distribution were produced for the Western Mining Corporation Oil Spill Contingency Plan.

The subsequent decision to proceed with Chervil Field, and the identification of the Nares prospect and other prospects on Barrow Shoal, has focused attention on the shallow habitats within the eastern part of Western Mining Corporation Limited's (WMC) lease area. Consequently the need was identified to define more accurately the distribution of the shallow water habitats of the eastern lease area.

To facilitate this study WMC commissioned a set of water-penetrating aerial photographs of the shallow water areas within their lease. These photographs were taken during the equinoctial low spring tides in October 1989 at a scale of 1:50,000. Figure 1 shows the area covered by the photographs and the WMC lease boundary.

These photographs were produced into a set of mosaics and selected portions of each mosaic were enlarged to a scale of 1:25,000 to provide detail of large shallow water areas. The photographs were subsequently ground-proofed during a five day field survey of all shallow areas within or immediately adjacent to the WMC lease. The survey was conducted during spring tides in December 1989.

The aim of the survey was to inspect as much of the shallow water areas as possible and subsequently map the distribution of the various habitats encountered. Owing to time constraints imposed by the low spring tidal regime, little time was available for rigorous sampling of biotic components within each habitat, however observations on the predominant character of various biotic assemblages were recorded where appropriate.

2 METHODS

Shallow water areas were inspected by two teams of marine biologists. One team inspected the intertidal zone and the other team inspected the shallow subtidal zone fringing the reef platform. The shallow water areas traversed were described on the basis of tidal influence, nature of substrate and biotic assemblage. Field maps and notes were recorded directly onto the plastic laminated aerial photomosaics for subsequent drafting and preparation of the survey report. Photographs were obtained for descriptive and recording purposes.

The habitat description survey focused on an area of approximately 1650 km^2 (Fig. 2) which extended from Twin Islands in the south, to the Barrow Island Shoals in the north. Within this area, habitats less than 5 m below LWS are considered to be potentially at risk from spills of light crude oil. These habitats include the intertidal and the shallow subtidal areas.

The areas potentially at risk from an oil spill are distributed within three zones:

- the islands and reefs in the southern part of the WMC lease, e.g. the Twin Islands and the Mangrove Islands;
- the islands and reef platforms in the Mary Anne Group of islands located in the eastern section of the WMC lease; and
- the Barrow Island Shoals in the northern part of the WMC lease, which comprise the most extensive area of shallow water habitat between Barrow Island and the mainland.

In addition to these are the areas previously described in the baseline survey report (LSC, 1989) (i.e. the shallow platform surrounding Airlie Island).

3 HABITATS

3.1 HABITAT TYPES AND CHARACTERISTICS

The shallow water habitats of the study area are defined in terms of their tidal zone, substrate type and biotic cover.

The main habitat types encountered in the survey area were as follows:

- sand spits, shoals and beaches;
- intertidal rocky shore (limestone cliff) and beach rock platform;
- intertidal limestone pavement;
- intertidal flats with samphires and mangroves;
- subtidal limestone pavement with seagrass, algae and sand; and
- subtidal coral reef.

The physical and biotic character of theses habitat types is outlined in the following sections.

3.1.1 Sand Spits, Shoals and Beaches

This habitat type is low in abundance in the survey area, being restricted mainly to the vicinity of the islands. It is generally comprised of medium to coarse sand, gravel and coral rubble. Seabirds such as pelicans, terns and gulls use these habitats as roosting sites. On the rising tide, the shallow waters of the spits are feeding grounds for wading birds and fish which feed on tidally-deposited organic matter.

The biota on the sandy beaches consist largely of infauna such as polychaete worms and bivalve molluscs. Ghost crabs (*Ocypodidae*), wading birds, seabirds and turtles were also observed on these beaches.

3.1.2 Intertidal Rocky Shore and Beach Rock

This habitat is a very minor component of the survey area. It generally occurs as a low (1-2 m) cliffed face. Rocky shores are found on eroding coastlines. This habitat occurs on the north side of the North Mangrove Island, the north side of False Island and the west coast of South Twin Island. Beach rock occurs on the west coast of North Mangrove Island. Oysters, barnacles, limpets, chitons and shore crabs were observed in this habitat.

3.1.3 Intertidal Limestone Pavement

An intertidal limestone pavement habitat is the major component of the survey area and forms the basement on which the islands and coral reefs have formed.

These pavements are either exposed or sand- and rubble-veneered. Where sand occurs, seagrass meadows comprising *Halophila ovalis, H. spinosa*, *Halodule* and *Thallasia* are common. Seagrass cover varies from 10-90%. Where the pavement is exposed, algae are prevalent with *Sargassum* being dominant. Other algae present include *Padina, Caulerpa* and *Laurencia*.

Turtles, dugong, reef sharks and rays were commonly observed feeding on this habitat during high tide.

Within this habitat type occur two localised areas of raised limestone platform. The platform is colonised by oysters in varying abundance. The platform is dissected and the shallow depressions are filled with medium to coarse sand and gravel, which are colonised by algae. Seagrasses and small encrusting corals were also observed in these depressions.

3.1.4 Intertidal Flats With Samphires and Mangroves

This habitat occurs exclusively around the Mangrove Islands in the study area. Mangrove species from four genera were found. These genera are *Rhizophora, Avicennia, Bruguiera* and *Aegialite*.

Samphires *(Halosarcia)* are located only on the eastern side of North Mangrove Island on sediments accumulated on the shoreward side of the mangals. Benthic fauna associated with the intertidal mudflat environment of the mangroves and samphire is depauperate. Very few animals were observed during the survey of the seaward side of the flat. Those that were observed in low abundance included mudskippers, hermit crabs and rock oysters.

3.1.5 Subtidal Limestone Pavement

This habitat is basically a subtidal extension of the intertidal limestone pavement. It is variously exposed or sand- and rubble-veneered. Small depressions tend to be filled with sand and gravel. Exposed limestone and coral rubble is primarily colonised by dense growth of the algae *Sargassum* with other algae such as *Padina* and *Halimeda* being present in minor abundance. In places this habitat supports dense beds of seagrasses *Thalassodendron* and *Halophila*. Most frequently observed animals were sponges, holothurians, starfish and scattered corals.

3.1.6 Coral Reefs

This habitat type occurs throughout the survey area, but tends to be prevalent of the fringes of the large limestone pavement habitat. It takes various forms, the most common being ribbons or groupings of large massive coral bommies of the *Porites* variety, which fringe the platforms.

In shallow waters a reef flat is sometimes developed which contains primarily plate, crown and staghorn *Acropora*. In some locations on Barrow Shoals, these flats are extensive, although coral mortality is high.

A small number of patch reefs were also observed encrusting shallow subtidal limestone pavement. These reefs tended to consist of a diverse assemblage of species including *Montipora, Turbinaria, Goniopora, Pectinia, Lobophyllia, Goriastrea* and several species of Faviids.

A wide diversity of reef fish occur within this habitat. The diversity and abundance of fish observed varied according to the condition of reefs encountered, with lowest diversity occurring in areas of high coral mortality.

3.2 HABITAT DISTRIBUTION

3.2.1 Twin Islands Group

The Twin Islands Group (Fig. 3) is comprised of two small sandy islands located at the eastern extremity of a larger subtidal shallow limestone pavement. Two other shallow limestone pavements occur to the north-east of the Twin Islands, one of which is known as Herald Reef. Two small intertidal sand and rubble shoals are situated on the eastern extremity of these limestone pavements. The shallow limestone pavements in this region are covered in an algae and sponge assemblage. The major algae observed included species of the genera *Sargassum, Padina* and *Halimeda*, with *Sargassum* being dominant (80% cover).

The western-facing shore of the Twin Islands is comprised of an intertidal limestone pavement and limestone rocky shore. South-west Twin Island is surrounded by a limestone platform, which has a small cliff approximately 1 to 2 m in height and is encrusted with an oyster and barnacle assemblage. The intertidal limestone platform around north-east Twin Island has less relief, but contains outcrops of beach rock which are also oyster- and barnacle-encrusted.

Small coral reefs occur on the south and north sides of south-west Twin Island and also on the south side of north-east Twin Island. All reefs inspected in this area were in good condition and supported a diverse assemblage of coral species. The major genera consist of *Montipora, Turbinaria, Goniopora, Pectinia, Lobophyllia, Goniastrea* and several genera of Faviids.

The reef flat consists of branching and table *Acropora,* while *Porites* bommies surround the fringing reef. Coral cover on the fringing reef slope is almost complete (80-90%) and a coral mortality of about 10% (mainly *Acropora*) occurs.

The eastern side of the islands is comprised largely of an intertidal sand spit, which progrades into a subtidal shoal. The disposition of the various habitats encountered in the Twin Island follows the same trend as that seen on other islands in the region in that the rocky shores tend to be located on the western side, while the sandy shores and sand spits occur on the eastern side of the islands, indicating that, in the long term, the islands are eroding from the west and accreting to the east.

3.2.2 Mangrove Islands

The Mangrove Islands Group (Fig. 4) is comprised of three islands, the southernmost of which (South Island) is comprised primarily of sand and is surrounded by a belt of mangroves comprising mainly of *Avicennia* with small pockets of *Rhizophora.* South Island and its surrounding mangrove assemblage is located centrally on an intertidal limestone pavement which fringes the island. The Middle and North Mangrove Islands occur at opposite ends of a larger intertidal limestone platform. Middle Island is also a sand island and contains no rock habitat. However, North Island is comprised of sand overlying a rocky base. Much of the island is bordered by a small 1 m to 2 m high limestone cliff. The north-western shore of North Island is comprised of sand and rubble and beach rock overlying a relatively barren limestone pavement, which is exposed at low tide (Plate 1). North Island contained abundant burrows which may have been rat holes. Rat footprints and the occasional rat skeleton were found, but no living rats were observed.

North Island supports the best developed and largest mangrove assemblages. It also supports a small samphire mudflat on its south-eastern shore (Plate 4). The mangroves are best developed on the south-western and south-eastern shores of North Island; the two main species being *Avicennia marina* and *Rhizophora stylosa,* but with occasional groupings of a third species, *Aegialites annulata.*

Mangroves also occur mainly on the eastern side of Middle Island, the dominant mangrove occurring there being *Rhizophora* (Plate 3). However, a small stand of *Avicennia* and *Bruguiera* also occurs near the north end of Middle Island. A narrow fringe of predominantly *Avicennia* mangroves occurs along the southern side of Middle Island.

The mangrove assemblages fringing to Middle Island tend to occur in a sandy substrate, while those surrounding the southern and south-eastern part of North Island tend to occur within a thin muddy substrate, which is overlying limestone pavement (Plate 1).

A large area of intertidal to shallow subtidal sand-veneered limestone pavement with seagrass cover occurs on the eastern side of North and Middle Islands (Plate 2). The seagrasses observed on the pavement included *Thalassia, Halophila* and *Halodule.* The stoloniferous alga *Caulerpa* was also commonly found. The main algae genera observed on the exposed limestone and sand-veneered pavement were *Sargassum, Padina* and *Caulerpa* (Plate 5). The high number of turtles observed in this habitat indicated its importance as a local feeding ground. Small numbers of birds such as beach curlews, oyster catchers and reef herons were observed feeding on this habitat during low tide.

The eastern end of this limestone platform was slightly raised and relatively barren, but as it dropped off into deeper water, it supported a fringing coral reef comprised mainly of *Porites* bommies and table and branching *Acropora* along its entire length. The coral appeared to be in reasonable condition, but it was difficult to determine the condition of the reef due to the poor visibility encountered at the time of the survey.

The intertidal area on the west side of North and Middle Mangrove Island is mostly barren exposed limestone overlain with a sand veneer closer to shore.

The cliffed rocky shore surrounding parts of the north Mangrove Islands supported an oyster barnacle assemblage. A sampling inspection of the intertidal limestone pavement on the eastern side of North Island and also into the seaward fringe of the mangrove assemblage revealed a dearth of fauna. Similar platform habitats adjacent to mangroves on the mainland usually support abundant numbers of fiddler crabs, small mangrove crabs, mudskippers and molluscs, but this reef and mangrove fringe area were noticeably depauperate in biota.

3.2.3 Mary Anne Group

The Mary Anne Group (Fig. 5) is comprised primarily of three large shallow limestone pavements which are exposed at low tide. The limestone pavement is either exposed or thinly sand-veneered. Where it is exposed, algae such as *Sargassum* and *Padina* occur, where the sand veneer is present seagrasses such as *Halodule, Halophila, Thalassia* and *Thalassodendron* occur. Superimposed on these three large limestone platforms are a number of sand shoals, sand cays and sand islands. False Island has a rocky base which is exposed on its western, southern and eastern sides as a rocky cliffed shore. This habitat supports an oyster and barnacle assemblage.

Seabird colonies occurred on all of the islands and also on some of the major shoals which were exposed at low tide. The main birds observed were pelicans, cormorants, terns and an occasional osprey.

Fringing coral reefs occur around the eastern and southern edges of most of the large limestone platforms. Most of these reefs are large amalgamations of *Porites* bommies with *Acropora* and other species superimposed (Plate 9). Many of the coral reefs in this region are highly degraded with large areas of dead and degraded coral. The reefs fringing the two southern limestone platforms are in particularly poor condition. However, those fringing the larger northern platform are in moderate condition. A number of deep gutters and channels occur on the northern limestone platform. These gutters are lined with healthy coral reef comprised largely of *Porites* sp. and *Acropora* sp.

The eastern edge of the northern limestone platform contains a habitat of raised limestone platform which supports an oyster assemblage. A similar habitat also occurs to the east of False Island. Judging by the high abundance of turtles and dugong sighted in this area, these platforms would appear to be a major feeding habitat for these organisms.

Large Island, which occurs to the east of the northernmost limestone platform, is the largest island in the region. It is a sand island with a rocky limestone base surrounded by a relatively narrow, raised intertidal limestone pavement, which supports an oyster and barnacle assemblage.

3.2.4 Barrow Shoals

Barrow Shoals (Fig. 6) is a very extensive area of shallow limestone pavement substrate. The Shoals rise gradually out of deep water (greater than 40 m) to the west and shallow across to become intertidal along most of the eastern margin. The eastern margin of the Shoals is marked by a steep slope running from intertidal to depths of 10 m and more. The steep eastern edge of the Shoals is generally fringed by coral reef habitat comprised mainly of patches or long thin ribbons of large *Porites* bommies, with associated species of coral. Extensive areas of coral reef also occur at discrete locations mainly along the eastern side of the Shoals. A large area of coral reef comprised mainly dead coral occurs at the southern end of the Shoals. A large reef was discovered in the north-east corner of the WMC lease area. This reef (termed 'Batman' because of its shape) is the largest single reef in the WMC lease. The reef was in moderate to poor condition with patches of living coral interspersed with patches of dead coral. Branching and tabular corals of the *Acropora* genus were the most degraded, while the massive corals such as *Porites* and *Favia* tended to be healthier (Plates 7 & 8).

Large expanses of coral rubble, gravel and sand are exposed at low tide, particularly on the southern and eastern portions of the Shoals.

The subtidal portions of the Shoals variously contain either sand and gravel veneer, dense seagrass beds, or algal beds. The main algae recorded in this habitat were *Sargassum, Padina* and *Caulerpa*, while the main seagrass species encountered were dense beds of *Thalassodendron* and the sparser, but more extensively distributed, *Halodule* and *Halophila* (Plate 6). Sponges and scattered encrusting corals were also occasionally observed.

Turtles were abundant on the Shoals, as were reef fish in areas of live coral. Seabirds were not noted in abundance.

3.3 BIOLOGICAL SIGNIFICANCE OF MAJOR HABITATS

Of the assemblages encountered during the survey, those considered to be of major ecological value were the mangrove assemblages, coral reefs, algae and seagrass-covered limestone pavements.

3.3.1 Mangrove and Samphire-Covered Mudflats

The mangrove and samphire habitat is an important site of primary productivity. Fallen leaves from mangroves are grazed by crustaceans and fish.

The mangrove assemblage on the Mangrove Islands is one of the few assemblages along the Pilbara coast which is truly marine in nature. Most other mangroves are located on the mainland. As such these islands have conservation value for scientific purposes. However, the islands appear to be rat-infested and the depauperate nature of the reef flat and low tidal mudflat may reflect predation by rats.

3.3.2 Coral Reefs

With the exception of the Twin Islands, some southern parts of the Barrow Shoals and parts of 'Batman Reef', many of the corals in the study area were in poor condition and showed signs of bleaching or were already dead and encrusted with algae. Although speculation can be made, the reasons for this occurrence or series of occurrences is unclear. The implications are that corals in the study area that are in reasonable condition are of significantly more ecological value because they provide a biological resource from which recruitment of other reefs can occur.

3.3.3 Limestone Pavement With Algae, Seagrass and Sediment

Both the intertidal and subtidal limestone pavement habitats are the major resources in the study area. They are a major source of primary productivity in the region as a result of the extensive algal and seagrass meadows which they support.

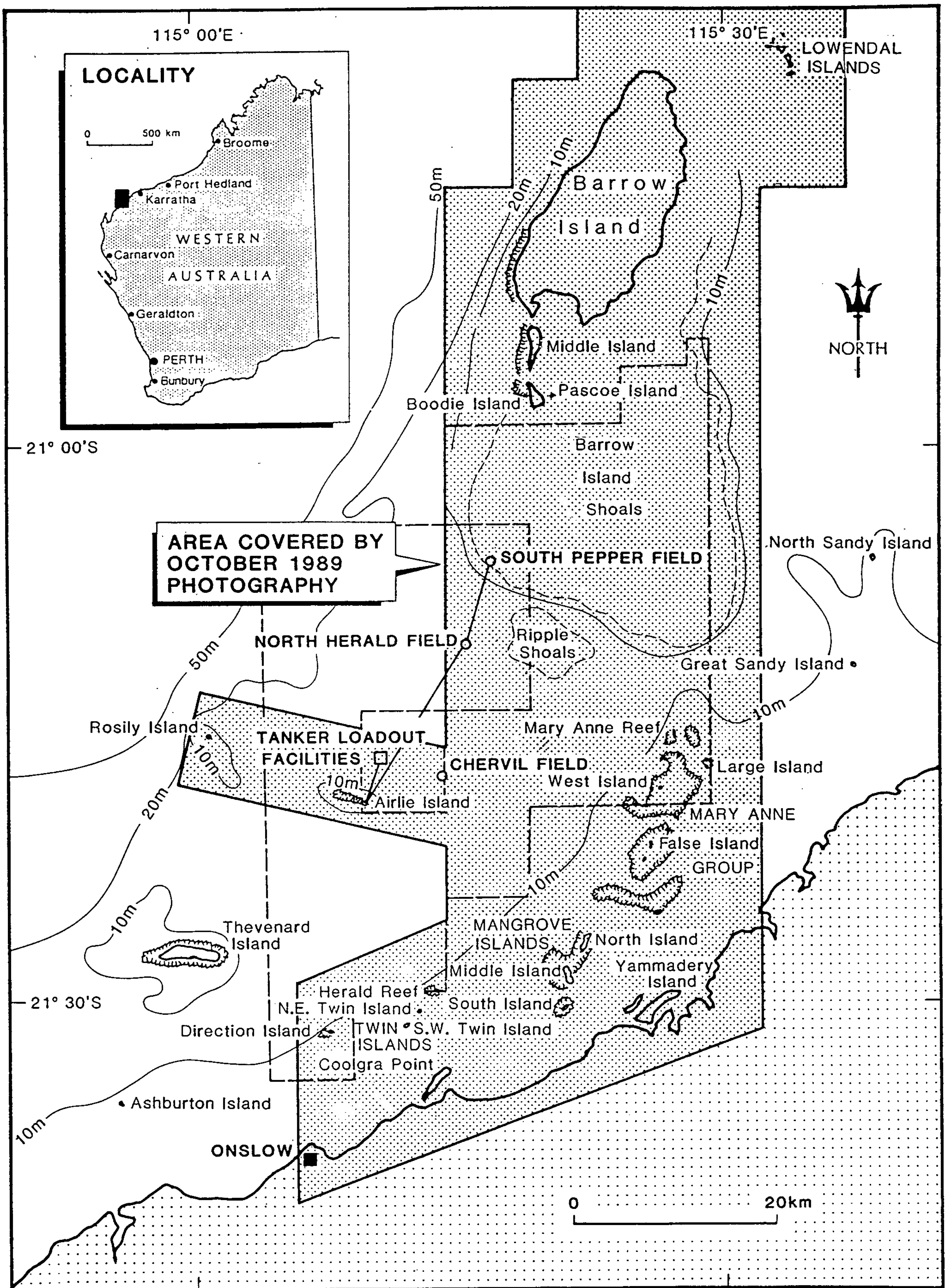
Seagrass and algae are an important food source for dugongs and turtles. Large numbers of turtles were sighted in the study area during the survey around the Mangrove Island and West Island. Numerous tracks and burrows of turtles were found around West Island. It would appear that these areas are important feeding and breeding grounds for the green sea turtle.

Dugong were also observed on the shallow platform between North and South Mangrove Island and on the flat east of West Island. Reef sharks and rays were also commonly observed feeding in this habitat during high tide.

During low tide the exposed pavement became feeding grounds for a range of wading birds such as oyster catchers, reef herons and beach curlews.

4 REFERENCE

LeProvost, Semeniuk & Chalmer, 1989. *South Pepper - North Herald Oilfield Marine Monitoring Programme. Baseline Survey and First Annual Report.* Unpublished report to Western Mining Corporation Limited, Petroleum Exploration Division. Report No. R224, LeProvost, Semeniuk & Chalmer, Perth, Western Australia, 73 pp plus appendices.



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LOCALITY MAP, LEASE BOUNDARIES AND PHOTOGRAPHIC COVERAGE

Figure 1

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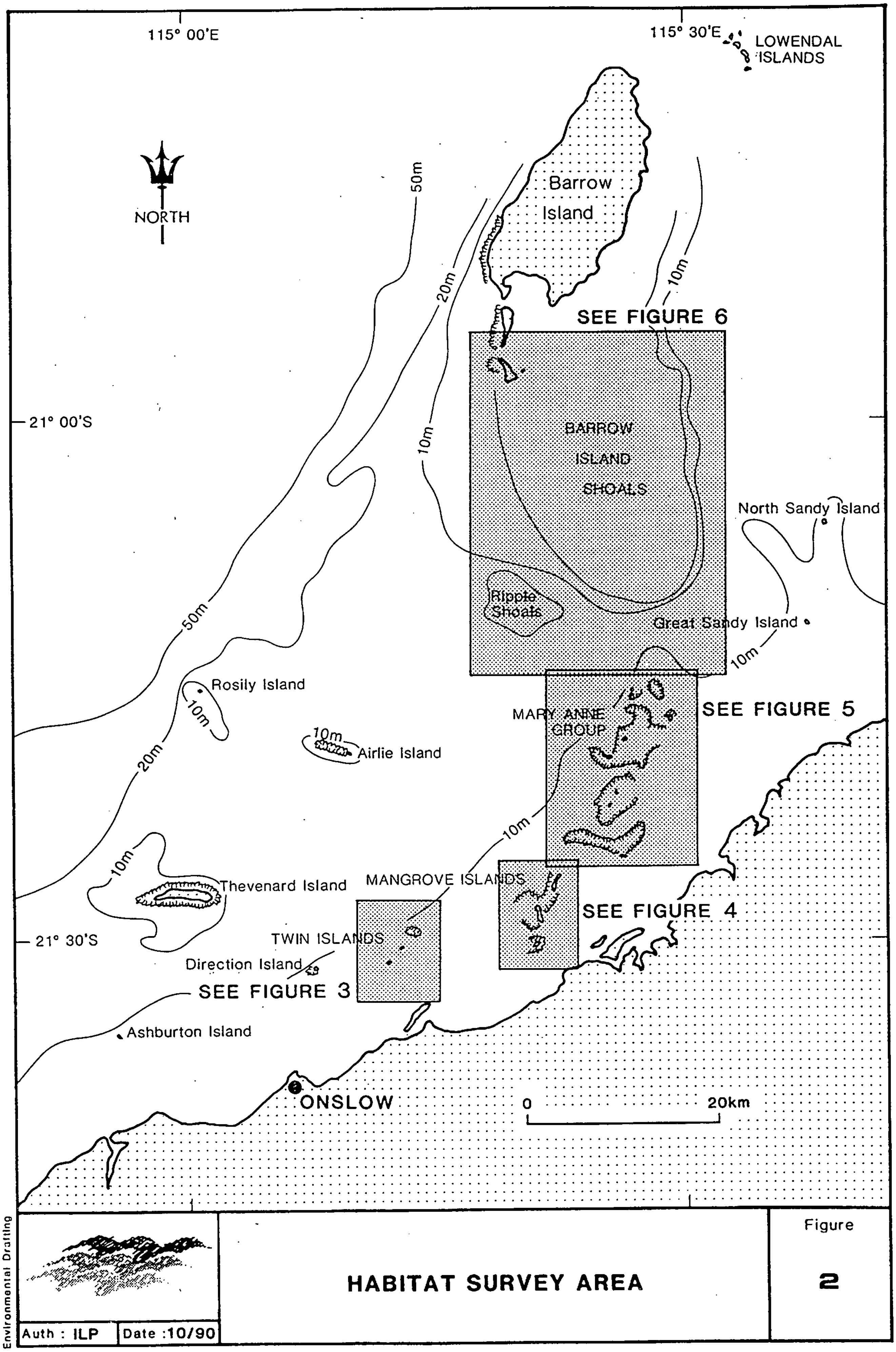
115° 00'E
115° 30'E
LOWENDAL ISLANDS
NORTH
Barrow Island
50m
20m
10m
SEE FIGURE 6
21° 00'S
BARROW ISLAND SHOALS
North Sandy Island
Ripple Shoals
Great Sandy Island
50m
Rosily Island
10m
Airlie Island
MARY ANNE GROUP
SEE FIGURE 5
20m
10m
Thevenard Island
MANGROVE ISLANDS
SEE FIGURE 4
21° 30'S
TWIN ISLANDS
Direction Island
SEE FIGURE 3
Ashburton Island
ONSLOW
0
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HABITAT SURVEY AREA
Figure
2

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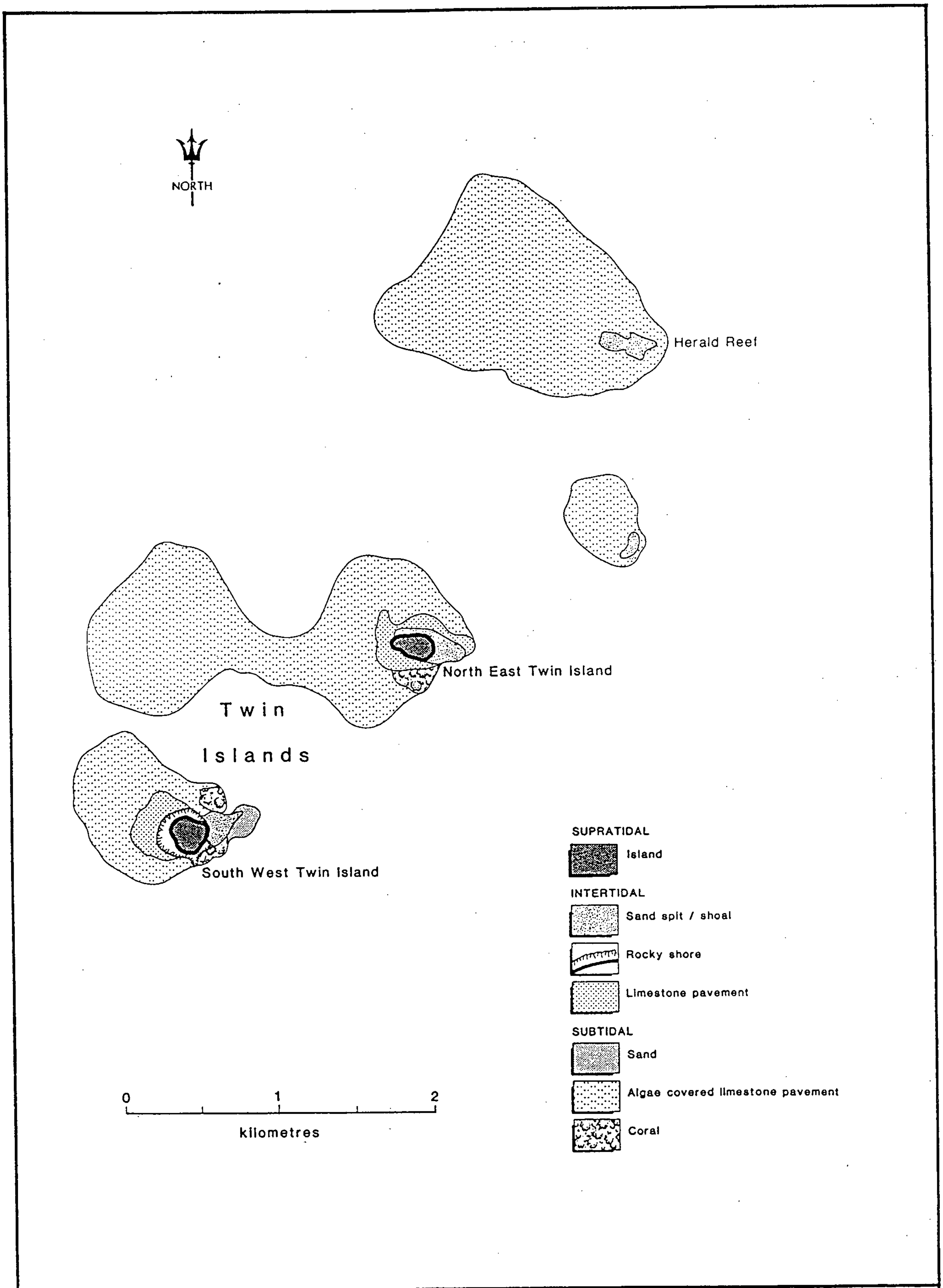

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MARINE HABITATS OF THE TWIN ISLANDS

Figure 3

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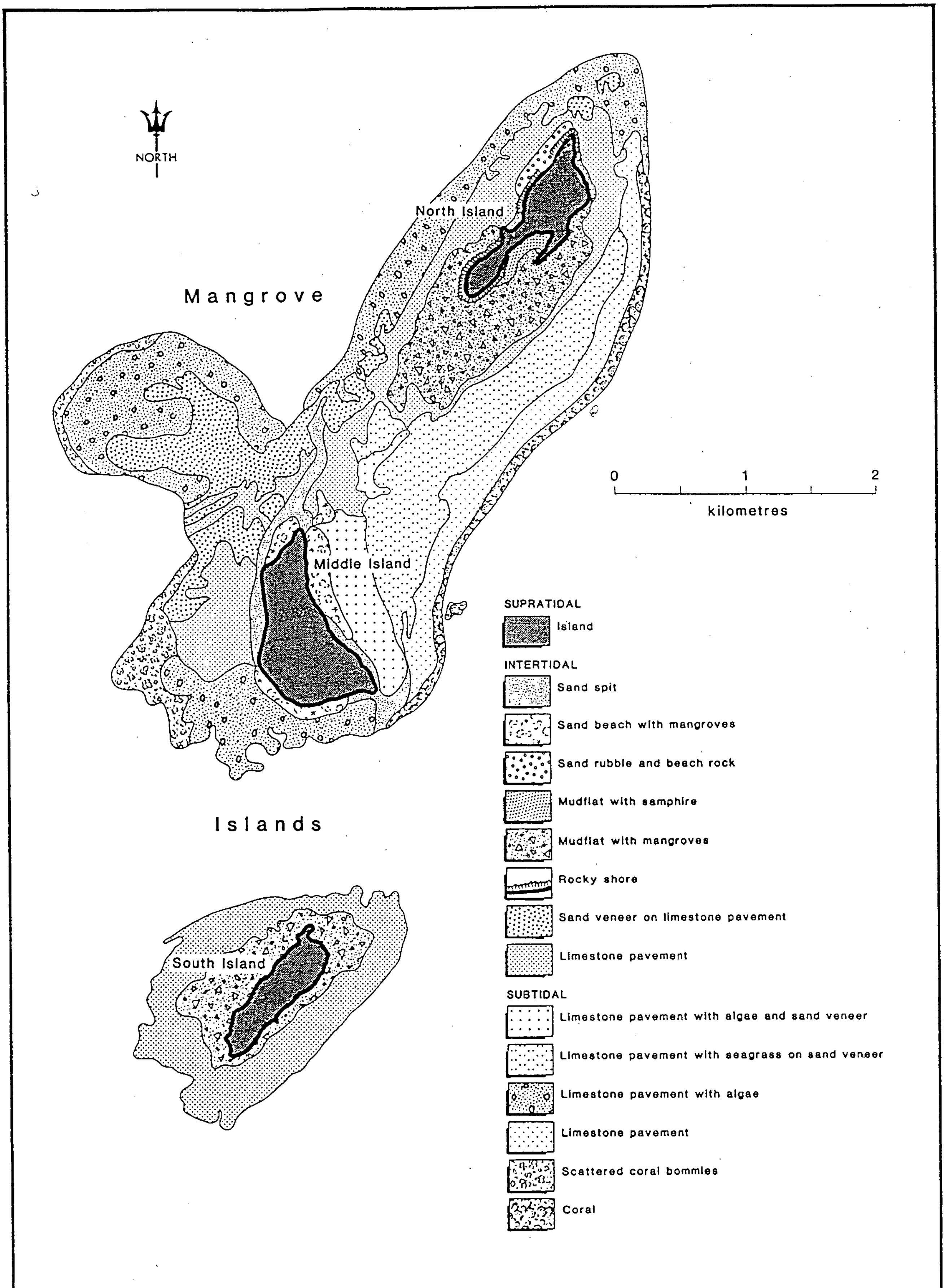

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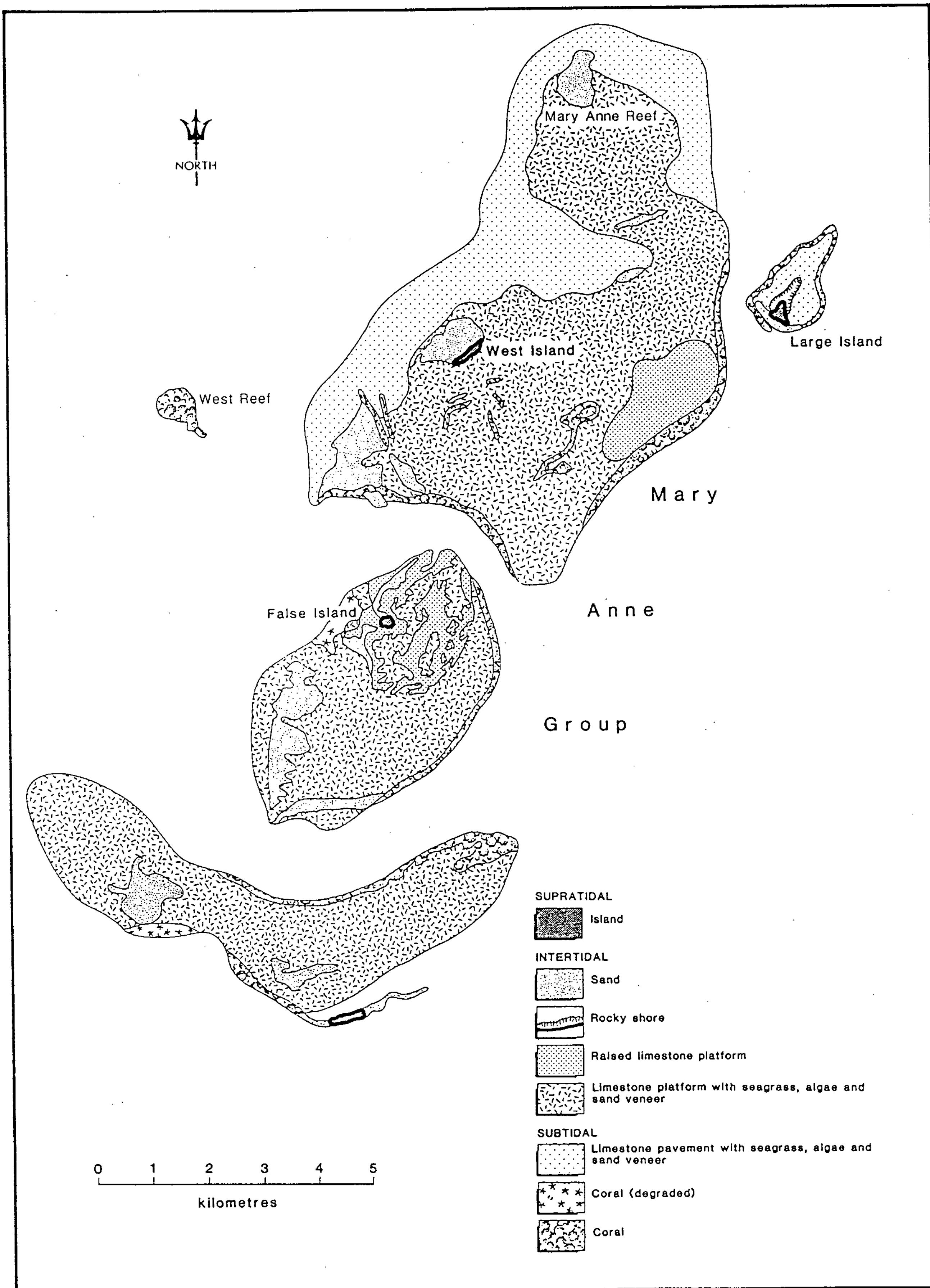
MARINE HABITATS OF THE MANGROVE ISLANDS

Figure 4



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MARINE HABITATS OF THE MARY ANNE GROUP

Figure **5**

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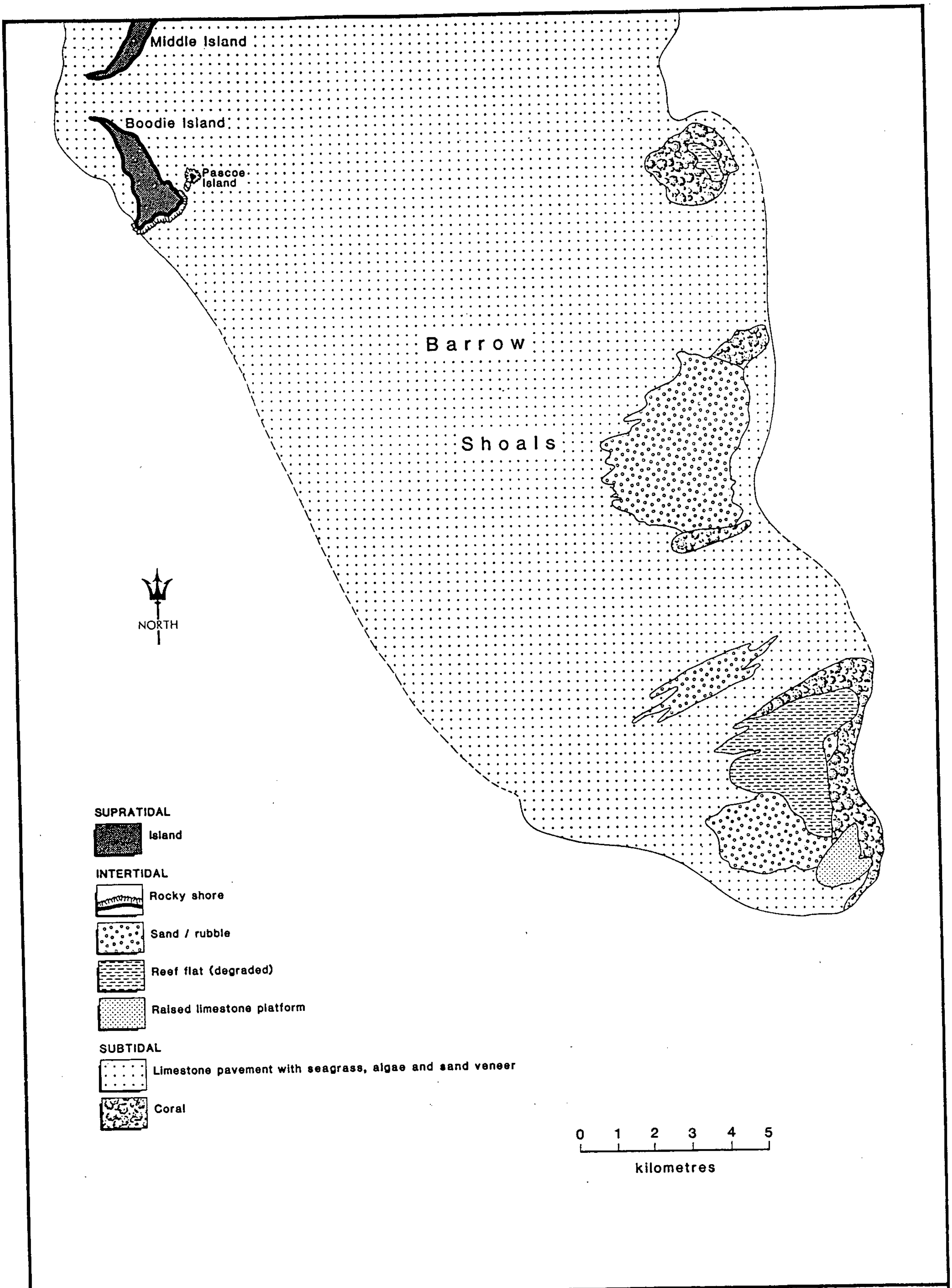

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MARINE HABITATS OF THE BARROW SHOALS

Figure 6

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Plate 1: Intertidal limestone pavement exposed at low tide on the east side of North Mangrove Island. Mangroves in the background are growing on the mud veneer.

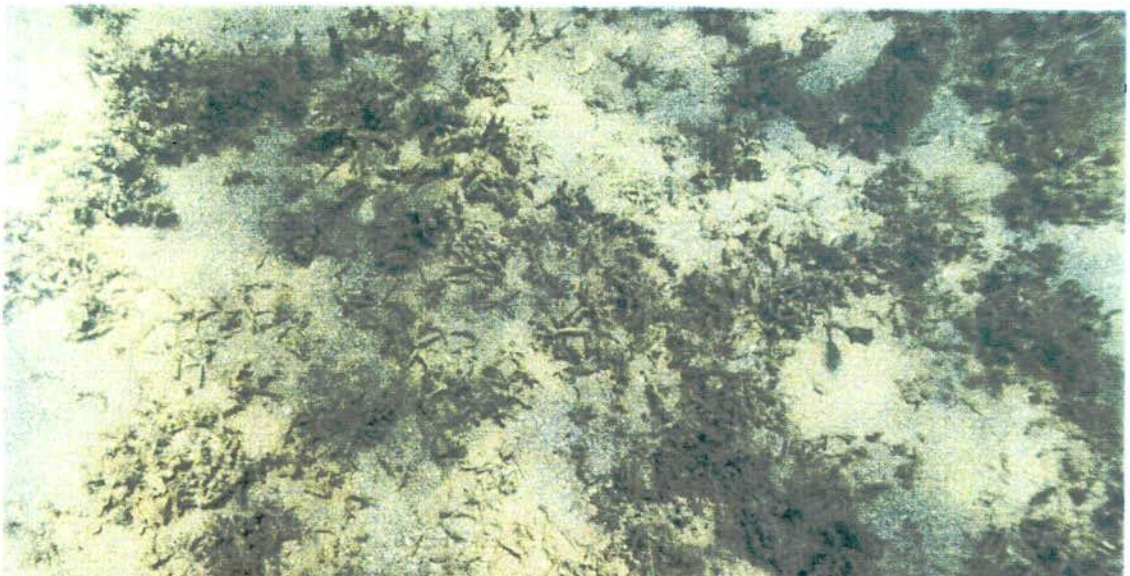

Plate 2: Seagrass *(Halophila)* on the intertidal sand-veneered limestone pavement on the eastern side of North Mangrove Island.

Plate 3: Dense *Avicennia* and *Rhizophora* mangal on the south side of North Mangrove Island.

Plate 4: Samphire flat on North Mangrove Island (mid ground) with mangroves in the background.

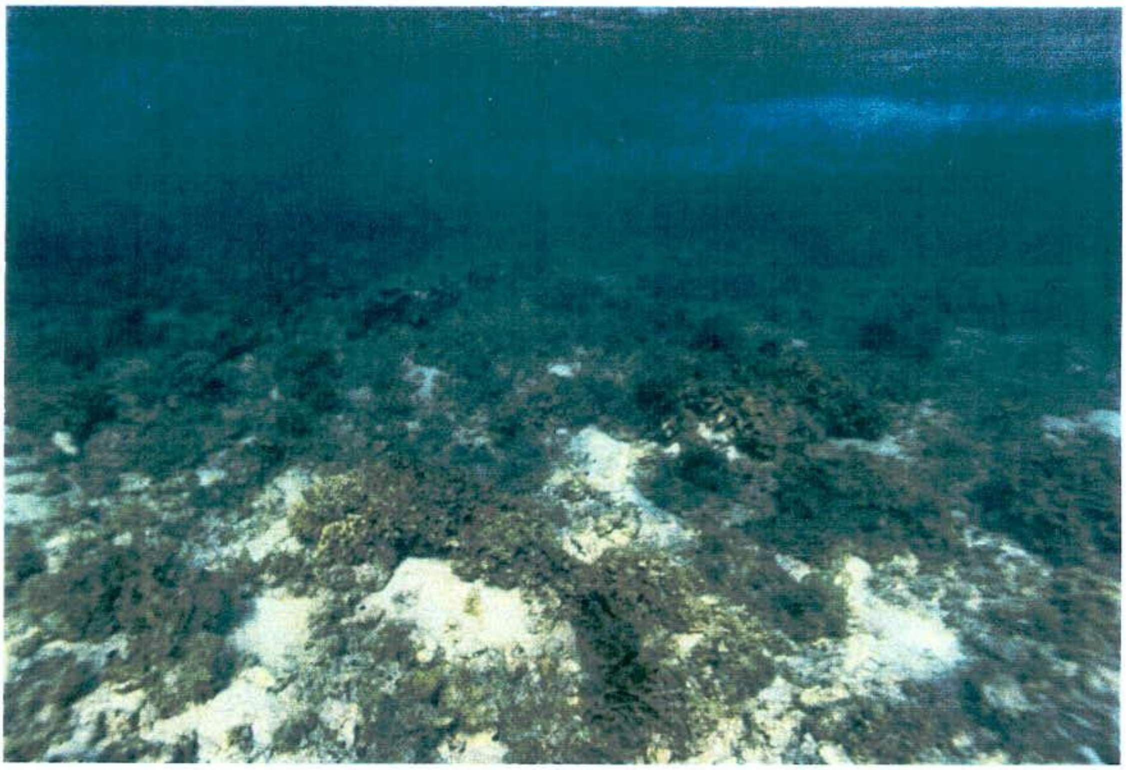

Plate 5: Algae on sand-veneered subtidal limestone pavement.

Plate 6: Seagrass (*Thalassodendron*) on shallow subtidal limestone pavement and sand veneer at South Barrow Island Shoals.

Plate 7: Reef flat comprised largely of branching and crown *Acropora*.

Plate 8: Dense coral assemblage on the east coast of Barrow Shoals.

Plate 9: *Lobophyllia* and *Porites* bommies on the outer edge of the fringing reef around False Island silted and encrusted with filamentous algae.