WEST AUSTRALIAN PETROLEUM PTY. LIMITED

ROLLER OILFIELD DEVELOPMENT

CONSULTATIVE ENVIRONMENTAL REVIEW

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SUMMARY

THE PROPOSAL

West Australian Petroleum Pty Limited (WAPET), as operator for the participants in Exploration Permit Area TP/3 Part 1, is seeking environmental approval to develop the Roller Oilfield. The Roller Oilfield is located approximately 6 km north of the Ashburton River delta and some 22 km west of Onslow. Water depths range from 5 m on shoals to over 11 m, and average 10 m.

Peak production from the field will be approximately 7,949 to 9,538 kL per day. The life of the field is estimated to be six to eight years. Roller crude is a medium weight oil (API gravity of 29.5°) not found before on the North West Shelf.

THE PROJECT

Development of the Roller Oilfield will require:

- four monopod wellhead structures;
- gas separation and compression facilities;
- subsea pipelines to Thevenard Island; and
- existing production and loading facilities on Thevenard Island.

Five development alternatives were evaluated, of which two have been selected for ongoing and detailed evaluation. Both of the preferred options involve:

- development drilling and installation and operation of four monopods at Roller A, B, C and D;
- subsea pipelines connecting the field to the existing production, storage and load-out facilities located on Thevenard Island (some 26 km to the north-north-east of the Roller Oilfield); and
- use of Thevenard Island storage facilities and tanker load-out facilities.

The two preferred options differ in the location of the gas separation/compression facilities. Option 1 proposes to transmit commingled production from all four monopods to Thevenard Island by a three-phase production pipeline and to utilise gas and water separation facilities on Thevenard Island. Option 2 proposes to install gas separation and compression facilities aboard a modified jack-up rig or fixed steel jacketed platform located adjacent to the Roller D monopod, and to pump oil and water to Thevenard Island via a 20.5 km long two-phase pipeline.

The final preferred option will be selected in September 1991 when feasibility and reservoir simulation studies are scheduled to be finalised. Subsequently a 15-month construction period will be initiated in May 1992, culminating in field commissioning in July 1993.

Construction of the project will require:

- a temporary workforce camp for about 40 construction personnel based in Onslow and ferried to the Roller Oilfield each day;

- increased supply vessel and aircraft movements in the project area;

- drilling of seven development wells at Roller A, B, C and D, plus re-entry and completion of one exploratory well at Roller D;

- installation of monopods at Roller A, B, C, and D and connection to trenched subsea three-phase production and gas-lift lines;

- installation of modified jack-up production rig, or fixed steel jacketed platform, alongside Roller D (if Option 2 is selected); and

- laying a two-phase production line, or a three-phase production line and gas-lift line from Roller to Thevenard Island (depending on which option is selected).

Operation of the project during the construction phase will require no additional facilities on Thevenard Island. Produced water will be discharged through the existing approved offshore outfall. Gas not required for fuel or compression for gas lift will be flared off, either from the existing ground flare on Thevenard Island (Option 1) or from the jack-up production rig at Roller D (Option 2).

During the production phase, the existing accommodation, storage tanks and ship loading facilities at Thevenard Island will be used. The number of ship movements are not expected to increase. Depending on the final option, either five additional personnel will be housed on Thevenard Island, or up to 18 personnel will be housed on Thevenard Island and/or the jack-up production rig at Roller D.

Up to two additional development wells may be drilled from any two of the four monopods later in the field life. At the end of the field life the field will be decommissioned in accordance with requirements administered by the Department of Mines Western Australia. However, the 10 year design life of the monopods allows for use of the Roller facilities into 2003.

EXISTING ENVIRONMENT

Physical Characteristics

The climate of the region is arid subtropical with very hot summers, moderate winters, and highly variable rainfall usually associated with summer cyclones. The prevailing summer wind pattern is characterised by moderate south-westerly breezes, with the strongest summer winds associated with cyclones and thunder squalls. In winter, moderate to strong easterlies ('South-East Trades') predominate. Water temperatures range between 20°C and 30°C.

Surface water movements in the region are dominated by wind-modified tidal currents. Tidal currents occur twice daily and are oriented predominantly along an east-west axis, except where shallow water bottom contours induce water flow parallel to nearby shorelines. Stronger currents prevail close to shore and in shallow areas, particularly during spring tides or storm conditions.

The mainland coastline is characterised by sandy beaches which are backed by sand dunes and tidal flats. Compared to the coastline east of Onslow, the section running between Onslow, the Ashburton River mouth and Tubridgi Point has fewer creeks. However, a large delta system has developed around the Ashburton River, the southernmost major river in the Pilbara, which has a catchment area greater than 70,000 km^2. After periods of high rainfall, the Ashburton River and smaller tidal creeks contribute terrigenous silty sediments which become transported to the offshore submarine shelf. The submarine shelf is composed of limestone sloping to depths of 20 m over 20 km from shore and locally interrupted by islands, reefs and cays. The seafloor in the Roller Oilfield is comprised of sand and silt sheets and shoals.

Ecological Characteristics

The marine ecosystem of the study region is diverse and contains all of the components characteristic of the Tropical Indo-Pacific Zoogeographic Region.

The offshore islands within the permit area are fringed by limestone pavement which supports algae and, further offshore, fringing coral reef. Coral reef is extensive on the north and south sides of Thevenard Island. Patchy seagrass beds, sand beaches utilised by sea birds and turtles for nesting sites and mangroves comprise the other important shallow water habitats.

Regionally-important mangrove forests are situated on mud and sand flats along the edges of the tidal creeks contained within the Ashburton River delta area and along smaller tidal creeks such as Beadon Creek, Hooley Creek and Urala Creek.

Mangrove-lined creeks are important sites of primary production, secondary consumption and decomposition, and provide important nursery areas for commercial species such as the brown tiger prawn. The coral reefs and seagrass beds are important habitat sites in offshore waters, providing food to a range of marine organisms including turtles and dugongs.

The ecological resources of the region are subject to both natural fluctuations in population characteristics and, to a lesser extent, man-induced fluctuations as a result of commercial and recreational fishing activities. The marine ecosystems of the Pilbara occasionally undergo natural catastrophic events as a result of cyclones, major river discharges, insolation during extreme low tides and occasional periods of very high surface water temperatures.

Social Characteristics

The town of Onslow was established in 1864 to service the pastoral, pearling and mining industries of the Ashburton district. Since the early 1960s, oil exploration and production has assumed a growing importance within the area. Onslow now forms a mainland base for supporting both exploration and production activities of the oil industry. The potential exists for further discoveries of oil in the region as WAPET, Hadson Energy Limited and Western Mining Corporation Limited all have active exploration programmes. Industries such as commercial fishing and tourism have also shown significant growth over the past 10 years.

Thevenard Island and Direction Island support holiday camps (Mackerel Islands Resort Pty Ltd) where fishing is the major recreational activity. The commercial fishery operating out of Onslow is a small, though locally important, industry responsible for approximately 2.6% of the weight of the annual total catch landed in Western Australia. The most important component of the commercial fishery is the Ashburton Roads (Area 1) prawn trawl fishery, which operates mostly near the mainland coast between March and October each year.

The Roller Oilfield is located within a Special Protection Locality (SPL) as defined by the Department of Conservation and Environment in Bulletin No. 104 (Jones, Field & Hancock, 1984). This area is regarded as an SPL due to its significant marine resources and their sensitivity to oil spills. The conservation significance of the region has been recognised and the following authorities have taken measures to help protect the area:

- National Estate and Heritage Commission;
- Conservation Through Reserves Committee, Environmental Protection Authority (EPA); and
- Department of Conservation and Environment (now EPA).

Most of the larger islands in the region are presently C-class reserves, while the smaller islands are Vacant Crown Land. Locker Island located to the south-west of the Roller Oilfield is an A-class reserve. The marine environment also supports a large number of the Beneficial Uses identified in Bulletin No. 103 (DCE, 1981).

ENVIRONMENTAL IMPACTS

Since 1985, three major offshore oilfield developments have been commissioned in the region. All have undergone environmental scrutiny and all have been regularly monitored. As a result, substantial local experience in offshore oilfield development exists on which to base impact assessment.

The main environmental concerns associated with the proposal are considered to be:

- the potential effect of routine discharges on the marine environment during the development or production phases;
- the restriction of access to part(s) of the local commercial prawn trawling grounds during the life of the field;
- the continued use by WAPET of production facilities adjacent to the Mackerel Island Resort Pty Ltd's lease on Thevenard Island; and
- the potential effects of an accidental oil spill.

Development Operations

Development operations will not cause any long-term impact on the marine or social environment. Water turbidity associated with the disposal of drilling mud and cuttings is highly unlikely to be detectable above background turbidity within 500 m from the rig, given the volumes discharged and the degree of natural water turbidity in this nearshore region. Nearshore waters become very turbid when the Ashburton River floods, and when reworking and resuspension of sediments is caused by spring tides or strong winds. Drill cuttings are sand to gravel-sized, which will form shallow mounds adjacent to each monopod. Drilling fluids will be those approved for offshore use by the Department of Mines and the EPA.

Production Operations

The amount and rate of production discharges and shipping movements is not expected to increase due to the simultaneous decline in output from the Saladin Oilfield, which is presently processed and shipped from Thevenard Island. The quality of discharges will remain the same (i.e. in accordance with stringent Department of Mines specifications).

Commercial Prawn Trawling

Commercial prawn trawling grounds occur throughout nearshore waters of the region. The shoals in the vicinity of the Roller Oilfield are considered to be particularly productive trawling grounds. Consultations with local fishermen, the Western Australian Fishing Industry Council and the Fisheries Department have been undertaken to help identify means of minimising adverse affects on the fishery. As a result, WAPET is currently investigating the feasibility of moving one of the monopods (Roller B) to the north in order to allow improved access to the rich trawl grounds near Roller Shoal.

Exclusion zones will be required for the monopods at Roller A, B, C, and D, but these will only restrict access to very minor parts of the trawling grounds as a result of the need to protect both the facilities and trawling gear from accidental damage. Since the subsea pipelines between these monopods and between the edge of the field and Ashburton Island will be trenched, no exclusion zones will be required to protect them from disturbance by trawling activities.

Following the selection of the preferred option (either Option 1 or 2), the exact size and shape of the marine exclusion zones that will be required for the Roller development will be determined through input and consultation between the Department of Marine and Harbours, Department of Mines, Fisheries Department and WAPET.

Continued Operations at Thevenard Island

The proposal will extend the life of WAPET's production, storage and shipping facilities at Thevenard Island. While the existing infrastructure and operations will not be increased to any significant or noticeable degree, the proposal will extend the time that they will detract from the aesthetic and partial 'wilderness' value of the nearby holiday units on Thevenard Island which are operated by the Mackerel Island Resort Pty Ltd.

Potential Effect of an Oil Spill

The potential effect of a large oil spill is the major concern associated with the proposal, particularly since the Roller Oilfield is located close to the mainland, lies within an SPL, and is immediately adjacent to productive prawn trawling grounds and coastline nursery area.

Even though the chance of a major oil spill occurring during either the development or production phases of the Roller Oilfield is shown to be exceedingly small, a thorough assessment of potential effects has been undertaken. This assessment has involved:

- characterising the type and weathering features of Roller crude;

- identifying areas potentially at risk by oil spill trajectory modelling;

- identifying resources most at risk within this area; and

- assessing the potential effects of both a mid-weight oil and the various oil spill combat procedures on these resources.

The assessment shows that:

(i) While Roller crude is heavier than other North West Shelf light crudes, it is highly biodegraded and contains few of the lighter and more toxic components. The crude is similar in weight to diesel fuel, and preliminary data indicates that it has similar weathering characteristics.

(ii) Since tidal currents typically flow parallel to the mainland shore (east-west) and since winds predominate from the west, south and south-eastern sectors, the coastlines most at risk are those located offshore. These comprise the limestone pavements and beaches of the nearby Ashburton and Thevenard Islands (Thevenard Island may be the most vulnerable, being 'downstream' of predominant south-west winds).

(iii) Although the mainland coastline, including the mangroves of Ashburton delta, is relatively close (some 6 km), these are considered to be less at risk because strong winds blowing for more than six hours from northern quadrants are relatively infrequent, and are typically associated with cyclones (i.e. events when both development and production operations will be halted and shut down for safety reasons).

(iv) The marine resources at risk from a serious oil spill are:

  - coastal mangrove assemblages (particularly those at the Ashburton River delta and in Beadon Creek);

  - offshore shallow water coral reefs and macroalgal-covered limestone pavement (particularly at low spring tide);

  - air-breathing vertebrates (particularly seabirds and turtles);

  - inshore prawn nursery grounds;

  - sand beaches utilised by tourists (i.e. at Thevenard Island, Direction Island and the 'Back Beach' at Onslow); and

  - Beadon Creek (which is used for navigation, harbour and anchorage purposes, as well as possibly the site of a saltwater intake for a solar salt field).

(v) The effects of a major spill of Roller crude oil are impossible to predict with accuracy. For example, it is likely that many shallow water resources (particularly those that do not come into direct contact with drifting oil) will not be adversely affected. However, sensitive resources, such as corals (if exposed at spring low tide) or mangroves, which come into direct contact with spilt oil may be affected. The degree of impact will depend not only on the tidal cycle (neaps or springs), but also on the amount of weathering that has occurred and whether dispersants have been used. Localised mortality of organisms can be expected, but experience from oil-affected tropical systems indicates that recovery would be rapid (except in the case of mangrove assemblages exposed to undispersed oil).

(vi) The local brown tiger prawn fishery in Area 1 would be at risk if a large oil spill was to occur between late spring and summer when juvenile stages are concentrated in shallow water nearshore nursery habitats. The impact of such an oil spill would depend on the direction of spill, the area and type of coastal habitat affected, and the treatment strategy utilised. Data from the Exmouth Gulf prawn fishery suggest that the impact would be exacerbated if a cyclone was to produce a major flow out of the Ashburton River at or just after the oil spill, but would be reduced if such flow occurred after the end of January. In the worst case, the effect of a major spill impinging on the tiger prawn nursery may require temporary cessation of trawling in Area 1 for one or more seasons to promote recruitment of a depleted local stock.

ENVIRONMENTAL MANAGEMENT

West Australian Petroleum Pty Limited will implement an Environmental Management Programme aimed at minimising the environmental effects of the proposed oilfield development. WAPET proposes to achieve this objective by:

(i) complying with all legal requirements;

(ii) adopting industry and government standards and guidelines for well design and control;

(iii) utilising low toxicity drilling fluids approved by the Department of Mines;

(iv) implementing a discharge strategy aimed at minimising environmental impacts;

(v) expanding the existing workforce education programme;

(vi) expanding the existing Saladin Marine Biological Monitoring Programme;

(vii) expanding the existing Oil Spill Contingency Plan to include Roller;

(viii) tuning the selected development design criteria to minimise effects on local prawn trawling grounds; and

(ix) field decommissioning, involving the removal of the monopods and all subsurface objects that could hinder renewed trawling, fishing and navigation activities within exclusion zones.

The close proximity of the existing Saladin Oilfield means that oil spill combat equipment and facilities are already available in the area and considerable management experience with offshore developments is also available. The management record of WAPET to date is excellent, and continues to set the standard for the local oil industry.

CONCLUSION

Development and operation of the Roller Oilfield as proposed by WAPET will cause no major or significant adverse impacts on either the marine ecosystem, valued local marine resources or on the local community.

One minor adverse effect identified by this assessment is the temporary loss of access to a minor part of the local prawn trawling grounds as a result of the development occurring beside productive local fishing grounds. However, the life of the field is anticipated to be approximately six to eight years, and such loss is unlikely to markedly affect the economic viability of the fishery given the relatively small area affected. WAPET has already initiated direct discussions with local fishermen, and will continue to pursue all viable means to ensure that only minimal amounts of ground will be temporarily lost to the trawl fishery for the life of the development.

An additional minor impact is that the life of the Thevenard Island facilities will be extended by six to eight years, thereby extending the period of aesthetic amenity loss to holiday-makers on the Mackerel Island Resort.

The single most significant environmental concern associated with the proposal is the risk and potential effects of a large oil spill arising from a major accident. The chances of such an event occurring are considered extremely small given the geological properties of the Carnarvon Basin, the extensive pool of knowledge that has already been gained from drilling in the area, the level and extent of industry and government regulations and guidelines, and WAPET's impressive management record which dates back to 1953. Furthermore, refinement of the Oil Spill Contingency Plan, together with the equipment and logistical resources that are already available locally, will ensure that combat effectiveness against any oil spill will be maximised. Finally, characterisation of the Roller crude shows that it is already a weathered oil which has lost most of its light weight and more toxic components due to biodegradation within the reservoir. Thus the effects of an accidental spill of Roller crude that directly impinges on sensitive marine resources in a warm tropical environment are not anticipated to be severe or long-term. In the case of mangrove-lined creeks, most of an encroaching oil slick could be deflected to the 'down current' side of the creek mouth, and/or dispersed before it enters (dispersants have been found to reduce the risk of long-term effects on mangroves).

It is therefore concluded that the proposed project can be managed in an environmentally acceptable manner, and that the advantages ensuing from project go-ahead will considerably outweigh the very small environmental risk that is attached to all such developments. For example, both the State and the local community will derive financial benefit from the construction and operation of the oilfield, as well as benefit from the resultant increased stimulus to search for more oil and gas reserves.

ROLLER OILFIELD DEVELOPMENT

CONSULTATIVE ENVIRONMENTAL REVIEW

1 INTRODUCTION

1.1 THIS DOCUMENT

This document is a Consultative Environmental Review (CER), which has been prepared by LeProvost Environmental Consultants with assistance from, and on behalf of, West Australian Pty Limited (WAPET). The contents of the CER have been prepared in accordance with the Environmental Protection Authority's (EPA) guidelines, which are listed in Appendix 1.

The objective of the CER is to provide State Government and any interested party with information on the development and operation of the Roller Oilfield, and to describe and assess the effects of the proposal (both actual and potential) on the existing environment. The CER also describes the safeguards that will be taken to minimise the risk of an oil spill, and provides details of the contingency plan that will enable rapid activation of oil spill counter measures.

This CER draws from a considerable number of reports that have already identified and described the pertinent marine resources of the region, as well as summarising the results of recent and ongoing studies undertaken specifically for the Roller development. These studies include additional field surveys (to delineate environmentally sensitive habitats along the nearby mainland coastline); simulated oil spill tracking exercises; and comprehensive oil spill trajectory modelling. Roller crude characterisation and weathering studies are not yet fully completed, and thus current assessment of trajectories and effects of an accidental oil spill have taken a very conservative approach.

Data from the various completed and ongoing studies will enable upgrading and refinement of WAPET's existing Oil Spill Contingency Plan (OSCP) covering Permit Area TP/3 Part 1 (Appendix 6).

Section 1 of the CER provides details on the proponent, project background, need for the project and the legislative framework. Section 2 describes the proposed two options for the Roller development, while Section 3 discusses alternative options which have been rejected on grounds relating to technical, financial and environmental aspects. Section 4 of the CER describes the existing environment and Section 5 assesses the effects and identifies all potential impacts of the project. The environmental management and monitoring programmes, which are aimed at minimising effects and reducing the risk of oil spill impacts from occurring, are presented in Section 6. Conclusions are given in Section 7. Details of consultations during the preparation of the CER are given in Section 8, and references cited in the text are listed in Section 9.

1.2 THE PROPONENT

West Australian Petroleum Pty Limited is a Perth-based petroleum exploration and production company. WAPET has been operating in the North West Shelf region since 1953, and in 1964 made the first commercial oil discovery in Western Australia on Barrow Island, 97 km north-east of Onslow (Fig. 1). Barrow Island, a large Class 'A' reserve for the conservation of fauna and flora, straddles the inner and outer sectors of a 'Special Conditions Zone' for the purposes of offshore oil exploration and production (Fig. 2; Jones, Field & Hancock, 1984).

WAPET has also developed and presently manages the Saladin Oilfield located beside and on Thevenard Island (Fig. 1). Much of this island is a C-class reserve for conservation of flora and fauna. The Saladin Oilfield was commissioned in 1989 and is now producing oil. Wells at the nearby and much smaller fields of Yammaderry and Cowle (which were drilled in July 1988 and December 1989) have been tied into the Saladin production facilities on Thevenard Island.

WAPET is the operator of Permit Area TP/3 Part 1, which includes the production licence area TL/4 and contains the Saladin Oilfield, wells at Yammaderry, Cowle and Roller, and prospects at Weld, Thringa, Curlew, Hastings, South Trap Reef, Bessieres, Lightfoot, Australind and Snark (Fig. 3). All of these sites are located on the inner Rowley Shelf, and lie within an area designated as a 'Special Protection Locality' (SPL No. 32) for oil exploration and production (Fig. 2; Jones, Field & Hancock, 1984). In conducting these operations within TP/3 Part 1, WAPET acts as operator for a joint venture comprising:

- Chevron Asiatic Limited (25.7%),
- Texaco Oil Development Company (25.7%),
- Ampol Exploration Limited (12.8%),
- Shell Development (Australia) Pty Limited (25.7%), and
- Western Mining Corporation Limited (10%).

WAPET has operated on the Rowley Shelf for many years, consequently it has gained considerable experience in conducting oil exploration and production activities across the Shelf's relatively shallow tropical waters. These waters contain a variety of sensitive marine ecosystems and habitats. To obtain environmental approval for developing the Saladin Oilfield, WAPET submitted to the EPA an Environmental Review and Management Programme (ERMP) and then developed a detailed Oil Spill Contingency Plan (OSCP). This plan addresses the distribution of shallow marine habitats in the region of Thevenard Island and their varying sensitivities to oil [LeProvost, Semeniuk & Chalmer (LSC) 1987, 1988a]. WAPET also supervises a comprehensive Environmental Management Plan (EMP) for the Saladin Oilfield.

1.3 PROJECT BACKGROUND AND DEVELOPMENTS

Following environmental approval to drill exploration wells on the Roller prospect (LSC, 1989a; EPA, 1989), WAPET drilled the Roller No. 1 well in January 1990 and encountered oil-bearing strata approximately 900 m below sea level. Flow testing demonstrated reservoir crude oil (API 29.5° gravity). This well site is located in 11 m of water at 21° 38' 06" S and 114° 55' 33" E, a position approximately 20 km south-west of Thevenard Island and 22 km west of Onslow (Fig. 3).

The Roller No. 1 well was suspended (i.e. temporarily capped to enable re-entry at a later date), and a second well was directionally drilled from the same surface location to delineate the areal extent of the discovery. This well (Roller No. 2) was also subsequently suspended in accordance with Department of Mines regulations. The extent of the field was then further assessed by drilling exploratory well Roller No. 4, located almost 4 km to the north-west of Roller Nos 1 and 2 (Figs 3 & 4). Roller No. 4 was subsequently suspended and a buoy positioned above its 30" diameter surface casing.

WAPET has now decided to proceed with the development of the Roller Oilfield following a detailed evaluation of the various possible development concepts. It is anticipated that seven additional wells drilled from four monopod structures, plus the completion of Roller No. 4 at one of these monopods, are needed to develop the field. Project evaluation indicates that a peak production of approximately 7,949 to 9,538 kL of oil per day can be obtained, and that the best option to process, store and ship such volumes will be to use the nearby oil production facilities and tanker terminal at Thevenard Island. The use of the Thevenard Island facilities for the development of nearby fields such as Roller was addressed in the environmental assessment of the Saladin development (p. 12 in LSC, 1987), and such use was recommended by the EPA (p. 9 in EPA, 1987).

Preliminary details on possible development options for the Roller field were submitted by WAPET to the Department of Mines and the EPA for review and to help determine the level of environmental assessment. The level of assessment for project appraisal by the EPA has been set as a CER. Guidelines issued by the EPA in January 1991 are contained in Appendix 1.

1.4 NEED FOR PROPOSAL

Both the Commonwealth and Western Australian Governments recognise the need for Australia to maximise its self-sufficiency in oil, and actively encourage oil exploration and development. In this respect, the North West Shelf is becoming increasing important as an area which can help maintain Australia's self-sufficiency. Australia's overall level of self-sufficiency in petroleum products is expected to fall during the 1990s, with production from new developments unlikely to offset the decline in output from the nation's major oil producing area in Bass Strait. The demand for crude oil from Western Australia is therefore forecast to remain at high levels throughout the foreseeable future, and the proposal will enable Australia to sustain a higher level of self sufficiency during a critical period of forecasted overall decline in domestic oil production.

Moreover, increased current excise levies and State royalties on crude oil production as a result of the Roller development will form a substantial public revenue, the precise amount depending on the life of the field.

Finally, the construction and operation phases of the proposed development will provide an important source of direct and flow-on employment opportunities to the State, since a significant proportion of the construction and installation of facilities will involve expenditure and activities within Western Australia. For example, over 100 people are likely to be directly involved with the various construction activities, while the operation/production phase will provide full-time employment for between 15 and 25 personnel on site and at Perth.

1.5 LEGISLATIVE REQUIREMENTS

Both the Roller field and the existing production, storage and shipping facilities at Thevenard Island are located within the State's territorial waters. The Roller development will also straddle the western boundary of the Onslow Port Limits.

Exploration and production permits within the State's territorial sea require the licence holder to comply with the regulations of the *Petroleum Act, 1967* and *Petroleum (Submerged Lands) Act 1982*. Under these State Acts, a successful explorer making a commercial discovery must notify the Minister for Mines. Following the Minister's subsequent declaration of a 'location' within the nominated discovery block, a production licence is then issued (normally within two years).

A production licence for the Roller field will authorise WAPET to recover petroleum from the licence area, to explore for further petroleum within the discovery block, and to carry out the operations and works necessary for producing the oil. To these ends, the same legislation covers the licensing for installation and operation of subsea pipelines. Conditions the Minister for Mines may attach to the issue of production and pipeline licences can be supplemented by additional environmental safeguards as recommended by the EPA under the provisions of the *Environmental Protection Act, 1986*. Other State laws whose provisions can directly or indirectly apply to the development and/or operation of the Roller field include the following:

Conservation and Land Management Act 1984 (WA);
Environment Protection (Sea Dumping) Act 1981 (Cwlth)*;
Fisheries Act 1905 (WA);
Marine and Harbours Act 1981 (WA);
Marine Archaeology Act 1973 (WA);
Marine Navigation Aids Act 1973 (WA);
Pollution of Waters by Oil and Noxious Substances Act 1987 (WA)*;
Prevention of Pollution of Water by Oil Act 1960 (WA)*;
Shipping and Pilotage Act 1967 (WA);
Western Australian Marine Act 1982 (WA);
Western Australian Marine (Sea Dumping) Act 1981 (WA)*;
Wildlife Conservation Act 1950-1980 (WA).

(* Refers to transfer and/or discharge operations on supply vessels, tankers, etc.)

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James Masters, Western Australian Marine Research Laboratories, Waterman; and

Nello Siragusa, Department of Marine and Harbours, Fremantle.

2 PROJECT DESCRIPTION

2.1 LOCATION AND DEVELOPMENT OF THE RESOURCE

The Roller Oilfield is located approximately 6 km from the mainland, halfway between the mouth of the Ashburton River and Ashburton Island (Figs 3 & 4). The position of Roller No. 4, which is the only exploratory well planned at this stage to be re-entered and developed, is 22 km west of Onslow at 21° 36' 46" S and 114° 56' 45" E. Water depths over the field average 10 m, ranging from 5 m over shoal areas to over 11 m in other areas. The bathymetry of the area is shown in Figure 4.

Existing wells between Roller and Thevenard Island (i.e. the Cowle No. 1 and Yammaderry No. 1 wells; Fig. 4) will not form part of the Roller development. Yammaderry is tied into the existing Saladin 'C' pipeline to Thevenard Island, while production from Cowle is piped directly to the facilities on Thevenard Island (Figs 5 & 6).

Development of the Roller field will involve a construction phase during which seven new development wells will be drilled at four locations. Drilling operations at one of these sites will also include re-entering and completing the Roller No. 4 well to produce a total of eight production wells. Field development will be followed by an operational/production phase, which in later life may require up to two additional wells to be drilled from the existing monopod wellhead structures in order to extend field life and/or maintain production rate.

Present data indicate that peak production from the field will be approximately 7,949 to 9,538 kL (50,000 to 60,000 bbl) of 29.5° API crude oil per day, with eight wells installed.

2.1.1 Installation of Development Wells

WAPET is presently examining two options for producing crude from the four monopod wellhead structures. Both options utilise the same monopod locations, and differ only by the location of the gas separation and compression facilities (see Figs 5 & 6). Therefore both options will require the following tasks:

- install monopods at four locations [i.e. one monopod (Roller D) at the existing Roller No. 4 well, and three others (Roller A, B & C) at sites up to 6 km south-east from Roller D];

- drill and complete development wells at the Roller A, Roller B, Roller C and Roller D monopods; and

- complete the Roller No. 4 well at Roller D.

Details of the proposed monopods are as follows:

	Roller A	Roller B	Roller C	Roller D
Probable location:				
Latitude	21° 38' 36" S	21° 38' 21" S	21° 37' 35" S	21° 36' 46" S
Longitude	114° 54' 33" E	114° 55' 35" E	114° 56' 05" E	114° 56' 45" E
Water depth (LAT)	9.0 m	10.4 m	10.0 m	9.7 m
Development wells:	2 wells 1 spare slot	2 wells 1 spare slot	2 wells 1 spare slot	Complete Roller 4 1 additional well 1 spare slot

Provision of the spare slots will allow for two additional development wells to be drilled at any two of the four monopods at a later date, if required. Depths at LAT refer to the water level at the lowest astronomical tide (maximum tidal range is approximately 1.8 m).

Roller D is 2.0 km south-south-east of Ashburton Island and will lie just inside the western boundary of the Onslow Port Limits (Fig. 4). The monopod closest to the mainland is Roller B, whose location is 6.3 km from Entrance Point (Fig. 4).

2.1.2 Completion of Field

The two proposed options for producing the field differ only in the location of the gas separation/compression facilities, which will be either installed offshore and alongside Roller D, or located onshore at WAPET's existing lease on Thevenard Island. The onshore location (Option 1) requires a 20" diameter, 26 km long, three-phase subsea production line to transmit produced fluid (gas/oil/water) from the Roller A, B, C and D monopods to Thevenard Island, while the offshore location (Option 2) will require a 10.75" diameter, 20.5 km long, two-phase subsea production line from the gas separation and compression facility on the jack-up rig to Thevenard Island. Compressed gas will be returned either from separation facilities on Thevenard Island (Option 1) through a 6.6" diameter line, or from the jack-up rig (Option 2) through a 4.5" diameter line, to the monopods to enhance oil recovery by gas lift. Whichever option is finally selected, it is planned to trench sections of the pipeline(s) between the Roller development and Ashburton Island to enable continued commercial prawning operations across trawl grounds.

(i) Option 1

This option is shown in Figure 5, and comprises the commingling of unseparated product at the field and its transmission to Thevenard Island via a large three-phase production line. Gas would be separated and compressed on Thevenard and returned to the four monopods for gas lift. A helideck installed on each of the unmanned monopods will allow access for testing of individual wells and maintenance operations during the life of the field. Access to the monopods by vessel is also possible.

Option 1 will require the following tasks:

(i) install a 26 km long, three-phase production line and gas-lift line between Thevenard Island and Roller A;

(ii) connect Roller B, C and D to the production and gas-lift lines; and

(iii) install additional equipment within the existing lease area on Thevenard Island to process the Roller crude oil.

(ii) Option 2

This option is shown in Figure 6, and comprises a single, but much shorter three-phase production line to transmit commingled production from the four monopods to gas separation and compression facilities aboard a modified jack-up rig or fixed steel jacketed platform. The potential environmental impacts associated with both the jack-up and fixed steel jacketed platform will not vary significantly, and therefore the two options have been considered together. For simplicity, the remainder of this document refers to a jack-up rig only. The rig (a jack-up or fixed platform) will be positioned alongside Roller D. Gas would be separated and the crude oil and water pumped to Thevenard Island via a two-phase production line. Gas would be compressed on the jack-up rig and returned to the monopods for gas lift, with excess gas flared off from the jack-up rig. Preliminary studies indicate that the total volume of gas in the Roller Oilfield is very low. The economic viability of marketing the gas was investigated by WAPET. Transporting of gas via a pipeline from the Roller Oilfield to the (then proposed) Tubridgi gas pipeline was found not to be economically feasible. Additional separation equipment will be installed on Thevenard Island to process the Roller crude oil.

Helidecks and test separators would be installed on all monopods except Roller D, which will be bridge-connected to the jack-up rig. The jack-up rig will be manned by up to 18 workers, and will provide essential overnight and domestic services in case bad weather prevents access by helicopter or vessel.

Option 2 therefore requires the following tasks:

(i) install a modified jack-up rig with gas compression and separation equipment alongside the Roller D monopod;

(ii) install a flexible, bridge-supported three-phase production hose and gas-lift hose between the jack-up rig and Roller D;

(iii) install a 5.4 km long, three-phase production line and a gas-lift line between Roller D and Roller A (via the Roller B and C monopods), and connect Roller B and Roller C to these lines;

(iv) install a flexible, bridge-supported hose for returning separated production (oil/water only) to Roller D from the jack-up rig; and

(v) install a 20.5 km long, two-phase (oil/water) crude transfer line from Roller D to WAPET's production and storage facilities on Thevenard Island.

2.2 PROJECT TIMETABLE

The present anticipated schedule for project development and operation is listed below:

September 1991: Complete feasibility studies, preliminary site investigations and reservoir engineering/simulation studies.

May 1992: Commence installation of production/separation facilities on Thevenard Island.

June 1992: Commence modifications to procured jack-up rig (if Option 2 development has been selected).

September 1992: Complete design, procurement and fabrication of Roller A monopod.

October 1992: Commence load-out and transport of monopods to Roller field.

November 1992: Commence development drilling and monopod installation at Roller field.

January 1993: Commence installation of subsea pipelines.

April 1993: Complete development drilling and monopod installation.

May 1993: Complete pipeline installation, install jack-up rig (if Option 2 selected), and begin commissioning production facilities.

July 1993: Complete field commissioning and enter full production phase.

Drilling operations and monopod installation at each wellhead are expected to take approximately six weeks, and a further four weeks will be required at Roller D to install the modified jack-up if Option 2 is selected. Installing the three or two-phase production line from Roller to Thevenard and the various pipelines in the field is expected to take four months.

The precise timing of drilling and other offshore development operations is always constrained by factors such as rig availability, work schedules in nearby areas, and commercial and/or environmental limitations. The present project timetable should therefore be viewed only as a guide to development timing.

2.3 DETAILS OF CONSTRUCTION PHASE

2.3.1 Well Development and Completion

The development wells at Roller A, B and C are planned to be drilled between November 1992 and March 1993. The single development well at Roller D will be drilled in March-April 1993, a period during which the suspended Roller No. 4 exploratory well will also be re-entered and developed.

The four prefabricated monopods, similar to those designed for Cowle and Yammaderry, will be transported to the Roller field and be secured to the seabed. The development wells will be drilled, and then the decks will be set.

2.3.1.1 Rig Operations

A cantilever jack-up drilling rig will be towed to each of the four monopod locations and jacked up to some 20-30 m above the sea surface. Two supply vessels will be used for rig towing and positioning, and to supply it with fresh water, fuel, dry bulk cement, drilling fluid materials, food and drilling hardware. These vessels will operate principally between Port Hedland or Dampier and the Roller field.

Prior to spudding in (initiating drilling) the rig operator will conduct a number of surveys and tests in accordance with Department of Mines regulations to ensure the stability of the rig and to minimise the risk of abnormal penetration of the seabed during storm conditions. Cyclone contingency plans are routine aspects of rig operations in tropical waters, and include procedures and directives for securing the well and rig and the evacuation of personnel. Cyclone warnings provide sufficient time to secure the well (wherein the well is temporarily plugged, the drill string is detached at the wellhead, and the blowout preventers above it are closed).

2.3.1.2 Drilling Procedures

Details of the development well designs are presented in Table 1 and schematically presented in Figure 7. One of the most important aspects of drilling is to prevent a blowout. This is achieved by ensuring that the density of the drilling fluid circulated down the hole produces a pressure greater than the opposing pressure of the formation being drilled. If the pressure of a permeable formation exceeds that of the drilling fluid column, the well can start to flow. Several procedures are utilised to contain an influx in this event, including the installation of a blowout preventer (BOP) stack during the initial stages of drilling.

One BOP contains several independently-controlled hydraulic pipe rams that can force together horizontal plates for sealing off the well. These plates have a rubber-lined semi-circular hole which provide a tight seal around the drill pipe. Above these plates is the annular BOP, a hard rubber bag that is inflated with hydraulic fluid. Inflating this ring also seals the hole, since the bag squeezes inwards onto the drill pipe or any other object protruding down this section of the well. The drill string and any cables, lines or objects passing through the BOP stack at the time of the emergency can also be chopped off by a set of shear rams located beneath the annular BOP.

The BOP stack is sealed to the riser of the casing and tested in accordance with Department of Mines regulations after this surface casing has been installed. All the casing strings below the casing are cemented in and pressure tested in accordance with Department of Mines regulations before drilling is resumed. Pressure testing includes the exertion of maximum drilling mud pressures that will be exerted on the formation during subsequent drilling.

Several procedures are employed to maintain sufficient drilling mud pressure and prevent formation fluids from entering the hole. These include various electronic and manual monitoring devices for monitoring formation pressures, and for detecting increases in the volume of returned drilling mud, methane traces or drill penetration rate. Other features, such as the shape of rock flakes and/or a decrease in the density of shale cuttings, are also monitored.

If formation fluids succeed in flowing into the hole, this event is detected by an increase in the volume of drilling fluid returning to the rig. This is known as a 'kick', and the well is immediately brought under control by closing it in with a BOP and pumping mud down the hole through the drill string. The mud then passes back up towards the rig, and past the annulus via the 'choke' line on the BOP stack. Pumping the mud provides increased back-pressure to prevent further kicks, whilst at the same time removes the initial influx of oil or gas. Normal operations can be resumed after increasing the density of the drilling mud until it exceeds the formation pressure.

Blowouts are very rare, but can result from insufficient knowledge of the type or condition of the various strata that are being penetrated. However, substantial experience has been gained from previous wells in Permit Area TP/3 and the Carnarvon Basin (including Roller Nos 1, 2 and 4), so the risk of a blowout occurring is extremely low (see Section 5.2).

2.3.1.3 Drilling and Rig Discharges

The various wastes and disposal methods used on the drilling rig are as follows:

- Drill cuttings - disposed of into the ocean after separation from drilling fluid through solids control equipment.
- Drilling fluid residue - disposed of into the ocean at infrequent, controlled intervals.
- Deck drainage and lubricating oil wastes - the former disposed of into the ocean after passing through an oily water separator, the latter collected and transported to a designated land site.
- Domestic wastes - comprising sanitary waste (comminuted and disinfected before disposal into the ocean), kitchen/food waste (macerated then disposed overboard), and solids/packaging waste (burned or disposed at a designated land site).

Details on these operational discharges are presented in the following sections.

(i) Drill cuttings

Drill cuttings, coated with a residue from the drilling fluid, form the predominant waste material. The residue originates from the mud slurry that is used to control pressure within the hole, to lubricate and cool the drill string and bit, to transport the cuttings from the bottom of the hole to the surface, and to stabilise the wall of the hole.

Operations for each well will first involve either the installation of a monopod, or drilling an initial hole and inserting and grouting a structural casing to -30 m. In the latter case, the umbilical used to convey the cuttings to the rig deck and to recirculate the drilling mud cannot be located at this stage, and therefore approximately 36 m^3 of limestone cuttings will be deposited directly on to the seabed. In the first case, sediments are displaced to the side of the hole since the monopod is inserted into a shallower but wider hole (produced by displacing sediment with a drill). The monopod is then grouted with concrete. In both cases, some 30 m^3 of inert drilling mud will also be lost when either the structural casing or the monopod is installed prior to drilling the remainder of the well.

The diameter of the hole drilled below the monopod or structural casing will be 17½" from -45m to -230 m. Below this level, the length of the subsequent smaller diameter hole will depend on the type of well that is being drilled (Table 1; Fig. 7). Vertical wells (Type A) will have a 12¼" hole from -230 m to -955 m, while horizontal wells (Type B) will have a longer 12¼" hole (length 1120 m), and then an 8½" hole some 300 m long (Table 1; Fig. 7). 'Hi-angle' Type C wells, which are not expected to be required, would have a 1075 m long 12¼" hole drilled from -225 m (Table 1; Fig. 7).

Whichever well type is drilled, cuttings from the sections below the initial casing will be lifted by the drilling fluid to the solids control equipment on the rig platform, where the solid and liquid phases are separated. Solids are discharged at the rig site, while liquids are returned to holding tanks before recirculation down the well. A minor quantity of this liquid adheres to the solids discharged overboard.

Previous drilling of Roller exploratory wells indicates that the cuttings will be of a consolidated carbonate nature to a depth of approximately -230 m, and that a total of some 36 m^3 of these carbonate cuttings will be discharged over one day (Table 2). From -230 m to -955 m, claystone, siltstone and minor amounts of sandstone will be drilled, with the total volume of discharged cuttings being approximately 70 m^3 over five days. The amount of sandstone/claystone cuttings generated below this depth depends on the well type (some 17 m^3 over 3.5 days provides a rough guide).

As with the exploratory wells, it is proposed to dispose the total of some 145 m^3 of drill cuttings at the rig sites for the following reasons:

- the cleaned cuttings are inert and consist mainly of particles approximately 0.6 mm^3 in volume;
- both the rate and total volume of the drill cutting discharge are low;
- none of the four proposed wellheads lie beside or close to shallow reef areas; and
- seawater turbidity at these relatively nearshore locations is often naturally high.

(ii) Drilling fluid

The composition of the drilling fluid used in drilling the geological structure at Yammaderry No. 1 is given in Table 3, along with the quantity and the percent of the total weight of materials added. Ninety percent of the drilling fluid is composed of seawater that has a density of 1.14 kg/L after the addition of the various chemical components.

The primary drilling fluid for the first 230 m will consist of seawater, with small additions of high viscosity materials such as bentonite or non-toxic polymers below -45 m. From approximately -230 m to the bottom of the well, a KCl-polymer-seawater drilling fluid will be used. These fluids are approved by the Department of Mines and the EPA, and meet United States Environmental Protection Agency criteria for offshore use.

The drilling mud programme shown in Table 3 is expected to be similar for all of the Roller wells. Based on WAPET's experience with wells in TP/3 Part 1, the total volume of drilling fluid per well is expected to average about 800 kL.

A small volume of the drilling fluid will be lost as a film coating on the cuttings discharged into the ocean. The balance of the used drilling fluid will be discharged at times when the volume contained in the rig's mud storage tanks approaches capacity. This discharge does not occur frequently, and will be confined to periods of strong tidal movement to ensure adequate dilution and dispersion before reaching shallow water and shorelines. The fluids will be discharged under the direction of the drilling superintendent at about 159 L/min.

(iii) Deck drainage and oily wastes

The rig storm drains are ducted to a separation tank where the oil is drawn off into drums for shipment onshore. The separated water is then discharged overboard. Containment areas exist at all areas where oil products are likely to be used or stored. These areas drain into a waste oil tank from which the oil is pumped out and transported to Thevenard Island or Barrow Island for separation in the production facilities.

(iv) Domestic wastes

Sanitary and liquid wastes from the kitchen, showers and laundry are passed through a sewage treatment plant for comminution and disinfection prior to being discharged overboard. The treated discharge amounts to approximately 80 m^3 of water per day. Solid food waste is macerated before disposal overboard.

Biodegradable detergents will be used for cleaning functions. Combustible materials such as packing cases, sacks and cardboard food cartons, etc. are burnt on the rig. All non-combustible material (e.g. glass, metal and plastic containers) will be returned to the shore base for disposal at an approved land site.

2.3.2 Wellhead Completion and Subsea Pipelines

Each monopod will have automatic safety controls. Flow from the reservoir will be directed into the three-phase production line. The production line will transmit commingled production from each monopod to Thevenard Island or the jack-up rig at Roller D.

All subsea lines will be stabilised. Pipelines will be trenched where they cross commercial trawling grounds lying between Roller A and Ashburton Island (see Section 4.3). If Option 2 is selected, the various lines between the monopod at Roller D and the modified jack-up rig will run along a piperack bridge (Fig. 6).

The pipeline route to Thevenard Island, which does not cross reef or shoal areas, is shown in Figure 8. The route traverses the north-west corner of the Onslow Port limits. Water depths along the route vary from 8 m to 13 m, with an average depth of 10 m. If ongoing field surveys indicate that the proposed trenching operations may be unworkable in prawn trawling areas, methods for further stabilising the pipelines to allow trawling will be reviewed.

It is anticipated that pipelaying operations will be conducted from a barge between January and April 1993. The shoreline crossing at the south-eastern corner of Thevenard Island will be achieved by re-entry of the existing Saladin 7 flowline traverse.

2.3.3 Completion of Separation/Production Facilities

As described earlier, Option 1 differs from Option 2 in the location of the gas separation and compression facilities at Thevenard Island instead of at a jack-up rig located next to the Roller D monopod.

(i) Option 1

Preliminary estimates of the combined total flow from Roller, Cowle, Yammaderry and Saladin to the production facilities at Thevenard Island suggest that one additional separator unit may be required at Thevenard Island. All other existing facilities at Thevenard Island will be analysed to determine if they have sufficient capacity to deal with the additional flow. Plans for upgrading accommodation facilities at Thevenard have already been submitted to and approved by the Department of Conservation and Land Management (CALM). Work is currently underway on upgrading the existing flare to meet EPA and CALM requirements on light emissions. Figure 9 shows the location of these facilities. The oil will be stored and transferred to tankers along with the produced oil from Saladin.

(ii) Option 2

Production facilities that would be installed offshore on the modified jack-up or fixed platform alongside Roller D include a liquid/gas separator, gas compressor and transfer pumps.

If sufficient gas is produced it will be separated from the produced fluid and compressed on board the rig for return to the monopods via the gas-lift line to assist with crude production (Fig. 6). Gas not required for fuel or gas-lift will be flared from the rig. Liquid production will be pumped 20.5 km via the two-phase production line to Thevenard Island, where water separation, crude oil storage and transfer to tankers will occur as with Option 1.

2.3.4 Crew Transport and Supply Vessel Operations

During development drilling, the drilling workforce (up to 82 personnel) will be accommodated on the drilling rig. The workforce that will install and complete the monopods and other offshore facilities (up to 40 personnel) will be accommodated at a temporary construction camp at Onslow, and/or on the development drilling rig. No additional temporary accommodation will be needed other than that currently deployed on Thevenard Island for the Cowle and Yammaderry development (Fig. 9).

Drilling rig crew changes will occur via Barrow Island using a helicopter which will visit the rig approximately six times per week. Pilots will be instructed not to overfly islands. Construction personnel based at Onslow will be transported to the field by fast ferry and/or helicopter on a daily basis.

Two supply vessels will transport heavy and bulk supplies between Port Hedland or Dampier and the drilling rig. Between one and two round trips per week per vessel is anticipated at the peak of the construction phase, with additional vessel movements out of Onslow. Masters of barges and supply vessels will be instructed not to allow crew to disturb islands or wreck sites, nor to anchor close to coral reefs. It will be a contractual requirement for the various supply vessels and barges to comply with all State and Commonwealth legislation for the control of pollution and dumping at sea.

Diesel fuel transfers from supply vessels to the drilling rig will take place approximately once a month during the period spent at each monopod location. All refuelling operations will be conducted in accordance with strict Port Authority requirements, including continuous visual monitoring and the use of reinforced hoses and fail-safe valves and fittings. A smaller stand-by vessel will have a mooring in close proximity to the drilling rig, and will be in the vicinity at all times to deploy an oil spill containment boom and skimmer in the event of an oil spill. The boom will be stored either on the drilling rig or the stand-by vessel. The skimmer will be held on Thevenard Island and can be mobilised by helicopter to the Roller location within one hour. Helicopters and self-propelled barges, presently contracted to WAPET and operating between Onslow, Thevenard Island and Barrow Island, can be used to transport additional oil spill equipment should the need arise.

2.4 PRODUCTION PHASE

2.4.1 General

The wells, monopods, subsea flowlines and offshore equipment planned for both development options are designed to operate automatically. Thus the offshore facilities at Roller will not require 24 hour attendance during normal operational conditions, except in the case of Option 2, where personnel will be required on the jack-up rig next to Roller D to monitor gas separation operations. All production operations on Thevenard Island are currently monitored on a 24 hour basis.

Produced Roller crude will be processed and shipped from Thevenard Island along with the declining volumes of crude produced from Saladin and the small fields at

Yammaderry and Cowle (Fig. 8). Crude produced from the Roller field is expected to be exhausted by 2001, two years before the end of the design life of the monopod wellhead structures.

2.4.2 Production and Shipping Operations

Operation and maintenance procedure manuals based on WAPET's experience of the Barrow Island and Saladin fields will be prepared and made available for review by relevant statutory authorities prior to project commissioning. These manuals will cover normal and emergency procedures.

The design, installation, testing, operation and maintenance of the various offshore components will be subject to the regulations and approval of the Department of Mines. Safety aspects of the automatic offshore facilities and lines are similar to those designed for the existing Saladin, Cowle and Yammaderry developments.

The subsurface valve located below seabed level in each producing well, and kept open by via hydraulic pressure lines running from the monopod platform, serves as an important safety device in the event of abnormal operation or accident. Apart from the safety valve, the pressure-actuated master valves, wing valves and annular valve on the stack are also able to be automatically or manually closed to provide full emergency shutdown. Shut-down can be effected manually from Thevenard Island as well as from control panels located on site.

The safety valve will close when hydraulic pressure falls as a consequence of sensors detecting pipeline rupture, abnormal pipeline pressures increases, or fire. Compressor failure, damage to the jack-up rig or the monopod will also lead to valve closure owing to the fracture of the hydraulic lines or the failure of the hydraulic accumulator or other plant on the platform. The volume of oil that can escape from a ruptured undersea pipeline is limited by the presence of non-return valves which prevent back-flow and over-pressurisation.

No additional storage or tanker transfer facilities will be required on Thevenard Island since the increase in Roller crude production will coincide with the decline in Saladin production. At present, four tankers (between 100,000 and 120,000 tonne DWT) are loaded at the offshore terminal each month. Local tanker movements and mooring are piloted by company mooring masters. The number of shipments will not increase, and are expected to remain at a level of four per month until 1998. Design and operational details of the tanker loading facility at Thevenard Island are described in LSC (1987), and were assessed by the EPA in 1987 (EPA, 1987).

2.4.3 Production Workforce

Accommodation arrangements for personnel associated with the Roller field production activities are still under review. It is presently anticipated that personnel requirements for Option 1 include an additional five people on Thevenard Island, with daily helicopter flights between Thevenard Island and the Roller monopods. Up to 18 personnel may be required should Option 2 (jack-up at Roller D) be selected. This workforce would be accommodated either on the platform on a 24 hour basis, or on Thevenard Island with day and night shifts being transported to the rig by helicopter or boat.

Regular visits by helicopter or vessel to the monopods are required for routine wellhead testing and monitoring purposes. Some visits will involve mandatory underwater inspections, maintenance and/or cleaning operations. Crew transfers between Roller, Thevenard Island and Perth will use existing routes involving helicopter/light aircraft transfers to Barrow Island, and then chartered commercial jet flight direct to Perth.

2.4.4 Production Discharges

If Option 2 is selected, routine domestic and sanitary waste discharges at the jack-up will be very low as only 18 workers will be on board the jack-up rig. The various production decks will contain storage areas to hold lubricants, oils and oil-based products for maintenance purposes. Old lubricants from oil changes, together with other oily wastes produced by servicing operations, will be removed at frequent intervals for onshore disposal through the Thevenard Island or Barrow Island production facilities.

The principal discharges from producing Roller crude (using either Option 1 or Option 2) will therefore comprise natural gas (flared either at Thevenard Island or the jack-up rig at Roller D) and produced water (compliance treated and discharged into the ocean at Thevenard Island) (Fig. 10).

Natural gas will be utilised for power requirements and gas-lift of product with the remainder flared off. It is not possible to forecast precisely the amount of water that will be produced from the field, although it is likely that very little will be produced for the first 12-18 months. Later on in field life, the volume of produced water can be expected to rise to a maximum ratio of approximately 95% water. Economics will dictate the ratio of oil to water at the end of the field life. The total amount of discharged water should not exceed the capacity of the existing Thevenard Island water treating facilities. The concentration of hydrocarbons in all produced water will be reduced by treatment plant so that discharges will comply with Clause 616 of the *Specific Requirements as to Offshore Petroleum Exploration and Production, 1990* [issued under the provisions of the *Petroleum (Submerged Lands) Act 1982*]. Thus concentrations will not exceed 50 ppm at any time, nor a 30 ppm average over 24 hour periods.

2.5 PROJECT DECOMMISSIONING

Present data indicate that production from the Roller field will gradually fall to a point where the volume of produced water is so large that operation of the field is no longer viable. At most, field life could be extended to 2003 given the design life of the monopods and the success of the planned additional development wells (see Section 2.1).

At the closure of the field, the wells will be plugged and sealed with concrete, and the surface casings cut off at 4 m below the surface of the seafloor, as is presently required by the Department of Mines for the abandonment of dry wells. The monopods and jack-up rig (if present at Roller D) will be removed. No subsurface structure will be left protruding from the seabed so as to cause a hazard to navigation or fishing operations. Subsea pipelines will be flooded with seawater and left *in situ*, unless specific requirements deem their removal in certain areas.

Decommissioning and removal of facilities at Thevenard Island may not be linked with the exhaustion of the Roller field, since their operational life will be affected by the status, location and life-expectancy of other fields and prospects located within Permit Area TP/3 Part 1.

3 EVALUATION OF ALTERNATIVE OPTIONS

Conceptual feasibility studies were undertaken for the Roller development using geological data and information from production tests at Roller Nos 1 and 4.

There are no viable alternatives to the transmission of produced crude to Thevenard Island for storage and transfer. For example, the wide area of relatively shallow water (less than 15 m deep) and proximity of islands, coral reefs and shoals do not permit the safe use of a 'Floating Production, Storage and Offloading Platform' (FPSOP), i.e. such as a converted oil tanker.

Apart from identifying the two preferred options described in Section 2, the feasibility studies also evaluated two other technically-feasible options enabling transfer of Roller crude to Thevenard Island. These options, which are described in the following sections, were found to be considerably less desirable for both financial and environmental reasons.

3.1 OPTION 3: USE OF ASHBURTON ISLAND

This option is also similar to Option 2 except that the gas separation and compression facilities would be installed on Ashburton Island instead of offshore at Roller D. Surplus gas would also be flared on this island, and a two-phase production line would transmit the Roller production from Ashburton to Thevenard Island. Day accommodation, a helicopter pad and a beach landing point for regular access by barge and supply vessel would also be required, as well as trenching and possibly reef blasting in order to achieve a suitable gradient for a secure nearshore and intertidal crossing of the pipelines.

The scale of the required facilities and the degree of disturbance to Ashburton Island, which is a C-class nature reserve and managed by CALM, were considered unlikely to be acceptable given the feasibility of alternatives. Ashburton Island is encircled by a nearshore and shallow subtidal coral reef and provides important bird nesting and turtle breeding grounds (see Section 4).

3.2 OPTION 4: MAINLAND FACILITY

Installing the gas separation and production equipment on the nearby mainland avoids the problem of disturbance to important island habitats, coral reefs and breeding grounds. However, the coastline closest to the Roller Oilfield comprises the Ashburton River delta, a remote area that contains one of the largest and least disturbed semi-arid mangrove assemblages on the Pilbara coastline (Section 4.2).

While this area could be avoided by installing the onshore gas separation and compression facilities further east and closer to Onslow, the increased distance from the Roller field makes this option uneconomic owing to the cost of installing, operating and maintaining the long subsea pipelines. The suitability of available land sites is also poor, since much of the low-lying land along this stretch of the coastline is susceptible to periodic inundation by either river flow or cyclonic surge (see Section 4).

3.3 THE 'NO DEVELOPMENT' OPTION

The disadvantages of not developing the Roller field are clearly recognisable from Section 1.4 ('Need for the Proposal'). Lack of development would also discourage future offshore exploration activities in Western Australia, since the considerable exploration expenditures of the Australian oil industry are made on the understanding that the discovery of economically recoverable hydrocarbon reserves entitle the discoverer to develop and produce them.

4 DESCRIPTION OF ENVIRONMENT

This section summarises the salient physical, biological and social features in the region of the Roller development. Much of the information has been drawn from environmental studies and appraisals pertaining to WAPET's activities in Permit Area TP/3 Part 1. These include the recent development and current management programme of the Saladin Oilfield at Thevenard Island, the recent exploratory drilling programme at Roller, and WAPET's current application for approval for permit-wide drilling (see LSC, 1987, 1988a, 1989a, 1989b, 1990; LEC, 1990). Pertinent information has also been obtained from the 1987 Onslow Coastal Study for the State Planning Commission (SPC, 1987), and from some recent technical studies associated with the proposed solar salt project at Onslow (in Gulf Holdings, 1990).

Information drawn from the above literature has been supplemented by the results of field studies which have been undertaken specifically for the Roller development. Full details on the methods and results of these studies are given in Appendices 2, 3 and 4.

4.1 PHYSICAL ENVIRONMENT

4.1.1 Climate

The Onslow region lies within the southern part of the arid tropical coastline of the Pilbara. The average maximum summer and winter temperatures for Onslow are 36°C and 26°C respectively. Very hot summers and mild to warm winters are experienced, with maximum temperatures exceeding 30°C and 40°C on an average of 217 days and 25 days each year, respectively. Daytime winter temperatures usually exceed 25°C, while night time minimum temperatures range between 12°C and 14°C.

Mean annual evaporation at Onslow is very high (3,166 mm), while annual rainfall is low (266 mm), but highly variable, with most falls occurring during the first half of a 'wet' season that extends from January to July. Significant rainfall is usually associated with summer thunderstorms or cyclones.

The heaviest falls accompany tropical cyclones that affect the region typically between January and April (Logan, Brown & Quilty, 1976). The annual average number of cyclones passing within 360 km of Barrow Island is 2.4, with an average of 1.5 cyclonic events having wind speeds of greater than 100 km/h affecting the Onslow region each year (LSC, 1987). Such events have produced the highest recorded 24 hour rainfalls in Onslow for January (158 mm), February (356 mm), March (283 mm) and April (157 mm), which in turn cause major distortions to the normally low annual average.

4.1.2 Winds

Winds from the southern quadrants are prevalent throughout all seasons in the Roller development area (Figs 11 & 12). Detailed descriptions of the synoptic meteorology and the various wind conditions affecting this region are given in Appendix 4.

Measurements of wind direction recorded at Thevenard Island between February 1987 and January 1988 (Table 4) show that winds from the west, south-west, south and south-east occur for 71% of the time. The mean wind speed at Thevenard Island (derived from 10 minute recording intervals) over this period was 18.75 km/h, with winds above 29 km/h (8 m/s) occurring for 6.9% of the time (Table 5).

During winter (June-August), winds from the south, south-east and east predominate as a consequence of the higher latitudinal position of the subtropical ridge (high pressure belt). Wind speeds of these relatively cool and dry 'south-east trades' typically range from 8 to 30 km/h. However, gradient intensification (produced by intense high pressure cells lying to the south of low pressure areas to the north) can produce easterly gales with wind speeds up to 72 km/h (20 m/s) (Appendix 4 & Steedman Science & Engineering, 1991).

The south-east trades can also be enhanced in the mornings by differential night time cooling of the land, and moderated in the afternoons following daytime heating. This feature is most noticeable during the transitional periods at the beginning and end of winter (i.e. April-May and September). The September transitional period generally marks the time when the subtropical ridge retreats to the south and the summer heat low begins to form for brief periods. Thus wind speeds and direction tend to be most variable in these transitional months (Steedman Ltd, 1986).

During the summer months (October to March), the main flow of air in the region is westerly to south-westerly, with wind speeds averaging between 15 and 30 km/h. The direction of this moist synoptic airstream results from the position of the semi-permanent heat low which forms over northern Australia. Its direction in the Roller development area is also influenced by local land and sea breezes, which are produced by the strong differential heating and cooling of the nearby mainland during the daily cycle (Fig. 12). Intensification of the pressure gradient between the 'summer low' and high pressure systems to the south can produce strong westerly to south-westerly winds that over-ride land breezes for periods between three and four days.

4.1.2.1 Storm Winds and Cyclones

Apart from pressure gradient intensification previously described, storm-strength winds in the region are produced by squalls associated with thunderstorms and tropical cyclones. The sources, principal months of occurrence, speed, duration and direction of storm-strength winds are summarised in Table 6.

Pressure gradient storms between May and September produce easterly gales with gusts often exceeding 80 km/h. Thunder squalls and occasionally water spouts (small tornados) occur between November and April, and can generate localised gusts of over 90 km/h and 180 km/h respectively (Table 6).

Strong winds from the north and north-west are usually associated with the passage cyclones (Logan, Brown & Quilty, 1976). Cyclones generally develop in the Timor Sea or Arafura Sea between November and April, and typically travel in a south-westerly direction parallel to the Kimberley and Pilbara coasts. However, sudden course alterations which move cyclones southwards (or even south-eastwards) towards the Onslow coastline are not uncommon; on average the Onslow area experiences strong winds (>80 km/h) from 1.5 cyclonic events each year.

The direction of cyclonic winds depends on the location of the cyclone eye, and whether the eye crosses the coast to the east or west of Onslow. The highest wind speed recorded for an Australian cyclone is 265 km/h (74 m/s), which was logged at Onslow during the passage of Cyclone Trixie in 1975 (Southern, 1979). Cyclone Orson is thought to have generated higher wind speeds across a narrow front, but no wind recording instruments were located directly in its path.

4.1.3 Oceanography

The oceanography of the nearshore component of Rowley Shelf in the Onslow region has been described by Steedman Limited (1986) and summarised in the Onslow Coastal Study (SPC, 1987). Information on water levels and currents has been obtained from Steedman Science & Engineering (1990) and Appendix 4, respectively.

4.1.3.1 Wind Waves

During winter, locally-generated wind waves are formed by prevailing easterlies, south-easterlies and southerlies. Maximum wave heights generated by easterly gales can exceed 2 m where depth and wind fetch are not restricted. Summer wind waves with heights of 0.5-1.5 m are generated from prevailing westerlies and south-westerlies. Swells from the Southern and Indian Oceans are refracted into the region from the north and north-west, but are considerably attenuated by the time they approach the coastline.

4.1.3.2 Tides and Water Levels

Tides in the permit area are semi-diurnal (twice daily), with a mean spring range of 1.8 m. Seasonal variation in mean sea level (MSL) is minor (0.2 m above MSL in summer, and 0.1 m below MSL in winter). Other factors influencing nearshore water levels are wind stress, atmospheric pressure forcing, long wave propagation (shelf waves), Leeuwin Current influences and river outflows.

Atmospheric pressure forcing during the passage of a cyclone can often generate storm surges up to 1 m with time scales of several hours to days. Return periods for cyclonic surges exceeding 2 m at Onslow have been estimated at 1 in 25 years (Steedman Science & Engineering, 1990). Shelf waves have periods of 5-30 days and produce 0.1-0.5 m variations in sea level, while river flooding may extend from one day to several weeks. Regional influences of the Leeuwin Current are slight and have time scales in the order of several months.

Water Authority of Western Australia records for the Ashburton River measured at the Nanutarra gauging station between 1971-1972 and 1981-1982 (Public Works Department Western Australia, 1984) have been analysed and show that, on average, maximum instantaneous river flows which exceed 100 m^3/s occur on at least one occasion in each of three months per year. Peak flows were typically recorded between December and May. The average number of months when maximum instantaneous river flow was less than or equal to 25 m^3/s is 71 months over the period June 1972 to December 1989 (Table 7). Flows of 15 m^3/s or more at Nanutarra occur on average only on 29.9 days/annum (Table 8), indicating that moderate-high flows at short-lived in duration.

4.1.3.3 Water Temperature and Currents

Sea water temperatures at Roller range between 22°C and 30°C (B. Brown, Steedman Science & Engineering, pers. comm.).

Surface water movements in the inshore area of the Rowley Shelf are driven principally by winds and tidal currents, with broad scale oceanic circulation and thermohaline currents exerting a minor effect (Appendix 4). The strength and direction of nearshore currents is modified by the subsurface topography.

The current regime is dominated by the semi-diurnal tides, which produce four current reversals per day and a pronounced spring/neap (14 day) cycle. Spring tidal mid-depth currents at the Roller field reach 0.4 m/s during spring tides, with an eastward flood tide direction and a south-westward ebb tide. Maximum neap tidal currents are approximately 0.1 m/s (Appendix 4). Increased water turbidity during spring tidal periods is most marked in nearshore regions (including the Roller field).

Nearshore turbidity can be further increased during occasional flows from the Ashburton River. Coriolis and density-gradient forces are likely to result in the north-westerly movement of river outflow over the Roller field at speeds of less than 0.2 m/s (Appendix 4).

While wind forcing is most dominant during neap periods, its effects are continuous when evaluating directions of surface drift. However, the effect of local bathymetric contours on surface flow becomes important in shallow and nearshore areas.

4.1.4 Geology and Geomorphology

The coastal and nearshore zone of the Ashburton coastline forms a small part of the extensive Pilbara coastal system. This system is backed by a hinterland of dissected Precambrian rocks and a coastal plain of Cenozoic sediments (SPC, 1987). The two main rock units in the coastal zone are:

- Late Quaternary (Holocene) sediments (comprising shelf sediments, coral accumulations, coastal sands and tidal flat accumulations);
- Quaternary (Pleistocene) limestone (termed the 'coastal limestone formation').

These units contribute surficial materials or form the substrates of both terrestrial and marine geomorphic units. The large-scale geomorphic components of the coastal region at Roller (Fig. 13) are:

(i) **Submarine shelf**: underlain by Pleistocene limestone and veneered with coarse- and medium-grained sands, gravels, and locally with coral biostromes. The inner shelf gently slopes to depths of 20 m some 20 km offshore, and is locally interrupted by limestone reefs, islands, cays and shoals. The deeper outer shelf is geomorphologically similar. The islands and cays are characterised by sandy beaches overlying shell gravel, coral biostrome and Pleistocene limestone.

(ii) **Coastal system**: comprising mangrove-lined tidal creeks and embayments (backed by tidal salt flats with samphire and/or algal mats on the high intertidal and supratidal zones), and beaches (backed by either shore-parallel coastal dunes, unconsolidated mobile dunes or tidal flats). The dunes form a thick blanket over the Pleistocene limestone, which is frequently exposed to form limestone pavements in the intertidal and shallow subtidal zones of beaches and islands.

(iii) **Ashburton River delta**: terrigenous sands, silts and clays materials discharged from this wave-modified delta contribute to the fluviatile sands and muds from tidal creeks, and which eventually settle on the offshore submarine shelf to varying extents. Medium to small scale geomorphic units within the Ashburton delta include spits, cheniers, tidal flats, distributary channels, sand sheets and partially-lithified dunes (Plates 1 & 2).

4.1.5 Coastal Processes

The Onslow Coastal Study (SPC, 1987) identified a net long-term erosional regime operating along the coast, which is interrupted by short-term periods of net accumulation. Wave and tidal regimes, in conjunction with prevailing summer winds, are thought to produce a net eastward littoral transport of sediments. Cyclones and storms can periodically interrupt the pattern and cause coastal erosion with sediment transport to the west or offshore (SPC, 1987). Net eastward transport is probably not high, since maintenance dredging has not yet been required for the Onslow boat channel into Beadon Creek (N. Siragusa, Department of Marine and Harbours, pers. comm.).

Sediment mobilisation by spring tidal currents produces longshore sediment transport, sand bar erosion and deposition (most marked at the mouth of tidal creeks and the Ashburton delta), and promotes mud accumulation at the headwaters of tidal creeks.

The catchment area of the Ashburton River is over 75,000 km^2, and this river contributes large quantities of fluviatile sediments to the coastal region during periods of heavy rainfall. Red muddy sediments discharged from the Ashburton River during peak flows have been recorded up to 25 km away in waters near Thevenard Island (LSC, 1988a). Coarser river sediments are reworked closer inshore and contribute to the series of sand spits, cheniers, bars and fans at the eastern and western mouths of the Ashburton delta (Appendix 2). These structures also trap and redistribute marine sands that are transported into the area by littoral drift.

4.2 BIOLOGICAL ENVIRONMENT

4.2.1 Overview

Most species and species assemblages within marine habitats in the vicinity of Roller are characteristic of the tropical Indo-Pacific Zoogeographic Region (Wilson, Hancock & Chittleborough, 1979). The principal marine habitats are listed as follows:

(i) **Mangroves and salt flats**: along tidal creeks (e.g. Urala Creek, Hooley Creek, 4 Mile Creek, Beadon Creek), but pre-eminent at the Ashburton River delta (Plates 3 & 4) (see Appendix 2).

(ii) **Sand beaches**: along the mainland coastline and encircling offshore islands.

(iii) **Intertidal limestone platforms**: abutting most sand beaches of islands, and along parts of the mainland coastline (e.g. Beadon Point, east of Entrance Point, Rocky Point, and west side of Locker Point).

(iv) **Shallow subtidal limestone pavement and low reef**: Often comprising an extension of the intertidal platform, or forming discrete reefs (e.g. inshore reefs near Tubridgi and Locker Points). Occasionally partially emergent at LLW (lowest low water springs). Inshore areas are either bare or colonised by macroalage, with coral cover typically less than 15%. Coral cover often over 25% in offshore areas (e.g. near Ward Reef).

(v) **Coral reefs**: areas where coral cover is extensive and frequently exceeds 40% on reef areas surrounding islands (including Serrurier, Bessieres, Locker, Ashburton, Tortoise, Direction and Thevenard Islands).

(vi) **Subtidal sand and silt sheets and shoals**: sand veneers around all offshore islands, with more silty sheets and shoals nearer to shore (e.g. Southwest Patch, Curlew Bank, Glennie Patches, Roller Shoals; see Appendix 3).

The following sections provide a summary of the distribution of these habitats and their associated species assemblages, details of which are provided in Appendices 2 and 3.

4.2.2 Intertidal Habitats and Assemblages

4.2.2.1 Mangroves and Tidal Salt Flats

Mangroves between Tubridgi Island and Onslow are confined to the Ashburton River delta and six tidal creek systems (from Urala Creek in the west to Beadon Creek in the east; Fig. 14). The most extensive and diverse stands occur in the Ashburton delta, where six mangrove species were recorded during a recent survey (Appendix 2). The two major mangrove species on this part of the coastline are *Avicennia marina* and *Rhizophora stylosa* (Appendix 2; Johnstone, 1990). Transects of mangrove stands in the delta revealed that the diversity of mangroves is highest in the eastern portion of the delta near Entrance Point. On the basis of present information, this area forms the southern geographical limit of at least one of the six mangrove species (Appendix 2).

The mangrove creeks provide important nursery areas for various fish and prawn species which provide important recreational and commercial fisheries in the region (Section 4.3.5.2). The mangroves also provide a feeding area for a number of birds, while the tidal salt flats can provide important feeding areas for migratory wading birds.

The extensive high tidal salt flats that lie behind the mangroves between Tubridgi and Onslow are connected to the ocean via the six creek systems or Ashburton River, and support algal mats and halophytic heath communities that are typical of the region (Appendix 2).

4.2.2.2 Sandy Beaches

Figures 14-17 show the wide distribution of sand beaches on island shores and along most of the mainland coastline between Tubridgi Point and Beadon Creek.

The sand beaches contain a limited range of burrowing infauna comprising crustaceans [isopods, ghost crabs (*Ocypode* spp.), soldier crabs and bubbler crabs], polychaetes (including lumbrinerid, phyllodocid and glycerid worms), and bivalve molluscs (e.g. mesodonaciids and donaciids). These shorelines are also used by birds for foraging along the waters edge or nesting at the back of the beach. Many of the island beaches are also used by turtles for laying eggs at the back of the beach (Plate 5).

Species distribution lists for beaches in the region are given in Appendix 2.

4.2.2.3 Limestone Platforms

Intertidal limestone platforms surround most sand beaches of offshore islands, but form a relatively minor component of the mainland coastline (Figs 14-17; Plates 5-6).

A range of organisms are distributed over the platform according to tidal height and variations in the degree of topography, shading, dampness and the presence of rock pools. Floral elements typically comprise films of blue-green algae, filamentous green algae at or just above mean sea level, and a short algal turf at the lower end of the tidal range. Larger algae, including *Digena simplex, Dictyota, Amphiroa, Codium, Padina, Caulerpa* and *Gracilaria* spp., as well as filamentous red algae, are present in, or beside persistent pools or splash zones.

Faunal diversity decreases above mean sea level. Typical members of the mid-to-high tidal zone community include littorinids, mytilids and rock oysters (*Saccostrea cuccullata*), limpets, chitons and barnacles (*Tetraclita porosa* and *Chthamalus* sp.). Below the mid-tide level, sea anemones, crabs (e.g. *Metapograpsus* sp.), and larger gastropod molluscs (e.g. *Morula granulata*) are frequently found. Diversity increases most sharply at the lowest intertidal level of the platform, and where a wide range of species including sponges, cowries, clams, hermit crabs, house crabs, spider crabs, sea urchins and sea cucumbers were recorded at both offshore and nearshore locations (Appendix 2).

4.2.3 Subtidal Habitats and Assemblages

4.2.3.1 Subtidal Limestone Pavement

Wide and occasionally extensive areas of shallow subtidal limestone pavement typically form offshore extensions to the sand beaches and/or low intertidal platforms of islands. They also form the uppermost points of isolated offshore reefs such as Wards Reef and the inshore reefs near Urala Creek and Tubridgi Point (Figs 4 & 14; Plate 7). Although an intertidal/subtidal reef named 'Parkes Reef' is depicted on R.A.N. Chart AUS 744 as being located immediately to the east of the main entrance to the Ashburton River (at 21° 41.2' S and 114° 55.2' E), a comprehensive grid search at low tide with an echosounder on 2 December 1990 revealed no evidence of this structure (Appendix 2).

The shallow subtidal pavements are typically peneplanar, strewn with limestone and coral rubble, and either thinly veneered with sands or covered in thick films of mud consolidated by blue-green algae and diatoms. Wider sand-filled depressions occasionally contain patches of seagrass.

The bare rocky areas are often colonised by varying amounts of macroalgae including *Sargassum, Halimeda, Laurencia, Hydroclathus*, and *Udotia* and both calcareous and foliose red algae. More extensive meadows of macroalgae are often present on the subtidal platforms of islands and reefs further offshore such as those surrounding Thevenard Island and Trap Reef.

Sponges and tunicates are common on nearshore subtidal pavements, but coral numbers are low, with coral cover typically less than 10% and rarely above 15%. The range of small coral colonies noted in the recent survey includes *Turbinaria, Porites, Galaxia, Montipora, Acropora, Goniastrea, Leptoria* and *Pocillophora.*

The outer edges of the platforms surrounding islands and offshore reefs are usually marked by the point where the water consistently attains depths exceeding 1 m, and where coral cover suddenly increases to values between 30% and 80% (Section 4.2.3.2). Along the mainland coast the subtidal pavements occur as extensions of the intertidal platforms adjoining the sandy beaches, and either merge or terminate beside thick veneers of silty sands and where water depths are between 1 m and 3 m.

Beyond the line of fringing coral reef and coral bommies in offshore areas, the subtidal pavement at depths between 5 m and 12 m is either covered by veneers of coarse sand (colonised by seagrasses and a burrowing infauna), or is bare and colonised by sponges, macroalgae, occasional corals and seawhips. The various subtidal algal and seagrass habitats provide important feeding grounds for green turtles, hawksbill turtles and dugongs.

4.2.3.2 Coral Reef

Coral reefs comprise diverse and productive shallow water ecosystems that provide food and shelter for a wide range of marine organisms, including numerous representatives of the cnidarians, sponges, echinoderms, molluscs, crustaceans and fishes.

All of the islands near the Roller field are at least partially and sometimes almost completely encircled by shallow (1-10 m) fringing coral reefs (Figs 15-17; Plate 8). In these regions, live coral cover typically exceeds 30%, and the substrate is either the skeleton of hermatypic corals or limestone (LSC, 1990). The largest area of coral reef in the region is located on the south side of Thevenard Island (Fig. 16). No coral reefs occur along the nearshore waters of the coastline between Tubridgi Point and Onslow, a feature probably related to the turbidity of the waters and the amount of silty sediments originating from the Ashburton River delta. The closest area to the mainland where coral cover exceeds 30% is Ward Reef, 18 km due east of Roller D and 5 km north-west of Beadon Point, Onslow (Figs 4 & 14). However, small patches of limestone reef with coral were located close to the mainland shore west of Locker Point (Fig. 14; Appendix 2).

4.2.3.3 Subtidal Sand and Silt Sheets and Shoals

Thick sheets of sands and silts occur over depressions in the limestone pavement on the inshore side of nearshore islands, and form a series of shoals between the Ashburton River mouth and Ashburton and Tortoise Islands (Figs 4 & 14). These shoals are probably formed from reworking of terrigenous sediments expelled from the Ashburton River during times of peak flow.

The silt and sand sheets are extensive and form most, if not all, of the seafloor substrate over the Roller field (Appendix 3). They are also probably common along nearshore areas along the mainland coastline, and they are intermixed with coarser marine sands to form the cheniers, spits and bars at the mouths of tidal creeks and Ashburton delta (Appendix 3).

The subtidal sand and silt habitats are inhabited by a relatively sparse sessile benthic fauna represented by sponges, hydroids, sea anemones, sea whips, sea stars, sand dollars and crinoids, and by a burrowing infauna of molluscs, polychaetes and crustaceans (Appendix 2). Isolated coral colonies of *Turbinaria*, fungiids and soft corals are also present. The lack of seagrass and algae beds (and their attendant fauna) on these nearshore sand and silt sheets can be related to the high water turbidity and sediment re-working by tidal currents and storms.

4.2.4 Ecological Considerations

Information on functions, processes and energy webs of the North West shelf coastal marine ecosystem is limited. However, ecological relationships within the study area can be deduced from published research pertaining to similar environments. The primary producers (plants) form the basis of all food chains and food webs. In tropical coastal marine systems, the primary producers are phytoplankton, seagrass and macroalgae beds, coral reefs and mangroves. With the exception of the pelagic phytoplankton, the other benthic primary producers are distributed according to the availability of suitable habitats.

The role of mangroves and mangal areas in making a direct contribution to offshore food chains, such as providing direct nutrient input for coastal fisheries, is now less clear than originally thought (Hatcher, Johannes & Robertson, 1989). For example, an Australian study has found that mangals may comprise net sinks for dissolved organic matter and nutrients such as phosphorous (Boto and Wellington 1988, in Hatcher, Johannes & Robertson, 1989).

However, while mangal communities may not provide a major and direct source of organic material and nutrients for marine communities, they are key sites of primary production, secondary consumption and decomposition, and also play a major role in coastal stabilisation. Moreover, the limited number of mangrove areas between Tubridgi Point and Onslow may have high regional importance, given the absence of extensive embayments and shallow intertidal mud flats that characterise most of Exmouth Gulf and other parts of the Pilbara coastline between Onslow and the Dampier Archipelago (Appendix 2).

The tidal creek and Ashburton River delta mangroves are therefore also likely to provide key nurseries for various recreationally and commercially important fisheries in the region. These include commercial prawn species such as the western king and brown tiger prawn, whose life cycle requirements are described in Section 4.3.5.

Regular fluctuations in the abundance and distribution of seagrasses and macroalgae are usually the result of seasonal factors such as temperature, wave energy and water clarity. More substantial and extensive mortalities to shallow water marine organisms can occur as a result of various 'catastrophic' natural events such as intense cyclones, plagues of marine predators (such as the marine snail *Drupella cornus*), exceedingly low tides coupled with high solar radiation, or major freshwater and turbid discharges from coastal rivers such as the Ashburton.

Recovery from such events can be slow, and it is widely accepted that sensitive marine environments should be given reasonable protection from exacerbatory factors such as oil spills, major sediment plumes from dredging or construction activities, dust and/or physical disturbance.

Since it is widely acknowledged that the mangrove communities may represent the most sensitive marine system in the region and have the slowest recovery rate, it is reasonable to accept that they deserve the greatest level of protection from the effects of an accidental oil spill.

The offshore benthic primary producers (coral reefs and shallow subtidal algae and seagrass beds) form key sources of food for important marine fauna, and the coral reefs which fringe most of the offshore islands are also an important conservation resource and social resource for the purposes of tourism and fishing. Thus the coral reefs and shallow areas containing extensive macroalgae and seagrass beds should also receive a high level of protection from oil spill effects.

4.3 SOCIAL ENVIRONMENT

4.3.1 Conservation Status

The area in the vicinity of the Roller field is not 'pristine' as a consequence of the commercial prawn trawling, tourism on Thevenard Island and Direction Island, and regular recreational fishing and boating trips to other offshore islands such Serrurier Island. The oil and gas industry has also altered the visual aesthetics and 'wilderness' value of the region to a certain degree. Nevertheless, the marine ecosystems in the region remain essentially intact, and they continue to provide or support key resources of international and national significance.

The significant wildlife resources in the area include seabird nesting sites, turtle nesting beaches, dugong breeding areas, fish and prawn nurseries, mangrove and tidal flats, coral reefs and other important areas of primary production for ecosystem processes (Fig. 18). Recognised and valued human-use requirements, apart from oil exploration and production, include commercial and recreational fishing and prawn trawling, tourism, shell collecting and water-based recreation.

The importance of the region was recognised by the National Estate and Heritage Commission, which nominated the area covered by the Exmouth Gulf and the Rowley Shelf islands as significant at the State/Territory level. The National Estate Register (21 July 1983) number is 05/08/190/004/01.

In 1975 the EPA, through its Conservation Through Reserves Committee (EPA, 1975) recommended that the area of Exmouth Gulf to Cape Keraudren be reserved as a nutrient and nursery area in order to prevent unsupervised or unapproved destruction of mangroves in the region (Sections 8.7 and 9.8). It further recommended that the offshore islands be proclaimed as A-class reserves for the purpose of conservation of flora and fauna, or B-class reserves for the purpose of recreation and conservation of flora (Fig. 19). Little progress has been made on these proposals. Most of the larger islands (Murion, Serrurier and Thevenard Islands) are presently C-class reserves, while the smaller islands remain Vacant Crown Land. Presently, Barrow Island and Locker Island are A-class reserves vested with the National Parks and Nature Conservation Authority for conservation of flora and fauna.

The DCE Bulletin No. 104 (Jones, Field & Hancock, 1984) delineates geographic areas of the Western Australian coast based on their biological sensitivity to oil spills. Most of the permit area is located within SPL No. 32 which extends between 114° 16' E, 21° 43' S (Ningaloo Marine Park boundary) and 114° 19' E, 21° 47' S (Tubridgi Point), and is bounded by the mainland to 116° E and the 20 m isobath, to include all islands within this area (Fig. 2). This area is regarded as an SPL due to its significant marine resources.

The DCE Bulletin No. 103 describes water quality criteria for recognised Beneficial Uses of marine and estuarine water (DCE, 1981).

The Beneficial Uses and attendant schedules which apply to the Rowley Shelf area include:

- Beneficial Use 1 - Direct Contact Recreation;
- Beneficial Use 2 - Harvesting of Aquatic Life (excluding molluscs) for Food;
- Beneficial Use 3 - Harvesting of Molluscs for Food;
- Beneficial Use 6 - Aquaculture;
- Beneficial Use 7 - Maintenance and Preservation of Aquatic Ecosystems (Classes 1, 2 and 3);
- Beneficial Use 14 - Industrial Water Supply; and
- Beneficial Use 16 - Navigation and Shipping.

4.3.2 Onslow

Onslow was established in 1884 to service the pastoral, pearling and mining industries for the Ashburton district. The decline in these industries has caused a significant change in the function of Onslow, which is now assuming increasing importance for tourism, recreation and as a mainland base for oil exploration and production from offshore wells and islands (SPC, 1987).

The present population of Onslow is approximately 500 people, a number that increases to around 1,500 in winter as a result of tourist influx. The tourists are attracted primarily by the recreational fishing opportunities offshore. Conditional environmental approval has recently been recommended by the EPA for a proposal to construct a solar salt project at Onslow (EPA, 1991).

4.3.3 Petroleum Exploration

WAPET has maintained a mainland base and barge loading facility at Onslow since 1964. Hadson Energy Ltd has also established similar facilities and these developments provide regular employment for a number of townspeople. In addition to servicing existing oilfield developments, Onslow also provides a minor base for hydrocarbon exploration activities in the region.

Several oil companies have conducted extensive seismic surveys in the region and with further exploratory drilling programmes forecasted by Hadson Energy Ltd, WAPET and Western Mining Corporation. Hence the potential remains for future discoveries of economically recoverable reserves.

4.3.4 Tourism

Tourism has been a growth industry in the West Pilbara region over the past decade. Locally it is an important development for both Onslow and Thevenard Island. Tourism was initiated on Thevenard Island in 1964 with a single shack and has developed to the present day collection of eight buildings, together with associated roads and an airstrip. For the 1986 season there were 576 guest weeks (Mackerel Islands Pty Ltd, pers. comm.). Dinghies and outboard motors are available for hire on the island and an estimated 5% of the guests take their own boats to the island. There are also a number of boat charter operations based in Fremantle, Exmouth, Onslow and Dampier which visit the Thevenard region during winter and spring.

Additional tourist facilities on offshore islands include one rental shack on Direction Island, and a leasehold arrangement with the Department of Conservation and Land Management (CALM) allows a maximum of eight people to camp on Serrurier (Long) Island.

The main tourist season has traditionally been limited by climate to the April - November period. However, the game fishing season extends from late October to early February (SPC, 1987).

4.3.5 Commercial Fisheries

The commercial fishery based at Onslow is a relatively small, though locally important industry. Major commercial species include prawns, deep sea and reef fish, tropical rock lobsters, crabs, bait fish and pearl shell.

The three main fisheries managed by the Fisheries Department in the Onslow region are the Pilbara Coast Shoreline Net Fishery, the Pilbara Coast Line & Trap Fishery, and the Area 1 (Onslow) prawn trawl fishery. Table 9 provides a breakdown of the total catch landed at Onslow for 1987-1988 and 1988-1989.

4.3.5.1 Onslow Prawn Fishery

The most valuable component of the commercial fishery operating from Onslow is the prawn trawl fishery. The impetus for establishing this fishery came from the recognition that the traditional fishing activities of Onslow fishermen required protection. Access criteria for this restricted-entry fishery are based on a proven historical residency in the Onslow township.

The Onslow fishery is concentrated close to the mainland coast in a region delineated as 'Area 1' by the Fisheries Department (Fig. 20). Management of the Pilbara prawn fishery involves access to delineated 'Areas' by licensed vessels operating mainly from Onslow, Dampier and Cape Lambert (Fig. 20).

Area 1 is located in the Ashburton Roads immediately to the west of Onslow, with a maximum of seven licensed boats. Area 2, to the north and east of Onslow, is trawled by up to 19 licensed vessels, while Area 3, most of which lies to the east of Barrow Island, is fished by 14 licensed units. Although a total of 40 trawlers are licensed to operate in Areas 1, 2 or 3 for management purposes, 11 of these units are also permitted to operate in both Areas 2 and 3, while all of the Onslow (Area 1) vessels have access to the Area 2 grounds.

The Onslow fishery presently comprises six active vessels which operate in Area 1 between April 2 and November 5. During a typical season the bulk of the prawn catch is taken during the first four months. Few prawns are caught during winter as the cooler water temperatures cause the prawns to become less active and consequently harder to catch. A second peak in catch rate occurs during October when water temperatures begin to increase. The Onslow 'Area 1' fleet targets principally the brown tiger prawn, which accounted for nearly 60% of the 1989 Area 1 catch by weight, and over 70% of the financial return due to the higher dockside price commanded by this species.

Preliminary Fisheries Department data indicate that the total Area 1 prawn catch for 1989 (which was an average, to good, year) was some 32,000 kg, which was worth an estimated $400,000. Estimates of the value of the Area 1 catch taken in recent 'good' years range from $550,000 to $800,000 (G. Leyland, WAFIC, pers. comm.). Little specific information is available on the contribution made by the Roller field portion of the Area 1 prawn fishery.

Capital investment in the fishery has been recently estimated at close to $1 million in vessels, fishing gear and vehicles. The livelihood of up to 40 people (including dependants) at least in part relies on the present fishery (data from WAFIC).

Meetings were held between WAPET environmental and engineering staff and local fishermen in November 1990 and February 1991. These were to keep the fishermen informed on progress of development options and to get their input on general field design so as to minimise the potential impacts of the development on their fishery. The main topics addressed during these discussions included exclusion zones, trenching pipelines and the location of monopods.

4.3.5.2 Prawn Nursery Grounds

The life cycle of both the western king prawn and the more lucrative brown tiger prawn involves a juvenile phase in shallow, inshore waters (Fig. 21). Fisheries Department officers believe that mangrove-lined creeks and protected shorelines probably form important settlement and nursery grounds for the brown tiger prawn (J. Masters, WAMRL, pers. comm.). The role played by mangroves in providing nutrients to the inshore (<10 m) trawling areas (where juvenile prawns are taken during the first few months of the season) is less clearly defined (see Section 4.2).

The prawn nursery areas in Shark Bay, Exmouth Gulf and Nicol Bay have been defined, but this is not the case for the Ashburton coastline [i.e. from Tubridgi Point to Coolgra Point (east of Onslow)]. This coastline is presently considered by the Fisheries Department to form the main nursery ground for the stock of brown tiger prawns utilised by the Area 1 (Onslow) fishery.

Compared with Exmouth Gulf, and areas east of Coolgra Point, the Ashburton coastline has fewer areas where dense and continuous stands of mangroves occur, and fewer areas of wide tidal flats and embayments (Appendix 2). The relative importance of the Ashburton delta, compared with the smaller tidal creeks and inshore areas where mangroves are reduced or absent remains unknown. That this delta might form one of the most important settlement and nearshore nursery areas for the Area 1 fishery is supported by data for juvenile brown tiger prawns from Exmouth Gulf and North Queensland (J. Masters, pers. comm.). It is also considered likely that, as with the Exmouth Gulf nursery, a cyclonic flooding/inundation event which affects the Ashburton delta probably leads to a boosted recruitment if it occurs after January 31, and a reduced recruitment before this time.

4.3.5.3 Other Commercial Fisheries

The shoreline net fishery comprised only three boats in 1990, while the wet line and trap fishery comprised between 10 and 40 active units (M. Anderson, pers. comm.). The wet line fishery catches a variety of species including tuna, spanish mackerel, parrot fish, trevally, shark, pink snapper, blue-spangled emperor, mulloway and cod (Fig. 22).

The line and trap fishing fleet is now operating offshore in relatively deep waters along the margins of the Rowley Shelf that extend southward from Barrow Island. Mary Anne Passage and the region surrounding North Sandy Island are also favoured. The 1988-1989 catch statistics are the most recently available data that have been compiled by the Australian Bureau of Statistics (Table 9). Much of the catch is processed in Onslow and sold to north-west mining towns or outlets in Perth. Since the line and trap fishery was opened in 1980, the nearshore coastal area has possibly been over-exploited, with consistent catches of reef fish tending to be taken from the more remote areas of the region (P. Lyons, pers. comm.).

Two pearl culture facilities operate in the region and are located adjacent to Weld Island and Middle Island to the north-east of Onslow. Little information is available about this industry. Further to the south lies Exmouth Gulf which is the site of a major commercial prawn fishery based at Learmonth. Some 26 boats operate during the season and two processing factories handle the catch.

5 ENVIRONMENTAL EFFECTS

5.1 INTRODUCTION

This section evaluates the actual and possible effects of the proposed Roller development on nearby marine and coastal resources to determine the significance of various potential impacts, and to identify which aspects of the project will require management to minimise the risk and/or degree of adverse impacts. Project evaluation is based primarily on published literature and on experience gained from the offshore operations of the local oil and gas industry in Western Australia.

This appraisal provides a list of potential impacts and issues which will require specific management, and is divided into the following sections:

(i) appraisal of routine effects from drilling development wells (Section 5.2);

(ii) effects from developing the field and producing Roller crude (Section 5.3);

(iii) sources, risks and potential effects of accidental oil spills (Section 5.4); and

(iv) identification of key marine resources and issues requiring specific attention (Section 5.5).

5.2 DEVELOPMENT DRILLING

Development drilling is planned for the summer period between November 1992 and April 1993 (Section 2.2). While it is possible that the drilling programme may be interrupted or suspended during the passage of one or two cyclones, cyclone contingency planning and responses to the various levels and categories of cyclone warnings have become routine parts of offshore drilling operations on the North West Shelf (see Section 2.3.1.1).

5.2.1 Effects of Drilling on Bio-Physical Environment

Routine drilling operations using non-toxic muds and following accepted discharge criteria do not cause any long-term adverse impact on the marine environment. The only long-term impact noted in a study of eight abandoned wells drilled on or beside coral reefs off the coast of Florida was physical disturbance to some 400 m^2 due to the imprints of the jack-up legs of the drilling rig (United States Geological Survey, 1990). The lack of significant long-term impacts from modern drilling operations on the Rowley Shelf is supported by the results of a survey of drilling fluid dispersion near Thevenard Island during and after WAPET's development of the Saladin Oilfield (LSC, 1988a). This survey found that controlled release of surplus drilling fluids enabled their dilution and dispersal to undetectable levels within 150-250 m from the point of discharge. The Saladin survey also found that the drill cuttings settled rapidly to the seafloor and that the plumes produced by the discharge of the relatively coarse sand- and gravel-size cuttings were small and localised to the immediate vicinity of the rig (LSC, 1988a).

The closest shallow reef and intertidal areas to the proposed development wells at Roller are at Ashburton Island, over 3 km to the north. The nearshore waters that flow over the Roller area are frequently naturally turbid as a result of spring tidal currents, strong winds and storms, and occasional outflows from the Ashburton River. Thus it can be predicted that beyond the immediate vicinity of the drilling rig, the turbidity associated with the disposal of inert drilling cuttings will rapidly reduce to background levels, and that the increased distance of any plume during spring tide conditions will be commensurate with the increased natural turbidity during this period of enhanced water current velocities.

The primary impact of drill cuttings on the marine environment is physical burial of the seafloor directly under the platform (Sanders & Tibbetts, 1987). Recent experience in Exmouth Gulf (LSC, 1990) showed that the drill cuttings are mostly sand/gravel size and in waters of 20 m depth they form low elliptical mounds of approximately 0.5 m high and 50 m wide and 50 m long.

The soft substrate of sand and silt sediments at the Roller field supports a widespread benthic fauna that is probably somewhat modified by commercial prawn trawling operations. Physical burial of this fauna by the inert drill cuttings beside the drilling rig is a direct, but not long-term impact, owing to the ability of the infauna to rapidly recolonise new sediments from adjacent undisturbed areas (George, 1975; Zingula, 1975).

The low volumes and large dilution factors of other discharges from the drilling rig (i.e. treated sewage and domestic wastes and treated water from deck drainage areas) will ensure that the effect of these discharges will be negligible. Large and non-biodegradable items accidentally lost from the various work decks can be retrieved by divers during routine operations.

5.2.2 Effect of Development Drilling on Social Environment

To improve operational safety, commercial and recreational vessels will not be permitted closer than 500 m to the drilling rig during the construction phase. Such a 'marine exclusion zone' in State territorial seas are routinely declared by the Minister for Mines under the provisions of Section 119 of the *Petroleum (Submerged Lands) Act 1982*.

Since the Roller field also straddles the Onslow Port limits, exclusion zones for navigational safety reasons could also be declared by the Onslow Harbour Master under the provisions of the *Shipping and Pilotage Act 1967*. Areas immediately beyond Port Limits could, if deemed necessary, be declared as a supply vessel 'mooring control area' for the purposes of the latter act, or be regulated and controlled under the provisions of the *Marine and Harbours Act 1971* and Western

Australian *Marine Act 1982*.

The precise boundaries and areas of exclusion zones are usually determined by inter-departmental consultation among representatives of the Department of Mines, Department of Marine and Harbours, Fisheries Department, EPA and, where relevant, with CALM. The impact of exclusion zones is discussed in the following sections and in Section 5.3.2.2.

5.2.2.1 Effect on Tourism

Development drilling is planned for the summer period. Thus tourist activities (including those at the Mackerel Island Holiday Resort on Thevenard Island) and recreational activities such as fishing and yachting are highly unlikely to be affected by the presence of the drilling rig, its supply vessels or its normal operations. Fish will not be adversely affected by the presence of the rig or its occasional discharges, and they are often attracted to drilling platforms which provide shelter from predators and a range of encrusting food organisms.

5.2.2.2 Effect on Commercial Fisheries

An adverse impact on the commercial prawn fishing industry during 1992 is not anticipated during normal drilling operations within the permit area since the season will be ending at the time drilling is planned to start. Even if the programme gets under way before November 1992, its impacts will be low because:

(i) the 500 m radius around the platform restricted to boating activity during drilling operations is a relatively small exclusion zone;

(ii) the low mounds of drill cuttings will not form a navigation hazard to trawlers; and

(iii) water turbidity generated by the drilling discharges is low.

5.2.3 Effect on Marine Resources, Conservation Areas and Beneficial Uses

Helicopter pilots will not overfly islands, and supply vessel will not anchor near reefs or shorelines. Given the distance from the nearest reef or shoreline, it is difficult to see how routine marine operations associated with the drilling programme can markedly affect marine resources or the Beneficial Uses identified for the area (Section 4.3). The drilling rig will temporarily attract fish from the surrounding waters and may provide temporary roosting space for seabirds.

5.2.4 Effect on Onslow

During the drilling programme, Onslow is expected to benefit in a small way from the provision of accommodation and services to personnel associated with flying and transport operations via Onslow aerodrome and WAPET's terminal at Beadon Creek. Changes to noise levels as a result of additional flights will not be significant because the aerodrome and flight paths are not close to residential areas.

5.3 FIELD DEVELOPMENT AND CRUDE OIL PRODUCTION

5.3.1 Effects of Field Development

Operations associated with the installation of wellheads, monopods and pipelines, and with the modification and installation of facilities on Thevenard Island will produce only short-term and localised effects on the marine biological environment.

5.3.1.1 Effects on Biological Environment

As discussed in Section 4, the seabed in the Roller field is relatively flat and composed of thick sheets of sands and silts overlying limestone. No benthic communities within the Roller development form important primary producing systems or contain significant or unusual species (Appendix 3).

The installation of the four monopods, and underwater diving operations to install pipeline spool pieces will exert minimal effect on the widespread benthic community. The positioning of the modified jack-up rig alongside the Roller D monopod (Option 2) may require installation of anchors.

The pipeline route between Roller D and Thevenard Island has an average depth of 10 m and does not traverse shoals or reefs (Fig. 8). Pipelines within the oilfield will be trenched and, where possible, the main flowline within the field and south of Ashburton Island will also be trenched to enable prawn trawling operations to continued.

It is anticipated that blasting will not be required to prepare the route or for the shoreline crossing at Thevenard Island. The flowline will be brought ashore alongside the existing flowline from Cowle and Saladin C, an operation involving exhumation and reburial of beach and intertidal sands by diver jetting and backhoe. Subsea pipelines will be layed from a barge, except at the beach crossing where the pipe string will be towed offshore from an assembly point within the Thevenard Island lease area.

Corrosion control of subsurface structures will be by paints, cathodic protection or by a continuous external barrier coating to standards cited by government codes. Production lines transmitting unseparated product (two-phase or three-phase) will be hydrostatically tested, with the test waters disposed of through the production plant at Thevenard Island.

Effects of project development, which are unlikely to produce adverse or long-term impacts on marine biota or communities, are summarised as follows:

- installation of four monopods, one modified jack-up rig (Option 2), and the various pipelines within the Roller field will remove or temporarily reduce benthic organisms in the immediate vicinity of these structures;

- minor localised scouring in the vicinity of the monopods and above-surface pipelines will occur until new seafloor profiles are established;

- localised turbidity and removal/disturbance of benthic biota during trenching operations between the Roller monopods and Ashburton Island;

- localised turbidity plumes and disturbance of beach shoreline and nearshore shallow subtidal sediments at Thevenard Island; and

- disposal and dispersion of hydrostatic test water through the Thevenard Island produced water outflow.

Direct beneficial effects to the marine communities are as follows:

- The structures that are installed offshore will create artificial reef habitats which will be colonised by a diverse range of encrusting organisms and attract a variety of fish species to the shelter and food resource provided by these structures.

- Exclusion zones around the monopods and exposed sections of the pipelines will provide refuge for the fish and crustaceans. These areas, which will be protected from fishing pressure, will provide havens for species recruitment that will assist in maintaining the fish resource in this heavily fished region.

5.3.1.2 Effects on Social Environment

The locations of known historic shipwrecks in the area are shown in Figure 23; none of these lie within the project area. However, WAPET is aware of the requirements and regulations of the *Marine Archaeology Act 1973*, and will ensure that surveyors and divers contracted for pipe laying operations will be made aware that the discovery of any new wreck must be promptly reported to the Maritime Department of the Western Australian Museum in accordance with the provisions of this Act.

Project development will require the establishment of long-term Marine Exclusion Zones around each monopod, and trawling/anchorage exclusion zones on either side of the underwater pipelines where these are not sufficiently buried or stabilised. The effect of these zones is further discussed in Section 5.3.2.2.

During the peak construction phase in early 1993, a workforce of up to 40 personnel will be accommodated in a temporary construction camp at Onslow. This camp will probably be sited near the WAPET landing at Beadon Creek. As with past camps, domestic waste and sewage lines would be linked into the existing town sewage system operated by the Western Australian Water Authority.

Development activities in the Roller field will not impinge on visitors to the Mackerel Island Resort on Thevenard Island. The single most demonstrable presence of heightened workforce activities on Thevenard Island will probably occur in early to mid 1993 during the shoreline traverse of the main flowline. During this period, the pipelaying barge will be operating near the south-east beach at Thevenard Island.

5.3.2 Effects of Crude Production

Production of Roller crude is planned to commence by July 1993 and will continue for the life of the field, which is presently estimated at six to eight years. Commencement of Roller production coincides with the projected marked downturn in Saladin production, and thus the total amount of produced water, gas and oil at Thevenard Island is unlikely to exceed present volumes. Thus transfer and shipping activities will remain at present levels. Apart from current changes to accommodation units on Thevenard Island, no additional domestic or workforce facilities will be required for Roller production.

5.3.2.1 Effect of Routine Discharges on Biological Environment

(i) Gas

Gas will be flared either offshore beside Roller D (Option 2), or from the ground flare presently located on Thevenard Island. The total volume of gas recovered from the Roller field is anticipated to be very low, hence the final volume that will be flared is also expected to be very low, particularly after the required volumes have been extracted for fuel gas for platform equipment and for gas-lift purposes. The protective casing of the Thevenard Island flare, which is required for the continued production of Saladin, Cowle and Yammaderry crude, is currently being modified to reduce light emissions.

(ii) Produced water

As with existing Saladin production, produced water from Roller will be separated on Thevenard Island, compliance treated and routinely checked before discharge to ensure that average hydrocarbon concentrations remain below 30 ppm.

Adequate dilution and dispersal of treated water at Thevenard (as well as a lack of significant spillages during tanker transfer operations) has been indirectly confirmed by regular analysis of intertidal beach sediments and coral surveys between 1988 and 1990. These surveys show that no hydrocarbon contamination of beach sediments has occurred and that coral growth is normal (LEC, 1990).

(iii) Domestic discharges

Existing volumes of treated domestic waste and sewage discharged at the submarine outfall off Thevenard Island (Fig. 9) will increase owing to the number of additional workforce members required for Roller crude production (up to 18).

5.3.2.2 Effect of Routine Operations on Social Environment

(i) Onslow

Both beneficial and adverse effects to the town's economy and amenities will be minor or even inconsequential, particularly if the proposed Onslow Solar Salt Project is commenced in the short or medium term.

(ii) Mackerel Island Resort

WAPET's discovery and development of crude from the Roller field means that the period before the facilities on Thevenard Island will be decommissioned and removed has been extended by approximately six to eight years.

Discernible differences between WAPET's existing activities and those occurring during the Roller production phase will be few and very minor. It is likely that the most discernible difference will be an increase in the number of helicopter flights made each day. The extra flights are required for routine inspection and servicing of automatic equipment at the Roller field. As with existing helicopter movements, however, noise will be minimal since the take off and approach paths are to and from the north-east side of the island.

(iii) Marine resource and conservation values

Routine discharges and the operational movements of helicopters and vessels will not significantly detract from the amenity value of the region or effect its conservation resources. It could be argued that a noticeable effect will be a reduction in visual aesthetics and 'wilderness' value in the vicinity of Ashburton Island. However, unlike the more offshore islands in the region, this small island is not often frequented by tourists since there are no sheltered anchorages or beaches with easy access, and its surrounding waters are often more turbid.

The movements of pleasure vessels less than 20 m in length are likely to be restricted only in the immediate vicinity of the monopods, all of which are located well offshore in relatively deep waters that do not provide favoured fishing or diving locations.

(iv) Commercial prawn fishery

The project area lies within the Area 1 fishery, which is the local prawn fishery based at Onslow (Fig. 20; Section 4.3). The imposition of a marine exclusion zone is required not only to protect the subsea pipelines from accidental damage by fishing gear and anchors, but also to prevent concomitant damage to trawl nets.

The boundaries and width of the long-term marine exclusion zone which will affect the Area 1 fishery will depend on how much of the main Roller-Thevenard pipeline can be trenched without inordinate expense and/or resort to blasting. Ease of trenching will depend on the mobility of the sand and silt sheets and the hardness of the underlying limestone. WAPET is presently consulting with Onslow fishermen and WAFIC to ascertain the location of popular trawl grounds in the region, and to assess more precisely the potential impacts of exclusion zones.

If the pipelines can be trenched where they pass close to, or traverse, popular trawl grounds, the main exclusion zones will be restricted to the area surrounding the monopods. The precise location and width of the exclusion zone(s) will probably be determined by consultations involving the Department of Mines, the Department of Marine and Harbours and Fisheries, the EPA and WAPET (who will be the licensed operator of the subsea pipelines).

If trenching burial of the pipelines proves impractical, a marine exclusion zone around the pipelines will also be required. The zone would become gazetted and shown on revised or updated versions of R.A.N. charts.

5.3.3 Effects From Project Decommissioning

Deleterious effects produced by project decommissioning (e.g. disturbance to the seabed during well plugging and removal of monopods) will be short-term and minor, and considerably outweighed by the benefits from completing the various tasks outlined in Section 2.5. For example, removal of subsea structures will enable rescindment of the various marine exclusion zones.

As with the Saladin development, the exhaustion and subsequent decommissioning of the Roller field may not necessarily lead to the removal of all facilities on Thevenard Island. This will depend on their suitability for facilitating the production of other crude reserves that WAPET may discover in the region.

5.4 OIL SPILLS

5.4.1 Introduction

Accidental oil spills represent the most significant potential impact of the proposal. Spill prevention and minimisation are the main management priorities in all offshore exploration and production activities because of the risk to the environment and to the safety of personnel, and also because of the costs of subsequent containment and clean-up measures. While such concerns apply to the industry in general, they are particularly pertinent to this project, which is located in a sensitive nearshore region designated as a 'Special Protection Locality' (Jones, Field & Hancock, 1984).

While modern drilling technology, equipment and safety procedures have considerably reduced the chances of large oil spillages, the various risks, effects and effectiveness of containment and clean-up strategies still require careful evaluation in order to assess the level of environmental risk. Such evaluation is facilitated in the following sections by:

(i) identifying the sources and volumes of oil that might be spilled and the probabilities of such spills (Section 5.4.2);

(ii) characterising the types of oil that might be spilled (Section 5.4.3);

(iii) assessing the weathering characteristics of spilled oil (Section 5.4.4);

(iv) determining the area(s) that could be affected by an oil spill and identifying the important resources within these areas (Section 5.4.5);

(v) outlining the potential effects of the oil on these resources (Section 5.4.6);

(vi) assessing both the procedures that could contain the spill (to reduce the size of affected areas), and the clean-up strategies that could minimise adverse effects (to speed the recovery of affected resources) (Section 5.4.6).

5.4.2 Oil Spill Sources, Sizes and Probabilities

5.4.2.1 Spills from Drilling Activities

Three discrete sources of oil spills have been identified by the EPA (1989) for drilling operations. Each source has a different probability of occurrence and a different strategy for risk management, and are described as follows:

(i) Refuelling operations

Fuel-handling mishaps during refuelling operations are one of the most common sources of spillages, and are usually caused by hose ruptures, coupling failures or fuel tank overfilling. The volume of fuel spillages is generally less than 1,600 L (10 bbl), and quantities are usually minimised by the prompt shutdown of pumps or by the automatic operation of safety valves.

The transfer of diesel oil from a supply vessels to the rig is the main potential source of spills, and should the 3" reinforced hose rupture up to 1,600 L can be spilt since this is the total volume held within the transfer hose. Such refuelling operations must be continuously monitored by either the vessel's Master or Second Officer, in accordance with the schedules and provisions of the *Petroleum (Submerged Lands) Act 1982*.

During the course of any drilling operation the rig will be refuelled every two weeks. The refuelling operation takes approximately two hours. Therefore both the amount and risk of spillage are low.

(ii) Testing production flows

Spills during production flow testing are less common. The maximum volume of oil lost could be up to 8,000 L (50 bbl), which is the maximum the volume of the gauge tank. Volumes that can escape from between shut-in stations on the test line are less. Much of the spillage would collect in containment areas on the deck of the drilling rig, and can be drained off or mopped up before escaping to the ocean.

The oil industry recognises the risk of this type of spillage, and key equipment must be operated by only trained engineers and technicians. Proposed procedures for flow testing must be approved by the Department of Mines prior to the commencement of such tests, with guidelines set out in schedules to the *Petroleum (Submerged Land) Act 1982*.

(iii) Blowout

Uncontrolled blowouts are by far the least common source of large oil spills (most of which result from major shipping accidents). Uncontrolled blowouts are extremely rare since all the warnings from monitoring devices and procedures must be ignored and the casing, wellhead or blowout preventer must completely fail (see Section 2.3). Volumes lost may be small or extremely large, with the period of an uncontrolled blowout varying between hours to several months.

Examination of the test flow figures from the four wells in the Roller field indicates that the maximum blowout flow rate could be 800 m^3/day (5,000 BLPD). However, the total amount of oil which would escape depends on several factors including the permeability of the producing formation, the thickness of the encountered producing interval, the viscosity of the product, the number and type of obstructions in the well hole, and the time taken to bring the flow under control. Drilling directional 'interception' wells to reduce the pressure of the flow is usually regarded as the last resort, since this can take several months to complete.

5.4.2.2 Spills Associated With Production Activities

The use of the existing Thevenard facilities for the development of new fields such as Roller was addressed in the Saladin development ERMP (LSC, 1987, p. 12), and such use was subsequently endorsed by the EPA (EPA, 1987, p. 9). Nevertheless, and in accordance with EPA guidelines listed in Appendix 1, potential spills associated with the production and shipping of crude oil at Thevenard Island are assessed to enable a comprehensive appraisal of cumulative effects.

Oil spills from offshore oilfields can result from transfer operations, from damage to facilities by accident, fire or explosion, or from tanker grounding or collision.

(i) Transfer operations

As with refuelling operations, small to medium oil spills (< 4 kL) associated with the transfer of crude oil to tankers is one of the most common sources of spills Hose ruptures or coupling failures do not result in large spills owing to the safety valves which automatically shut-off the supply when the fall in line pressure is detected by the transfer valve located at the end of the hose. Valves can be closed manually and fuel pumps can be switched off either manually or automatically. Moreover, the amount of oil that can escape is less than the volume of the transfer line since these are equipped with automatic suck-back pumps which markedly reduce the volume of oil remaining within the hose.

(ii) Damage to development

Fire or explosion in production and storage facilities are extremely rare events owing to strict regulations ensuring the highest possible standards of safety equipment, servicing and maintenance, and safety training. Oil escaping as a consequence of major damage to the facilities on Thevenard Island would be contained in the bunds which surround the tanks, and cannot escape to the beach or sea or infiltrate the groundwater.

Safety devices and emergency shut down valves described in Section 2.4 ensure that damage or overturning of the monopods can lead to only minor spills of oil entrapped between valve stations inserted along the process stream.

(iii) Shipping accidents

The design and operation of the tanker terminal at Thevenard Island has already been subjected to review and assessment by the Department of Mines and the EPA during the environmental assessment of the Saladin development (EPA, 1987). On average, tankers between 100,000 and 120,000 tonnes DWT have been visiting the Thevenard terminal four times per month during 1989 and 1990.

A number of routine operational procedures are used to minimise the chance of a shipping accident. These include:

(i) State Government gazetted Mooring Masters (pilots) employed by WAPET, who board each tanker to provide navigational advice and local experience advice during the mooring and loading of the vessel;

(ii) a tug and mooring line vessel, which remain on standby at the tanker location at all times a tanker is present;

(iii) continual monitoring of real-time meteorological and oceanographic (metocean) data during mooring and loading operations (if metocean conditions exceed any of the predetermined limits, loading is stopped and the vessel is moved offshore to a safer anchorage in deep water); and

(iv) cessation of mooring or loading activities if a cyclone approaches within approximately 640 km of Thevenard Island, with the decoupled tanker moved to an offshore anchorage. Further details on cyclone procedures are contained in the WAPET Emergency Procedures Manual.

5.4.2.3 Probability of Oil Spills

(i) Risk during development drilling phase

A spill risk assessment conducted by the Commonwealth Department of Transport in 1983 calculated an estimated spill rate for offshore drilling rigs of one for every 455 wells drilled (size of spill unspecified). It is widely accepted that the likelihood of a major blowout is now much less than that calculated in 1983. Information on the Western Australian experience with offshore drilling shows that to date, no significant oil spills have been associated with a total of 314 offshore wells drilled to 30 June 1990 (K. Gammie, Department of Mines, pers. comm.).

WAPET has gained over 20 years of experience in drilling wells in the Carnarvon Basin and is now very familiar with the geological structures and pressure zones that occur within the region. This experience includes the successful drilling of 96 wells in offshore locations (including all offshore islands except Barrow) and 750 wells on Barrow Island. Eighteen of these wells have been drilled within Permit Area TP/3 Part 1.

The risk of a large spill during the development drilling of the Roller field is now extremely remote as a result of both modern drilling technology and the fact that the formation and reservoir pressures in the Roller field appear to be stable. The Carnarvon Basin, in which the Roller field is located, is also considered predictable in its geological composition, and therefore data for additional production well requirements are not expected to be unreliable.

(ii) Risk during production phase

Various data show that the chances of one or more small spills (< 4 kL) are possible during the production life of an oilfield as a consequence of human error or equipment failure. Most of these minor spills (< 4 kL) are associated with diesel refuelling operations or tanker loading operations.

Records have been kept since July 1989 by the Department of Mines Western Australia on all oil spill incidents associated with offshore exploration, development and producing activities on the North West Shelf. These show that WAPET has an exemplary record; only one very minor loss of oil (< 636 L from a gas flare tower as a result of equipment malfunction) has occurred. This record sets a standard for all Western Australian oilfield operators.

5.4.3 Characteristics of Oil Types

As discussed above, present experience indicates that small volumes of two types of oil may be spilled during both the development and production phases of the Roller field. These are diesel fuel spills (during refuelling operations) and crude oil spills (during either flow testing or loading).

5.4.3.1 Diesel Fuel

This is a light end petroleum distillate with an API gravity of about 30°. Diesel fuels are typically characterised by a 75:25 mixture of saturate and aromatic compounds respectively.

5.4.3.2 Roller Crude

This medium to light crude has an API gravity of 29.5° (Table 10). Based on its gravity, Roller oil more closely resembles Prudhoe Bay, Nigerian and Tijuana crude oils than the typical lighter North West Shelf oils such as that from the Saladin field. Preliminary chemical characterisation of the oil has shown that it is composed primarily of aromatics and aliphatics. Characterisation of the Roller crude at the BHP Petroleum laboratory (Clayton, Victoria) indicates that the oil is a moderately heavy naphthenic/aromatic crude that has a low pour point due to its cyclic nature and lack of paraffin wax.

The oil is essentially highly biodegraded, and therefore its chromatographic trace is characterised by an unidentified complex mixture (UCM), a lack of normal alkanes and a suite of branched and cyclic hydrocarbons. Degradation within the reservoir is the main reason why the oil is heavier than equivalent oils from Saladin and other North West Shelf fields (Table 10) and similar in weight to diesel fuel.

5.4.4 Fate of Spilt Oil

Once oil enters the sea it undergoes weathering, which comprises a variety of physical and chemical changes including spread, evaporation, dissolution, photo-oxidation, emulsification, biodegradation, sinking and beaching. As these processes occur, the volume, concentration and toxicity of the spilt oil is reduced with time. The various processes have been described in detail by LSC (1987) and Jones (1986).

Both types of potential oil spills (i.e. diesel fuel and Roller crude) are likely to weather rapidly. This is because the key processes which regulate the rate of weathering are to a large extent temperature dependent. Thus the warm water and atmospheric temperatures of the Onslow coastline will increase the rate of spread, evaporation, photo-oxidation and dissolution of spilled oil.

While tests on the weathering behaviour and dispersability of Roller crude are still ongoing at the Marine Science Laboratories in Queenscliff, Victoria, the results of a study on the weathering characteristics of diesel fuel by Kagi, Fisher and Alexander (1988) provides a reasonable indication as to how this medium weight crude will evaporate. For example, it can be expected that all the fractions lighter than C_{13} will evaporate rapidly from a slick.

The results of Kagi, Fisher and Alexander (1988) also suggest that, with the exception of a large and rapid release of more than 100 m^3 of oil in very still conditions, Roller crude will spread out and evaporate rapidly and after one day leave a residue of approximately 50% of the initial volume. The residue would subsequently be gradually dispersed over a period of several days. It is also likely that, as with diesel fuel, Roller crude will spread out rapidly over the surface of the ocean to a thickness of less than 0.1 mm. This value is significant for clean-up strategies, since slicks less than 0.1 mm thick are very difficult to recover from the open ocean.

Additional physical and chemical processes affecting the oil are photo-oxidation, emulsion formation and sinking. Thinly-spread oil is photo-oxidised easily and this will probably be a significant breakdown mechanism in the Ashburton region owing to the high amount of sunlight and warm temperatures. Natural dispersion of the oil will occur if the weather conditions are severe enough to break up the oil and force oil droplets to be entrained throughout the water column, thereby enhancing natural biodegradation and weathering processes. The lightness of Roller crude will prevent moussing (i.e. the production of 'smothering' water-in-oil mixtures that are resistant to dispersal and degradation).

5.4.5 Areas and Resources Potentially at Risk

5.4.5.1 Areas Most at Risk From an Oil Spill

Areas potentially at risk have been delineated by modelling trajectories of simulated oil spill envelopes (Appendix 4). The predictions are summarised in Table 11. Predictions are derived from hourly wind measurement data (10 minute averages) recorded at Thevenard Island between 1 February 1987 and 31 January 1988 (Table 4).

Plots of oil spill excursions for 6, 12, 24 and 48 hour periods and for a range of scenarios are given in Appendix 4. Modelling is based on an understanding of the likely effects of local meteorological and oceanographic influences on surface water movements. Predictions for cyclonic events are not useful since wind direction cannot be predicted, and sensitive operations such as drilling or loading would have already ceased.

Oil spill envelopes based on scenarios comparable to typical metocean conditions at the time of an oil spill are shown in Appendix 4. The modelled trajectories agree with the results of exercises undertaken near the proposed Roller B monopod in 1989. These exercises involved the tracking of surface and tidal currents using floating mats and drogues respectively. The drogue studies confirmed the predictions of the modelling by demonstrating that tidal currents are constrained by local bathymetry to the east-west direction, and that local windforcing is important during neap periods (S. Buchan, Steedman Science & Engineering, pers. comm., 13 March 1991).

The modelled oil spill predictions are probabilistic and conservative (e.g. the models do not account for weathering effects and assume a continuous release of discrete parcels of oil over the time period). These assumptions lead to an over-estimate of the distance of travel of the slick. The predictions also assume that wind direction and strength (36 km/h or 10 m/s) remain constant for the 6-48 hour periods. This is highly conservative in the case of northerly winds, since the 1987-1988 wind data collected at Thevenard indicate that the probability of northerly winds blowing in excess of 10 m/s for more than six hours is less than 6:10,000 (i.e. less than one occurrence per year) (S. Buchan, Steedman Science & Engineering, pers. comm., 13 March 1991).

Predictions presented in Table 11 and described in more detail in Appendix 4, demonstrate that the shorelines most potentially at risk are those in the immediate proximity to the Roller field, i.e. Ashburton Island, Thevenard Island, Entrance Point, and the adjacent mainland coastline running westward to Rocky Point. Other shorelines in the area are at a very low risk, with frequencies less than 0.5%.

5.4.5.2 Resources Most at Risk From an Oil Spill

From the conclusions of the oil spill trajectory modelling, it is clear that the resources most potentially at risk are the areas of coral reef, macroalgae-covered limestone pavement and sand beach areas surrounding Ashburton and Thevenard Islands. The resources at next highest risk are the mangrove assemblages at the Ashburton River delta near Entrance Point. These resources are important for ecological and conservation values and, with the possible exception of shallow areas of macroalgae, for human-use values including recreation, tourism and both commercial and recreational fisheries.

5.4.6 Oil Spill Effects

5.4.6.1 Background

Very little is known about the effect of Western Australian oils on local tropical marine organisms since there have been very few spills of any significance. So far local experience has simply indicated that minor oil spills in unconfined marine waters have not caused major mortalities of marine biota. For example, in July 1986 a minor spill (approximately 1.6 kL) of light Australian crude occurred at the Harriet A production platform. The spill was tracked and within 30 hours was observed moving over a coral reef located mid-way between Varanus Island and the Montebello Islands. Hydrocarbon concentrations in oyster tissue subsequently collected from islands near the reef confirmed the passage of the spill, but further monitoring of both these rocky shore assemblages and the coral reef found no increase in mortality of organisms in either habitat (LSC, 1988b).

Effects of oil spills on marine resources and associated activities have been reviewed on an international basis by Jones [1986 (Part 2)], who placed them into a Western Australian context. A review of oil spill effects on tropical marine environments was subsequently provided by LSC (1987) (Saladin ERMP; Appendix 6).

Since 1985 increased effort has been expended overseas on research into oil spill effects on tropical marine communities, using both laboratory and field studies (e.g. Getter, Ballou & Koons, 1985; Ballou *et al.,* 1987; Teas & Duerr, 1987; Ballou *et al.,* 1989; LeGore *et al.,* 1989; Thorhaug *et al.,* 1989). Most of these studies typically centred on mangroves, corals and/or seagrasses, since these components of the tropical coastal ecosystem are widely recognised as crucial habitats for a range of important marine species.

A summary of oil spill effects is provided in Table 12. This lists the type of effect and potential damage to susceptible tropical assemblages; their sensitivity to oil; their recovery rates; and the range of beneficial clean-up actions that are available. Since this table was originally based on the effects of light Australian crudes, it has been updated following a survey of current literature to ascertain the impacts of medium weight crude oil spills in tropical marine environments. This recent review is presented in full in Appendix 5.

Nevertheless, it remains difficult to predict all the various possible effects of a serious oil spill which might impinge upon more confined intertidal systems on the inner Rowley Shelf. Experience of such oil spills in other tropical regions does show, however, that while localised reductions in the abundance and diversity of organisms may occur immediately after the spill, recovery takes place relatively more rapidly than in temperate marine systems.

The one exception where long-term adverse impacts have been detected as a result of tropical oil spill, consists of mangrove environments (Appendix 5). By contrast, tropical intertidal zones such as rocky shores can typically be the most affected in the immediate-term, with substantial mortalities being recorded. On the other hand, these zones were also found to be among the quickest to recover, and generally do so within 12 months (Appendix 5).

The following sections summarise the information oil spill effects on coral reefs, mangroves, seagrasses and prawn fisheries that is reviewed in Appendix 5. Where possible, consideration is given to both of the crude oil types that will be produced on Thevenard Island (i.e. the light Saladin crude and the medium weight Roller crude).

5.4.6.2 Effects on Important Marine Communities

(i) Coral reefs

There are many inconsistencies in the literature on the impact of oil on coral reef organisms. It is generally accepted, however, that the effects of oil spills are acute rather than chronic, and thus any impacts following a spill will be immediate. Not all effects are lethal, and a substantial amount of literature highlights the sublethal effects of both oils and dispersants on corals (Loya & Rinkevich, 1979; Neff & Anderson, 1981; Wyers *et al.*, 1986).

Recent studies on the impacts of oil spills on corals have either followed the effects of an actual oil spill, or comprised field studies that simulated a spill. Deliberate release of a large volume of unweathered (medium weight) oil into a nearshore shallow water area caused extensive mortality of corals located in water less than or equal to 3 m deep, while corals in deeper water were largely unaffected (Jackson *et al.*, 1989). This experimental finding is supported by field observations following an oil spill in Egypt. Roberts and Sheppard (1988) reported that a spill of heavy weight Bunker C crude oil in an area of coral reefs caused little damage despite reports of unbroken sheets of oil at the water surface which covered (but did not contact) the reefs for several days. This fortuitous situation is believed to have resulted because the spill occurred during neap tides.

An experimental spill of light weight crude oil indicated that healthy reef corals tolerated relatively short exposures (one to five days) to floating and dispersed oil with no observable effect (LeGore *et al.*, 1989). The results of studies on dispersed medium weight crude oil contrast these findings. For example, Ballou *et al.* (1989) conducted a field survey in which pre-dispersed oil was applied to experimental coral plots. Observed impacts were severe, although it was concluded that the severity of the impact was higher than would be expected under more realistic conditions (i.e. where natural weathering of the oil prior to subsequent dispersal would reduce the level of the more toxic volatile components). It is generally agreed that dispersants added to fresh oil spills in the vicinity of subtidal coral reefs will increase, instead of decrease, adverse effects of the spill.

(ii) Mangroves

Mangrove stands that are exposed to spills of untreated light and medium weight crude oils typically display one or more signs of a toxic response including defoliation, leaf blackening and curling, chlorosis and pneumatophore damage. These may lead to death of the trees.

The variability of the response of mangroves to oil spills is due to a wide range of biological, chemical and physical factors which make generalisations difficult. For example, the effects of spillages of two medium weight crude oils in two different mangrove areas included defoliation then recovery at one site (a semi-enclosed estuary; Snowden & Ekweozor, 1987), and mortality at the other site (an open coastal setting; Nadeau & Bergquist, 1977).

The acute toxic response of the mangroves to oil appears to be restricted to a four month time frame following the spill (Getter, Ballou & Koons, 1985), with regrowth of leaves and re-emergence of seedlings generally occurring within 12 months (Snowden & Ekweozor, 1987; Page *et al.*, 1979; Teas *et al.*, 1989). However, the result of chronic effects would take longer to confirm.

Mechanical clean-up methods are likely to cause more harm to mangroves than oiling alone, so a substantial amount of work has been conducted on investigating the impacts of chemically dispersing oil as a clean-up option. There is a general consensus regarding the positive effect dispersing oil before it enters mangrove areas compared with the effects of leaving the oil untreated, or treating the oil after it entered mangrove areas. For example, Ballou *et al.* (1987) showed that dispersing oil prior to its encroachment on mangroves reduced or prevented adverse impacts to mature trees, and that seedling sprouting success and survival rates were much higher at 'pre-dispersed' sites than at untreated sites.

Dispersing oil prior to its entry into mangrove forest is now a management strategy recommended by the majority of mangrove researchers (e.g. Getter, Ballou & Koons, 1985; Ballou *et al.*, 1987; Teas *et al.*, 1987; Ballou *et al.*, 1989; Thorhaug, 1987). As with all oil spills, however, this must be viewed in the context of other factors operating at the time of the spill.

(iii) Seagrasses

Experiments and field observations involving spills of medium weight crudes suggest that seagrasses experience little or no observable adverse impact as a result of crude oil floating on the sea surface (Ballou *et al.*, 1989; Jackson *et al.*, 1989; Thorhaug *et al.*, 1989; Thorhaug & Marcus, 1987).

Dispersed light weight and medium weight crudes both appear to be slightly more toxic to seagrasses than when left untreated. Recent evidence suggests that species specific responses of seagrasses to dispersed oil can be markedly different, and that *Thalassia* was the most tolerant compared to *Halodule* and *Syringodium* (Thorhaug *et al.*, 1989; Thorhaug, 1987).

The relatively high degree of tolerance of tropical seagrasses to crude oil spills has been corroborated by observations made after a large spill of medium weight crude oil in Panama. Thus monitoring of a heavily-oiled subtidal seagrass bed found discolouration and heavy epiphytic growth on the seagrass blades for several months after the spill, but that seagrass bed eventually survived these perturbations (Jackson *et al.*, 1989).

(iv) Prawn fisheries

As with most groups of marine organisms, the reported impacts of oil on prawns are highly variable (Neff & Anderson, 1981). General conclusions that can be drawn from the available literature are that pelagic larval stages are more sensitive to oil than adult life stages (Kasymov & Gasanov, 1987), and that fresh light weight crudes (containing relatively high concentrations of low molecular weight aromatic compounds) are more toxic to prawns than both weathered light weight crude and medium weight crudes (Neff & Anderson, 1981; Anderson *et al.*, 1987).

Rigorous studies on the effects on prawns of oils treated with dispersants are few. A recent report on the impacts of a dispersed light crude oil on shrimps suggested that toxic effects are restricted to the first six hours of a spill, and that if shrimps survive this time frame they could recover and survive (Shuba & Heikamp, 1989). While dispersing an oil slick will expose a greater number of prawns or larval stages to the effects of the oil, dispersion accelerates the volatilisation of the lighter and more toxic aromatic components, and can markedly lessen the impact on mangroves (see above).

Petroleum hydrocarbons responsible for toxicity and tainting in prawns are the light end polycyclic aromatic hydrocarbons (PAHs). These are among the first groups to be weathered from oil following a spill. It is not anticipated that Roller crude will contain a high percentage of PAHs and thus the toxicity of this oil is expected to be low.

Reduced amounts of low molecular weight toxic compounds also reduce the tainting potential. Tainting of prawn flesh has been found to be potentially a greater concern than the actual toxic effects, since tainting can be as much a perceptual concern to consumers as a real concern. Natural sources have also been found to cause tainting in prawns and thus reports of 'off-flavours' following a spill require careful investigation.

Due to their commercial importance, studies on the effects of oil on prawns have often been undertaken in the field after a spill has occurred. Many of these studies were unable to detect a significant change to a prawn fishery as a result of an oil spill (Hester, 1977 and references therein; Blackman & Law, 1980; Boehm *et al.*, 1983; Moller, Dicks & Goodman, 1989). None of the reviewed reports could conclude that long-term impacts on commercial penaeid prawn (shrimp) fisheries was a direct result of an oil spill, with most authors conceding that it would be extremely difficult to separate the effects of an oil spill from marked seasonal variations in catch statistics.

5.4.6.3 Effects on Social Resources

(i) Tourism

The tourism industry is unlikely to be significantly affected by an oil spill unless it beached on Thevenard Island, Direction Island or the coastline at Onslow. Contaminated beaches at Thevenard would detract amenity value of the Mackerel Island Resort. However, the effect from small to medium spills would be temporary and clean-up operations would be rapid given the availability of WAPET personnel. Thus effects are likely to be temporary and short-term, affecting only those tourists visiting the area at the time of the spill.

In the event of a major oil spill, the number and duration of effected beaches could be extended and include those such as Serrurier Island. Natural weathering assisted by raking can be expected to return contaminated beaches to pre-spill conditions within 12 months following a major spill.

(ii) Commercial fisheries

Local commercial fisheries are likely to be adversely affected by a large oil spill, particularly in the short-term. The magnitude of the effect will depend on the time of year, size of the initial slick, the treatment strategy that is adopted, and the type of shoreline and shallow water habitats affected.

Reported effects of oil spills on fisheries include reduced abundance of catch due to mortality in the catch population, real or perceived tainting of prawn, fish, and shellfish tissues, and fouling of boats and fishing gear by oil. Widespread tainting of prawn and demersal fish flesh is not commonly associated with untreated oil spills because the oil remains at or near the water surface and is therefore not likely to come into contact with these species. Prawns and fish that become tainted by hydrocarbons have the ability to depurate hydrocarbons from their bodies within a few weeks. Pelagic fish are not expected to be greatly affected due to their mobility.

The fishery that is most at risk from a major oil spill is the nearshore brown tiger prawn fishery in Area 1. Both pelagic larval stages and benthic juvenile and adult stages of prawns are more sensitive to oil than fin fish or molluscs. Larval and juvenile stages are particularly sensitive. Penaeid prawn stocks are dependent on adequate recruitment each year (few, if any adults survive to spawn in their second year of life).

An oil spill during the spring spawning season would probably result in localised but high mortalities of the highly sensitive eggs and larvae which at this stage are drifting between the offshore spawning grounds and the inshore settlement areas. However, since the spawning season extends throughout spring and into early summer for the brown tiger prawn and a similar, but slightly longer period for the western king prawn, it is likely that small to medium spills would not be capable of depleting the fishery to a major extent.

A major spill during summer that is caused by (or coincides with) a cyclone has the potential to cause the most damage to the brown tiger prawn fishery, particularly if the slick is driven by northerly winds into tidal creeks and mangrove habitats of the Ashburton delta (i.e. places where the juveniles are believed to concentrate). Strong winds from the north are relatively uncommon but are associated with the passage of cyclones. If cyclonic rainfall in the Ashburton catchment produces high river flow soon after the oil spill has occurred, both the remnants of the spill and the juvenile prawns would be expelled into the nearshore region. Such flooding events by themselves are known to produce poor recruitment in the Exmouth Gulf if they occur before the end of January.

Thus the local stock of tiger prawns could be seriously depleted if a large oil spill was to impinge inshore shallow water nursery areas between November and January, a period when numbers of recently-settled juvenile prawns have peaked and when the last of the pelagic larvae are drifting in from the spawning grounds.

Recovery of the local stocks from such a combined event, or 'worst-case scenario', would depend on the size of the area affected by the spill, the persistence of the oil, and the treatment strategy that is employed (dispersants would exacerbate effects). Recovery will also depend on:

- the location and extent of the area along the Ashburton coastline that forms the main settlement and nursery grounds for the Area 1 stock; and

- the degree to which the Area 1 stocks are isolated from stocks to the west (in Exmouth Gulf), and to the east (Passage Islands) of Onslow.

Present information on brown tiger prawns in Exmouth Gulf and North Queensland suggest that the Ashburton River delta could form the main settlement and nursery area, and that 'cross-recruitment' from other regions is low (Section 4.3.5.2). Thus if the spill was allowed to impinge upon the Ashburton delta, it is possible that the fishery could be depleted to the point where catch rates were no longer economic and where cessation of trawling would be required to facilitate the recovery of the stock over ensuing years.

5.4.6.4 Synthesis of Oil Spill Effects and Their Potential Containment

The chances of an uncontrolled blowout are negligible (Section 5.4.2.3), but a spill originating from an oil tanker accident near Thevenard Island is conceivable, and could cause widespread damage to coral reefs, sand beaches and seagrass beds in the region.

Information in Sections 4.2 (biological environment), 4.3 (social environment), 5.4.5 (oil spill trajectories and predictions) and 5.4.6 (effects of oil spills) show that the coastal and marine resources most at risk from accidental oil spills comprise:

- the mangrove assemblages of the tidal flats, rivers and creeks in the vicinity of Entrance Point and the Ashburton River delta;
- coral reefs and macroalgae/seagrass beds in shallow waters surrounding Ashburton Island and Thevenard Island;
- sand beaches at Onslow, Thevenard Island and possibly Direction Island;
- other island beaches used by seabirds for feeding and nesting and by turtles for nesting (e.g. Locker Island, which is also an A-class reserve);
- the Area 1 prawn fishery, which targets brown tiger prawns; and
- Beadon Creek, since this mangrove-lined creek provides the only harbour and port facilities in the region, and may become the location where salt water is extracted for the proposed solar salt project.

Dispersants are likely to exacerbate the effects of an oil spill on all of these resources except for the mangrove communities (although the latter case would be true only if dispersants could be applied before the oil entered mangrove habitats).

On the other hand, it is the mangroves which may take the longest period to recover from the effects of an oil spill. Nevertheless, it is a requirement of the Environmental Protection Authority Western Australia that dispersants should not be used where water depths are less than 8 m deep, or in areas less than 8 km from the coastline (Fig. 24). In the case of the Ashburton coastline, it is possible that an exception can be made given the lack of coral reefs and both macroalgae and seagrass beds between the Roller development and the Ashburton delta and river mouth.

A spill could only cause significant and possibly unacceptable impacts to mainland mangrove systems if the oil was pushed into them by winds blowing from northerly quadrants. In the case of the tiger prawn stock, potentially deleterious impacts would be much more likely during the period between mid-spring and early summer when the juveniles are utilising the shallow inshore waters (October to end of January). However, while the Roller Oilfield is close to both the Ashburton mangrove system and a possibly very important nursery area for the brown tiger prawns, the data on local winds indicate that the percentage of time when strong northerlies occur is very small (6:10,000), and local tidal currents flow along east-west axes (Section 5.4.5.1).

Despite the very low risk, the chance of mangrove oiling should not be ignored given the potential for these systems to suffer long-term effects. Thus the permissibility of dispersant usage in the rare event that a spill coincided with strong northerly breezes may require further discussion, particularly since other measures (such as deployment of deflecting booms at the entrance of a creek in order to deflect oil onto nearby sand beaches) may be more desirable under certain scenarios.

In most spill scenarios, however, prevailing winds will cause the oil to move away from the mainland coastline and towards either Ashburton Island or Thevenard Island. In these situations, the choice over oil spill control and containment measure are generally more clear cut, since the need for dispersants would be reduced.

During any spill event, WAPET would make available all oil spill equipment, and as many vessels, aircraft and personnel as could be safely relinquished to help with containment and clean-up measures.

Oil that ultimately beaches on offshore islands could either be removed manually or allowed to weather naturally. Damage to coral reefs that may occur as a result of small or medium size oil spill would depend on the state of the tides at the time of the spill, but this damage can be expected to be short-term and the recovery potential appears high. The risk to these resources is also mitigated by the fact that they are usually submerged except during short periods of very low spring tides. The combination of the subsurface topography and faster tidal currents during this phase of the lunar cycle helps to maintain flows parallel to the shore, unless wind strengths are high.

5.5 CONCLUSION

The chance of a major spill from an uncontrolled blowout during development drilling is considered negligible, and both routine drilling and production operations will produce negligible effects that will not adversely affect the marine or social environment.

While the main environmental concern arising from the proposal is the risk of a serious spill, this risk can be minimised and reduced to acceptable levels by careful management and implementation of an appropriate Oil Spill Contingency Plan. WAPET is an experienced company that has established an enviable record in the management of oilfield operation effects on the environment.

Roller crude is a medium weight, low-sulphur oil that appears to have low levels of the more toxic low molecular weight PAH and alkanes. Its weathering ability will be similar to that of diesel fuel. Minor oil spills can be readily contained and dealt with using equipment that will be based at Thevenard Island, Barrow Island and Onslow. In the highly unlikely event of a serious oil spill at the Roller field, it has been shown that the marine resources that would be in most need of protection in the region are those surrounding Ashburton, Thevenard and Locker Islands, the mangrove assemblages and prawn nursery grounds within the Ashburton River delta, and the beaches and creeks of high social amenity value (i.e. the popular 'Back Beach' and 4 Mile Creek near Onslow, and the mangals and harbour facilities within Beadon Creek).

6 ENVIRONMENTAL MANAGEMENT

6.1 INTRODUCTION

The Environmental Management Programme (EMP) which will be implemented for Roller Oilfield development is detailed in this section. The objective of the programme is to minimise the environmental effect of the development as much as practicable and financially reasonable.

WAPET proposes to achieve this objective by:

(i) complying with all legal requirements;

(ii) adopting industry and government standards and guidelines for well design and control;

(iii) utilising drilling fluids approved by the Department of Mines primarily composed of non-toxic polymers and clays;

(iv) implementing a drilling operations discharge strategy aimed at minimising environmental impact;

(v) continuing the existing Saladin production discharge strategy at Thevenard Island for processing and transferring Roller crude;

(vi) expanding its existing workforce education programme;

(vii) updating the existing Oil Spill Contingency Plan for Permit Area TP/3 Part 1.

Details of most of the above tasks are presented in subsequent sections. WAPET agrees to meet the existing legislative requirements and industry standards that are applicable to oilfield development. Facts pertinent to WAPET's proposed development include:

(i) there are laws, regulations and standards for the safe and environmentally acceptable development and operation of offshore oilfields;

(ii) these laws and standards are administered and supervised by government authorities, mainly the Department of Mines Western Australia; and

(iii) there exists a long history of experience in this State by both operators and regulators with offshore oilfield development and operation.

6.2 OPERATIONAL MANAGEMENT

6.2.1 Development Well Drilling

6.2.1.1 Drilling Fluid Disposal

During drilling, drilling fluid and formation cuttings are brought to the rig floor via the well casing. These are passed through solids control equipment which separates the drilling fluid from the cuttings. The cuttings are continuously discharged from the rig while the drilling fluid is recirculated down the well. However, there is occasionally the need to discharge drilling fluid into the sea as a result of drilling through formations that lead to excess drilling fluid (e.g. shale), or when the properties of the drilling fluid have to be modified to improve drilling efficiency.

To minimise the area affected by turbidity and to maximise the dilution rate, WAPET will discharge excess drilling fluids only when tidal and wind currents are at their strongest and when currents are moving away from sensitive marine resources and at rates as stated in Section 2.3.1.3 (i.e. no more than 159 L/min) .

6.2.1.2 Drill Cuttings Disposal

It is proposed to continuously discharge cuttings from the rig. Oil industry experience shows that this disposal of cuttings will cause minimal effects because:

(i) the material is inert and are likely to settle quickly on the seafloor to form small elliptical mounds; and

(ii) the mounds of cuttings are usually rapidly colonised by benthic organisms, unless they are disturbed by rig relocation procedures.

6.2.1.3 Responses to Cyclones

Development drilling is likely to overlap the cyclone season (November-April), and thus routine measures will be implemented to safeguard both the well, rig and personnel. The drilling rig to be contracted will be capable of withstanding cyclonic wind and wave conditions. Detailed procedures which set out the various levels of response to cyclones will be contained in the operator's Emergency Procedures Manual.

During the cyclone season, WAPET's Perth office and the rig obtain advice on cyclonic developments via the Cyclone Watch Centre in Perth on a 24 hour basis. Alerts are based on three stages, with the second and third stages (notices to shut down operations with all convenient speed and to evacuate personnel respectively) involve pre-planned procedures. These procedures include securing the well by temporary plugging and by closing the blowout preventers (BOPs) so that no fluids may escape, and to shut down and secure the drilling rig. Finally all personnel are evacuated to the mainland.

Recommencement of operations following the passage of a cyclone involve various procedures, depending on whether a hydrocarbon zone was being penetrated at the time of shut down. In this case, any hydrocarbons entrained in the drilling fluid that may have migrated to below the temporary plug are carefully circulated out of the well and passed through the oil stripping plant on board the rig.

6.2.2 Production Phase

Produced fluid pumped to Thevenard Island will be separated and treated within existing facilities, and operational discharges will be controlled and regulated in the same manner as already occurs for Saladin production at Thevenard Island. Existing procedures on Thevenard Island for fire control, workforce movements, island flora and fauna protection, custody transfer of produced crude to tankers will be maintained.

Procedures for cyclone alerts will also be similar to those utilised for the production of Saladin crude. These procedures include full shut down of wells and evacuation of offshore monopods and structures, the postponement of tanker mooring operations, the cessation of crude transfer operations and the temporary departure of moored tankers into deeper waters and away from reefs and coastlines.

6.2.3 Education Programme

Prior to commencement of their duties, each worker or contractor (including workboat and supply vessel crews), will be given an induction including advice on the sensitive nature of the environment in which the drilling rig and oilfield is located. The 'dos and don'ts' of drilling in the area will be emphasised in documents similar to those already utilised at Thevenard Island, and presented in the Notice of Intent for exploratory drilling in the Roller prospect (LSC, 1989a).

6.3 MONITORING PROGRAMME

6.3.1 Background

WAPET presently manages an Environmental Monitoring Programme (EMP) for the Saladin Oilfield and Thevenard Island. This programme comprises terrestrial and marine monitoring components. The Marine Biological Monitoring Programme (MBMP) was instigated in 1988, with baseline data collected in May 1988. Production from Saladin commenced in late 1989, and there have now been two annual reports of the MBMP (LSC, 1989b; LEC, 1990). At present, the Saladin

MBMP consists of routine six monthly surveys of corals, seagrass and algae and 12 monthly analyses of hydrocarbons in the intertidal zones of sand beaches.

The objectives the MBMP are to provide data confirming that important marine resources in the vicinity of the project were not adversely affected by the construction phase of the Saladin development, that these resources are not being adversely affected by oil spills, and to provide important long-term 'baseline' data to ascertain the types and scope of natural variations. The latter objective is important with respect to determining (with reasonable accuracy) the nature and extent of impact of a serious oil spill on these important resources, should one occur. Objectives are met by comparing results of sites close to the Saladin field with those from sites at distant locations (such as Serrurier and Bessieres Islands).

6.3.2 Proposed Action

It is planned to expand the existing MBMP to ensure that important marine resources that could be affected by either development or operation of the Roller field are adequately monitored for the same rationale and objectives as stated above. To this end, surveys of the marine and intertidal resources have already been undertaken (Appendices 2 & 3). The results of these surveys, combined with the oil spill trajectory modelling (Appendix 4), indicate that selection of the following sites will enable optimal monitoring of key ecological resources of the region which would be most at risk in the event of an accidental oil spill:

Site location	Resource	Proposed Action
Ashburton Island	Coral reef	Establish second site on south-east side of the Island.
	Sand beaches	Maintain existing hydrocarbon testing site.
Ashburton delta	Mangroves	Establish suitable monitoring sites (details to be advised).
	Tidal flats	Establish hydrocarbon test sites.
Entrance Point (east)	Rocky shoreline	Establish hydrocarbon test site (oysters).
Tubridgi (east)	Nearshore reef	Establish coral monitoring site.
	Sand beach	Establish hydrocarbon test site.
Locker Island	Coral reef	Establish monitoring transect.
	Seagrass/algae	Establish monitoring transect.
	Sand beaches	Establish hydrocarbon test site.

Beadon Point and the Back Beach at Onslow	Rocky shoreline and sand beach	Install oyster and sediment hydrocarbon test sites.

The proposed expansion to the existing MBMP is planned to commence in mid-1992, so that 'baseline' data will be obtained prior to construction and production activities.

6.4 OIL SPILL CONTINGENCY PLAN

6.4.1 Background

Selection of appropriate techniques for the control and treatment of an offshore oil spill depends on the type of oil spilt, the location and size of the slick, the weather, sea state and direction of wind, and the strength of tides. Effects of possible treatments must also be evaluated to ensure that these will not inflict a greater impact than that of the spill itself.

The favoured nearshore technique for contingency plans is the containment of spilt oil with booms and/or deflection devices, and its subsequent collection with skimmers. Other options include physical agitation to promote evaporation, and dispersion with approved chemical treatments (particularly for spills in offshore, deep water areas that threaten to be blown onshore in a short space of time). Approved dispersants can also be used as a 'last resort', i.e. in difficult weather and ocean conditions, and can be deployed rapidly by specially adapted light aircraft and helicopters. Such use of dispersants in inshore areas requires express permission from the EPA.

DCE Bulletin No. 104 (Jones, Field & Hancock, 1984) outlines procedures formulated for the protection of SPLs during offshore oil exploration or production, including the submission of an Oil Spill Contingency Plan for review and approval by the State Committee for Combating Oil Pollution. The main feature of these plans is that operators within SPLs must be able to cope by themselves for the first 24 hours of any spill. This means having adequate mechanical diversion equipment and stocks of approved dispersant at the nearest regional centres, in this case Thevenard Island or Barrow Island.

Since the Roller field is within SPL No. 32, WAPET will ensure that an oil spill containment boom will be present at the site during the drilling programme. The boom will be stored on board the drilling rig and can be deployed by the standby vessel that is present at the rig site at all times. Additional equipment at Thevenard and Barrow Islands can be mobilised to the site within hours.

6.4.2 Operational Procedures

Appendix 6 summarises WAPET's Oil Spill Contingency Plan (OSCP) which applies to exploration and development drilling within Permit Area TP/3 Part 1. This OSCP has been approved by all pertinent Government Authorities, including the EPA, Department of Mines and State Combat Committee. It will be expanded by WAPET with the insertion of appropriate relevant information derived from studies undertaken for the development and this CER. WAPET will be committed to following the upgraded plan, which will include additional information on coastal bathymetry, coastal and nearshore marine habitats, and on important marine resources of the area requiring protection (described in Sections 4 and 5).

As part of the OSCP, a plan has been devised to maximise protection of environmentally important resources in the region by specifying strategies for dealing with oil spills in different circumstances. The proposed strategy is summarised in Figure 25.

Containment with booms and removal of oil will be attempted if at all possible, unless effective deployment of booms is hampered in rough water or near islands and shoals (where navigation is hazardous and currents are stronger). If containment is not possible, further treatment will depend on the direction in which the oil slick is travelling, its state of weathering, and on the proximity of important environmental resources.

If the uncontained oil moves along a trajectory that poses no threat to islands or the mainland coastline, the slick will be monitored and left to biodegrade naturally. Dispersants could be used to aid dispersion if the slick reaches relatively deep water outside environmentally sensitive areas, and if there is a risk that tidal flow may eventually move return the slick to shorelines.

If the uncontained oil moves toward intertidal habitats on islands, deflection booms could be deployed in an attempt to prevent beaching. If it is not possible to prevent the oil from beaching, booms could be deployed (weather permitting) to protect vulnerable and important habitats, such as shallow coral reef areas, or entrances to the Ashburton delta or other creeks. In these cases, the oil could be deflected and allowed to beach on nearby or adjacent sandy beaches.

Stranded oil will be left to biodegrade naturally without treatment (unless it has stranded on beaches at a time when they are being used by tourists or turtles), with monitoring of oil decomposition and biota recovery. Contaminated seabirds or turtles would be cleaned.

Natural biodegradation and weathering is usually the most appropriate strategy, since attempts to clean habitats such as mangroves and intertidal mud flats often cause more damage than the oil itself. Covering stranded oil with sand only inhibits biodegradation. If natural degradation is not considered acceptable for biological or social grounds, oil on sand beaches may be removed by bulldozers and scraping. Pollution of beaches used by turtles for nesting may warrant such treatment, depending on the time of year and amount of oil spilt.

Dispersants will not be used near coral reefs, or algae and seagrass beds or near beaches without authorisation from the EPA. However, in the case of the Roller development, both the type of oil and the relatively distance from sensitive mangrove habitats on the mainland coast means that the use of dispersants must be contemplated if a slick moves towards the mainland coast (Section 5.4.6.4). In this case, dispersants may be necessary if standard containment procedures have proved unsuccessful owing to weather conditions.

6.5 SUMMARY OF COMMITMENTS

WAPET hereby agrees to comply with all commitments made in this document. A full list of commitments is provided in Appendix 7. In summary, WAPET will:

(i) comply with all legislative requirements pertaining to this project;

(ii) adopt industry and government standards and guidelines for safe oilfield operations;

(iii) expand the existing Environmental Management Programme as outlined in this document;

(iv) comply with all guidelines and directives to be listed within the Oil Spill Contingency Plan;

(v) decommission the field by means stated in this document.

6.6 AUTHORITIES RESPONSIBLE FOR MANAGEMENT

The principal authorities responsible for management of the Roller Oilfield operations are West Australian Petroleum Pty Limited and the Department of Mines Western Australia.

Other authorities indirectly involved with the project are the Department of Marine and Harbours (tanker movements in the vicinity of the Thevenard Island and mooring operations at the terminal), the Department of Conservation and Land Management (responsible for the management of island reserves), and the Fisheries Department (responsible for the management of the various commercial fisheries which utilise Onslow).

6.6.1 West Australian Petroleum

WAPET is responsible for:

(i) compliance with the conditions of the licence area;

(ii) compliance with all relevant legislation; and

(iii) compliance with the commitments made in this document.

6.6.2 Department of Mines

The Department of Mines is responsible for ensuring that all industry standards, guidelines and legal requirements are complied with by WAPET.

7 CONCLUSIONS

Since 1985, three major offshore oilfield production developments have been commissioned in the region. All have undergone environmental scrutiny and all have been regularly monitored. Together with the various offshore oil exploration activities undertaken over the North West Shelf, these developments produce a substantial amount of local experience on which to identify and assess the level of potential impacts.

This assessment shows that the development and operation of the Roller Oilfield as proposed by WAPET will cause no important adverse impacts on either the marine ecosystems or the local community. For example, the amount and rate of production discharges and shipping movements are not expected to increase due to the decline in output from the Saladin Oilfield which is presently processed and shipped from Thevenard Island. The quality of discharges will not decrease, and will remain within stringent Department of Mines specifications.

A minor impact will result from the need to provide marine exclusion zones around the monopods at Roller A, B, C, and D. These zones will restrict access to very minor parts of the local trawling grounds as a result of the need to protect both the facilities and trawling gear from accidental damage. These restrictions will be temporary and WAPET, which has already initiated direct discussions with local fishermen, will continue to pursue all viable means to ensure that the area that will temporarily be lost to the Area 1 fishery will be minimised.

The main environmental concern arising from the proposal is the risk and potential scale of an accidental oil spill. However, the chance of a major oil spill occurring during either the development or production phases of the Roller Oilfield is exceedingly small, and WAPET has an impressive management record dating back to 1953. The assessment has also shown that while the mainland coastline (including the mangroves of Ashburton delta) is relatively close to the development, it is not likely to be at serious risk because strong northerly winds blowing for more than six hours are relatively infrequent and typically associated with cyclones, i.e. a time when both development and production operations will be shut down for safety reasons. Moreover, in the case of the mangrove-lined creeks within the delta or at Onslow, any encroaching oil slick could be deflected to the 'down current' side of the creek entrance.

Nevertheless, it is recommended that any spilt crude oil should be dispersed if weather conditions are unfavourable for spill deflection, or if it is considered possible during oil spill tracking that a significant area of mangrove habitat could be impinged. This recommendation is based on the positive results of such actions reported in recent literature, which also provide evidence that mangrove habitats appear more susceptible to long-term damage from an oil spill than penaeid prawn fisheries. Such refinements to the OSCP for Permit Area TP/3 Part 1, together with the equipment and logistical resources that are available locally, would ensure that combat effectiveness against an oil spill will be maximised.

Roller crude is already a weathered oil which has lost most of its light weight and more toxic components due to biodegradation within the reservoir. Thus the effects of an accidental spill that directly impinges on sensitive marine resources in a warm tropical environment are not anticipated to be severe or long-term. It is therefore concluded that the proposed project can be managed in an environmentally acceptable manner, and that the advantages ensuing from project go-ahead will considerably outweigh the very small environmental risk that is attached to all such developments. For example, both the State and the local community will derive financial benefit from the construction and operation of the field, as well as benefit from the resultant increased stimulus to search for more oil and gas reserves.

8 CONSULTATION LIST

Area 1 prawn fishery

Don Fenwick, Mick Manifes et al.	Professional prawn fishermen	Onslow
James Masters	Western Australian Marine Research Laboratories	Waterman
Guy Leyland	Western Australian Fishing Industries Council	

Other Onslow fisheries

Guy Leyland	Western Australian Fishing Industries Council	Osborne Park
F. Yeo	Australian Bureau of Statistics	East Perth

Oil spill records

Keith Gammie	Western Australian Department of Mines	East Perth

Social impacts of development

Mackerel Islands Pty Ltd	Holiday resort	Subiaco
Jim Cullen	Local Councillor	Urala Station, Onslow

Regional meteorology and oil spill predictions

Barbara Brown Steve Buchan	Steedman Science & Engineering	Jolimont

Ashburton River flow data

Rowley Dowd	Water Authority of Western Australia	Leederville

Coastal processes

Nello Siragusa	Department of Marine & Harbours	Fremantle

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TABLE 1

DETAILS FOR WELL DESIGN - TYPE A, B AND C

CASING SIZE (LINER)	HOLE SIZE	HOLE LENGTH (MD)		SHOE DEPTH (MD)	PROPOSED TOP OF CEMENT
		FROM	TO		
TYPE A - VERTICAL WELL					
20"	26"	10 m	45 m	45	To mudline.
13 3/8"	17 1/2"	45 m	225 m	220	To surface.
9 5/8"	12 1/4"	225 m	955 m	950	To surface.
TYPE B - HORIZONTAL WELL*					
9 5/8"	12 1/4"	225	1,346	1,340	To surface.
7"	8 1/2"	1,346	1,746		
TYPE C - HI-ANGLE WELL*					
9 5/8"	12 1/4"	225	1,330	1,325	To surface.

* 20" & 13 3/8" casings, and 26" and 17 1/2" holes, are the same as for vertical well (Type A)

Note: Approximately equal numbers of Type A and B wells are envisaged (i.e. three Type A and four Type B). A Type C well will only be drilled if required to re-establish vertical depth of payzone.

TABLE 2

TYPICAL COMPOSITION AND VOLUME OF CUTTINGS

HOLE SIZE	EXPECTED TOTAL (m^3) INCLUDES CAVING	CARBONATES (m^3)	CLAY/ SILTSTONE (m^3)	SANDSTONE (m^3)	CAVING FACTOR
36"	30	30	-	-	50%
17½"	36	36	-	-	30%
12¼"	60	-	54	6	30%
8½"	17	-	10	7	5%
TOTAL	143	66	64	13	

* based on Roller No. 1 experience

TABLE 3

TYPICAL DRILLING FLUID MATERIAL CONSUMPTION

PRODUCT	CHEMICAL DESCRIPTION	QUANTITY (kg)	% OF TOTAL MATERIALS*
KCl	KCl	35,500	37.7
Barite	$BaSO_4$ -inert	26,495	28.1
Bentonite	Montmorillonite clay - inert	18,569	19.7
Polysal	Modified polysaccharide	4,150	4.4
Drillam PA	Polyanionic cellulose	2,625	2.8
Soda Ash	Na_2CO_3	1,840	2.0
Caustic Soda	NaOH in solution	1,775	1.9
Lime	CaO	825	0.9
Sodium Sulphite	NaSO	700	0.7
Mica	Muscovite - inert	660	0.7
Spersene	+Lignosulphonate	500	0.5
Magco A-303	Water-soluble filming amine	410	0.4
XCD Polymer	Xanthan gum	150	0.2
Polyplus	High molecular weight anionic polymer	38	-
TOTAL		94,237	100.0

* These percentages are of total added materials. The bulk of the drilling fluid (90%) is seawater and colloidal clays from the formations drilled.

* Based on Yammaderry No. 1 drilling fluid programme.

\+ Usually in the form of ferro-lignosulphonate.

TABLE 4

OCCURRENCE OF WIND SPEED AND DIRECTION AT THEVENARD ISLAND BETWEEN 1 FEBRUARY 1987 AND 31 JANUARY 1988

DIRECTION	WIND SPEED								TOTALS (%)
	(km/h) <7	7-14	14-22	22-29	29-36	36-43	43-50	>50	
	(m/s) 0.1-2.0	2.1-4.0	4.1-6.0	6.1-8.0	8.1-10.0	10.1-12.0	12.1-14.0	>14.1	
North	1.3	3.1	2.3	1.3	0.3	0.0	-	-	**8.4**
North-east	0.8	1.8	1.9	1.8	1.1	0.4	0.1	0.0	**8.0**
East	0.7	2.0	2.1	1.1	0.4	0.1	0.0	-	**6.4**
South-east	0.7	3.2	2.8	1.8	0.6	0.0	-	-	**9.1**
South	0.9	3.4	4.9	5.7	2.8	0.5	0.0	-	**18.1**
South-west	0.9	5.3	9.2	9.8	3.2	0.4	0.1	0.0	**28.8**
West	0.7	4.3	4.8	4.0	1.0	0.0	-	-	**14.8**
North-west	0.7	3.1	2.1	0.2	0.0	-	-	-	**6.1**
Total (%)	**6.7**	**26.3**	**30.1**	**25.7**	**9.3**	**1.5**	**0.1**	**0.0**	***100.0**

* Includes occurrence of calm periods (0.3%)

Source: Steedman Science & Engineering (1991)

TABLE 5

PERCENTAGE DURATION OF WINDS AT THEVENARD ISLAND BETWEEN 1 FEBRUARY 1987 AND 31 JANUARY 1988

WIND SPEED		DURATION (hours)								TOTAL (%)
km/h	m/s	>6	>12	>18	>24	>30	>36	>48	>96	
≥43	≥12	0.0	-	-	-	-	-	-	-	0.0
≥36	≥10	0.7	0.0	-	-	-	-	-	-	0.7
≥29	≥8	6.9	3.9	1.6	0.5	0.5	0.5	0.0	-	6.9
≥22	≥6	30.2	21.4	12.2	7.1	5.4	4.2	2.0	0.0	30.2
≥14	≥4	61.5	52.4	44.6	36.1	35.0	33.1	26.4	13.7	61.5
≥7	≥2	91.7	88.9	83.9	75.5	71.7	68.4	61.0	48.7	**91.7**
0-7	≥0	8.3	-	-	-	-	-	-	-	**8.3**
										100.0

Source: Steedman Science & Engineering (1991)

TABLE 6

SUMMARY OF STORM WIND OCCURRENCES

STORM TYPE	PRINCIPAL MONTHS OF OCCURRENCE	TYPICAL WIND SPEED AND DURATION	TYPICAL EXTREME WIND SPEEDS	TYPICAL WIND DIRECTION
Tropical Cyclone	November-April	15-30 m/s (54-108 km/h) 4 - 16 hours	30-50 m/s (108-180 km/h)	All directions dependent on eye location
Trade Wind/ Pressure Gradient	May-September	10-15 m/s (36-54 km/h) 24 - 72 hours	20-30 m/s (72-108 km/h)	South-east/East
Squalls	November-April	15-25 m/s (54-90 km/h) 1 - 2 hours	25-30 m/s (90-108 km/h)	All directions
Tornadoes	November-April	Unknown, but assumed to be 40 m/s (144 km/h) 1 - 5 minutes	Unknown, but assumed to be 50 m/s (180 km/h)	All directions

Source: Steedman Science & Engineering (1991)

TABLE 7

MAXIMUM INSTANTANEOUS FLOW RECORDS FROM THE ASHBURTON RIVER# BETWEEN JUNE 1972 AND DECEMBER 1989*

OCCURRENCE	MAXIMUM INSTANTANEOUS FLOW (m^3/s)					
	0	> 0	> 25	> 50	> 100	> 200
NUMBER OF MONTHS	66	137	66	59	47	35
PERCENTAGE OF TOTAL RECORD	33	67	33	29	23	17

TABLE 8

INSTANTANEOUS FLOW RECORDS FROM THE ASHBURTON RIVER# BETWEEN OCTOBER 1971 AND DECEMBER 1989*

OCCURRENCE	INSTANTANEOUS FLOW RANGES (m^3/s)					
	0.0	0.0 - 1.5	1.5 - 15.0	15.0 - 68.0	68.0 - 320.0	320.0 - 3200.0
FLOW DURATION (DAYS/ANNUM)	162.3	103.0	39.4	16.4	8.8	4.7
PERCENTAGE OF TOTAL RECORD	48.5	30.8	11.8	4.9	2.6	1.4

\# Recorded at the Nanutarra gauging station which is located approximately 60 km upstream from the mouth of the Ashburton River; latitude 22° 32' 42" S, longitude 115° 29' 51" E.

* Derived from Public Works Department Western Australia (1984) and supplementary data from the Water Authority of Western Australia, Surface Water Branch (Ashburton River Catchment, Nanutarra Gauging Station).

TABLE 9

COMPOSITION OF TOTAL COMMERCIAL FISH CATCH FOR ONSLOW (1987-1988 AND 1988-1989)

SPECIES	LIVE WEIGHT (kg)	
	1987-1988	1988-1989
Barramundi	4,361	7,101
Cod	55,942	72,492
Nor-west Snapper	123,329	98,340
Mackerel (all species)	36,858	24,212
Red Emperor	90,650	38,565
Trevally (golden)	5,775	2,604
Total all fish species	324,000	257,872
Total rock lobster	335	8,348
Total crab	651	121
Banana prawn	1,101	2,699
Brown tiger prawn	48,044	28,178
Endeavour prawn	13,551	17,467
Western king prawn	51,181	38,810
Western school prawn	257	
Other prawn	9,398	21,026
Total	123,532	108,180
Total molluscs	19,605	778
Grand total all species	468,370	405,299
Average grand total Western Australia (average for 1983-1986)	32,942,000	

Source: Australian Bureau of Statistics, Western Australia

TABLE 10

API GRAVITY OF VARIOUS NORTH WEST SHELF CRUDES

OIL PRODUCT	*API GRAVITY
Barrow Island	34°
Harriet	37°
South Pepper	44°
Chervil	44°
Saladin	48°
Roller	29°
Cowle	45°
Yammaderry	50°
Rough Range	34°
Mardie	17°
Fuel Oil	27°

*API - American Petroleum Institute

API Classification Scale

API Gravity	Classification
<20°	heavy crude oil
20° - 30°	medium crude oil
30° - 48°	light crude oil
>48°	condensate

TABLE 11

RISK FREQUENCY AND TIME TO IMPACT OF AN OIL SPILL

RELEASE POINT	SHORELINES AT RISK	RISK FREQUENCY (%)	WIND DIRECTION	TIME TO IMPACT (HOURS)
Roller North (near Roller D)	Ashburton Island	44.3	Calm, SW, W	6
	Entrance Point	8.4	N	6
	Thevenard Island	0.5	SW	12
	Rocky Point	0.5	NE	12
	Locker Island	0.1	E	12
	Fly Island	0.1	E	24
	Serrurier Island	<0.1	SE	24
	Coolgra Point	<0.1	NW	24
	Sunday Island	<0.1	SE	48
Roller Central (near Roller C)	Ashburton Island	43.6	SW, W	6
	Entrance Point	8.4	N	6
	Thevenard Island	8.0	NE	6
	Rocky Point	0.5	SW	18
	Locker Island	0.1	E	12
	Fly Island	0.1	E	24
	Onslow	<0.1	NW	12
	Coolgra Point	<0.1	NW	24
	Sunday Island	<0.1	SE	48
Roller South (near Roller A and B)	Ashburton Island	28.8	SW	6
	Entrance Point	8.4	N	6
	Thevenard Island	8.0	NE	6
	Rocky Point	0.5	SW	18
	Locker Island	0.1	E	12
	Onslow	<0.1	NW	12
	Coolgra Point	<0.1	NW	24
	Sunday Island	<0.1	SE	48

Source: Steedman Science & Engineering (1991)

TABLE 12

THE EFFECTS OF OIL ON TROPICAL MARINE HABITATS AND POPULATIONS AND MANAGEMENT OPTIONS

HABITAT/ POPULATION TYPE	DAMAGE AND TYPE OF EFFECT	SENSITIVITY TO OIL AND RECOVERY RATES FOLLOWING DAMAGE	TREATMENT OPTIONS	WHAT TO AVOID
CORAL REEFS	Impacts range from no affect (particularly on corals in deep, well flushed areas) to mortality of entire assemblages in shallow water (dispersed oil). Abortion effects have been reported, direct coating is lethal and corals are expected to be highly sensitive during mass spawning.	Sensitive. Behavioural effects temporary. Recovery rates poorly known. Corals have been observed self cleaning after an acute exposure.	Booms can be used to deflect oil around shallow reef areas.	No dispersants in shallow (less than 10 m) deep water.
SEAGRASS BEDS	Some species show short-term local denuding. Dispersed oil causes severe damage to intertidal organisms and produces higher sediment hydrocarbon concentrations than in undispersed areas.	Moderately sensitive. Recovery may be rapid after short-term impact. Retention of oil in sediments may cause long-term damage.	Booms can be used to deflect oil around shallow seabed area.	No dispersants increases residence time of oil in sediments.
MANGROVES	Highly susceptible to even light oiling resulting in defoliation and death. Faunal mortalities leading to decrease in population density.	Very sensitive. Diversion of spill the highest priority. Estimates from 10s-100s of years to attain a mature forest. Retention of oil in sediments may cause long-term problems.	Dispersants should be applied to oil that is approaching mangroves. Best treatment is to leave stranded oil alone to weather naturally.	Dispersants should not be used on oil stranded in mangroves. Mechanical clean-up methods must not be attempted in mangroves.
INTERTIDAL MUD AND SAND FLATS	These areas support a great variety of marine flora and fauna and often are spawning or nursery grounds, and fish and bird feeding areas. The above components are all highly susceptible to the impacts of oil. Turtles mating in shallow nearshore waters may be seriously affected.	Sensitive. Recoveries vary from rapid (months to years) to slow (10s of years) depending on the degree of oil retention and availability of recolonising species.	Booms can be used to deflect oil away from area possibly onto a beach for later clean-up.	Dispersants should be avoided.

TABLE 12 (Cont'd)

THE EFFECTS OF OIL ON TROPICAL MARINE HABITATS AND POPULATIONS AND MANAGEMENT OPTIONS

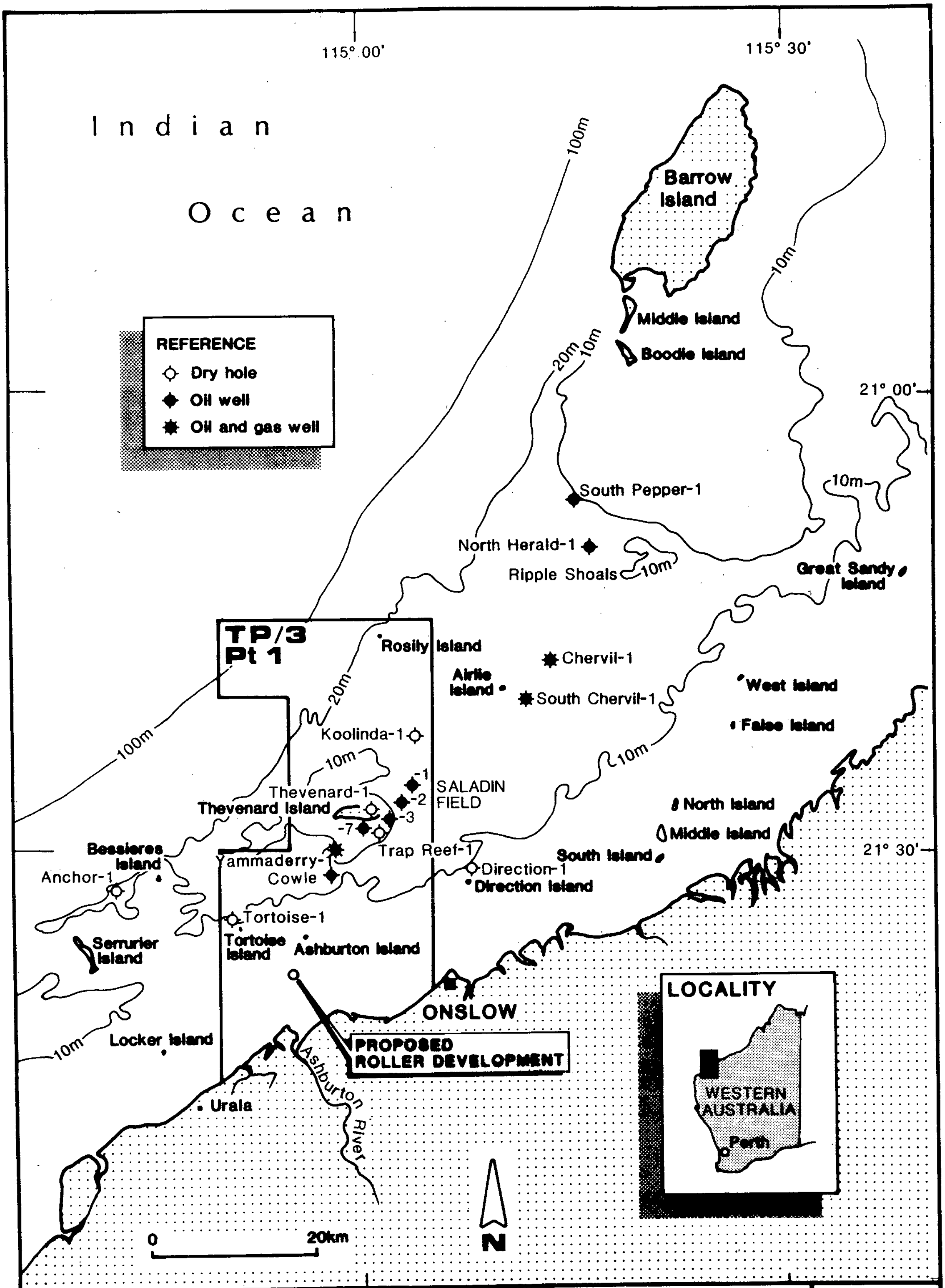
HABITAT/ POPULATION TYPE	DAMAGE AND TYPE OF EFFECT	SENSITIVITY TO OIL AND RECOVERY RATES FOLLOWING DAMAGE	TREATMENT OPTIONS	WHAT TO AVOID
ROCKY INTERTIDAL	Little or no effect. Organisms hardy. Damage caused by coating leading to suffocation or loss of purchase on substrate.	Low sensitivity. Fast recovery. Rapid recolonisation by more species.	None required.	
OPEN WATERS	Surface dwelling organisms may suffer (birds, mammals, plankton). Sublethal to lethal effects on fish. Tainting of fish or prawn flesh may occur.	Some components sensitive. Unknown. Birds severely impacted. Local breeding populations of larval fish and shellfish may take a long time to recover. Plankton is expected to recover rapidly.	If there is a potential for landfall, disperse oil in deep water. If not, leave alone.	
BENTHIC COMMUNITIES	Mortalities lead to decrease in population density and age distributions. Change in species abundance and distribution, imbalance between interacting populations.	Some components sensitive. Immigration from surrounding areas are expected to speed up recovery.	None identified.	
BIRDS	Very easily damaged, oiling of plumage and ingestion of oil result in large mortalities.	Very sensitive. Damage to breeding population will cause slow recovery.	Clean-up of birds may be attempted, it is rarely successful.	Trampling nests above high tide line of sandy beaches.
SANDY BEACHES	Severe impact on egg laying turtles and hatchlings, feeding and breeding wading birds and intertidal fauna.	Some components very sensitive on a seasonal basis. Recovery of fauna will depend on the time it takes for the sandy beach to be cleansed of oil. Affected breeding populations will be slow to recover.	Beaches should be raked to promote evaporation. Mechanical or manual removal may be necessary on nesting beaches.	Dispersants should never be applied to a sandy beach. Avoid trampling of the beach and dune areas.

TABLE 12 (Cont'd)

THE EFFECTS OF OIL ON TROPICAL MARINE HABITATS AND POPULATIONS AND MANAGEMENT OPTIONS

HABITAT POPULATION TYPE	DAMAGE AND TYPE OF EFFECT	SENSITIVITY TO OIL AND RECOVERY RATES FOLLOWING DAMAGE	TREATMENT OPTIONS	WHAT TO AVOID
FISH	Possible for them to avoid spills. Mortality and tainting of flesh can occur. Greatest danger to breeding populations in confined waterways or benthic fish in heavily polluted substrates.	Moderate sensitivity. Fast to moderate recovery rates. Fast immigration of larvae and adults.	Dispersants will make oil more available to the fish, however, its use may be necessary to protect higher priority habitats.	
MAMMALS	Chances of impact reduced by low abundance of mammals and ability to escape the area impacted. Conclusive evidence of death due to oil is rare. Possible effects include ingestion of oil during grooming, loss of thermal insulation and/or water-proofing and eye irritation. Indirect effects include destruction of food sources.	Unknown sensitivity. Slow if population is seriously affected.		

References: Dicks (1984)
Hyland & Schneider (1977)
Thorhaug (1987)
Knap (1987)



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ROLLER FIELD DEVELOPMENT

LOCALITY DIAGRAM

Figure 1

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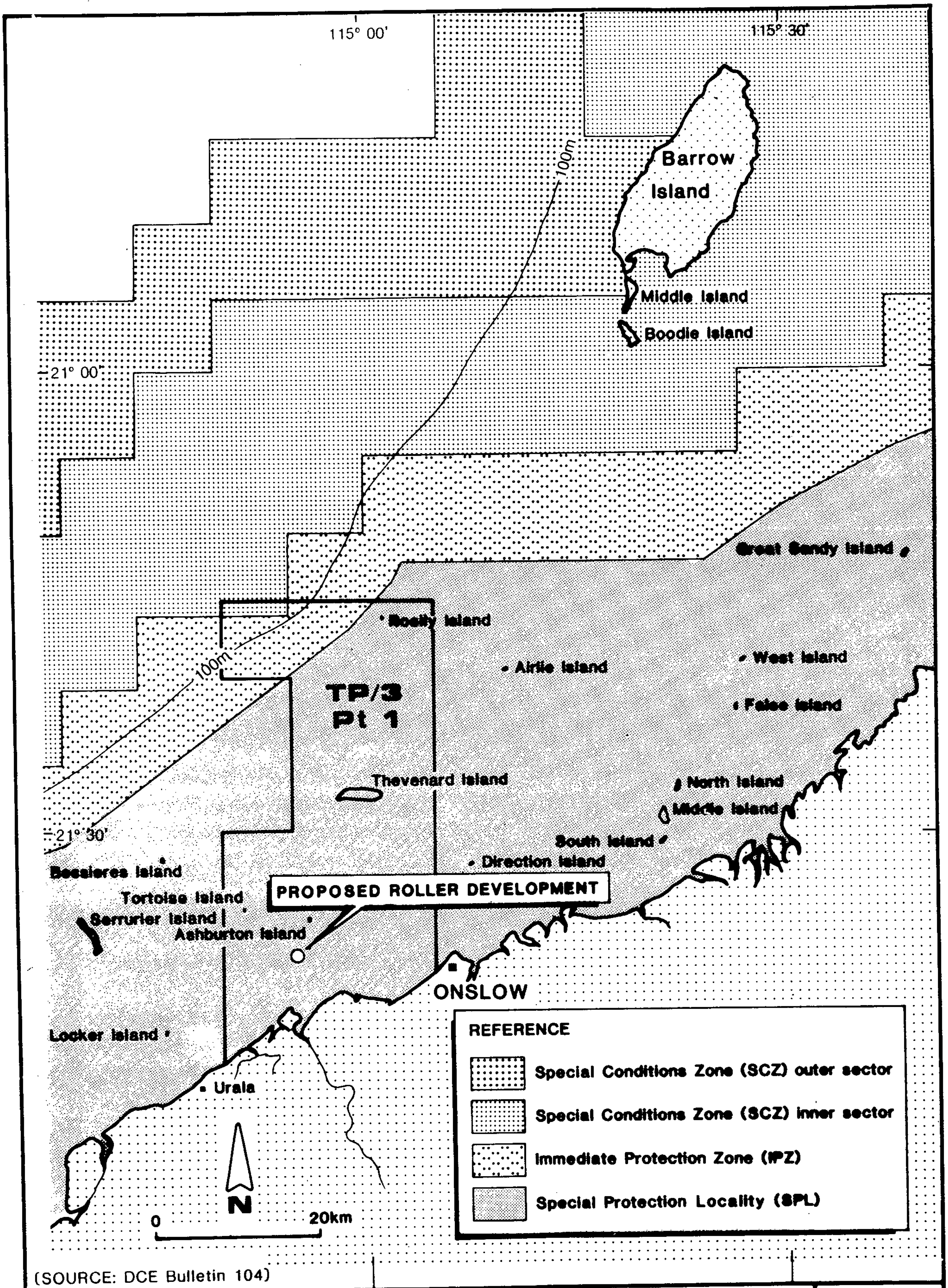

(SOURCE: DCE Bulletin 104)

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ROLLER FIELD DEVELOPMENT

ENVIRONMENTALLY SENSITIVE AREAS

Figure 2

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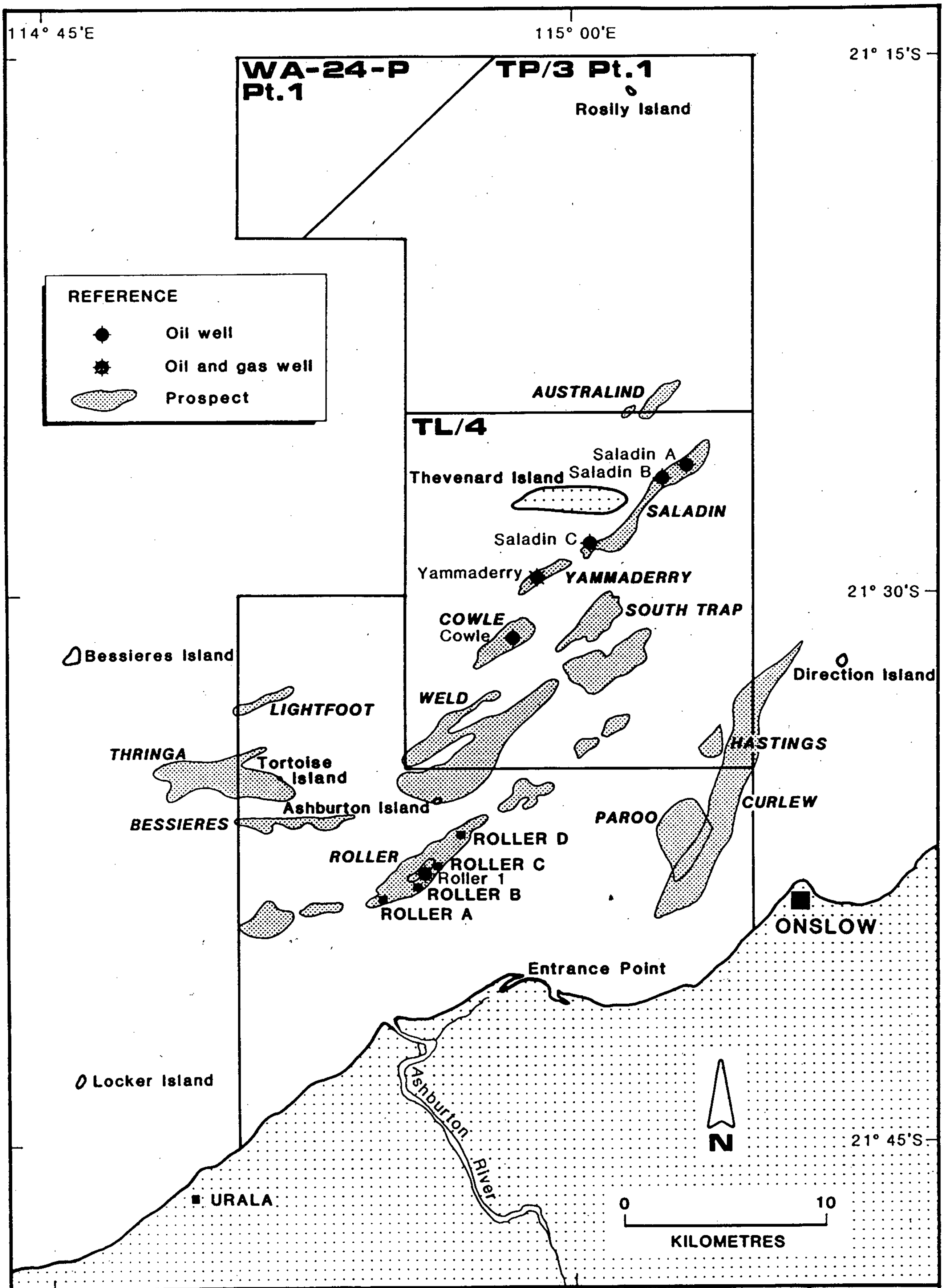

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ROLLER FIELD DEVELOPMENT

OIL FIELD AND PROSPECT OUTLINES IN TP/3 Pt.1

Figure 3

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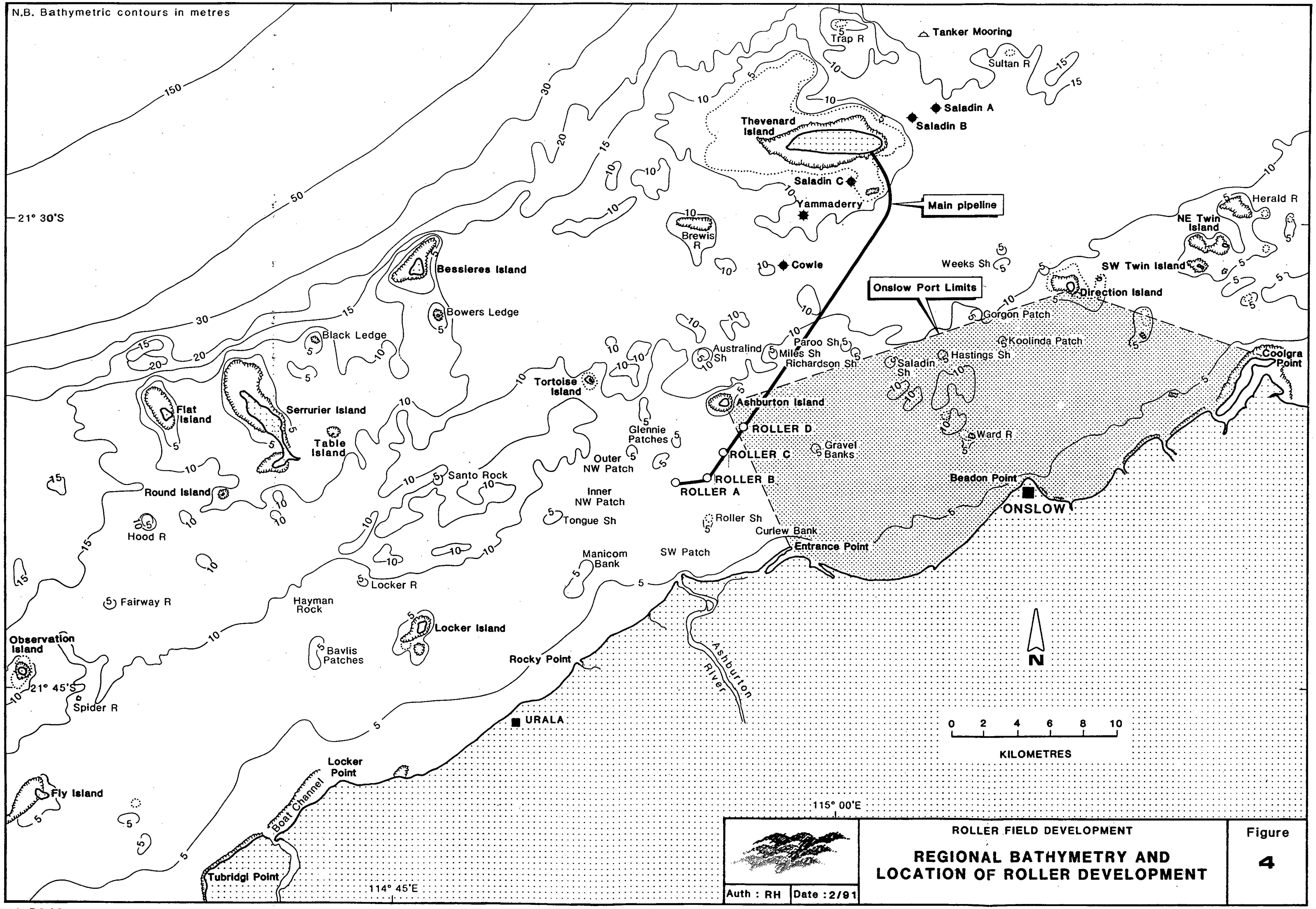

ROLLER FIELD DEVELOPMENT

REGIONAL BATHYMETRY AND LOCATION OF ROLLER DEVELOPMENT

Figure 4

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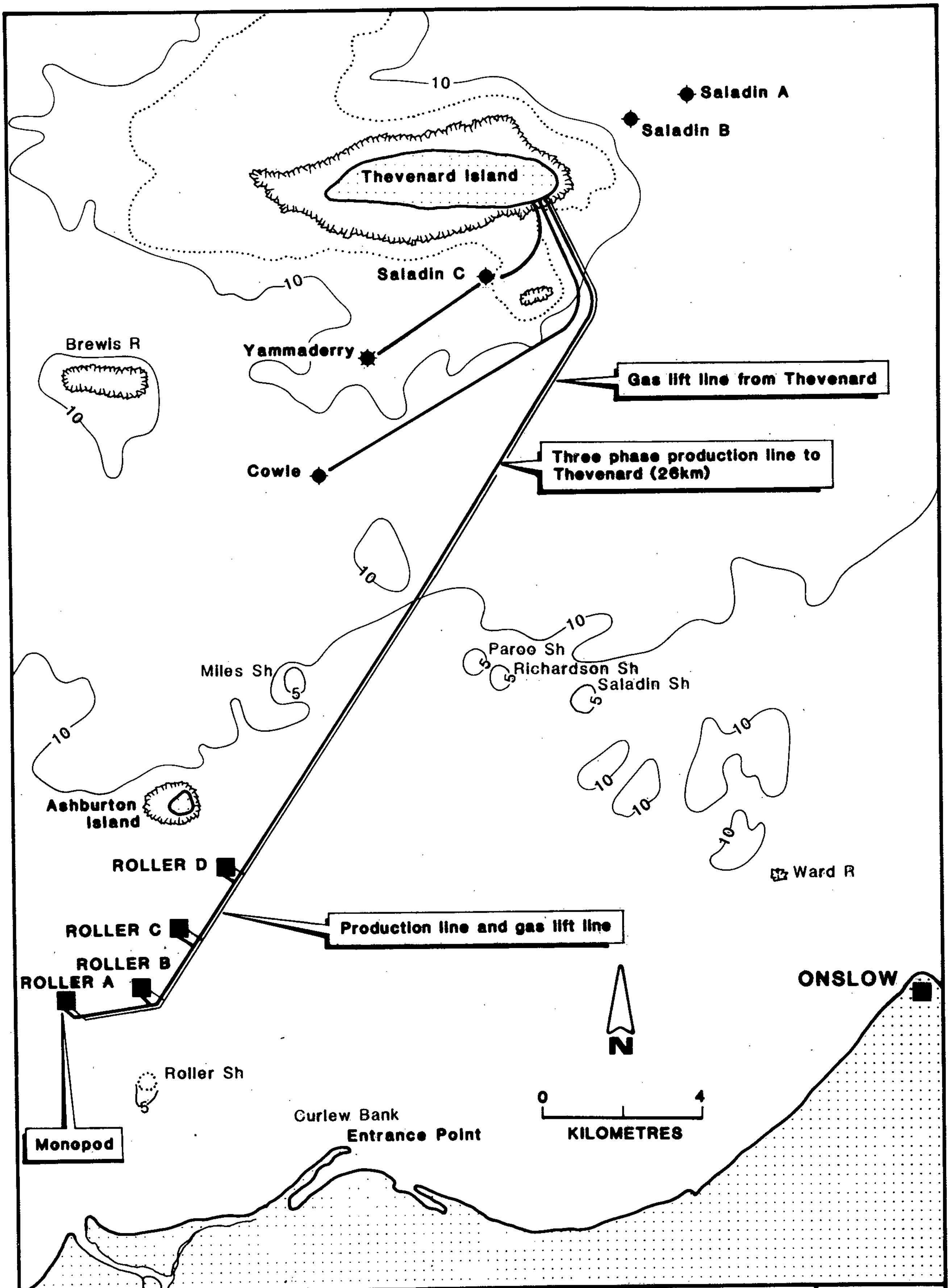

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ROLLER FIELD DEVELOPMENT

OFFSHORE FACILITIES FOR THE PROPOSED DEVELOPMENT OPTION 1

Figure 5

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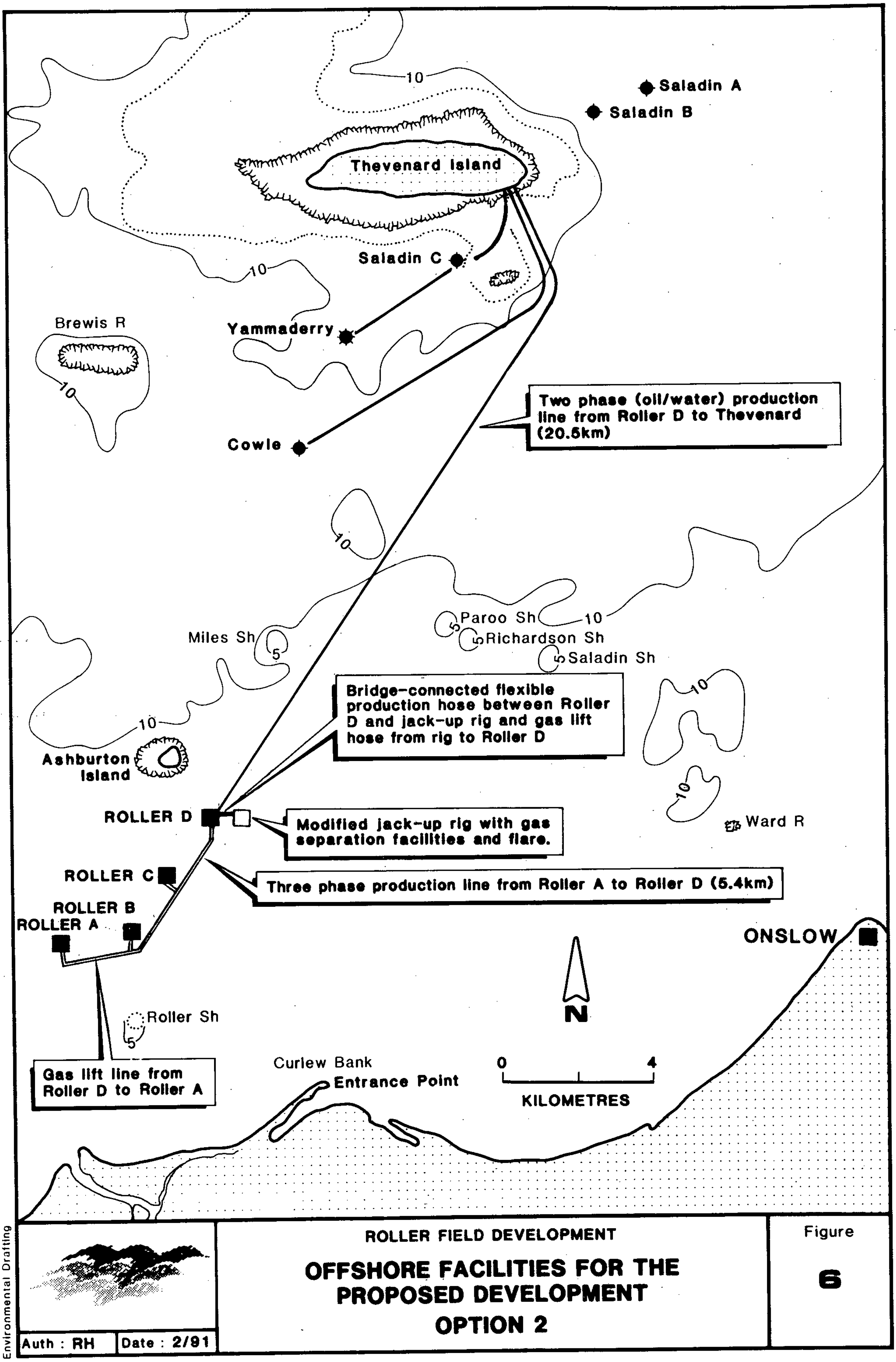

ROLLER FIELD DEVELOPMENT

OFFSHORE FACILITIES FOR THE PROPOSED DEVELOPMENT OPTION 2

Figure 6

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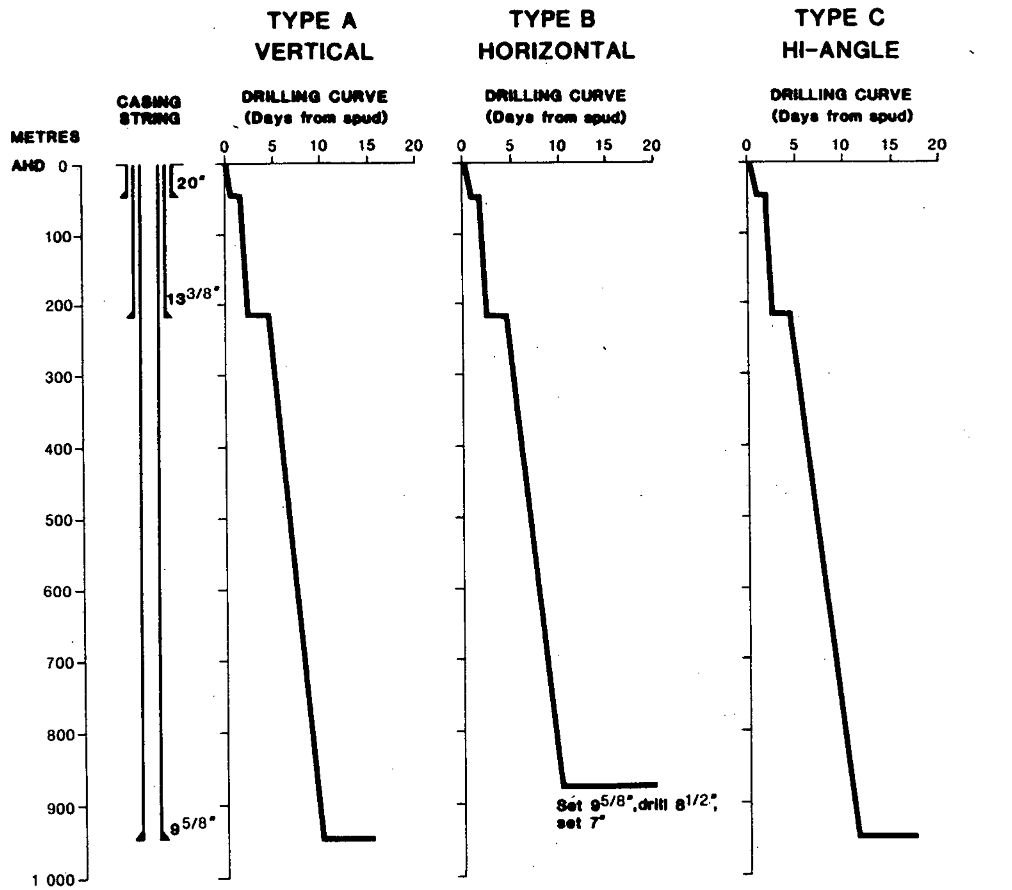
CASING SIZE (inches)	HOLE SIZE (inches)	HOLE LENGTH (metres) MD		SHOE DEPTH (metres)	PROPOSED TOP OF CEMENT
		from	to		
TYPE A : VERTICAL					
20	26	10	45	45	to mudline
$13^{3/8}$	$17^{1/2}$	45	225	220	to surface
$9^{5/8}$	$12^{1/4}$	225	955	950	to surface
TYPE B : HORIZONTAL Note: 30" and $13^{3/8}$" casings are same as for vertical well					
$9^{5/8}$	$12^{1/4}$	225	1346	1340	to surface
7	$8^{1/2}$	1346	1746		
TYPE C : HI-ANGLE Note: 30" and $13^{3/8}$" casings are same as for vertical well					
$9^{5/8}$	$12^{1/4}$	225	1330	1325	to surface

Note: Approximately equal numbers of "A" and "B" type wells are envisaged at this point. i.e. 3 type "A" and 4 type "B".

A type "C" well will only be drilled if required to re-establish vertical depth of pay zone.



Note: Days shown are from start of drilling 36" hole – time to drill and install caisson (monopod) is excluded.

	ROLLER FIELD DEVELOPMENT	Figure
Auth : RH / Date : 2/91	TYPICAL WELL DESIGN FOR ROLLER FIELD DEVELOPMENT	7

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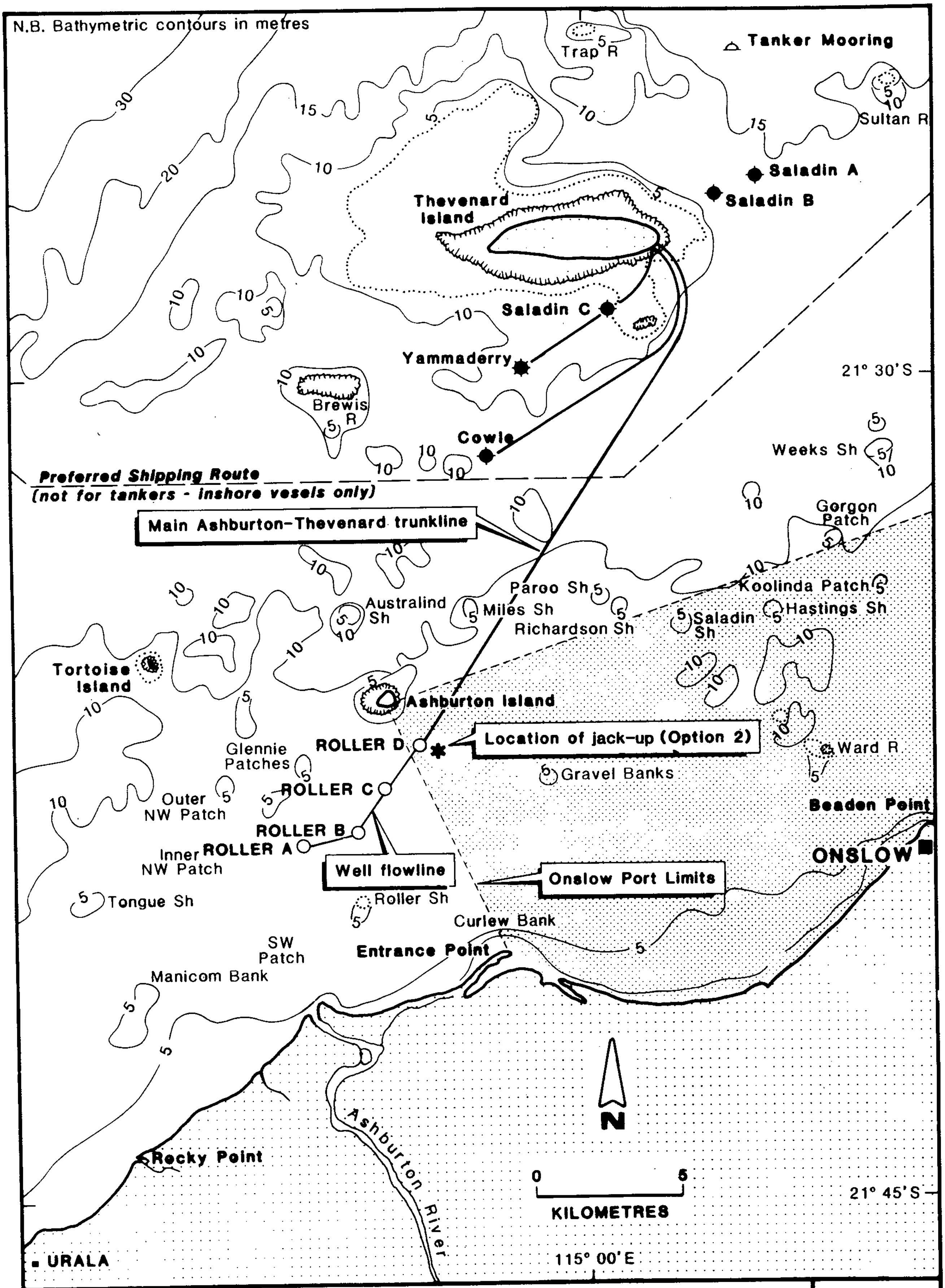

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ROLLER FIELD DEVELOPMENT

PROPOSED ROUTE FOR THE PIPELINE/S FROM ROLLER TO THEVENARD ISLAND

Figure 8

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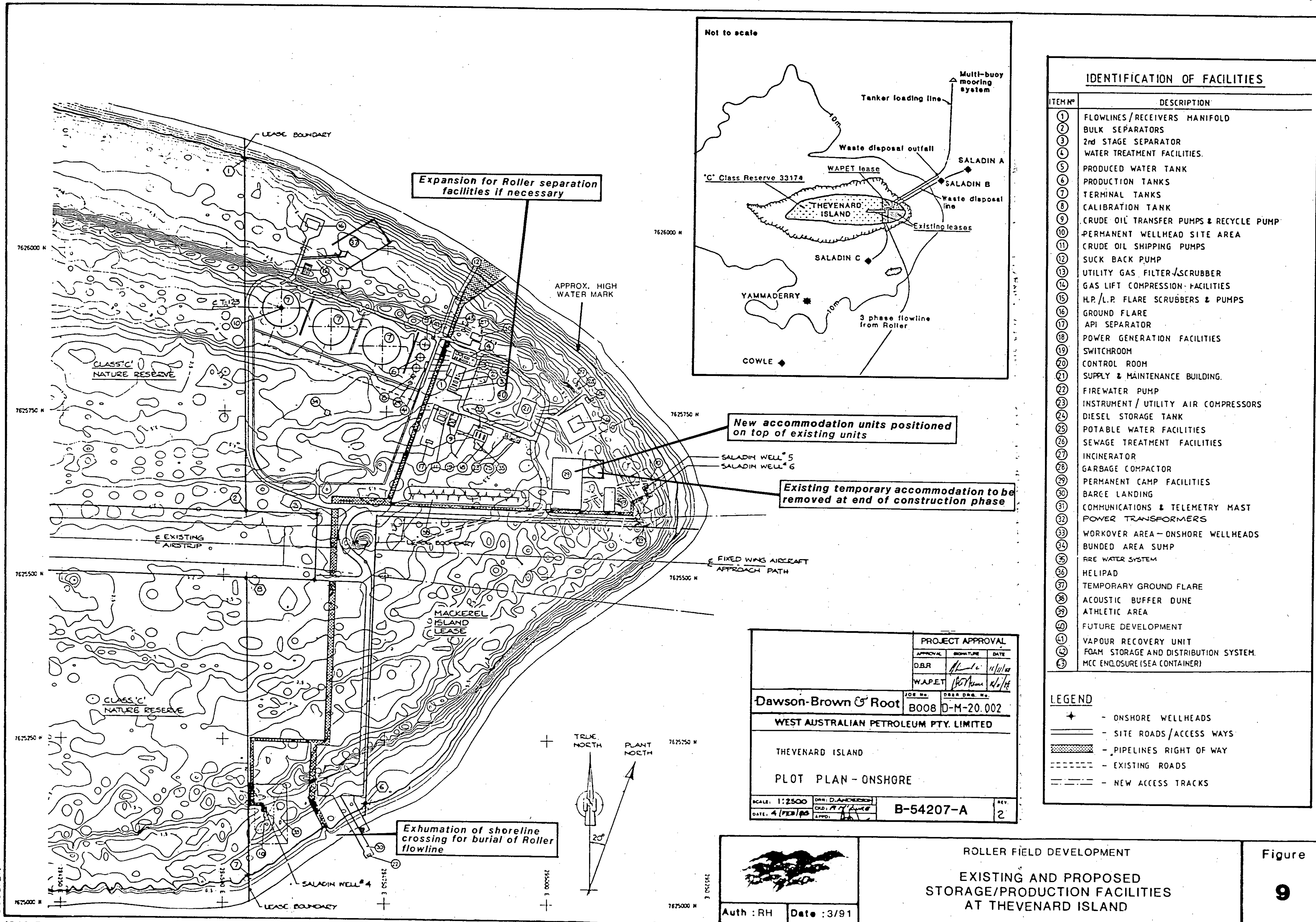

ROLLER FIELD DEVELOPMENT

EXISTING AND PROPOSED STORAGE/PRODUCTION FACILITIES AT THEVENARD ISLAND

Figure 9

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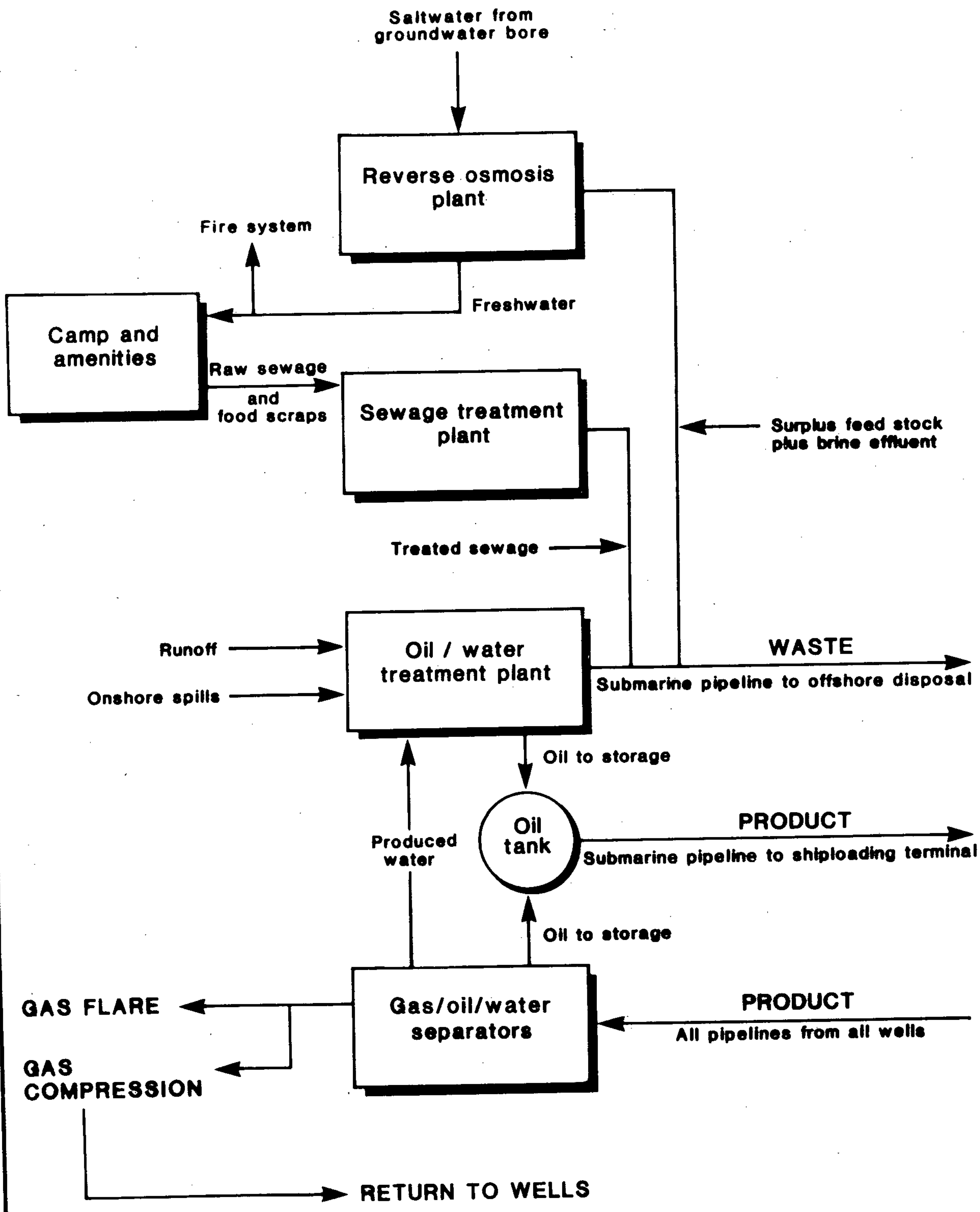

ROLLER FIELD DEVELOPMENT

PRODUCT AND WASTE LIQUID FLOW PATH AT THEVENARD ISLAND

Figure **10**

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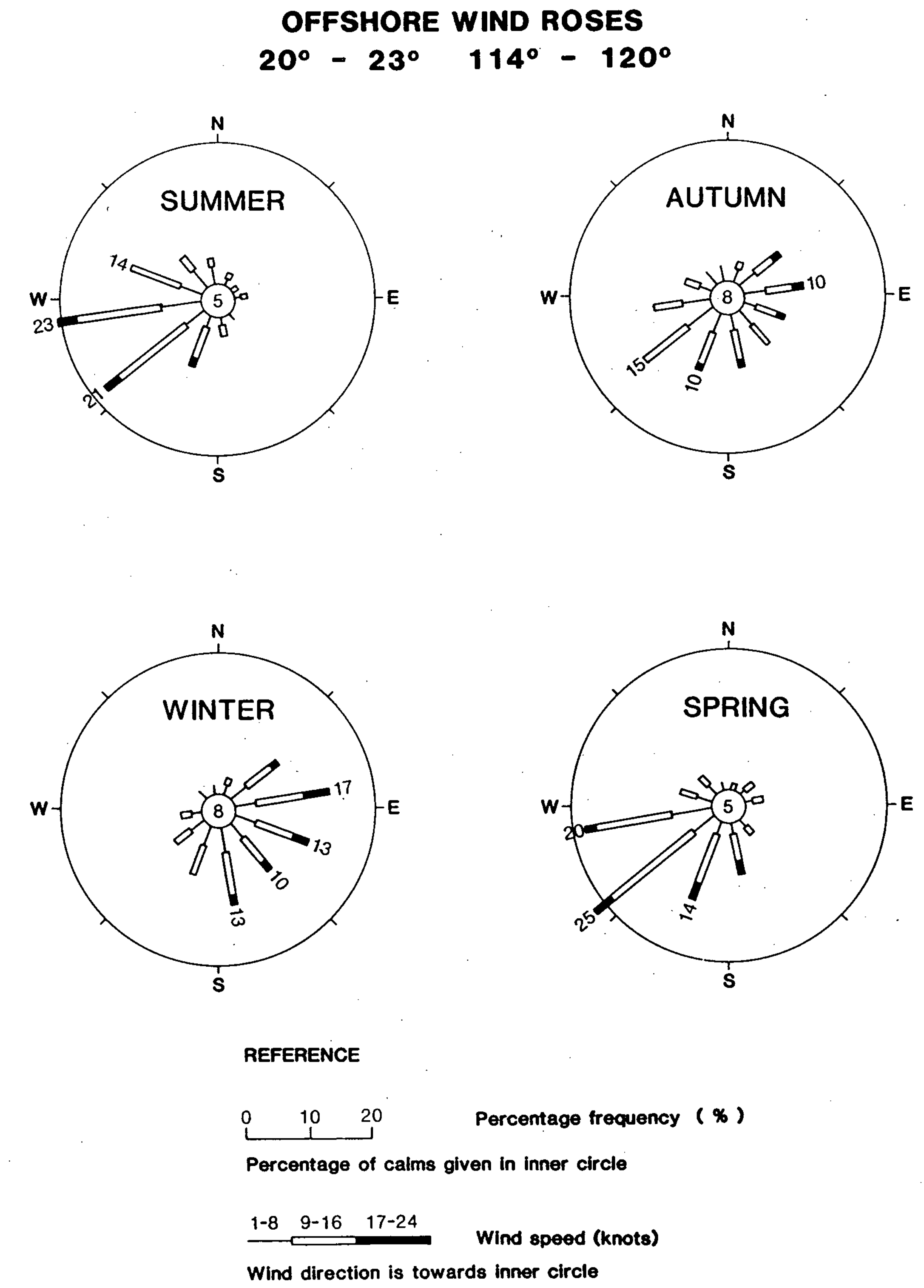

(Source: Jones 1986)

ROLLER FIELD DEVELOPMENT

OFFSHORE WIND ROSES FOR ROWLEY SHELF

Figure 11

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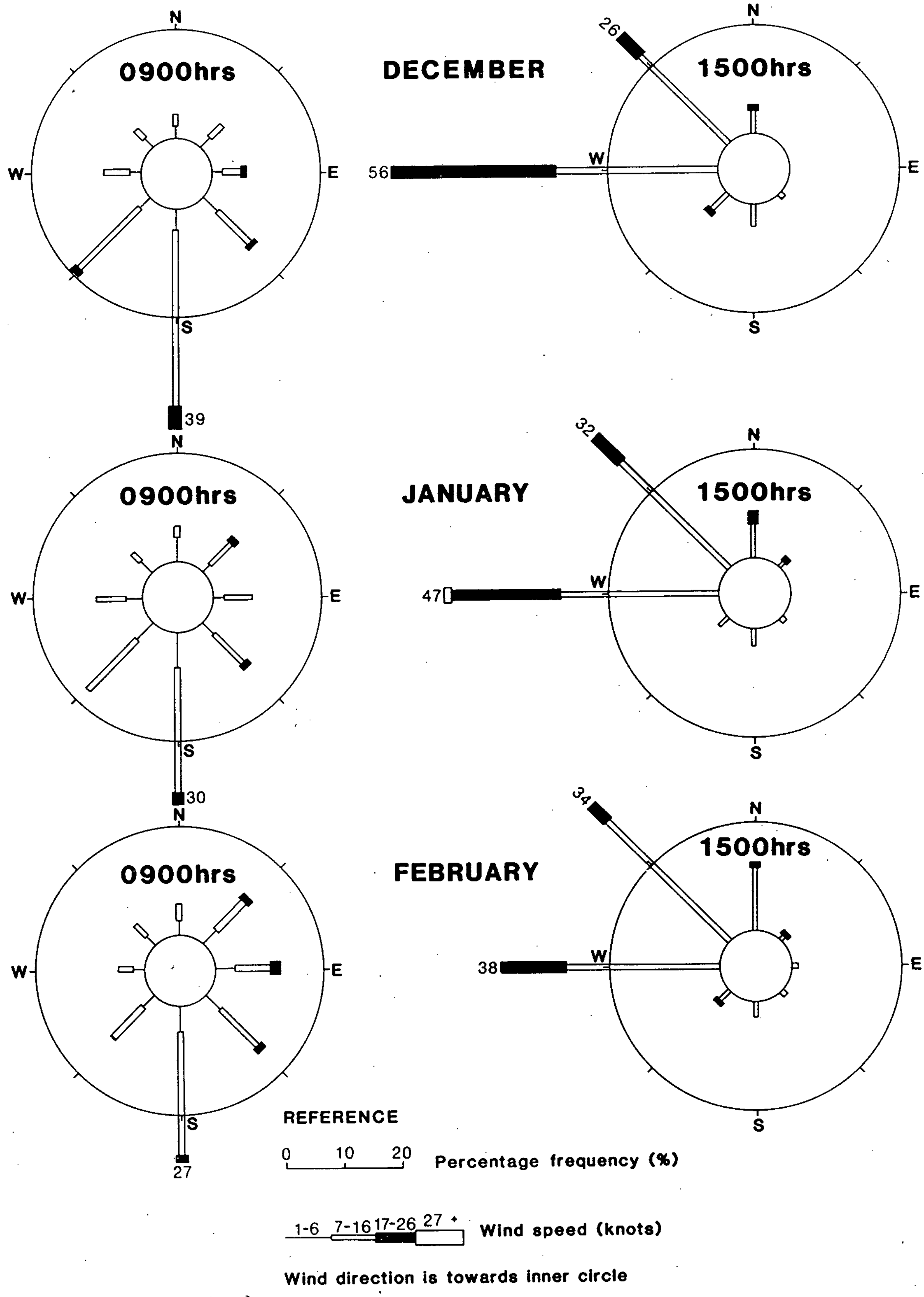

(Source: Bureau of Meteorology)

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ROLLER FIELD DEVELOPMENT

ONSHORE WIND ROSES FOR ONSLOW

Figure 12

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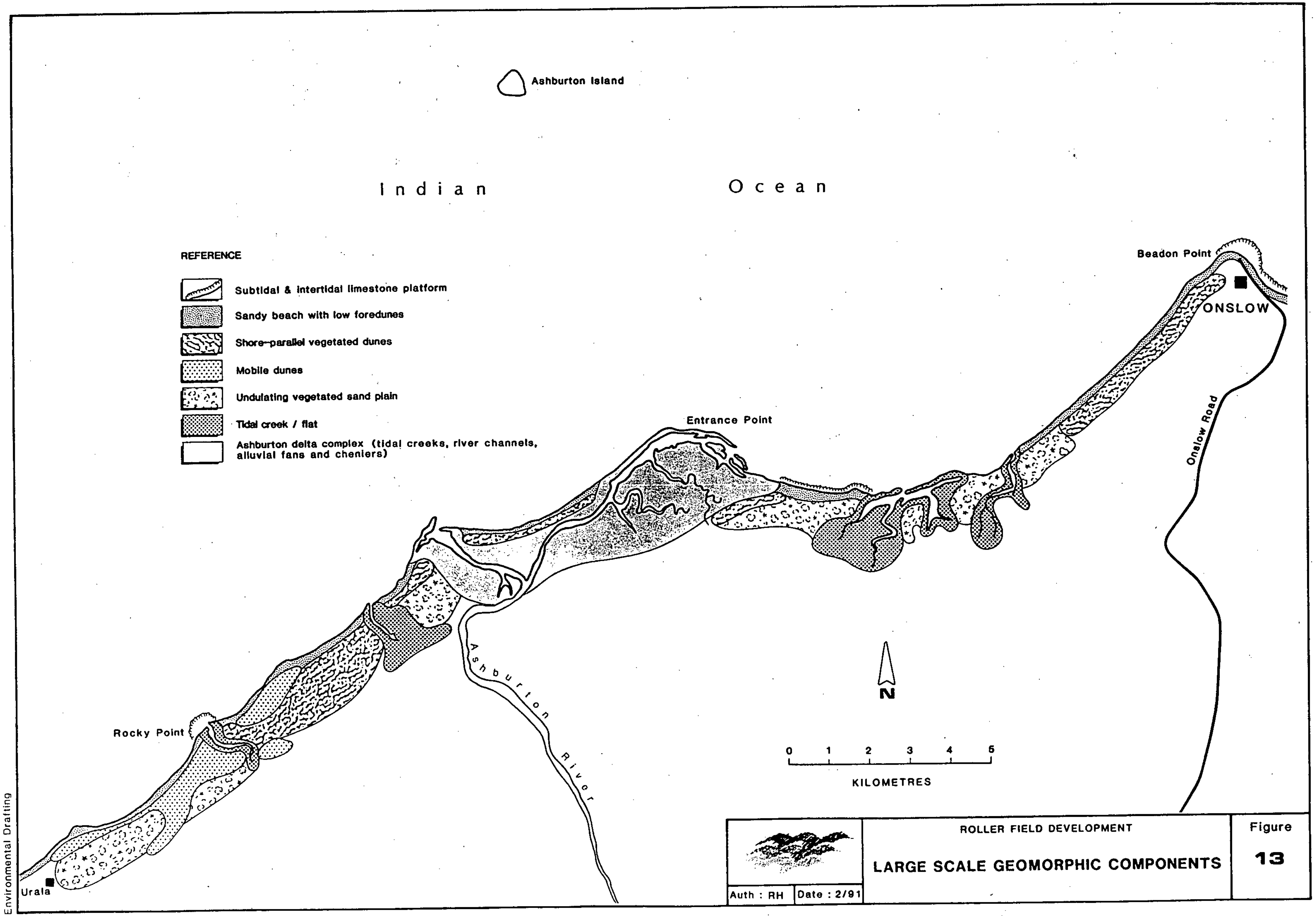

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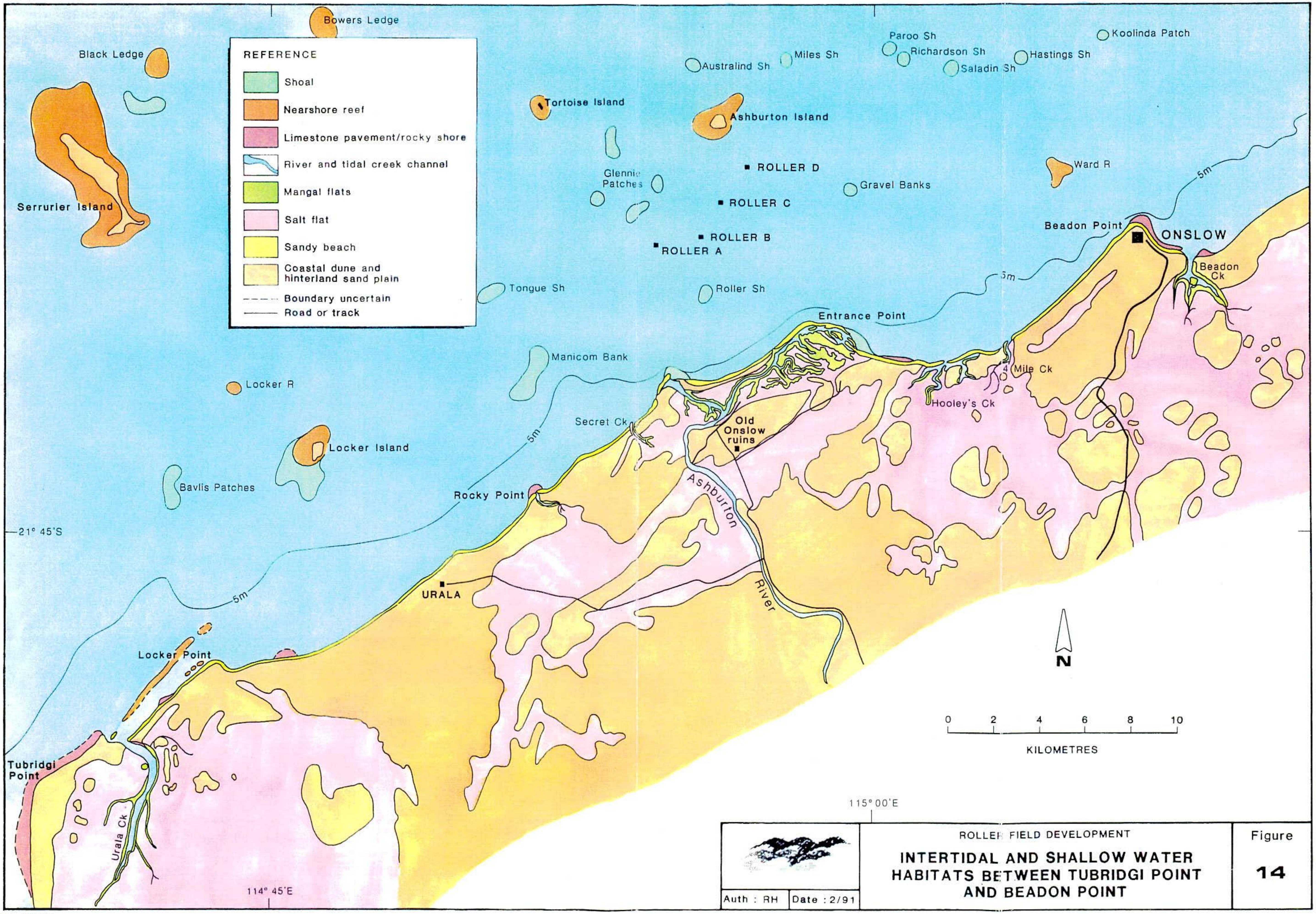

ROLLER FIELD DEVELOPMENT

INTERTIDAL AND SHALLOW WATER HABITATS BETWEEN TUBRIDGI POINT AND BEADON POINT

Figure 14

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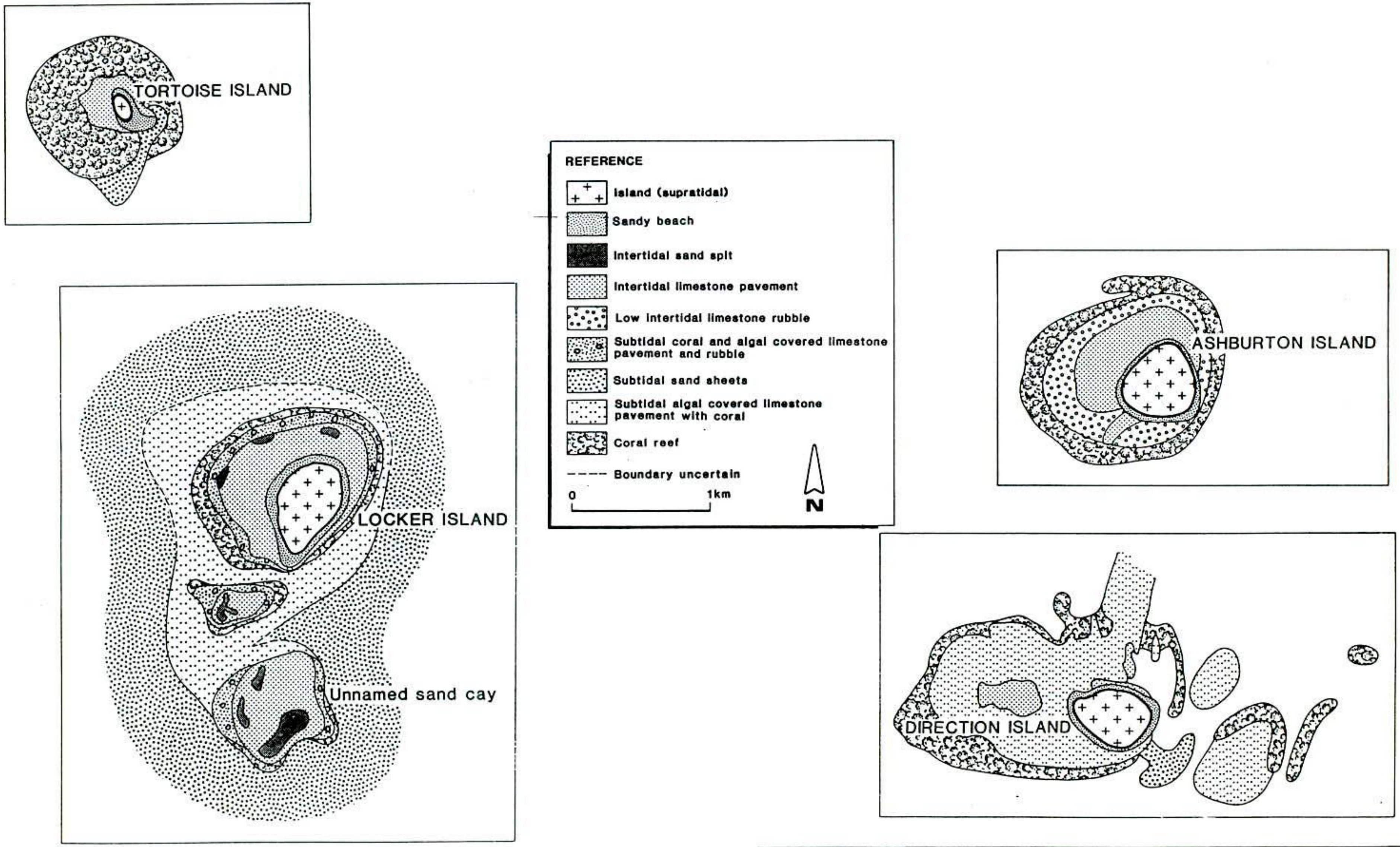
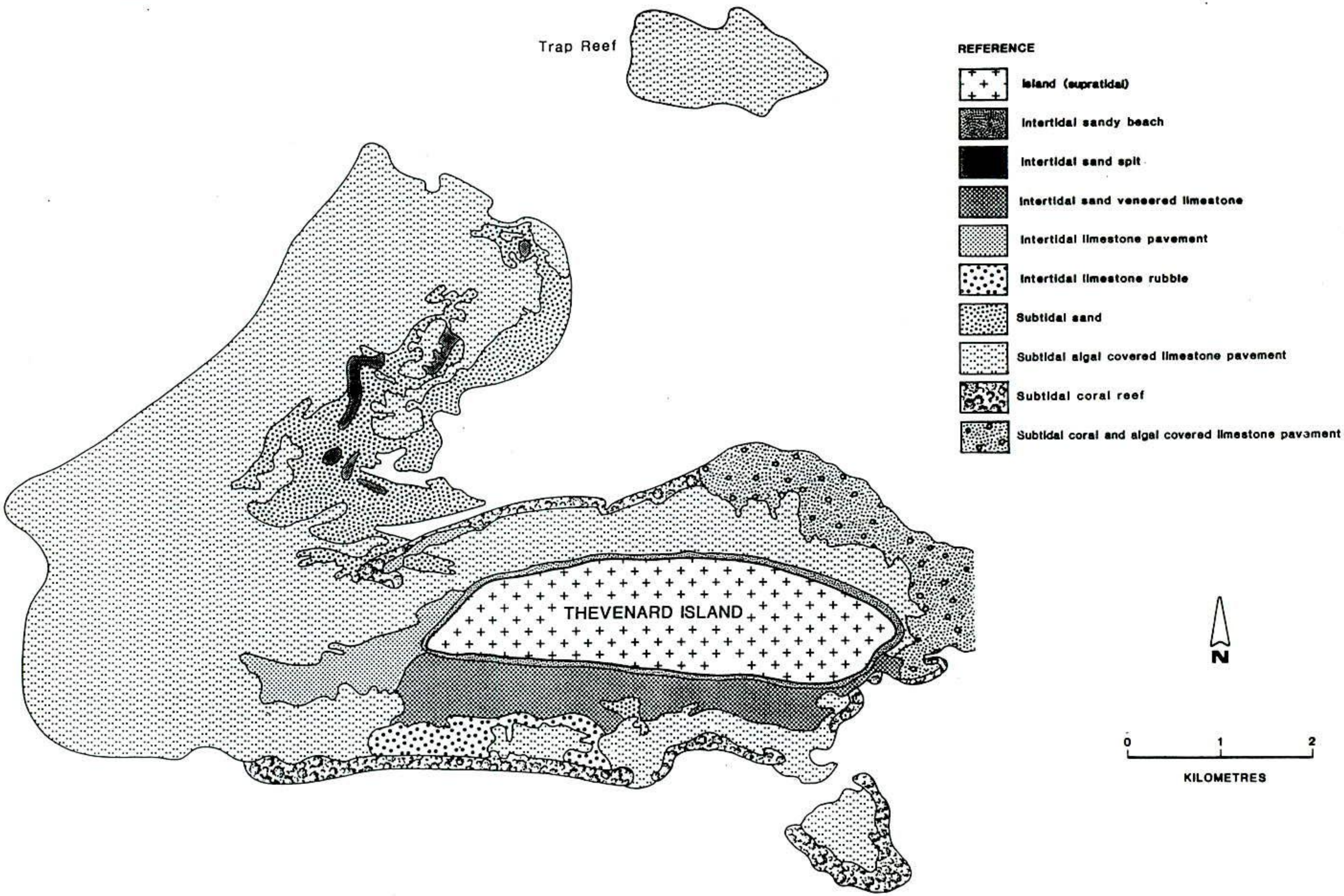


Auth : RH / Date : 2/91	ROLLER FIELD DEVELOPMENT **HABITAT DISTRIBUTION AT ASHBURTON, TORTOISE, LOCKER AND DIRECTION ISLANDS**	Figure **15**



ROLLER FIELD DEVELOPMENT

HABITAT DISTRIBUTION AT THEVENARD ISLAND

Figure 16

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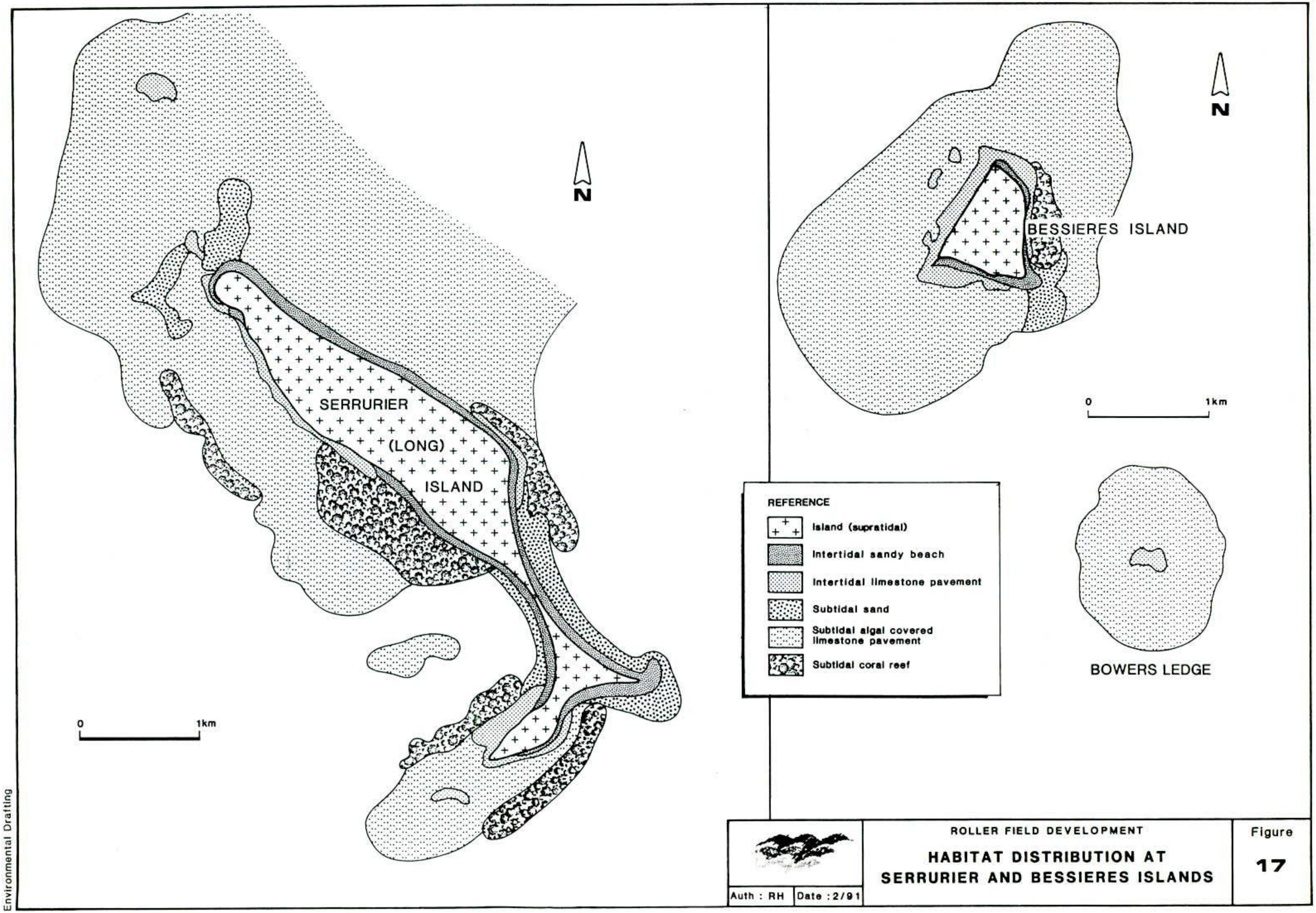

ROLLER FIELD DEVELOPMENT

HABITAT DISTRIBUTION AT SERRURIER AND BESSIERES ISLANDS

Figure 17

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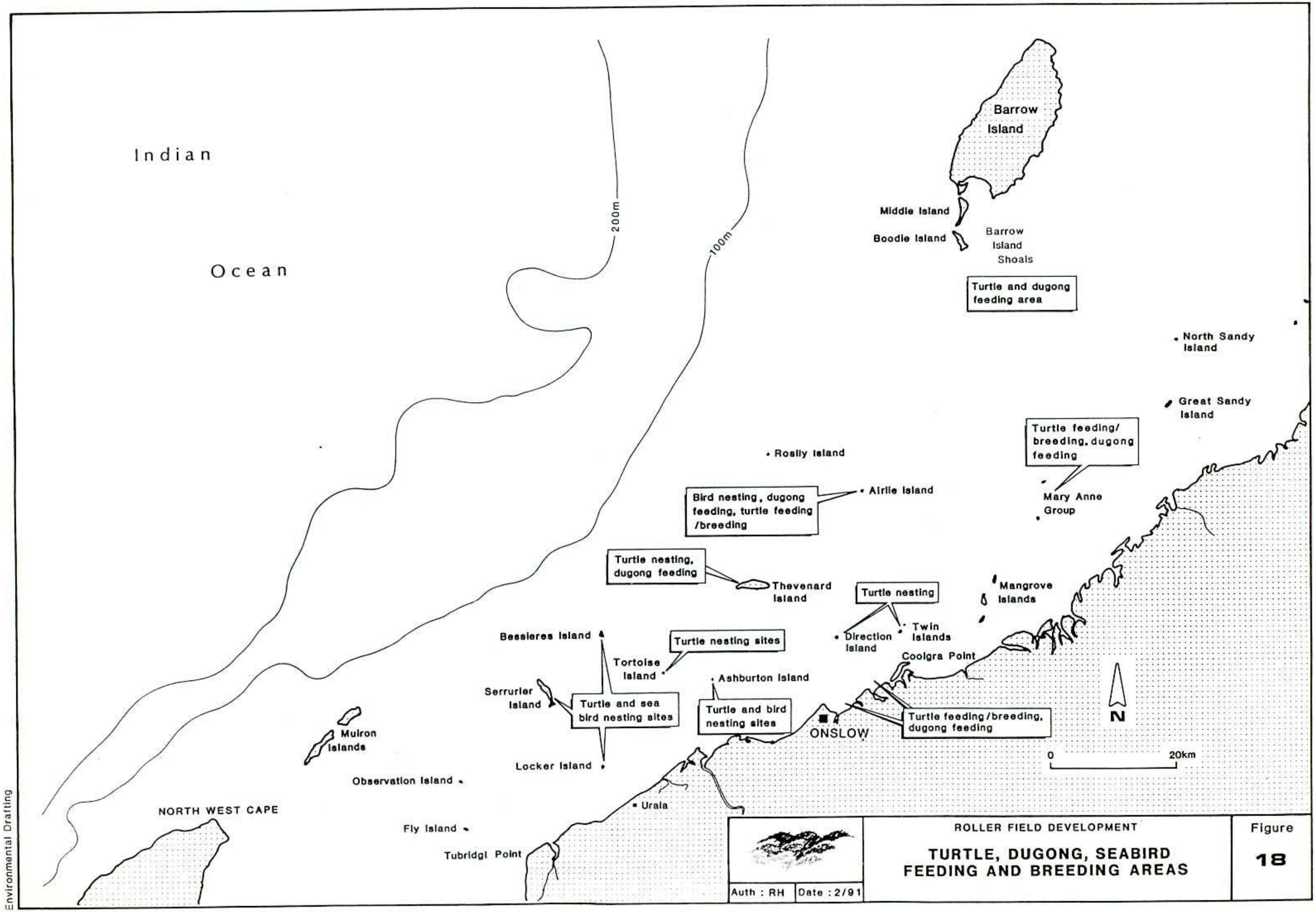
Indian
Ocean
200m
100m
Barrow
Island
Middle Island
Boodie Island
Barrow
Island
Shoals
Turtle and dugong feeding area
North Sandy Island
Great Sandy Island
Turtle feeding/ breeding, dugong feeding
Mary Anne Group
Rosily Island
Airlie Island
Bird nesting, dugong feeding, turtle feeding /breeding
Turtle nesting, dugong feeding
Thevenard Island
Turtle nesting
Mangrove Islands
Direction Island
Twin Islands
Coolgra Point
Bessieres Island
Turtle nesting sites
Tortoise Island
Ashburton Island
Serrurier Island
Turtle and sea bird nesting sites
Turtle and bird nesting sites
ONSLOW
Turtle feeding/breeding, dugong feeding
N
0
20km
Muiron Islands
Locker Island
Observation Island
NORTH WEST CAPE
Urala
Fly Island
Tubridgi Point
ROLLER FIELD DEVELOPMENT
TURTLE, DUGONG, SEABIRD FEEDING AND BREEDING AREAS
Figure
18
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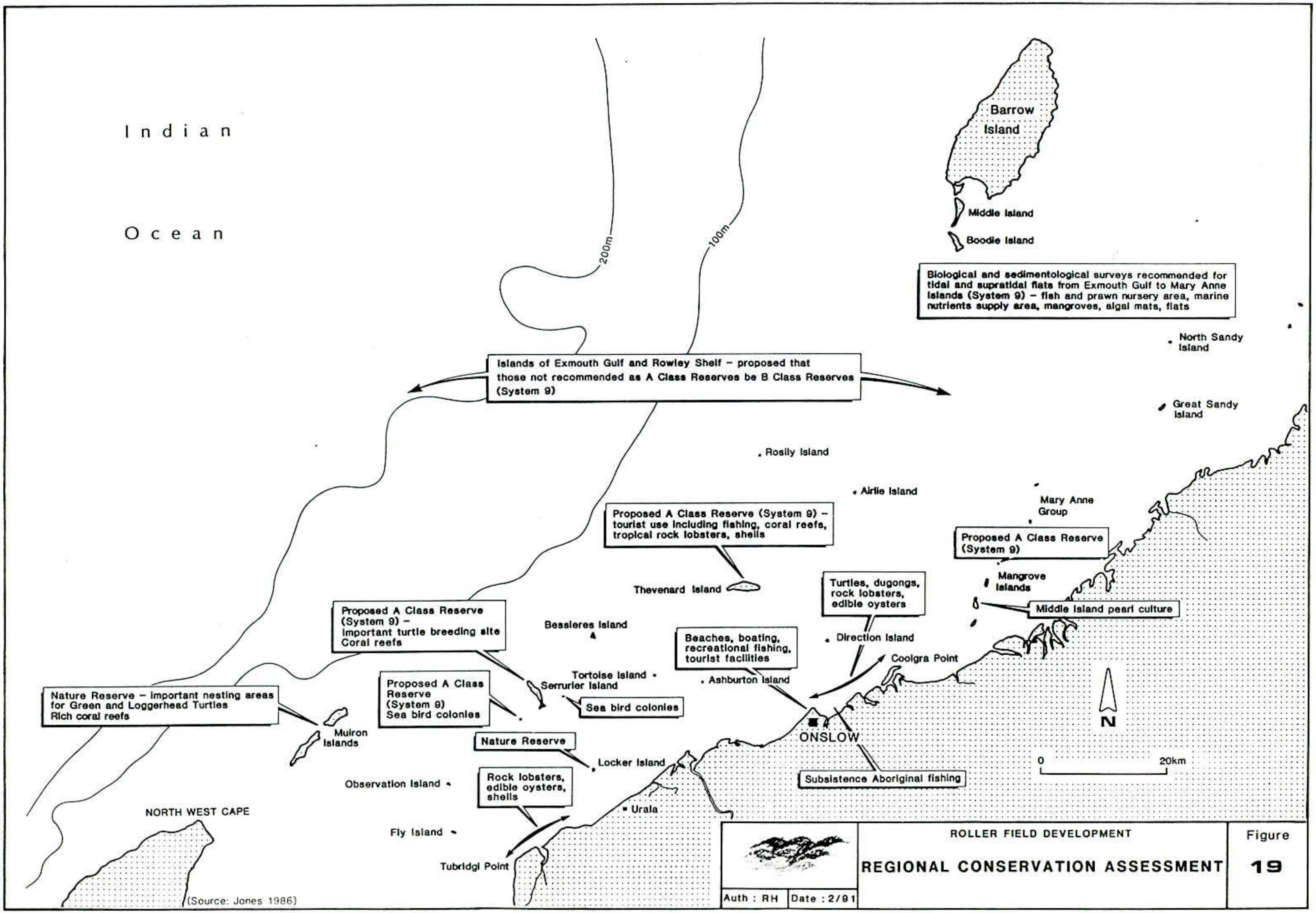

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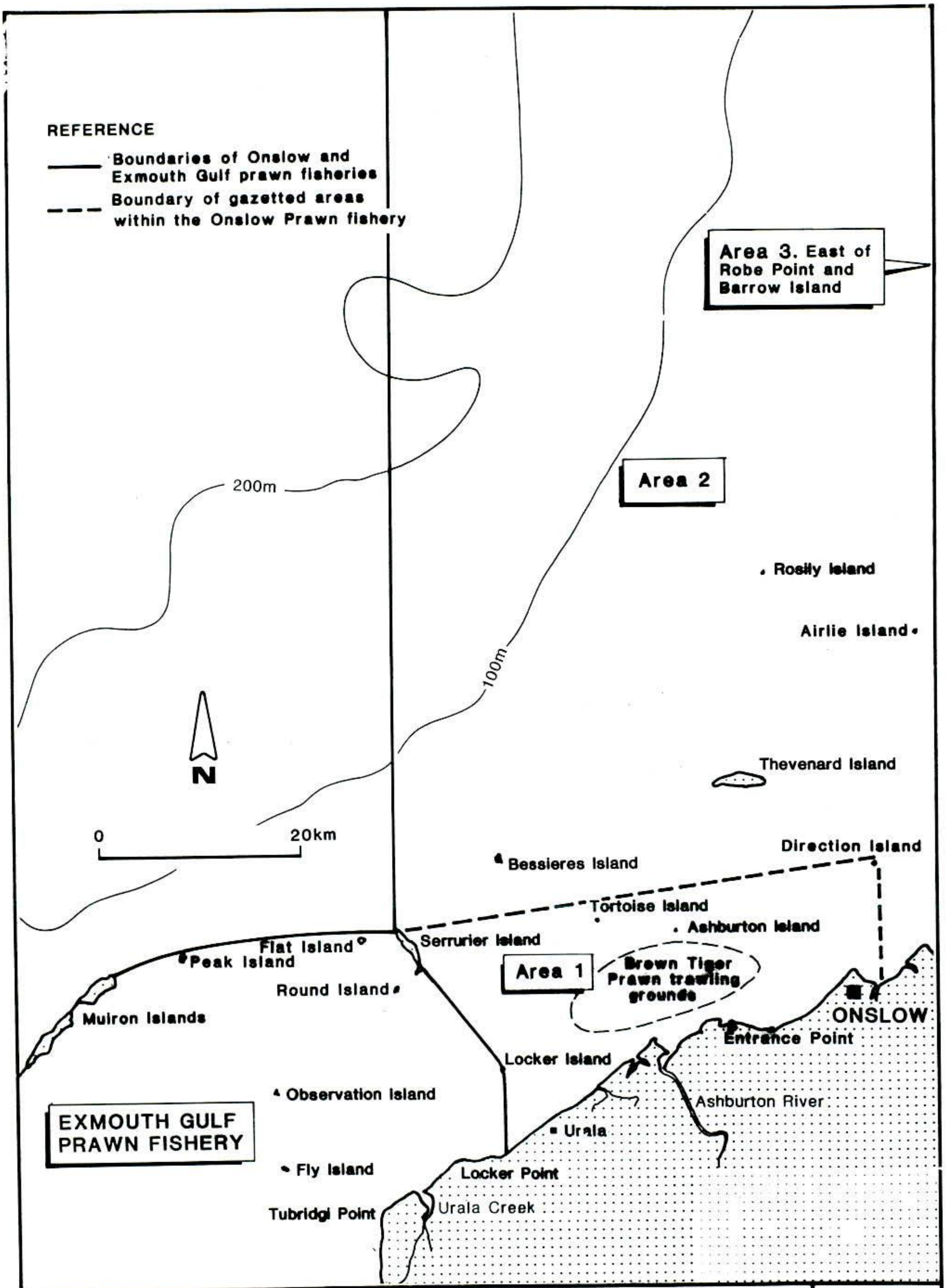

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ROLLER FIELD DEVELOPMENT

ONSLOW FISHERY
PRAWN TRAWLING AREAS
(Gazetted 13 Jan 1989)

Figure **20**

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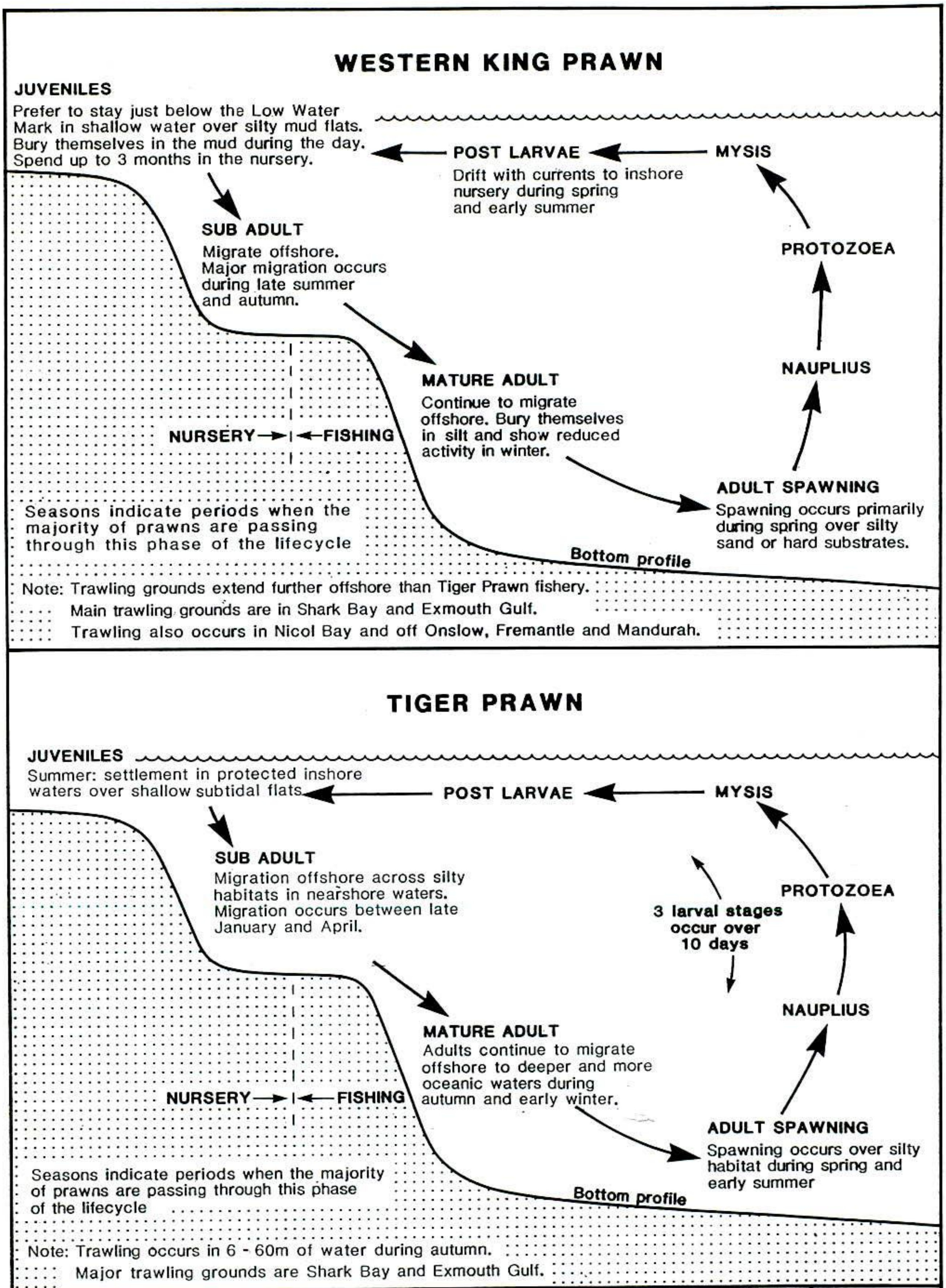

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ROLLER FIELD DEVELOPMENT

LIFE CYCLE REQUIREMENTS OF BROWN TIGER AND WESTERN KING PRAWNS

Figure 21

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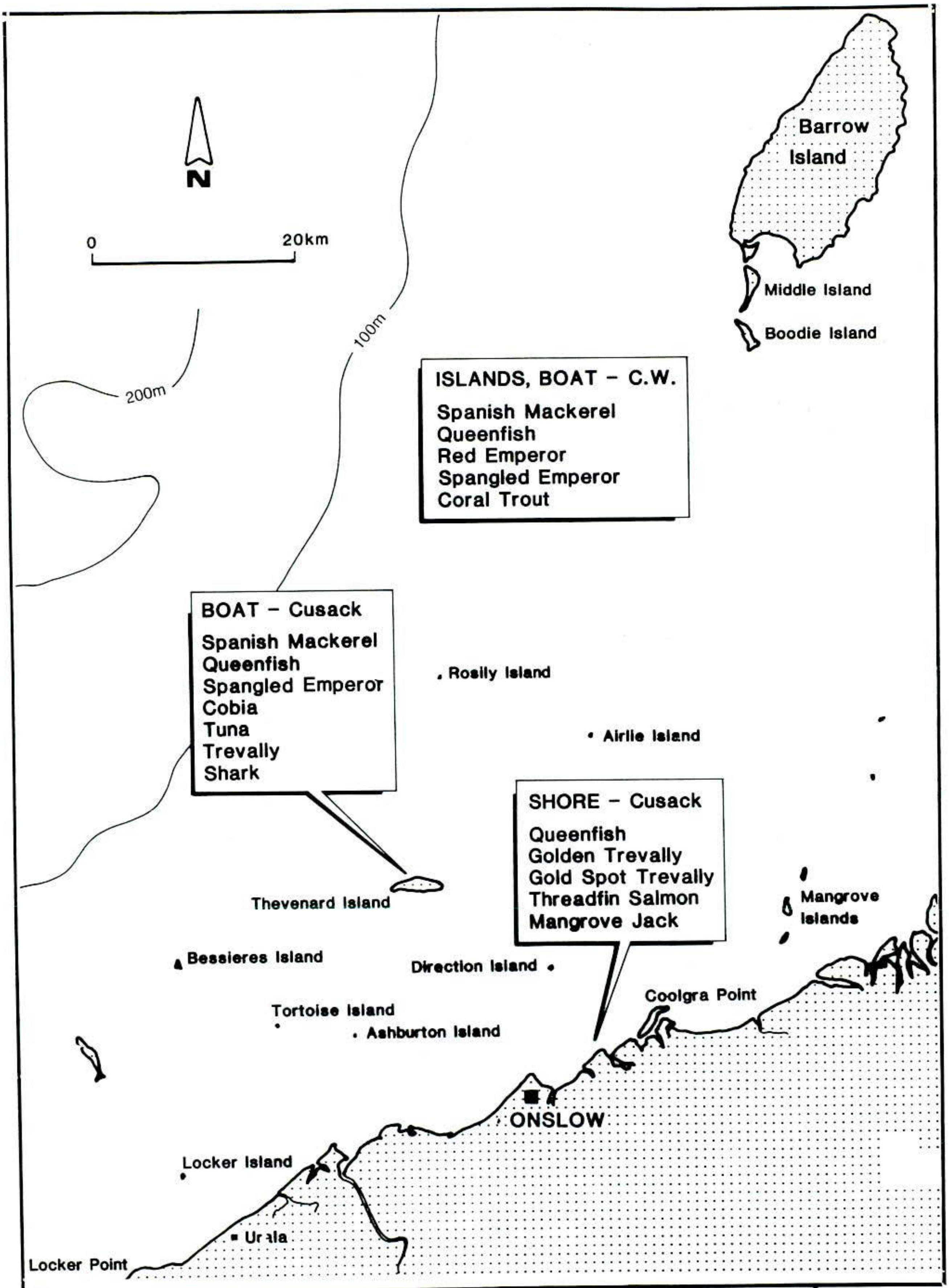

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ROLLER FIELD DEVELOPMENT

MAJOR SPECIES OF THE ONSLOW WET LINE FISHERY

Figure 22

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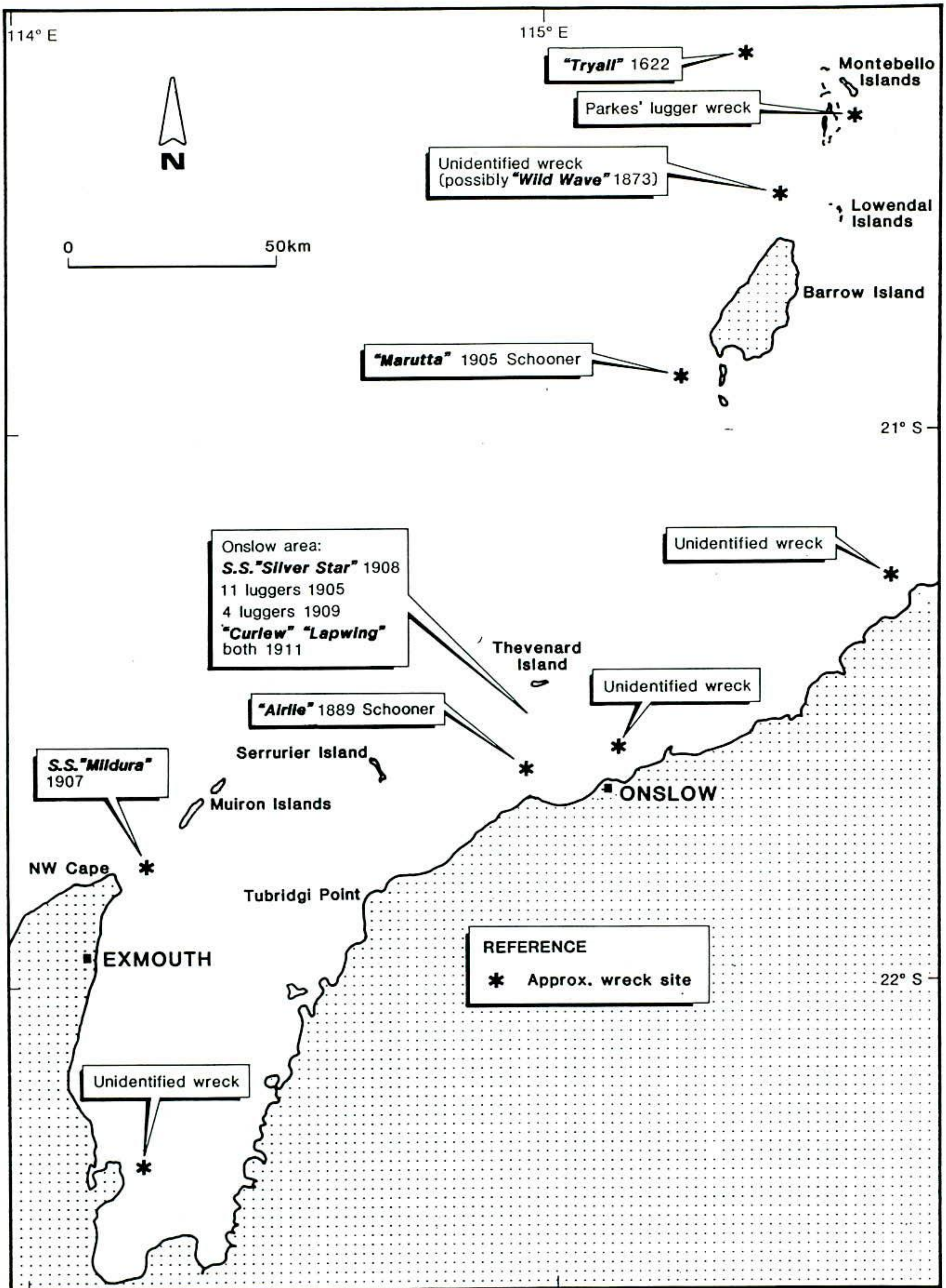

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Auth : RH / Date : 2/91	ROLLER FIELD DEVELOPMENT **HISTORIC SHIPWRECKS IN THE ONSLOW AREA**	Figure **23**

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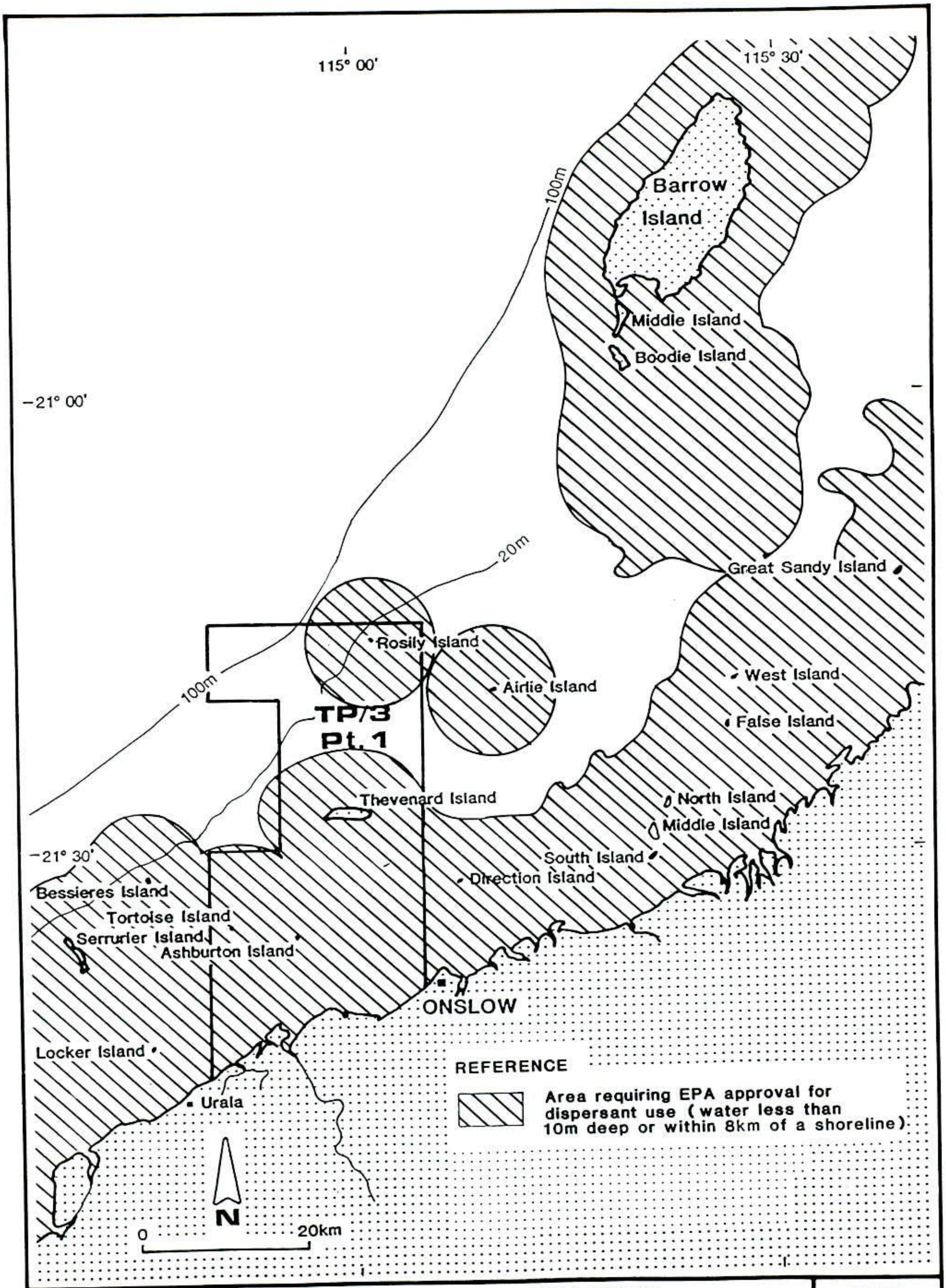

ROLLER FIELD DEVELOPMENT

AREAS RESTRICTED FROM DISPERSANT USE PENDING EPA APPROVAL

Figure **24**

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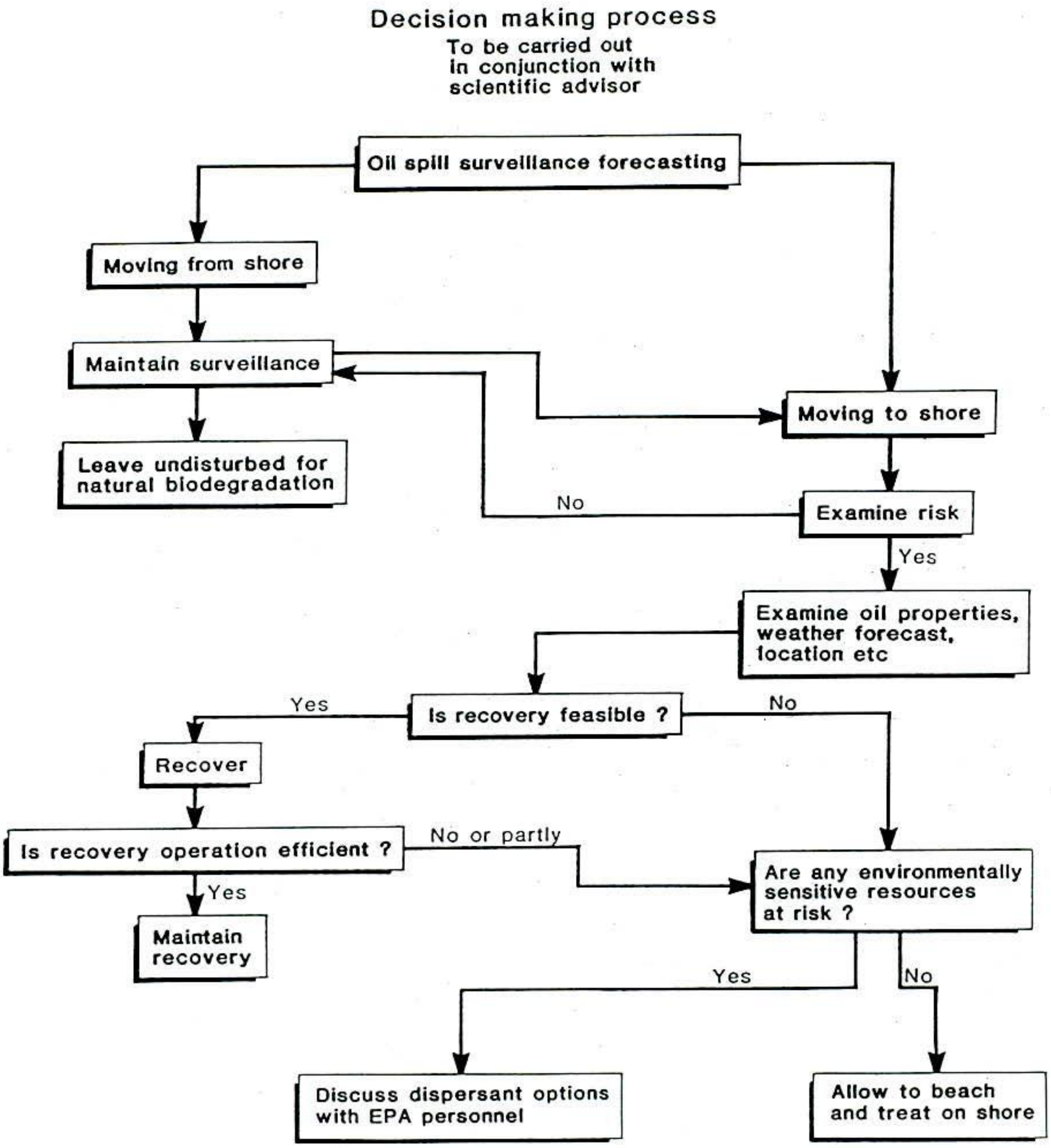

ROLLER FIELD DEVELOPMENT

OIL SPILL TREATMENT

Figure 25

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Plate 1: Main channel mouth of the Ashburton River delta. Note sand spits on either side of shallow entrance. Photograph taken on high tide.

Plate 2: Eastern entrance of Ashburton River delta (Entrance Point). Note sand cheniers, lagoon and mangrove flats.

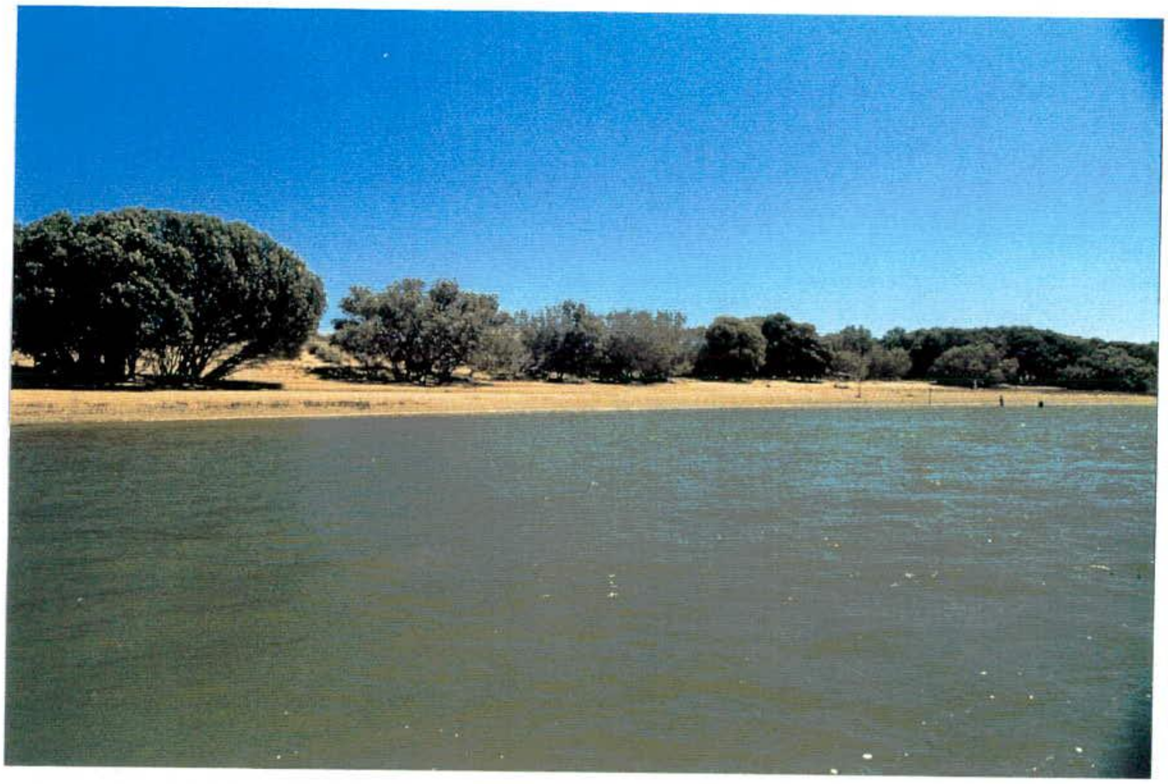

Plate 3: Mangroves (*Avicennia marina*) fringing Urala Creek.

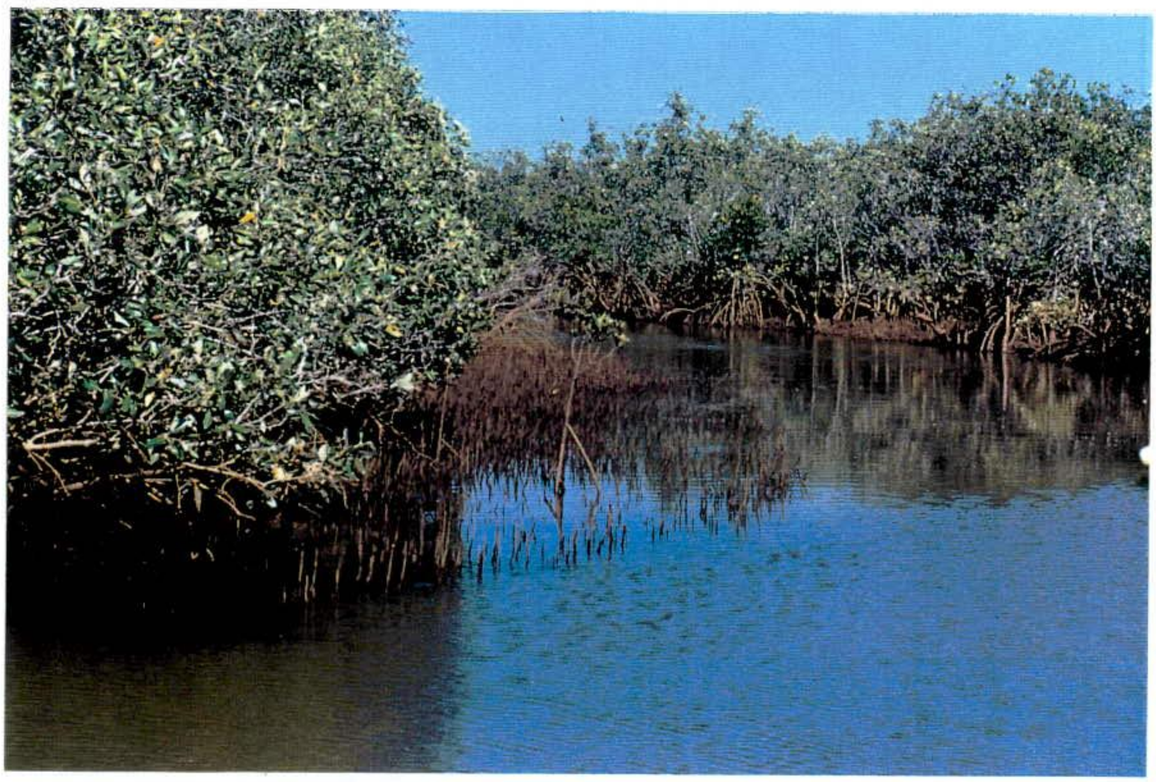

Plate 4: Mangroves fringing a tidal creek in the Ashburton delta. *Avicennia marina* in left foreground, *Rhizophora stylosa* with stilt roots in background.

Plate 5: Sandy beach on the northern side of Locker Island. Turtle tracks and nest in foreground.

Plate 6: Narrow rocky shoreline immediately east of Entrance Point and the Ashburton River delta.

Plate 7: Low coverage of corals (<10%) on nearshore reef near Locker Point.

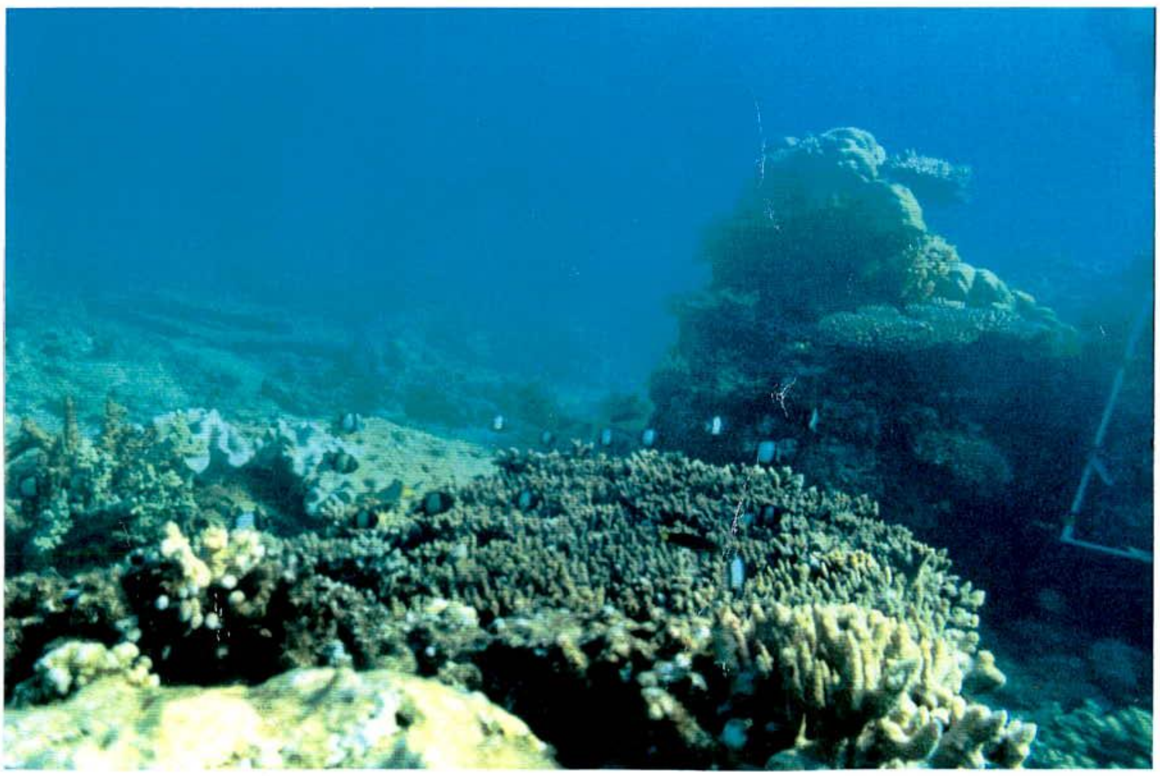

Plate 8: Fringing coral reef in 2 m of water at Tortoise Island.