Coral Coast marina, residential subdivision and quarry, Exmouth

Department of Marine and Harbours

Report and recommendations of the Environmental Protection Authority

Environmental Protection Authority
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Summary and recommendations

This proposal essentially has three interdependent elements; the Coral Coast marina, a residential subdivision, and a quarry to provide limestone for groynes. The provision of services such as drainage, sewerage and water supply are an essential part of the marina and residential subdivision.

Following public review of the Notice of Intent[1], the Department of Marine and Harbours requested permission to undertake further investigations into the sites' hydrological and geological characteristics by constructing a test pit. Conditional approval for the test pit was granted.

The Authority requested further information on the proposed residential subdivision, the quarry and drainage flows.

Recommendation 1

The Environmental Protection Authority concludes that the proposal by the Department of Marine and Harbours to construct the Coral Coast Marina and the associated residential subdivision, as modified during the process of interaction between the proponent, the Environmental Protection Authority, the public and government agencies that were consulted, is environmentally acceptable.

In reaching this conclusion the Environmental Protection Authority identified the main environmental factors requiring detailed consideration as:

- **impacts which would result if de-watering techniques were used, particularly on the unique cave fauna of the region;**
- **dredge spoil disposal;**
- **marina water quality;**
- **management of the large flows from the adjacent range to new drainage outlets; and**
- **location, management and rehabilitation of the quarry and its access road;**

The Environmental Protection Authority concludes that the environmental factors mentioned above have been addressed adequately by either environmental management commitments given by the proponent or by the Environmental Protection Authority's recommendations in this report.

Accordingly, the Environmental Protection Authority recommends that the proposal could proceed subject to:

- **the Environmental Protection Authority's recommendations in this Assessment Report; and**
- **the proponent's commitments which were given in both the Notice of Intent and subsequent documentation (Appendix 2).**

Marina proposal

The Department of Marine and Harbours would construct and operate the proposed marina. Commercial facilities within the marina resort would be constructed and operated by private parties under lease agreements with the Department.

The proposal is consistent with planning policies for Exmouth, incorporates provision for anticipated greenhouse sea level rises, maintains public access to the foreshore and adequately addresses management of former tip sites within the marina. The marina is proposed to be located behind the coastal dunes except for the entrance channel to the harbour, which coincides with an existing breach in the dune. The Department of Marine and Harbours proposes to prepare and implement a management plan for the dunes.

No Aboriginal Sites having archaeological or ethnographic significance were found in a survey of the proposed marina development area.

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[1] In September 1989 the Authority revised its administrative procedures and re-named Notice of Intent documents prepared by proponents in response to Authority assessment requirements as Consultative Environmental Review documents.

The marina basin could be constructed either by the use of conventional earthmoving equipment if the harbour area can be de-watered or it could be constructed "in the wet" using either a land based hydraulic excavator or a cutter suction dredge.

Testing at the site has shown that de-watering to construct the marina is likely to affect private bore water supplies and could affect species of a unique subterranean aquatic fauna comprising two species each of fishes and shrimps which may occur at the marina site.

Up to 11 bores may be affected by de-watering and the nearest of these is about 350 m from the marina basin.

The unique subterranean fauna are known as troglobitic fauna because they are obligate cave dwellers. All four species of troglobitic fauna have been proposed for inclusion in amendments to the gazetted fauna under the Wildlife Conservation Act (WA) and one of these, the Blind or Cave Gudgeon is classified as rare. De-watering could create a salt water wedge which could bisect the range of the fauna, which appears to be coastal, and isolate part of the population. Little is known of the distribution or abundance of these fauna and the potential effect of isolating part of the population is unknown. They are quite small and may live in small channels in the limestone. The Authority understands that the small channels in which troglobitic fauna may live cannot be detected by non-destructive or remote survey methods. The Western Australian Museum strongly recommended that de-watering not take place.

A permeable settling pond for the disposal of de-watering water or dredge spoil could result in heavy siltation or blocking of subterranean passages containing troglobitic fauna if it was located above their habitat.

Recommendation 2

The Environmental Protection Authority considers that the potential impacts of de-watering on private bores around the marina site and on the rare troglobitic fauna are unacceptable and recommends that de-watering should not take place unless the impacts can be confined to within 300 m of the marina basin. The Environmental Protection Authority further recommends that de-watering should cease when monitoring detects de-watering effects at 300 m from the marina basin. If de-watering criteria cannot be met then the proponent could construct the Marina in an environmentally acceptable manner "in the wet" using either a land based hydraulic excavator or a cutter suction dredge. The Environmental Protection Authority recommends that settling ponds be constructed to the east of the westernmost edge of the proposed marina as near as practicable to the ocean.

Blasting would be required to construct the marina harbour, which is about 350 m from the nearest building and 1.9 km from Exmouth Town Centre. The Department of Marine and Harbours has undertaken to include clauses in contract documents to require that blasting only occurs when weather conditions are deemed to be suitable, to notify the Exmouth community in advance of proposed blasts, and to repair any obvious damage caused by blasting

Sediments dredged from the entrance channel would be either used as core material for breakwater construction or disposed off-shore. An artificial reef or island off-shore from the marina could be created from the spoil. The Authority concurs with the proponent's assessment that disposal sites would be recolonised rapidly. Concerns regarding the stability of the dredge spoil disposal can be addressed when this aspect of the proposal is referred to the Environmental Protection Authority.

As the proposal includes a recreational beach within the marina it is essential that water quality parameters stay within the criteria specified for direct contact recreation. The Authority considers that the flushing characteristics of the marina and measures to reduce pollutant inputs to the marina, such as directing drainage away from the marina basin, ensuring all developments are connected to sewerage, prohibiting discharge of liquid and solid wastes into the marina waters from boats, sound design of refueling facilities and implementation of the proposed Environmental Protection Authority regulations on tributyl tin should ensure that water quality parameters remain within acceptable criteria. Regular monitoring of water quality and contaminant levels in sediments is proposed.

The shoreline near the marina appears to be stable and the marina appears unlikely to cause significant coastal instability. It is proposed that coastal stability will be monitored. It is also unlikely that sand by-passing would be required except perhaps on an occasional basis, which would be done on an as-needs basis by the Department of Marine and Harbours.

Noise and dust during construction would be controlled as necessary.

Quarry

The quarry site proposed in the Notice of Intent was found to be within the proposed extension to Cape Range National Park as recommended by the Environmental Protection Authority in the 'Conservation Reserves for Western Australia' reports. The Department of Marine and Harbours has since found another site located about 6 km south of Exmouth and 2 km from two existing mining leases. The existing mining leases have not been greatly disturbed.

Comment was sought regarding the new proposed site from all organisations which had responded to the Notice of Intent.

The proposed site is within an area utilised by the Water Authority for groundwater extraction. Advice from Geological Survey indicates that quarrying could proceed with negligible impact on groundwater quality.

The Authority considers that the environmental impacts which would result from quarrying the existing mining leases or from quarrying at the site proposed by the Department and Marine and Harbours would be similar.

Recommendation 6

The Environmental Protection Authority considers that the proposed quarry site as located subsequent to the process of interaction between the proponent and the Environmental Protection Authority, is environmentally acceptable and recommends that quarrying could proceed subject to:

- **the Department of Marine and Harbours fulfilling the requirements of other relevant Acts, particularly the requirements of the Western Australian Aboriginal Heritage Act 1972-80, prior to commencement of quarrying operations; and**
- **preparation of a environmental management programme for the quarry prior to the commencement of quarry operations to the satisfaction of the Shire of Exmouth on advice of the Water Authority of Western Australia. The environmental management programme should be based on the draft guidelines of the Working Party on Conservation and Rehabilitation in the Mining Industry, address concerns expressed by the Water Authority, and include details of the proposed access road to the quarry. The environmental management programme should be implemented by the proponent to the satisfaction of the Shire of Exmouth on advice of the Water Authority of Western Australia.**

The Authority 's experience is that it is common for details of a proposal to alter through the detailed design and construction phase. In many cases alterations are not environmentally significant or have a positive effect on the environmental performance of the project. The Authority believes that such non-substantial changes, and especially those which improve environmental performance and protection, should be provided for.

The Authority believes that any approval for the proposal based on this assessment should be limited to five years. Accordingly, if the proposal has not been substantially commenced within five years of the date of this report, then such approval should lapse. After that time, further consideration of the proposal should occur only following a new referral to the Authority.

Residential subdivision

The residential subdivision would be developed immediately inland of the marina using 800 000 m^3 of material excavated from the marina harbour to shape the land for residential development. The Department of Marine and Harbours would prepare the proposed residential development for subdivision and then offer the subdivided Freehold Titles for public sale.

It is proposed to create 377 lots and 6 ha of public open space from a total area of about 58 ha. The fill from the marina would be compacted in accordance with requirements for building purposes, and existing topsoil would be removed and replaced on top of the fill. Sewerage would be available to all lots.

The Authority is concerned that the slope of 1 in 8 proposed along most of the western boundary of the proposed subdivision and along part of a drainage channel may erode rapidly, be difficult to revegetate and does not reflect the topography elsewhere within the coastal strip. Slopes of 1 in 12 are more characteristic of local topography, are more likely to be successfully revegetated and less likely to erode.

Recommendation 3

The Environmental Protection Authority recommends that the proponent should ensure that slopes used in the residential subdivision are likely to be stable in the long term to the satisfaction of the Environmental Protection Authority.

Noise and dust would be controlled as necessary.

Drainage, sewerage and water supply.

The proposed site of the marina presently receives stormwater drainage from an extensive catchment which discharges through the site of the proposed marina entrance channel, which is currently a naturally formed drainage outlet through the coastal dunes to Exmouth Gulf. It is proposed to divert this water through a formal open drainage system with compensating basins to a new outlet constructed to the north of the development area. The Shire of Exmouth has advised that it considers the proposed route would be capable of carrying the estimated volumes of water without significantly affecting land owners or land uses in the area. The beach and dune in the vicinity of the outlet would be stabilized and rehabilitated.

The Authority is concerned that drainage outlets be located away from important biological communities, such as corals, which could be affected by outlets with a high sediment load

Recommendation 4

The Environmental Protection Authority recommends that the proponent ensure the proposed drainage design and outlets are constructed so there is no impact from sediments on important biological communities such as corals to the satisfaction of the Environmental Protection Authority.

The town sewerage plant can cope with the anticipated increase in sewage.

The Water Authority consider that water supply requirements can be met.

Given the potential for troglobitic fauna to occur under the subdivision private bores should not be permitted.

Recommendation 5

The Environmental Protection Authority recommends that private bores not be permitted in the subdivision nor within the marina development and that titles and lease documents be appropriately endorsed with this requirement.

1. Introduction and background

The Department of Marine and Harbours proposes to construct the 'Coral Coast Marina', facilitate development of facilities around the marina and develop a residential area inland of the marina. The Coral Coast Marina is proposed to be built at Exmouth immediately to the south of the township, between the Yacht Club and the Race course. A quarry is required to provide suitably sized armour stone for the breakwaters and groynes.

The development would provide up to 250 berths for both recreational and commercial craft, and would include associated facilities for recreation, tourism, the fishing industry and commercial services.

The marina proposal is similar to a proposal in 1986 by Skywest Holdings Pty Ltd (Skywest), then the owner of Norcape Lodge Resort. Skywest proposed to develop a marina resort adjacent to the northern boundary of Norcape Lodge, which is approximately 1 km north of the presently proposed marina.

Skywest prepared a Public Environmental Report describing its proposal (Le Provost, Semeniuk and Chalmers, 1986), which was made available for public review for a period of 8 weeks. However, prior to the Authority completing its assessment, Skywest sold Norcape Lodge and withdrew the proposal. Therefore, the Environmental Protection Authority did not publish its report to the Minister for the Environment.

Following the withdrawal of Skywest, other developers and potential users of the marina have approached the Department of Marine and Harbours with a view to constructing a similar facility.

To assess the different interests of the various organisations the Minister for Transport established a Working Group comprising fishing industry representatives and senior officers from the Fisheries Department and the Department of Marine and Harbours. There was strong community support for this initiative, particularly through the Exmouth Marina Development Committee, elected at a public meeting held in Exmouth in August 1987. The Working Group investigated the feasibility of developing a marina at four possible sites near Exmouth, namely Badjirrajirra Creek, South Bundegi, Norcape Lodge and the proposed site. The proposed site was the working group's recommended marina site.

The Working Group recommended a multi-user facility to service the requirements of the fishing industry, the tourist industry, the recreational boating public and the Royal Australian Navy.

The concept plans for the proposed marina have been widely publicised in Exmouth, including substantial coverage in the local newspaper. Interest in, and support for, the marina in Exmouth is reportedly very high.

The Department of Marine and Harbours prepared a document (entitled a Notice of Intent[1]) which the Environmental Protection Authority considered adequate for a Consultative Environmental Review, and the documentation was sent out for comment to those who had commented on the previous proposal. The availability of the document was also advertised in the local paper.

Following public review of the 'Notice of Intent', the Department of Marine and Harbours supplied further information to the Authority to assist in assessment of the proposal and requested permission to undertake further investigations into the hydrological and geological characteristics of the proposed marina site by constructing a test pit.

2. Description of proposal

The proposed development concept for the Coral Coast Marina Resort is for a marina, an associated recreational holiday resort, commercial facilities and a residential subdivision inland from the marina development. Significant drainage diversion works are necessary to accommodate the proposed marina and residential development. A quarry is required to provide armour stone for breakwater and groyne construction.

The proposed development concept is shown in Figure 1. The Stage 1 marina would have a harbour with an approximate water area of 15.5 ha and could include boat repair facilities, a fuel depot and boat refuelling facilities. Construction and design details for the facilities to be built around the marina have

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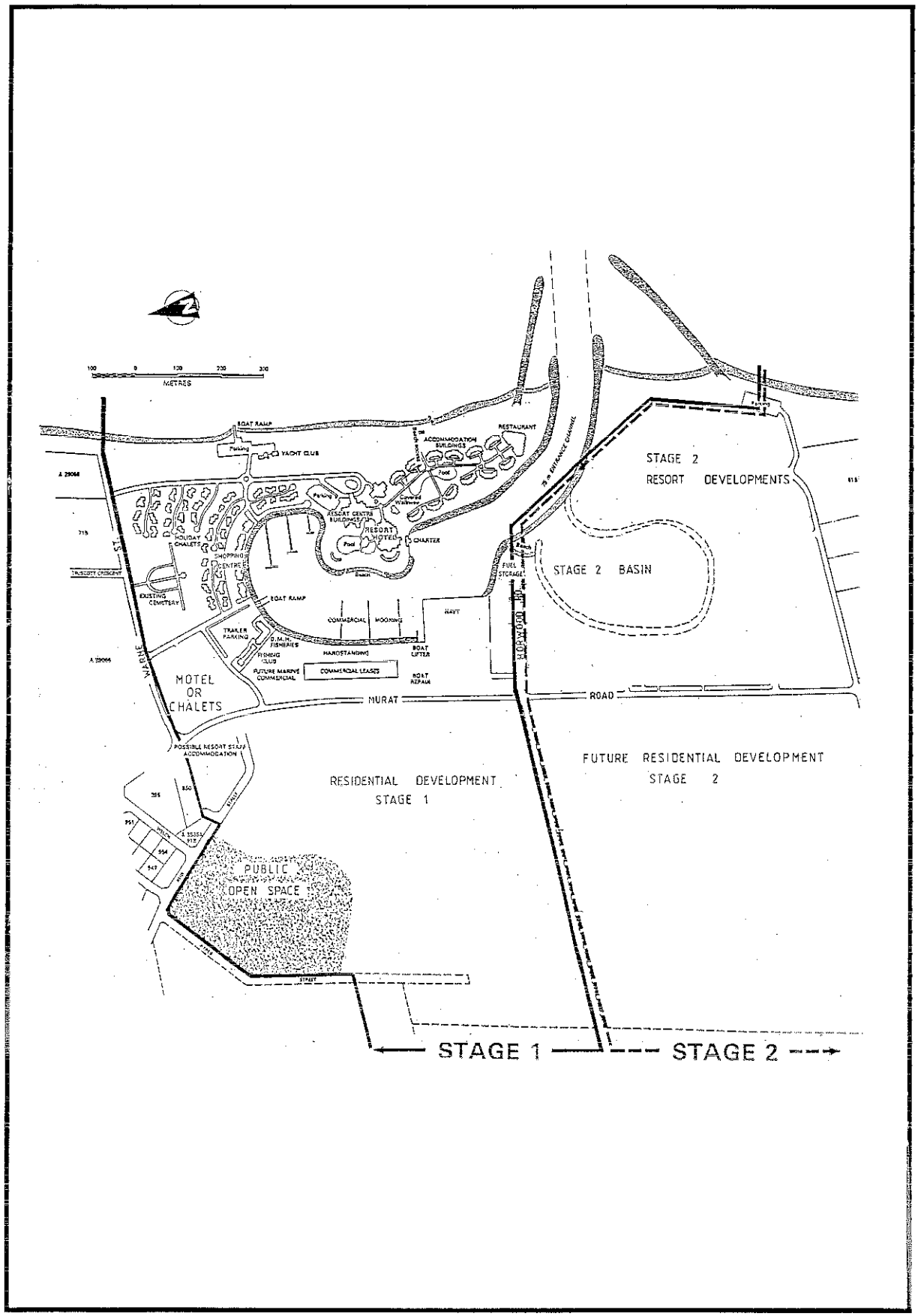

Figure 1: Proposed development concept for Coral Coast Marina

not yet been defined. Facilities within the harbour could include a number of jetties for commercial and public mooring and a public boat ramp. Additional wharfage for commercial lessees, and for charter boat operations associated with the resort, may also be provided. Recreation and holiday facilities would be located within the eastern and northern area of the marina, and commercial facilities in the western area adjacent to Murat Road.

The proposed residential subdivision would provide 377 fully serviced residential housing lots, with approximately 6 ha being set aside as public open space. Fill material excavated during marina construction would be placed within the proposed residential development.

The proposed development concept anticipates the possible future development of a Stage 2 marina and associated facilities, together with an additional residential subdivision. Concept plans for the Stage 2 development have not yet been finalized, but are accommodated within the proposed marina design. Stage 2 and the proposed developments around the marina such as the resort hotel and holiday facilities are not assessed in this report.

The proposal essentially has three interdependent elements; the marina, the quarry and the residential subdivision. The provision of services such as drainage, sewerage and water supply are an essential part of the marina and residential subdivision.

2.1 The marina

The Exmouth Structure Plan (State Planning Commission, 1988) recommends that the proposed marina site be used for "Tourist" purposes, and the proposed residential development site be used for "Residential" purposes. Amendment of the existing zoning under the Exmouth Town Planning Scheme No. 1 would be required in order to facilitate these recommendations. Alternatively a new Town Planning Scheme would be developed and an interim development order obtained to allow construction to proceed prior to finalisation of the new Scheme. Relocation of some existing land-uses would also be necessary, and this has been agreed to by the Exmouth Shire Council.

The Stage 1 harbour would be excavated to -4.8 m AHD in the northern area, to -5.3 m AHD in the central area and to -5.8 m AHD in the southern area (adjacent to the entrance channel). Figure 2 shows the site relief following harbour excavation.

The retaining walls of the harbour, including the entrance channel, would be 1.5 horizontal to 1 vertical down to the excavated depth, and would be armoured with limestone rock.

The entrance channel would be 75 m wide and would be excavated to -5.8 m AHD. The entrance channel would be aligned in an east-south-easterly direction to cut through an existing break in the coastal dune, and would extend approximately 800 m off-shore.

The breakwaters would be standard limestone groyne structures, with a core of quarry rock and rubble armoured with large boulders. The size of the armour stone that would be used would vary with distance from shore, and would be up to 8 tonnes.

Secondary groynes would be constructed at the shoreline to protect the mouth of the entrance channel. These groynes would extend for approximately 50 m from the beach.

Existing access to Town Beach would be maintained. Public access to the beach and northern breakwater would be accommodated by the provision of controlled pathways from the proposed resort complex. Public access to the southern breakwater would be via Horwood Road.

A swimming beach would be established within the harbour adjacent to the proposed resort area.

Access to the marina commercial areas would be via an internal roadway from Horwood Road. The resort complex, holiday chalets, shopping centre, caravan park and public boat ramp would be accessed via Warne Street.

2.1.1 Excavation and dredging

The Department of Marine and Harbours indicated the marina basin could be constructed either by the use of conventional earthmoving equipment if the harbour area could be de-watered (i.e. groundwater would be pumped from the basin to lower the water table) or it could be constructed "in the wet" using either a land based hydraulic excavator or a cutter suction dredge.

Land based excavation "in the wet" would occur within a land-locked basin, with the excavator operating from the edge of the basin and working progressively along the face. A cutter suction dredge would excavate into the harbour from the entrance channel.

If the harbour is excavated using either hydraulic excavators or a cutter suction dredge, the excavated material would be deposited adjacent to the marina and allowed to drain of water prior to its transport and placement on the adjoining land area proposed for residential development. The drainage water would be directed to a settling basin to reduce suspended sediment material prior to discharge to Exmouth Gulf.

The Department of Marine and Harbours would prefer to de-water and use conventional earthmoving equipment because this would allow for direct transfer of the excavated material to the proposed residential development. Section 5.1.4 (De-watering Impacts) reports the results of further investigations by the Department of Marine and Harbours into the feasibility of de-watering.

The investigations confirmed the need for some blasting within the marina harbour basin to occur to facilitate excavation.

No excavation is proposed in the old tip within the proposed marina precinct. However, the north eastern area of the old rubbish tip contains some items of industrial waste such as car bodies, stoves, refrigerators, steel cabinets, building materials and the like. These items would be unsuitable foundation for building sites, and will be removed to the Shire's current refuse disposal site or buried within the old rubbish tip site in the north western corner of the proposed residential development area.

The seaward section of the entrance channel would probably be dredged using barge mounted equipment, either a hydraulic excavator or a clam-shell grab. Alternatively, though less likely, a cutter suction dredge would be used.

Further specific investigations would be conducted by the Department of Marine and Harbours in order to define the engineering requirements, including blasting requirements. The results of these investigations would be submitted to the Environmental Protection Authority and approval would be sought prior to initiation of dredging.

2.1.2 Disposal and use of excavated and dredged material

The overall quantity of material excavated from the marina basin that would require disposal is approximately 1.2 million m^3. Up to 400,000 m^3 would be used to elevate the land area of the marina complex to provide desired relief and drainage. The remaining 800,000 m^3 of excavated material would be used to shape the land area of the proposed residential development. A stabilisation plan for filled areas has been prepared.

Approximately 160,000 m^3 of sediments dredged from the entrance channel would be disposed in Exmouth Gulf. Three alternatives for disposing these materials are to be considered, depending on the nature of the material:

- suitable hard-rock sediments may be used as core material for breakwater construction;
- the dredged material may be used to construct an artificial reef or island off-shore from the proposed marina; or
- the sediments would be disposed in deeper water in Exmouth Gulf.

Engineering and environmental management details of the preferred disposal strategy would be referred to the Environmental Protection Authority and the Commonwealth Department of Arts, Sport, Environment, Tourism and Territories for approval.

2.1.3 Operation and on-going management

The proposed marina would be vested in the Minister of Transport and would be operated and managed by the Department of Marine and Harbours. The marina facilities, possibly including the jetties and wharfage, would be constructed and operated by private developers under lease agreements with the Minister of Transport.

The Department of Marine and Harbours would be responsible for the management of the site, including maintenance of jetties and wharfs constructed by the Department, foreshore treatments, the navigable depth and water quality and has committed to maintain an environmental monitoring programme and coastal management plan (See Commitment No 23, Appendix 1).

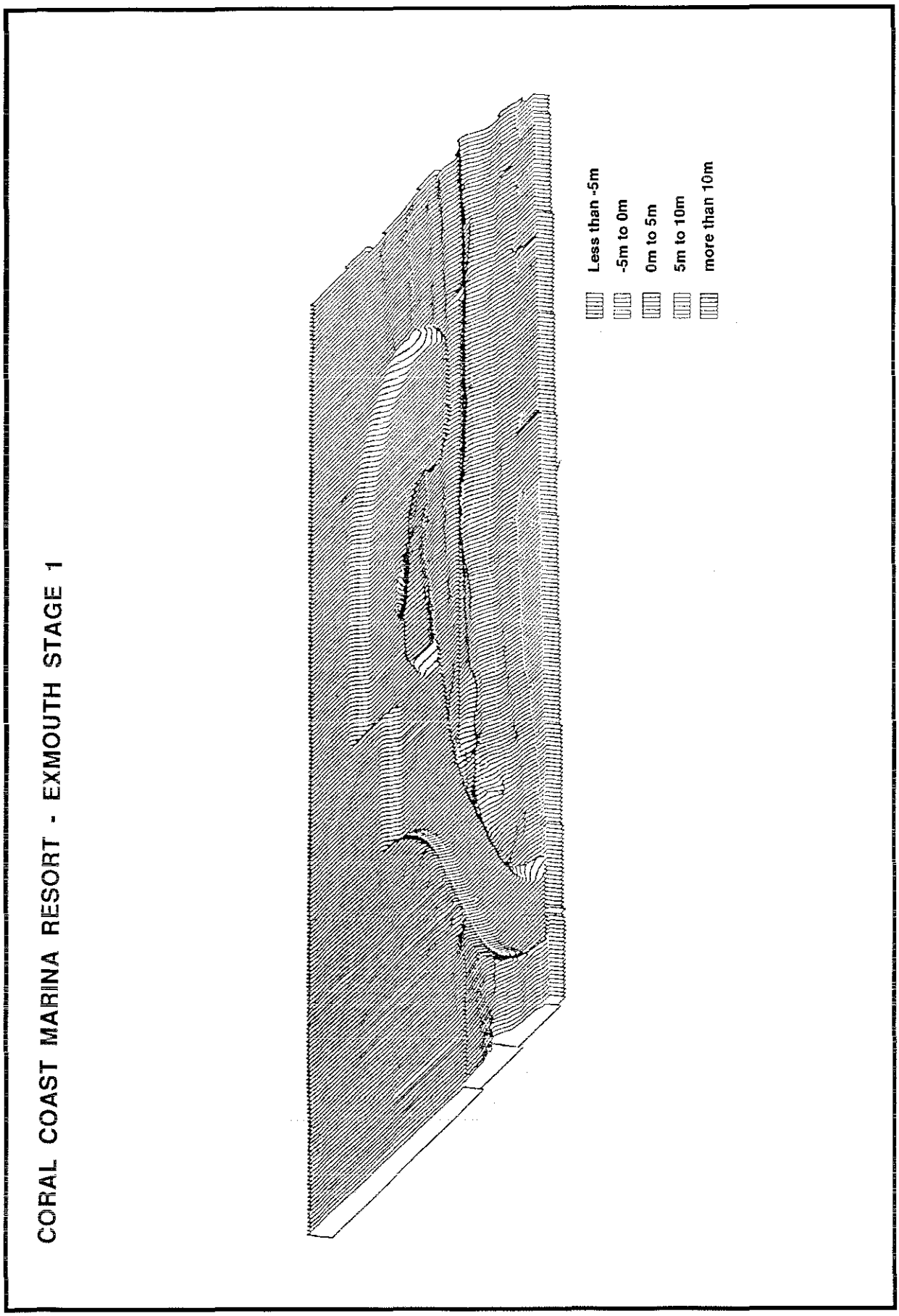

Figure 2: Marina harbour relief following excavation

2.2 Residential subdivision

The Department of Marine and Harbours requested that the Authority consider the proposed residential subdivision as part of the Coral Coast Marina proposal for which approval was being sought. As few details were provided in the Notice of Intent the Authority requested that further details be provided to assist the Authority in its assessment. A planning report was prepared for the Department of Marine and Harbours by Warren F Johnson & Co and forwarded to the Authority for comment. Further information was then provided to the Authority on the basis of its comments.

The proposed residential area would be developed for subdivision by the Department of Marine and Harbours, then the subdivided freehold lots would be offered for sale to the public.

Figure 3 shows the proposed residential subdivision which will create 377 lots and 6 ha of public open space from a total area of 57.95 ha.

The proposed subdivision is consistent with the Exmouth Structure Plan. It is proposed that Welch Street would be extended and be 30 m wide to provide a physical barrier between the existing industrial area and the proposed residential area.

The proposed contours which would result from the relocation of about 800,000 m^3 of excavated material from the marina site are shown in Figure 3. The fill would be compacted in accordance with the requirements for building purposes.

Existing topsoil would be removed from designated areas prior to their use as landfill sites and would later be utilized for resurfacing these sites once landfilling was complete.

The subdivision would incorporate the concepts noted in the "Water Conservation Through Good Design" booklet which is produced by the Western Australian Water Resources Council.

Information regarding drainage and sewerage of the residential development appears under Section 2.3, Service works required.

A former refuse site is located near Ayres Street in the north western area of the proposed residential area. This site was not a domestic rubbish site, but accepted "industrial" wastes such as car bodies and whitegoods. It is proposed to remove unsuitable materials such as car bodies, level and compact the site and then cover the site with an average of 2 m of fill from the Marina. This area will form part of the public open space of residential subdivision.

Management of land uses, compliance with building standards and maintenance of public roads, drains and recreation areas would be the responsibility of the Shire of Exmouth.

2.3 Service works required

2.3.1 Drainage

The proposed site of the marina presently receives stormwater drainage from an extensive catchment. The site of the marina entrance channel is the only naturally formed drainage outlet through the coastal dunes to Exmouth Gulf along several kilometres of the coastline. A formal open drainage system would be constructed to intersect incoming runoff and streamflows, and divert them around the proposed development to ensure that the site is not flooded and that the project does not cause flooding of peripheral areas. The diverted drainage would discharge to the Gulf via major culverts under Murat Road, around the western side of Norcape Lodge and the Pony Club to an outlet constructed at a suitable location north of Norcape Lodge.

The conceptual drainage plan has been revised since the Notice of Intent and is shown in Figure 4. Figure 3 shows the peak flows for 100 year average recurrence interval. It is proposed to construct a 6 000 m^3 compensating basin to intercept flow from the creeks and to use the oval as a compensating basin. The plan for an ocean outfall which was to be constructed through the dunes about 500 m south of the Marina has been withdrawn. The Stage 1 development would not require construction of any of the drainage works which would flow to the south.

The proposed new drainage outlet to Exmouth Gulf would be designed in consultation with the Shire of Exmouth and the Commissioner for Soil Conservation, and would be referred to the Environmental Protection Authority for approval prior to initiation of construction activities. Appropriate rehabilitation procedures would be implemented in order to ensure stability of the beach and dune in the vicinity of the outlets.

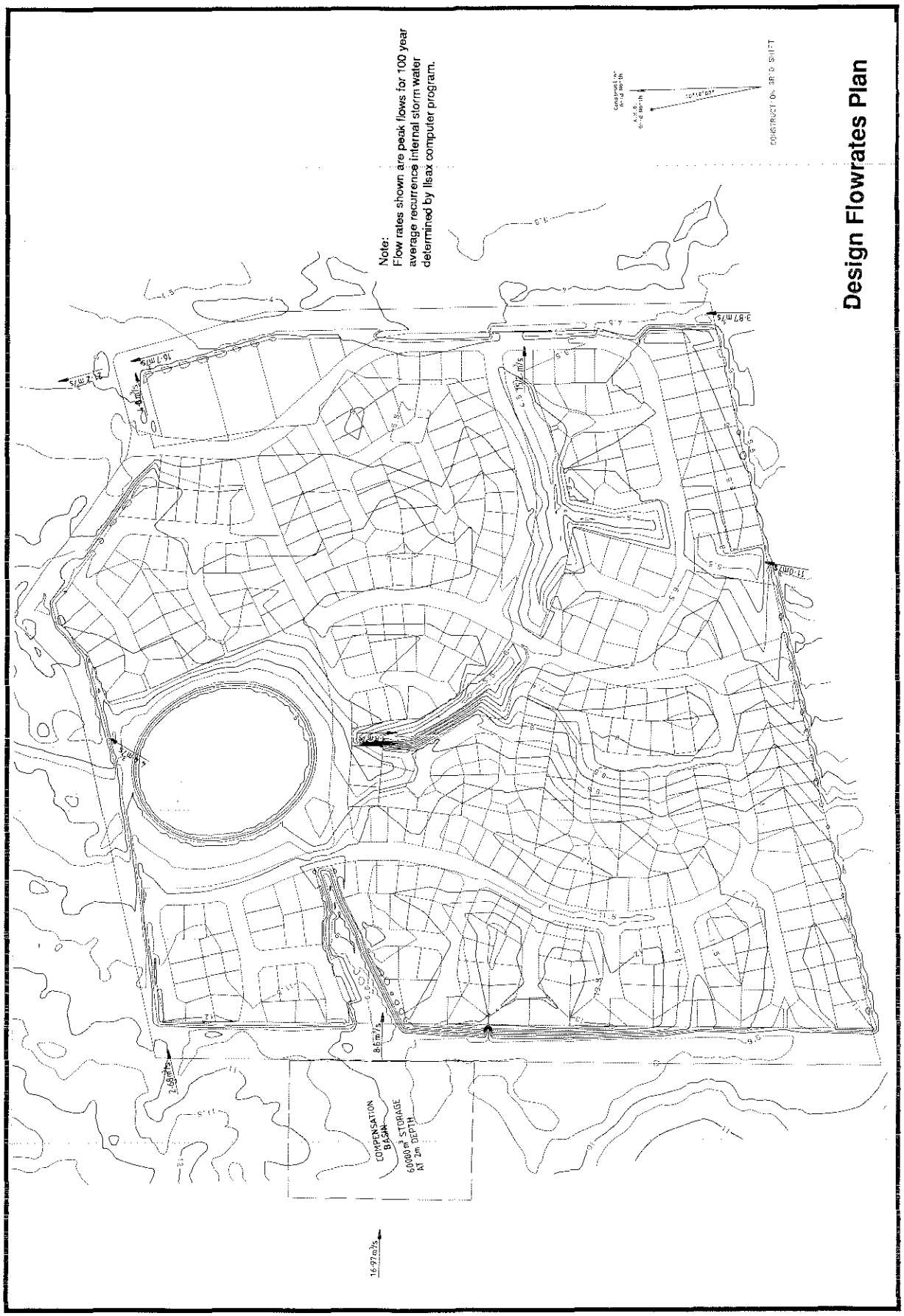

Figure 3: Proposed residential subdivision plan showing proposed contours and 1 in 100 year recurrence interval flows

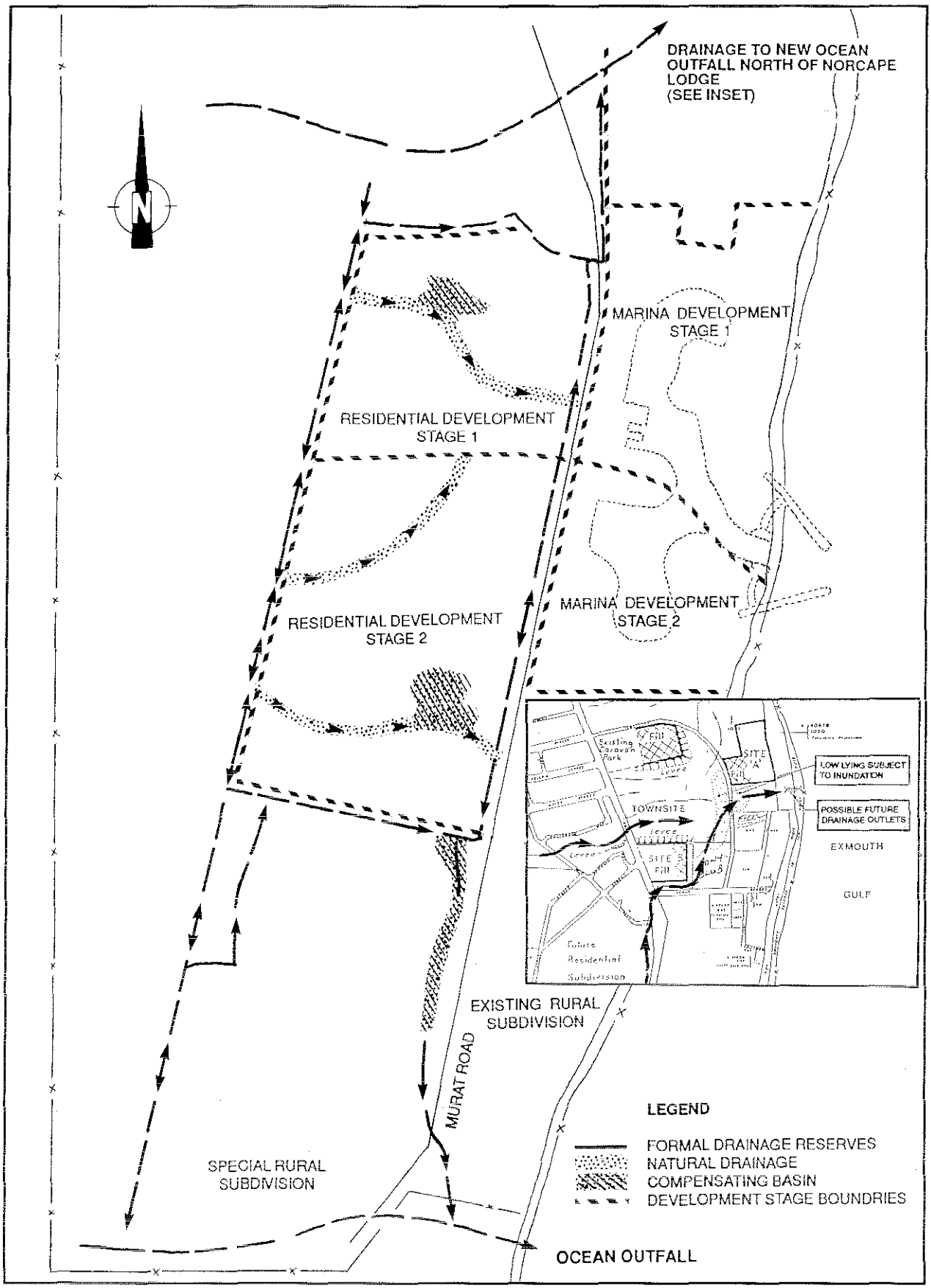

Figure 4: Revised drainage concept plan

The marina development would be elevated above the estimated 1 in 100 year flood level, thereby preventing any flow from adjacent low lying land from contributing to the drainage in the marina area. Drainage within the marina precinct would be directed away from the harbour and discharged to the main drainage via silt traps. There would be provision for drainage overflow into the marina harbour during more extreme events.

2.3.2 Sewerage

All facilities around the marina and the lots in the residential subdivision would be serviced by reticulated sewerage. The existing treatment plant can accommodate significant town development and is located between the town and the coast, approximately 1,200 m north of the proposed marina development.

2.3.3 Water supply

Exmouth's water supplies come from two borefields situated in the Cape Range to the west and south west of the town. A total of 42 bores extract from a thin lens of fresh water above a saline layer. Consumption is presently around 800,000 m^3/a, and advice from the Water Authority is that, with careful management, the aquifer could service approximately two times the existing population.

Numerous Exmouth residents also have private bores. A licence from the Water Authority to extract groundwater is required for all private bores.

2.4 The quarry

The site proposed in the Notice of Intent was found to be within the proposed extension to Cape Range National Park as recommended by the Environmental Protection Authority in the Conservation Reserves for Western Australia reports. The Department of Marine and Harbours has since found another site outside the proposed extension to the National Park. The new proposed quarry site is shown in Figure 5.

It is proposed that the quarry be closed after sufficient stone for this project has been won.

3. Existing environment

The Notice of Intent describes the existing environment in detail. Results of further investigations into geomorphology, soils and hydrology appear in Appendix 4 and on significant wave heights appear in Appendix 2F.

Aspects of the existing environment particularly relevant to the project include:

- much of Exmouth's rainfall is cyclone generated; rainfall is rapid and strong winds occur;
- the residential subdivision and marina are located behind the foredune on sandy soil which is above fractured limestone;
- the proposed entrance channel for the marina is located in a breach of the foredune caused by a drainage channel which drains an extensive catchment from the adjacent ranges;
- the sites for the residential development and marina are uncleared except for two former refuse sites and structures associated with horse paddocks located in the proposed residential development area. The vegetation present is common in the region;
- tides are diurnal and vary from +1.4 m to -1.3 m AHD;
- storm surges and wave setups are calculated to be 1.1 m on a 50 year return period;
- under prevailing conditions sediment transport along the beach appears to be negligible and shorelines have changed little over 24 years;
- isolated corals occur along the Gulf, and in general the water is relatively cloudy;
- troglobitic fauna occur along the coast;
- adjacent, existing and proposed land uses are shown in Figure 6.

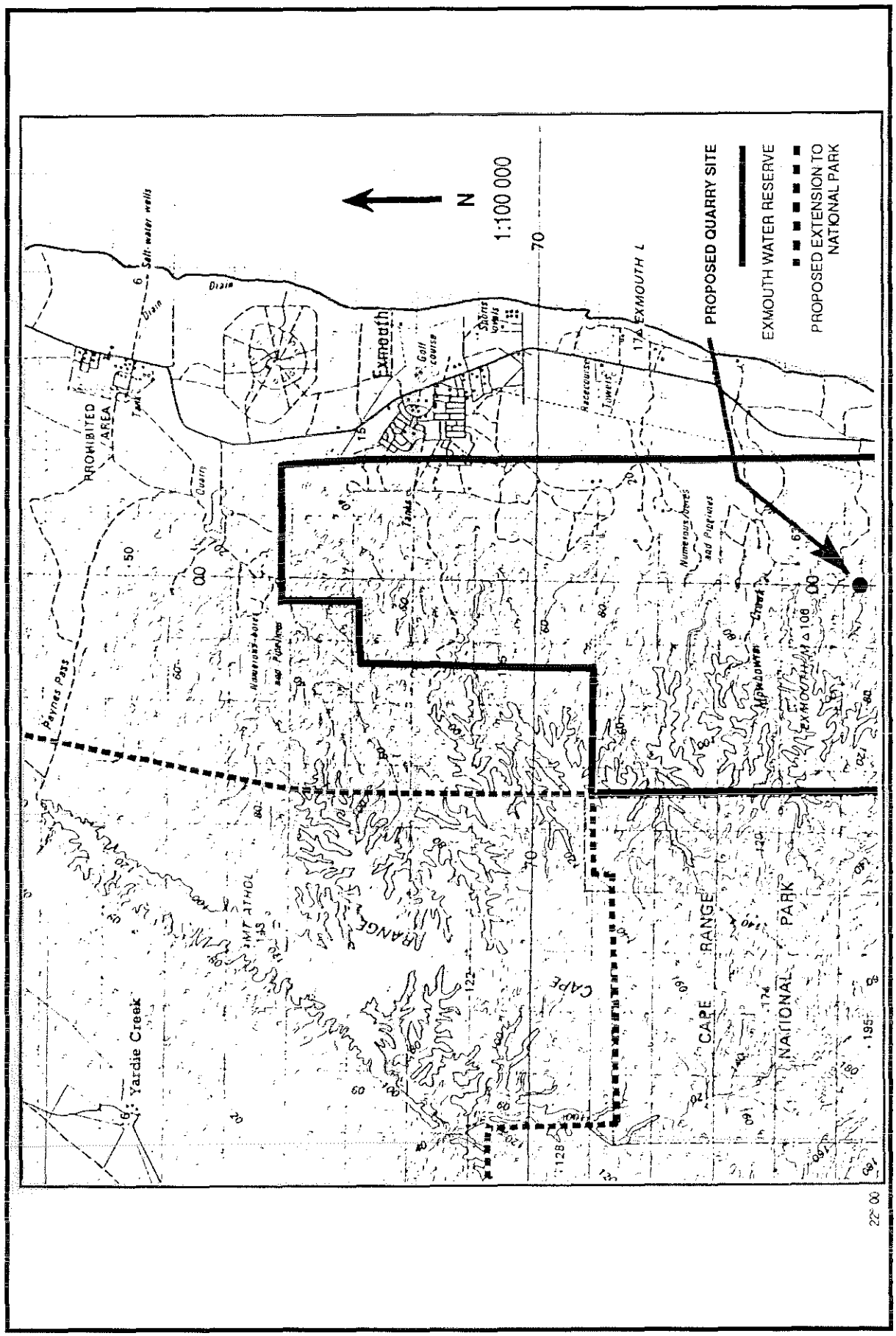

Figure 5: Location of proposed quarry

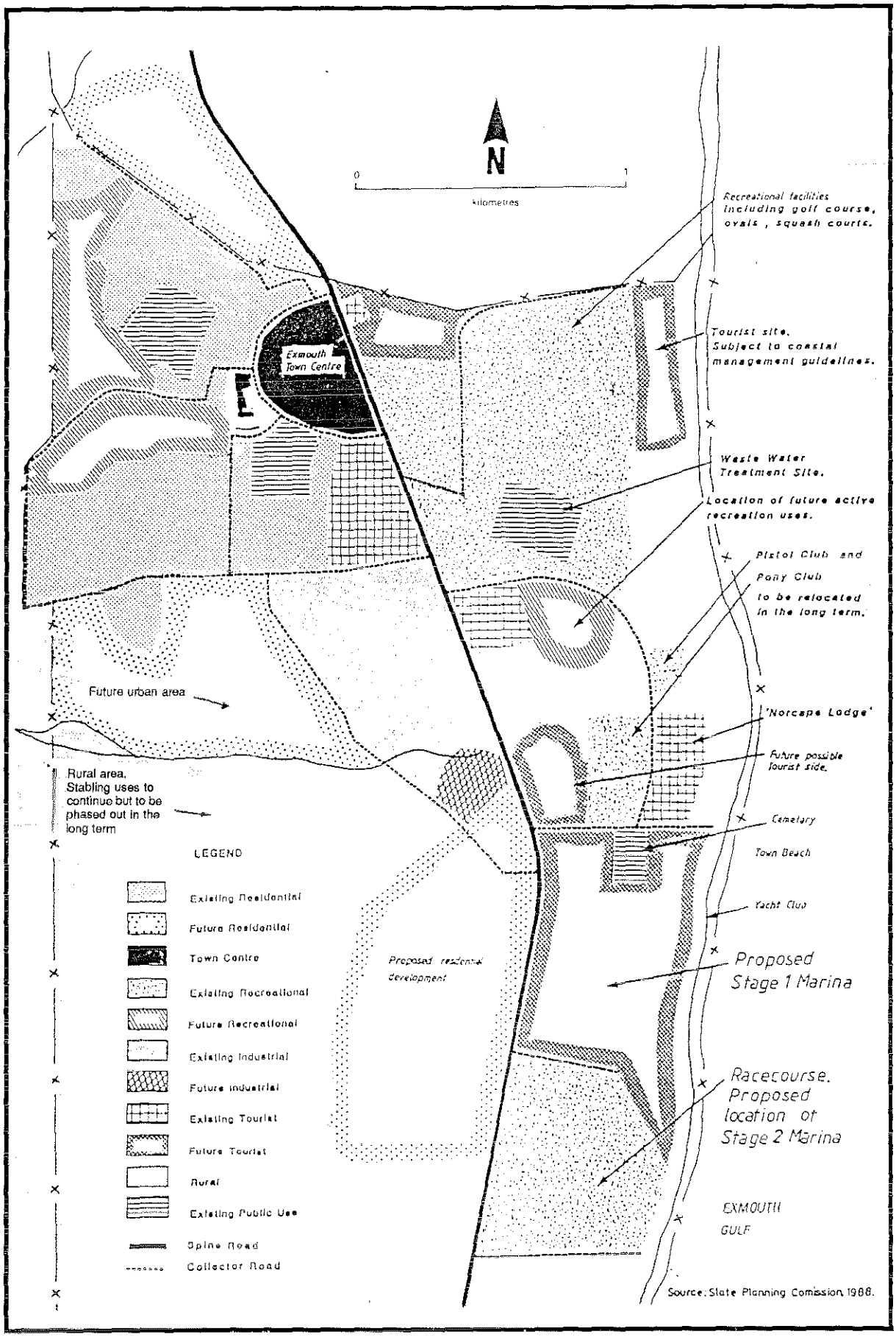

Figure 6 Project location, showing adjacent, existing and future land uses

4. Consultation

As noted in the introduction the Authority had recently sought public comment on the Skywest marina proposal which was being assessed at a Public Environmental Review level. The Authority decided that for this assessment, it should consult with those organisations which had responded to the previous proposal. The following nine organisations were consulted, of which the first seven responded with written comments; Department of Conservation and Land Management, Department of Land Administration, Shire of Exmouth, Fisheries Department, Department of Planning and Urban Development, Water Authority of Western Australia, Western Australian Museum, Conservation Council of Western Australia and the Department of Agriculture.

A full list of issues raised as a result of the consultation process appears in Appendix 2A. Issues which were identified as areas of concern included, the likelihood of rare troglobitic fauna at the marina site, potential adverse impacts from de-watering, the potential for flooding as a result of drainage modifications, the location of the quarry within an area proposed as an extension to Cape Range National Park, the potential impacts on buildings in Exmouth from blasting at the marina, and the need for an oil spill contingency plan.

5. Environmental assessment

5.1 Marina proposal

5.1.1 Planning aspects, public access and dune protection

The proposal conforms with town planning recommendations in the Exmouth Structure Plan and the Department of Conservation and Land Management's policy that tourist developments in the Exmouth area should be restricted to the existing settlements.

The Authority is satisfied that the Department of Marine and Harbours has followed the Country Coastal Planning Policy "as near as practicable in this proposal" (See Item 2.7 Appendix 2).

The Authority considers that the proposed ground levels provide adequate allowance for cyclones and anticipated sea level rise from the greenhouse effect

The Department of Marine & Harbours has made a commitment to maintain public access to Town Beach.

Contract documents prepared by the Department of Marine and Harbours relating to construction on the site will state that the dunes are not to be disturbed by construction equipment (See Commitments 1 and 6 in Appendix 1 and Item 2.8 Appendix 2). This should ensure appropriate care is taken to avoid incursion of machinery into conserved areas of the dune and foreshore.

5.1.2 Former tip site (Horwood Rd)

There is a disused rubbish dump immediately landward of the dunes, adjacent to Horwood Road, at the proposed marina site. No excavation is proposed in the old tip however the Department of Marine & Harbours proposes to remove items such as car bodies, stoves, refrigerators, steel cabinets, building materials and the like from the north eastern area of tip to the Shire's current refuse disposal site or to the old rubbish tip site in the north western corner of the proposed residential development. Accumulated loose refuse around the perimeter of the site will also be removed, the site will be compacted and the remaining refuse covered with clean fill.

There is no apparent groundwater contamination from the rubbish tip. Groundwater sampled from a borehole immediately seaward of the old rubbish tip showed no anomalous values for heavy metals, and other indicators of pollution, such as nitrates, phosphate and alkalinity are normal for a fossiliferous marine limestone aquifer in the tropics. The water did not have any offensive odour or colouration.

The Authority is satisfied that the measures proposed are unlikely to cause significant pollution.

5.1.3 Heritage values

Subsequent to public review of the Notice of Intent the Department of Marine & Harbours commissioned an archeological and ethnographic survey which indicated that "No archeological sites occur within, or adjacent to, the boundaries of the proposed development" (Veth & Wright, 1989).

No other heritage values are known at the site.

5.1.4 De-watering impacts

The Department of Marine & Harbours approached the Environmental Protection Authority and the Water Authority in October 1989 for permission to construct a test pit in order to determine if conventional earthmoving equipment could be utilised and to quantify the de-watering process. After consultation with the Western Australian Museum and the Water Authority the Environmental Protection Authority decided that the test pit could proceed, subject to certain conditions. A copy of the Authority's advice appears as Appendix 3.

A copy of the conclusion and recommendations resulting from the test pit investigations appears as Appendix 4 (Morgan & Associates, 1990). In summary the test pit report concluded that:

- de-watering could permit the use of conventional earthmoving equipment to remove the soil and rock down to the hard rock. Blasting of the hard rock would probably be required. A plan showing hard rock levels appears as part of Appendix 4;
- hydrogeological results obtained during the test pit construction apply mainly to the saturated section above the hard rock layer;
- further investigations (such as pumping tests and test drilling) are warranted to help determine de-watering design, de-watering effects and blasting requirements;
- at maximum harbour depth prolonged de-watering is projected to have a radius of influence about 1000 metres; and
- recommendations for groundwater de-watering monitoring during harbour construction were provided.

The Department of Marine and Harbours has adopted one recommendation from the test pit report, namely the installation and monitoring of piezometers around the marina basin. (See Recommendation 9.2 in Appendix 4).

Subsequent to the test pit report, the Water Authority provided the Department of Marine and Harbours with advice (See Appendix 2B) on the potential impacts of de-watering on private bores which said:

"Although drawdown in WRL at 1 000 m radius may be negligible the drawdown at lesser distances is significant and may impact upon the operation of private wells. It is quite likely that the quality of water pumped from private wells in the area will deteriorate during the period of de-watering. However there should be some improvement when de-watering ceases, followed by some deterioration after the harbour is opened. The effect on private wells may be variable if the flow is in fractures as suggested in the report. During de-watering bore owners should be warned to be wary of increases in salinity and reduction in water levels to avoid damage to vegetation and pumps."

A total of 11 bores may be affected and the Department of Marine and Harbours has not made plans for alternative water supplies or compensation for private bores owners affected by the proposal. The nearest bores are located 350 m from the edge of the proposed marina basin The Authority therefore considers that de-watering impacts should be confined to within 300 m of the edge of the marina basin. De-watering activities should cease when monitoring detects drawdown at this distance.

The Department of Marine and Harbours have indicated that the Water Authority advice, which relates only to monitoring of de-watering impacts, would be followed (See Item 2.1, Appendix 2).

5.1.5 Troglobitic fauna

The proposed development may overlie a unique subterranean aquatic fauna comprising two species each of fishes and shrimps. All four species have been proposed for inclusion in amendments to the gazetted fauna under the Wildlife Conservation Act (W.A.). These are;

The Blind or Cave Gudgeon *Milyeringa veritas* (Whitley 1945) classified as rare and total protection recommended (Michaelis, 1985).

The Blind Cave Eel, *Anommatophasma candidum* (Mees, 1962) classified as vunerable (Michaelis, 1985).

Stygiocaris lancifers (Holthuis 1960) and *S stylifera* (Holthuis) 1960 (Crustacea: Decapoda).

Little is known of the distribution or abundance of the coastal troglobitic fauna, however it seems to be limited to limestones adjacent to the shore on both the western and eastern sides of the North West Cape peninsula. Troglobitic fauna are quite small and may live in small channels in the limestone.

The following concerns were expressed by the Western Australian Museum:

- troglobitic fauna may occur in the limestone which is to be excavated for the marina;
- proposals for de-watering may affect the troglobitic fauna over a wide area;
- a salt water wedge resulting from the excavation of the proposed marina could bisect the range of the coastal fauna and isolate part of the population; and
- a permeable settling pond could result in heavy siltation or blocking of subterranean passages containing troglobitic fauna.

The Western Australian Museum strongly recommended that de-watering not take place.

A copy of information received from the Western Australian Museum in regard to troglobitic fauna appears as Appendix 5 to this report, and a report for the Department of Marine and Harbours by a consultant geologist concerning the potential de-watering impact on troglobitic fauna appears as Appendix 2C.

No comments on the potential impacts of blasting were made by either the Western Australian Museum of the Department of Marine and Harbours.

The likelihood of troglobitic fauna occurring in the limestone at the marina site is difficult to evaluate. The Authority understands there is no reliable non-destructive or remote method of surveying the limestone to determine if channels which could support troglobitic fauna are present, partly because of the small size of channel that could support such fauna. In the face of this uncertainty the Authority considers that the conservative approach to dewatering outlined above (ensuring no effects beyond 300 m) is appropriate.

The Department of Marine and Harbours has not specified the proposed location of the settlement pond. Given the concerns expressed by the Western Australian Museum it should be located as close as practicable to the ocean.

Recommendation 2

The Environmental Protection Authority considers that the potential impacts of de-watering on private bores around the marina site and on the rare troglobitic fauna are unacceptable and recommends that de-watering should not take place unless the impacts can be confined to within 300 m of the marina basin. The Environmental Protection Authority further recommends that de-watering should cease when monitoring detects de-watering effects at 300 m from the marina basin. If de-watering criteria cannot be met then the proponent could construct the Marina in an environmentally acceptable manner "in the wet" using either a land based hydraulic excavator or a cutter suction dredge. The Environmental Protection Authority recommends that settling ponds be constructed to the east of the westernmost edge of the proposed marina as near as practicable to the ocean.

5.1.6 Blasting

The test pit investigation determined that blasting would be required to construct the marina harbour. Blasting could occur within 350 m of the property boundary of Norcape Lodge and 1.9 km of the Exmouth Town Centre. The Department of Marine and Harbours has undertaken to include Clauses in contract documents to require that blasting only occurs when weather conditions are deemed to be suitable, to notify the Exmouth community in advance of proposed blasts, and to repair obvious damage caused by blasting (See Commitment No's 5 & 26 in Appendix 1).

5.1.7 Dredge spoil disposal and turbidity

The Notice of Intent outlines three possibilities for the disposal of dredge spoil namely:

- suitable hard-rock sediments may be used as core material for breakwater construction;
- the dredged material may be used to construct an artificial reef or island off-shore from the proposed marina; or
- the sediments may be deposited in waters to the south of the channel in several deeper areas within a range of approximately 700 m of the channel.

The Department of Marine and Harbours expect that little turbidity will be generated during dredging operations because of the nature of the material to be dredged, which is largely old coral. During recent underwater core drilling, finely ground coral was produced that formed a white plume. It apparently dispersed quickly due to slight currents and settling out. The Department also considers that the dredge material would stabilise quickly.

Should an artificial reef be created the Authority and the Western Australian Museum agree with the proponents belief that the area, when stabilised, would be rapidly recolonised. Concerns were expressed that the reef must be stabilised in order to prevent it washing away with currents generated by cyclones or tides.

The Department of Marine and Harbours intends to seek approval from the Environmental Protection Authority and the Commonwealth Department of Arts, Sport, Environment, Tourism and Territories for dredged material disposal prior to the initiation of dredging. These two approvals should ensure adequate measures are taken to stabilise spoil.

5.1.8 Other construction impacts

No assessment of potential noise impacts has been made. The Department of Marine and Harbours propose to restrict construction activities to "normal daylight hours". The Authority considers that the Department should ensure compliance with the Authority's environmental noise management procedure.

The Department has made a commitment that dust suppression techniques would be employed if necessary. The Dust Control Guidelines as published by the Authority in September 1990 should be used to determine when dust suppression measures are necessary and which measures should be used.

5.2 Marina on-going management considerations

5.2.1 Responsibility for on-going maintenance of marina

The Authority considers it essential that one body should be clearly identified as having responsibility for maintenance of the marina. Under commitment 20 (See Appendix 1) operation and maintenance of the marina would remain the responsibility of the Department of Marine and Harbours.

5.2.2 Water quality

At the Authority's request the proponent requested its consultants to review metal and hydrocarbon contamination of marina waters elsewhere and make a qualitative assessment of the potential pollution concerns at Exmouth. A copy of the consultants report appears as Appendix 2D. The review indicates that the Coral Coast Marina is unlikely to experience high levels of metal or hydrocarbon pollution if built as indicated in the Notice of Intent. The Authority concurs with the conclusions in the review and notes that the Department of Marine and Harbours has made a number of commitments to protect and monitor water quality in the marina (See Commitment No's 14 to 21 in Appendix 1)

5.2.3 Coastal stability and dune protection

Section 6.1.2 of the Notice of Intent indicates that the coast is stable in the vicinity of the development and that little sand drift occurs. The Department of Marine and Harbours has made a commitment to monitor coastal stability and to by-pass sand if it becomes necessary (See Commitment 23 in Appendix 1).

The Department of Marine and Harbours propose to prepare and implement an environmental management plan for the rehabilitation and conservation of the dunes bordering the development site in consultation with the Shire, the Department of Planning and Urban Development and the Commissioner for Soil Conservation to the satisfaction of the Commissioner for Soil Conservation (See Commitment 2 in Appendix 1)

5.3 Residential subdivision

The Department of Marine and Harbours has made a commitment regarding re-contouring with fill from the marina which addresses most of the Authority's concerns (See Commitment No 10 Appendix 1), however the Authority is concerned that adequate stabilisation of 1 in 8 slopes proposed on the western boundary of the site and along parts of the drainage channels may be difficult. Furthermore the Authority questions whether a 1 in 8 slope 3.5 m high as is proposed along part of the western boundary of the site is consistent with the Department of Marine and Harbour's commitment that fill contours would reflect naturally occurring topography elsewhere within the coastal strip. The Authority understands that slopes of between 1 in 12 and 1 in 15 would better reflect the topography elsewhere within the coastal strip and considers that the slopes along the western side of the subdivision should be varied to provide a more aesthetic appearance.

Recommendation 3

The Environmental Protection Authority recommends that the proponent should ensure that slopes used in the residential subdivision are likely to be stable in the long term to the satisfaction of the Environmental Protection Authority.

5.4 Stormwater drainage, sewerage and water supply

The Department of Marine and Harbours has addressed many of the Authority's concerns regarding stormwater drainage and disposal (See Commitments 13, 15 & 16 in Appendix 1)

The Department of Marine and Harbours, in response to concerns expressed by the Authority, has calculated the likely volumes of water that would have to be disposed of through the proposed outfall north of Norcape Lodge The Shire of Exmouth has advised that it considers the proposed route would be capable of carrying the estimated volumes of water without significantly affecting land owners or land uses in the area.

The Authority also expressed concern that proposed outlets should be located away from important biological communities, such as corals, which could be affected by outlets with a high sediment load. The Authority notes that the flow rates along the proposed drainage channel are quite high and that there are no compensating basins downstream of the residential subdivision to settle out suspended solids before the water enters the Gulf. Furthermore the Authority has not received any information on the biological community at the proposed northern ocean outfall. The proponent has made a commitment to refer the drainage proposal the the Authority (See Commitment 13, Appendix 1)

Recommendation 4

The Environmental Protection Authority recommends that the proponent ensure the proposed drainage design and outlets are constructed so there is no impact from sediments on important biological communities such as corals to the satisfaction of the Environmental Protection Authority.

The Department of Marine and Harbours has indicated that the residential subdivision and marina developments will be sewered and that the town's sewerage facilities can cope with the anticipated increase in sewage production.

Advice from the Water Authority is that, with careful management, the aquifer supplying Exmouth's water could service approximately two times the existing population. This proposal is unlikely to cause a doubling in population.

Given that the proposed development may overlie a population of unique and possibly rare troglobitic fauna the Authority is concerned that private groundwater usage may harm the population. Therefore the Authority considers that private bores should not be permitted within the proposed development,

particularly within the proposed subdivision. The Authority understands that the Water Authority requires that all bores in Exmouth be licensed.

Recommendation 5

The Environmental Protection Authority recommends that private bores not be permitted in the subdivision nor within the marina development and that titles and lease documents be appropriately endorsed with this requirement.

5.5 Proposed quarry

As noted in Section 2.4 the proposed quarry site has been relocated so that it is no longer within the proposed extension to Cape Range National Park.

The proposed quarry is now within about 2 km of two existing mining leases which are for the purpose of extracting rock (Mining lease numbers 08/46 and 08/62). Both existing leases are owned by a local contractor and are located close to the town boundary. The Authority understands that currently material is being won from creek beds where the limestone gravel is crushed to provide material for road construction. Disturbance of the remainder of the existing mining leases has apparently been minimal.

Although both the proposed site and existing quarry are essentially untested, information available to the Authority indicates that both sites would be able to provide suitably sized armour stone.

If the stone was to be won from the existing leases, the effects on site drainage and the proximity of bores and pipelines would need to be considered. The Authority understands that excavation would need to take place below the level of the adjacent creek bed to obtain stone which would meet the requirements of the Department of Marine and Harbours for breakwater armourstone.

The Authority requested that the Department of Marine and Harbours consult with the organisations which responded to the Notice of Intent document in respect of the proposed site. The following points are a summary of submissions:

- the proposed site is outside the proposed extension to Cape Range National Park;
- the site is not likely to have any declared rare flora or fauna;
- an archeological and ethnographic survey should be undertaken prior to final approval being given, as is required by the Western Australian Aboriginal Heritage Act 1972-80;
- the proposed quarry site is within a groundwater extraction area;
- a liquid waste management plan should be prepared and implemented;
- it should be demonstrated that explosive residue from blasting operations would not pollute groundwater;
- the Department of Marine and Harbours should apply for a formal reserve and consult Geological Survey about conditions and safeguards to prevent contamination of groundwater.

Geological Survey has advised the Authority that with appropriate management groundwater contamination could be prevented.

The Authority notes that 2 to 3 km of access road would need to be located and constructed along a perennial creek. The impacts and rehabilitation of the road access should be considered concurrently with the quarry.

The Department of Marine and Harbours has indicated in correspondence to the Authority (dated 10 July 1990) that a quarry management plan would be prepared using the Draft Guidelines provided by the Working Party on Conservation and Rehabilitation in the Mining Industry.

The Authority considers that the environmental impacts which would result from quarrying the existing mining leases or from quarrying at the site proposed by the Department and Marine and Harbours would be similar and therefore considers that the Department of Marine and Harbours could obtain rock from either site. If the Department chooses its proposed site the following recommendation would apply.

Recommendation 6

The Environmental Protection Authority considers that the proposed quarry site as located subsequent to the process of interaction between the proponent and the Environmental Protection Authority, is environmentally acceptable and recommends that quarrying could proceed subject to:

- **the Department of Marine and Harbours fulfilling the requirements of other relevant Acts, particularly the requirements of the Western Australian Aboriginal Heritage Act 1972-80, prior to commencement of quarrying operations; and**
- **preparation of a environmental management programme for the quarry prior to the commencement of quarry operations to the satisfaction of the Shire of Exmouth on advice of the Water Authority of Western Australia. The environmental management programme should be based on the draft guidelines of the Working Party on Conservation and Rehabilitation in the Mining Industry, address concerns expressed by the Water Authority, and include details of the proposed access road to the quarry. The environmental management programme should be implemented by the proponent to the satisfaction of the Shire of Exmouth on advice of the Water Authority of Western Australia.**

5.6 Management of off-site environmental impacts

5.6.1 Increased visitation impacts

The potential for increased visitation impacts at Ningaloo Marine Park was raised as an issue The Department of Marine and Harbours responded to this concern by providing an undertaking that all promotional material under the control of the Department of Marine and Harbours would incorporate a conservation ethic as advocated by CALM (See Item 2.16 in Appendix 1). The Authority supports this concept.

5.6.2 Re-location of race course

Re-location of the race course would only be required for Stage 2 of the Marina proposal. This assessment report only considers Stage 1 of the proposal.

6. Conclusion

The Environmental Protection Authority concludes that the proposal by the Department of Marine and Harbours to construct the Coral Coast Marina and the associated residential subdivision, as modified during the process of interaction between the proponent, the Environmental Protection Authority, the public and government agencies that were consulted, is environmentally acceptable.

In reaching this conclusion the Environmental Protection Authority identified the main environmental factors requiring detailed consideration as:

- impacts which would result if de-watering techniques were used, particularly on the unique cave fauna of the region;
- dredge spoil disposal;
- marina water quality;
- management of the large flows from the adjacent range to new drainage outlets; and
- location, management and rehabilitation of the quarry and its access road.

The Environmental Protection Authority concludes that the environmental factors mentioned above have been addressed adequately by either environmental management commitments given by the proponent or by the Environmental Protection Authority's recommendations in this report.

Accordingly, the Environmental Protection Authority recommends that the proposal could proceed subject to:

- the Environmental Protection Authority's recommendations in this Assessment Report; and
- the proponent's commitments which were given in both the Notice of Intent and subsequent documentation (Appendix 1)

7. References

Coleman, F. 1971. Frequencies, tracks and intensities of tropical cyclones in the Australian region - November, 1909 to June, 1969. Commonwealth Bureau of Meteorology, Canberra, A.C.T.

Department of Conservation and Environment. 1981. Water quality criteria for marine and estuarine water of Western Australia. Bulletin 103. Environmental Protection Authority, Perth, WA.

Department of Conservation and Land Management. 1988. Ningaloo Marine Park Draft Management Plan. Department of Conservation and Land Management, Perth, W.A.

Johnson, W. F. 1990 Exmouth Marina Residential Subdivision Stage 1 Planning Report. Department of Marine and Harbours, Perth, WA.

Le Provost, Semeniuk and Chalmer. 1986. Norcape Marina Resort, Exmouth. Public Environmental Report. Skywest Holdings Pty. Ltd., Perth, W.A.

Logan, B. W., R. G. Brown and P. G. Quilty. 1976. Carbonate sediments of the west coast of Western Australia. Excursion Guide No. 37A, 25th International Geological Congress : 75-96.

Mees, G. F. 1962 The subterranean fauna of Yardie Creek station, North West Cape, Western Australia. Journal of the Royal Society of Western Australia 45: 24-32.

Michaelis, F. 1985. Threatened fish. A report on the threatened fish of inland waters of Australia. Report Series No 3. Australian National Parks and Wildlife Service, Canberra.

Morgan K H & Associates, 1990. Report on the trial excavation at the proposed small boat harbour, Exmouth, Western Australia. for the Department of Marine & Harbours.

Playford P. E., R. N. Cope, A. E. Cockbain, G. H. Low and D. C. Lowry. 1975. Phanerozoic. In: Geology of Western Australia. West. Aust. Geol. Sur., Mem. 2: 269-309.

Riedel and Byrne. 1986a. Exmouth patrol boat base. Preliminary feasibility study. Riedel and Byrne, Perth, W.A.

Riedel and Byrne. 1986b. Exmouth Marina - engineering considerations. Appendix 2 in Le Provost Semeniuk and Chalmer (1986).

State Planning Commission. 1988. Exmouth Structure Plan. State Planning Commission, Perth, W.A.

Steedman Ltd. 1986. Storm wind, wave and surge analysis, Exmouth Gulf, Western Australia. Unpublished report to the Department of Marine and Harbours, Fremantle, W.A.

Wallace D.F. 1988. Australian observed sea level trends. Unpublished paper prepared for Greenhouse '88 by Hydrographic Survey Division, Department of Marine and Harbours, Fremantle, W.A.

Waterways Commission, 1989 Canal Guidelines

Western Australian Department of Tourism. 1986. Tourism, Development Plan. Gascoyne Region. Dept. of Tourism, Perth, W.A.

Appendix 1

Summary of commitments

The Department of Marine and Harbours makes the following commitments:

1. The marina facilities will be constructed behind the frontal dune and will not encroach upon the dune except for the harbour entrance and a constructed walkway from the resort to the beach.

2. An environmental management plan for the rehabilitation and conservation of the dunes bordering the development site will be prepared in consultation with the Shire, the Department of Planning and Urban Development and the Commissioner for Soil Conservation and implemented by the Department of Marine and Harbours to the satisfaction of the Commissioner for Soil Conservation.

3. Existing access to Town Beach will be maintained. Additional public access to the beach and northern breakwater will be accommodated by the provision of controlled pathways from the proposed resort complex.

4. The marina and all associated facilities would comply fully with applicable legislation, regulations and by-laws. All construction materials and practices would be in accordance with the relevant Australian and international codes.

5. Construction activities would be restricted to normal daylight hours and, if found to be necessary, appropriate dust suppression techniques would be employed. Any blasting that is required to enable excavation of the marina harbour and entrance channel will be conducted between 9.00 am and 5.00 pm on weekdays, and will be publicised in the Exmouth community.

6. During earthworks and construction, appropriate care will be taken to avoid incursion of machinery into conserved areas of the dune and foreshore.

7. The Department will be responsible for quarrying operations to provide armourstone for the breakwaters and will liaise with the Department of Mines, the Shire and the Environmental Protection Authority to define appropriate environmental management measures, including rehabilitation of the quarry site and access roads.

8. If the harbour is to be de-watered for excavation then the extracted water will be directed to a settling pond to reduce suspended solids prior to discharge to Exmouth Gulf. If excavation were to occur "in the wet", drainage water from the excavated material will be similarly directed to a settling basin prior to discharge to Exmouth Gulf.

9. DELETED

10. Recontouring of areas receiving fill material will meet the following objectives:

    a) The redeveloped areas should form a stable and varied landscape, reflecting naturally occurring topography elsewhere within the coastal strip.

    b) The boundary relief should co-ordinate with existing contours.

    c) The land should be contoured in order to facilitate its development into a prime residential and holiday area.

    d) The filled sites will be compacted in accordance with the requirements for building purposes and covered with previously stockpiled topsoil. Filled areas will be stabilized, if necessary, using brush matting, sprayed membranes or mulch.

11. The Department will undertake further investigations to define the nature of the sediments to be dredged from the entrance channel, and to identify the preferred dredging methodology and requirements for blasting. The results and proposed works will be referred to the Environmental Protection Authority for approval prior to initiation of dredging.

12. Engineering and environmental management details of the proposed disposal strategy for material dredged from the entrance channel will be referred to the Environmental Protection Authority and the Commonwealth Department of Arts, Sport, Environment, Tourism and Territories for approval.

13. Formal drainage will be constructed to ensure that the project site is not flooded and that it does not cause flooding of the hinterland behind it. Approval to conduct two new drainage outlets across the shore, and to incorporate an existing natural drainage outlet within the formal drainage, will be sought from the Environmental Protection Authority following

finalization of the proposed drainage design. Appropriate rehabilitation procedures will be implemented in order to ensure stability of the beach and dune in the vicinity of the new outlets, to the satisfaction of the Commissioner for Soil Conservation.

14. All facilities to the proposed development will be deep sewered.

15. Drainage from marina hardstand areas will be directed away from the harbour and discharged to general drainage via silt traps.

16. The design criteria for drainage will be for the dissipation of at least a one in 100 year rainfall without unacceptable flooding, and without overflow into the marina harbour. There will be provision for drainage overflow into the harbour during more extreme rainfall events.

17. Fuel storage facilities in the marina will be above ground and contained within a sealed bund capable of holding the entire tank contents. Boat refuelling facilities will include manually operated nozzle valves with automatic shut-off. The fuel storage and refuelling facilities will comply with the requirements of the Explosives and Dangerous Goods Division of the Department of Mines.

18. The discharge of sewage, hydrocarbons or litter from boats into the marina will be prohibited, with appropriate signs to inform all users of the marina. Waste disposal facilities, including rubbish bins, oil recycling bins and sewered public toilets will be provided around the marina. A sewage pump out facility will be provided for boats equipped with holding tanks.

19. The use of antifouling paints containing tributyl tin will be prohibited in the marina, and this will be included as a lease condition for boat repair facilities in the marina.

20. Operation and maintenance of the marina will remain the responsibility of the Department of Marine and Harbours, and will include:

    a) daily inspection of the marina harbour and immediate implementation of any corrective action required to maintain water quality and aesthetics to the required standard;

    b) maintenance of specified navigable depths;

    c) maintenance of breakwaters, jetties, wharves, revetments and foreshores.

21. Water quality in the marina harbour and the adjacent area of Exmouth Gulf will be monitored to confirm the predictions made in this NOI regarding the adequacy of flushing and the maintenance of suitable water quality. The minimum water quality criteria required to be met are described in Schedule 2 of Environmental Protection Authority Bulletin 103 (Department of Conservation and Environment, 1981). The proposed monitoring programme is described in Section 7.4 2 of this NOI, and the results will be reported to the Environmental Protection Authority.

    Section 7.4.2 of the NOI reads;

    Water quality and contaminant levels in sediments and organisms would be monitored during operation of the marina.

    Water quality parameters measured would be those specified in the Canal Guidelines (Steering Committee on Canal Developments, 1984), and would include suspended solids, pH, dissolved oxygen, temperature, bacterial counts and nutrient concentrations. Monitoring would be conducted quarterly for the first year and thereafter at intervals dictated by experience. Samples would be collected from surface and bottom water at representative sites in the marina and adjacent Gulf waters.

    Sediments and mussels within the marina would be monitored for toxic trace metals and hydrocarbons. Surface sediments would be sampled from the central basin of the marina where deposition is anticipated, and the fine fraction would be analysed for nickel, zinc, copper, lead, polyaromatic hydrocarbons (PAHs) and phosphorus levels. Mussels collected from the marina would be analysed for tissue concentrations of nickel, zinc, copper, lead and PAHs, using standard methods for the mussel watch programme. Lipid levels would also be determined to assist in data interpretation. The sediment and mussels would initially be monitored at six-monthly intervals.

    Specialist marine scientists engaged by the Department of Marine and Harbours would supervise monitoring and interpretation of the results and recommend management action. The results would be presented to the E.P.A. for review on an annual basis.

22. The level of revetments and areas surrounding the proposed harbour will be +3.0 m AHD, and floor levels will be at least +3.5 m AHD. This is sufficient to contain extreme seawater levels, including anticipated seawater level rises due to the "Greenhouse Effect".

23. Coastal sediment movement will be monitored following construction of the marina as outlined in Section 7.4.1. If by-passing of sand around the breakwaters is occasionally necessary it will be undertaken by the Department of Marine and Harbours.

Section 7.4.1 of the Notice of Intent is reproduced below.

The position of the shoreline, vegetation line and dune profiles adjacent to the breakwaters will be established prior to construction. Surveys will be conducted at distances of 50 m, 100 m, 200 m, 500 m, 1 km and 2 km to the north and south of the entrance channel.

Following construction, water depth in the marina and entrance channel, and the position of the shoreline, vegetation line and the dune profile, will be regularly monitored. Surveys will be conducted quarterly for the first year and thereafter at intervals to be determined in consultation with the Commissioner for Soil Conservation.

Additional commitments provided since the Notice of Intent

24 Recommendation adopted from Test Pit Report

a) Prior to commencement of harbour excavations, it is strongly advised that a series of piezometers be drilled and constructed along the perimeter of the harbour and along the estimated radius of influence, which roughly correspond to Warne and Murat Roads, and northern edge of the race course. These will allow the monitoring of any effects of de-watering on the adjacent areas.

b) Piezometer monitoring will be performed by technician not employed by the earthmoving contractor (possibly the Water Authority). The data should be analysed and reported on by a hydrogeologist.

c) One or two de-watering bores should be sunk into suitable locations to penetrate the hard rock layer and pumping tests carried out to determine:

(1) Magnitude of water flow expected in the full scale operation.

(2) Allow for a more accurate method of de-watering design.

(3) Provide more reliable data on the possible zone of influence during the main excavation phase.

25. Monitoring of private bores as recommended by the Water Authority (See Item 2.1 in Appendix 2)

With regard to their (ie Water Authority letters 16 March and 5 June 1990 in Appendix 2B of this report) comments concerning impacts on private bores in the vicinity of the marina site, water samples will be collected and tested before, during and after construction to monitor any variation on quality. This work will be undertaken by the Water Authority.

26. Blasting (See Item 2.15 Appendix 2)

a) The earthworks Contract document will include Clauses that require the Contractor to consider weather conditions prior to and during blasting, with the aim of minimising adverse impacts.

b) The Department of Marine and Harbours undertakes to repair obvious damage caused by blasting activity associated with excavation of the marina.

27. Drainage outfalls (See Item 2.13, Appendix 2)

Where possible drainage outfalls to the sea will be located at natural outfalls. Compensating basins will be used to settle sediment.

28. Conservation ethic (See Item 2.16 Appendix 2)

All promotional material under the control of the Department of Marine and Harbours will incorporate a conservation ethic as advocated by CALM.

Appendix 2

Department of Marine and Harbours response to issues raised from the NOI.

EXMOUTH MARINA
DEPARTMENT OF
MARINE AND HARBOURS

RESPONSE TO THE ISSUES RAISED FROM THE NOI.

JUNE 1990

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APPENDICES

EXMOUTH MARINA

ENVIRONMENTAL MATTERS

1. INTRODUCTION

This document summarises the position of the Department of Marine and Harbours with respect to environmental matters concerning the proposed marina at Exmouth.

A meeting was held at the EPA on 22 December 1989. All the issues identified by the Authority and raised in response to the Notice of Intent were discussed. Appendix A contains relevant correspondence.

It was agreed that the issues could be broadly divided into two groups:

those which have been resolved on the basis of investigations undertaken; and

those which can be resolved by commitment from the Department of Marine and Harbours.

A description of each issue and supporting details follows.

2. ISSUES

2.1 WATER AUTHORITY APPROVAL TO COMMENCE DEWATERING ACTIVITIES

An officer from the Water Authority inspected the marina site test pit while it was being excavated.

The geologist's report concerning the test pit was forwarded to the Authority's Geraldton Office.

Advice has been received from the Authority, and is included in Appendix B.

Authority approval will be sought prior to the commencement of any dewatering activities.

With regard to their comments concerning impacts on private bores in the vicinity of the marina site, water samples will be collected and tested before, during and after construction to monitor any variation in quality. This work will be undertaken by the Water Authority.

2.2 GROUNDWATER RESOURCES

The impact of excavation on the groundwater resources is addressed in the geologist's report on the test pit. This report has been forwarded under separate cover.
At maximum harbour depth, prolonged dewatering is projected to have a radius of influence of about 1000m.

Prior to excavation piezometers will be installed along the perimeter of the marine precinct, which roughly corresponds to Warne & Murat Roads and the northern edge

of the race course. These will then be monitored during construction for any effects of dewatering.

DMH's consultant geologist has advised that the effect of drawdown or change in water quality is likely to be negligible at even the closest private bore, some 350m from the excavation. This was verified during test pit construction.

2.3 RARE TROGLOBITIC FAUNA

Investigations by a consultant geologist, and excavation of the test pit indicate that the possibility of caverns or continuous fissures being present that could support troglobitic fauna is slight.

This is stated in the geologist's report included in Appendix C.

2.4 POLLUTION CONTROL

The Department of Marine and Harbours will prepare an oil spill contingency plan for the marina as a matter of course.

The Department's Director Marine is the Chairman of the State Committee for Combating Marine Oil Pollution.

Leases for sites at the marina will include conditions for pollution control. Runoff from paved areas will be collected via silt and oil traps and discharged outside the marina basin wherever possible.

Disposal of oil by-products from the silt traps is being discussed with the Shire. Options for breaking down the waste, such as land farming, will be considered.

The use of hazardous compounds will be prohibited.

2.5 WATER QUALITY IN HARBOUR

Based on tidal flushing analysis, the natural tide action is considered adequate to maintain an acceptable water quality in the harbour. It is understood that the EPA Marine Division concurs with this opinion.

The Department of Marine and Harbours is committed to monitoring the water quality as per section 8.0 of the NOI.

An assessment of potential pollutant loadings into the marina has been made by Bowman Bishaw Gorham and is included in Appendix D.

2.6 DISPOSAL OF EXCAVATED MATERIAL FROM THE CHANNEL

The material in the channel is mostly old coral. It is anticipated that some of it will be used in the construction of the breakwaters. The balance may be disposed of off shore or carted to fill on land, depending on the method of channel excavation.

There are two possibilities for offshore disposal. The spoil could be deposited to the south of the channel in several low-lying areas within a range of approximately 700m. Alternatively, an artificial reef could be constructed.

DMH commitments are as per the Notice of Intent.

Should an artificial reef be proposed, then a thorough design will be undertaken by the Department.

Onshore disposal would involve construction of a causeway along the channel alignment and subsequent excavation from the causeway, removing both channel and causeway material in the one operation.

The main environmental concern of the disposal operations is the effect on biota. Dumped material will directly impact the marine life at the dump sites, and the accompanying turbidity and subsequent fallout may effect surrounding biological communities in the short term. As was stated in the NOI, recolonisation should be rapid.

During recent underwater core drilling, finely ground coral was produced that formed a white plume. It dispersed quickly due to slight currents and settling out.

Approval will be sought for either offshore dumping or causeway construction from the relevant authorities. In the event that offshore dumping is utilised a permit will be obtained under the requirements of the Sea Dumping Act.

2.7 COUNTRY COASTAL PLANNING POLICY

This policy is intended to assist relevant parties involved in the development and subdivision of coastal areas.

The Department of Marine and Harbours has a representative on the Coastal Management Co-ordinating Committee and supports the principles and guidelines of the policy and has followed them as near as practicable in this proposal.

Several commitments in the NOI are concerned with the environmental management of the dunes adjacent to the development.

The project brief to the architectural consultants requested, in part, the identification of an architectural theme appropriate to the site and the region, and to document this theme in a form suitable for the guidance and constraint of developers. Buildings within the Marina precinct will be limited in height to two storeys in accordance with the Country Coastal Planning policy.

2.8 PROTECTION OF DUNES AND FORESHORE

The contract documents relating to construction on the site will state that the dunes are not to be disturbed by construction equipment.

Some movement along and across the foreshore will be necessary, particularly during breakwater construction.

2.9 COASTAL DRIFT

The Department of Marine and Harbours is committed to a programme for monitoring the coastal sediment movements and to carrying out any re-establishment works if necessary. `As existing' surveys of the beach and nearshore areas have already been undertaken.

2.10 ARCHAEOLOGICAL AND ETHNOGRAPHIC SURVEY

Stage 1 of the development was surveyed by consultants from the Centre for Prehistory at UWA in compliance with the Aboriginal Heritage Act (1972-80). A report was prepared and has been forwarded under separate cover.

Their recommendation is that the development is acceptable with respect to ethnographic and archaeological considerations.

2.11 RELOCATION OF RACE COURSE

The new race course site and associated rural subdivision will not have any major adverse impact on the total natural environment which is widespread throughout the region.

Localised impact is caused by clearing for the track, buildings and roads.

Planning approval for the relocated racecourse and associated Special Rural Subdivision has already been granted. It should be noted that the racecourse will only be relocated if Stage 2 of the proposed development proceeds.

2.12 RESIDENTIAL SUBDIVISION

Substantial design of contour, drainage and servicing for the residential subdivision has been carried out by W F Johnston and Associates.

Relevant plans are contained in Appendix E. These plans have been examined by all the relevant decision-making authorities.

2.13 DRAINAGE

Where possible drainage outfalls to the sea will be located at natural outfalls. Compensating basins will be used to settle sediment. This should minimise the impact on coastal biological communities.

Plan No. C2005 Rev. 1 from Warren Johnson & Co. shows the overall drainage scheme for the development. This is included in Appendix E.

Drainage design for the residential subdivision is based on 1 in 10 year and 1 in 100 year events. Flow details are shown on the plans in Appendix E.

The effects of sea level rise during cyclones is not expected to effect the functioning of the drainage system. Consultants have prepared several reports on storm wind, wave and surge analysis for Exmouth Gulf. A summary of these is included in Appendix F.

2.14 REHABILITATION PLANS FOR THE RUBBISH TIP IN THE PROPOSED RESIDENTIAL AREA

The refuse in the rubbish tip will be overlain with an average of 2m of fill. Unsuitable material will be disposed of as approved by the Shire.

2.15 BLASTING ACTIVITIES

Site investigations indicate that some of the material in the marina basin will need to be blasted.

The earthworks Contract document will include clauses that require the Contractor to consider weather conditions prior to and during blasting, with the aim of minimising adverse impacts.

Relevant atmospheric information is recorded by the Bureau of Meteorology at Learmonth Airport every morning.

The most significant factor at short range is wind speed and direction. Low level temperature inversion and wind shear will also be assessed prior to blasting.

DMH undertakes to repair obvious damage caused by blasting activity associated with the excavation of the marina.

2.16 CONSERVATION ETHIC

All promotional material under the control of the Department of Marine and Harbours will incorporate the conservation ethic as advocated by CALM.

The project brief to the architectural consultants emphasised the water conservation theme in landscape design. The design of the residential subdivision has also incorporated water-harvesting methods.

2.17 RECOMMENDATIONS OF REPORT ON TRIAL EXCAVATION

DMH will adopt one recommendation from the report on the trial excavation by K H Morgan, namely the installation and monitoring of piezometers around the marine basin.

2.18 QUARRY

The Department of Marine and Harbours acknowledges that the exposed canyon face, identified by evidence of previous blasting, is not suitable for the quarry site.

At present, the Department is arranging a position survey of a nearby location that is hidden from the Exmouth-Minilya Road and Charles Knife Road.

This site was discussed with CALM's officer in Exmouth who suggested that it would be acceptable. A further inspection was conducted on 15 February 1990 with representatives of CALM's environmental group who indicated that the site would be suitable on provision of a quarry management plan.

Further correspondence from the EPA on 2 April 1990 indicates that a report similar to a Consultative Environmental Review must be prepared with respect to the establishment and operation of the quarry. DMH undertakes to provide this report later in the year if necessary however we understand that CALM and the Shire of Exmouth agree to the alternative site and that only a quarry management plan is necessary.

3.0 SITE INVESTIGATIONS

Summary of the following site investigations have been undertaken by DMH to date:-

November 1988	Wave rider buoy deployed off Exmouth town beach.
March 1989	Survey of potential quarry sites. Report prepared. (R Gozzard)
April 1989	Geological Investigation of harbour basin. Report prepared. (K H Morgan)
October 1989	Core drilling of entrance channel.
November 1989	Test pit excavated at harbour basin. Report prepared. (K H Morgan)
February 1990	Quarry site at Charles Knife Road inspected with representative from CALM.

4.0 REQUEST FOR ENVIRONMENTAL CLEARANCE

The Department of Marine and Harbours forwards this document in consideration of issues raised in response to the Notice of Intent.

DMH requests approval from the Environmental Protection Authority, with respect to environmental matters, to commence construction of the Exmouth Marina on the basis of the NOI and this document.

Pending the availablity of funding it is intended that works will commence in October 1990.

N. SIRAGUSA
PROJECT MANAGER
DEPT OF MARINE & HARBOURS

April 1990

[r21erw.lt]PC2

APPENDIX A
ISSUES FOR DISCUSSION

ENVIRONMENTAL PROTECTION AUTHORITY
1 MOUNT STREET, PERTH, WESTERN AUSTRALIA 6000
Telephone (09) 222 7000

EXECUTIVE DIRECTOR
DEPARTMENT OF MARINE & HARBOURS

Attention Mr Alan Dougan

Your Ref: AD/1W3/205/89
Our Ref: 184/78
Enquiries: Ron Van Delft

PROPOSED CORAL COAST MARINA RESORT; EXMOUTH

Subsequent to a site visit by an officer of the Authority to Exmouth and further consideration of the Notice of Intent the Authority has identified a number of issues for discussion. A list of issues is provided below and it is suggested that a meeting be called in the near future to discuss these and other issues with officers of the Authority.

At the meeting the Authority would be keen to know of your intended responses to issues raised in public submissions. The Authority has prepared a summary of issues raised in public submissions, a copy of which is enclosed for your information.

The Authority would also be keen to know the results of the test pit.

When the Department of Marine & Harbours wishes to set a meeting date Mr Ron Van Delft of the Authority should be contacted.

RAD Sippe
DIRECTOR
EVALUATION DIVISION

24 November 1989

EXMOUTH CORAL COAST MARINA

SUMMARY OF ISSUES RAISED IN SUBMISSIONS:

- Proponent should liaise with and obtain Water Authority approval prior to commencement of de-watering activities.

- Rare troglobitic fauna
  - western limit of habitat should be determined.
  - marina may disect habitat.
  - excavation should be made without de-watering.
  - increased consumption for town water supply may adversely affect troglobitic fauna.
  - settling pond may block subterranean passages containing troglobitic fauna.

- Artificial reef may be advantageous to marine biota.

- Water quality in harbour - suggest connecting yacht basin to the sea via pipes to enhance flushing.

- Quarry site should be examined for caves and significant fauna - fossils.

- An archeological and ethnographic survey of the area should be undertaken.

- In order to comply with the Aboriginal Heritage Act (1972-80) and anthropologist/archeologist should conduct a study of the area.

- Likely flow volumes for the proposed drainage systems should be calculated and the impact of such flows evaluated.

- Marina should conform with the Department of Planning and Urban Developments Country Coastal Planning Policy:

- A lot more design work is needed before comment can be made.

- Residential development - design work/staging not done.

- Relocation of race-course - will it have any environmental impacts.

- Quarry works should not be visible from Exmouth/Minilya Road or Charles Knife Road. Exmouth Shire should be consulted on this.

- Marina excavation impacts on groundwater resources a concern - further investigations of likely impacts should be undertaken.

- CALM may not wish to establish office at Marina.

- Proponents promotional material should incorporate conservation ethic.

- Tourism impacts on Cape Range National Park.

ISSUES FOR DISCUSSION

- The need to insure against potential adverse effects of blasting activities at the Marina. Blast effects such as blowing out windows have been recorded as far away as 20 km from a blast!.

- The stability of the artificial reef (created by the disposal of 160 000 m^3 of soil in ocean) in cyclones.

- The potential use of lease conditions to help control pollution.

- The need to fence dune areas prior to construction to prevent earthmoving equipment and people causing dune erosion.

- The desired level of approval sought by Department of Marine & Harbours in respect to the residential areas. The Authority can grant approvals for zoning and subdivision separately. The Authority is also keen to promote the principles discussed in Water Conservation through Good Design book.

- The proposed rehabilitation plans for the rubbish tip in the proposed residential area.

- The Authority would like further detail regarding the drainage outfalls and the effects of sea level rises from cyclones on the functioning of the drainage system.

- Further information on the disposal of collected waste oil and liquids from the waste storage tanks is requested.

- An oil spill contingency plan for the marina has not been discussed.

- The proposed source of armour stone needs further discussion and consideration because;
  - the gazetted quarry site is some 600 m from the site where previous stone removal has taken place.
  - both the gazetted site and site where previous activities have taken place are within land proposed for National Park status. The gorge is very scenic.
  - recent blasting at the site where previous stone removal has taken place highlights the visibility of this site from the highway and the road.

NOTES FROM EPA MARINE IMPACTS BRANCH REGARDING PROPOSED CORAL COAST MARINA, EXMOUTH.

The issues that need to be further elaborated upon are:

Water Quality

- In view of the proposed swimming beach (as indicated on the colour plate in the front cover or the NOI) the beneficial use water quality criteria for swimming detailed in Department of Conservation and Environment Bulletin 103 should be adopted for the environmental assessment process.
- Potential pollutant loadings into the marina should be quantified. Short and long term predictions of expected ambient concentrations of substances are required and a monitoring programme should be formulated. The monitoring program should verify that the predicted flushing times are sufficient to reduce pollutant levels to the Bulletin 103 water quality criteria as above. Particular reference should be made to toxic pollutants and Tribytyl Tin. Monitoring results should be forwarded to the EPA.
- Regular water quality monitoring in the marina should include salinity and temperature profiles around the marina at a vertical resolution of at least 0.5 m. A more intensive study would be warranted for critical environmental conditions such as a calm summer period.

Disposal of Dredge Spoil

- The proposed dumping of dredge spoil should not proceed without a quantification of the spread of turbidity and consequent fall-out of sediment on surrounding biological communities.

- The possibility of raising finished levels to use all the dredge spoil be should be investigated, as a preferred option.

Drainage

- It should be verified that site outfalls are away from important biological communities, such as corals, which occur along the coastline in this region.

Coastal drift

- A monitoring programme to determine any interruption to the present equilibrium coastline shape and alteration of coastal sediment movements should be prepared.

Management of recreational pressures

- This needs further discussion.

APPENDIX B
DEWATERING FOR CONSTRUCTION
ADVICE FROM WAWA

WATER AUTHORITY
of Western Australia

Your Ref
Our Ref GW00016
Enquiries MR K GRIFFIN
Tele Direct (099)21 0850

1ST FLOOR, S.G.I.O. BUILDING
45 CATHEDRAL AVENUE
GERALDTON W.A.
Postal Address: P.O. Box 43 Geraldton
Western Australia 6530
Telephone: (099) 21 0888 Fax: (099) 21 7675

DEPARTMENT OF MARINE HARBOURS
MARINE HOUSE
1 ESSEX STREET
FREMANTLE WA 6160

ATTENTION: MR R WALLWORK

Dear Sir

EXMOUTH MARINA - DEWATERING FOR CONSTRUCTION

In reply to your telephone query to Mr Harry of this office regarding impact dewatering for new marina construction at Exmouth on private bores and reply required by mid February.

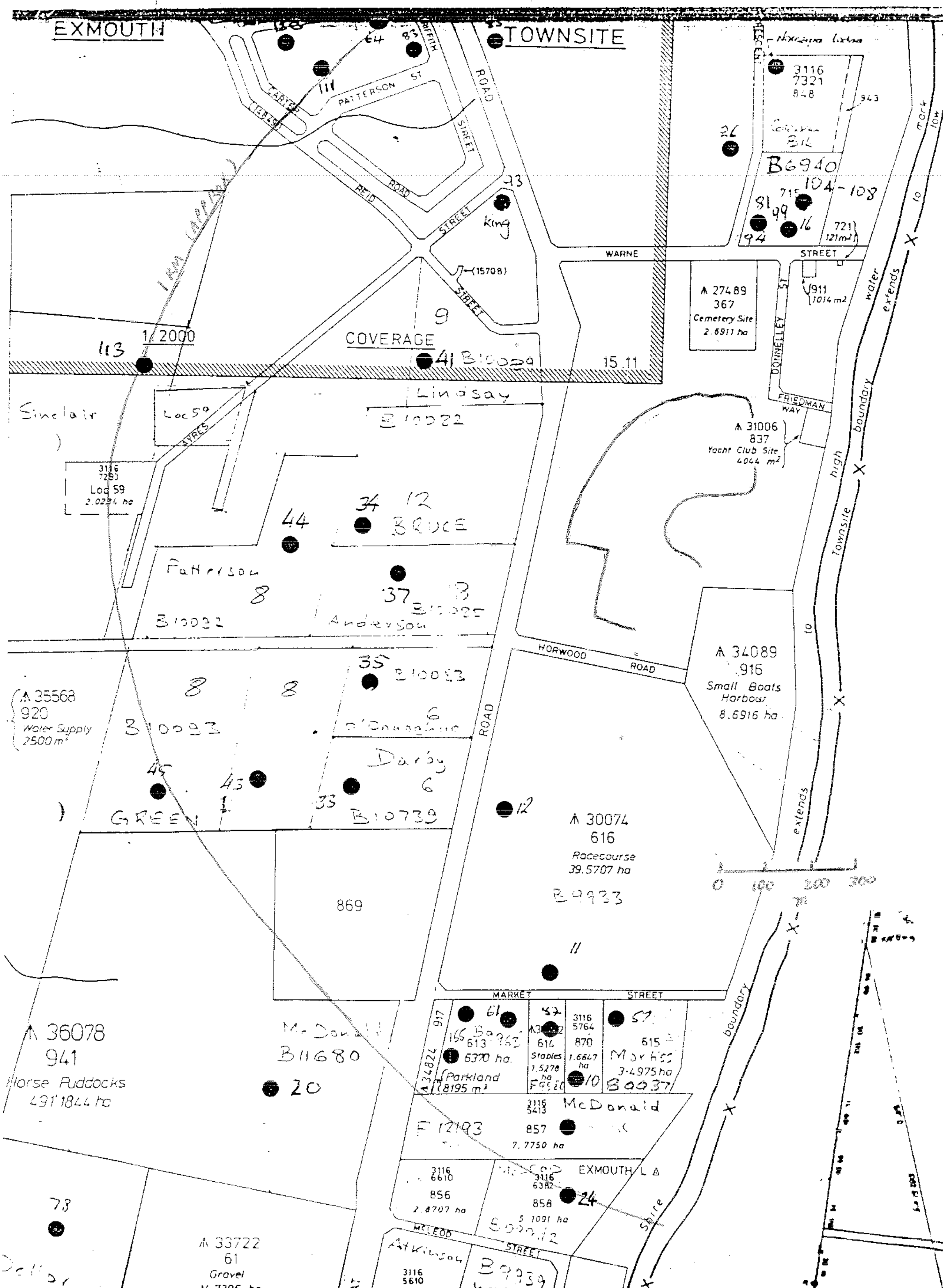
Firstly the reply has taken longer than required as the KH Morgan report needed to be referred to Groundwater Branch, Perth for comment.

Advice received is that although the drawdown in WRL at 1 000m radius may be negligible, the drawdown at lesser distances is significant and may impact upon operation of private wells. It is quite likely that the quality of water pumped from private wells in the area will deteriorate during the period of dewatering. However, there should be some improvement when dewatering ceases, followed by some deterioration after the harbour is opened. The effect on private wells may be variable if the flow is in fractures as suggested in the report. during dewatering, bore owners should be warned to be wary of increases in salinity and reduction in water levels to avoid damage to vegetation and pumps.

Yours faithfully

K GRIFFIN
REGIONAL HYDROGRAPHER
MIDWEST REGION

16 MARCH 1990
(11G422)FG


EXMOUTH TOWNSITE
PATTERSON ST
CARTER
GRIFFITH
ROAD
STREET
REID
ROAD
STREET
STREET
WARNE
STREET
(15708)
COVERAGE
1:2000
15.11
9
Lindsay
B10022
Sinclair
Loc 59
AYRES
3116
7293
Loc 59
2.0234 ha
44
34
12
BRUCE
Patterson
8
37
Anderson
B10032
HORWOOD
ROAD
35
B10083
8
8
B10093
O'Donoghue
6
ROAD
Darby
6
45
43
33
GREEN
B10739
12
ₐ 35568
920
Water Supply
2500 m²
ₐ 27489
367
Cemetery Site
2.6911 ha
DONNELLEY ST
911
1014 m²
FRIEDMAN WAY
ₐ 31006
837
Yacht Club Site
4044 m²
ₐ 34089
916
Small Boats Harbour
8.6916 ha
ₐ 30074
616
Racecourse
39.5707 ha
B9933
11
3116
7321
848
943
B6940
104-108
715
721
121 m²
high water mark
low water mark
boundary extends 10
Townsite boundary
extends 10
0 100 200 300
869
MARKET
STREET
917
A34824
613
6370 ha.
Parkland
8195 m²
614
Stables
1.5278 ha
3116
5764
870
1.6647 ha
615
3.4975 ha
McDonald
B11680
ₐ 36078
941
Horse Paddocks
4911844 ha
20
3116
5413
857
7.7750 ha
McDonald
EXMOUTH L.A.
3116
6610
856
2.8707 ha
3116
6382
858
5.1091 ha
24
Shire boundary
MCLEOD STREET
Atkinson
B9939
3116
5610
78
ₐ 33722
61
Gravel

WATER AUTHORITY of Western Australia

Your Ref NS/2W4/35/89
Our Ref GWOOO16
Enquiries K GRIFFIN
Tele Direct 099 210850

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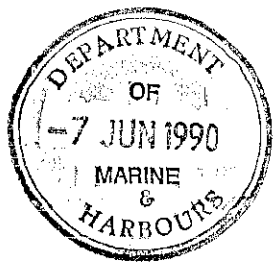
DEPARTMENT OF MARINE & HARBOURS
MARINE HOUSE
1 ESSEX STREET
FREMANTLE WA 6160



ATTENTION: MR N SIRAGUSA

Dear Sir,

RE: EXMOUTH MARINA - GROUNDWATER MONITORING

Due to the variable nature of the fractured rock in the aquifer system, monitoring of extra bores to those noted in letter dated 30th April 1988 is recommended

It is suggested that bores within a 0.5 Km radius of the development be monitored, initially for several months to determine any immediate effect on the aquifer and bores and then assess whether more should be monitored or rationalise the monitoring.

All bores should be monitored for conductivity and level if possible. Monitoring should commence before construction to determine base level data.

Bores to be monitored:

OWNER	LOCATION	WAWA BORE NO.
Mortiss	Market St.	57
Racecourse		11 and 12
Darby	Murat St	33
O'Donoghue	Murat St	35
Anderson	Murat St	37
Bruce	Murat St	34
Lindsay	Reid St	41
King	Ayres St.	93
McAlphine	Norcap Lodge	94 and 99
		11

The Water Authority would be able to carry out this monitoring with Exmouth staff.

The charge for this monitoring would be $30 per hour. Please indicate if this is satisfactory.

Can you supply a construction timetable in order for us to determine how soon to contact the licenced bore owners to enable sampling to commence.

Yours faithfully,

K GRIFFIN
REGIONAL HYDROGRAPHER

5th June, 1990
(23G090.DOC) KB

APPENDIX C
GEOLOGISTS REPORT CONCERNING TROGLOBITIC FAUNA AND DEWATERING

PROJECT 691.03

DEWATERING AND EXCAVATION IMPACT

SMALL BOAT HARBOUR - EXMOUTH

WESTERN AUSTRALIA

FOR

DEPARTMENT OF MARINE AND HARBOURS

30TH APRIL, 1990

CONSULTING GEOLOGISTS
- GROUNDWATER
- EXPLORATION
- MINING
- ENVIRONMENT

K. H. Morgan and Associates

34 GEDDES STREET, VICTORIA PARK
WESTERN AUSTRALIA 6100
Telephone 361 6554

DEWATERING AND EXCAVATION IMPACT

SMALL BOAT HARBOUR - EXMOUTH

WESTERN AUSTRALIA

DEPARTMENT OF MARINE AND HARBOURS

1. INTRODUCTION

A the request of the Department of Marine and Harbours our comments have been prepared on the following queries:

1. The likelihood of caves being present in the harbour, or harbour complex area, which may provide habitat for troglobitic fauna and

2. Should caves be present, then what will the effect on these be:

* during dewatering for harbour excavation;

* as a result of the marine embayment provided by the harbour basin;

* as a result of construction buildings and civil works around the harbour.

2. COMMENTS

2.1 The Occurrence of Caves

A telephone discussion was held with W Humphries of the Western Australian Museum on 24th April, 1990 and this covered the following aspects:

* Most of the published information on subterranean marine (troglobitic) fauna refers to habitats in the caves close to the boundaries of Cape Range. Fauna potentially influenced by the harbour development is coastal and because of their restricted endemic habitats, they could be of different composition to those further inland.

* The animals involved; gudgeon fish, shrimps and eels are small and may require only small channels a few centimetres in diameter to allow interbreeding.

* Coastal caves containing troglobitic fauna are known both to the north and south of the harbour although the eel has not been observed for many years.

These localities seem to have similar topographic and geological characters to the proposed harbour location.

During the harbour investigation eighteen NQ core holes were drilled on a variable spaced grid essentially within the area proposed for excavation. The holes ranged in depth between 7.5m to 24m and the depth to water below ground level ranged between 00m to 5.59m.

The upper section is soft to partly indurated calcareous sand while the lower part is cemented limestone. Except for minor joints no open caverns or channels were encountered.

No drilling has been carried out in the area surrounding the harbour basin.

Limestone caverns, if they exist, are expected to be very sporadic in their distribution, therefore there is still a slight possibility for the occurrence of such caverns.

The lithologies present suggest that these caverns may be relatively small and confined to the lower levels of the harbour basin.

2.2 Effect of Dewatering

Should cavernous zones be encountered during excavation they will serve as the main water conductors inhibiting dewatering operations. Therefore dewatering would preferentially travel along the channels and the dewatering influence would spread locally greater distances than might be anticipated with a homogeneous formation.

The hydraulic assessment tests suggest that if a homogeneous formation is present then the effects of dewatering of the basin would have an influence radially up to 1000m.

However, a noticeable effect (say a decline of water level of 10 cm) is not likely to be present over a distance of more than 100m from the basin perimeter.

The dewatering effect will not be radially uniform. The presence of the sea to the east will restrict drawdown influence to the beach.

Flow upwards is inhibited by decreasing permeability with depth, while lateral influence will be influenced by the distribution of joints and possibly of limestone solution cavities.

If large joints or cavities are encountered and markedly inhibit dewatering operations then these could be grouted with the option of removing the grout on completion of the excavation.

The presence of the harbour embayment is not unlikely to result in more than a highly localised influence on the groundwater hydrology. The direct marine water interchange zone will be moved from the present beach line to the periphery of the harbour basin.

Additional influence of the hydrology of the area and to any possible cavernous zones could result from buildings and civil works around the harbour.

3. RECOMMENDATIONS

1. The observation bores as suggested in KH MORGAN and ASSOCIATES Report No 691.02 dated 4th January 1990 should be constructed and tested.

These will have the dual purpose of:

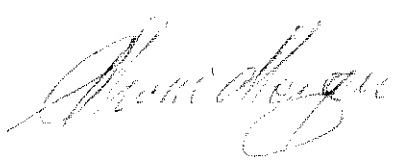
(a) providing additional geological information including any occurrence of solution channels that could provide a habitat for troglobitic fauna and

(b) monitoring the influence of dewatering drawdown and salinity.

2. Hydrological testing by drilling and sampling should be extended to cover the area set up for building development around the harbour.

Approximately an additional 10 piezometers should be established in this area to monitor the hydrology of the region prior to and following development.

Particular attention should be given to establishing the boundary of the marine water interface westwards and the configurations of the overlying fresher water lens.



KH MORGAN BSc FAusIMM MMICA MAIG FGAA
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APPENDIX D
REPORT ON WATER QUALITY

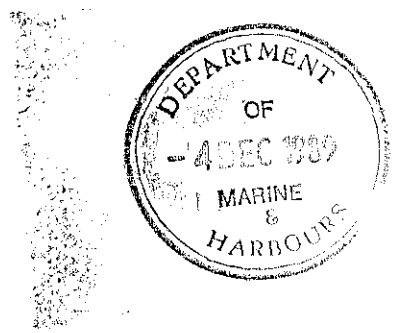
BOWMAN BISHAW GORHAM
ENVIRONMENTAL MANAGEMENT CONSULTANTS

Martin P. Bowman B.Sc. (Hons)
Michael Bishaw B.Sc. (Hons)
Richard A. Gorham LL.B., M.Sc.

P.O. Box 404
Subiaco 6008
294-296 Rokeby Road
Subiaco, Perth W.A.
Telephone (09) 388 1859
Facsimile (09) 381 7362

Our Reference: RI9123

1 December 1989



Executive Director
Department of Marine & Harbours
1 Essex Street
FREMANTLE WA 6160

Attention: Mr Nello Siragusa

Dear Sir

Coral Coast Marina Resort

The Marine Impacts Branch, Environmental Protection Authority have requested elaboration of potential pollutant loadings into this marina, including short and long term predictions of expected ambient concentrations. I am pleased to provide herein a review of metal and hydrocarbon contamination of marina waters elsewhere, together with a qualitative assessment of the potential pollution concerns at Exmouth.

The proposed marina development at Exmouth includes provision for up to 250 berths for recreational and commercial craft, commercial marine facilities to service the users of the marina, boat repair facilities and boat refuelling facilities. It is also anticipated that a public swimming beach would be developed adjacent to the proposed resort hotel complex.

The potential inputs of contaminants to the proposed marina would be minimized by appropriate environmental design and management. Specific elements of the proposal are as follows:

- All facilities within the marina, as well as in the proposed residential development, would be deep sewered.

- Stormwater drainage from all marina hardstand areas would be directed away from the marina and discharged to general drainage via silt traps.

- The fuel storage facilities in the marina would be above ground and contained within a sealed bund capable of holding the entire tank contents.

- Boat refuelling hoses would have manually operated nozzle valves with automatic shut-off.

- The discharge of sewage, hydrocarbons or litter from boats into the marina would be prohibited, and all users of the marina would be informed of this. Waste disposal facilities, including rubbish bins, oil recycling deposit bins and sewered toilets would be provided around the marina. A sewage pumpout facility would be provided for boats equipped with holding tanks.

- The use of antifouling points containing tributyl tin (TBT) would be prohibited in the marina. This would be a condition of the lease of all boat repair facilities in the marina.

Monitoring studies in marinas elsewhere have shown that the primary sources of heavy metals to marina waters include the following:

1. Stormwater runoff from boat maintenance areas can introduce flakes and dust of paints stripped from boats. Mercury, tin and copper and common constituents in antifouling paints, while chromium, lead and zinc are constituents of paint primers. Cadmium is also used as a pigment in some marine paints. However, appropriate drainage design to direct stormwater runoff away from the marina, and incorporation of silt traps to reduce the suspended solids load, would minimise contributions from this source at the Coral Coast Marina Resort.

2. Continuous leaching of antifouling paints and sacrificial anodes (zinc or aluminium) from boats moored in the marina have a direct although minor contribution.

3. Exhaust from outboard motors contribute lead to the water column.

The potential sources of petroleum hydrocarbons to the marina at Exmouth include exhausts from marine engines, spillage at the fuel dock, discharge of bilge water and run-off from the public boat ramp. Other hardstand areas within the marina resort would not drain to the marina.

The Australian Environment Council* studied four marinas near Brisbane to determine, inter alia, the nature, extent and sources of petroleum hydrocarbon and heavy metal pollution. Specific findings of the study, with relevant comments pertaining to the proposed marina at Exmouth, were as follows:

- Sedimentary levels of total chromium, nickel and cadmium were not statistically different from those in the parent water body.

- Sedimentary levels of total copper, lead and zinc, and at one marine mercury, were significantly elevated in the marinas. Metal levels were highest in marinas with the highest boating density or where boat maintenance areas drained directly into the marina. It is noted that the proposed peak boat density at Exmouth would be approximately 16 boats per hectare of water area, which is substantially less than at the four marinas studies here (range of 45 to 80 boats/ha). Also, drainage from hardstand areas at the Coral Coast Marina would be directed away from the marina.

- Copper, zinc and lead were accumulated significantly by oysters transplanted into the marinas. This was considered to be due to a combination of point sources (drainage, fuel dock and maintenance area drains) and non-point sources (motor exhaust and leaching of marine paint).

- There was no significant increase in total hydrocarbon concentrations in the water or sediments of the marinas, although a significantly higher proportion of the total hydrocarbon levels were petroleum hydrocarbons. Fuel docks were identified as a point source of elevated petroleum hydrocarbons. Concentrations in water also showed localised effects due to bilge discharges from vessels.

* Australian Environment Council. 1988. Impact of Marinas on Water Quality. AEC Report No. 24.

It was concluded overall that, while accumulation of metals and petroleum hydrocarbons in sediments and biota had been demonstrated, the levels were not considered indicative of any significant water pollution. There was no evidence of ecological impact due to heavy metals or petroleum hydrocarbons in any of the four marinas that were investigated.

Environmental monitoring studies in Western Australia marinas have established an extensive data base of sedimentary heavy metal levels inside marinas (V. Talbot, E.P.A., Pers. Comm., 1989). In those marinas oriented primarily towards recreational boating (e.g. Hillarys, Ocean Reef, Americas Cup Harbour), the sedimentary levels of heavy metals are not significantly different from those in the adjacent open-water environment. However, there has been significant accumulation of heavy metals in the sediments of marinas and harbours with substantial commercial activities or repair facilities, such as Geraldton Fisherman's Harbour, Geraldton Harbour, Fremantle Harbour, Fremantle Fishing Boat Harbour and Success Harbour. Each of these latter examples have shown elevated copper, lead and zinc levels, and individual harbours have also variously shown significant sedimentary accumulation of chromium, cobalt, nickel, iron, manganese, titanium and vanadium.

Although the Coral Coast Marina Resort would include significant commercial components, drainage of these areas to direct stormwater away from the marina and the incorporation of silt traps would greatly reduce the associated water quality concerns in the marina.

It is not possible to provide confident quantitative predictions of the potential pollutant loadings to the Coral Coast Marina, but they are expected to be low. As described in Section 6.1.5 and Appendix B of the Notice of Intent (NOI), the anticipated water flushing rate is considered adequate to ensure that water quality in the marina remains essentially similar to that of the adjacent Gulf. However the Department of Marine and Harbours is committed to monitoring water quality in the marina and the adjacent Gulf in order to confirm the predictions made in the NOI regarding the adequacy of flushing and the maintenance of suitable water quality. The minimum water quality criteria required to be met are described in Schedule 2 of E.P.A. Bulletin 103. The proposed monitoring programme is described in Section 7.4 of the NOI, and the results would be reported to the E.P.A.

The proposed approach to monitoring possible contaminant levels in the marina reflects the environmental behaviour of the contaminants of concern. Because metals and persistent petroleum hydrocarbons tend to accumulate in the sediments and biota, priority is given to monitoring the levels within these environmental compartments rather than in the water. Accumulation in the sediments and biota over time would produce higher levels for detection, and the sediments and biota can integrate fluctuations in contaminant levels that occur in the water column.

The proposed monitoring programme for the marina does not presently include analysis of TBT in either the sediments or biota. The use of antifouling paints containing TBT would be expressly prohibited in the marina, but it is recognized that very low level releases of TBT from boats using the marina may still cause contamination. With acute toxic effects observed from aquatic organisms at concentrations as low as 1 mg/L (ppb) and sublethal effects detected at concentrations of 0.01 mg/L, TBT has been shown to be damaging at levels far below those yet recorded for any other marine pollutant. As a hydrophilic compound, TBT also bioaccumulates to high concentrations (up to 3 orders of magnitude above ambient levels).

Monitoring TBT levels in sediment or biota requires very rigorous and expensive sampling and analysis procedures and, to my knowledge, the Commonwealth Laboratories at Lucas Heights in N.S.W. currently offer the only suitable analytical facilities in Australia.

With regard to the high cost of TBT monitoring and the small likelihood of TBT contamination in the proposed marina (cf. established marinas where TBT paints are not presently prohibited), I recommend that analysis for TBT is not included in the proposed monitoring programme. This would be reconsidered in the unlikely event that the proposed monitoring programme shows a significant accumulation of other paint constituents (eg. copper, lead. zinc). If the proposed monitoring programme evidences significant contamination, then it is anticipated that more detailed studies would be initiated, in conjunction with the EPA. The range of parameters that would be monitored in such an event would reasonably be extended to include TBT.

It trust that the foregoing fulfills your requirement for additional information, but would be pleased to answer any further enquiries you may have.

Yours faithfully

Richard Gorham

R.A. GORHAM

APPENDIX E
PLANS OF RESIDENTIAL SUBDIVISION

(REFER TO FIGURE 3, PAGE 7)

APPENDIX F
SUMMARY OF REPORTS
ON
SIGNIFICANT WAVE HEIGHT

Exmouth - Coral Coast Marina

Significant Wave Height

1.0 Introduction

At present, an empirical evaluation of a significant wave height for the proposed Coral Coast Marina site at Exmouth Town Beach is not feasible. This is because a statistical analysis of the local wave spectrum cannot be performed until more data is collected from a waverider bouy which was recently deployed in Exmouth Gulf by the Department of Marine and Harbours.

An alternative approach is to estimate the significant wave height by established theoretical methods. Previous investigators have used such methods to determine wave characteristics at several locations along the western coastline of the Exmouth Gulf Peninsula. Thus, the purpose of this report is to review the available literature and thereby identify a significant wave height for the proposed Coral Coast Marina site.

2.0 Literature Review

Significant wave height predictions in the nearshore region adjacent to the town of Exmouth are described in the following three reports:

(1) "Exmouth Marine Supply Base Study"
Maunsell & Partners, (1981),

(2) "Norcape Marina Resort - Public Environment Report"
Le Provost, Semeniuk & Chalmer, (1986),
Riedel & Byrne, (1986),

(3) "Storm Wind, Wave and Surge Analysis for Exmouth Gulf"
Steedman Ltd., (1986).

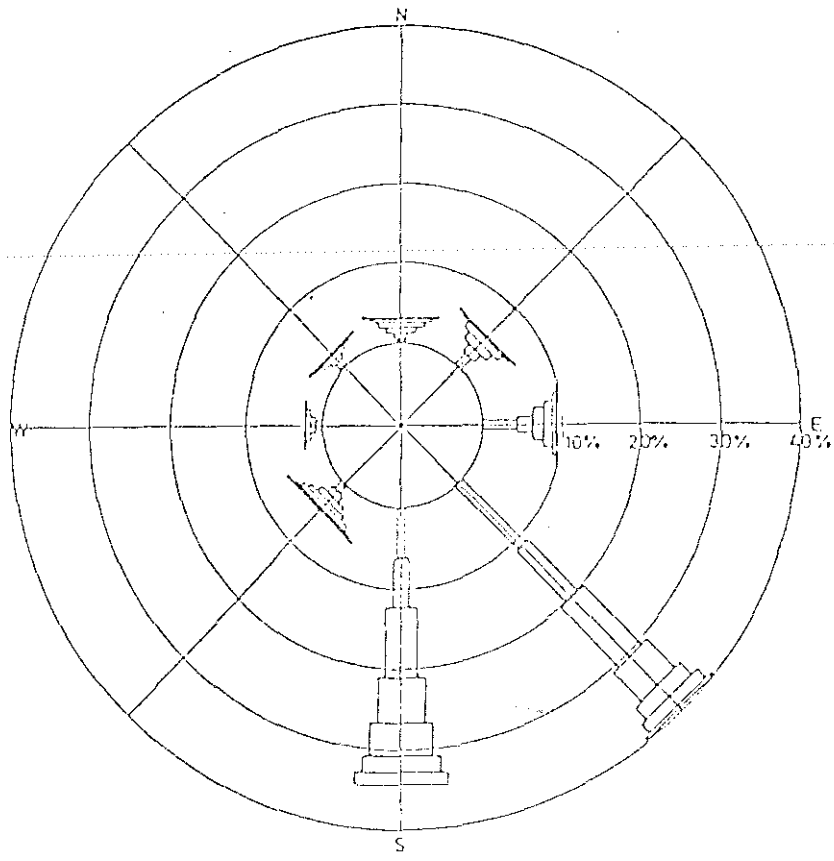
(1) "Exmouth Marine Supply Base Study"
(Maunsell & Partners, 1981)

Maunsell & Partners (1981) hindcast a wind generated wave climate for a proposed Exmouth marine base using local wind measurements which were recorded daily at 9 am and 3 pm over a nine year period between 1967 and 1976. The respective wind roses depicted in Figure 2.1 clearly show the predominance of south and south east winds, particularly in the morning. The wave hindcasting results presented in Table 2.1 indicate that wind waves as high as 1.5 m and periods up to 5 s can be expected from all directions at the Exmouth town site.

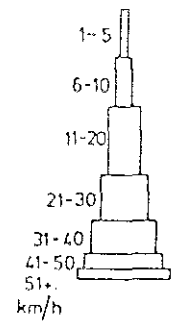
Cyclone waves generated in deep water outside Exmouth Gulf were estimated to have wave heights up to 8.3 m with an 11 s period for a 1 in 10 year design cyclone pressure of 970 mb. When a deep water cyclone wave propagates into the nearshore region adjacent to the Exmouth town site, its attenuated wave height was predicted to be between 2.8 m and 3.4 m. Furthermore, a 2.7 m increase in the water level above the normal astronomical tide was predicted due to the combined effects of reduced barometric pressure and wind stress associated with a 970 mb central pressure cyclone.

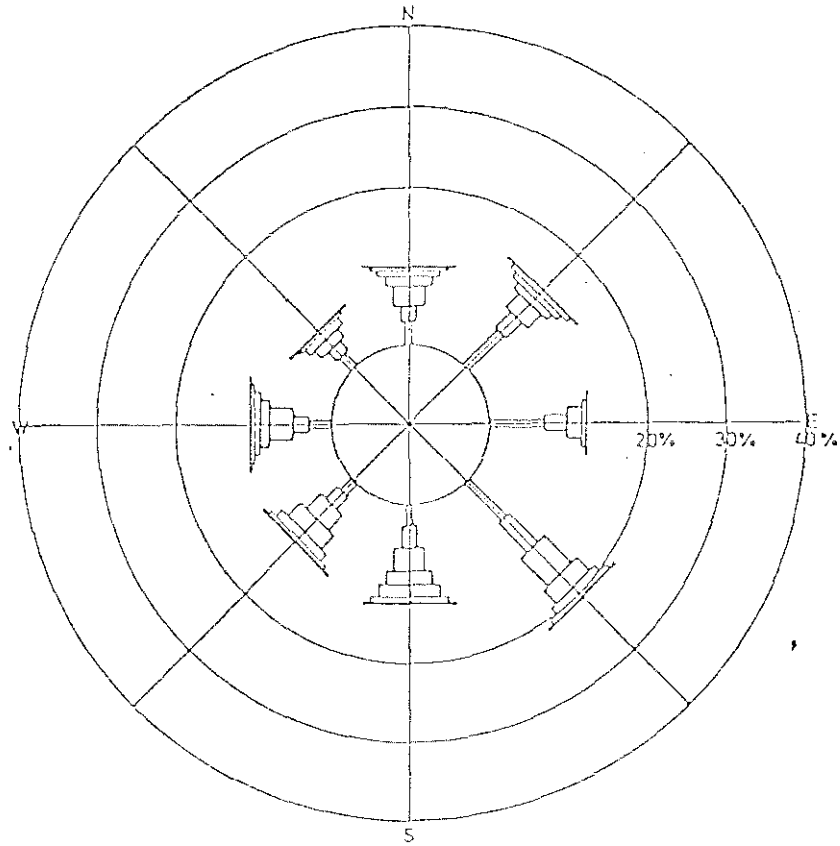
Table 2.1 Hindcast Sea Wave Statitics for Exmouth Town Site

Upper Limit Wind Speed	Direction	Fetch (km)	Duration to Fully Arisen Sea	Height (m)	Period (sec)
5 m/s	NE	65 km	10.5 hrs	0.6	3.1
	E	50	8.5	0.5	2.9
	SE	50	8.5	0.5	2.9
7.5 m/s	NE	60	8.0	1.2	4.3
	E	50	6.5	1.0	4.0
	SE	50	6.5	1.0	4.0
10 m/s	NE	60	7.0	1.5	5.2
	E	50	5.5	1.5	4.8
	SE	50	5.5	1.5	4.8



9am.





3pm.

EXMOUTH (TOWN)

WIND ROSES

(2) "Norcape Marina Resort - Public Environment Report"

(Le Provost, Semeniuk & Chalmer, 1986 / Riedel & Byrne, 1986)

Locally generated wind waves for a proposed Exmouth marina were hindcast by Riedel & Byrne (1986) using the same wind data used by Maunsell & Partners (1981). As shown in Table 2.2, Riedel & Byrne (1986) predicted a maximum 2.4 m high wave with a 6.5 s period from the North East and a 2.0 m high wave with a 5.5 s period from the South East. The results of a refraction analysis shown in Table 2.3 indicate that locally generated sea waves from the North East together with swell waves generated in deepwater offshore from Exmouth Gulf arrive at Exmouth Town Beach within a narrow direction band of between 60° and 70°. Due to the limited fetch within Exmouth Gulf, waves from the South East are predominantly short period sea waves which arrive at Exmouth Town Beach with directions between 90° and 100°.

A cyclonic wave climate was hindcast by Riedel & Byrne (1986) for two hypothetical cyclones with nominally 10 and 100 year return periods. The hindcast cyclonic wave conditions shown in Table 2.4 represent deepwater waves which would be significantly attenuated by the effects of refraction, shoaling and bottom friction as the waves approach Exmouth Town Beach. It was concluded that a deepwater significant wave height of 3.5 m could be expected under the most severe storm conditions in which case the corresponding wave set-up is 0.5 m (Table 2.5).

An 0.4 m storm surge with a return period of about 50 years for the Exmouth Town Beach site was hindcast using a return period analysis on a number of previously recorded cyclones. A second approach assigned certain cyclone parameters to a design storm and predicted a surge level of 1.1 m. Thus, a conservative design ocean water level was given as the combination of a storm surge, wave set-up and Mean High Water Spring tide which results in the following:

Design surge	+1.1 m
Wave set-up	+0.5 m
Mean High Water Springs	+0.9 m AHD
Design Ocean Water Level	+2.5 m AHD

Table 2.2 Hindcast Wave Conditions at Exmouth Town Beach

FREQUENCY	DIRECTION	WAVE HEIGHT (m)	WAVE PERIOD (seconds)
	NE	0.9	4.5
10 per year	E	0.6	3.0
	SE	1.3	4.5
	NE	1.4	5.5
5 per year	E	0.9	4.0
	SE	1.5	5.0
	NE	2.4	6.5
1 per year	E	1.4	4.5
	SE	2.0	5.5

Swell Wave Height (m)	Percentage occurrence
0.0 to 0.25	82.9
0.25 to 0.75	4.1
0.75 to 1.25	0.2

Calms = 13%

Table 2.3 Inshore Wave Directions for Peak Periods

Inshore Location: EXMOUTH MARINA SITE
Water Depth at Site: 1.8 m

Wave Type: SEA

Offshore Direction (deg.)	Peak Period (s) 2.0	3.0	4.0	5.0
45.0	54	57	60	63
67.5	68	68	68	70
90.0	86	84	83	82
112.5	103	97	93	90
135.0	120	109	100	95
157.5	133	122	110	99
180.0	140	128	120	103

Wave Type: SWELL

Offshore Direction (deg.)	Peak Period (s) 5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0
225.0	180	61	72	73	73	73	73	73	73	73	73
247.5	180	71	72	73	73	73	73	73	73	73	73
270.0	74	72	72	73	73	73	73	73	73	73	73
292.5	73	73	73	73	73	73	73	73	73	73	73
315.0	70	72	73	73	72	72	71	71	71	72	72
337.5	64	67	69	70	70	70	70	70	70	70	71
360.0	59	62	64	66	68	69	70	70	70	71	71
22.5	57	60	63	65	67	68	69	70	70	71	71
45.0	57	61	63	65	67	68	69	69	70	70	70
67.5	61	63	64	66	67	68	69	69	70	70	70

Table 2.4 Hindcast Deepwater Cyclone Conditions

Storm Nominal Return Period	Time (hrs)	Significant Wave Ht (m)	Period (sec)
10 years	0 - 2	1.5	11
	2 - 4	4.0	10
	4 - 6	6.6	10
	6 - 8	4.0	9
	8 - 10	3.0	8
	10 - 12	1.5	7
100 years	0 - 2	2.0	12
	2 - 4	6.0	12
	4 - 6	9.5	11
	6 - 8	6.0	11
	8 - 10	4.0	10
	10 - 12	2.0	8

Table 2.5 Wave Set-up at Exmouth Town Beach

Wave Height (m)	Period (seconds)		
	6	8	11
2.0	0.30	0.29	0.31
3.0	0.47	0.44	0.45
4.0	0.57	0.60	0.60

(3) "Storm Wind, Wave and Surge Analysis for Exmouth Gulf" (Steedman Ltd., 1986)

Steedman Ltd. (1986) hindcast wave conditions at Exmouth Town Beach for gradient intensification storms and tropical cyclones. Following the prediction of the relevant wave characteristics, a univariate analysis was applied to estimate the return period of the individual storm variables such as wind, wave and surge.

Wind data from the Bureau of Meteorology station at Exmouth together with surface synoptic data provided the necessary input for hindcasting the maximum wind speed, wave height and period at Exmouth Town Beach for gradient intensification storms. The results are shown in Table 2.6

The Bureau of Meteorology wind data were assessed to be unsuitable for predicting tropical cyclone conditions. Instead, a modified Bretschneider wind field model was used to estimate the relevant meteorological forcing parameters. The maximum wind speed, wave height and period at Exmouth Town Beach were then determined for tropical cyclone conditions using the same hindcasting method that was used for gradient intesification storms. The results are shown in Table 2.7.

A Maximum Likelihood Estimation (MLE) technique was used to obtain the return periods of the univariate parameters by treating the gradient intensification and tropical cyclone storms as distinct populations. The return period estimates of the wind, wave height, wave period and storm surge for tropical cyclones and gradient intesification storms are given in Table 2.8. Plots of the fitted distributions are given in Figure 2.2.

The Steedman Ltd. (1986) study concluded that a 1 in 10 year significant wave height of 2.0 m with a significant wave period close to 6.0 s could be expected at Exmouth Town Beach under gradient intensification storm and tropical cyclone storm conditions. The 1 in 30 and 1 in 50 year significant wave heights were estimated to be 2.4 m and 2.6 m respectively with significant wave periods near 7.0 s. A maximum 0.4 m storm surge was predicted with a 50 year return period. These results are compared with those from the previous two investigations in Section 3.0 of this report.

Table 2.6 List of Times and Magnitudes of the Hindcast Peak Storm Wind, Wave and Surge at Exmouth Town Beach for Selected Gradient Intensification Storms.

Storm No.	Time (hrs)	Date	Wind Speed (m/s)	Wind Dirn (deg)	Time (hrs)	Date	Wave Hmax (m)	Wave Hs (m)	Time (hrs)	Date	Wave Ts (sec)	Time (hrs)	Date	Storm Surge (m)
1	1800	27.10.75	12.9	191	900	28.10.75	1.84	.97	900	28.10.75	3.9	1500	28.10.75	.05
2	1500	19.10.76	12.9	191	1500	20.10.76	1.96	1.03	1500	20.10.76	4.0	1200	20.10.76	.01
3	1800	17.11.76	13.9	213	900	18.11.76	1.84	.97	900	18.11.76	3.9	1600	18.11.76	.02
4	1000	3.12.76	12.9	213	900	3.12.76	1.61	.85	900	3.12.76	3.7	1600	4.12.76	.03
5	1800	18. 1.77	13.4	191	900	22. 1.77	1.49	.78	900	22. 1.77	3.6	1600	17. 1.77	.03
6	1800	4. 2.77	13.9	191	2100	3. 2.77	2.84	1.49	2100	3. 2.77	4.8	2300	3. 2.77	.12
7	1800	18. 2.77	12.9	191	1200	18. 2.77	.48	.25	1200	18. 2.77	2.3	100	19. 2.77	.05
8	1000	12.12.77	12.9	191	1200	12.12.77	2.40	1.26	1200	12.12.77	4.4	1600	9.12.77	.04
9	1500	26. 1.78	13.4	11	2100	25. 1.78	1.84	.97	2100	25. 1.78	3.9	1700	26. 1.78	.15
10	1600	25.12.78	13.4	213	900	26.12.78	2.05	1.08	900	26.12.78	4.1	1500	23.12.78	.01
11	1000	4. 1.79	13.4	213	900	5. 1.79	1.37	.72	900	5. 1.79	3.5	000	5. 1.79	.01
12	1800	16. 1.79	12.9	213	1200	14. 1.79	1.60	.84	1200	14. 1.79	3.7	800	13. 1.79	.01
13	1800	6.12.79	12.9	191	900	6.12.79	2.28	1.20	900	6.12.79	4.3	800	6.12.79	.03
14	900	26.10.80	13.4	168								1600	26.10.80	.04
15	2100	19. 5.82	15.9	56	2100	19. 5.82	4.04	2.13	2100	19. 5.82	6.1	2300	19. 5.82	.19
16	1800	26.12.82	12.9	213								1400	26.12.82	.02
17	1200	7. 7.83	13.9	33	1200	7. 7.83	3.71	1.95	1200	7. 7.83	5.9	000	7. 7.83	.13
18	900	27. 9.83	12.9	168	900	27. 9.83	2.48	1.26	900	27. 9.83	4.4	1500	27. 9.83	.03
19	1800	14. 1.84	12.9	213	900	15. 1.84	1.60	.84	900	15. 1.84	3.7	0	15. 1.84	.02
20	1200	2. 8.84	12.9	191	2100	2. 8.84	1.03	.54	2100	2. 8.84	3.1	1800	2. 8.84	.03
21	1800	17.12.84	13.4	191	0	18.12.84	2.05	1.08	0	18.12.84	4.1	1500	18.12.84	.03
22	1800	12. 1.85	13.4	191	300	14. 1.85	1.71	.90	300	14. 1.85	3.8	100	13. 1.85	.02
23	900	3. 6.85	12.9	56	900	3. 6.85	3.17	1.67	900	3. 6.85	5.5	1100	3. 6.85	.10

Table 2.7 List of Times and Magnitudes of the Hindcast Peak Storm Wind, Wave and Surge at Exmouth Town Beach for Selected Tropical Cyclones.

Tropical Cyclone No.	Name	Time (hrs)	Date	Wind Speed (m/s)	Wind Dirn (deg)	Time (hrs)	Date	Wave Hmax (m)	Wave Hs (m)	Time (hrs)	Date	Wave Ts (sec)	Time (hrs)	Date	Storm Surge (m)
167		2000	2. 2.45	31.7	359	1900	2. 2.45	4.71	2.48	1900	2. 2.45	6.0	2300	2. 2.45	.37
295		400	25. 1.61	27.5	201	200	25. 1.61	3.76	1.90	100	25. 1.61	5.2	1200	25. 1.61	.06
298		1600	12. 2.61	14.6	350	1400	12. 2.61	2.00	1.10	1400	12. 2.61	4.3	1800	12. 2.61	.07
300		1800	2. 3.61	21.5	267	800	2. 3.61	1.59	.84	600	2. 3.61	3.5	2300	2. 3.61	.13
307		1500	3. 2.62	4.7	121	1500	3. 2.62	.57	.30	1600	3. 2.62	2.4	2300	4. 2.62	.00
313		2100	12. 1.63	8.1	12	1800	12. 1.63	1.24	.65	1800	12. 1.63	3.5	1600	12. 1.63	.02
677		500	26. 1.63	8.5	41	600	26. 1.63	1.33	.70	600	26. 1.63	3.6	500	26. 1.63	.02
318		2300	7. 2.63	19.6	193	2100	7. 2.63	2.78	1.46	1900	7. 2.63	4.6	1400	6. 2.63	.00
335	KATIE	2300	29. 3.64	31.0	299	2100	29. 3.64	4.14	2.18	2100	29. 3.64	5.6	200	30. 3.64	.38
344	JOAN	1800	18. 3.65	12.1	190	1600	18. 3.65	1.62	.85	1500	18. 3.65	3.6	2000	8. 3.65	.00
345	MAVIS	1100	23. 3.65	8.7	67	1400	23. 3.65	1.27	.67	1500	23. 3.65	3.5	1300	23. 3.65	.02
353	SHIRLEY	2000	2. 4.66	11.0	170	1900	2. 4.66	1.57	.83	1900	2. 4.66	3.6	1200	3. 4.66	.01
356	ELSIE	1100	20. 1.67	22.1	338	700	20. 1.67	3.07	1.62	600	20. 1.67	5.0	1100	20. 1.67	.17
366	BERTHA	1900	25. 1.68	7.2	29	1900	25. 1.68	1.10	.58	1900	25. 1.68	3.3	2000	25. 1.68	.01
378	GLADYS	0	18. 2.69	5.8	124	0	18. 2.69	.77	.41	0	18. 2.69	2.7	1000	19. 2.69	.00
384	GLYNIS	1800	1. 2.70	20.8	59	1900	1. 2.70	3.20	1.69	2000	1. 2.70	5.2	2100	1. 2.70	.19
385	INGRID	400	16. 2.70	16.6	344	200	16. 2.70	2.21	1.16	100	16. 2.70	4.4	600	16. 2.70	.11
393	RITA	1800	25. 1.71	18.5	255	1300	25. 1.71	2.61	1.37	1300	25. 1.71	4.8	1600	25. 1.71	.18
394	SHEILASOPHIE	1200	3. 2.71	18.5	188	800	3. 2.71	1.45	.77	800	3. 2.71	3.5	2000	1. 2.71	.00
429	BERYL	2100	3.12.73	13.9	13	2100	3.12.73	2.18	1.15	2100	3.12.73	4.4	2100	3.12.73	.05
432	ERICA	000	1. 1.74	14.4	209	400	1. 1.74	1.00	.57	400	1. 1.74	3.0	1100	1. 1.74	.17
433	FIONA-GWENDA	1400	11. 1.74	5.6	125					1500	11. 1.74	2.7	1100	12. 1.74	.00
438	HELEN	2000	2. 3.74	11.7	97	2100	2. 3.74	1.67	.88	2100	2. 3.74	3.7	0	3. 3.74	.02
448	TRIXIE	1700	19. 2.75	24.4	200	1200	19. 2.75	3.00	1.58	1100	19. 2.75	4.7	500	20. 2.75	.02
452	BEVERLY	700	31. 3.75	28.6	327	500	31. 3.75	3.71	1.95	500	31. 3.75	5.5	1000	31. 3.75	.30
457	JOAN	600	8.12.75	9.6	181	600	8.12.75	1.34	.70	500	8.12.75	3.4	2000	7.12.75	.01
462	VANESSA	1500	25. 1.76	14.6	62	1700	25. 1.76	2.24	1.18	1900	25. 1.76	4.5	1800	25. 1.76	.08
465	WALLY	200	26. 2.76	17.3	48	200	26. 2.76	2.70	1.42	300	26. 2.76	4.8	500	26. 2.76	.11
481	KAREN	600	8. 3.77	19.8	343	200	8. 3.77	2.43	1.28	200	8. 3.77	4.4	800	8. 3.77	.18
498	HAZEL	1300	13. 3.79	19.8	347	900	13. 3.79	2.79	1.47	800	13. 3.79	4.9	1600	13. 3.79	.14
506	AMY												200	11. 1.80	.02
519	MABEL	300	19. 1.81	21.3	37	300	19. 1.81	3.35	1.76	300	19. 1.81	5.3	500	19. 1.81	.20
522	NEIL	2200	5. 3.81	18.8	323	2000	5. 3.81	2.00	1.05	1900	5. 3.81	4.0	100	6. 3.81	.17
704	BRUNO												800	20. 1.82	.10
708	IAN	1400	6. 3.82	18.9	286	1100	6. 3.82	2.15	1.13	1100	6. 3.82	4.1	1600	6. 3.82	.13

Table 2.8 Univariate return period values of storm wave height and period, storm surge and wind speed for Exmouth Town Beach.

Return Period	Wind Speed	Sign. Wave Height H_s	Max. Wave Height H_{max}	Max. Crest Height H_c	Sign. Wave Period T_s	Storm Surge
(years)	(m s^{-1})	(m)	(m)	(m)	(sec)	(m)
(a) Tropical Cyclones						
3	20.3	1.4	2.7	2.2	4.7	0.2
5	23.7	1.7	3.2	2.6	5.1	0.2
10	28.1	1.9	3.7	3.0	5.7	0.3
30	34.7	2.4	4.6	3.7	6.5	0.4
50	37.8	2.6	5.0	4.0	6.9	0.4
(b) Gradient Intensification Storms						
3	13.7	1.5	2.9	2.3	5.1	0.1
5	13.8	1.7	3.2	2.6	5.5	0.1
10	14.1	2.0	3.8	3.0	6.1	0.1
30	14.5	2.4	4.5	3.6	7.0	0.2
50	14.7	2.6	4.9	3.9	7.4	0.2

Notes:

1. maximum wave height $H_{max} = 1.90\ H_s$;
2. wave crest elevation $H_c = 0.8\ H_{max}$;
3. storm surge does not include astronomical tide.

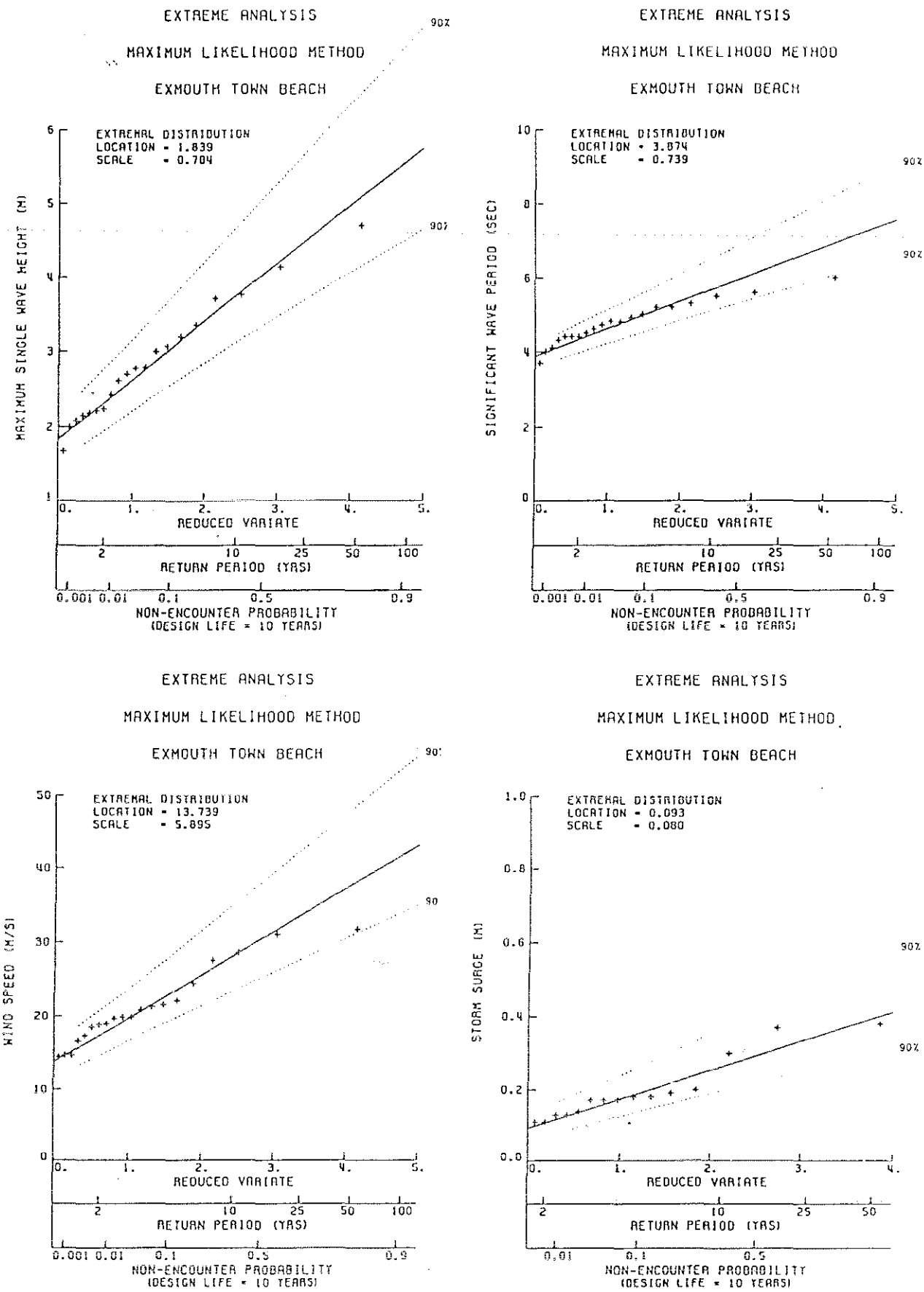


Figure 2.2 Plot of the extreme value distributions for 10 minute average wind speed, storm surge, maximum single wave height and significant wave period due to tropical cyclones for the Exmouth town beach location in Exmouth Gulf.

3.0 Results and Recommendations

Results from three independent reports which predict the wave climate at Exmouth Town Beach for locally generated seas and tropical cyclone swells are discussed in Section 2.0. The results are summarised in Tables 3.1 and 3.2 for comparison purposes.

Table 3.1 Locally Generated Waves

Investigators	H_S	H_{max}	Dirn.	T_S	Storm Surge
Maunsell & Partners	---	1.5 m	Any	~ 5 s	---
Riedel & Byrne	---	2.4 m	NE	6.5 s	---
	---	2.0 m	SE	5.5 s	---
Steedman Ltd.	2.0 m*	3.8 m*	---	6.1 s*	0.1 m*

* 10 yr. return period

Table 3.2 Cyclone Waves (10 year return period)

Investigators	H_S	H_{max}	Dirn.	T_S	Storm Surge
Maunsell & Partners	---	~ 3 m	---	~ 11 s	2.7 m
Riedel & Byrne	3.5 m**	---	---	---	1.1 m
Steedman Ltd.	1.9 m	3.7 m	---	5.7 s	0.3 m

** Deepwater Conditions

Given the limited resources, the choice of a significant wave height for the Coral Coast Marina site is somewhat subjective. However, the available published information suggests that a prudent decision would be to use a 2.0 m significant wave height with a 6.0 s period for preliminary design purposes until a long term analysis of the waverider bouy measurements becomes available.

Appendix 3

Copy of letter from EPA to the Department of Marine and Harbours giving permission for test pit.

ENVIRONMENTAL PROTECTION AUTHORITY
1 MOUNT STREET, PERTH, WESTERN AUSTRALIA 6000
Telephone (09) 222 7000

EXECUTIVE DIRECTOR
DEPARTMENT OF MARINE & HARBOURS

Attention Mr Alan Dougan

Your Ref: AD/3W2/36/89
Our Ref: 184/78
Enquiries: Ron Van Delft

PROPOSED TEST PIT FOR CORAL COAST MARINA RESORT; EXMOUTH

Further to your letter of 3 October and our subsequent meeting of 25 October in regards to the above proposal the Authority considers that the test pit may proceed subject to the following undertakings being given;

(1) The Department of Marine and Harbours conduct an anthropological/archeological survey as required by the Aboriginal Heritage Act 1972-80, prior to the commencement of works for the test pit, to the satisfaction of the Western Australian Museum.

(2) If troglobitic fauna are discovered during the test pit construction, works should cease and appropriate action taken in accordance with the requirements of the Wildlife Conservation Act. The Western Australian Museum and Environmental Protection Authority should be informed if troglobitic fauna are encountered.

(3) The results of drawdown tests be made available to the Water Authority of Western Australia and the Environmental Protection Authority.

(4) The Department of Marine & Harbours rehabilitate the test pit if the Coral Coast Marina project is not to proceed or is to be deferred, to the satisfaction of the Environmental Protection Authority.

(5) Appropriate containment or control of groundwater if flows are excessive.

RAD Sippe
DIRECTOR
EVALUATION DIVISION

9 November, 1989

Appendix 4

Conclusions and recommendations from the test pit investigations.

8. Conclusions

8.1 Geotechnical

- Within the harbour there are four distinct rock types based on their rock excavation parameters:

1. Unconsolidated dune and beach deposits. This type can be excavated by digging methods at maximum rates. Rates would depend on operational factors. Slope stabilization may warrant attention.

2. Dark grey muddy sandstone. Very soft and puggy when saturated and will not support heavy machinery without probably a metre of firm overburden cover. Whether saturated or de-watered this unit should be easily dug by excavator.

3. Brown clayey rubbly rock. A variable unit which can probably be dug by excavator with some difficulty and requiring light ripping in places.

4. Hard rock (conglomerate, pebbly calcarenite and brown clayey rubbly rock). A variable unit comprising very hard and strong rocks of uncertain fracture frequency and relatively weak rocks. Much of this unit will probably require at least moderate to heavy ripping and probable blasting in places.

- The excavation work was hampered by inadequate de-watering with machinery either working in boggy conditions or on a rock floor partially covered by water.

- A better designed de-watering system would have allowed more systematic information to have been obtained and would be strongly recommended in the main construction phase of the harbour excavation.

8.2 Hydrogeological

- The problems with sump pumping did not allow a systematic evaluation of hydrological information and therefore, only estimator methods could be used both in the collection of data and its analysis. De-watering by a bore would have provided dry working conditions and allowed for the collection of data for more meaningful hydraulic analysis.

- The hydrgeological results apply mainly to the saturated section above the hard rock layer. The low penetration of the hard rock section has not provided reliable data on the hydrogeolgoical characteristic soft this unit because the main water flows will be expected from fissures in the hard rock unit. Investigation is warranted for de-watering design.

- Drawdown data while pumping could not be used for hydraulic modelling due to the intermittent pumping and disturbance caused by the excavation itself.

- The recovery stage of the monitoring showed that the distal piezometers were significantly drawdown at the time pumping stopped. Water levels did not recover but continue to decline and were not suitable for the objectives of the programme.

- Piezometers in close proximity to the excavation displayed a delayed response to cessation of pumping before recovery. Transmissivity valves range from 25.2 to 78m^3d^{-1}. Storativity is 0.048.

- Radius of influence with the inlet set at 3.75m below static water level is about 155 metres. At maximum harbour depth prolonged de-watering is projected to have a radius of influence about 1000 metres.

9. Recommendations

9.1 Geotechnical

- It is suggested that further drilling be carried out to define areas and layers or rock which will/may require blasting to enable the contractor to better estimate costs and completion time for the project.

- A better definition of the distribution of rock materials will also assist in the use of the rock for development fill areas outside the boundaries of the harbour.

9.2 Hydrogeological

- Prior to commencement of harbour excavations, it is strongly advised that a series of piezometers be drilled and constructed along the perimeter of the harbour and along the estimated radius of influence, which roughly correspond to Warne and Murat Roads, and northern edge of the race course. These will allow the monitoring of any effects of de-watering on the adjacent areas.

- Piezometer monitoring should be performed by technician not employed by the earthmoving contractor (possibly the Water Authority). The data should be analysed and reported on by a hydrogeologist.

- One or two de-watering bores should be sunk into suitable locations to penetrate the hard rock layer and pumping tests carried out to determine:

(1) Magnitude of water flow expected in the full scale operation.

(2) Allow for a more accurate method of de-watering design.

(3) Provide more reliable data on the possible zone of influence during the main excavation phase.

Appendix 5

Information from the Western Australian Museum regarding troglobitic fauna.

Western
Australian
museum

Francis Street Perth
Western Australia 6000
Telephone (09) 328 4411
Facsimile (09) 328 8686

Date: 22 September 1989

Your Ref: 134/78

Our Ref: 306/77
cc DAS 77236

Chairman
Environmental Protection Authority
BP House
1 Mount Street
PERTH WA 6000

ATTENTION: Ron Van Delft

Dear Sir

PROPOSED CORAL COAST MARINE RESORT AT EXMOUTH

I refer to your request for comments on the above Notice of Intent. The Museum's Divisions of Natural Science, Human Studies and Aboriginal Sites have commented on this proposal and those comments are attached.

Yours faithfully

J.L. BANNISTER
Director

COMMENTS FROM THE MUSEUM'S DIVISION OF NATURAL SCIENCE

p. 30 While we support the concept plan for the marina we are concerned for the rare troglobitic fauna of the coastal plain and therefore strongly recommend that de-watering of the area does not take place during excavation of the harbour as this would be very likely to affect the subterranean fauna.

p. 43 and 64 Since the proposed harbour overlies saline groundwater which will extend further inland after harbour construction the western limit of the habitat available to the troglobitic fauna should be ascertained so that the plans can be modified to ensure that the westward intrusion of salt water does not bisect the range of this fauna.

p. 54 *Water supply*
Concern is felt that increased consumption may adversely affect the troglobitic fauna, either directly or indirectly (by intrusion of saline water). Consideration should be given to desalination, in the long term, to provide the town supply.

p. 32 *Sediment disposal*
Sediment disposal in the gulf will undoubtedly affect the marine benthos, however I agree with the consultants that the area, when stabilized, would be recolonised.

p. 75 Construction of an artificial reef may be advantageous for the marine biota.

p. 76 *Water quality of harbour*
While the flushing rate may appear adequate account should taken of the high temperature likely to be reached in summer by this body of shallow, enclosed water. High temperature, combined with nutrients leached from nearby gardens and vegetated areas, may well lead to phytoplankton blooms. Consideration could be given to improving the circulation by connecting the yacht basin to the sea (just south of the yacht club) by underground pipes to promote harbour flushing.

Conclusion

Provided strict environmental guidelines are adhered to I see no objection to the construction of the marina as envisaged in the N.O.I. provided the excavation is made without de-watering and that every effort is made to avoid danger to the troglobitic fauna.

Natural Science Comments continued

The proposed development overlies a unique subterranean aquatic fauna comprising two species each of fishes and shrimps (p. 65). All four species have been proposed for inclusion in amendments to the gazetted fauna under the Wildlife Conservation Act (W.A.). These are:-

> The Blind or Cave Gudgeon, *Milyeringa veritas* Whitley 1945; classified as rare and total protection recommended (Michaelis 1985).
>
> The Blind Cave Eel, *Anommatophasma candidum* (Mees 1962); classified as vulnerable (Michaelis 1985).
>
> *Stygiocaris lancifera* Holthuis 1960 and *S. stylifera* Holthuis 1960 (Crustacea: Decapoda).

As noted on p. 66, little is known of the distribution or abundance of the coastal troglobitic fauna. However, it seems to be limited to limestones adjacent to the shore on both the western and eastern sides of the North West Cape peninsula. A salt water wedge resulting from the excavation of the proposed marina could bisect the range of the coastal fauna and isolate part of the population. Knowledge of the environment, abundance and genetic continuity of these coastal populations is needed before judgement can be made on the likely effects of range fragmentation, particularly as they occupy an essentially linear range. This is most likely to effect The Blind Cave Eel as it has rarely been seen, and was last seen south of the proposed marina (in C-105) in 1988, the only known sighting in more than a decade.

(p. 66). The distance to the nearest known gnamma hole is not indicative of the likely impact on the troglobitic fauna, as the fauna extends widely throught the coastal limestone. Quarrying to the south of the proposed marina has opened two cavities, one containing The Blind Cave Eel.

In addition the coastal troglobitic fauna, there is an extensive and diverse cave fauna in Cape Range itself (Humphreys 1989, Humphreys *et al.* 1989), extending throughout the Tulki Limestone. This fauna has extreme endemism and contains new families for Australia or Western Australia, as well as numerous undescribed genera. The two faunae are known to interconnect at least at one location. Speciation has occurred between adjacent cave areas within Cape Range, but the genetic continuity of the coastal troglobitic fauna is unknown.

Excavation by dewatering (p. 30) may disrupt the troglobitic fauna by lowering the water table, causing mixing of fresh and salt water. In addition refilling after dewatering may permit seawater to extend, albeit temporarily, much further inland than will eventually result after the system has stabilized. Hence the impact of seawater on the troglobitic fauna may extend further inland than the 500 m envisaged (p. 64). The results of the hydrological investigations, to be separately referred to the EPA (p. 65), should be made available for comment by interested parties.

Limestone quarrying (p.33): the quarry site (Lyndon Loc. 126) should be examined for caves and their contents before quarrying commences. Many caves on ridges in Cape Range contain significant fauna and fossils. More than 300 caves are known from the N-W Cape peninsula and many contain material of wide significance.

Flood control (p. 33): damming canyons to the west of the proposed marina could flood important caves containing troglobites which differ from those known from the rest of Cape Range. Further consultation should occur before dam sites are fixed.

Settling pond (p. 82): a permeable settling pond could result in heavy siltation or blocking of subterranean passages containg troglobitic fauna.

References

Holthuis, L.B. 1960. Two new species of Atyid shrimps from subterranean waters in N.W. Australia (Decapoda: Natantia). **Crustaceana 1**: 47-57.

Humphreys, W.F. 1989. The status of relict cave fauna of Cape Range, Western Australia, especially the Schizomida. **Report to the Australian National Parks and Wildlife Service, Canberra.** 104 pp.

Humphreys, W.F., Adams, M. and Vine, B. 1989. The biology of *Schizomus vinei* (Chelicerata: Schizomida) in the caves of Cape Range, Western Australia. **Journal of Zoology, London 217**:177-201.

Mees, G.F. 1962. The subterranean fauna of Yardie Creek station, North West Cape, Western Australia. **J. Roy. Soc. West. Aust. 45**: 24-32.

Michaelis, F. 1985. **Threatened fish. A report on the threatened fish of inland waters of Australia.** Report Series **No. 3**. 45 pp. Australian National Parks and Wildlife Service Canberra.

Whitley, G.P. 1945. New sharks and fishes from Western Australia. Part 2. **Aust. Zool. 11**: 35-37.