DEPARTMENT OF
MARINE & HARBOURS

MANGLES BAY MARINA

PUBLIC ENVIRONMENTAL REVIEW

OCTOBER 1992

REPORT NO. DMH P15/92

MANGLES BAY MARINA

PUBLIC ENVIRONMENTAL REVIEW

Prepared by

Department of Marine and Harbours
Technical Services Division
1 Essex St
FREMANTLE WA

October 1992

Report No. DMH P15/92

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PROPOSED MANGLES BAY MARINA
PUBLIC ENVIRONMENTAL REVIEW

INVITATION

The Environmental Protection Authority (EPA) invites people to make a submission on this proposal.

This Public Environmental Review (PER) for the proposed Mangles Bay Marina has been prepared in accordance with Western Australian Government procedures. The report will be available for comment until 14 December, 1992.

Comments from Government agencies and the public will assist the EPA in preparing an assessment report with recommendations to Government.

Why Write a Submission?

A submission is a way to provide information, express your opinion and put forward your suggested course of action - including any alternative approach. It is useful if you indicate any suggestions you have to improve the proposal.

All submissions received by the EPA will be acknowledged. Submissions will be treated as public comments, unless confidentiality is requested, and may be quoted either in full or in part.

Why Not Join a Group?

If you prefer not to write your own comments, it may be worthwhile joining with a group or other groups interested in making a submission on similar issues. Joint submissions may help to reduce the workload for an individual or group, as well as increase the pool of ideas and information. If you form a small group (up to 10 people), please indicate all the names of the participants. If your group is larger, please indicate how many people your submission represents.

Developing a Submission

You may agree or disagree with, or comment on, the general issues discussed in the PER or the specific proposal. It helps if you give reasons for your conclusions, supported by relevant data. You may make an important contribution by suggesting ways to make the proposal environmentally more acceptable.

When making comments on specific proposals in the PER:

- clearly state your point of view,
- indicate the source of your information or argument if this is applicable,
- suggest recommendations, safeguards or alternatives.

Points to Keep in Mind

By keeping the following points in mind, you will make it easier for your submission to be analysed:

- Attempt to list points so that the issues raised are clear. A summary of your submission is helpful.
- Refer each point to the appropriate section, chapter or recommendation in the PER.
- If you discuss different sections of the PER, keep them distinct and separate, so there is no confusion as to which section you are considering.
- Attach any factual information you wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name,
- address, and
- date.

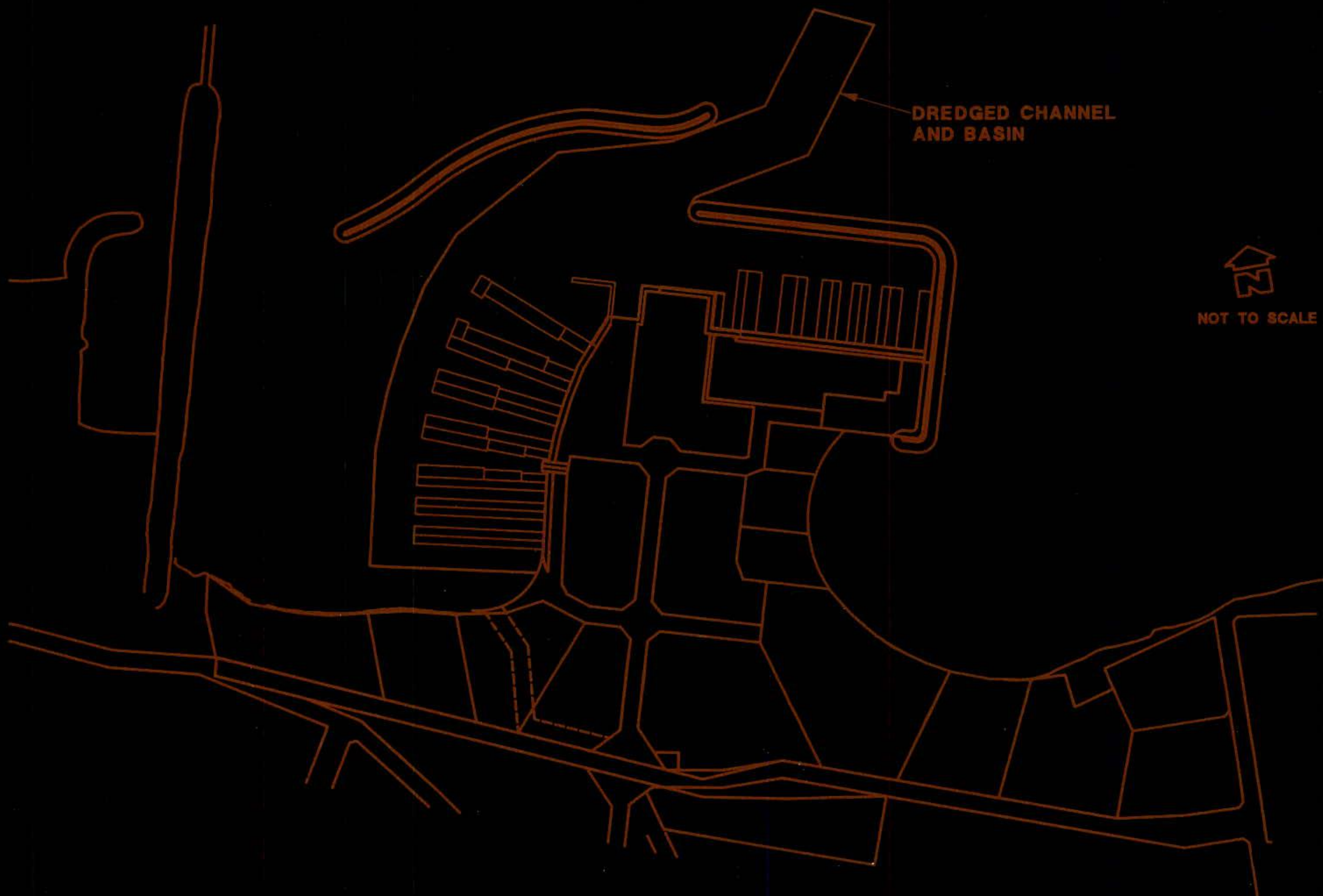
The closing date for submission is:

14 December 1992

Submissions should be addressed to:

The Chairman
Environmental Protection Authority
Westralia Square
36 Mounts Bay Road
PERTH WA 6000

Attention: Ms. K Wilson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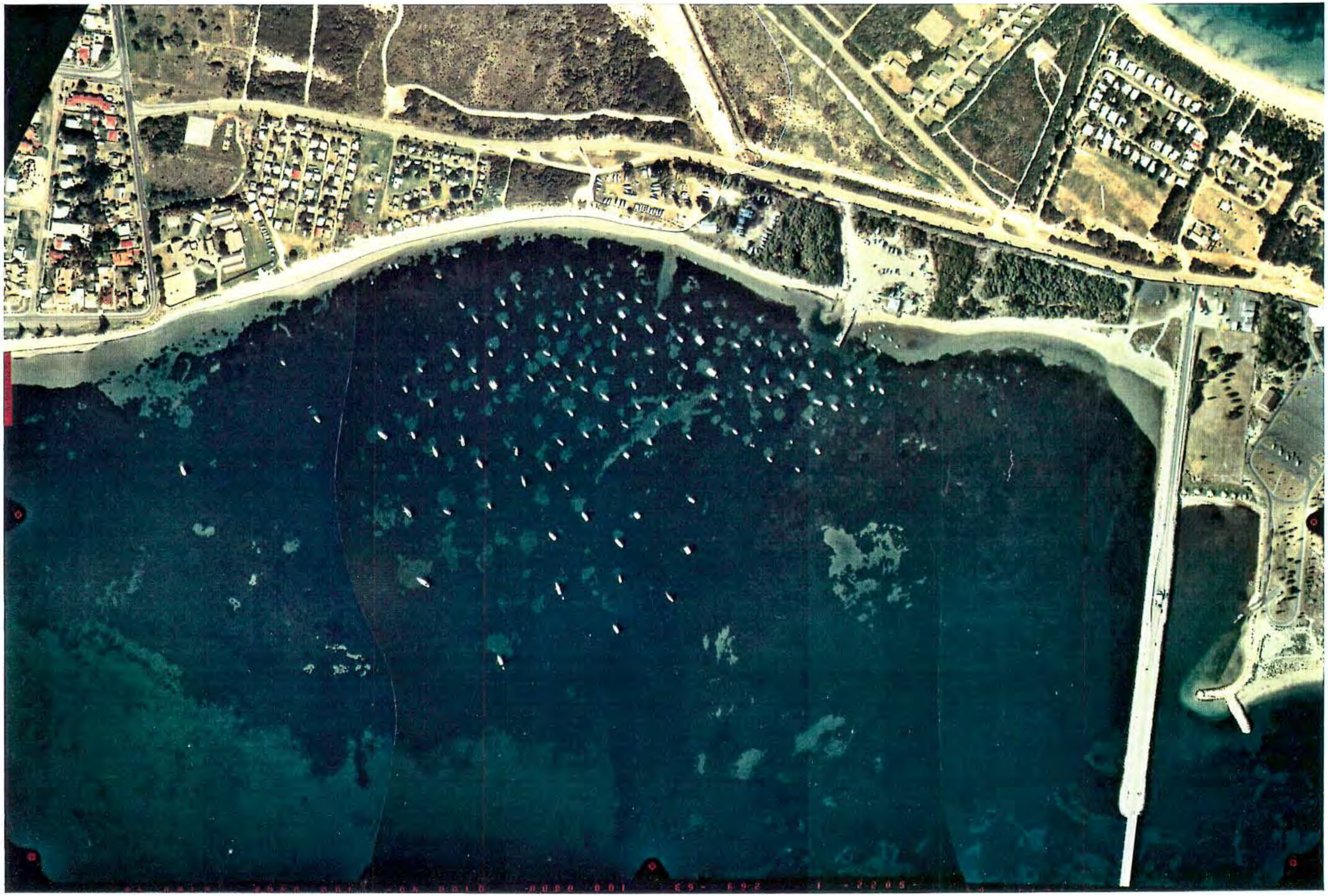


MANGLES BAY MARINA
PUBLIC ENVIRONMENTAL REVIEW

1.0 SUMMARY

1.1 Introduction.

The Department of Marine and Harbours (DMH), acting on behalf of the Western Australian Government, is proposing a public marina in Mangles Bay, Rockingham, between the Garden Island Causeway and Hymus Street.

1.2 Description.

The proposed marina will have an ultimate capacity of 500 pens and cater for boats up to 20 metres in length. Two breakwaters each 500 metres long will enclose 15 hectares of protected waters. Reclaimed land and adjacent foreshore land will be developed to provide the marina infrastructure and boat oriented recreational/tourist facilities with the emphasis on family holiday accommodation (see Fig .1a).

The facilities will include:-

- Chalets
- Boatel
- Yacht Club
- Commercial Centre
  - Tavern, shops, town square, restaurants, DMH and CALM offices, chandlery (including fuel, bait, boat sales, etc.)
- Caravan Park
- Lodge
- Sports complex
  - Health club, tennis courts mini-golf, etc.
- Light marine industry
- Secure boat hardstanding, dingy/trailer park
- Public open space
  - Green belts, conservation areas, foreshore public space, picnic areas
- Public beaches
- Public toilets
- Boat pens
- Public parking
- Ferry Landing
- Sullage Pumpout

The proposed marina will provide safe moorings and refuge for this section of the coast, and the associated land development will complement the existing holiday and recreational usages of Cape Peron.

1.3 Development Options

A number of alternative sites and proposals, many of which were private enterprise initiatives, have been considered.

Under present circumstances, the selected site in Mangles Bay is the most suitable location for the proposed marina. The site is well protected both from winds from the south-west quadrant, and from deep water swell waves. There is an existing community in Rockingham which is in need of a safe home base for boats, and several studies have identified the preferred site as suited for marina development. There is a complementary relationship between the proposed marina and the existing holiday/recreational usage of Cape Peron. The area is already utilised for both swing moorings and boat hardstanding.

The adjacent foreshore is crown land vested in or held in fee simple by the Minister for Transport and is available for marina development.

The proposed development has evolved through a consultative process which involved the City of Rockingham, the Cruising Yacht Club and various Government departments. These included the Department of Sport and Recreation which controls the balance of the adjacent reserve and the Department of Planning and Urban Development which prepared the Cape Peron Development Plan.

The initial proposal was conceived by DMH, who also carried out the engineering investigation and design work. Architectural consultants Hocking Patman Antill Pty Ltd. were engaged to refine the concept. At the same time, Brookes Laughton Marketing Intelligence (WA) Pty Ltd undertook an evaluation of the marketing potential and carried out a series of financial analyses. The final development concept as presented in this PER is a result of input from all these groups, and DMH is satisfied that this proposal will adequately and economically serve the boating needs of the region.

A draft of this document was submitted to the EPA. After reviewing this draft, the EPA indicated that they were concerned about the loss of seagrass which would result from the construction of this marina. In response to this concern, an alternative layout (Option 2), centred on an area of patchy meadow already damaged by swing moorings, was investigated (see Fig. 1b). The EPA reviewed this alternative and were still concerned about the impact on the sea-grass, but stated that a marina which was based more closely on the area covered by the original John Holland proposal, which already had environmental approval, would be acceptable. Following this advice, another layout (Option 3) was included in this document (see Fig. 1c).

Although Option 2 (shown in Fig 1b) significantly reduces the area of healthy seagrass destroyed by the proposal, it also reduces the land area available for development and, in a commercial sense, is not favoured. Option 3 (shown in Fig. 1c) has a similar loss of healthy seagrass as the first option, but has very little impact on the area of patchy seagrass. However, it not only reduces the land available for commercial development, but also puts most of the developable area within the one kilometre buffer zone around the sewerage treatment plant, and so reduces development options. All three development options are discussed in detail in

LEGEND

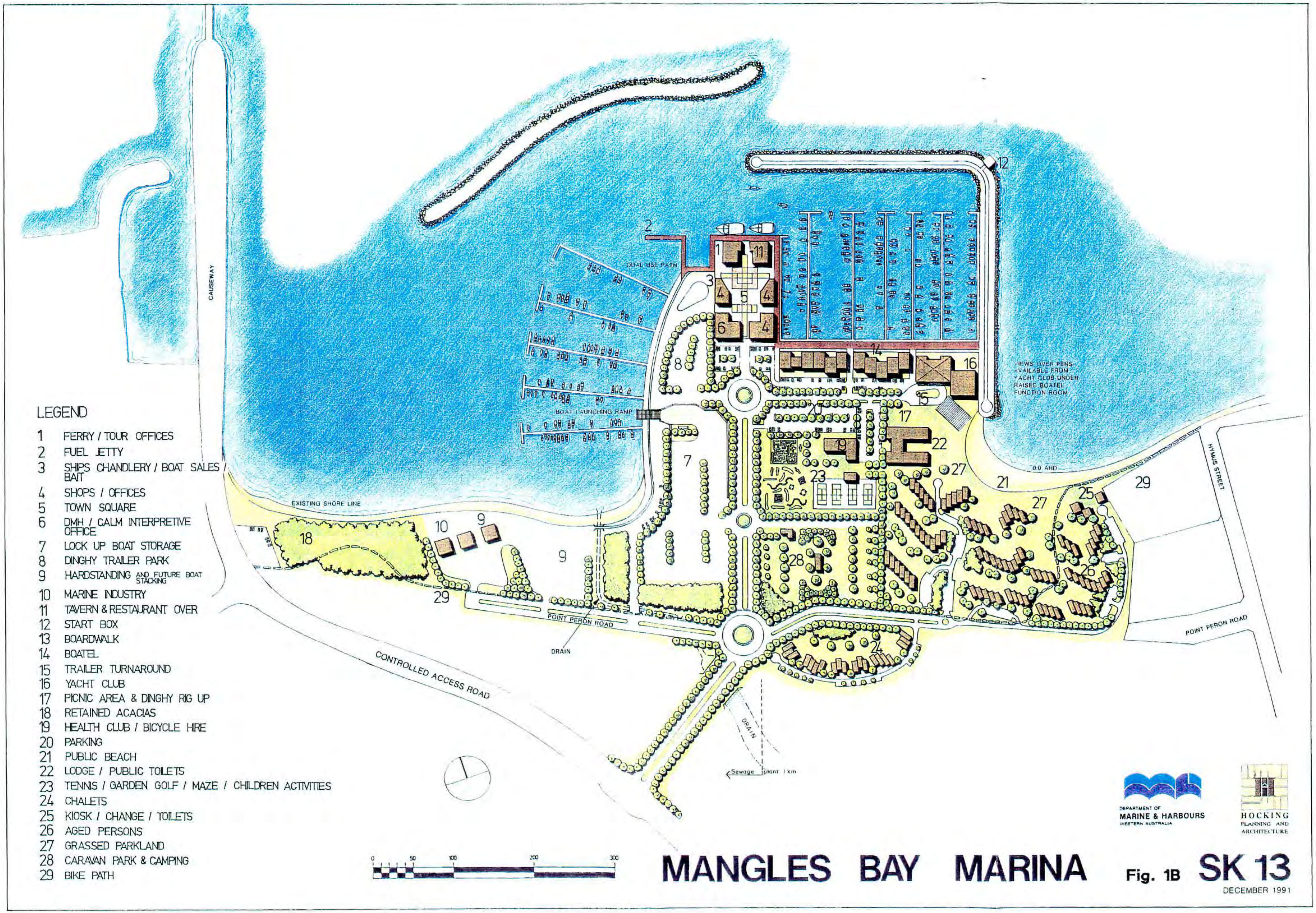
1 FERRY / TOUR OFFICES
2 FUEL JETTY
3 SHIPS CHANDLERY / BOAT SALES / BAIT
4 SHOPS / OFFICES
5 TOWN SQUARE
6 DMH / CALM INTERPRETIVE OFFICE
7 LOCK UP BOAT STORAGE
8 DINGHY TRAILER PARK
9 HARDSTANDING AND FUTURE BOAT STACKING
10 MARINE INDUSTRY
11 TAVERN & RESTAURANT OVER
12 START BOX
13 BOARDWALK
14 BOATEL
15 TRAILER TURNAROUND
16 YACHT CLUB
17 PICNIC AREA & DINGHY RIG UP
18 RETAINED ACACIAS
19 HEALTH CLUB / BICYCLE HIRE
20 PARKING
21 PUBLIC BEACH
22 LODGE / PUBLIC TOILETS
23 TENNIS / GARDEN GOLF / MAZE / CHILDREN ACTIVITIES
24 CHALETS
25 KIOSK / CHANGE / TOILETS
26 AGED PERSONS
27 GRASSED PARKLAND
28 CARAVAN PARK & CAMPING
29 BIKE PATH

DEPARTMENT OF MARINE & HARBOURS WESTERN AUSTRALIA

HOCKING PATMAN ANTILL PTY LTD

MANGLES BAY MARINA Fig. 1A SK 12

MAY 1990



LEGEND

1 FERRY / TOUR OFFICES
2 FUEL JETTY
3 SHIPS CHANDLERY / BOAT SALES / BAIT
4 SHOPS / OFFICES
5 TOWN SQUARE
6 DMH / CALM INTERPRETIVE OFFICE
7 LOCK UP BOAT STORAGE
8 DINGHY TRAILER PARK
9 HARDSTANDING AND FUTURE BOAT STACKING
10 MARINE INDUSTRY
11 TAVERN & RESTAURANT OVER
12 START BOX
13 BOARDWALK
14 BOATEL
15 TRAILER TURNAROUND
16 YACHT CLUB
17 PICNIC AREA & DINGHY RIG UP
18 RETAINED ACACIAS
19 HEALTH CLUB / BICYCLE HIRE
20 PARKING
21 PUBLIC BEACH
22 LODGE / PUBLIC TOILETS
23 TENNIS / GARDEN GOLF / MAZE / CHILDREN ACTIVITIES
24 CHALETS
25 KIOSK / CHANGE / TOILETS
26 AGED PERSONS
27 GRASSED PARKLAND
28 CARAVAN PARK & CAMPING
29 BIKE PATH

MANGLES BAY MARINA

Fig. 1B **SK 13**

DECEMBER 1991

LEGEND

1 FERRY / TOUR OFFICES
2 FUEL JETTY
3 SHIPS CHANDLERY / BOAT SALES / BAIT
4 SHOPS / OFFICES
5 TOWN SQUARE
6 CALM INTERPRETIVE OFFICE
7 DEPT. OF MARINE AND HARBOURS
8 LOCK UP BOAT STORE
9 DINGHY TRAILER PARK
10 HARDSTANDING AND FUTURE BOAT STACKING
11 BOAT REPAIRS
12 TAVERN AND RESTAURANT OVER
13 START BOX
14 BOARDWALK
15 TRAILER TURNAROUND
16 YACHT CLUB
17 PICNIC AREA AND DINGHY RIG UP
18 HEALTH CLUB / CYCLE HIRE
19 PUBLIC PARKING
20 PUBLIC BEACH
21 LODGE / PUBLIC TOILETS
22 CHALETS
23 KIOSK / CHANGE / TOILETS
24 AGED PERSONS
25 GRASSED PARKLAND
26 DUAL-USE PATH

0 50 100 200 300

DEPARTMENT OF MARINE & HARBOURS WESTERN AUSTRALIA

HOCKING PLANNING AND ARCHITECTURE

MANGLES BAY MARINA SK 14

Fig. 1C AUGUST 1992

this document, with the emphasis placed on the original proposal, since this presents a worst case scenario for environmental impacts.

1.4 Operation.

Once environmental approval of the proposal has been obtained, and the extent of the approved project has been agreed, expressions of interest in the development will be called from the private sector.

Ownership of the project site and the long term responsibility for management, including environmental management, are matters which will be decided in negotiation with the project developers. The yacht club site will be available for lease to a recognised Yacht club. The boat hardstanding area will be made available to the general public.

1.5 Receiving Environment.

The marina site in Mangles Bay is on the northern side of Rockingham Bank at the southern end of Cockburn Sound. The site is particularly well sheltered and is only exposed to winds and waves of any significance from the north to north-east. The Rockingham Bank is now a plain some 10 kilometres wide connecting the Spearwood Ridge to the Garden Island Ridge at Cape Peron and overlaying the older Tamala limestone formation. Inshore waters are shallow and the marina will be constructed in depths less than 4.0 metres.

The inshore seabed down to a depth of about 5.0 metres is occupied by dense seagrass meadows, predominantly *Posidonia*. The meadow has sustained some damage from swing moorings at the marina site.

The Garden Island Causeway has stopped the longshore transport to the east, and the shoreline up to about Bell Street has been receding steadily. The foreshore is relatively low-lying and colonised by a range of common native and exotic plant species. The majority of the foreshore land to be included in the development is vested in or held in fee simple by the Minister for Transport and will be zoned for Harbour Purposes.

1.6 Potential Impacts.

Careful attention to site selection and design have avoided or minimised most environmental impacts. The major impact will be the loss of about 18.4 hectares of healthy seagrass meadow and 13.7 hectares of patchy meadow which has been damaged by swing moorings. This loss may be offset to some degree by regeneration in the unused swing mooring areas and possible recolonisation of the marina basin and entrance channel, but this is only likely to occur in the very long tem..

The alternative proposals considered in response to the EPA's concern with seagrass damage reduced the area of seagrass affected to about 13.3 hectares of healthy meadow and about 12.7 hectares of patchy meadow in Option 2, and about 19.0 hectares of healthy meadow in Option 3.

A marina at the site will have little impact on the residential areas of Rockingham, either during construction or in operation. The development is in accordance with the general recommendations of the Cape Peron Study and will complement the existing and proposed holiday/recreational uses of Cape Peron.

The Water Authority of Western Australia (WAWA) is opposed to certain types of development, principally residential, within a 1 kilometre radius of the Point Peron wastewater treatment plant. In the three layouts proposed, only development acceptable to WAWA will occur within this buffer zone.

There are no known marine or terrestrial sites or artefacts of archaeological or ethnographic importance, either European or Aboriginal, within the development area.

The beaches at and to the east of the marina site are presently eroding. The new marina is not expected to affect this erosion but never-the-less, the proposed monitoring of the new beach on the east side of the marina will be extended to include the adjacent mainland beaches.

Investigations by DMH indicate that the water quality within the marina will be suitable for direct contact recreation. A monitoring programme to confirm this will be initiated.

1.7 Potential Benefits

The benefits of the proposed marina at Mangles Bay (for the preferred option) include:-

* a facility to meet the needs of the recreational and commercial boating public in the southern metropolitan and adjacent rural region into the next century,
* a safe refuge for boats in the region and for those in transit between Fremantle and points south,
* the opportunity to contribute to a change in the perceptions of the region and to act as a major catalyst for tourism,
* provision of a range of holiday accommodation, including low-cost accommodation, for the general public as an alternative to the existing holiday accommodation which is on foreshore land leased to private groups and not generally available to the public,
* provision of a safe mooring in Cockburn Sound with direct access to world class sailing waters,

* provision of an alternative boating destination near to Fremantle which could reduce the boating and tourist pressure on and around Rottnest Island,

* recreational opportunities plus visitor accommodation to serve the 2000 plus personnel expected to be based at Garden Island,

* a new sheltered beach with facilities adjacent which will provide an alternative to the heavily patronised main beach at Rockingham,

* development of under-utilised land owned by the state and the generation of revenue which will allow the marina to be self-funding.

1.8 Conclusions.

The only significant environmental impact of the proposed marina in Mangles Bay will be the loss of about 18.4 hectares of healthy seagrass meadow and 13.7 hectares of patchy meadow which has been badly damaged by swing moorings. This represents about 1.8% of the seagrass in Cockburn Sound, including Parmelia and Success Banks. All other perceived environmental impacts have either been avoided by careful design or can be properly managed.

When reviewing a preliminary draft of this document, the EPA expressed concern over the amount of seagrass affected by the proposed marina. In response to this concern, two alternative marina layouts were investigated, each of which reduced the area of seagrass destroyed. However, these layouts reduce the amount of land available for development. The reduction in area not only lessens the financial returns from the project, but also reduces the amenities which can be provided, such as the number of holiday chalets, the amount of protected public beach, public camping areas and public open space and conservation areas. The third option, which places the majority of the available land within the WAWA buffer zone, also has limited acceptable uses. For these reasons, these reduced area proposals are not favoured.

The Steering Committee believes that the advantages to the community of a marina at this site are significant and outweigh the disadvantages of the loss of a small amount of the remaining seagrass in Cockburn Sound.

2.0 INTRODUCTION

This Public Environmental Review (PER) has been prepared for a proposed recreational boat harbour and associated land development at Mangles Bay, Rockingham, between Hymus Street and the Garden Island Causeway (Fig. 2).

2.1 Project Description.

The proposed marina is intended to cater for the recreational boating needs of the southern Metropolitan Area well into the first quarter of the next century. The project will include 30 hectares of existing foreshore and proposed landfill, plus 15 hectares of protected water and will have an ultimate capacity of approximately 500 boats. The proposal incorporates a yacht club, marine related commercial areas and an area set aside for the development of light marine industry sites. The marina will complement the existing and proposed family oriented holiday recreational uses of Cape Peron, and will include chalets, a hotel, and caravan, camping and motel type holiday accommodation. Ferry landings, fuel supplies and sewage pumpout facilities will also be provided.

It is not expected that the mooring capacity will be fully utilised until after the year 2010. Initially, some 275 pens are proposed to meet the latent demand, with more added as and when the demand arises.

Dry land storage for boats will be provided in addition to pen storage.

Construction of the first stage is expected to start in April 1993 (See Section 5.8), but this is dependent on available funding.

A second stage expansion has been considered for the area between the proposed marina and the Causeway. This would expand the total mooring capacity to around 900 boats. Projections of boat mooring requirements indicate that this would not be required for 15 to 20 years, and an environmental assessment of this expansion is not considered appropriate at this time. This PER relates only to a marina with a maximum capacity of about 500 boats.

Any later expansion in the direction of the causeway is likely to require the approval and co-operation of the Royal Australian Navy, as the controllers of the Causeway and adjacent land.

2.2 Proponent.

The Department of Marine and Harbours (DMH), acting on behalf of the Western Australian Government, is the project proponent, and is acting in accordance with the functions of the Department as defined by Section 5(i) of the Marine and Harbours Act, 1981 i.e.

> **"..To construct, provide and maintain facilities and services both on land and on water, that are desirable to meet the needs of effective and efficient shipping and boating, both recreational and commercial..."**

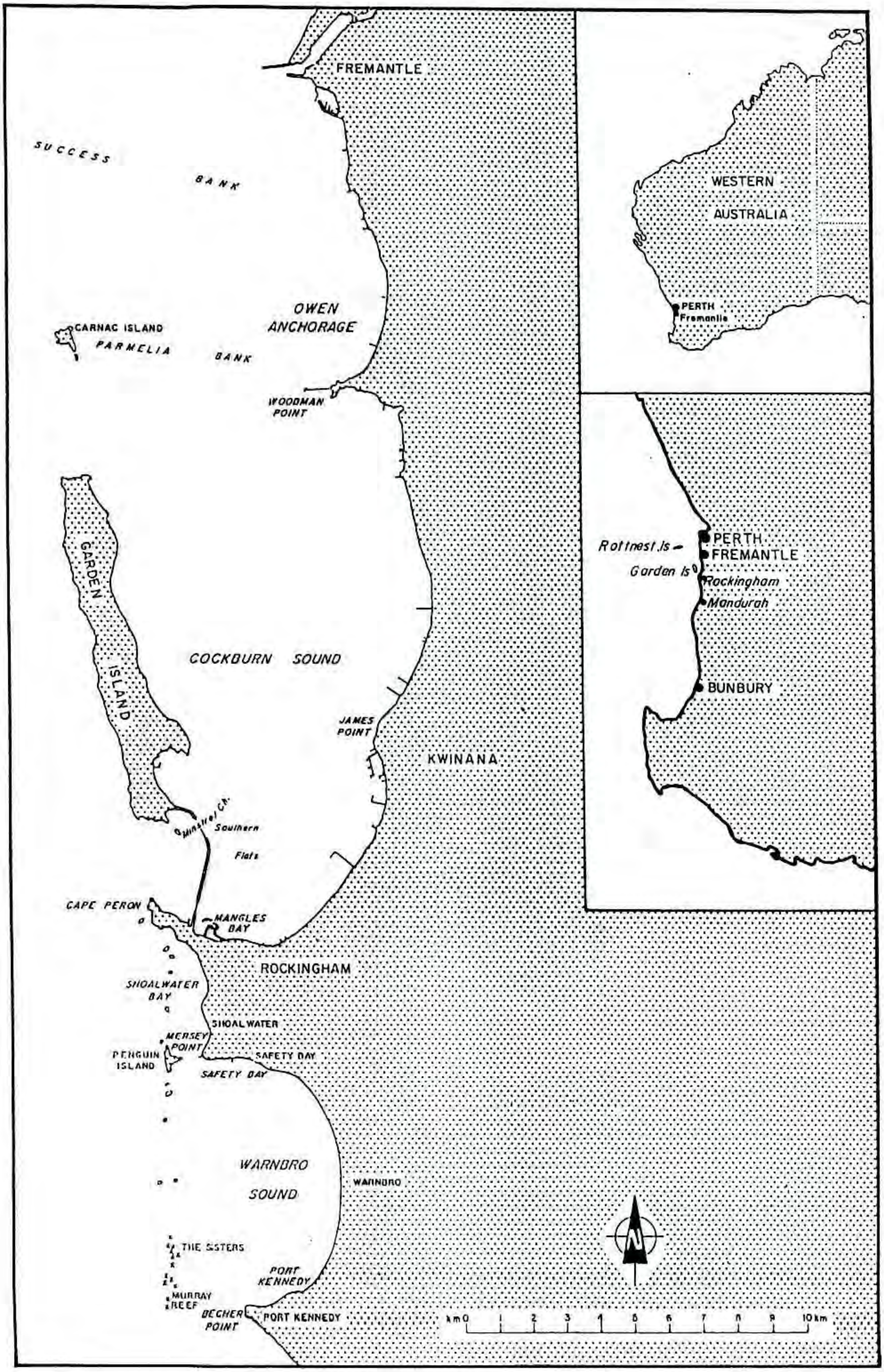


Fig. 2 LOCATION MAP

DMH has extensive experience in the design and construction of public small boat harbours on the Western Australian coastline. Previous works include:-

* Bandy Creek Boat Harbour, Esperance
* Challenger Harbour,Fremantle
* Hillarys Boat Harbour, Hillarys
* Jurien Boat Harbour, Jurien Bay
* Dennison Boat Harbour, Dongara
* Carnarvon Boat Harbour, Carnarvon
* Johns Creek Boat Harbour, Point Samson
* Geraldton Boat Harbour, Geraldton (under construction)

The Head Office of the Department of Marine and Harbours is at 1 Essex Street, Fremantle.

2.3 Approval Process.

The principle of a marina in Mangles Bay was endorsed in the Cape Peron Study (1988) prepared by the (then) State Planning Commission (now Department of Planning and Urban Development). In keeping with the philosophy of a 'whole of government' approach, the study was prepared with the assistance of a Steering Committee and a Technical Committee consisting of representatives from State and Local Government. The Cape Peron study was a draft report put out for public comment. It is presently being reviewed, but the concept of a marina is still endorsed.

The Cape Peron Study Steering Committee included representation from:-

* State Planning Commission (now Dept of Planning and Urban Development)
* Department of Marine and Harbours
* Department of Sport and Recreation
* City of Rockingham
* WA Development Corporation
* Environmental Protection Authority
* Fremantle Port Authority

The Cape Peron Study Technical Committee included representation from:-

* State Planning Commission
* Department of Marine and Harbours
* Main Roads Department
* Department of Sport and Recreation
* WA Tourism Commission
* Environmental Protection Authority
* Department of Conservation and Land Management
* Westrail
* City of Rockingham

A separate Marina Consultative Committee was formed to oversee the marina project. This committee was chaired by DMH. The Hon. Mike Barnett MLA, Member for Rockingham, was a member of the committee, as were representatives from:-

* City of Rockingham
* Department of Sport and Recreation
* Department of Planning and Urban Development
* Department of Marine and Harbours
* Department of Conservation and Land Management

Planning and development proposals for the marina are being negotiated within this consultative committee, and formal approval applications will be submitted to the appropriate bodies after environmental approval has been received.

2.4 Objectives.

The primary reasons for construction of this boat harbour are:-

* **To provide a facility to meet the needs of the recreational and commercial boating public in the southern metropolitan and adjacent rural area into the next century.**

  The majority of the metropolitan boating facilities are concentrated in the Swan River and the small boat harbours at Fremantle. Recently, DMH built the Hillarys Boat Harbour to provide accessible local facilities for the northern suburbs. The proposed Mangles Bay Marina will complement Hillarys by providing a similar facility in the south.

  Although the harbour is primarily for recreational boat users, there is a small but viable commercial fishing fleet operating around Rockingham which will benefit from improved facilities.

  A demand study carried out by the Department indicates that there would be a requirement for almost 600 pens in Mangles Bay by the year 2014 (See Appendix 3). It is expected that there will also be a large demand for boat hard-standing, but at present no firm predictions are available.

  There are presently in excess of one hundred boats on swing moorings in Mangles Bay. There are a similar number on hardstanding at the proposed marina site.

* **To provide a safe refuge for boats in the region and for boats in transit between Fremantle and points south.**

  It is commonplace for boats on swing moorings in the Rockingham area to break free and wash ashore during storms, and there is an established need for better protection. Further, there is no safe refuge suitable for all craft in transit between Fremantle and Bunbury, although some craft can find refuge at Mandurah if they are of sufficiently shallow draught to cross the sand bar at the mouth of the estuary.

Access to the marina from the open ocean will be via Minstral Channel for those boats which can pass under the high level bridge. There is 12.9 metres clearance under the bridge at low water. Boats within Cockburn Sound will have direct access.

2.5 Background.

The need for some form of recreational boating facility in the south of Cockburn Sound has been recognised for some time, and the concept has been promoted in several tourism and recreational studies of the area. (This is discussed in detail in Section 3).

Mangles Bay was reserved for Port Purposes under the Metropolitan Region Scheme as a possible site for the construction of new berths for Fremantle Harbour. In 1985 however, Cabinet agreed that Mangles Bay was not a suitable berthing site, and requested that the Port Installation Reserve be deleted from the Scheme. Cabinet also supported the establishment of the Steering and Technical Committees which eventually produced the draft plan for the recreational and tourist development of the Cape Peron/Mangles Bay area (The Cape Peron Study, 1988).

After it was decided that Mangles Bay would not be used for port purposes, funds were made available to the (then) Shire of Rockingham to construct a boat ramp and parking area west of the Garden Island Causeway. The Shire also sought expressions of interest from prospective developers in regard to a possible marina in Mangles Bay. The favoured developer, John Holland Constructions (JHC), proposed a 330 pen marina immediately east of the causeway with abutting land to be developed for commercial and hotel/chalet accommodation.

The Environmental Protection Authority (EPA) formally assessed the proposal in 1985 and found it to be environmentally acceptable subject to eight recommendations. In the event, the proposal did not proceed.

The Steering and Technical committees set up by the 1985 Cabinet directive produced the draft Cape Peron Study in 1988. This Study examined the previous reports and recommended a guided development of the Cape. The recommended development included a marina at Mangles Bay incorporating the Cruising Yacht Club as well as a range of tourist and recreational activities. Although the draft study is currently being reviewed in the light of public submissions, the concept of a marina in Mangles Bay is still endorsed.

In 1988, following representation by the Cruising Yacht Club, it was resolved that DMH would prepare a preliminary report on the proposals for a marina development in Mangles Bay. Following consideration of this report, Cabinet allocated funding to carry out the required investigations and prepare the documentation required for environmental assessment. The Marina Consultative Committee (see Section 2.3) was also formed.

2.6 Public Environmental Review.

Following discussions between the EPA and DMH, the EPA set the level of assessment for the proposed marina as a Public Environmental Review (PER).

Although JHC produced a PER for their 1985 proposal, the EPA considered that, as this present proposal was for a much larger marina, with a variety of more extensive facilities, reassessment at a PER level was appropriate.

Guidelines for the PER issued by the EPA are included in Appendix 1.

This PER deals with:-

* the background to the marina project, the need for the project, the alternatives considered and a detailed description of the proposal

* the existing physical, biological and human environment in which it is proposed to locate the project

* the likely environmental impacts that the proposed marina will have in the above areas

* the environmental management and monitoring procedures, safeguards and commitments which are proposed to reduce the loss of environmental values which may result from the known impacts or unpredictable circumstances associated with the construction or operation.

* the specific areas of concern raised by the EPA in their assessment of the 1985 JHC proposal.

At the request of the EPA, this PER also considers two alternative marina layouts (Options 2 & 3).

This PER will be released for an eight week public review period. During this time the public are invited to submit comments on the PER to the EPA. Following this, the EPA will evaluate the document, taking into account issues raised in the public submissions, and make recommendations to the Minister for the Environment.

3.0 DEVELOPMENT RATIONALE

3.1 Study Recommendations.

The desirability of some form of boating facilities at Rockingham and, more specifically, a marina in Mangles Bay, has been recognised for some time.

The Perth Regional Tourism Study 1977, envisaged a 200 hectare land park and a 500 hectare marine park centred on Cape Peron, with a marina in Mangles Bay.

The Cockburn Sound Recreational Study 1978, identified the high use given to Cockburn Sound beaches, particularly by family groups. It recommended the development of a public marina, incorporating the Cruising Yacht Club, in Mangles Bay. Public holiday camp accommodation was also recommended.

Recreational Boating Facilities in WA 1981, identified Cockburn Sound as having the heaviest usage of any boating area in the State, and stated that it warranted a very high priority for launching, berthing and mooring facilities.

The South West Metropolitan Tourism Development Plan 1985, identified Cape Peron as an area for future tourism development. While diversification of traditional attractions was recommended, Cape Peron was identified as important for traditional chalet and caravan park accommodation. Low key, family oriented accommodation designed to fit into a recreational theme, including a marina, was recommended. The plan envisaged 100 to 150 chalets, a strata titled caravan park with 100 to 150 bays, a youth camp and a retail facility.

The Rockingham Coastal Study 1988, recognised the anticipated boat population in the Rockingham area and the need for launching and marina facilities.

The draft **Cape Peron Study 1988,** examined the previous reports and recommended that a marina and resort be developed east of the causeway (Rec. 8.1c), and that the Cruising Yacht Club and the professional fishermen be relocated to the marina (Rec 8.6). This report also noted that, while environmental clearance (with conditions) had already been given for a 330 pen marina, it was important that the marina was not precluded from future development, and an ultimate capacity of 1500 boats was mentioned. The holiday recreation/accommodation (chalets, hotel, caravan parks etc.) concept with some commercial and retail areas was endorsed. Although this draft is currently being reviewed in light of public submissions, this marina concept is still favoured.

The above reports all recognised a need for a recreational marina in the Rockingham area and later reports, prepared after the port proposal was abandoned, favoured a site in Mangles Bay. The value of the area for family oriented recreation and holiday accommodation was also acknowledged, and there was a preference that any marina and associated infrastructure would complement this concept.

3.2 Mooring Demand Estimation

A mooring demand study has been undertaken for the proposed marina (see Appendix 3.). The primary market catchment area for this marina is expected to include not only the Rockingham/Cockburn region, but much of the southern metropolitan area from Armadale through Gosnells and into Canning as well as the rural areas of Serpentine/Jarrahdale. Departmental records indicate that there are some 7800 boats registered in this region, of which some 1100 are large enough to consider as potential marina pen users. It cannot be assumed that all of these boats will transfer to the proposed new Mangles Bay marina. The Department's calculations, however, indicate that there is a latent demand for around 226 pens, and an expected growth rate of about 4% per annum. The latent demand includes the 100 or so boats presently on moorings in Mangles bay. Using the above figures, and assuming that the latent demand is taken up in the first two years, predicted pen usage has been calculated and is shown in Table 1.

	Year	Estimated Pen Occupancy
0	1994	132
1	1995	275
2	1996	286
3	1997	297
4	1998	309
5	1999	372
10	2004	391
15	2009	476
20	2014	579
25	2019	705

Table 1. Predicted Pen Occupancy

Marketing strategies, variations in economic conditions and variations in population growth rates are some of the many factors which can, and will, affect these predictions.

The boats presently in Mangles Bay are served by the existing swing moorings and hard-standing. However, it is not possible to satisfy the longterm demand indicated in Table 1 above with swing moorings, primarily due to limitations of space.

It is intended that extensive hardstanding areas will be provided within the Harbour Reserve. These will cater for the 100 or so boats already on hardstanding in the Bay, as well as provide an attractive storage option for trailer boat owners. In W.A. approximately 85% of pleasure boats are trailerable, and presently, only about 2.5% are kept on hardstanding, mostly at yacht clubs.

3.3 Regional Considerations.

3.3.1 Safe Haven.

The Swan River and the adjacent small boat harbours at Fremantle form the largest and most important small boat haven in Western Australia. The nearest haven to the south of Fremantle is Mandurah, although this is only useable by boats with a sufficiently shallow draft to cross the sand bar which often forms across the mouth of the entrance to the estuary. Bunbury is the next haven for larger boats. The Mangles Bay marina would provide a haven between Fremantle and Mandurah/Bunbury with access from the open ocean via Minstral Channel (See Fig. 2).

3.3.2 Swan River.

The Swan River Management Strategy (1988) recognised the increasing boating pressure on the Swan and Canning Rivers and recommended that ocean boating facilities be upgraded (Recommendation 96). The marinas at both Mangles Bay and Hillarys will provide alternative facilities to the river. It is expected that Mangles Bay, with direct access to the relatively protected waters of Cockburn Sound, will be an increasingly attractive alternative.

3.3.3 Rottnest Island.

Rottnest is the most popular boating destination in W.A. Due to resistance to a public marina on the island, private ownership of moorings and increasing boat ownership, it is becoming more difficult for the boating public to moor at Rottnest. Furthermore, surveys of the seagrass meadows around the island (Lukatelich et. al.,1987) show that about 3.2 hectares have been destroyed by swing moorings. This represents approximately 1.9% of the meadows surrounding Rottnest Island.

Mangles Bay, providing a similar holiday recreation/ accommodation environment to the Island, could become an alternative destination which will be better able to cater for the boating public.

3.3.4 State Marina Strategy

DMH, in co-operation with other Government instrumentalities, is developing a strategy for marina and related development on the Western Australian coast. Although the development of this strategy has only just begun, a recreational marina in the Rockingham region is seen as an important element in the marina requirements for the Metropolitan area, complementing as it will the Hillarys Marina to the north, and is likely to be included in the State Plan.

3.4 Land Development.

DMH has a statutory responsibility to provide safe mooring facilities for the boating public. In January,1986, the Government directed that:-

> **"the Department of Marine and Harbours develop a more commercial approach to boat harbour and marina projects aimed at optimising the functional and financial returns from each project."**

Essentially, this means that a project such as the proposed Mangles Bay Marina should be financially self-sufficient. Fees charged for public pens in WA are generally sufficient to cover the capital and maintenance costs of the pens, but do not contribute significantly to the cost of the infrastructure (eg. breakwaters, dredging, landfill, services, access roads, parking, etc). In order for the project to be financially self-sufficient it is necessary to develop associated land as a source of revenue. Commercial studies commissioned by DMH indicate that with the land area available, the price structure and intensity and type of development proposed will generate the required revenue, and accordingly, on receiving environmental approval, the agreed project will be offered to the private sector for development.

4.0 EVALUATION OF ALTERNATIVES

4.1 Alternative Sites

Several recent development proposals for the coast south of Perth (see Fig. 2.) have made some provision for sheltered boat moorings and ancillary support facilities. These proposals include:-

4.1.1 Secret Harbour.

This is a private development, authorised by an Act of Parliament, which originally proposed to centre a large urban population around an excavated harbour basin and canal system located south of Becher Point. The EPA assessed the proposal in 1982 (Department of Conservation and Environment, 1982) and recommended environmental approval subject to 33 conditions. However, the final development plan, which now has planning approval, is for a dry lot sub-division and does not include any harbour or canal elements.

4.1.2 Westport Canal Estate.

This is a private subdivision proposal located in Warnbro Sound immediately north Becher Point. In its original form it incorporated canals and some harbour area. The proposal was assessed by the EPA in 1987 (EPA,1987) and found to be environmentally acceptable subject to 10 conditions. However,current planning indicates that it is unlikely that a harbour will now be included in this development.

4.1.3 Port Kennedy.

This concept proposes a harbour on the north side of Becher Point with holiday accommodation developed on the adjacent Crown land. The proposal was assessed by the EPA in 1989 (EPA, 1989) and environmental approval was granted subject to 9 conditions.

4.1.4 Safety Bay Launching Ramp/Commercial Basin.

This was a concept developed by DMH for the Shire of Rockingham and located at the northern edge of the Warnbro Basin. It proposed trailer boat launching and a small fishing industry base. Funding was not available and the proposal was not pursued.

4.1.5 East of Mangles Bay.

In the PER for the 1985 Mangles Bay Marina proposal, John Holland Construction (JHC) considered four sites between the Causeway and the CBH jetty. Their preferred site was immediately east of, and abutting, the Causeway.

4.2 Alternative Proposals.

The Department reviewed the original John Holland proposal and considered the consequences of the"do-nothing" option. Variations to the preferred option were also considered.

4.2.1 John Holland Proposal.

The original 1985 proposal prepared by JHC was reviewed by DMH. It was decided that this option would not be pursued because:-

* In responding to the PER, the Water Authority of Western Australia (WAWA) raised strong objections to any form of residential development within one kilometre of the Point Peron treatment works. Short term holiday accommodation is considered to be an essential component of the new marina.

* There was insufficient mooring capacity to serve the perceived longterm needs of the community.

* There was not enough land area available to provide the income required to make the marina financially self-sufficient.

* The Causeway and adjacent land is presently controlled by the Royal Australian Navy (RAN), and there was no guarantee that the land would be made available to the State.

These issues have been resolved by the present proposal.

4.2.2 The "Do-nothing" Option.

The need for a small boat marina to serve the south metropolitan area and provide a safe refuge has been justified in preceding discussions. This need has been recognised in the several studies of the area and it is also expected that it will be an important element of the state strategic marine development plan. The "do-nothing" option would not provide the marine facilities which are clearly required in the region and is not, therefore, considered an acceptable alternative.

4.2.3 Development Options

The EPA reviewed a draft of this document and expressed concern about the amount of seagrass which would be lost if the project proceeds. An alternative layout (Option 2) which would reduce the impact on the seagrass meadows was considered. This alternative involved moving the marina a little further east to locate the landfill and dredging more centrally over the areas of patchy meadow, and reducing the total area of landfill. Although this variation reduces the damage to the seagrass meadows, it is not favoured by the Department of Marine and Harbours because:-

* it reduces the extent and variety of land-based facilities which can be provided, including public open space.

* it will intrude upon development proposals for the rest of the Cape by reducing the buffering effect resulting from the graded development between the more commercial northern side of the marina and the principally accommodation oriented southern side

* the reduction in available land will provide diminished returns on the investment by reducing development/lease opportunities.

* there will be a reduction in the amount of beach available to the public. It will only be possible to provide about 200 metres of beach on the east side of the landfill area to replace the beach taken by the development. This is a significant reduction in the approximately 500 metres of protected, family-oriented beach close to facilities which is a feature of the preferred option.

The EPA reviewed a further draft of this document which included Option 2 outlined above, and were still not satisfied that the impact on the seagrass had been kept to an acceptable level. However, they did state that another option, more closely aligned to the area covered by the original John Holland proposal (which already had environmental approval) would be acceptable. In response to this, Option 3 has been included in this PER.

This option places the marina adjacent to the Garden Island Causeway. The Navy have indicated that, for security reasons, they would oppose a development which is attached to the causeway, so this proposal relies on a separate area of landfill. Although this variation also reduces the damage to the seagrass meadows, it is not favoured by the Department of Marine and Harbours because:-

* it reduces the extent and variety of land-based facilities which can be provided, including public open space.

* it will intrude upon development proposals for the rest of the Cape by reducing the buffering effect resulting from the graded development

* the reduction in available land will provide diminished returns on the investment by reducing development/lease opportunities.

* there will be a reduction in the amount of beach available to the public. It will not be possible to replace the beach taken by the development.

* all the reclaimed land and much of the available foreshore land is within the buffer zone set by WAWA around the Point Peron Sewerage Treatment Works. There are restrictions on the types of development permitted in this zone. All form of residential development are particularly excluded. This will prevent the inclusion of a boatel/ hotel in the marina proper, restrict the variety of other type of accommodation and limit chalet development to a relatively small area of foreshore land east of the marina.

* The type of development which can be undertaken and the limited variety of accommodation which can be provided will make the marina a less desirable destination, and so is unlikely to provide the alternative destination to Rottnest which was expected with the larger proposal

Some of these problems would be overcome if additional land south of Cape Peron Road were included in the development. However, this would involve the acquisition of more land,

and would conflict with the recommendations of the Cape Peron Study by requiring more commercial types of development on the Cape Peron mainland.

These variations are discussed in more detail in Section 5.11 as part of the description of the preferred option.

4.3 Preferred Option

Both DMH and the Marina Consultative Committee consider that the selected site in Mangles Bay is the most suitable location for the proposed marina. There is an existing community in Rockingham which is in need of a safe home base for it's boats and, as discussed in Section 3.1, several studies have identified the preferred site as suited for marina development. The site is on a north facing coast and, with the causeway and islands to the west, is protected from strong winds, particularly those from the south-west quadrant, and from deep water swell waves. There is a complementary relationship between marina usage and the existing holiday/recreational usage of Cape Peron. The area is already utilised for both swing mooring and boat hardstanding.

The site is approximately 40 kilometres from central Perth at the southern end of the South-West Corridor and will be served by a major new traffic route to the Garden Island Causeway.

Secret Harbour and Westport no longer include a marina element. Port Kennedy is remote from existing population centres and services and even if the final development does include a marina, the marine component is secondary to the associated real estate development and would best serve the new local population. As this is a private developments, it could not be guaranteed that the marine component would provide the most appropriate facilities and services for the people of Western Australia.

The Safety Bay Launching Ramp/Commercial Basin Concept was basically a protected launching ramp with some pens attached for use by commercial fishermen. The concept was too limited to provide the required complete and long term facilities for the south metropolitan region which can be provided at Mangles Bay.

Cockburn Sound was identified in the PA Australia Report (1981) as the most popular ocean boating area in the State, and it is important that it is adequately serviced. Neither the Port Kennedy proposal or the Safety Bay proposal would give direct access to the Sound.

The coastline between Hymus Street and the CBH jetty was investigated by JHC and considered less suitable than the preferred site for the following reasons:-

* narrow foreshore with adjacent residential and commercial areas limit available developable land

* probability of conflict with existing residential and commercial users

* between Palm Beach and Winlass St the sea floor slopes steeply to 15 metres only 120 metres offshore, and the cost of breakwaters, landfill and jetty construction in this depth of water is prohibitive

* tidal flushing is and important mechanism for maintaining water quality in a marina basin. As the water gets deeper, tidal flushing becomes less effective and water quality can deteriorate.

DMH looked closely at the coastline from Hymus Street to Jervoise Bay and, for the same reasons as JHC, concluded that there were no suitable alternative sites.

Water depth at the proposed site is generally less than 4.0 metres, and the site is relatively well protected. The shallow water and natural protection will help to keep construction cost down.

As an added benefit, the marina development will offer the opportunity to change the perception of the area and could act as a major catalyst for tourism development in the region.

The marina proposal presented in this report has evolved through a number of stages. The initial concept was conceived by DMH. This concept recognised the need for land development, both for the marina infrastructure and to provide a financial base. However, the design was based primarily on navigation and engineering requirements. Further input was then sought from various groups, mainly through the Marina Steering Committee, but including the City of Rockingham, the Cruising Yacht Club and various government departments. This consultative process confirmed and refined the suggested family oriented holiday and recreational theme of the development and provided added input to the planning process.

Architectural consultants Hocking Patman Antill Pty Ltd. were engaged to refine the concept. This involved an intensive consultation process which included DMH, the City of Rockingham and the Committee. At the same time, Brookes Laughton Marketing Intelligence (WA) Pty Ltd undertook an evaluation of the marketing potential and carried out a series of financial analyses. The preferred development concept as presented in this PER is a result of input from all these groups, and the Marina Consultative Committee is satisfied that this proposal will adequately and economically serve the boating needs of the region.

5.0 DESCRIPTION OF PROPOSAL.

5.1 Overall Concept.

The proposed marina will have an ultimate capacity of around 500 pens and cater for boats up to 20 metres in length. Two breakwaters each 500 metres long will enclose 15 hectares of protected waters. The 17.5 hectares of reclaimed land and 12.5 hectares of adjacent foreshore land will be developed to provide the marina infrastructure and boat oriented recreational/tourist facilities with the emphasis on family type holiday accommodation (see Fig. 1a).

The marina will provide safe moorings and refuge for this section of the coast, and the associated land development will complement the existing holiday and recreational usages of Cape Peron.

5.2 Location.

The site for the proposed Mangles Bay marina is between the Garden Island Causeway and Hymus Street, and is some 28 kilometres south of Fremantle and about 3 kilometres west of the Rockingham Town Centre (see Fig. 2). The proposed marina will be entirely outside of the area of Naval jurisdiction adjacent to the causeway (see Fig. 3). The offshore portion will be entirely within waters controlled by DMH, and the land components will be on land vested in the Minister for Transport.

5.3 Land Ownership and Vesting

The following existing foreshore land will be included in the development (see Fig 4):-

* Part of 'C' class reserve 32771 consisting of locations 2301 and 2328.
  This land is presently vested in the Minister for Transport (with power to lease) for marine purposes. The development will require about 2.5 hectares of the 3.29 hectares in the reserve.

* Lots 1,2 and 3 of Cockburn Sound Location 700.
  This land is held in fee simple by the Minister for Transport. Total area of the three lots is 4.4 hectares.

* Lot 5 of Cockburn Sound Location 700.
  This land is held in fee simple by the Water Authority of WA and has an area of 0.21 hectares. The Department will negotiate with WAWA to transfer this land to the Minister for Transport in exchange for a drainage reserve over the existing drain in lot 3.

* Part of 'C' class reserve 27853 consisting of the 1.71 hectares of Cockburn Sound Loc. 2058 and 2.17 hectares of Cockburn Sound Loc. 2057.
  This reserve is presently vested in the Department of Sport and Recreation (with the power to lease for 21 years) for the purpose of recreation. The Department is negotiating with DSR to transfer this land to the Minister for Transport.

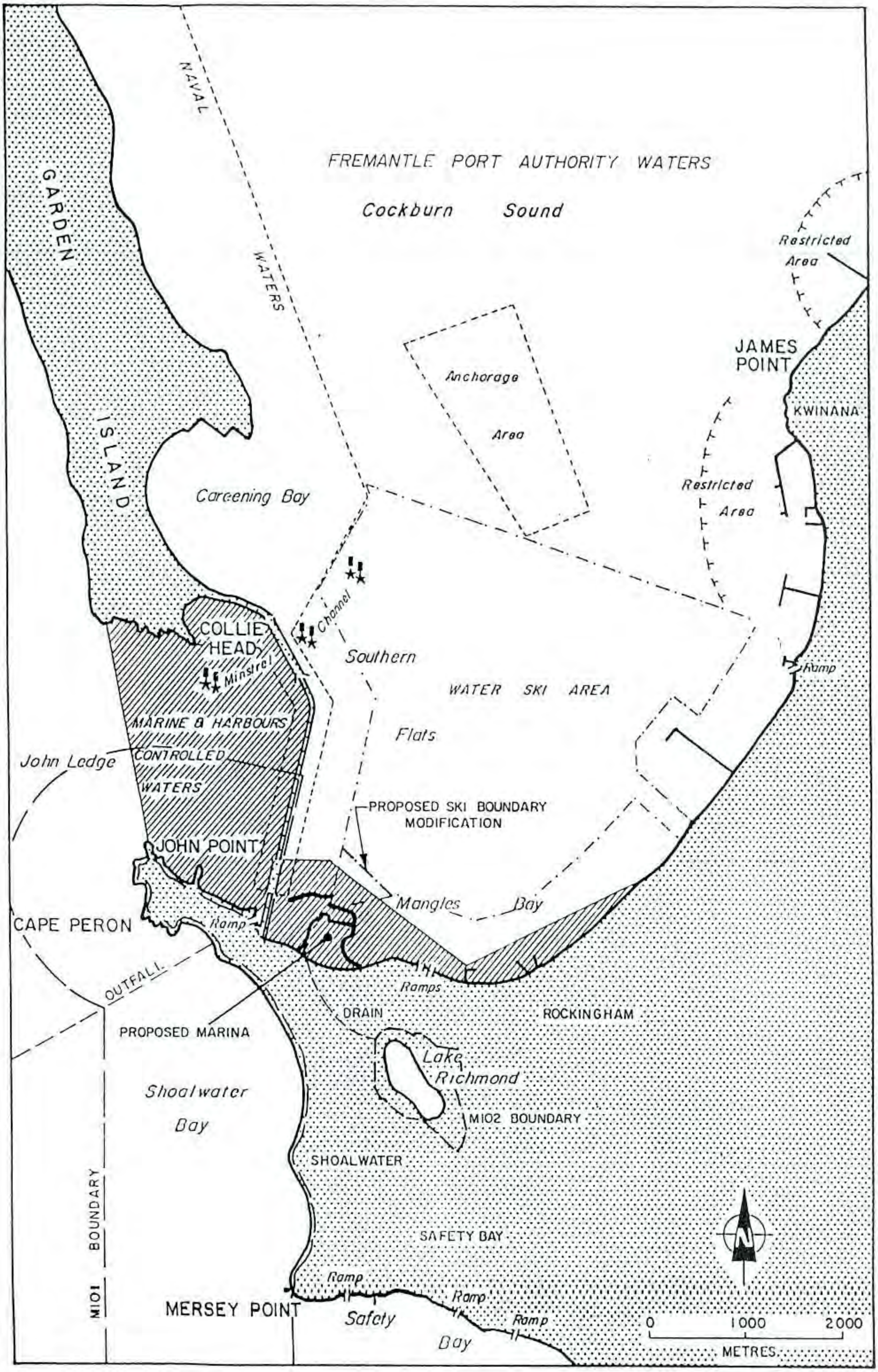


Fig. 3 JURISDICTIONS IN ADJACENT WATER AREAS

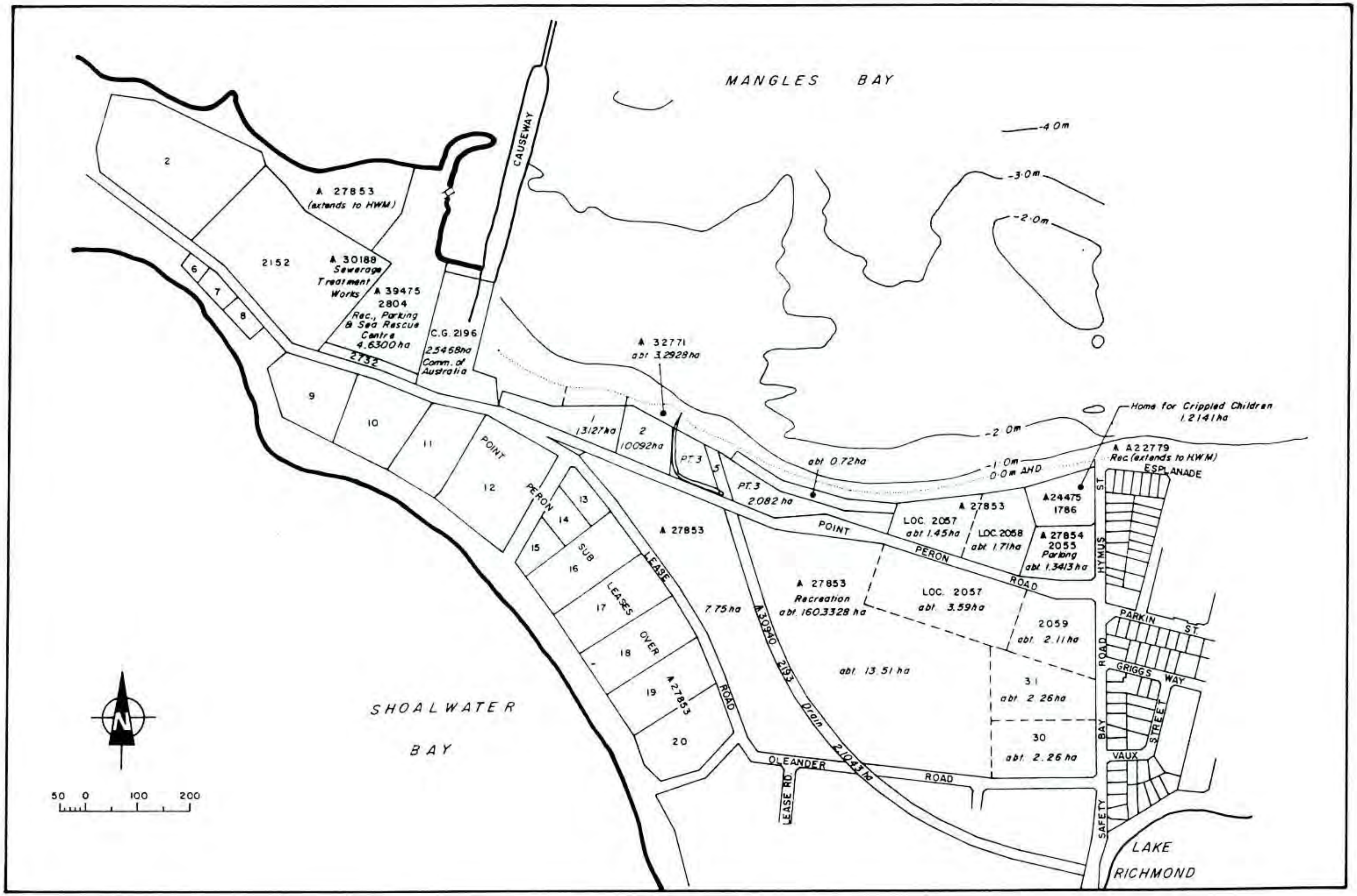


Fig. 4 EXISTING RESERVES & TENURES

* Approximately 2 hectares of Loc. 2056 on 'C' class Reserve 27853 south of Point Peron Road and adjacent to drainage reserve 30940.
  This land is presently vested in the Department of Sport and Recreation. The Department will negotiate with DSR to transfer this land to the Minister for Transport.

When the controlled access highway to Garden Island is built, there will be a need for access from this road to the development via Loc. 2056 on reserve 27853.

The newly created landfill areas will initially be vested in the Minister for Transport for Harbour Purposes. All the subject land will then be made available for development purposes.

Adjacent reserves 24475, Loc. 1786, vested in the CG Crippled Children's Seaside Home Society for the purpose of a Home For Crippled Children, and 27854, Loc 2055, vested in the City of Rockingham for parking, are not included in the development area. Loc 2196 adjacent to the Causeway, is held in fee simple by the Commonwealth Government,and is not affected by the development.

The Navy have indicated that they will require a small part of Loc. 2328 in reserve 32771 adjacent to the Causeway and it is expected that this land will be transferred to their control unless development option 3 is selected, in which case this land will be incorporated in the marina development..

The surrounding water area as shown in Fig. 3 is presently under the control of DMH. Also shown in Fig 3 are the areas adjacent to the Causeway, controlled by the Commonwealth.

5.4 Layout and Land Use.

The harbour basin will be dredged to RL -4.2 mAHD and the dredge spoil will be used to create a 17.5 hectare peninsular of landfill located as shown in Fig. 5a. This, combined with 12.5 hectares of foreshore land, gives a total of 30 hectares available for the development. The 15 hectares of harbour basin will be protected by a 500 metre long offshore breakwater to the north-west and a second, 'L'-shaped, breakwater, also approximately 500 metres long, to the north. The northern breakwater will be connected to the landfill, and public access will be permitted. Normal pedestrian access will not be possible to the offshore breakwater. The main harbour entrance will be through the gap between the two breakwaters, and an entrance channel 60 metres wide and 150 metres long, extending out at 35°, will connect the entrance to the RL -4.2 mAHD contour. The northern offshore breakwater will cover about 1 ha, and the entrance channel will require about 1 ha of dredging.

All of the western, and most of the northern, edges of the landfill will be protected by revetment walls. The remaining 90 metres of the northern edge is to be used for ferry landings, and will be protected by a vertical land backed wharf face. To the east of the ferry wharf, a land-backed jetty will be built over the revetment wall for use as short-term mooring by day visitors. The eastern edge, between the northern breakwater and the natural shoreline, will be formed into a public beach. This beach will be only marginally shorter than that which will be lost to landfill on the original shoreline.

Public access will be provided all around the land/water interface.

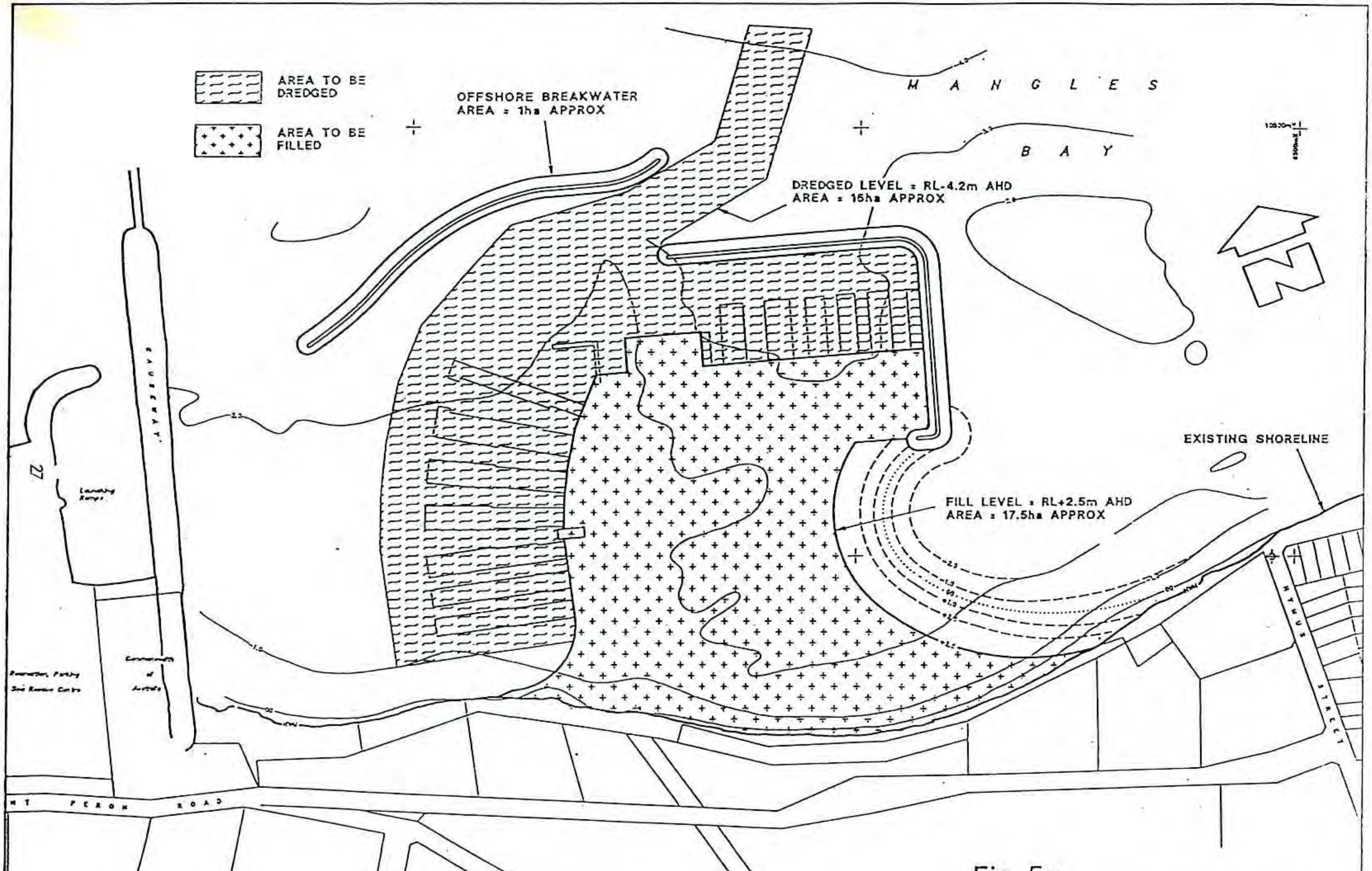


Fig 5a
DREDGING & LAND FILL

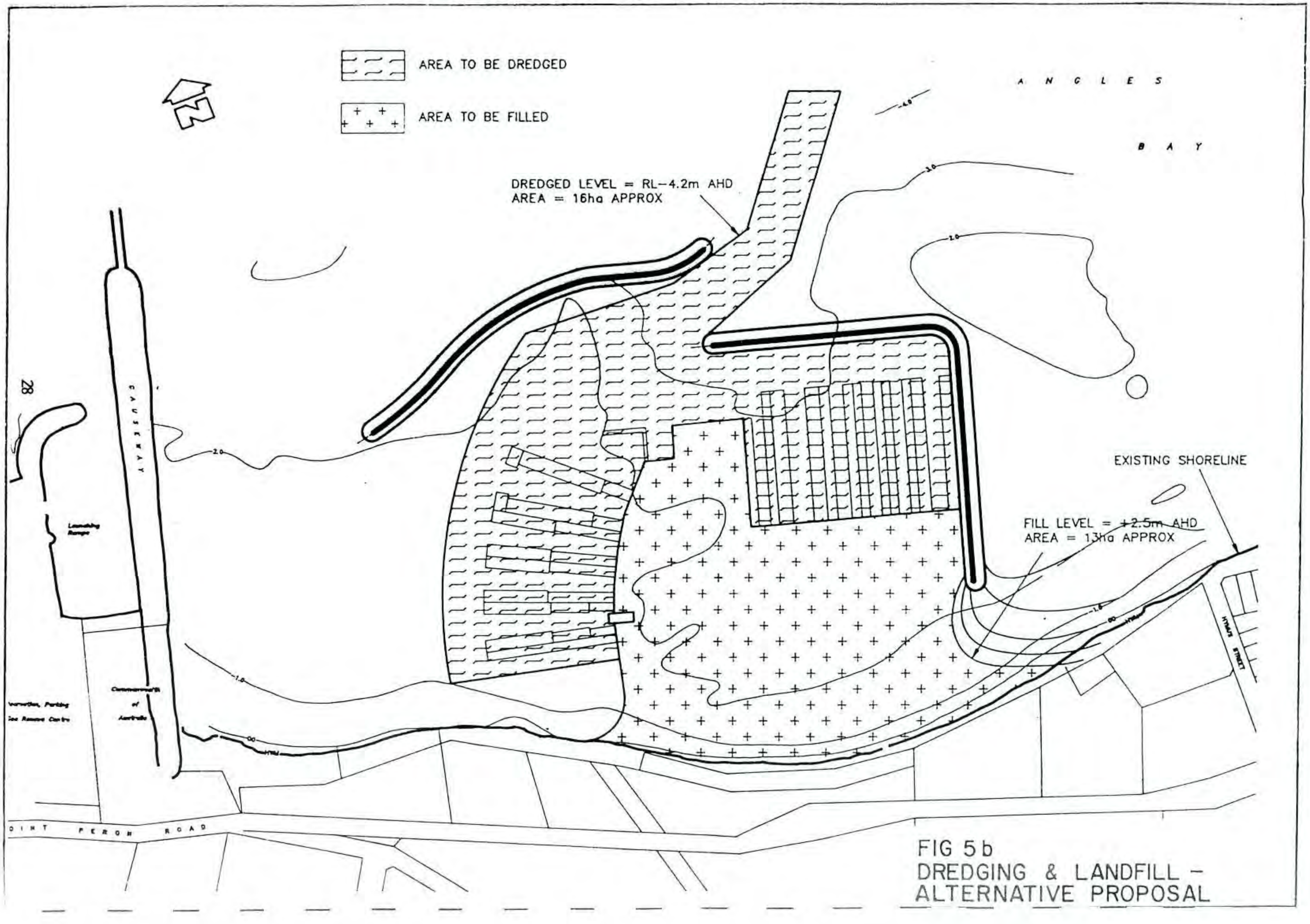


FIG 5b
DREDGING & LANDFILL –
ALTERNATIVE PROPOSAL

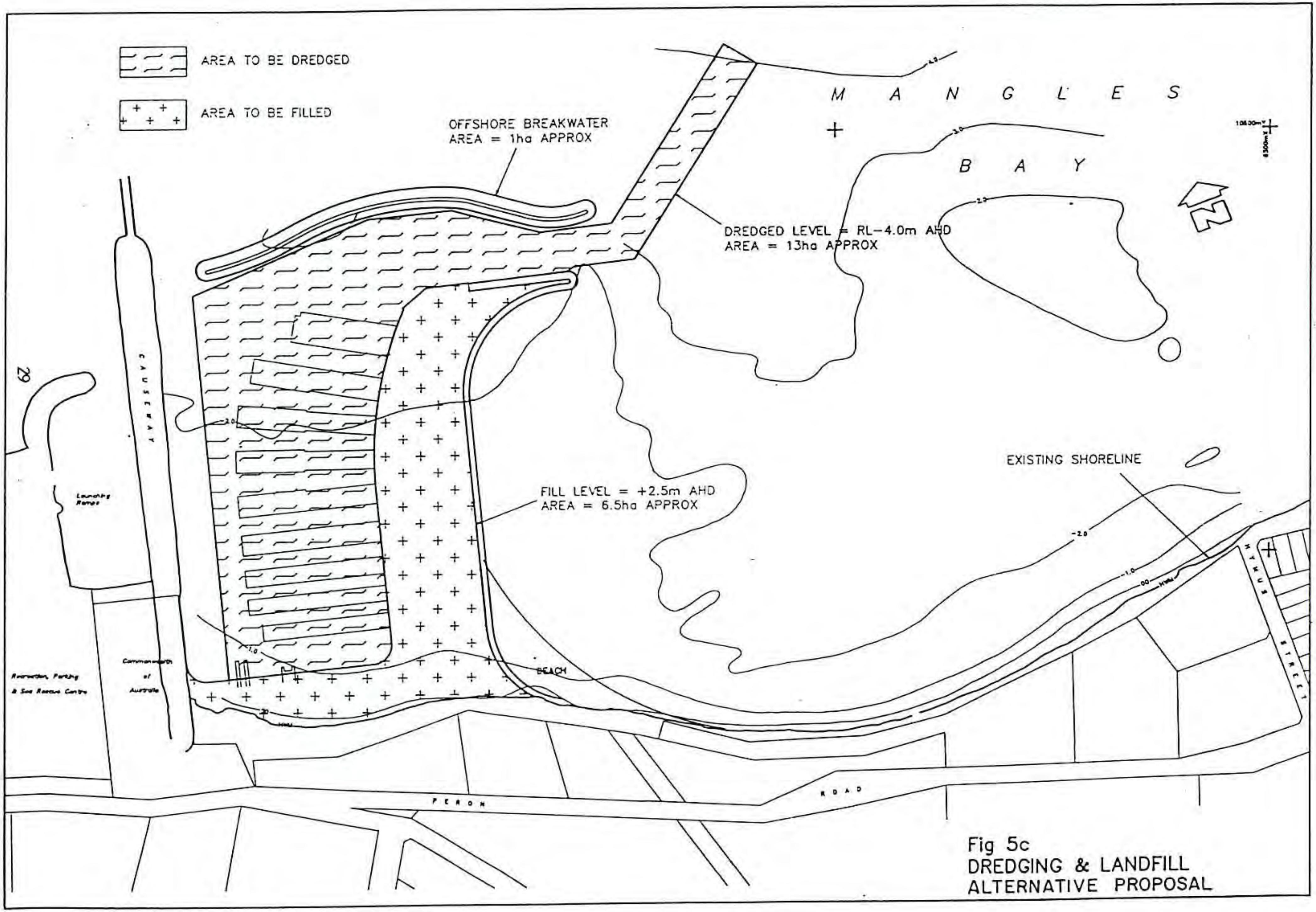


Fig 5c
DREDGING & LANDFILL
ALTERNATIVE PROPOSAL

Eight fixed mooring jetties, each 150 metres long will be built out from the western revetment. These eight jetties will have a total of 360 pens of which almost half will be for boats up to 8 metres. The largest boats catered for will be 20 metres long. The pens will be built in stages, dictated by demand, and will be available for long term lease by the general public.

A further five mooring jetties will be built out from the northern revetment between the land backed jetty/ferry wharf and the northern breakwater. A row of pens will also be built out from the breakwater. There will be 150 pens in this section, 24 of which will be set aside for the exclusive use of the resident Yacht Club. The remainder will be available for short term rental by visitors enjoying the marina facilities. Depending on usage compared to demand for permanent pens, some of the short-term pens may eventually revert to permanent moorings.

A service jetty incorporating the fuel supply and sewage pumpout facilities will be built out from the north-west of the landfill area, close to the main entrance.

The 17.5 hectares of reclaimed land and the 12.5 hectares of available foreshore land will be developed to provide a recreational tourist facility aimed primarily at the family holiday market. This is in keeping with the present and proposed usages of Cape Peron.

Vehicle movement within the development area will be limited, but pedestrian and cycle access will be encouraged. Land superlots will be leased for suitable private development. Each leaseholder will be responsible for their own parking requirements. The parking for the public facilities including the boat pens, beaches and public hardstanding areas will also be provided.

The major elements of the proposed land development are shown in Fig 1a. and will include:-

Chalets	6.63 ha
Boatel	1.36 ha
Yacht Club	0.65 ha
Commercial Centre Tavern, shops, town square, restaurants, DMH and CALM offices, chandlery (including fuel, bait, boat sales, etc.)	1.81 ha
Caravan Park and camping area	2.46 ha
Lodge	0.53 ha
Sports complex Health club, tennis courts mini-golf.	1.75 ha
Light marine industry	1.45 ha
Secure boat hardstanding, dingy/trailer park	2.56 ha
Public open space, green belts, conservation areas, foreshore public space, public toilets, picnic areas, etc	8.00 ha
Roads and public parking	3.18 ha
TOTAL	30.38 ha

5.5 Services.

All necessary services including power, water and telephone are available at the site. Agreement in principle has been reached with the Water Authority for injection of sewerage from the marina development into the pressure main to the Point Peron Treatment Plant.

5.6 Stormwater Runoff

The internal drainage system will be designed to dispose of runoff on-site for an up to 5 year average recurrence interval rainfall. Rainfall in excess of this will be discharged directly to the ocean via overflow pipes. Although direct discharge to the marina is not expected for any other than storm runoffs, if there is any direct discharge it will be via silt and oil traps.

5.7 Access.

Initial road access to the development will be via Oleander and Lease Roads to Point Peron Road. Eventually, it is proposed to close Point Peron Road between Hymus Street and the development. This is intended to reduce vehicular movement through the primarily holiday residential areas.

A limited access highway to the Garden Island Causeway is planned, and eventually vehicular access to the marina will be from this road. Point Peron Road will not be closed until this alternative access road is completed.

A railway reserve was set aside to allow for rail access to the container terminal. However, when the Cape Peron Study is finalised, DPUD will take steps to cancel this reserve.

Vehicular movement through the development will be restricted as heavy traffic movement is not considered compatible with the proposed recreational/holiday accommodation theme. Pedestrian and cycle movement, on the other hand, will be encouraged with the provision of a network of dual use pathways.

Apart from the boat storage areas, marine industry sites, and tourist/recreational accommodation, the development area will be fully accessible to the public. This includes all beaches, foreshore areas, waterfront areas, and the breakwater. The commercial and recreational facilities will be available for use by the general public as well as by resident holidaymakers.

5.8 Construction Schedule and Method.

The general construction sequence will be:-

* construct the western and northern bunds and revetments for access to the northern breakwater

* construct the northern breakwater

* construct temporary access from the northern breakwater to the western breakwater, build the western breakwater and remove the access

* as soon as there is protected water, commence dredging in the lee of the northern breakwater. Place the dredge spoil on the alignment of the eastern beach. This will create a fully bunded area into which the remainder of the spoil can be placed

* continue dredging in the marina basin, placing spoil in the bunded area. Place imported fill. Level fill and foreshore area to grade. Fill areas to be stabilised and seeded with hydromulch at the earliest time.

* construct 275 pens in the northern and western section of the basin to cater for the latent demand plus about two years growth. Complete land-backed wharfs and boat ramp.

* seal and fence boat hardstanding area.

* subdivide, construct roads and install services

* Seal public parking areas.

* lease development sites

* relocate drain and develop industrial sites for leasing

* install pens as required until the full number are in place

The armour and core for the breakwaters and revetments will be supplied by contractors, and at this stage it is not possible to define exactly from which quarries the material will come. However, economic considerations indicate that the source will probably be one or more of the established quarries in the adjacent Spearwood Ridge. The closest, and largest, of these is in Millar Road. There are other possible quarries further north between Munster and Wattleup.

An estimated 660,000 cubic metres of fill will be required. Of this 340,000 cubic metres will be supplied from the dredging of the harbour basin. The remaining 320,000 cubic metres will be imported from existing land based sand quarries.

The construction access will go through the existing hardstanding areas. Owners of affected boats will be encouraged to relocate off-site temporarily. The remainder will be moved temporarily, probably to the eastern end of Lot 3.

The moorings in the construction site will be removed as required. Some of the boats on the moorings will be relocated by their owners, either off-site or to the temporary hard standing. It will be possible, as a temporary measure, to place up to about thirty boats on swing moorings in the protected waters created by the construction. Others will be moved into completed pens.

The two camps within the Harbour Reserve will be closed when the leases expire in 1993.

5.9 Operation.

Once environmental approval of the proposal has been obtained, and the extent of the approved project has been agreed, expressions of interest in the development will be called from the private sector.

Ownership of the project site and the long term responsibility for management, including environmental management, are matters which will be decided in negotiation with the project developers. The yacht club site will be available for lease to a recognised Yacht club. The boat hardstanding area will be made available to the general public.

5.10 Project Lifetime.

Although the marina is intended to be a permanent public facility, some elements will have a limited life. Jetties and mooring pens, for example, usually have a design life of around 30 years. Buildings are usually designed with a longer life, but often their original functions change and they may be modified or replaced well before their design life is reached. However, all functions will remain consistent with the recommendations of the Cape Peron Study.

5.11 Alternative Development Options

The EPA reviewed a draft of this document and were concerned that 18.4 hectares of healthy seagrass meadow and about 13.7 hectares of patchy meadows (damaged by swing moorings) would be lost if the project proceeds. An alternative layout (Option 2) which would reduce the impact on the seagrass meadows was considered and is shown in Fig 1b. Option 2 involves moving the marina a little further east to locate the landfill and dredging more centrally over the areas of patchy meadow, and reducing the total area of landfill.

The EPA reviewed a further draft of this document which included Option 2 and were still not satisfied that the impact on the seagrass had been kept to an acceptable level. However, they did state that a third alternative, more closely aligned to the area covered by the original

John Holland proposal (which already had environmental approval) would be acceptable. A third option was therefore considered.

5.11.1 Development Option 2

In this option, the general layout and pen capacity is retained, but the area of landfill is reduced to about 14 hectares (including the off-shore breakwater). The area to be dredged remains the same at about 15 hectares for the basin and one hectare for the entrance channel (Fig 5b). This reduces the seagrass loss to about 13.3 hectares of healthy seagrass and 12.7 hectares of patchy seagrass. This compares to a loss of about 10 to 15 hectares of healthy seagrass in the original John Holland proposal.

The total amount of land available for development is reduced to 11.0 hectares of reclaimed land and 12.5 hectares of existing foreshore land presently controlled by the Minister for Transport.

Reduction in the mooring area is not considered an option. The 500 pens planned for the preferred option are expected to be filled in 15 to 20 years. Reducing the capacity to say 400 would see the marina full in about 10 years. This clearly does not account for the long-term needs of the State.

The major elements of the proposed land development are shown in Fig 1b. and the areas of each element are listed in Table 2. The areas for the original proposal have been included in Table 2 for comparison.

5.11.2 Development Option 3

Option 3 places the marina adjacent to the Garden Island Causeway. The Navy have indicated that, for security reasons, they would oppose a development which is attached to the causeway, so this proposal relies on a separate area of landfill.

The area of landfill is reduced to about 7.5 hectares (including breakwaters) and the area to be dredged decreases to about 13 hectares (Fig 5c). This reduces the seagrass loss to about 19 hectares. This compares to a loss of about 10 to 15 hectares of healthy seagrass in the original John Holland proposal.

The total amount of land available for development is reduced to 6.5 hectares of reclaimed land and 12.5 hectares of existing foreshore land presently controlled by the Minister for Transport.

Again, reduction in the mooring area is not considered an option, and this proposal still allows for 500 pens.

The major elements of the proposed land development are shown in Fig 1c and the areas of each element are listed in Table 2.

Land Use	Option 1 (ha)	Option 2 (ha)	Option 3 (ha)
Chalets	6.63	6.72	4.90
Boatel/ motel	1.36	1.36	-
Yacht Club	0.65	0.65	1.00
Commercial Centres Tavern, shops, town square,restaurants,DMH and CALM offices, chandlery (including fuel,bait,boat sales etc)	1.81	1.04	1.80
Caravan park and camping areas	2.46	1.99	-
Lodge	0.53	0.85	0.50
Sports complex Health club, tennis courts, mini golf	1.75	1.6	0.50
Light marine industry	1.45	2.2	0.70
Boat hardstanding, dingy trailer park	2.56	2.38	2.70
Public open space, green belts, conservation areas, foreshore public space, public toilets, picnic areas, etc	8.00	2.63	2.20
Roads and public parking	3.18	2.10	4.70
TOTAL	30.38	23.52	19.00

Table 2 Land Uses for Options 1, 2 &3

In Option 3, much of the available land is within the buffer zone, and uses are restricted. In this proposal, some of this land has been used to provide extra parking for the pens, the beach and adjacent facilities, but it is recognised that this may be modified in the final plan.

The reduction in available land in both of these alternative proposals will result in diminished returns on the investment by reducing development/lease opportunities although, in both alternatives, much of the land reduction has been absorbed by reducing public open space. This could be offset by the acquisition of more land, but expanding the marina precinct into the adjacent reserves would conflict with the recommendations of the Cape Peron Study by requiring more commercial types of development on the Cape Peron mainland.

Reducing the reclamation areas in these alternatives will allow the landfill requirements to be balanced by the dredged volume and so do away with the need to import fill. To some extent, the resultant reduction in capital costs will offset the income losses due to the reduced land area available. However, any further reduction in land area will involve a cost for the disposal of dredge spoil while reducing the income potential still further.

Apart from not having to import fill, the construction schedules and methods would be similar to the preferred option.

Although these variations reduce the damage to the seagrass meadows, they are not favoured by the Department of Marine and Harbours because:-

* they reduce the extent and variety of land-based facilities which can be provided, including public open space.

* it will intrude upon development proposals for the rest of the Cape by reducing the buffering effect resulting from the graded development between the more commercial northern side of the marina and the principally accommodation oriented southern side

* the reduction in available land will provide diminished returns on the investment by reducing development/lease opportunities.

* There will be a significant reduction in the approximately 500 metres of protected, family-oriented beach close to facilities which is a feature of the preferred option. In Option 2 it will be possible to provide about 200 metres of beach on the east side of the landfill area to replace the beach taken by the development, but no replacement beach can be included in Option 3.

* The type of development which can be undertaken and the limited variety of accommodation which can be provided in Option 3 will make the marina a less desirable destination, and so is unlikely to provide the alternative destination to Rottnest which was expected with the larger proposal

* in Option 3, all the reclaimed land and much of the available foreshore land is within the buffer zone set by WAWA around the Point Peron Sewerage Treatment Works. There are restrictions on the types of development permitted in this zone. All form of residential development are particularly excluded. This will prevent the inclusion of a boatel/ hotel in the marina proper, and limit chalet development to a relatively small area of foreshore land east of the marina.

6.0 EXISTING ENVIRONMENT.

The existing physical, biological and human environment has been comprehensively described in a number of reports. This PER generally contains only sufficient material to give an overall understanding of the environment of the region, although the results of specific investigations for this report have been described in detail.

6.1 Physical Environment.

6.1.1 Meteorology.

The meteorology of the Cockburn Sound area has been documented by Steedman and Craig (1979,1983). On the west coast of Western Australia, a south-west sea breeze up to about 15 m/s (29 knots) develops nearly every afternoon during summer. In winter, the sea-breeze is more westerly, and the coast is also subject to storm winds of 5 to 20 m/s (9.7 to 38.8 knots) from the south-west to north-west quadrant. Occasional summer cyclones generate winds from all quadrants. Overall, the mean wind is from the south-west at 6 m/s (11.7 knots). Quarterly wind roses are shown in Fig. 6.

Average annual rainfall for Rockingham is 829 mm, with most rain between May and August (average 600 mm). The annual average maximum temperature for Fremantle, the nearest coastal recording station, is 22.5° C, and the hottest months, with average maximums of 27.9° C and 28.8° C respectively, are January and February.

Surface water temperatures have an approximate annual range of 8°C from about 15°C in winter to about 23°C in summer. The range between lowest astronomic tide (LAT) and highest astronomic tide (HAT) is about 1.1 metres, but the actual tide range is extended by atmospheric effects. The tide is generally diurnal.

6.1.2 Oceanography.

Mangles Bay is on a north facing coast at the southern end of Cockburn Sound and is well protected from the south and west by Cape Peron, Garden Island and the Garden Island Causeway, and from the north by Parmelia Bank and Southern Flats Bank. Wave modelling carried out by DMH shows that there is no penetration to the site by deepwater swell waves down Cockburn Sound although there is some penetration through the low level bridge (see Appendix 4.).

The wave characteristics at the bridge were predicted by applying numerically generated wave transformation coefficients to hindcast offshore wave spectra. A significant wave of 0.7 metres with a period of 6.0 seconds was determined for the bridge gap. It is expected that this would be further attenuated by diffraction effects as it passed through the gap under the bridge.

The site is also subjected to sea waves from the north and north-west quadrant generated in the Sound. The 1.6 metre significant wave height reported in the JHC PER represented the maximum breaking wave height over the Southern Flats. Using the same 50 year return period

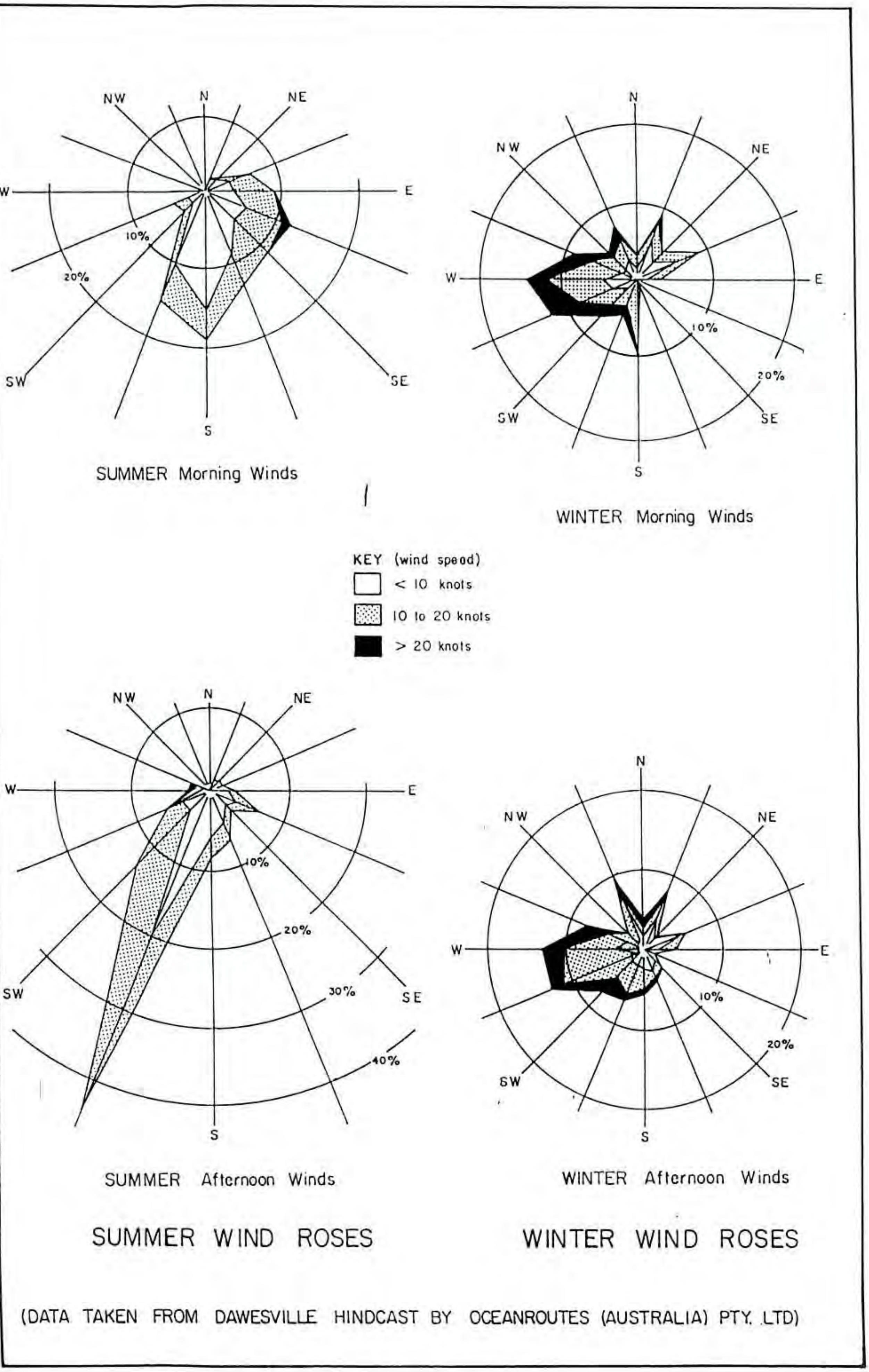


Fig. 6 SEASONAL WIND ROSES

wind speed of 22 m/s as was used in the JHC report, DMH calculated the design wave height for locally generated wind waves to be 1.2 metres with a 4.0 second period. That is, the waves which pass over the flats do not reach breaking height.

Combining the predicted swell and wind waves, a design wave height of 1.5 metres with a 4.0 second period was selected. This is considered conservative.

Current flow through the low level causeway has been studied by Steedman and Associates (1975a,1975b,1975c,1976). A statistical analysis of 214 flow values through the causeway taken between 1974 and 1976 gave a mean flow of 22.8 m^3/s out of Cockburn Sound (ie. westward) with a standard deviation of 255.0 m^3/s. The oscillating part of this flow was made up of the diurnal tide and a meteorologically driven component of considerable magnitude and variable at a time scale of days.

6.1.3 Geology and Geomorphology.

The project site is underlain by Tamala limestone over Rockingham sand. The Tamala limestone is aeolian in origin and consists largely of carbonate, skeletal material and quartz. It was deposited in the Pleistocene (100,000 years BP) as a series of north-south trending ridges. The earlier Spearwood Ridge forms the mainland shore. The central Garden Island Ridge is partly drowned and eroded and forms a chain of islands and reefs including, as the name implies, Garden Island. The Five Fathom Bank Ridge is about 6 kilometres west of the Garden Island Ridge. It is completely submerged and forms a linear shoal between Cape Bouvard and Rottnest Island. The Warnbro-Cockburn Depression lies between the Spearwood and Garden Island Ridges, and the Sepia Depression lies between the Garden Island and the Five Fathom Bank Ridges. Both depressions are about 24 metres deep (see Fig. 7).

Since this ridge and depression topography was inundated some 10,000 years ago, it has been intensively modified by erosion and superimposition of Holocene landforms. Generation, transport and deposition of sediments has resulted in the development of the Becher and Rockingham banks that have partitioned the Warnbro-Cockburn Depression into the three distinct basins of Madora Bay, Warnbro Sound and Cockburn Sound. The Rockingham bank is now a plain some 10 kilometres wide which connected to the Garden Island Ridge at Cape Peron some 2500 years ago. Since that time the coast in the vicinity of the project site has remained relatively static while the shoreline at Becher Point continues to advance. This implies that the sediments transported into the region are now trapped at Becher Point and are no longer contributing to the growth of the Rockingham Plain.

The Becher-Rockingham beach ridge plain is characterised by a landform of continuous linear ridges which mark old shorelines. The plain is generally low-lying (RL +5 to 10 mAHD) although a band of higher (RL +20 mAHD) transgressive dunes exist around the shores of Shoalwater Bay and Warnbro Sound. The Mangles Bay shoreline is backed by lower ridges.

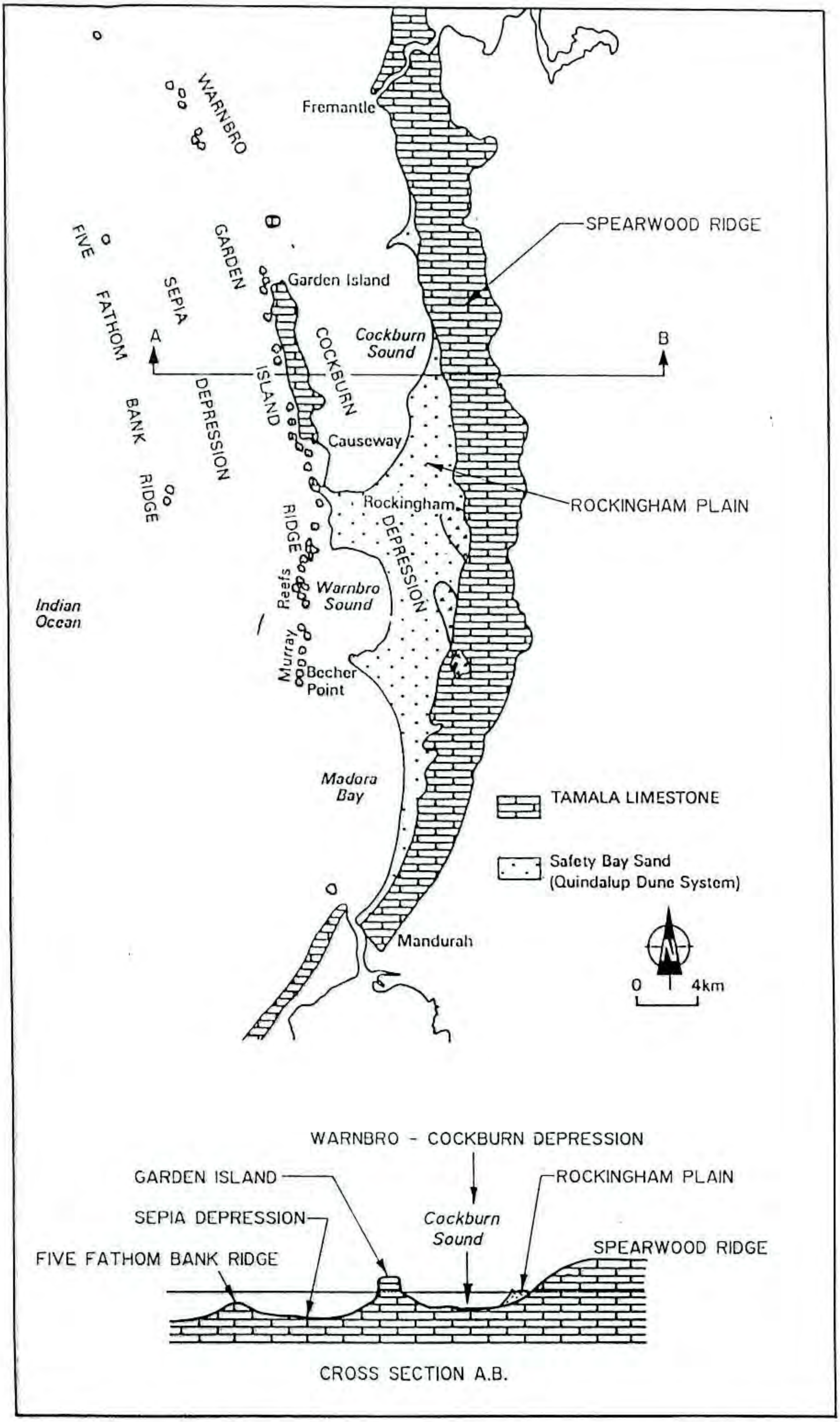


Fig. 7 GEOLOGY & GEOMORPHOLOGY ROCKINGHAM AREA

6.1.4 Soils.

Soils on the Rockingham Plain are generally immature and show little profile differentiation. The soils are typical of the Quindalup Association and have low agricultural value because of their deficiencies of trace elements. There is, however, a leaching of carbonate in the older material and some accumulation of organic material, up to a metre depth in some localised areas.

6.1.5 Sedimentology.

Particle size analysis of the sediments along the line of the Garden Island Causeway by Coffey and Hollingsworth (1971) indicate that the Becher sands here are typically fine-medium grained with a mean size of 0.25 mm and less than 5% silt. In their 1985 PER, JHC presented the results of further analysis of the upper one metre of the Becher sands just east and west of the causeway which confirmed this grading and added that the beach sands have a lower silt content.

In 1989 DMH collected and analysed vibro-cores from offshore in the vicinity of the proposed marina (see Fig. 8). The cores were taken to a depth of RL -4.95 mAHD and RL -7.75 mAHD. The sediment analysed was predominantly a grey calcareous sand, medium to fine grained with approximately 1 to 2% gravel sized shell fragments. Particle densities showed little variation and specific gravities ranged from 2.71 to 2.73. Mean grain size was in the order of 0.23-0.24 mm. The upper part of some cores was not recovered (see Fig. 10).

The RANR seabed survey of 1987 (RANR 1987) confirms that there are some areas of mud and silts in the area. The same survey confirmed that the seabed was generally smooth.

6.1.6 Coastal Processes.

From available data, it is apparent that about 80,000 m^3 of sand is moving north past Mandurah annually. Some 70,000 m^3 per year is deposited along the accreting coast south of Becher Point, and of the remainder, the bulk must be contributing to the growth of Becher Point. It is probable, however, that up to 10,000 m^3 per year is passing the Point in pulses. There is sand transport both north and south in Warnbro Sound, with the small net northerly drift possibly accreting in Safety Bay.

In Shoalwater Bay seasonal transport of a small volume of sand probably takes place with almost no net transport. Mersey Point, like Becher Point, appears to be readjusting with sand being eroded from the southern shore and accretion taking place to the north.

East of Cape Peron, around which little transport takes place, sand is still arriving from offshore. Historically, the Mangles Bay coastline was dynamically stable, and sand lost from the beach during storm events was replaced by material moving east from the Cape. Since the construction of the causeway there has been no replenishment from the west, and this material is now accumulating on the west side of the launching ramp groyne. This accumulated sand appears stable, and some vegetation has already established.

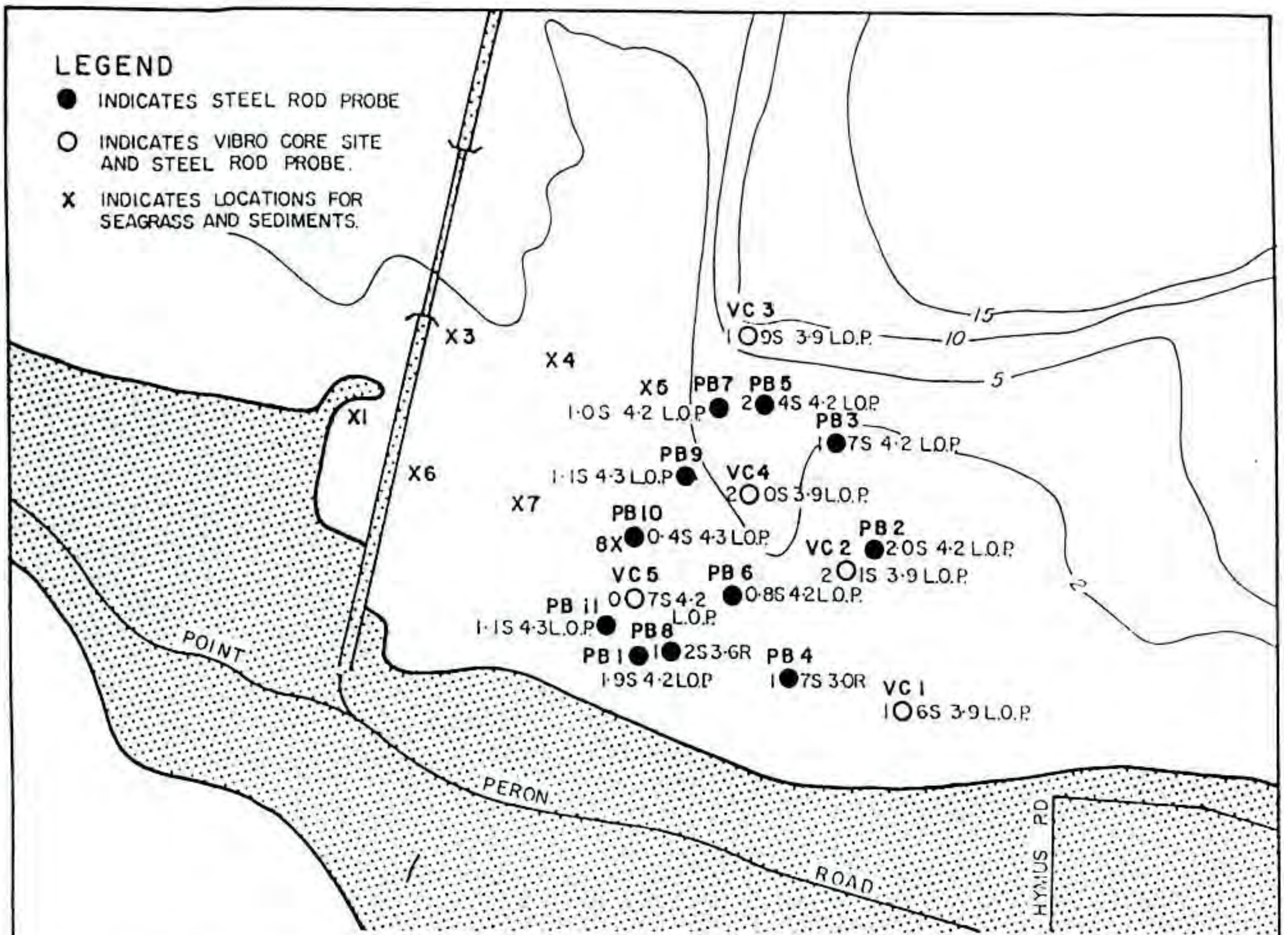


Fig. 8 CORE SAMPLE SITES

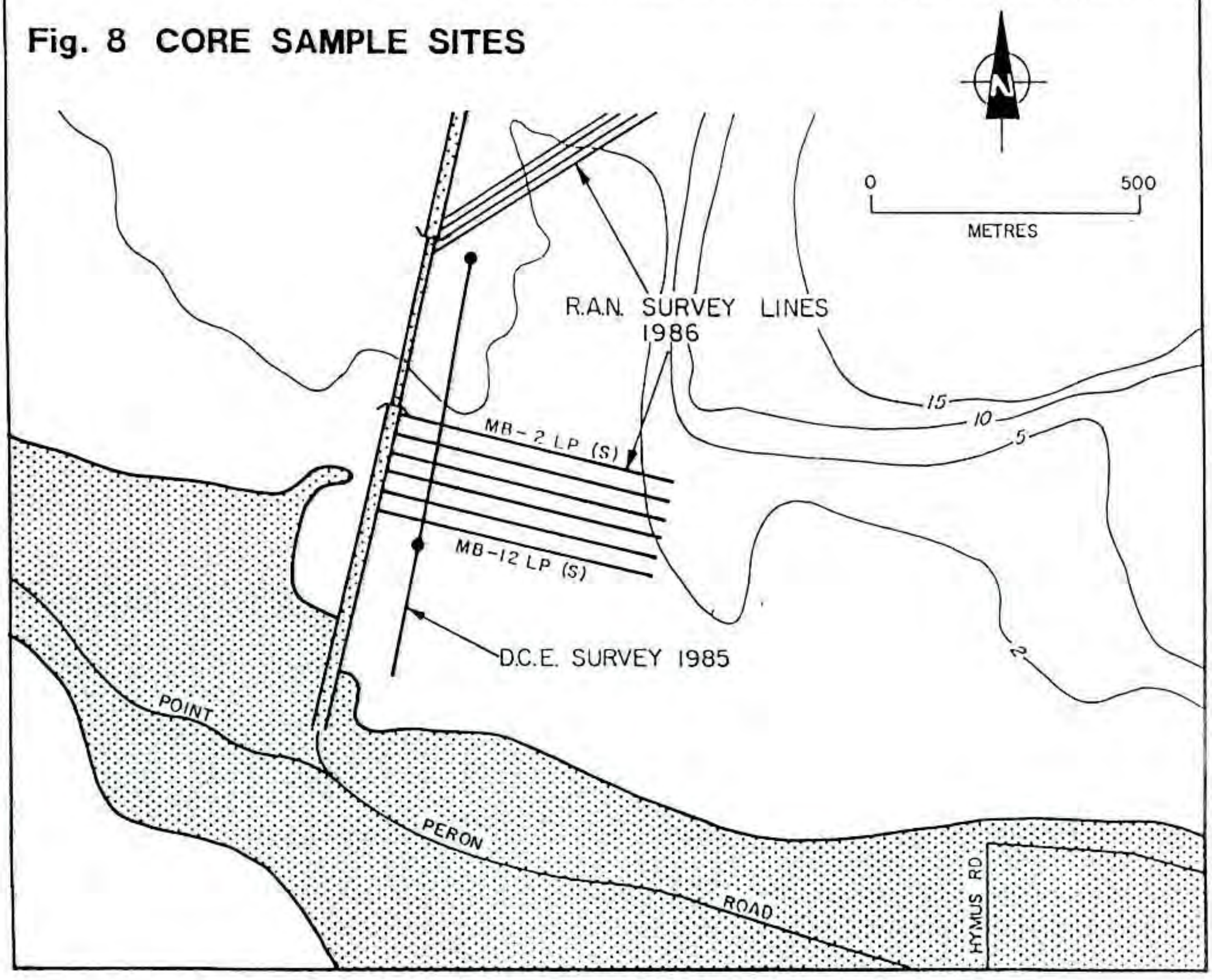


Fig. 9 TRANSECTS OF SEAGRASS MONITORING SURVEYS

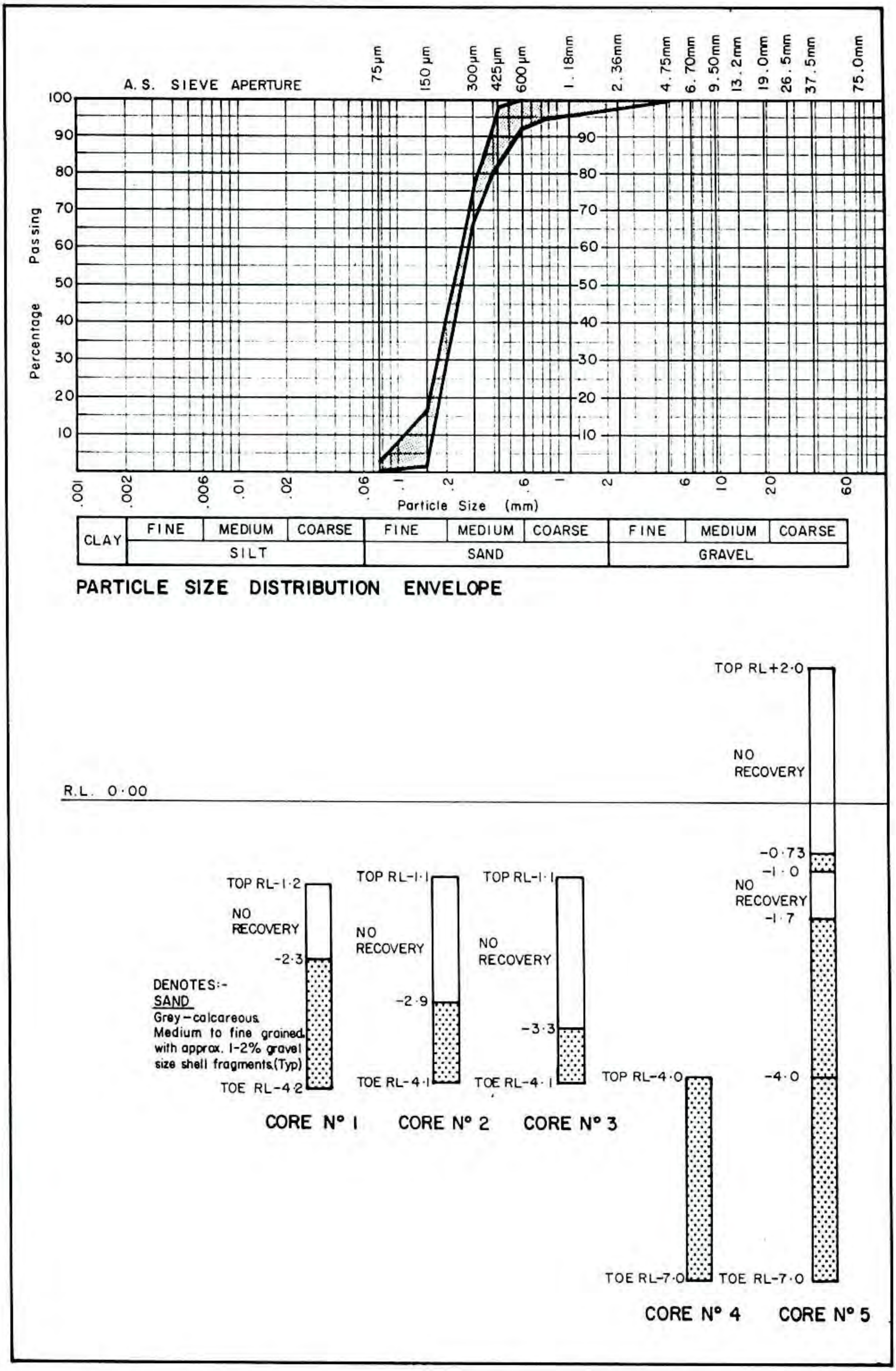


Fig. 10 CORE SAMPLE COMPOSITIONS

From the analysis of the shoreline movements plots in Fig. 11., it is apparent that the beach up to the Bell Street boat ramps has been receding steadily. The boat ramps have been acting as a groyne and have slowed the erosion to their immediate west, whilst exacerbating the erosion to the east. The beach is accreting to the west of a point about half way between Bell Street and Fisher Street.

6.1.7 Groundwater.

Groundwater in the Cockburn Sound area has been studied by Passmore (1967) and Layton Groundwater Consultants (1979). Unconfined groundwater occurs at shallow depths in the Safety Bay sands with the natural direction of flow towards the Sound. Groundwater analysis in the Rockingham area reported by Layton are considered typical for near coastal groundwaters.

6.1.8 Drainage.

The only surface drainage in the area is the open drain which carries the overflow from Lake Richmond and discharges into Mangles Bay at the marina site. The lake forms part of an urban drainage compensating scheme, receiving runoff from the predominantly urban areas of Rockingham and Safety Bay. The marina development, being downstream, will not affect the water quality in the lake. However, since the overflow drain discharges into the marina mooring basin, the discharge from the lake could affect the marina water quality.

Irregular water quality sampling has been carried out in Lake Richmond since 1970. The statistics of the sampling are presented in Table 3.

Estimates of discharges of total phosphorus, total nitrogen and inorganic nitrogen were made by WAWA (Appendix 5). The data is sparse, and results should be treated with caution. There was insufficient data to give any realistic estimates of chlorophyll or dissolved oxygen.

The statistics on the chlorine levels are slightly misleading. Drainage of Rockingham and Safety Bay localities for urban development has increased the flow of fresh water to the lake, and the salinity has fallen from about 540 mg/l in 1970 to around 100 mg/l in 1986. There was no data later than 1986 available at the time of writing.

Lake discharges have also been synthesised by WAWA (Appendix 5). Again, the available data is sparse, and the final results should be treated with caution.

The average annual discharge of the drain is 2.27 million cubic metres, and the highest flows are between July and October. The outflow hydrograph is modified by the lake, and peaks are attenuated and flows vary only slowly. A frequency analysis of maximum annual flows is given in Table 4.

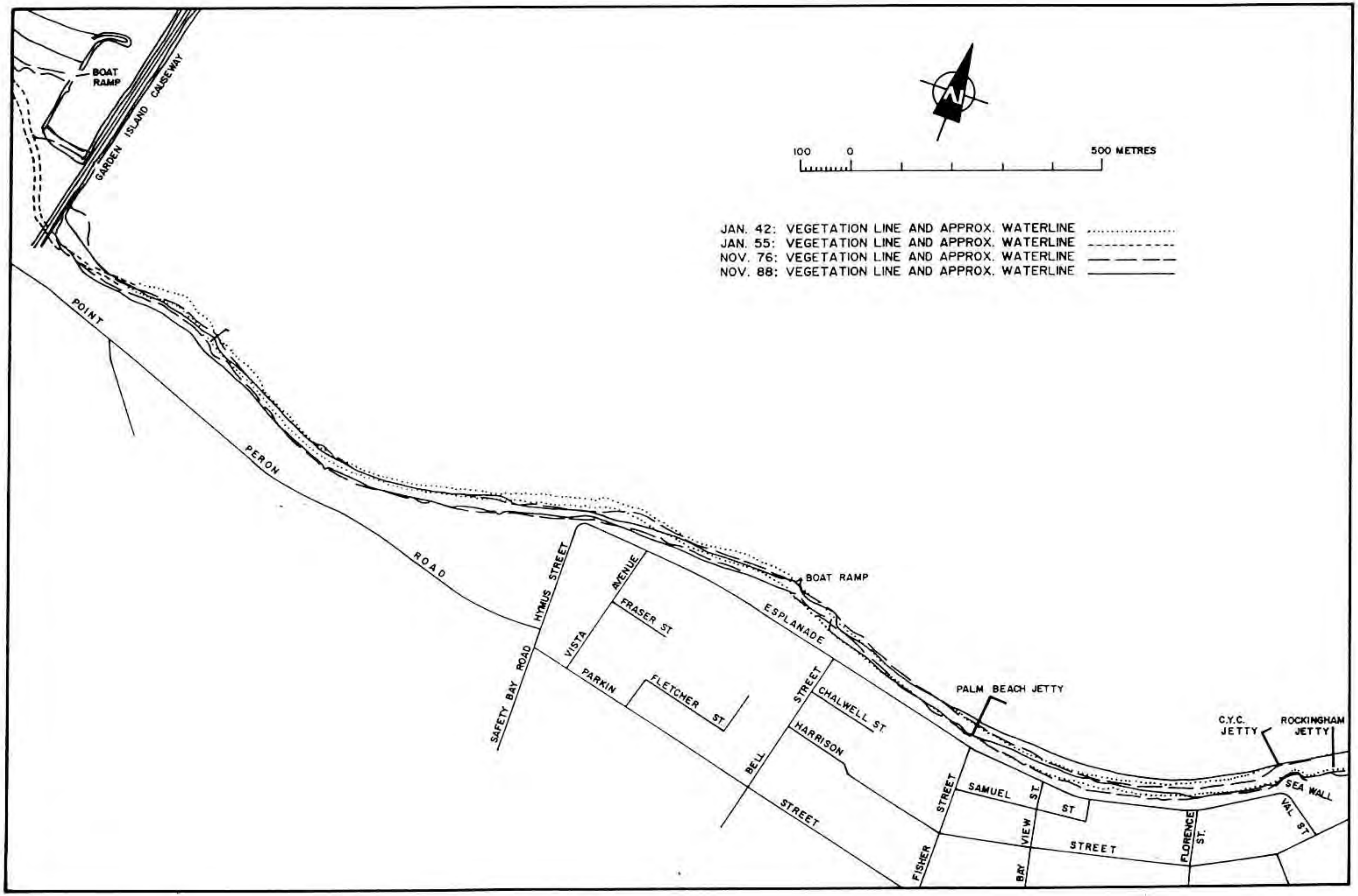


Fig. 11 SHORELINE MOVEMENTS PLOTS - 1942 TO 1988

Parameter	Units	No. Samples	Maximum	Minimum	Average
Stor. Lev.	m AHD	149	1.823	0.132	0.788
Strept Fae 100	C/100ml	10	200.	0.0	56.
Coliform Tot	C/100ml	18	460.	0.0	77.
Coliform Fae	C/100ml	35	1200.	0.0	105.
BOD 5 U/F	mg/l	29	1000.	40.0	283.
Susp Solids (Gulp)	mg/l	28	34.	1.0	6.
TDS 180C	mg/l	30	1416.	420.	607.
Surfactants MBAS	mg/l	26	0.	0.0	0.0
pH Lab	mg/l	34	9.3	7.9	8.3
N Organic	mg/l	30	4.1	0.1	0.9
N Tot U/F	mg/l	31	4.4	0.1	1.1
N Inorganic	mg/l	28	0.4	0.05	0.16
Chloride (F)	mg/l	34	540.	64.0	159.
P Tot (F)	mg/l	33	1.3	0.01	0.22
Fluoride	mg/l	23	1.25	0.6	0.84
Iron (U/F)	mg/l	25	0.17	0.0	0.06
Chromium (F)	mg/l	19	0.05	0.02	0.022
Zinc (F)	mg/l	19	0.32	0.01	0.046
Cadmium (F)	mg/l	16	0.01	0.01	0.01
Lead (F)	mg/l	19	0.10	0.04	0.043
Copper (F)	mg/l	16	0.03	0.01	0.014
Mercury (F)	mg/l	16	0.0	0.0	0.00
Ammonium as N	mg/l	4	0.25	0.05	0.137
Nitrite as N	mg/l	4	0.05	0.05	0.05
Nitrate as N	mg/l	4	1.3	0.05	0.425
Oxy dis situ	mg/l	3	13.6	9.2	10.93
Water Temp	Deg C	2	25.6	18.5	22.1
Chlorophyll	ug/l	1	0.5	0.5	0.5

Table 3. Statistics of Water Quality Data
Lake Richmond - 1970-1986

ARI (years)	95% Conf Limit	Freq. Curve	5% Conf Limit
2	232	251	271
5	326	352	381
10	382	417	455
20	429	477	530
50	481	552	634
100	514	607	716
200	543	660	802
500	576	729	923

Table 4. Frequency Curve
Lake Richmond Outflows (litres/s)

6.2 The Biological Environment.

6.2.1 Marine Ecosystems.

The marine plants and animals in the vicinity of the marina site are similar to those described elsewhere on the metropolitan coast generally and in Cockburn Sound specifically. The sandy seafloor habitat is colonised by seagrass meadows and an assemblage of molluscs, fishes, and crustacea together with epyphites (attached algae) which colonise the seagrass leaves.

In November, 1985, the (then) Department of Conservation and Environment carried out manta board surveys on a series of transects between Becher Point and Cape Peron, including one in Mangles Bay, parallel to the Garden Island Causeway (see Fig 9.). The results of this survey indicate that the dominant plant species are *Posidonia sinuosa* and *Posidonia australis*, with some *Amphibolis* species and some *Halophila ovalis*.

During May 1986 and June 1987, the Royal Australian Navy Reserve (RANR) undertook more seabed surveys, including six transects each of 500 metres at right angles to the causeway (see Fig. 9). These surveys reported Posidonia species on all transects in generally dense meadows, although some thinner areas were observed. Algae was found on 96% of observation points on the most northerly transect, and 33% of points on the second most southerly line.

6.2.2 Seagrass Distribution.

Before the industrialisation of the adjacent land areas began in the mid 1950's, the depth limit for seagrasses in Cockburn Sound was about RL -10 mAHD (similar to present-day Warnbro Sound) and covered about 4000 hectares. The Cockburn Sound Environmental Study (1979) found that by 1979, only around 900 hectares remained, generally above RL -5 mAHD (See

Fig. 12). The loss of seagrass was attributed primarily to a reduction in light supply due to excessive growth of epiphytes. Loss of seagrass in deeper water was also considered to be due in part to increased water turbidity associated with phytoplankton blooms. The Cockburn Sound Study recommended that nitrogen loads to the Sound should be reduced to improve water quality and arrest the seagrass dieback.

By 1985, the water quality in the Sound had improved substantially, and a further study was undertaken to assess the status of seagrass. Hillman (1985) found that the seagrass dieback appeared to have halted, and in some areas, notably on the shores of Garden Island and on the Southern Flats, almost 200 hectares appeared to have regenerated (See Fig. 13a & 13b). The study also found an improvement in the condition of the meadows, with the heavy epiphytic growth reported in previous studies no longer evident.

A further study by Hillman and Bastyn in 1989, (see Appendix 6) concentrated on the southern end of the Sound. The results of this study indicated that, although the main areas of seagrass meadow on the Southern flats and in the waters off the Rockingham shore have remained healthy and unchanged since 1985, there was definite evidence that the eastern fringe of the Southern Flats meadows has been receding. An area classified in 1985 as "patchy, deteriorating sea grass with mussels and fibre" (Fig. 14a) was almost entirely devoid of seagrass cover in November 1989 (Fig. 14b). It was also found that the seagrass on the eastern and southern fringes of the Southern Flats were heavily epiphytised, and those in the main boat mooring area in Mangles Bay were in poor condition, with low percentage cover and leaves that were lying flat and covered with a thick epiphytic scum.

6.2.3 Fisheries.

Although Cockburn Sound has long been a commercial fishing area supplying much of the fresh fish for the Perth market, it was not registered as such until 1977 (Fisheries Dept., 1987). The status of the fishery has, therefore, only been reported since 1977/78. Of the 29 or so species fished commercially in Cockburn Sound, scaly mackerel, pilchard and Perth herring are used as bait fish and comprise the bulk of the catch. Crabs and mussels are the most important species caught commercially for human consumption. Other, less important, species fished commercially include squid, octopus, snapper, mulloway, shark, sea and yelloweye mullet and Australian herring.

A restricted entry regime was introduced for Cockburn Sound in October 1985. This regime will remain in force until long term management plans for the fisheries are adopted.

The commercial catch has varied from about 500 tonnes to nearly 1500 tonnes since reporting began in 1977/78. Most of the variation is in the catch of scaly mackerel which ranged from 13.6 tonnes in 1978/79 to nearly 800 tonnes in 1984/85 (see Table 5.).

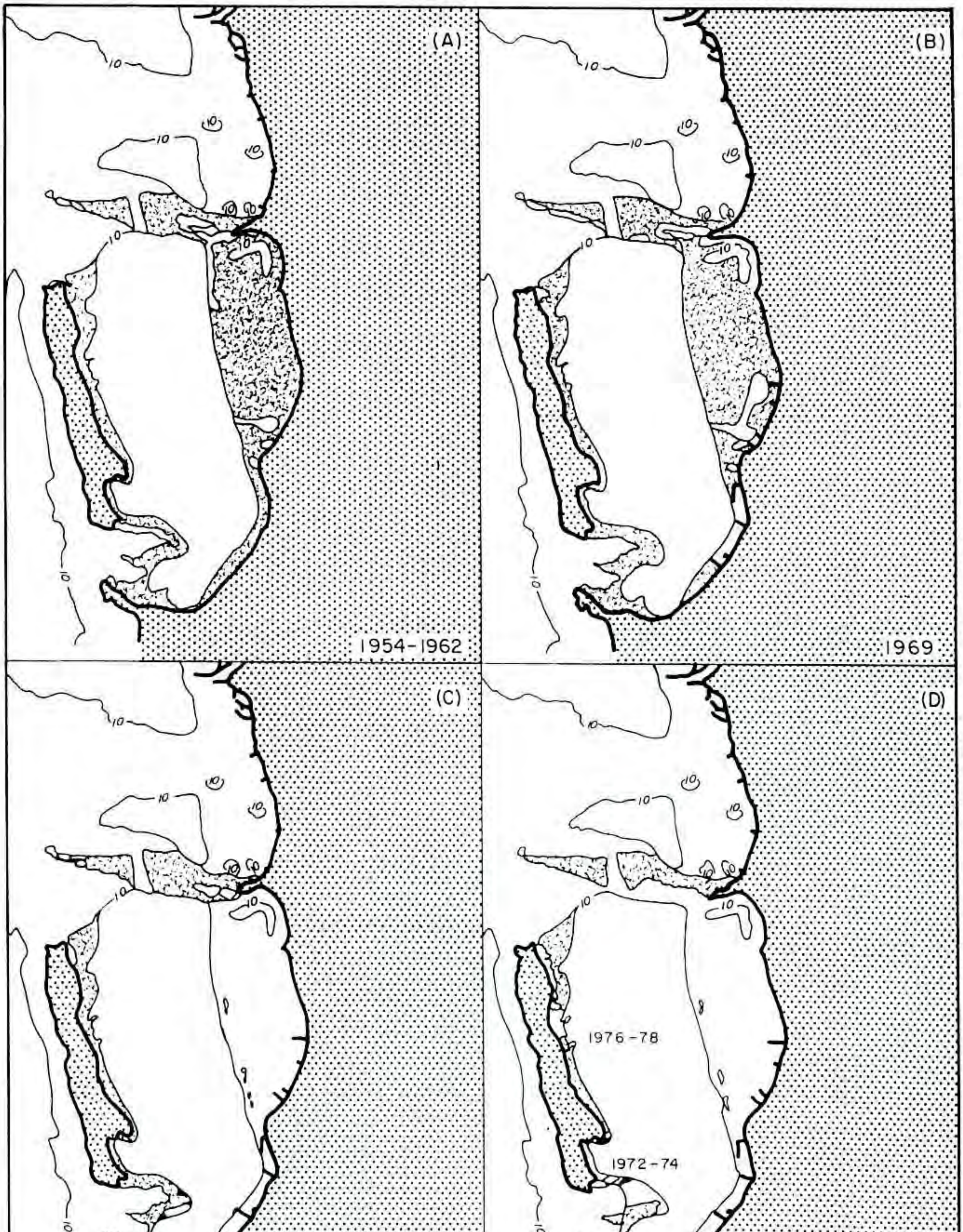


Fig. 12 SEAGRASS DISTRIBUTION IN COCKBURN SOUND - 1954 TO 1978

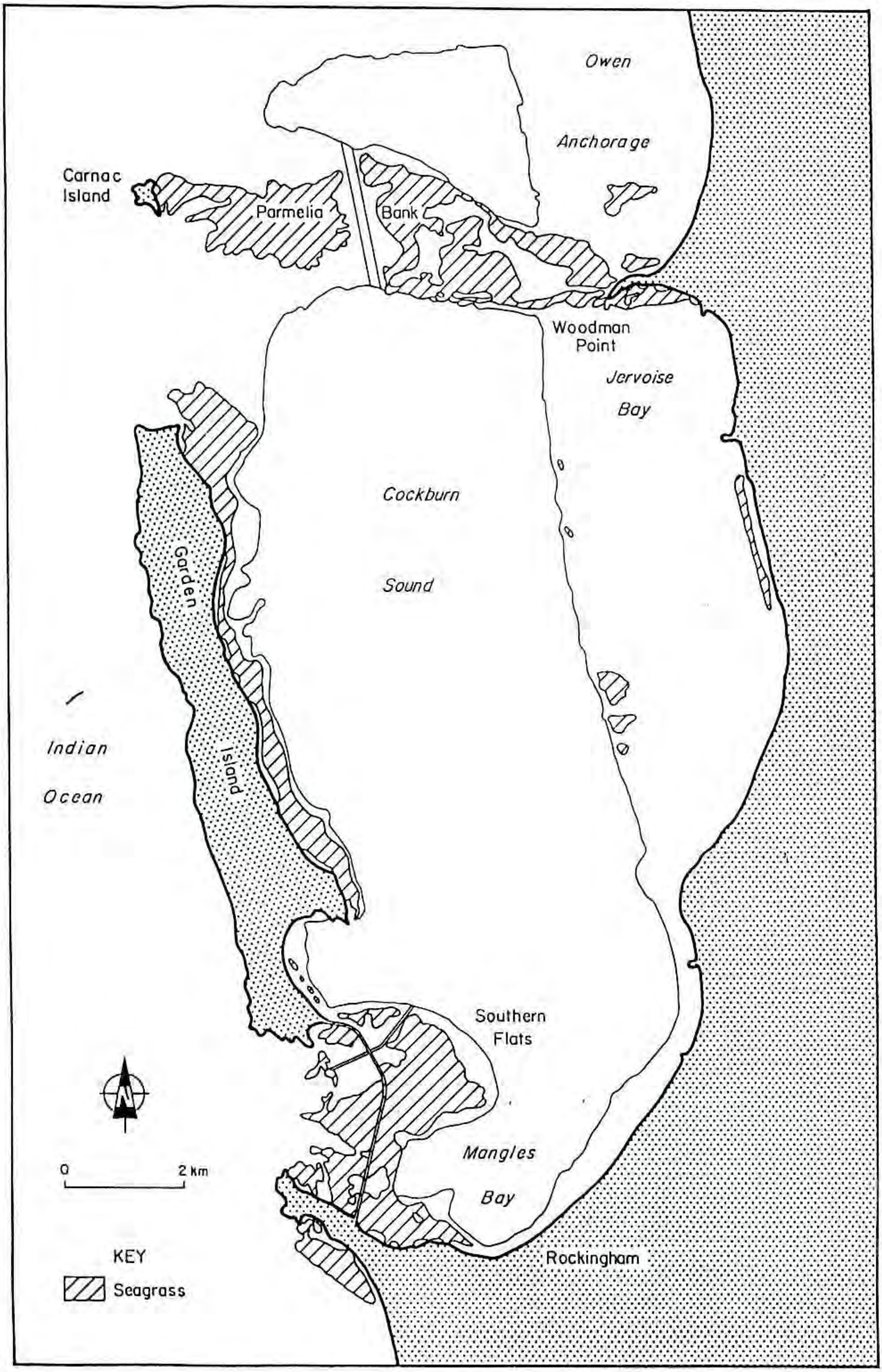


Fig. 13(a) SEAGRASS DISTRIBUTION IN COCKBURN SOUND 1977

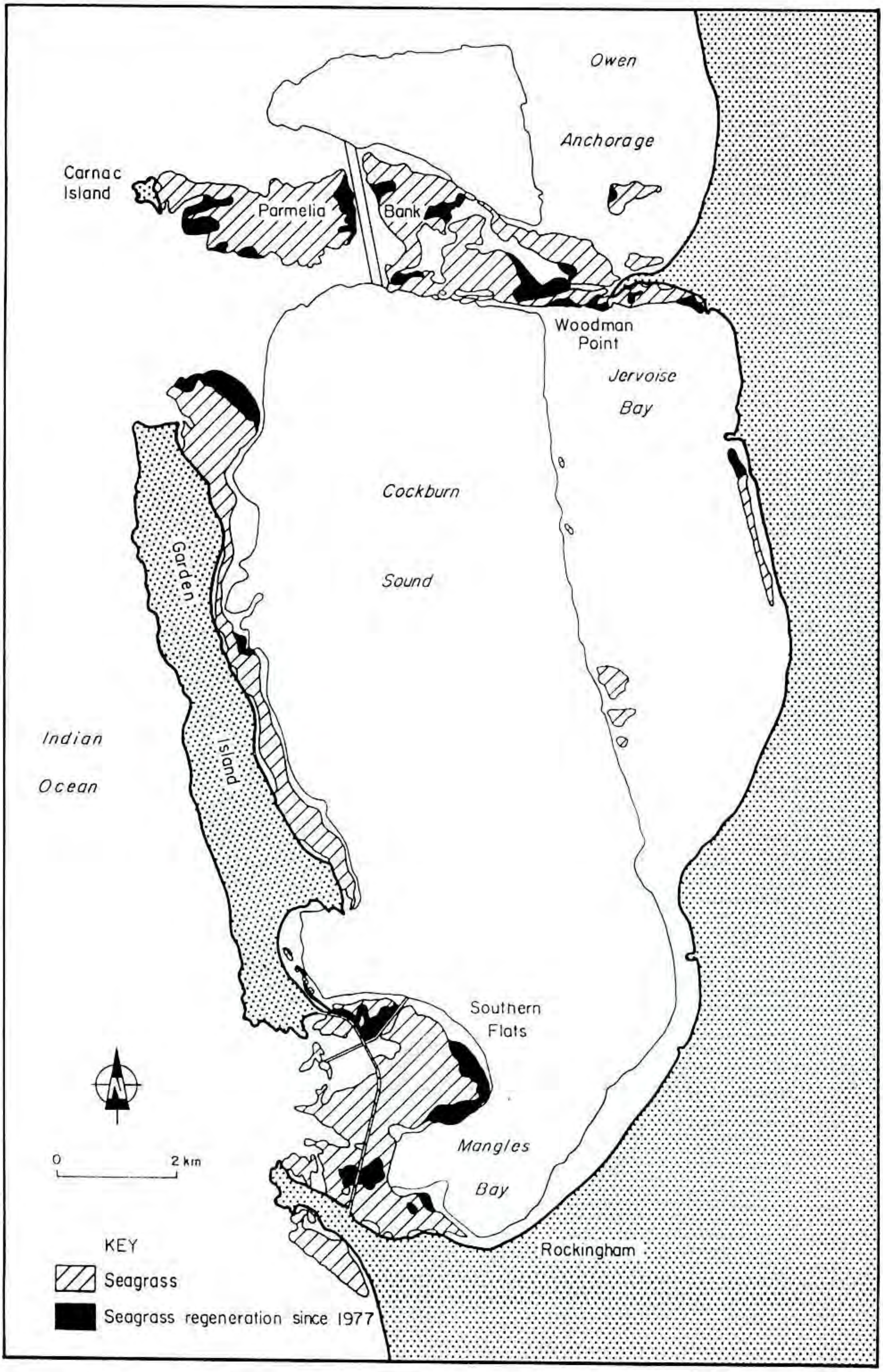


Fig. 13(b) SEAGRASS DISTRIBUTION IN COCKBURN SOUND 1985

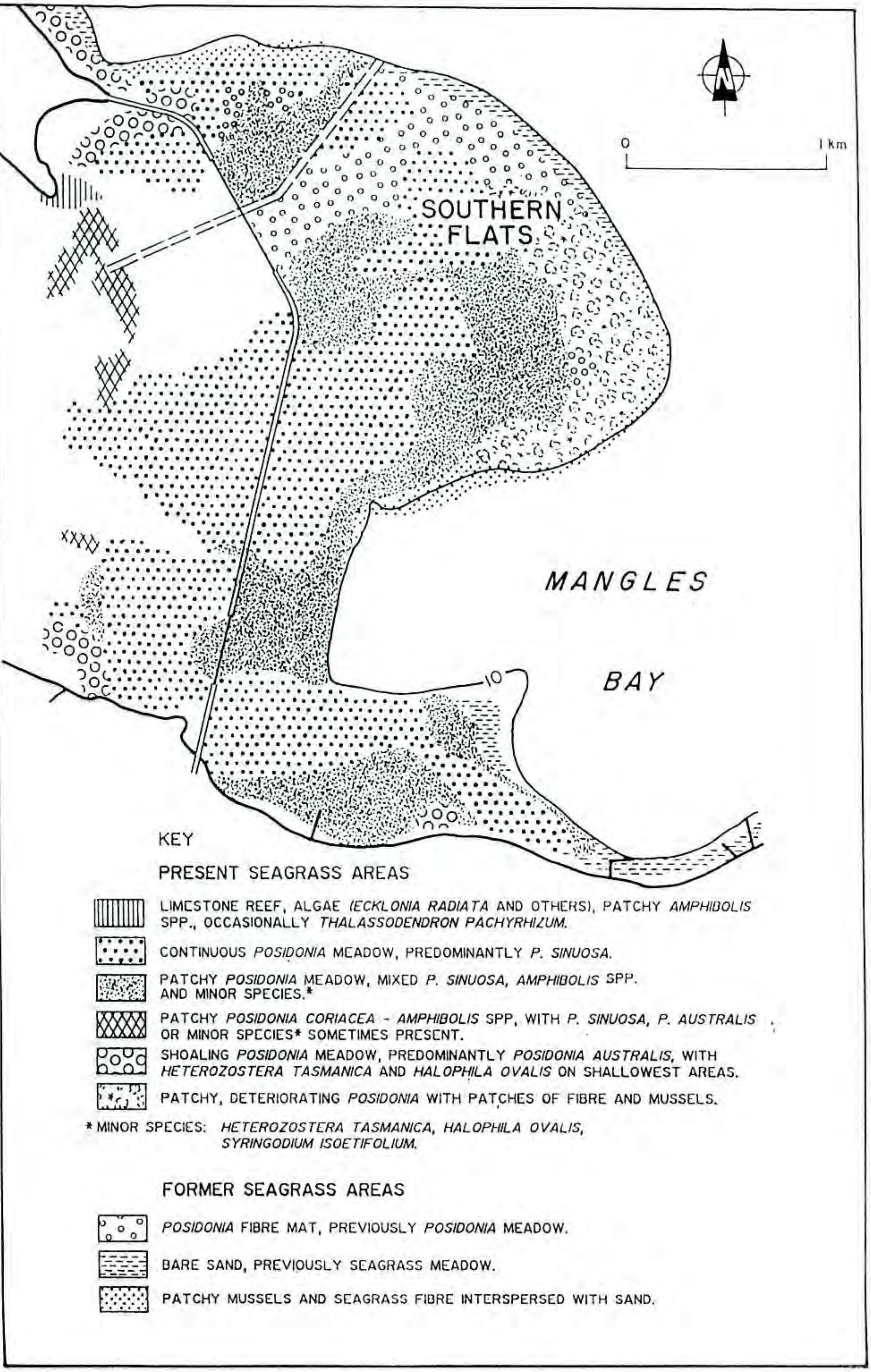


Fig. 14(a) SEAGRASS MANGLES BAY 1985

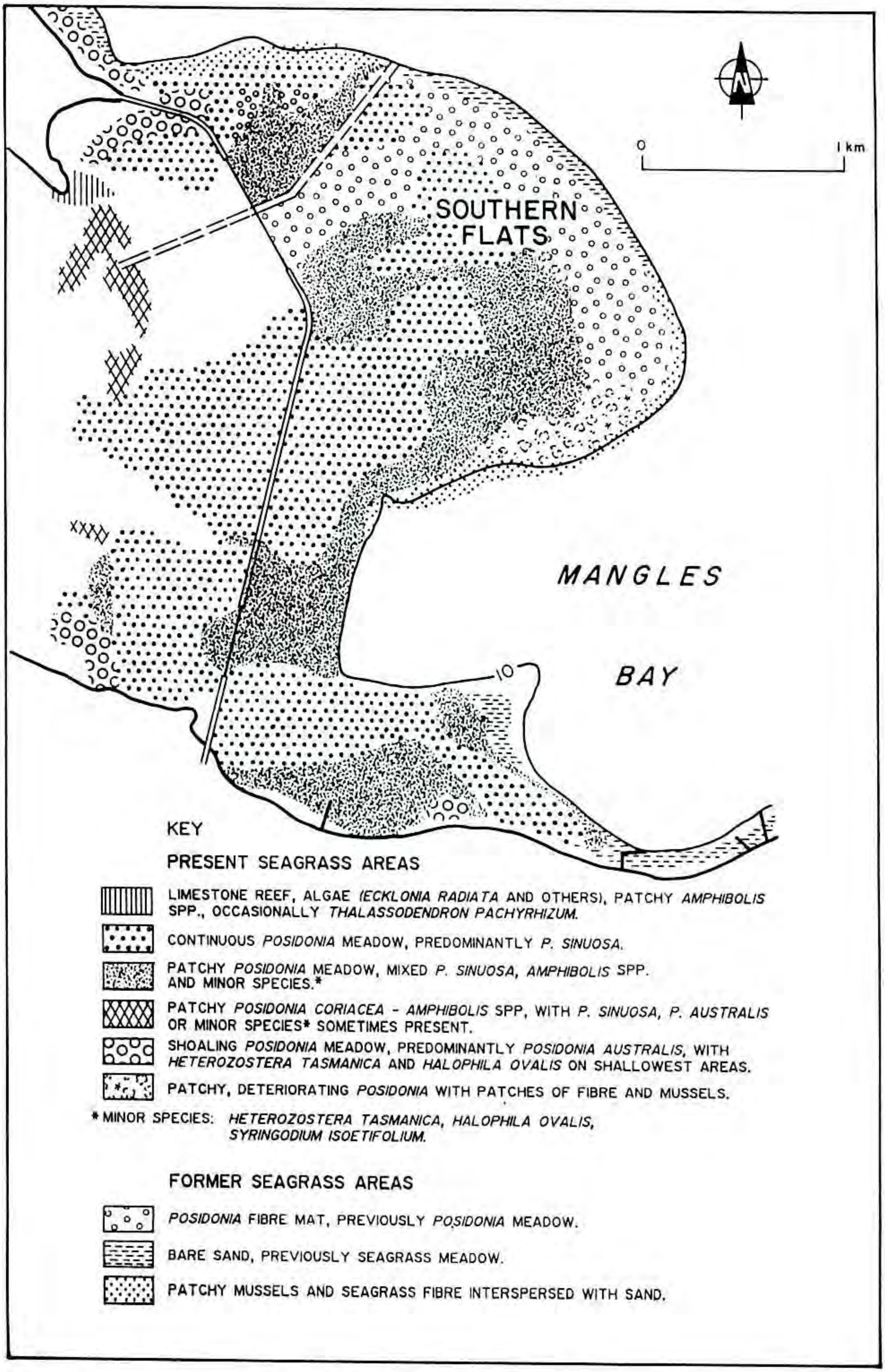


Fig. 14(b) SEAGRASS MANGLES BAY 1989

Year	Species						
	Scaly Mackerel	Pilchard	Perth Herring	Crabs	Mussels	Other	Total
77/78	149.5	319.4	71.5	27.6	156.2	36.7	760.9
78/79	13.5	389.1	58.4	44.2	765.2	32.6	614.1
79/80	614.4	46.7	16.5	39.7	202.2	66.5	986.1
80/81	285.9	183.4	16.0	26.3	181.7	77.8	771.1
81/82	97.6	109.4	4.6	38.6	52.6	201.7	504.4
82/83	105.9	260.4	2.1	52.1	222.5	73.6	716.7
83/84	182.5	299.4	6.8	94.6	211.5	97.0	891.8
84/85	791.0	259.6	1.5	94.3	259.3	78.2	1483.9
85/86	727.1	179.0	4.3	95.6	389.3	75.2	1478.8
86/87	186.7	485.1	2.7	89.6	219.9	81.8	1065.8
87/88	136.9	530.8	34.9	82.9	491.1	183.7	1460.3

Table 5. Commercial Fisheries Catches - Cockburn Sound. (Dept of Fisheries ,1979 to 1988)

Although the importance and impact of the amateur fishery in Cockburn Sound is not known, it is one of the most popular recreational fishing areas close to Perth. For example, Dybdahl (1979) estimated that amateur fishermen took more than 2.5 million fish in 1978. A creel census in 1977/78 indicated that 120 tons of five selected fin species and 210 tonnes of crabs would be taken by amateur fishermen in that year. This compares with the professional catches of 3 tonnes and 27 tonnes respectively. The most important species taken by amateurs are blue manna crab, Australian herring, whiting and skipjack trevally.

Dybdahl (1979) also estimated that Cockburn Sound supported 130 fish species and 14 large crustacean and mollusc species.

6.2.4 The Terrestrial Environment.

The existing land area to be included in the proposed development has been highly modified and, because of its disturbed state and small area, the habitat value is low. Much of the area is taken up by the two holiday camps, the yacht club hardstanding area and the existing Professional Fishermans Association lease.

The Rockingham Marina PER (1985), reported 27 species of plants in the area, eleven of which are exotics. There are about 2 hectares of predominantly *Acacia rostellifera* up to 4 metres tall interspersed with some *Acacia cyclops* and *Spyridium globulosum*. This is typical of the habitat of the Cape Peron and Garden Island areas. *Eucalyptus platypus* has been planted along the Point Peron Road reserve.

The understory has been highly disturbed and contains a mixture of native and introduced sedges, grasses and herbs. The most common species include couch grass (*Cynodon dactylon*), barley grass (*Hordeum leporinum*), perennial ryegrass (*Lolium perenne*), spinifex (*Spinifex longifolius*), coast sword sedge (*Lepidosperma gladiatum*), onion weeds (*Trachyandra divaricarta* and *Asphodelus fistulosus*) and wild geranium (*Pelargonium capitatum*).

There is a mixture of species above the high water mark, including primary colonisers such as sea rocket (*Cakile maritima*), spinifex (*Spinifex longifolius*) and sea spinach (*Tetragonia decumbens*), and some less typical species such as cape weed (*Arctotheca calendula*), couch grass (*Cynodon dactylon*) and perennial ryegrass (*Lolium perenne*).

There are several species of birds in the area, but none which are exclusive to this particular small region.

6.2.5 System Six Recommendations.

There are two areas covered by System Six recommendations in the vicinity.

* M101 - Cape Peron, Shoalwater Bay and Warnbro Sound.

  This area starts immediately west of the causeway and runs offshore down the Garden Island Ridge south to Becher Point (See Fig 3.).

  The M101 marine reserve was declared a marine park in May 1990, in accordance with the Recommendations of the System Six Report. Some of the park is included in water areas controlled by DMH.

* M102 - Lake Richmond.

  This region includes Lake Richmond and some surrounding lake foreshore land (See Fig. 3.).

6.3 The Human Environment.

6.3.1 Recreation.

The major recreational uses of Cockburn Sound are beach use, including swimming, sunbathing picnicking, etc. and boating uses such as sailing, fishing and waterskiing.

The beaches of Cockburn Sound and Shoalwater Bay are considered to be recreational resources of regional significance. However, the Cockburn Sound Recreational Study (1978) indicates that about half the beach users in the Sound frequent the 700 or so metres of Rockingham Beach, while the majority of the remainder use Palm Beach, Kwinana Beach, Coogee Beach or South Beach. Only 4.2% use all the remaining available beaches, and the

1200 metres between the Causeway and Hymus Street is not well patronised. This is apparently because of difficulty of access and lack of facilities. The popular beaches in the area cater primarily for family groups seeking calm, protected water with shade, shops and other facilities ready to hand. This has been recognised in the design of the marina, and the new beach on the eastern side, together with the nearby kiosks, toilets, grassed and shaded areas and other amenities, has been included to satisfy these requirements.

There are several boat ramps in and around Mangles Bay which cater for the trailer boat users (see Fig. 3.). This includes the ramp built in 1985 immediately west of the causeway. For this reason a public ramp will not be included in the new marina.

6.3.2 Adjacent Land Ownership and Use.

As discussed in Section 5.3, the existing and reclaimed land to be used for the development is, or will be, vested in the Minister for Transport for Harbour Purposes. The majority of the Cape Peron area west of Hymus Street is a 'C' class reserve No. 27853, vested in the Department of Sport and Recreation for recreation. Within the reserve, there are 15 leases for holiday camps. Two of these are on the land for which DMH is negotiating a transfer from DSR to the Harbour Reserve.

Other land vestings and use in the area include:-

* The Point Peron Waste Water Treatment Plant located on reserve 32771 vested in the Water Authority.

* Reserve 27854, vested in the City of Rockingham for parking and presently unused.

* Reserve 24475 vested in the CG Crippled Children's Seaside Home Society for a home for crippled children, and used for this purpose.

* Crown Grant 2196 at the end of the causeway held in fee simple by the Commonwealth Government.

* Reserve 39475 to the west of the causeway is vested in the City of Rockingham and the Recreational Camps and Reserves Board (now Department of Sport and Recreation) with power to lease for 21 years. The reserve is used primarily for boat ramps and associated parking.

* Privately owned residential land to the east of Hymus Street.

None of the vestings outside the Harbour Reserve will be affected by the proposal.

6.3.3 Harbour Reserve - Present Land Use.

Two of the holiday camp leases (R.S.L Perth and A.I.W Recreation Centre) are within the proposed Harbour Reserve. When the leases on the Cape Peron camp sites expire in October, 1993, it is not expected that the leases for these two camps will be renewed.

The Cruising Yacht Club presently leases 1.54 hectares of Lot 3 for boat hardstanding. As can be seen from the development plan, boat hardstanding will continue, but at a different site, and will be available to both the club and the general public.

The Point Peron Professional Fishermans Association lease 0.95 hectares of Lot 2. This is in the area proposed for light marine industry. When this area is upgraded and expanded, the Association will be given the opportunity to lease a new light marine industry block.

As discussed in Section 6.3.1, the beach at the site is used for recreation, although patronage is low.

6.3.4 Water Areas.

As discussed in Section 5.3, the adjacent water area is controlled by the Department of Marine and Harbours out to the Port boundary (see Fig. 3.), and from there north by the Fremantle Port Authority except for the strip adjacent to the causeway. This is under the jurisdiction of the Commonwealth.

The waters in the marina site are used for swing moorings. There is also a Gazetted water-ski area to the north of the site.

6.3.5 Access

6.3.5.1 Existing Roads. Road access to the area from the north is via Patterson Road to the Rockingham town centre, and from there to the site is via local streets. From the south, access is via Safety Bay Road and Rae Street.

A controlled access highway has been proposed to give direct access to the Causeway and the Garden Island Naval Base.

6.3.5.2 Existing Rail. A standard gauge rail currently serves the industrial areas at Kwinana, and terminates about 5 kilometres east of the site.

Land was reserved for a spur line to serve the container terminal proposed for Mangles Bay. The proposal for a spur line was discarded with the container terminal proposal, and the rail reserve has now been deleted from the Region Scheme.

6.3.6 Archaeological

6.3.6.1 Shipwrecks. The WA Maritime Museum has confirmed that there are three known wrecks in the area which is controlled by DMH but, as far as they are aware, there are no historic wrecks in the development area. In the region between Victoria Street and John Point, there are the wrecks of the **Contest** (1894), **August Tellefson** (1898) and a turtle boat of 20th century origin (see Fig. 15). The remains of the **Rockingham** may lie in the region, but are most likely in the Careening Bay area. North of Victoria Street is the Wreck of the **Amur**. This is outside the water area controlled by DMH, but is shown on Fig 15, as are several other wrecks in the southern end of Cockburn Sound.

Any wrecks lost before 1900 are protected by the **WA Maritime Archaeology Act 1973**, whether known or yet to be found. Should any previously unreported historic material be found, the Inspector of Wrecks at the WA Museum will be informed, and his advice on the best way to deal with the material will be sought.

6.3.6.2 Aboriginal Sites. An ethnographic and archaeological survey of the area was carried out for this project (see Appendices 7 & 8). No sites of significance as defined by Section 5 of the **Western Australian Aboriginal Heritage Act 1972-80** were located in the survey area. Although archival research revealed no known ethnographic sites in the area, the survey uncovered a hitherto unrecorded mythological site. The informant requested that the mythological connection be signposted.

The findings of the survey were submitted to the Minister for Aboriginal Affairs through the Aboriginal Cultural Materials Committee. Consent to develop the land has been given by the Minister, as required under Section 18(3) of the Aboriginal Heritage Act.

6.3.6.3 European Sites. There are no known European historic sites or artefacts in the area.

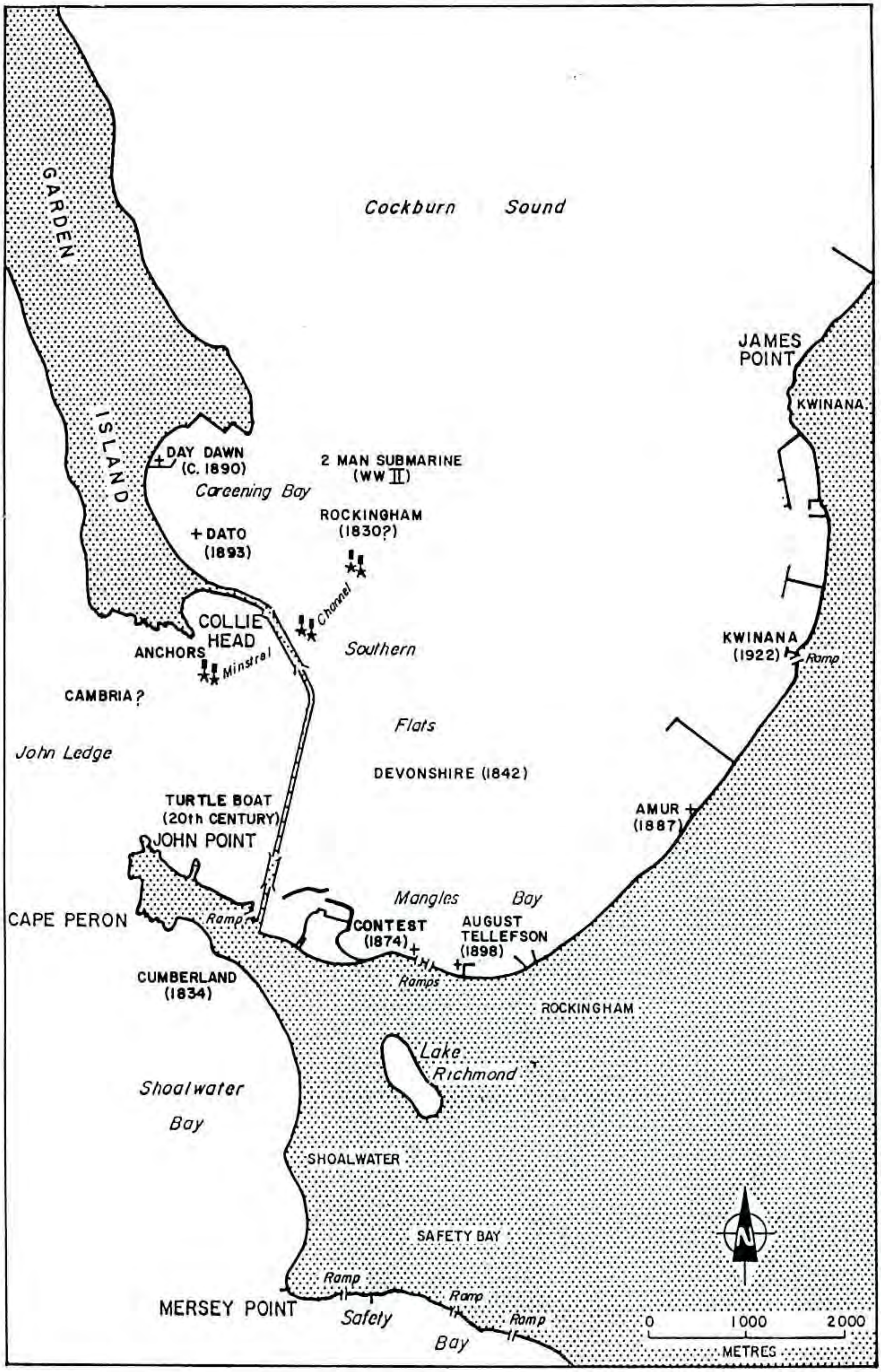


Fig. 15 SHIPWRECKS IN MANGLES BAY

7.0 ENVIRONMENTAL IMPACTS.

7.1 Introduction.

The environmental impacts considered in the 1985 PER by JHC are dealt with only briefly in this document except where this present proposal differs significantly from the 1985 proposal. The EPA raised specific questions in their review of the 1985 document and, where relevant, these questions will also be considered in detail.

The construction of a marina will inevitably have an impact on the physical, biological and human environment. These impacts can be temporary, such as increased truck traffic during construction or permanent such as alterations to drainage networks. Many of these impacts can be minimised, or even avoided, by careful planning and design followed by proper management.

Section 2.2 lists several of the major boat harbours in Western Australia designed, constructed and managed by the Department of Marine and Harbours. As a Government instrumentality and having extensive experience in the field, the Department is able to undertake responsible negotiations for long term development and management of marinas in Western Australia, including environmental management.

7.2 Impact on the Physical Environment.

7.2.1 Coastal Processes.

As discussed in Section 6.1.6, the beach at the marina site was dynamically stable, and sand lost from the beach during storm events was replaced by material moving east from the Cape. The construction of the causeway cut off the supply from the east, and the beach is now slowly receding. The construction of the marina on the already receding section of coast will not increase the existing erosion.

The placement of the landfill will halt the erosion on the 1.1 kilometres of beach east of the causeway, although it is expected that there will be some minor realignment of the beach between the causeway and the main landfill area. However, this beach is part of the Harbour Reserve, and the shoreline towards the landfill will be backed by light marine industry. The remainder will remain backed by the existing acacia grove. The predicted realignment of the beach is not considered to be a problem as the beach in front of the acacias is expected to accrete and the existing marine industry area on Lot 2 will not be upgraded until the development is well established, at which time the beach will have stabilised.

Preliminary modelling has shown that the new beach on the east of the development will be stable at the alignment shown in the predominant wave climate. However, the Department will be carrying out detailed computer modelling during the design phase to confirm this. Unusual storm conditions could cause some movement of this beach from time to time, but this is considered to be a maintenance matter. Any sand lost from the new beach will move to the eastern beaches, and provide them with some degree of renourishment. If necessary, the new beach will be maintained by artificial renourishment.

Regular monitoring surveys of the adjacent beaches will be carried out following completion of construction.

Overall, the new marina will not exacerbate erosion on the Mangles Bay shore, but may contribute to some minor beach realignment, mostly within the Harbour Reserve.

7.2.2 Seabed Stability.

7.2.2.1 Seabed Stability. As part of the investigations for the John Holland marina proposal, Hunter and Hearn (1985) modelled tide and wind induced currents in the area around the proposed marina using a two-dimensional, vertically averaged finite-difference model. This modelling considered conditions in both the pre- and post-construction states. For modelling purposes, a flow under the bridge of 250 m^3/s derived from work by Steedman and Associates (1975a, 1975b, 1975c, 1976) was assumed. The majority of model predictions were based on a typical wind of 5 m/s from the south-west.

Hunter used the same model with the same assumptions of flow and wind speed, but with extended boundaries, to predict the hydrodynamic effects of the present proposal (see Appendix 9). Winds from the east, south-west and north-west were modelled. The model was first run without a marina to establish ambient conditions, and then with a breakwater connected to the causeway on the south side of the bridge. In the marina proposal, it is not intended that the breakwater will connect with the causeway, but for modelling purposes, this was considered to be a "worst-case" and would generate maximum velocities east of the bridge.

With flow into Cockburn Sound (ie west to east), the dominant feature is a stream of water with maximum vertically averaged velocities under the bridge of up to 0.4 m/s generally reducing to 0.2 m/s or less by about 600 metres east. Flow out of the Sound is dominated by a similar stream with maximum vertically averaged velocities under the bridge of about 0.35 m/s reducing to around 0.2 m/s about 500 metres north-west of the bridge. In both cases, mean flow velocities towards the bridge are generally low, with maxima of less than 0.2 m/s.

Comparison of predicted currents for before and after construction of the breakwater indicates that, for flow into Cockburn Sound:-

* there is no increase in velocity of flow under the bridge after construction. This is the case for all wind directions.

* there is no increase in maximum vertically averaged velocities east of the bridge after the construction, but there is an alteration in the flow pattern. The velocities on the northern side of the stream decrease, and those adjacent to the breakwater increase by up to 0.1 m/s.

and for flow out of Cockburn Sound:-

* there is no increase in velocity of flow under the bridge after construction. This is the case for all wind directions.

* although there are some increases in vertically averaged velocities east of the bridge after the construction, these are generally less than 0.1 m/s. There is also an alteration in the flow pattern.

* there are only minor changes in the flow pattern west of the bridge.

In summary, the modelling indicated that the maximum vertically averaged current velocity in the vicinity of the marina would not increase after the construction of a breakwater although the flow pattern would change slightly. This indicates that bed scour would not occur. To confirm this, the bed shear velocity was computed and compared with the standard "Shields" criterion (eg Jansen et al, 1979).

The bed shear velocity (u_*) can be computed from the vertically averaged velocity ($\bar{u}$) by means of the Chézy relation

$$u_* = \frac{\bar{u}\sqrt{g}}{C}$$

in which

$$C = 18\log\frac{12h}{D_{90}}$$

and h = depth of water
D_{90} = 90% grain size

Particle size analysis was carried out on samples from the seabed at the marina site. Inspection of the results of the analysis (See Fig 9) shows that the D_{90} for the sand adjacent to the marina varies from 0.425 mm to 0.6 mm. Water depth adjacent to the proposed breakwater is a minimum of 3.0 metres.

A maximum bed shear velocity (u_*) of 0.032 m/s was calculated using a minimum D_{90} of 0.425 mm, a minimum depth of 3.0 metres and a maximum vertically averaged velocity of 0.35 m/s. As this calculation was based on extremes of current velocity, grain size, water depth and breakwater location, it is expected that actual velocities would be lower.

Using the standard Shields criterion, it was determined that a shear velocity of 0.032 m/s is insufficient to initiate bed movement.

The results of the modelling indicate that the new marina will not cause significant increases in current velocities around the low level bridge, and will not contribute to seabed erosion around the bridge or the marina.

7.2.2.2 Navigable Depths. The Department of Marine and Harbours is the body responsible for the control of navigation in coastal waters. DMH will determine an appropriate minimum navigable depth for the harbour and the entrance channel.

Although there are no identified sources of sediment which could cause siltation of the marina or the entrance channel, and current velocities are too low to initiate bed scour, there is a possibility that boat wash or localised currents could cause some small movement of bed sediments. Regular depth monitoring surveys will be carried out and dredging to maintain a safe navigable depth throughout the marina will be undertaken as required.

A safe navigable depth in the marina basin and entrance channel will be maintained.

7.2.3 Groundwater

There may be a small elevation of groundwater levels immediately inshore of the landfill area.

Surface drainage from the development, including irrigation water, will be disposed of on site where possible. The groundwater under the landfill area will initially be saline, but in time the fresher surface drainage will displace the saline water, and a freshwater lens will form under the development.

Neither the elevation of the existing groundwater levels or the formation of a freshwater lens under the landfill area will cause any detrimental environmental effects.

The marina will not cause any significant impact on existing groundwater.

7.2.4 Drainage

The new marina will not affect the existing onshore surface drainage systems. There will, however, be some surface drainage from the development area, and the open drain from Lake Richmond will flow into the new harbour basin.

7.2.4.1 Internal Surface Drainage. The internal drainage system will be designed to dispose of runoff on-site for an up to 5 year average recurrence interval rainfall. Rainfall in excess of this will be discharged directly to the ocean via overflow pipes.

Runoff from roads, parking areas, hardstanding areas and the like will pass through silt and oil traps to subsurface drains in vegetated areas such as road verges and grassed recreation areas. Drainage from buildings will be passed directly to the same subsurface drainage system Rainfall falling directly on the vegetated areas will go directly to the drains. There will be overflow provisions to cater for high intensity rainfalls.

The majority of surface drainage from the new marina will be disposed of on site. Only excess runoff from high intensity storms will overflow direct to the marina basin.

7.2.4.2 Lake Richmond Drain. The water quality in Lake Richmond has been discussed in detail in Section 6.1.8. There is no information available on the water quality in the overflow drain, but it has been assumed that it is the same as that in the lake. Since the drain flows through a mostly vacant public reserve with no known sources of pollution, this assumption is considered realistic. Drain outflows will be monitored after construction.

The effect of the discharge from the drain is discussed in detail in Section 7.2.5 Marina Water Quality.

The drainage reserve passes through the Harbour Reserve between Point Peron Road and the ocean. The drain, however, does not flow along the reserve, but along an easement to the west. Reclamation will move the drain outflow seaward by some 40 to 50 metres. When the light marine industry area is developed, the drain will be piped from the road to the sea.

7.2.5 Marina Water Quality.

Cockburn Sound is widely recognised as a eutrophic (detrimentally enriched) environment which has suffered from excessive contaminant loading for several decades. Various soluble and particular pollutants enter the waters of Cockburn Sound daily via surface water drainage, groundwater seepage, airborne fallout and discharge from industry. There is also some pollution from recreational activity. These pollutants include nutrients, metals, pesticide, hydrocarbons and various synthetic compounds.

7.2.5.1 Marina Flushing The flushing time for the proposed marina has been estimated in Appendix 11. The tidal flushing time has been estimated at seven days. However, this flushing time will be significantly reduced by wind induced currents, density currents and ground water inflows. Studies carried out at Hillarys Boat Harbour indicate that this reduction could be of the order of 50%, bringing the flushing time down to between three and four days. The two entrances proposed for this marina, combined with the strong east-west tidal currents under the Causeway, will further enhance the flushing and the actual flushing time is expected to be in the order of one to two days. This is considered to be an acceptable flushing time to maintain water quality suitable for direct contact recreation.

7.2.5.2 Nutrient Loading. Historically, excessive nutrient loadings have been seen as a primary cause of reduced water quality in Cockburn Sound. Nitrogen is believed to be the growth limiting nutrient in the Sound during summer, with temperature and light limitation during winter. Other contaminants of concern are metals, hydrocarbons and microbiological levels.

Coastal systems have an "assimilative capacity" which the EPA has defined as the capacity of a system to absorb pollutants without long term damage. One of the components of a system's assimilative capacity is its capacity to disperse pollutants through the receiving environment. This dispersal capacity is particularly relevant to marinas. Reduced dispersion may cause accumulation of particulate material which may otherwise be diluted over a wide area, and may also allow biological reductions in water quality to compound.

When nutrients enter a water body they are diluted in relation to their degree of dispersion. At low levels of dispersion relatively high levels of nutrients may be available for algae (phytoplankton) growth. This in turn may lead to reduced light penetration, odours, detrital carbon loading and other reductions in water quality. Large phytoplankton growths could, when dispersed, reduce light penetration in the surrounding waters and this in turn could affect existing benthic communities, such as seagrass meadows, which rely on light for their survival. Within a marina basin there is a potential to restrict dispersion, and it has been suggested that this could give rise to this situation.

As discussed above, Cockburn Sound is eutrophic, and algal blooms have been noticed since 1973-74. Thus, there is clearly a potential for phytoplankton growth in the marina. The probability, frequency and intensity of these blooms is dependant upon the ambient water quality, the quality of discharges to the marina and the flushing time of the marina.

Although the marina itself is not a significant nutrient source, the existing overflow drain from Lake Richmond will flow into the marina basin. WAWA have made estimates of the total nutrient input to the Sound from this drain (Appendix 4). These estimates are based on a limited data set for the lake (see Table 3.) and should be treated with caution. Given that there are no known sources of pollution between the lake and the drain outfall, the assumption that the water quality in the drain is the same as that in the lake is considered valid.

As nitrogen is considered to be the main growth limiting nutrient in Cockburn Sound, Halpern Glick Maunsell (HGM) have used this data to determine total nitrogen input to the marina basin (Appendix 12.). From the WAWA estimate, the drain discharged an average of 2150 kg of nitrogen per year between 1978 and 1986, with a maximum of 8290 kg in 1985. This high value should be treated with caution, as it is based on a single high sample of 4.4 mg/l of total nitrogen in September of that year. HGM have estimated of that there is a further 200 kg/yr nitrogen input from groundwater and 56 kg/yr released from sediments.

The total loading of nitrogen to the marina basin estimated by HGM is :-

	Maximum	Average
Lake Richmond Drain	8290 kg/yr	2150 kg/yr
Groundwater input	200 kg/yr	200 kg/yr
Sediment release	56 kg/yr	56 kg/yr
Total	8546 kg/yr	2406 kg/yr

For the purposes of assessing water quality, the marina basin is considered to include all the water between the proposed landfill and the Causeway and out to the island breakwater. This is a surface area of 285,990 m^2. Unit nitrogen loadings are therefore:-

	Maximum	Average
Lake Richmond Drain	28.99 $gm/m^2/yr$	7.52 $gm/m^2/yr$
Groundwater input	0.70 $gm/m^2/yr$	0.70 $gm/m^2/yr$
Sediment release	0.20 $gm/m^2/yr$	0.20 $gm/m^2/yr$
Total	29.88 $kg/m^2/yr$	8.41 $kg/m^2/yr$

Total nitrogen loading to the Sound has been estimated at between 6.0 $kg/m^2/yr$ and 9.9 $kg/m^2/yr$. In Appendix 12, HGM have reported work by Jawonski (1981) which indicates that a maximum permissible nitrogen loading of around 5.4 $kg/m^2/yr$ is appropriate for nitrogen limited systems. Thus, although the average nitrogen input to the marina is of the same order as that for the rest of the Sound, it is still greater than the tentative permissible level. The Lake Richmond drain is the major contributor of nitrogen to the marina.

The EPA has indicated a relationship between nutrient loading and phytoplankton biomass, between phytoplankton biomass and light penetration and between light penetration and seagrass survival. Simply put, an increase in nutrient loading will cause an increase in phytoplankton which will in turn reduce light penetration. Seagrasses can only survive to a certain depth defined by light penetration and, with reduced light penetration, can be starved of light and die. HGM have indicated in Appendix 12 that maximum loadings rather that average loadings should be considered when assessing downstream environmental impacts, on the basis that high loadings will cause habitat destruction and therefore this must be the limiting case. However, this argument does not consider the period of exposure.

It has been proposed that a high nutrient loading in the marina basin, combined with a long retention time, could cause phytoplankton growths of sufficient density that, when they are flushed from the marina, they could reduce the light penetration to the adjacent seagrass meadows. This in turn could damage the meadows. The possibility of this occurring at the proposed Mangles Bay Marina is considered low.

The main nutrient contributor to the marina is the Lake Richmond drain and, in common with other streamflows in the south west of WA, the discharge is typified by highly variable flows, normally during winter, and zero summer flows (see Appendix 4). Even with the attenuation caused by the lake, a flood hydrography would only be expected to cover a matter of days. Thus, high nitrogen loadings would only be expected to last a matter of days. Damage to seagrass beds will only occur after prolonged periods of light starvation.

Although it is evident that seagrass beds can be damaged by light attenuation resulting from high nutrient loadings and poor dispersion, the probability of damage to beds adjacent to the proposed marina must be assessed considering that:-

* the flushing time of the marina is estimated at one to two days and phytoplankton growth within the basin will be limited

* the average nutrient loading from the drain is of the same order as the ambient loading to the Sound

* high nutrient loadings would only be expected over short periods (days).

* high nutrient loadings occur during winter. Phytoplankton blooms are a summer phenomena.

* tidal currents under and around the adjacent Causeway would be expected to cause rapid dispersal of nutrients outside the basin.

* the bed level outside the entrance channel drops rapidly to below the depth suitable for seagrass growth.

However, although the probability of the marina contributing to damage to adjacent seagrass beds is small, the possibility still exists, and would be most likely under conditions of late winter flow combined with early summer light restriction. The developer will, therefore:-

* monitor water quality in the marina and adjacent waters, Lake Richmond and the Lake Richmond drain

* carry out flushing studies of the completed marina

* if a problem with nutrients exists, the drain outfall will be moved outside of the marina basin. Considering that the Lake has an urbanised catchment with no controls on input, it is not considered feasible to improve the water quality in the Lake.

7.2.5.3 Metal Contamination Tributyl tin (TBT) is one of the most notorious of metal contaminants and, as a residue of anti-fouling treatment, is commonly found in marinas. However, under regulations in place for the use of anti-fouling agents in Western Australia, it is unlikely that excessive loading of TBT would result from operation of the proposed marina. The site for the proposed marina does, however, already contain relatively high concentrations of TBT in both mussels and sediments (314 ng TBT/gm in mussels and 159 ng TBT/gm in sediments). Little is known of the release and dispersion of TBT from sediments during dredging. There is a possibility that the material may be resuspended and released to the water column during dredging. Alternatively, dredging may promote stripping of material from the water column. However, given that there is little or no TBT in the water column, this is of little interest. If the material is resuspended, dispersal will be restricted by the dredging strategy which will require the dredged material to be placed in a bunded area, and the contaminants will remain in the fill.

Drainage from any boat work areas will be via silt and oil traps. Drainage from the remaining areas, including parking areas, will be disposed of on site. Although there is some metal contamination from the Lake Richmond drain, there will be no net increase in metal contamination.

7.2.5.4 Seagrass Dredging. Compared to the nutrient loading offered by the Lake Richmond drain, recycling from the sediment will be minimal on a yearly basis. The burial of dredged benthic plant communities will release nutrients as they are remineralised, and this process may exert an undesirable oxygen stress on the overlying water column. However, this is only likely to be a problem where organic matter will decompose at or near the sediment surface. Burial greater than a few centimetres will allow for reduced bacterial activity, permanent burial of an amount below the remineralisation and dissolution zone and an remaining gradual nutrient release likely to be insignificant compared to external loadings.

As the benthic plant communities in the fill area will be covered by several metres of spoil and surrounded by an armoured bund, there will be little material within centimetres of the surface in the marina basin, and it is not expected that placing spoil on top of seagrass or dredging seagrass into the spoil area will result in any longterm problems.

7.2.5.5 Oil Spills. DMH is responsible for the administration of the **Pollution of Waters by Oil and Noxious Substances Act - 1987** and chairs the "State Committee for Combating Marine Oil Pollution". The Department, therefore, has the lead role in the State in the combating of oil spills in inshore waters and has the equipment and experienced staff to discharge this role. Oil absorbent boom will be kept at the marina for use as a first response in case of a spill. Other equipment for combating oil spills is kept at Fremantle and can be deployed to Rockingham by DMH at short notice. Response procedures will be detailed in the Emergency Plan (see 7.2.7).

With proper management, the marina will not cause any net worsening of the water quality in and around the marina site.

7.2.6 Greenhouse Effect.

There is growing evidence to suggest that the "Greenhouse Effect" will lead to a rise in sea level. The middle scenario suggested by the Villach experts group in 1987 of 55 mm/decade is presently considered the most acceptable hypothesis for planning purposes. This will result in a rise of sea level by about 0.3 metres in the next 50 years, and 0.5 metres over the next century.

Jetties and similar marine structures have relatively short lifespans of around 30 years, and no allowance for Greenhouse is required in their design. Foreshore walkways and paths can be raised easily and cheaply and again, it is not usual for an allowance to be made for rising sea levels. Buildings of the type envisaged for this development normally are designed for a life of less than 50 years, and so floor levels will incorporate an allowance of 0.3 metres for sea level rise.

The "Greenhouse Effect" has been considered in the marina design.

7.2.7 Emergency Plan.

The Department has developed an emergency plan for Hillarys Boat Harbour detailing responses to a range of threats. A similar emergency plan will be developed for Mangles Bay Marina. The threats considered in this plan are:-

* fire on board vessels
* collisions
* fire at refuelling jetty
* fire at service jetty
* fuel and oil pollution
* petrol explosion
* bombs and hazardous devices
* toxic gas leaks
* explosions
* sewerage and effluent spills
* hazardous chemical spills

7.3 Impact on the Biological Environment

7.3.1 Marine Ecosystems.

The reclamation and the offshore breakwater will cover approximately 18.5 hectares of the sea bed. The channel and basin dredging will modify another 16 hectares. Seagrass communities cover most of this area, and the impact on them is discussed in detail in Section 7.3.2.

The newly dredged marina basin and approach channel will be colonised by animals and plants able to exploit this habitat. These will include species of fish and invertebrates typical of sandy bottoms, as well as colonising species of seagrass such as *Halophila* and *Heterozostera*. The dense meadows of *Posidonia* presently in the area may re-establish in the dredged areas, but this will be a slow process. The jetty piles and the rocks of the breakwaters and revetments will be colonised by a variety of attached algaes and encrusting marine animals.

7.3.2 Seagrass.

The proposed development will remove about 18.4 hectares of healthy *Posidonia* meadow and about 13.7 hectares of patchy *Posidonia* meadow in the present boat mooring area. Of this meadow area, about 17.4 hectares will be filled and 14.7 hectares will be dredged. The remaining 2.4 hectares of water area included in the development is the mostly inshore sandy bottomed portion with no seagrass growth.

Although the 32.1 hectares of seagrass which will be lost is a very small part of the estimated 20 000 square kilometres of *Posidonia* meadow in the shallow waters off the Western Australian coast (Kirkman and Walker, 1989), it represents around 1.8% of the remaining seagrass meadows in Cockburn Sound. While this cannot be regarded as a serious threat to the ecology of the area, it is unfortunate that it includes 18.4 hectares of the healthiest seagrass in the Sound. (Appendix 6).

The area used to calculate the percentages of seagrass includes Parmelia and Success Banks, and is the same area used in previous studies (DCE, 1979; Hillman, 1985; Hillman and Bastyn, 1989). In their review of the earlier draft, the EPA redefined the area of Cockburn Sound as the area south of a line joining the northern end of Garden Island and Woodman Point. They have estimated that there are 750 hectares of seagrass remaining in this area, and so the 32.1 hectares which will be destroyed by this project represents 4.3% of the surviving seagrass. To avoid confusion, both percentages have been mentioned where appropriate.

The first alternative marina layout discussed in this document (Fig. 1b) will reduce the area of seagrass affected by the proposal to about 13.3 hectares of healthy meadow and 12.7 hectares of patchy meadow. The second alternative marina layout (Fig. 1c) will reduce the area of seagrass affected by the proposal to about 19 hectares.

In time, it is expected that all swing moorings in the south of the Sound will be removed, and the boats relocated to the marina. This will allow some of the patchy meadow area a chance to recover, albeit slowly. Although it is unlikely that the original *Posidonia* species will reestablish in the approach channel and fairways within the marina, other faster growing species are likely to colonise the area. This could offset the total seagrass loss by up to about 6 hectares. It is expected that shading by boats and jetties will prevent seagrass re-establishment in the pen areas.

The marina will destroy up to 32.1 hectares of both healthy and deteriorated sea grass meadows. There are 6 hectares in the dredged area which may recolonise, and a further 5 or so hectares in the remaining mooring area which may regenerate after the swing moorings are removed.

7.3.3 Fisheries.

7.3.3.1 Commercial The new marina will provide sheltered mooring facilities for professional fishermen operating in Cockburn Sound. The Cockburn Sound fishery is presently a limited access fishery operated by the Fisheries Department, and will not be increased by the new marina.

The new marina will not increase the pressure on the existing commercial fishery.

7.3.3.2 Amateur. A marina in Mangles Bay will increase the amateur fishing pressure in the adjacent waters. It is not possible to assess the impact of at this stage, but the Fisheries Department have indicated that they will respond appropriately to ensure protection of the fishery if required.

There may be some increase in amateur fishing in the region but, if necessary, this will be controlled by the Fisheries Department.

7.3.4 Terrestrial

As discussed in Section 6.2.4, the existing foreshore land in the development area is highly disturbed, and the habitat value is low. Never-the-less, the existing *Acacia* groves will be substantially retained and incorporated into the development. Eight of the thirty hectares of land in the Harbour Reserve have been allocated for public open space, green belts, conservation areas and so forth. In addition, the 6.6 hectares reserved for chalets and the 2.5 hectares reserved for a caravan park will be extensively vegetated, as will road verges and car park edges. When the development is completed, it will include more extensive quality vegetated areas than presently exist.

There will be a net gain in terrestrial habitats.

7.3.5 System Six Reserves

7.3.5.1 M101 Marine Park. Although the marina will not have any direct impact on the adjacent Marine Park, it will attract more boat users to the area and this in turn will increase the recreational usage of the park. However, given that some 85% of boats in W.A. are trailerable, and the marina is primarily catering for the 15% of larger boats plus a small amount of hardstanding, the impact will be limited.

The Department of Conservation and Land Management manage the park and, although they do not expect the increasing usage to have any adverse effect, they will monitor it and can control activities which could be detrimental.

7.3.5.2 M102 Lake Richmond. The Lake Richmond reserve is distant from the development site, and will not be affected.

The marina development will not have any major impact on the nearby M101 and M102 reserves.

7.3.6 Sediment Plumes.

Section 5.7 outlines the construction program. Briefly, the intention is to build an access way long the alignment of the western revetment to the eastern breakwater, construct the eastern breakwater, then build a temporary access and construct the western breakwater. The temporary access would then be removed and the surplus material used to complete the eastern breakwater. The basin and access channel would be dredged and the spoil used to fill the site. Extra fill would be imported. The construction, dredging and land filling will all cause sediment plumes.

Sediment plumes caused by construction of the access to the eastern breakwater will be contained almost entirely within the area to be either dredged or filled, and as such have no impact on the surrounding area.

During and after the construction of both the Hillarys Marina and the Mindarie harbour, the effect of the sediment plumes from the construction of the breakwaters on the adjacent seagrass beds was monitored. There was no noticeable detrimental effects in either case. This confirms the hypothesis made by Hillman (1985) that seagrass communities can cope with the short term (ie. less than 12 months) increases in turbidity which can result from breakwater construction.

The dredging itself will cause little increase in turbidity, and this will be localised and contained within the harbour basin and entrance channel. The spoil dumping, on the other hand, will cause a plume. As reported in the 1985 PER, the sediments to be dredged are predominantly sands, and thus have settling times in the depths of water in the bay of less than ten minutes. The less than 5% silts will be the only contributors to turbid plumes and, as in the case of breakwater construction, this will have little effect on the adjacent marine ecosystems. It is intended, however, to build a bund as dredging begins, and place the majority of spoil behind this bund. The wash-water will discharge from the bunded area via overflow pipes placed as far as possible from the input. This will minimise turbidity in the immediate area.

Regardless of the low likelihood of adverse effects on the environment from sediment plumes, they will be monitored by the Department.

Sediment plumes from breakwater construction, dredging and spoil placing are temporary and will have little effect on adjacent marine ecosystems. Sediment plumes from spoil dumping will be contained as much as possible within bunded areas.

7.4 Effect on the Human Environment

7.4.1 Recreation and Land Use.

7.4.1.1 The Beaches. The landfill for the marina construction will remove 700 metres of the existing beach. In addition, access may be restricted on up to 100 metres of foreshore in front of the proposed light marine industry strip to the west of the landfill. As discussed in Section 6.3.1, the 1200 metres of beach between the causeway and Hymus Street is not heavily used for recreation and the inclusion of 700 metres in the marina will have little impact on present beach usage, especially given that there is an estimated 12.5 kilometres of available beach suited for intensive recreation in Cockburn Sound and Owen Anchorage. However, beaches in Western Australia are an important recreational asset and, as the population grows, will become even more valuable as pressure for access to beaches and water increases. In recognition of this, the marina design incorporates two beaches, one about 150 metres long west of the landfill and a main beach about 400 metres long on the east side of the development.

The Cockburn Sound Recreation Survey (1978) reports that 92% of beach users in Cockburn Sound are family groups, and that the main reasons for using the Sound, apart from being close to home (18%), were safety and suitability for children (18.5%) and availability of parks, shade and picnic areas (13.8%). This is confirmed by the high percentage of users attracted to beaches such as Rockingham and Coogee where these facilities are available, compared to the very small numbers who use the unserviced beaches. The new eastern beach at the marina will provide protected waters and have facilities adjacent such as parks, shade, picnic areas, shops and toilets. This is not unlike the beach environment which has been created in the new Hillarys Boat Harbour and is expected to prove as popular, and provide an alternative to the more heavily used Cockburn Sound beaches.

The 250 metres of beach immediately east of the causeway will not be affected by the development and will remain available for recreation. The water quality will be suitable for direct contact recreation. This is to allow swimming from the beach near the Causeway. Swimming will not be permitted in the mooring areas. The existing parking area on Crown Land will not be affected.

Development Option 2 will take about 550 metres of existing beach, but only allows for about 100 metres of replacement beach. Option three will only take 450 metres of existing beach, but does not allow for any beach replacement

Access to the existing and proposed beaches will be restricted during the construction period.

7.4.1.2 The Holiday Camps. There are no detailed figures available on the patronage of the fifteen holiday camps on Cape Peron although, in their annual report for 1988/89, the Department of Sport and Recreation reported occupancy rates of around 75% for their Cape Peron camp. This camp is available for public use.

The Cape Peron Study recommends that the holiday camp leases, all of which expire in October, 1993, not be renewed. This recommendation included the two camps which are expected to be included in the proposed Harbour Reserve (the RSL and the AIW Recreation

Centre). These have a total of about 120 holiday shacks between them but are only available for use by the "owners" of these shacks. They are not available for use by the general public. When the leases on these camps expire, their will be an opportunity for redevelopment, partly for public open space and partly for holiday chalets. These new chalets will be similar in concept to those at Rottnest, and the public will be able to rent them for holidays in the same way. There will be no permanent or private residential development within the Harbour Reserve.

The remaining camps will not be directly affected by the marina development. However, in line with the Cape Peron Study recommendations, DSR have indicated that they do not intend to re-issue long term leases, and are preparing plans for the future recreation and tourist development of the Point. The presence of the marina will inevitably influence these plans.

7.4.1.3 Other Lessees The Cruising Yacht Club presently leases part of Lot 3 from DMH for boat hardstanding. As this area will no longer be available, club members presently utilising the area will be offered alternative space in the proposed secure hardstanding area. The main construction access road to the site will go through the present hardstanding area, and it will be necessary to find temporary accommodation for some of the boats, until the new areas are completed. It is likely that this will be on the eastern end of Lot 3.

The Point Peron Professional Fishermen's Association's operation on Lot 2 will not be affected during the initial construction phase. The development of the light marine industry area will not begin until at least 2 years after the primary construction is completed, and at this time the Association will be offered a new industrial site. The ongoing use of the existing club building will be considered at that time.

7.4.1.4 Cape Peron Land Use. As discussed, the majority of the Cape Peron peninsular is controlled by DSR and is intended for public recreation. Traditionally, this has meant holiday camps. Although DSR are presently reviewing the land usage, they intend to retain an element of holiday camps. DSR have been closely involved in this development through the Marina Consultative Committee (see Section 2.3) and are in agreement with the proposal and accept that it will complement both present and proposed land use.

7.4.2 Water Use.

The marina entrance channel will intrude into the south-west corner of the gazetted water ski area and it will be necessary to move the ski area boundary (see Fig. 3.). The ski area covers nearly 12 square kilometres, and the small reduction in area resulting from the boundary change will not have a significant effect on the amenity.

There are about 150 to 200 moorings in Mangles Bay at the marina site and although up to 100 boats have been counted, an exact figure of how many moorings are active has not been determined. The majority the moorings are in the water area which will be filled or dredged. These moorings will be removed progressively as construction advances. In order to minimise damage to the seagrass meadows, these moorings will not be relocated, although up to 30 boats may be accommodated on temporary moorings within the harbour basin. After the harbour is completed, it is the intention of the Department to encourage the removal of the remaining moorings and relocate the boats to the harbour pens. Incentives will be offered to the boat owners to encourage them to relocate.

7.4.3 Access.

Initially, access to the marina will be via existing roads. After construction, Point Peron Road between Hymus Street and the marina entrance will be closed. Access will then be around Oleander Drive and Lease Road to Point Peron Road west of the entrance. This will tend to reduce through traffic in the adjacent residential areas. It will also provide unobstructed pedestrian access to the now vacant part of Reserve 27853 immediately south of Point Peron Road. Future chalet or camp development on this land can then be simply and safely integrated with the main marina development.

If the proposed Controlled Access Highway to the Garden Island Causeway is constructed, then Point Peron Road will be closed off at the highway, and a new access road connecting the marina entrance south to the new highway will be built.

7.4.4 Archaeological

As discussed in Section 6.3.6, there are no known significant Aboriginal or European archaeological or ethnographic sites in the development area, and no known shipwrecks. However, should any evidence of any of these be found during construction the appropriate body will be informed.

7.4.5 Emissions.

7.4.5.1 Noise. Noise will be generated during construction of the harbour and throughout it's operation. Noise sources are:-

* Road Traffic
* Boat Traffic
* Construction

Herring Storer Acoustics have conducted out an initial acoustical survey on behalf of the Department (see Appendix 10).

Traffic flow data for relevant roads in the vicinity were obtained from the Main Roads Department. This was combined with traffic flow data from Hillarys Marina to synthesise the future traffic flows on which the predictions of traffic noise levels were based. The "worst case" predictions were 4 dBA increases at Parkin Street, Safety Bay Road and the intersection of Safety Bay Road and Lake Street.

Noise levels were measured at the exhaust of the DMH patrol vessel "MV Vigilant". This was considered representative of the higher noise levels from large vessels. An Environmental Noise Model based on two such large boats leaving the harbour at full power was used to predict noise contours (See Fig SK-2, Appendix 10). Use of two large boats operating at full power in the entrance channel with a 5 m/second wind from the north-west was considered an extreme case. The residential areas were outside the 45 dBA contour (see Fig SK-2,

Appendix 10) and, considering the already existing noise levels, the impact will be negligible.

The holiday residential parts of the reserve are not unlike normal residential areas, and noise generated by normal day to day activities will not have any noticeable impact on the surrounding areas. The commercial and light industrial areas are almost a kilometre from the nearest residences, and similarly will not cause any noise impact.

Section 7.4.6.1 dealing with construction traffic discusses the probable sources of material for the breakwater construction and the associated haul routes. As discussed in that section, the haul routes and the truck numbers cannot be defined exactly at this stage. However, it is unlikely that the total number of truck trips will exceed twenty per hour, and it is probable that the haul routes will be predominantly along major roads presently carrying up to 11000 vehicles per day. Noise from haul vehicles will not, therefore, be significant.

Construction activities such as pile driving and heavy equipment operation can not be defined until details of the contractors plant and equipment are known. However, DMH will require that the contractors operate within the noise limits set by the EPA.

Informal discussions on noise emissions from the project have been held with the EPA and will continue. Should construction activity, either at the site or along the haulage route, cause an inconvenience, then application for the necessary licence will be made, and adherence by the contractors to the conditions of the licence will be a condition of the various construction contracts.

Working hours during construction will be 7.00 am to 6.00 pm Monday to Saturday excluding public holidays.

Noise levels during construction are unlikely to be high enough to constitute a nuisance, but never-the-less, DMH will liaise with the EPA to ensure that the levels are within acceptable limits. Road and water traffic noises generated by the marina operation will not be high enough to significantly affect the existing environment.

7.4.5.2 Dust. The bulk of the earthworks construction will be in winter, when the problem of windblown dust is minimised. Over half of the fill will be placed hydraulically, and will not cause a dust problem. Also the site is over a kilometre from the nearest houses. However, the landfill will be watered down during construction in the normal way as and when required and the filled areas will be stabilised by hydromulching and seeding or by some similar method. DMH will ensure that an adequate supply of water is available for dust control at all times and for all wind conditions.

Problems from windblown dust will be reduced and probably eliminated by combination of a winter construction program, the distance from the nearest houses, hydraulic placement of most of the fill, regular watering and early stabilisation.

7.4.5.3 Sewerage. A sewerage pumpout facility will be provided for use by boat owners and the waste will be disposed of via the main sewer system with the sewerage from the rest of the development.

7.4.5.4 Waste. The marina operator will be responsible for removing flotsam from the harbour as well as keeping the marina environs rubbish free. Disposal of rubbish will be via the normal Council disposal system.

7.4.6 Traffic.

7.4.6.1 Construction Traffic. Contracts for the supply and transporting of material to the site will be let by public tender, and so the sources of material for the breakwaters and the landfill cannot be positively identified at this stage. However, economic considerations indicate that the source of the breakwater material will probably be one or more of the established quarries in the adjacent Spearwood Ridge. The closest, and largest, of these is in Millar Road. There are other possible quarries further north between Munster and Wattleup (See Fig 16). The probable sources of landfill are more difficult to define, but it is expected that the haul route will be the same as that for the breakwater material west of Ennis Street and probably west of Mandurah Road.

Preliminary discussions have been held with the City of Rockingham, and the proposed haul route from the Millar Road quarry, if this quarry is used, will be along Millar Road, Mandurah Road, Dixon Road, Patterson Road, Parkin Road and Point Peron Road (see Fig. 16). This route, from Mandurah Road on, is the one which was used for the construction of the Garden Island Causeway.

During the breakwater construction, there will be a maximum of ten trucks per hour carting armour and core material to the site. This is dictated by the number of trucks which can unload at the breakwater in an hour. Quarry operation restrictions may reduce this number. Each truck is likely to have a maximum capacity of 18 tonnes.

Carting of armour and core material is expected to continue for 16 weeks.

The sand placement area is more accessible than the breakwater and it is likely that a larger truck fleet will be use for sand carting, and up to 15 trucks per hour could be expected. Sand carting is expected to take 24 weeks, but this is dependant on the length of the haul route.

It is unlikely that sand and rock carting will both be at maximum at the same time and, from experience with similar works, 20 trucks per hour to the site would be the maximum expected.

Figure 16 shows likely quarry sites and haul routes. Average weekday traffic flows supplied by the Main Roads Department for the likely haul route are listed in Table 6. Also shown in Table 6. is the percentage increase in daily traffic flow from a maximum of 20 trucks per hour for eight hours to and from the site.

Location		Average Weekday Traffic Flows	% Increase
Mandurah Rd	S of Dixon Rd	5380	5.9
Dixon Rd	W of Mandurah Rd	1570	20.4
Dixon Rd	E of Ennis Ave	4500	7.0
Dixon Rd	W of Ennis Ave	7510	4.2
Dixon Rd	E of Patterson St	4320	7.4
Patterson St	E of Read St	11490	2.8
Patterson St	W of Read St	10942	3.0
Parkin St	W of Patterson St	7070	4.5
Parkin St	E of Safety Bay Rd	5410	5.8
Pt Peron Rd	W of Safety Bay Rd	2950	10.8

Table 6. Average Weekday Traffic Flows on Likely Haul Routes and % Increase With Construction Vehicles.

Although the construction period is relatively long, the impact of the haulage will be ameliorated by the low number of truck trips per day, and the relatively small percentage increase in traffic loadings

7.4.6.2 Operational Traffic. Although accurate estimates of operational traffic are not available, around 500 vehicles per day during on weekdays is expected. These would be spread between Safety Bay Road and Patterson Road. The total number of vehicles on these two roads is 12030 (See Fig 16). A extra 500 vehicles per day in and out represents and increase of around 8.5%. It is expected that anticipated increases in traffic of this order generated by the marina can be absorbed by the existing road system. The proposed limited access highway to the Garden Island Causeway will also serve the marina.

7.4.7 Water Treatment Plant.

The Water Authority of W.A. wishes to maintain a 1 kilometre buffer zone around it's treatment plants. Developments such as hotels, tavern restaurants, shops and chalet accommodation would not be compatible with a wastewater treatment plant and should not be permitted in the buffer zone. Boat storage, hardstanding service areas, car parking and the like are considered acceptable activities within the buffer zone. The Mangles Bay Marina has been designed to meet this criteria, and there will be no unsuitable development within one kilometre of the Point Peron Treatment Plant. All residential development is planned for the eastern side of the marina, and only boat mooring, boat hardstanding and light marine industry will be allowed within the non-development zone (See Fig. 1).

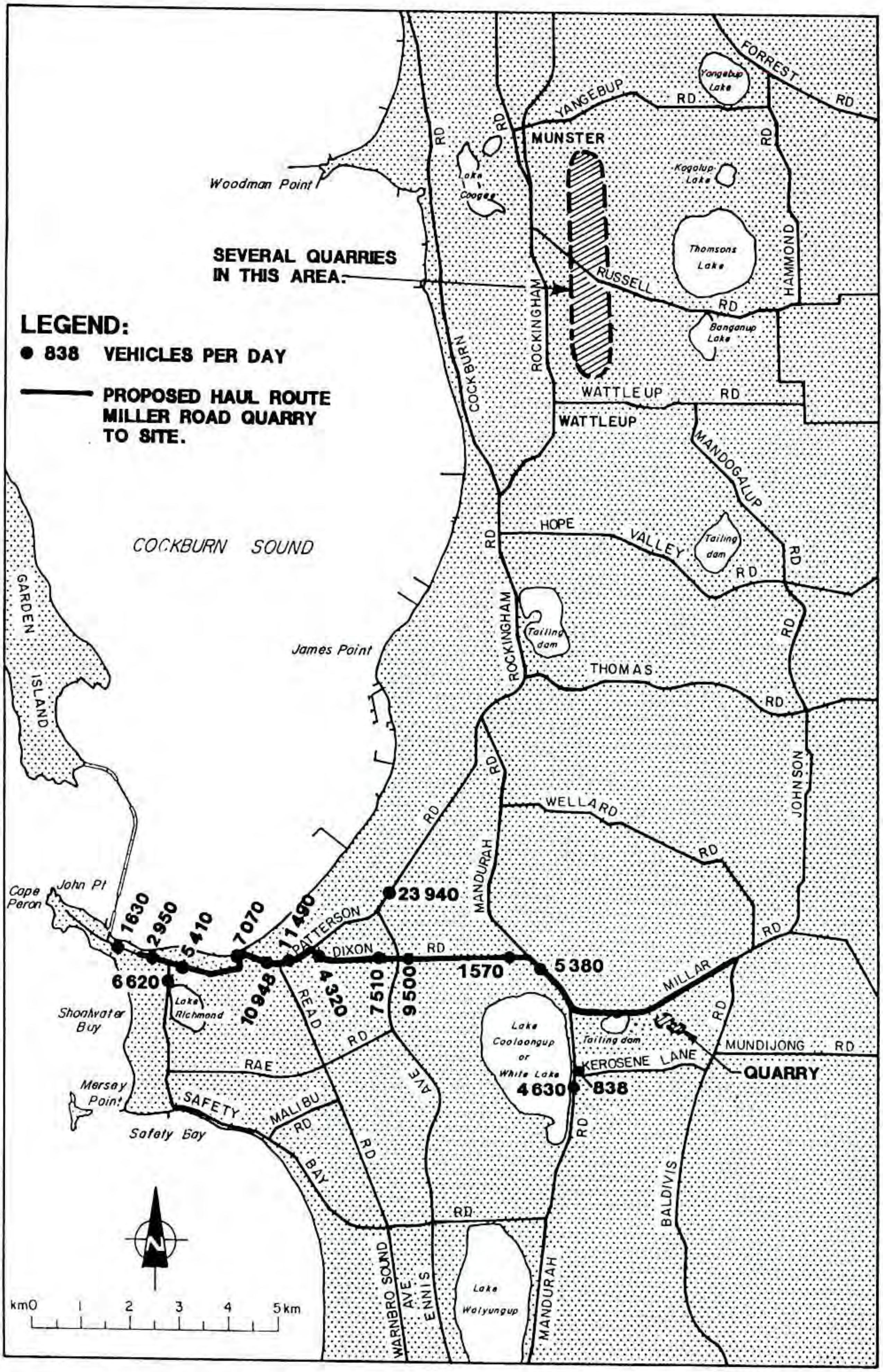


Fig. 16 PROBABLE QUARRY SITES & HAUL ROUTES

8.0 ENVIRONMENTAL MANAGEMENT AND MONITORING.

8.1 Introduction.

The effects of a marina in Mangles Bay on the physical, biological and human environment are outlined in Section 7. The most significant of these effects will be the loss of 18.4 hectares of healthy seagrass beds and 13.7 hectares of patchy seagrass beds which have been damaged by swing moorings. Although most other impacts have either been avoided or minimised by careful design, there are some which will require management. This section describes the proposed monitoring programs associated with the management of the environmental impacts of the development.

The major management issues associated with construction are expected to be :-

* noise from the construction site
* dust from the construction site
* sediment plumes associated with dredging, landfill and breakwater construction

Once the marina is completed, the following will require management:-

* water quality in the marina
* water quality in the adjacent waters
* stability of the eastern beach
* water depths in the marina
* water depth in the entrance channel

A monitoring program will be initiated to guide management action.

8.2 Management Responsibilities.

The developer will enter into a commitment to manage the marina and accept all management responsibilities, including those of environmental management.

The developer will also prepare and operate an Environmental Management and Monitoring Program as required by the Environmental Protection Authority.

8.3 Objectives.

The objectives of the management program during construction will be :-

* to ensure that the noise from the construction site does not exceed levels set by the EPA

* to ensure that dust from the construction site does not cause a nuisance to the nearby community

* to ensure that any sediment plumes from the construction do not have a serious impact on the surrounding marine biota

The objectives of the long term management program are:-

* to ensure that the water quality in the harbour is maintained at a level suitable for direct contact recreation as defined in DCE Bulletin No.103. If development option 3 is implemented, there will not be any provision for swimming in the marina basin, and a less stringent criteria may be appropriate.

* to ensure that the conditions for phytoplankton growth within the marina do not reach a level which could become a threat to the surrounding benthic biota.

* maintain the new eastern beach at an alignment and width such that the adjacent development is not endangered and the beach remains a useable recreation facility

* maintain sufficient depth of water in the marina and entrance channel for safe navigation for marina users

8.4 Management Program.

8.4.1 Construction.

8.4.1.1 Noise. As discussed in Section 7.4.5.1, because of the distance between the construction site and the nearest residential area, construction noise is not expected to be a problem. None-the-less, DMH will carry out monitoring required by the EPA, and will undertake to keep noise levels below statutory limits.

8.4.1.2 Dust. Problems from windblown dust will be minimised by a combination of a winter construction program, the distance from the nearest houses, hydraulic placement of most of the fill, regular watering and early stabilisation (see Sec. 7.4.5.2). DMH will ensure that an adequate supply of water is available for dust control at all times and for all wind conditions.

8.4.1.3 Sediment Plumes. As discussed in Sect. 7.3.6, the construction, dredging and land filling will all cause sediment plumes. The plume from the dredging will be small and contained mostly within the dredged area. Sediment plumes from spoil dumping will be contained as much as possible within bunded areas. However, the plumes from the breakwater construction will disperse in part over the adjacent sea-grass beds. Experience from similar construction sites along the coast indicates that this type of short-term exposure to suspended sediments will have no noticeable effect on the adjacent marine biota. Never-the-less, DMH will monitor the effect on the adjacent sea-grass using aerial photography.

8.4.2 Operation.

Once the marina has been completed an ongoing management program will be required to achieve the objective set out in 8.3 above.

8.4.2.1 Water Quality. Water quality in the marina will be maintained primarily through:-

* a marina design which will ensure adequate flushing.
* disposal of stormwater on-site with only excess runoff from severe storm events discharging directly to the ocean
* provision of sewerage pumpout facilities
* collection and removal of flotsam and other rubbish
* implementation of the provisions of the Emergency Plan in the event of spillage of oil, fuel, sewage etc.
* monitoring of water quality in and around the marina

8.4.2.2 Beach Stability. Detailed modelling of the proposed eastern beach and the existing eastern beaches will be carried out to ensure that a stable beach configuration is achieved. However, the supply of sand to the beaches in Mangles Bay was cut off when the causeway was built, and if there is any erosion of the new beach during unusual storm events, artificial renourishment will be required. This will be done if and when required. The new marina will not increase erosion on the existing beaches. If anything, sand lost from the new beach will nourish the existing beaches.

There may be some realignment of the beach between the causeway and the marina landfill. This land is part of the marina reserve, and any realignment of this beach is not considered a problem by the Department.

8.4.2.3 Navigable Depths. The Department of Marine and Harbours is the body responsible for the control of navigation in coastal waters. DMH will determine an appropriate minimum navigable depth for the harbour and the entrance channel and the developer will ensure that this is maintained. Although there are no identified sources of sediment which could cause siltation of the marina or the entrance channel, there is a possibility that boat wash or tidal currents could cause some small localised movement of bed sediments. Regular depth monitoring surveys will be carried out, and dredging to maintain a safe navigable depth throughout will be carried out as required.

8.5 Monitoring Program.

A monitoring program will be initiated to provide guidance in the management of the marina, especially in the areas outlined in 8.4 above.

8.5.1 Pre-construction.

The sea-bed in Mangles Bay has been surveyed, as have the beaches to the east. Coastline movements plots for the bay and adjacent beaches have been prepared (see Fig 11). This information will provide base data for the assessment of the movement of the existing beaches and the stability of the seabed adjacent to the causeway.

Information on ambient water quality and condition of the seabed biota has been collected by others and is available as baseline data.

Pre- and post-dredge sampling of the bed sediments, particularly for metals, will be undertaken.

8.5.2 Construction.

8.5.2.1 Noise. Noise levels from construction, which will be between the hours of 7.00 a.m. and 6.00 p.m. each day, excepting Sundays and public holidays, will be monitored as directed by the EPA.

8.5.2.2 Dust. No formal monitoring of the dust emissions from the site is proposed. However, dust emissions will be monitored on an ad hoc basis as directed by the EPA if any problems arise. Contractors on the site will be required to adhere to the "Dust Control Guidelines - Guidelines for Assessment and Control of Dust and Windborne Material for Land Development Sites" prepared by and available from the EPA.

8.5.2.3 Sediment Plumes. The sediment plumes from construction will be monitored by monthly aerial photography.

8.5.3 Operation.

8.5.3.1 Water Quality. The water quality in the marina basin and the adjacent waters, Lake Richmond and the Lake Richmond Drain will be monitored. The parameters monitored will be as directed by the EPA, but will include nitrogen, phosphate, dissolved oxygen, light attenuation and some metals. The marina sediments will also be monitored for heavy metal build-up..

8.5.3.2 Beach Stability. Annual surveys of beach profiles of the existing and proposed beaches between the Causeway and Palm Beach will be carried out. Coastline movements plots for the same area will be prepared from aerial photography bi-annually.

8.5.3.3 Navigable Depth. Annual surveys of the harbour basin and approach channels will be carried out.

8.5.3.4 Seabed Stability. Although the studies so far undertaken for the Department indicate that the construction of the marina will not cause erosion of the seabed adjacent to the marina, seabed stability will be monitored with annual surveys.

8.6 Monitoring and Interpretation.

The monitoring program, including analysis and interpretation of the data, will be carried out by the developer.

8.7 Reporting and Review.

Results of the monitoring program and any management action will be collated into a single report and presented to the EPA annually.

The monitoring program will operate for five years. A major review of the impact of the project will take place after this, and a modified monitoring program may be recommended.

The monitoring program will be modified at any time if required by the EPA or if unforseen circumstance arise.

9.0 CONCLUSIONS.

Various planning and land use studies of the Cape Peron region have recognised the need for a marina in Mangles Bay. The proposed marina discussed in this PER is compatible with these studies and will complement the existing and proposed land uses of the Cape Peron area.

Careful attention to site selection and design have avoided or minimised most environmental impacts. Other potential impacts can be avoided or controlled with proper management.

The benefits of the proposed marina at Mangles Bay include:-

* provision of a facility to meet the needs of the recreational and commercial boating public in the southern metropolitan and adjacent rural region into the next century

* provision of safe refuge for boats in the region and for those in transit between Fremantle and points south

* opportunity to change the perceptions of the region and act as a major catalyst for tourism

* low-cost holiday accommodation for the general public as an alternative to the existing holiday accommodation which is on foreshore land leased to private groups and not generally available to the public

* a safe mooring in Cockburn Sound with direct access to world class sailing waters.

* access to Cockburn Sound which could eventually reduce the pressures on the Swan River as a sailing venue

* an alternative boating destination near to Fremantle which could reduce the boating and tourist pressure on and around Rottnest island

* recreational opportunities plus visitor accommodation to serve the 2000 plus personnel expected to be based at Garden Island.

* a new sheltered beach with facilities adjacent which will provide an alternative to the heavily patronised main beach at Rockingham

* development of under-utilised land owned by the state and the generation of revenue which will eventually cover the capital and maintenance costs of the marina

Disadvantages of the development are :-

* loss of up to 18.4 hectares of healthy seagrass meadows and 13.7 hectares of patchy meadows

The damage to the seagrass meadows could be reduced to about 13.3 hectares of healthy meadow and 12.7 hectares of patchy meadow if Option 2 discussed in this document is adopted, and 19 hectares of healthy seagrass if Option 3 is adopted. However, these are not favoured as the preferred option will, when fully developed, provide more public facilities and a greater income.

DMH believes that the advantages to the community of a marina at this site are significant and outweigh the disadvantages of the loss of a small amount of the remaining seagrass in Cockburn Sound.

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MANGLES BAY MARINA

PUBLIC ENVIRONMENTAL REVIEW APPENDICES

APPENDICES

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Appendix 1.

Guidelines for the Public Environmental Review
For
The Proposed Mangles Bay Marina.

GUIDELINES FOR THE PUBLIC ENVIRONMENTAL REVIEW (PER) FOR THE PROPOSED MANGLES BAY MARINA

DEPARTMENT OF MARINE AND HARBOURS

The area included within the proposed Mangles Bay Marina has been the subject of a previous marina proposal, entitled 'Rockingham Marina' by the John Holland Group in 1985. This proposal involved the construction of a 330 berth marina adjacent to the Garden Island causeway, and was subject to environmental impact assessment by the Environmental Protection Authority as a PER in January 1986. At the time of this assessment, the key environmental issues associated with a development of this kind were considered to be:

* habitat disturbance and destruction of seagrass meadows;
* water quality;
* interruption and modification of coastal processes;
* air and noise emissions;
* odour problems associated with the Water Authority of Western Australia's waste water treatment plant; and
* social and community impacts.

It is noted that the site of the proposed Mangles Bay Marina includes the area previously included within the Rockingham Marina, however it is planned to be significantly bigger, and would ultimately cater for 1,000 to 1,200 boats. While it is appreciated that the proposed Mangles Bay Marina would be constructed on a staged basis, it is considered that all environmental impacts associated with the proposal should be addressed prior to the development commencing.

The above environmental issues, and those listed in Section 7 of these guidelines, have been identified as impacts associated with a marina at this location, and should be addressed within the PER. This list is not intended to be exhaustive and the proponent may consider that other issues should also be included in the document.

The PER is intended to be a brief document, its purpose should be explained, and the contents should be concise and accurate as well as being readily understood by interested members of the public.

Specialist information and technical description should be included where it assists in the understanding of the proposal.

1. SUMMARY

This section should contain a brief summary of:

* salient features of the proposal;
* alternatives considered;
* description of receiving environment and analysis of potential impacts and their significance:
* impacts of the environment on the proposal, eg odours from the Water Authority of Western Australia's waste water treatment plant, and water quality management issues;
* environmental monitoring, management and safeguards and associated commitments; and
* conclusions.

2. INTRODUCTION

The introduction should include:

* identification of proponent and responsible authorities;
* background and objectives of the proposal;
* brief details and timing of the proposal;
* relevant statutory requirements and approval procedures; and
* purpose and structure of the PER.

3. NEED FOR DEVELOPMENT

This section is concerned with the justification for the project and projected costs (in the broad sense) and benefits at local and regional levels.

4. EVALUATION OF ALTERNATIVES

A discussion of the alternatives to the proposal, including alternative sites should be given. A comparison of these alternatives in the context of the stated objectives of the proposal should be included as well as the respective costs and benefits at both construction and operational stages. In this way the rationale for not choosing certain alternatives should be clear as will the basis for choosing the preferred option. The preferred option should also be discussed in relation to regional proposals, for example, those discussed within the Cape Peron Study, prepared by the State Planning Commission in May 1988.

5. DESCRIPTION OF PROPOSAL

This should include:

* overall concept;
* location and layout;
* proposed land uses, land tenures and a clear indication between boundaries of private, public and Metropolitan Regional Scheme reserved land (Commonwealth jurisdiction relating to the Garden Island causeway needs to be considered);
* construction schedule and methods of construction including source of materials and disposal of wastes;
* infrastructure and auxiliary services (eg power, water and sewerage);
* access;
* operation during and after construction; and
* projected lifetime.

6. EXISTING ENVIRONMENT

This section should concentrate on the significant aspects of the environment likely to be impacted by the development (ie in particular, the processes sustaining the system). Only the processes, habitats, resources and potential resources which could be influenced should be defined.

6.1 PHYSICAL

This section should set the project in the context of local:

* meteorology;
* oceanography;
* offshore and onshore geology and geomorphology; and
* drainage.

The following issues should be addressed in detail;

* near shore water quality; and
* coastal processes.

6.2 BIOLOGICAL

Offshore biota, in particular seagrass cover, and onshore biota should be discussed within a regional context.

6.3 HUMAN

The following issues should be mentioned:

* land use zoning and reservation;
* current land use, including conservation and recreation aspects;
* adjacent areas affected by System Six recommendations;
* adjacent urban developments; and
* current use of offshore waters in the vicinity of the proposal.

This section should, where appropriate, take into consideration other known developments within the area which may affect the proposal, for example, the proposed major redevelopment of the Cape Peron Peninsula.

7. ENVIRONMENTAL IMPACTS

This is a key part of the document and the results should show the overall effect on the total ecosystem and surroundings of the location both during and after construction.

The objective of this section is to predict potential impacts upon the environment. This should include an assessment of the resilience of the systems identified in 6 to natural and man-induced pressures.

Construction of the new marina may have significant permanent and temporary impacts on the environment, as well as impacts that may only become evident in the long term. Based on the Environmental Protection Authority's previous assessment of the former Rockingham Marina, the following environmental impacts have been identified, which need to be addressed within the PER.

7.1 PERMANENT ENVIRONMENTAL IMPACTS

The following impacts should be addressed briefly:

* alteration of natural drainage network;
* infrastructure, including construction of access roads, parking facilities and services (power, water, sewage); and
* impact on existing local community facilities.

The following impacts should be addressed in detail:

* emissions associated with the marina (including air, water, noise and waste disposal).

* interruption of off-shore coastal processes, in particular off-shore sediment movement associated with littoral drift, exacerbation of foreshore erosion east of the Garden Island causeway and possible increased scouring in the vicinity of the causeway low level bridge;

* loss of ecosystems sustaining off-shore and on-shore biota, in particular seagrass communities in Cockburn Sound (discussion should include specific and cumulative impacts);

* water quality within the proposed marine and adjacent waters, including issues such as contingency plans for fuel spillage, effects of boat anti-fouling paints;

* social and community impact associated with the loss of a section of unmodified beach foreshore (include discussion on the change in current beach use, ie from conventional beach use to commercial marine orientated use); and

* increased traffic associated with the marina.

7.2 TEMPORARY ENVIRONMENTAL IMPACTS

These are mostly associated with the construction phase of the project. The following issues should be addressed briefly:

* land stability during construction;

* impact on adjacent System 6 area (M102); and

* alienation of foreshore area for recreation purposes.

The following issues should be addressed in details:

* noise and dust associated with the transport of raw materials; and

* generation of off-shore plumes associated with the breakwater construction.

7.3 LONG TERM ENVIRONMENTAL IMPACTS

These impacts may not become evident until after construction of the marina, however, they may have significant long term environmental implications, and should be addressed within the PER:

* impact of odour associated with the nearby Water Authority of Western Australia Waste Water Treatment Plant; and

* impact of poor water quality from within Cockburn Sound on marina water quality.

Impacts should be quantified where possible, criteria for making assessments of their significance should be outlined, and compliance with relevant standards should be demonstrated. The significance and timing of the various potential impacts should also be examined.

8. ENVIRONMENTAL MANAGEMENT AND MONITORING

A management and monitoring program should be described on the basis of (and cross-referenced to) the potential environmental impacts described in Section 7.

The purpose of the management program is to demonstrate the manner in which potential environmental impacts can be ameliorated.

Authorities responsible for management should be clearly identified as should management administration, costs and funding, including long-term financial contingencies.

Emphasis should be placed on the manner in which monitoring results will lead, where appropriate, to amendments to the management program.

Environmental safeguards, including contingency planning for infrequent events (eg damage to groynes through overtopping during storm events) should be included.

Procedures for reporting the results of monitoring and management to appropriate authorities should be given.

It is important that specific commitments are given to all components and procedures of the management and monitoring program.

9. CONCLUSION

An assessment of the environmental acceptability of the project in terms of its overall environmental impact and in the context of the proposed.

10. REFERENCES

11. APPENDICES

These should include the following:

* Glossary - definitions of technical terms, abbreviations.
* PER Guidelines.
* List of commitments given within the PER on environmental matters made by the proponent.

* Ancillary or lengthy technical information related to discussion in the body of the report.

Appendix 2.

Summary of Commitments
Made in the PER

Summary of the Commitments Made in the PER

The following is a summary of the commitments made in the PER. The successful developer will be required to accept responsibility for fulfilling these commitments in regard to the proposed marina at Mangles Bay, Rockingham.

1. The Developer will be responsible for the construction and management of the marina. This includes environmental management.

2. The Developer will be responsible for keeping the waters and public areas of the marina tidy and free of rubbish and flotsam.

3. Public access will be provided all around the land/water interface.

4. A sewerage pumpout facility will be provided for use by boat owners. The waste will be disposed of via the main sewer system with the sewerage from the rest of the development.

5. The internal drainage system will be designed to dispose of runoff on-site for an up to 5 year average recurrence interval rainfall. Rainfall in excess of this will be discharged directly to the ocean via overflow pipes. Although it is not expected that there will any other than flood flows discharged directly to the ocean, if there are any direct discharges, they will be via silt and oil traps.

6. Vehicular movement through the development will be restricted as heavy traffic movement is not considered compatible with the proposed recreational/residential theme. Pedestrian and cycle movement, on the other hand, will be encouraged with the provision of a network of dual use pathways.

7. Detailed computer modelling will be carried out during the design phase to confirm the stability of the eastern beaches, both existing and proposed. If necessary the alignment of the proposed beach will be modified. Unusual storm conditions could cause some movement of this beach from time to time and if necessary, the new beach will be maintained by artificial renourishment.

8. There will be no development in the marina which is unacceptable to WAWA within 1 kilometre of the Point Peron Treatment Plant.

9. An emergency plan will be developed for the marina and will detail responses to threats including:-

    * fire on board vessels
    * collisions
    * fire at refuelling jetty
    * fire at service jetty
    * fuel and oil pollution
    * petrol explosion
    * bombs and hazardous devices

Appendix 3.

Mangles Bay Marina
Mooring Demand Study

MANGLES BAY MARINA
MOORING DEMAND ANALYSIS

1. INTRODUCTION

The Department of Marine and Harbours (DMH) is planning for a small boat marina for Mangles Bay, Rockingham. This is in response to recommendations from several planning reports and to community requests. The Department also sees a marina at this site as a logical component of the states public marine facilities.

The purpose of this report is to estimate the demand for moorings in the new marina, including the expected boat size distribution and rate of growth of demand.

2. BOAT SIZE DISTRIBUTION

The statistics on boat size distribution in the postcode areas around Mangles Bay have been extracted from DMH boat registration records for 1989.

Post Code	Size Ranges (metres)								
	0 -6	6 -7	7 -8	8 -10	10 -12	12 -15	15 -20	20+	Total
6164-6172	3051	212	91	66	24	26	1	1	3472
6110-6113	1692	130	47	26	9	5	1	0	1910
6155	1889	164	86	77	43	14	3	2	2278
6201	100	4	1	4	1	1	0	0	111
6202	56	1	2	0	2	1	1	0	63
6203	10	0	0	0	0	0	0	0	10
Total	6798	511	227	173	79	47	6	3	7844

Table 1. Boat Size Distribution in Areas Around Mangles Bay

The PA Consulting Report (1980) looked at the distribution of boat storage, and found that 13% were stored in pens or on swing moorings. Based on this value, the number of boats below 8 metres (ie, the range of trailerable boats) has been adjusted to give a total of 13% of the available 7844 boats as potential pen users.

% Users	5%	37%	80%	100%	100%	100%	100%	100 %	
No. Users	340	190	182	173	79	43	6	3	

It is proposed that the minimum pen size in the new marina will be for 8 metre boats. All boats up to 8 metres in length have therefore been combined into a single group.

No. Users	**712**	**173**	**79**	**43**	**6**	**3**	**1034**

The PA Consulting Report also indicated that 6.9% of boats did not have motors and so did not require licenses. The boat numbers have been increased to reflect this.

No. Users (adjusted)	**761**	**185**	**85**	**50**	**6**	**3**	**1090**
% Dist	**69.8**	**17.0**	**7.8**	**4.6**	**0.6**	**0.3**	**100**

The percentage distribution of the boat sizes of potential users was been determined based on the above numbers of possible users. As this was only a theoretical size distribution, the actual percentage distributions of boats in Hillarys Marina was also determined (As at 24/10/89; total of 242 boats) for comparison.

However, it was felt that as:-

a) Cockburn Sound is more protected than Hillarys, and therefore more attractive to small boats

b) Rockingham has a lower average income than the Hillarys catchment.

c) There is a high percentage of retired people in Rockingham

there would be a higher percentage of small boats in the Mangles Bay Marina catchment than the Hillarys Marina catchment. To reflect this, the two boat size distribution estimates (theoretical and Hillarys) were averaged and rounded to give the recommended pen size distribution as shown below.

% Dist	**69.8**	**17.0**	**7.8**	**4.6**	**0.6**	**0.3**	
Hillarys % Dist	**34.7**	**22.7**	**32.6**	**7.9**	**1.7**	**0.4**	
Average Dist	**52.3**	**19.9**	**20.2**	**6.3**	**1.2**	**0.35**	
Recommended Distribution	**50%**	**20%**	**20%**	**6%**	**3%**	**1%**	

3. LATENT DEMAND

Data prepared in 1987 showed that there were 15701 licensed boats within 20 kilometres of Hillarys Marina. Of those, 1444 were 7.5 metres or over. On the 29 October, 1989, there were

242 boat in Hillarys. All except four of these were above 7.5 metres. It has been assumed that these 242 boats represented the latent mooring demand in the Hillarys Marina catchment. (Or, alternatively, it takes two years for a marina to absorb the local latent demand). Based on these figures, the latent demand (L_d) is:-

$$L_d = (242/1444) \times 100 = 16.8\% \text{ say } 17\%$$

The latent demand can be considered as 17% of the potential market.

The latent demand for the proposed Mangles Bay marina is therefore:-

$$L_d = 1090 \times 0.17 = 185$$

There are already in excess of 100 boats moored in Mangles Bay, whereas there were none moored at Hillarys. The latent demand could, therefore, be 17% of the potential market excluding those moored in the bay (ie, 1090 - 100 = 990), plus all the boat moored in the bay, ie :-

$$L_d = ((1090 - 100) \times 0.17) + 100 = 268$$

To reflect this uncertainty, an average value has been taken, and therefore the latent demand for moorings at the proposed Mangles Bay marina has been assessed at :-

$$L_d = (185 + 268)/2 = 226 \text{ boats}$$

4. RATE OF PEN TAKEUP

Figure 1. shows the total number of licensed boats on DMH records and the number of licensed boats per million people for the period 1966 to 1989. Unfortunately, not all boats are re-licensed each year, and therefore these figures are likely to underestimate the total number of boats in the community. The total numbers of boats on record has been included in Table 2. However, for the purpose of estimating the rate of growth of the boating market, it is sufficient to know that, since 1980, licensed boat ownership has been nearly static at about 30,000 boats per million people. The rate of growth in boat ownership is, therefore, about the same as the rate of growth of the population.

The population of WA increased from 1,301,629 in 1981 to 1,500,100 in 1987; an average rate of 2.4% per year. However, the customers for the Mangles Bay marina are expected to come predominantly from Serpentine/Jarrahdale, Armadale, Cockburn, Gosnells, Canning and Rockingham. The population of this area has grown from 208,866 in 1981 to 264,029 in 1987; an average of 4% per year.

Based on these boat ownership and population growth rates, it has been assumed that the demand for pens at the new Mangles Bay marina will increase at 4% per year from a latent demand of 226 boats. The predicted usage is shown in table 3. This table assumes that the pens become available in 1994, that demand increase at 4% per year and that the latent demand is taken up in the first two years. The demand also increases at 4% per year between now and 1994.

	Year	Estimated Pen Occupancy
0	**1994**	**132**
1	**1995**	**275**
2	**1996**	**286**
3	**1997**	**297**
4	**1998**	**309**
5	**1999**	**372**
10	**2004**	**391**
15	**2009**	**476**
20	**2014**	**579**
25	**2019**	**705**

Table 3. Predicted Pen Occupancy

5. COMMENTS

No consideration has been given to hardstanding of boats. However, although about 87% of boats in WA are trailerable, and many larger boats can also be kept on hardstanding, there is only limited hardstanding available. It is felt that this is a largely untapped opportunity, and that a large market for boat hardstanding could be developed with aggressive marketing. There are presently some 100 boats on hardstanding at the marina site.

Although the pen demand figures given in this paper are estimates, and based on a range of assumptions, it is considered that they are sufficiently accurate to form a basis for the preliminary marina development strategy. It is expected that the longterm development programmes would reflect the actual marina usage.

The annual rental cost for pens will have a major impact on the demand. Changes in the economic circumstances could increase or decrease the demand for pens.

An aggressive marketing strategy which promotes boat ownership in general, attracts boat owners away from Fremantle and the Swan River, promotes Cockburn Sound as pre-eminent sailing waters, promotes the marine park, etc could increase the demand for pens.

6. SUMMARY

The present latent demand is estimated at 226 boats. This will rise to 275 by 1995, when the first pens have been occupied and the latent demand is expected to have been absorbed. The expected increase in pen occupancy is 4% per year. At this rate, the western set of pens will be full to capacity by 2003, and the marina will be fully occupied by permanent pen-holders by 2012.

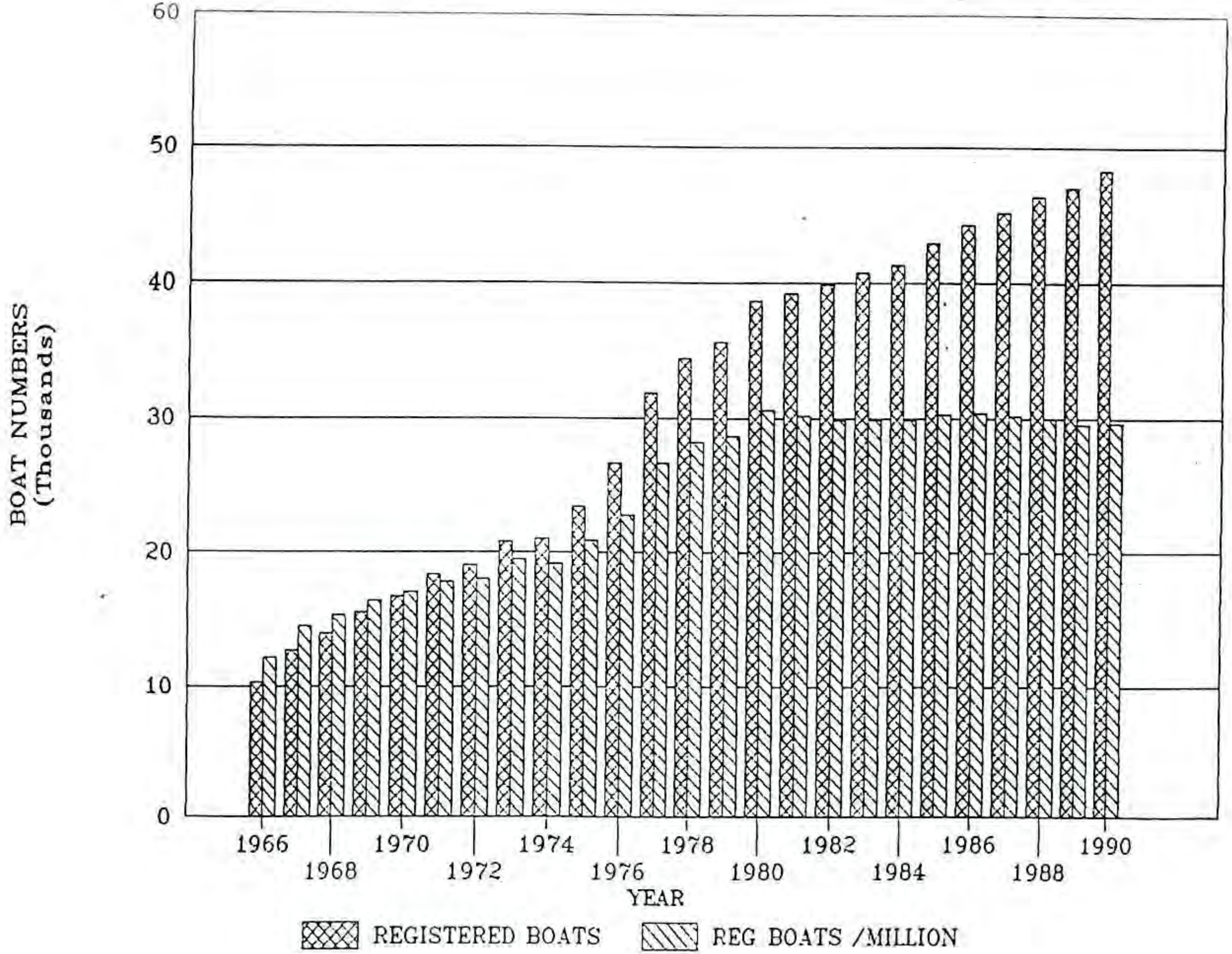

Figure 1: CURRENT REGISTERED BOATS AND OWNERSHIP RATIOS 1966 - 1990

Appendix 4.

Selection of the Breakwater Design Wave for
Mangles Bay Marina.

1. Introduction.

As no field measurements exist for the wave climate in Mangles Bay, the breakwater design wave criteria for the proposed marina were determined from theoretical estimates of swell wave and wind wave conditions. A numerical model was used to quantify an inshore swell wave climate, and locally generated wind wave conditions were predicted using an analytical technique taken from the U.S. Army Shore Protection Manual (1984). The numerical and analytical estimates were then combined to give a significant wave height and period which were used for design purposes.

2. Swell Waves.

The predicted wave climate for the nominated site was obtained by applying numerically generated wave transformation coefficients to a hindcast offshore wave spectra. The wave transformation coefficients represent the combined effects of wave refraction, shoaling and bed friction. They were computed by a numerical model which used the reverse ray technique to generate wave orthogonals from the nominated marina site out to deepwater. A complete range of wave directions were investigated for a variety of wave periods, but only those wave orthogonals which reached deep water were used to determine the wave transformation coefficients. From this investigation it was concluded that, due to the protection afforded by Parmelia Bank (see Fig 1), the amount of swell wave energy entering Cockburn Sound from the north is insignificant. Swell waves entering the Sound through the narrow gap under the low-level bridge in the causeway required further study.

The potential for swell waves entering the Sound through the causeway gap was investigated by relocating the origin of the wave orthogonals from the marina site to the centre of the gap. The wave transformation coefficients for this location are presented in Table 1 together with the predicted inshore wave directions. Some of the wave orthogonals which reached deep water for 5.0 second and 10.0 second period waves are shown in Figures 2 and 3 respectively. A significant wave height for waves passing through the gap was calculated by multiplying a representative deepwater wave height with a corresponding wave transformation coefficient from Table 1.

An annual percentage joint occurrence matrix of significant wave height versus period for deep water off Fremantle Port from November 1984 to October 1985 is shown in Fig.4. From this matrix it can be seen that offshore wave heights did not exceed 2.0 metres and were less than 1.0 metre for 75% of the year. Furthermore, 70% of the wave periods were between 4.0 and 8.0 seconds.

From the second joint occurrence matrix shown in Fig 5, it can be seen that the bearing of the offshore significant wave was between 270 and 290 degrees for over 90% of the time. On the basis of the data in Figures 4 and 5, an offshore significant wave was selected with a height of 1.0 m, a period of 6.0 seconds and a direction of 280 degrees.

Since the wave attenuation coefficient in Table 1 is larger for the smaller period waves approaching from 280 degrees, a transformation coefficient of 0.70 was selected. Thus, an inshore significant wave height equal to (0.70) x 1.0 metres = 0.70 metres was specified for the gap location. It can be expected that this significant wave height would be further attenuated by diffraction effects as the wave passes through the gap and is refracted by the bed slope as it approaches the site of the proposed marina.

3. Wind Waves.

The highest locally generated wind waves capable of reaching the marina are those which have been developed over the longest distance. The longest fetch length extends 12 kilometres from the marina site northwards up Cockburn Sound to Parmelia Bank (see Fig. 1).

The spectral wave height and period for this fetch limited situation was determined using an analytical method described in the U.S. Army Shore Protection Manual (1984). A 50 year return period wind speed of 22 m/s was selected. This is the same wind speed as that used in the design of the John Holland Construction (JHC) 1985 marina proposal. Using this wind speed and a 12 kilometre fetch, a locally generated wind wave of 1.2 metres with a period of 4.0 seconds was determined. This is considerably less than the 1.6 metres significant wave reported in the JHC PER. The John Holland's value, however, represented the maximum breaking wave height over the Southern Flats Bank, whereas the results presented here indicate that the breaking limit is not a realistic design criteria in this case.

4. Conclusion.

The predicted wave heights and periods for offshore and locally generated waves are given below.

Predicted Wave Characteristics

	Wave Height	Wave Period
Offshore Wave (gap location)	0.7 m	6.0 sec
Local Wave	1.2 m	4.0 sec

Using the above predictions, a design wave was selected with a height of 1.5 metres and a period of 4.0 seconds. This was considered conservative as the joint probability of maximum offshore and local wave occurrence is low. Also, there will be further attenuation, especially of the offshore wave, at the marina site.

References.

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WAVE CLIMATE STUDY

MANGLES BAY (GAP POINT)

INSHORE WAVE CONDITIONS

WAVE COEFFICIENTS

OFFSHORE DIRECTIONS & STANDARD DEVIATIONS

ZERO CROSSING PERIOD	270.0 (5.0)	280.0 (5.0)	290.0 (5.0)	300.0 (5.0)	310.0 (5.0)	320.0 (5.0)	330.0 (5.0)	340.0 (5.0)	350.0 (5.0)	360.0 (5.0)
3.0	.63	.69	.70	.70	.70	.69	.68	.68	.68	.57
4.0	.47	.45	.45	.45	.46	.44	.43	.43	.43	.36
5.0	.37	.30	.31	.31	.32	.31	.29	.29	.29	.24
6.0	.33	.23	.24	.22	.24	.23	.21	.20	.20	.17
7.0	.31	.20	.20	.16	.18	.18	.15	.15	.15	.12
8.0	.30	.19	.17	.13	.14	.14	.12	.11	.11	.10
9.0	.32	.22	.15	.10	.11	.11	.09	.09	.09	.08
10.0	.36	.28	.15	.08	.09	.09	.08	.07	.07	.06
11.0	.40	.32	.15	.07	.08	.07	.06	.06	.06	.05
12.0	.42	.35	.15	.06	.07	.06	.05	.05	.05	.04

INSHORE DIRECTIONS

3.0	281.39	281.49	291.19	301.05	310.64	320.04	330.00	340.00	349.93	357.40
4.0	292.50	283.16	293.26	302.40	312.02	320.25	329.99	340.00	349.93	357.40
5.0	300.93	285.25	295.35	303.37	313.62	320.98	329.95	340.00	349.93	357.40
6.0	308.33	291.91	300.10	303.95	314.69	321.61	329.90	340.00	349.93	357.40
7.0	313.51	300.50	306.23	304.37	315.27	321.97	329.87	340.00	349.93	357.40
8.0	316.43	308.36	310.53	304.67	315.59	322.16	329.85	340.00	349.93	357.40
9.0	318.70	318.25	314.32	304.89	315.76	322.27	329.84	340.00	349.93	357.40
10.0	320.06	323.08	318.10	305.06	315.86	322.33	329.84	340.00	349.93	357.40
11.0	320.65	324.69	320.84	305.22	315.92	322.37	329.83	340.00	349.93	357.40
12.0	320.90	325.30	322.48	305.36	315.96	322.40	329.83	340.00	349.93	357.40

TABLE 1

GAP POINT WAVE TRANSFORMATION COEFFICIENTS

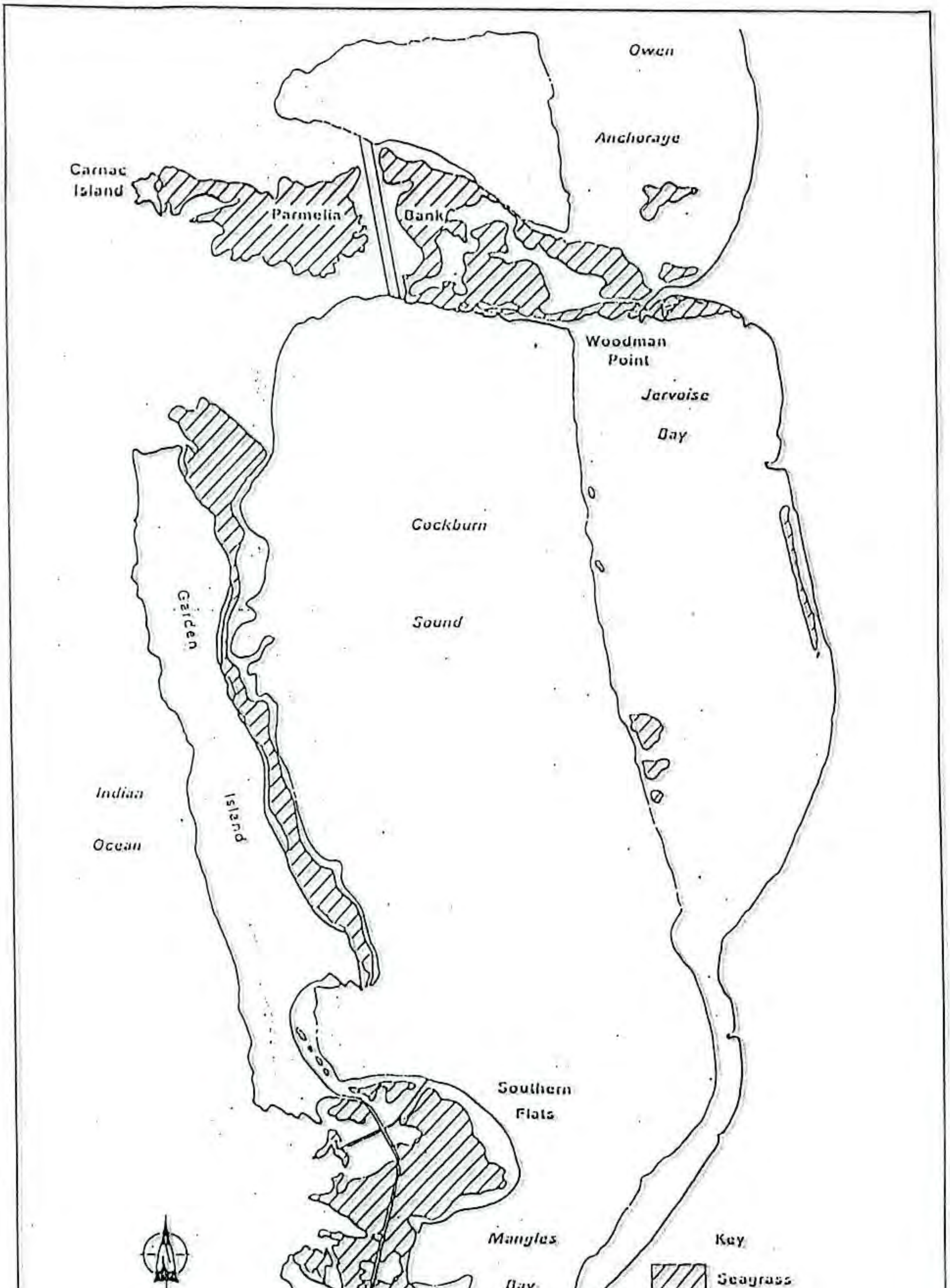


FIGURE 1

LOCALITY PLAN

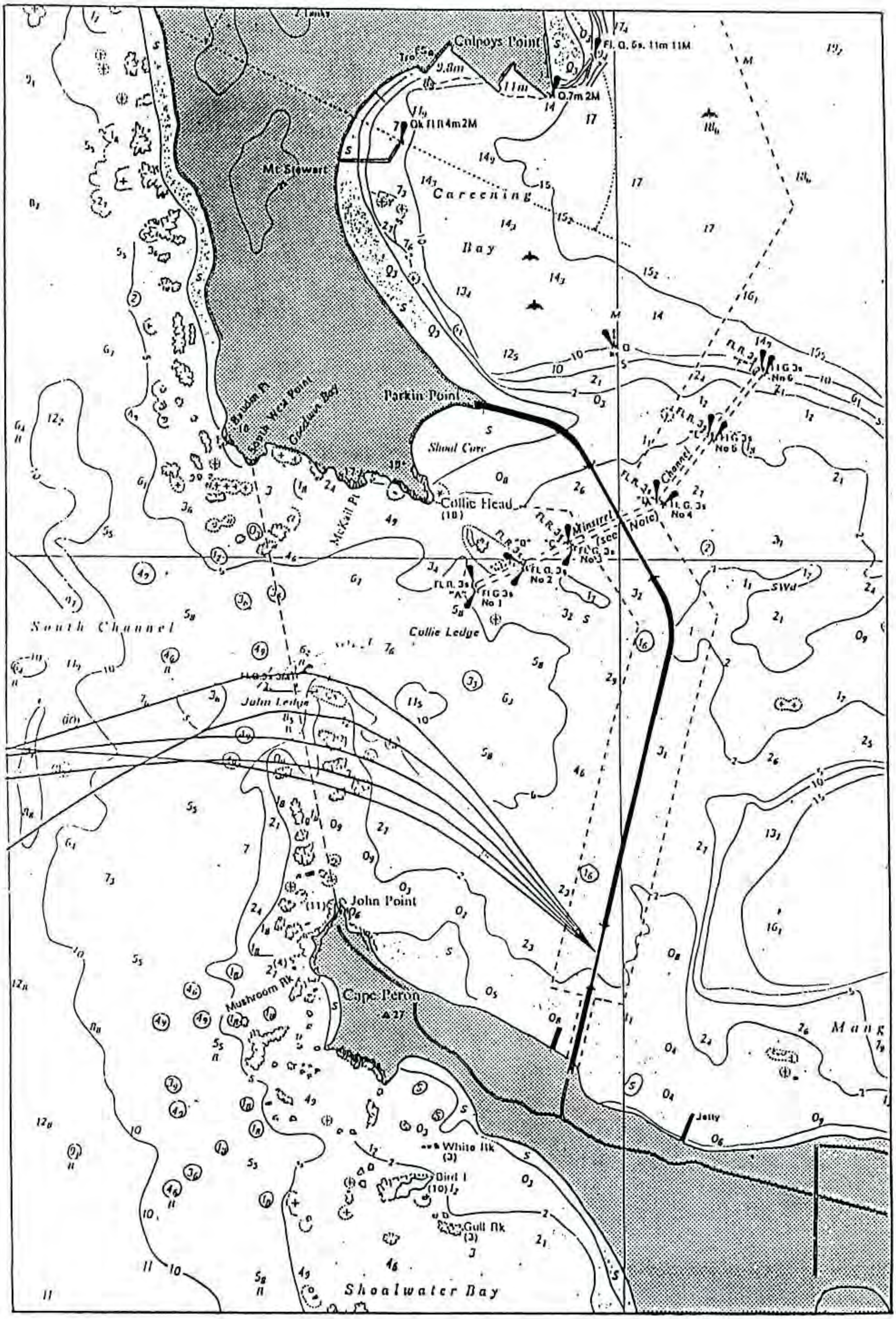


FIGURE 2

EXAMPLES OF WAVE ORTHOGONALS FROM DEEPWATER (T=5.0s)

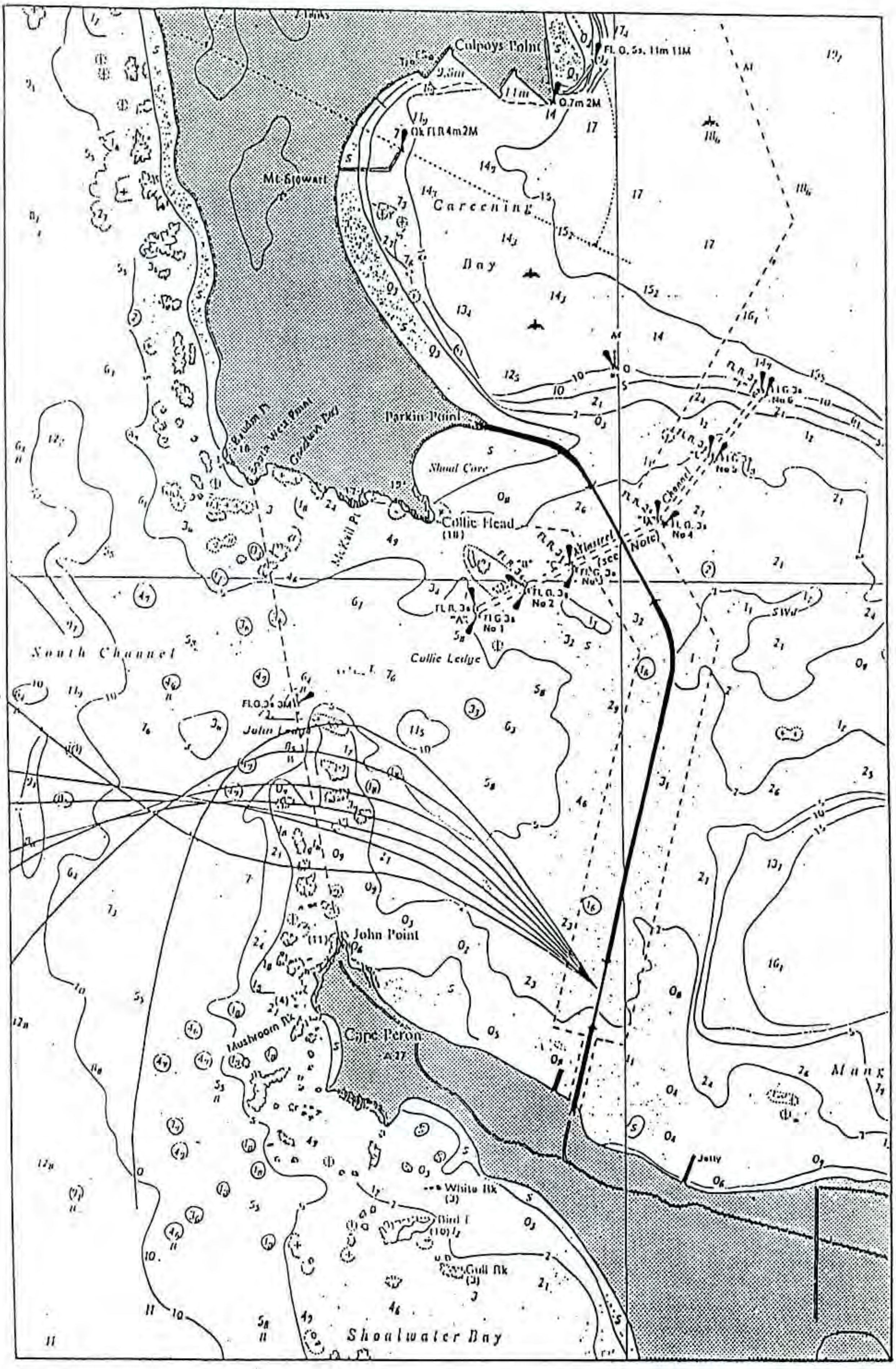


FIGURE 3

EXAMPLES OF WAVE ORTHOGONALS FROM DEEPWATER (T=10.0s)

OFF FREMANTLE PORT
NOV 84 TO OCT 85

PERCENTAGE OCCURRENCE OF SIGNIFICANT WAVE HT.(M) VS. PERIOD (SEC)

ANNUAL HEIGHT / PERIOD	0	TO 0.5	TO 1.0	TO 1.5	TO 2.0	TO 2.5	TO 3.0	TO 3.5	TO 4.0	TO 4.5	> 4.5	TOTAL
1		.68	.00	.00	.00	.00	.00	.00	.00	.00	.00	.68
2		2.88	.07	.00	.00	.00	.00	.00	.00	.00	.00	2.95
3		2.47	6.44	.00	.00	.00	.00	.00	.00	.00	.00	8.90
4		1.23	11.10	3.49	.00	.00	.00	.00	.00	.00	.00	15.82
5		1.10	9.45	6.71	1.23	.00	.00	.00	.00	.00	.00	18.49
6		3.29	6.99	4.04	.62	.00	.00	.00	.00	.00	.00	14.93
7.		1.92	7.12	2.60	.07	.00	.00	.00	.00	.00	.00	11.71
8		1.30	7.47	1.51	.00	.00	.00	.00	.00	.00	.00	10.27
9		.62	4.04	1.37	.00	.00	.00	.00	.00	.00	.00	6.03
10		.62	2.74	1.71	.00	.00	.00	.00	.00	.00	.00	5.07
11		.34	1.30	.96	.00	.00	.00	.00	.00	.00	.00	2.60
12		.21	.27	.55	.00	.00	.00	.00	.00	.00	.00	1.03
13		.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14
14		.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07
15		.07	.00	.00	.00	.00	.00	.00	.00	.00	.00	.07
>15		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ZERO	1.23											1.23
TOTAL	1.23	16.92	56.99	22.95	1.92	.00	.00	.00	.00	.00	.00	

NUMBER OF OBSERVATIONS 1460

FIGURE 4 Annual percentage joint occurrence matrix of Hs and Tz, derived from Hindcast data base for period November'84 to October'85.
("Fremantle wave climate study", DMH 6/88.)

OFF FREMANTLE PORT
NOV 84 TO OCT 85

PERCENTAGE OCCURRENCE OF SIGN.WAVE HEIGHT (H) VS. SIGN.WAVE DIRECTION

ANNUAL

HEIGHT	0	TO 0.5	TO 1.0	TO 1.5	TO 2.0	TO 2.5	TO 3.0	TO 3.5	TO 4.0	TO 4.5	> 4.5	TOTAL
NNE		.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14
NE		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ENE		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
E		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
ESE		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SE		.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SSE		.21	.00	.00	.00	.00	.00	.00	.00	.00	.00	.21
S		.21	.07	.00	.00	.00	.00	.00	.00	.00	.00	.27
SSW		.34	.00	.00	.00	.00	.00	.00	.00	.00	.00	.34
SW		.48	.55	.00	.00	.00	.00	.00	.00	.00	.00	1.03
WSW		11.23	35.96	9.79	.27	.00	.00	.00	.00	.00	.00	57.26
W		3.06	19.32	12.33	1.16	.00	.00	.00	.00	.00	.00	35.89
WNW		.89	.89	.82	.48	.00	.00	.00	.00	.00	.00	3.06
NW		.00	.14	.00	.00	.00	.00	.00	.00	.00	.00	.14
NNW		.14	.00	.00	.00	.00	.00	.00	.00	.00	.00	.14
N		.21	.07	.00	.00	.00	.00	.00	.00	.00	.00	.27
ZERO	1.23											1.23
TOTAL	1.23	16.92	56.99	22.95	1.92	.00	.00	.00	.00	.00	.00	

NUMBER OF OBSERVATIONS 1460

FIGURE 5 Annual percentage joint occurrence matrix of Hs and mean wave direction, derived from Hindcast data base for period November'84 to October'85. ("Fremantle wave climate study",DMH 6/88.)

Appendix 5.

Lake Richmond Discharge and Water Quality
Data (including Supplementary Report)

MANGLES BAY MARINA

LAKE RICHMOND DISCHARGE AND WATER QUALITY DATA

ENGINEERING HYDROLOGY

SURFACE WATER BRANCH

WATER AUTHORITY OF W.A.

FEBRUARY 1990

MANGLES BAY MARINA
LAKE RICHMOND DISCHARGE AND WATER QUALITY DATA

CONTENTS

CHAPTER 1. INTRODUCTION

This aim of this study is to prepare discharge estimates for Lake Richmond at Rockingham for the Department of Marine and Harbours.

This report gives the results of the discharge estimates from Lake Richmond. Estimates of discharges of total phosphorous, total nitrogen, inorganic nitrogen, chlorophyll and dissolved oxygen were also provided.

LAKE RICHMOND

Lake Richmond is located in Rockingham and is part of the Cooloongup wetland suites on the Quindalup Dunes. It is a permanent, freshwater lake. It was considered to have been formed as a result of a marine embayment of part of Cockburn Sound. The lake is unspoilt, although it is surrounded by urbanised areas.

It forms part of a urban drainage compensating scheme, accepting stormwater runoffs from the Rockingham and Safety Bay areas. Lake Richmond discharges to the ocean at Mangles Bay via an outlet drain located at the north west side of the lake.

DATA AVAILABILITY

The data required were available from the Water Authority's State Water Resources Information System (SWRIS). Post 1986 water quality data were not yet available from SWRIS. Table 1 shows the periods of record available.

TABLE 1: DATA AVAILABILITY

DATA	PERIOD
water level	1945 - 1978 (sparse data) 1878 - 1989 (monthly data)
total Nitrogen	1970 - 1986
inorganic Nitrogen	1970 - 1986
total Phosphorous	1970 - 1986
chlorophyll	1 reading only in 1985
dissolved oxygen	1985 - 1986

CHAPTER 2. LAKE RICHMOND LEVEL-DISCHARGE RELATIONSHIP

The discharges at Lake Richmond is currently unguaged. In order to estimate the discharges, a level-discharge relationship has to be derived first. The outlet drain was used to derive the level-discharge relationship.

The level-discharge relationship was determined using principles of open channel hydraulics. Two approaches were used.

> **Backwater Method** - backwater calculations to derive the flows which would correlate to the levels at Lake Richmond. HEC2 program was used to model the backwater profiles.
>
> **Normal Depth Method** - assumption of normal depths for flows in the outlet drain, with channel slopes and roughness estimated from survey information.

Backwater Method

This method uses the HEC2 steady state backwater program to compute the surface water profiles in the outlet drain. By computing the surface water profiles in the drain and water levels at Lake Richmond for a range of flows, a level-discharge relationship can be derived.

The outlet drain has a very flat channel slopes. The backwater effect is therefore sensitive to downstream conditions. Under extreme high tide conditions at Mangles Bay, flows from Lake Richmond can be affected by backwater. The lake level is also sensitive to channel characteristics such as weed growths and local obstructions in the drain.

The water profile in the outlet drain was surveyed on the 18th December 1989 to provide data to calibrate the backwater model. The flap gate located on the downstream end of the culvert at Cape Peron Road was found to be badly obstructed and choked with debris. The backing up of water appeared to commence from this flap gate.

Because of the flatness of the channel slope, the backwater method is sensitive to channel undulations, channel roughness and downstream water levels. We had to assume a set of channel characteristics that will apply to the whole record. Since channel characteristics are unlikely to be the same over the years, the derived level-discharge relationship is therefore considered to be very approximate. The results were used to enhance the values obtained using the normal depth method.

Normal Depth Method

This method was used as an alternative to the backwater method. The normal depth method is simple and reliable if applied to a well defined control point in the outlet channel.

A suitable control point was found at about 185m downstream of Lake Richmond. Flow was measured by the hydrographer at this cross-section.

Normal depths were calculated for a range of flows using the channel resistance formula based on Manning and a level-discharge curve was derived.

The rating curve compared well with data measured by the hydrographer. On this basis and because of its simplicity, the normal depth method was adopted. The derived level-discharge relationship is shown in Table 2 and Figure 1 & 2.

TABLE 2: ESTIMATED LEVEL-DISCHARGE RELATIONSHIP

LAKE LEVEL metres AHD	DISCHARGES litres/sec
0.698	0.0 (weir flow)
0.700	0.5
0.705	3.1
0.710	6.9
0.715	12
0.720	17
0.725	23
0.777	41 (channel flow)
0.833	64
0.890	91
0.946	120
1.003	152
1.059	186
1.115	222
1.171	259
1.223	293
1.276	330
1.330	372
1.383	419
1.437	471
1.491	528
1.545	590
1.600	658
1.654	731
1.709	811
1.764	897
1.819	989
1.874	1087
1.929	1193
1.984	1305
2.040	1425
2.096	1551
2.151	1686

<u>Note:</u>
weir flow below 0.725m AHD
channel flow above 0.725m AHD

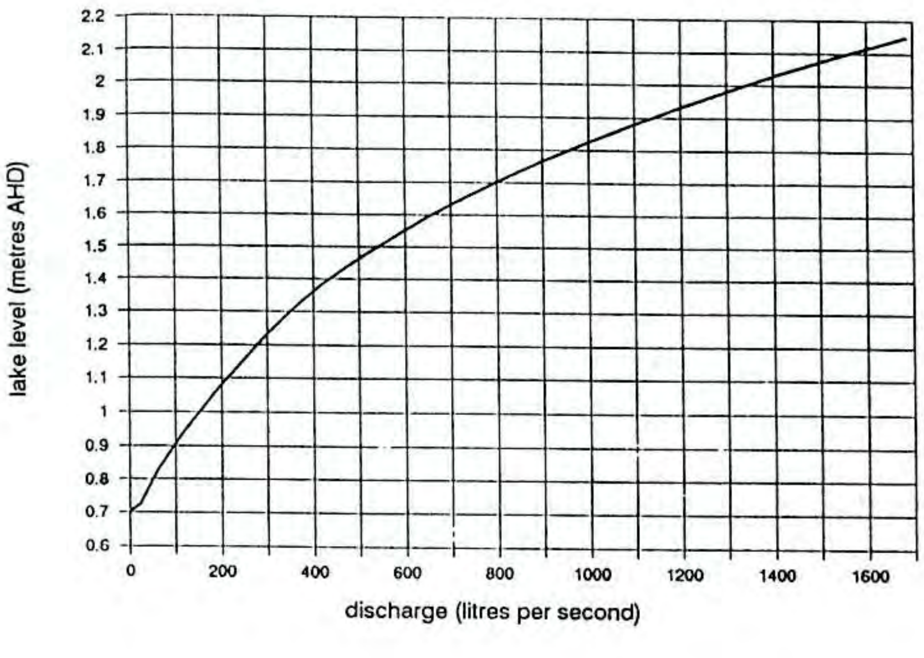


FIG 1: LAKE RICHMOND LEVEL-DISCHARGE RELATIONSHIP

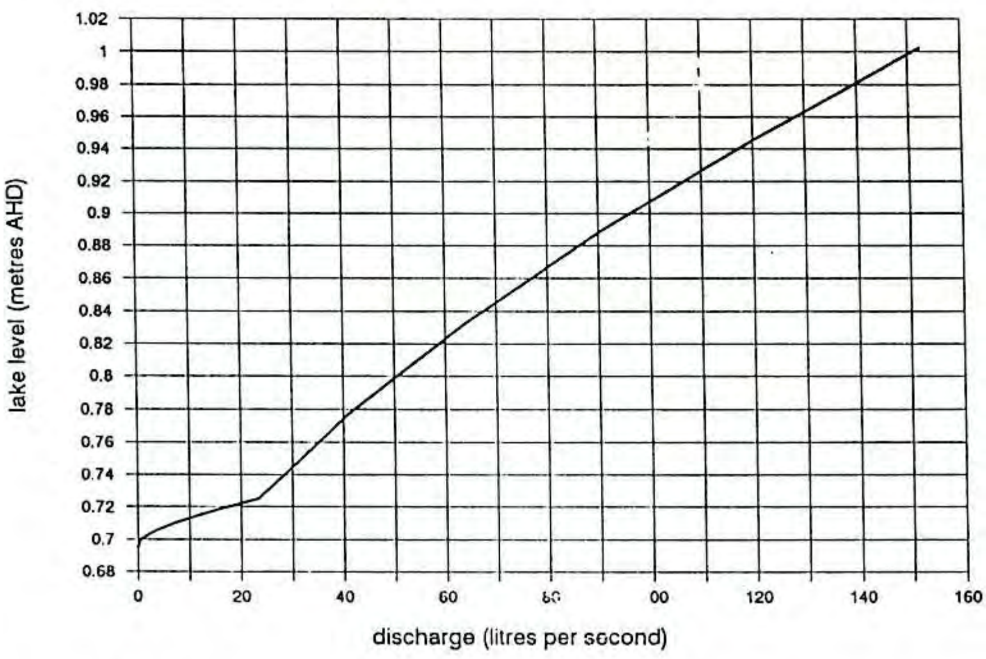


FIG 2: LAKE RICHMOND LEVEL-DISCHARGE RELATIONSHIP (MAGNIFIED)

CHAPTER 3. LAKE RICHMOND RECORDED LEVELS AND ESTIMATED DISCHARGES

Using the rating curve in Table 2, the recorded water levels at Lake Richmond were converted to discharges. The results are shown in Table 3 below.

TABLE 3: LAKE RICHMOND RECORDED LEVELS AND ESTIMATED DISCHARGE

DATE	RECORDED LAKE LEVEL m AHD	CALC FLOW L/s	DATE	RECORDED LAKE LEVEL m AHD	CALC FLOW L/s	DATE	RECORDED LAKE LEVEL m AHD	CALC FLOW L/s
15/08/45	1.308	355	28/10/80	0.995	148	22/02/85	0.520	0
11/08/53	1.167	257	27/11/80	0.835	65	28/03/85	0.445	0
29/10/53	1.055	184	19/12/80	0.595	0	30/04/85	0.540	0
12/04/54	0.223	0	30/01/81	0.395	0	20/05/85	0.530	0
14/09/54	0.988	144	27/02/81	0.280	0	10/06/85	0.750	32
02/03/55	0.759	35	30/03/81	0.255	0	30/07/85	0.960	128
07/10/55	1.823	996	30/04/81	0.245	0	28/08/85	1.050	181
01/11/55	1.783	928	26/05/81	0.695	0	24/09/85	1.080	200
09/08/56	1.438	472	30/06/81	0.895	94	29/10/85	1.030	169
12/07/57	1.244	307	27/07/81	1.135	235	25/11/85	0.920	107
13/05/58	0.421	0	27/08/81	1.045	178	01/05/86	0.461	0
25/08/58	1.329	371	29/09/81	0.915	104	04/06/86	0.699	0
12/05/59	0.445	0	28/10/81	0.855	75	23/06/86	0.746	30
14/09/61	1.247	310	26/11/81	0.765	37	27/08/86	1.256	316
15/05/62	0.485	0	29/12/81	0.615	0	24/09/86	1.137	237
17/04/63	0.280	0	29/01/82	0.860	77	29/10/86	1.058	186
07/08/63	1.405	440	26/02/82	0.730	25	27/11/86	0.963	130
11/09/64	1.667	750	31/03/82	0.580	0	29/12/86	0.702	2
20/10/65	1.250	312	30/04/82	0.390	0	04/02/87	0.533	0
15/06/66	0.506	0	26/05/82	0.290	0	04/03/87	0.385	0
20/06/66	0.536	0	30/06/82	0.750	32	30/03/87	0.373	0
27/09/68	1.286	338	30/07/82	0.950	123	28/04/87	0.568	0
19/08/69	0.866	80	27/08/82	0.880	86	25/05/87	0.673	0
21/03/73	0.271	0	30/09/82	0.880	86	25/06/87	0.862	78
26/10/73	0.570	0	28/10/82	0.790	46	22/07/87	0.872	83
10/10/74	1.270	326	26/11/82	0.590	0	26/08/87	1.146	243
15/05/78	0.305	0	31/12/82	0.440	0	21/09/87	1.117	223
13/06/78	0.615	0	19/01/83	0.380	0	26/10/87	0.909	101
27/07/78	1.020	163	24/02/83	0.590	0	23/11/87	0.838	67
31/08/78	0.810	55	29/03/83	0.590	0	21/12/87	0.756	34
02/10/78	0.990	145	28/04/83	0.560	0	28/01/88	0.588	0
25/10/78	0.892	92	30/05/83	0.580	0	29/02/88	0.371	0
15/11/78	0.867	80	29/06/83	0.890	91	28/03/88	0.236	0
15/12/78	0.667	0	28/07/83	1.008	155	28/04/88	0.416	0
16/01/79	0.592	0	30/08/83	0.840	67	18/05/88	0.668	0
27/02/79	0.372	0	29/09/83	0.810	55	15/06/88	0.995	148
23/03/79	0.252	0	28/11/83	0.840	67	14/07/88	1.094	209
21/05/79	0.392	0	30/12/83	0.770	38	16/08/88	1.148	244
28/06/79	0.742	29	26/01/84	0.590	0	22/09/88	1.100	212
20/07/79	1.042	176	29/02/84	0.374	0	18/10/88	1.113	221
24/08/79	1.017	161	19/03/84	0.225	0	16/11/88	1.073	195
24/09/79	0.917	105	30/04/84	0.370	0	12/12/88	0.910	101
29/10/79	0.767	37	30/05/84	1.040	175	12/01/89	0.740	28
23/11/79	0.692	0	28/06/84	1.080	200	24/02/89	0.580	0
24/12/79	0.532	0	31/07/84	1.030	169	30/03/89	0.619	0
25/01/80	0.342	0	27/08/84	1.130	232	26/04/89	0.657	0
28/02/80	0.212	0	28/09/84	1.270	326	25/05/89	0.825	61
26/03/80	0.132	0	31/10/84	1.160	252	19/06/89	0.843	69
04/07/80	1.242	306	28/11/84	0.980	139	18/07/89	0.984	142
30/09/80	1.072	195	23/01/85	0.640	0			

CHAPTER 4. LAKE RICHMOND ESTIMATED AVERAGE MONTHLY DISCHARGE

Although monthly records of water level at Lake Richmond were available, they were not taken at a strict time interval. To estimate average monthly discharges, the data had to be interpolated at the first of each month. This was done only for the data from 1978 onwards since the records contain less missing data. The estimated lake levels are shown in Table 4.

The estimated lake levels in Table 4 were then converted to total average monthly discharges. The average monthly discharge is the mean of the first of one month and the next. The estimated average monthly discharges are shown in Table 5.

TABLE 4: ESTIMATED LAKE LEVELS AT FIRST OF MONTH (m AHD)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1978						0.487	0.781	0.990	0.816	0.994	0.884	0.760
1979	0.627	0.508	0.362	0.273	0.345	0.493	0.783	1.033	0.991	0.887	0.758	0.651
1980	0.485	0.315	0.206	0.132	0.532	0.876	1.242	1.188	1.128	1.069	0.974	0.791
1981	0.533	0.387	0.278	0.254	0.262	0.729	0.904	1.120	1.025	0.911	0.843	0.742
1982	0.639	0.846	0.716	0.574	0.386	0.369	0.757	0.945	0.880	0.877	0.762	0.569
1983	0.437	0.456	0.590	0.587	0.562	0.601	0.898	0.988	0.838	0.811	0.827	0.833
1984	0.757	0.552	0.366	0.270	0.392	1.043	1.075	1.034	1.152	1.260	1.154	0.962
1985	0.774	0.604	0.505	0.457	0.540	0.656	0.838	0.966	1.054	1.070	1.018	0.900
1986	0.700	0.570	0.350	0.265	0.461	0.678	0.809	1.052	1.235	1.121	1.048	0.930
1987	0.688	0.547	0.401	0.386	0.580	0.716	0.864	0.950	1.139	1.058	0.894	0.815
1988	0.707	0.561	0.366	0.259	0.454	0.832	1.050	1.123	1.127	1.105	1.094	0.979
1989	0.800	0.666	0.586	0.622	0.686	0.830	0.901					
ave	0.650	0.546	0.430	0.371	0.473	0.692	0.909	1.035	1.035	1.015	0.932	0.812

TABLE 5: ESTIMATED TOTAL AVERAGE MONTHLY DISCHARGES (Thousands of Cubic Metres)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	total
1978						55.0	251.1	270.7	264.9	315.3	159.7	47.0	1363.6
1979	0.0	0.0	0.0	0.0	0.0	56.1	286.3	423.3	304.8	166.0	44.6	0.0	1281.1
1980	0.0	0.0	0.0	0.0	113.0	506.0	771.7	670.7	548.6	440.2	236.8	62.4	3349.4
1981	0.0	0.0	0.0	0.0	33.2	159.6	433.4	523.6	346.9	228.9	127.0	39.0	1891.6
1982	94.2	100.5	17.1	0.0	0.0	44.2	206.3	276.1	221.8	161.5	46.3	0.0	1168.0
1983	0.0	0.0	0.0	0.0	0.0	123.3	320.2	281.9	157.5	156.3	163.2	131.7	1334.0
1984	45.7	0.0	0.0	0.0	236.4	483.4	492.2	559.5	732.8	759.0	489.1	226.5	4024.7
1985	53.2	0.0	0.0	0.0	0.0	86.3	265.4	421.7	487.9	475.0	333.9	129.5	2252.8
1986	0.6	0.0	0.0	0.0	0.0	70.2	316.3	646.9	683.1	543.1	377.9	150.0	2788.2
1987	0.0	0.0	0.0	0.0	17.1	118.6	269.8	483.0	549.0	373.2	194.0	82.1	2086.9
1988	6.2	0.0	0.0	0.0	85.4	317.0	546.6	612.4	577.5	568.1	450.3	253.5	3417.0
1989	67.5	0.0	0.0	0.0	84.3	207.0							
ave	24.3	9.1	1.6	0.0	51.8	185.5	378.1	470.0	443.2	380.6	238.5	102.0	2268.9

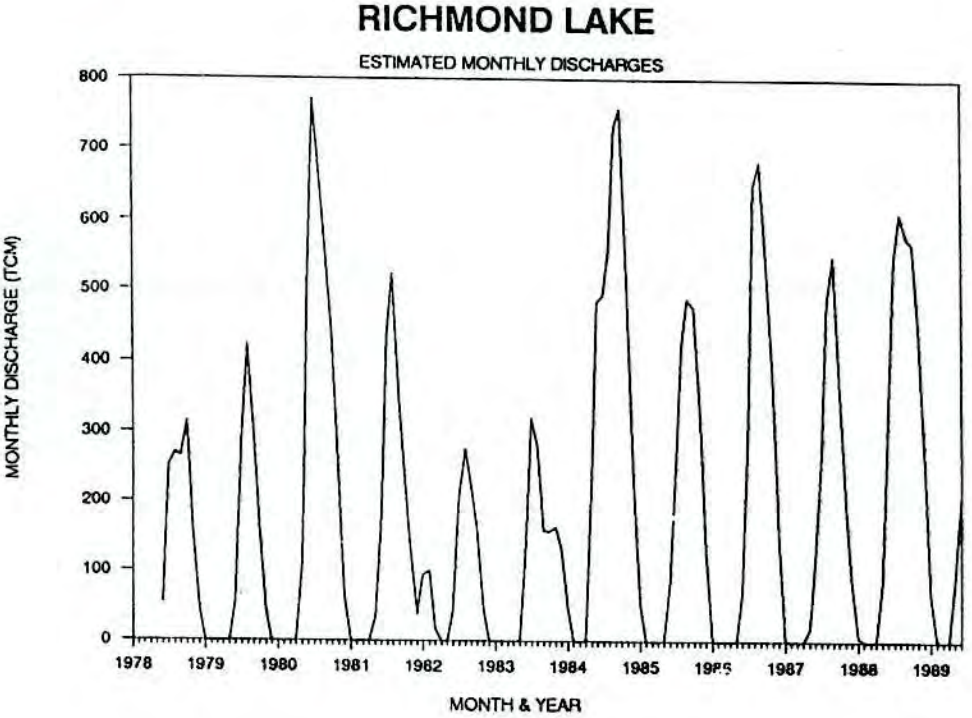


FIG 3: ESTIMATED MONTHLY DISCHARGES

CHAPTER 5. LAKE RICHMOND RECORDED WATER QUALITY SAMPLES

The recorded water quality samples extracted from SWRIS are shown below in Table 6 and in tabular form in Table 7,8 & 9. There were only a few spot samples readings for dissolved oxygen and chlorophyll. The water quality data for nutrients were taken mainly during the months of February, March, September and October.

For the missing months where the water quality data are not available, the nutrient levels were estimated by straight line interpolation. The method is considered crude. A more detailed method was not warranted since the nutrient levels do not vary significantly. The estimated and interpolated water quality data are shown in Table 10,11 & 12

TABLE 6: RECORDED WATER QUALITY SAMPLES

	Total Phosphorous mg/L	Total Nitrogen mg/L	Inorganic Nitrogen mg/L	Dissolved Oxygen mg/L	Chlorophyll mg/l
02/04/1970	0.01	1.40	0.20		
24/11/1970		1.30	0.30		
07/09/1971	1.30	0.10			
24/02/1972	0.06	0.85	0.10		
06/09/1972	0.04	1.00	0.20		
01/02/1973	0.03	1.70	0.20		
02/10/1973	0.10	0.30	0.30		
13/03/1974	0.15	1.00	0.40		
03/09/1974	<0.01	1.20	0.30		
25/02/1975	0.48	1.35	0.05		
01/10/1975	0.05	0.80	0.25		
25/02/1976	0.03	4.15	0.05		
12/10/1976	0.05	0.85	0.10		
09/02/1977	0.70	0.45	0.05		
03/10/1977	<0.05	0.25	0.15		
27/02/1978	0.90	1.35	0.10		
07/03/1978	0.90	1.35	0.10		
03/10/1978	<0.05	0.70	0.20		
13/02/1979	<0.05	0.85	<0.05		
02/10/1979	<0.05	0.95	0.30		
12/02/1980	<0.05	0.50	0.10		
01/10/1980	<0.05	0.85	0.35		
23/02/1981	<0.05	0.50	0.25		
08/10/1981	<0.05	0.40	0.05		
17/03/1982	0.30	0.95	0.05		
23/09/1982	0.30	0.70	0.15		
22/03/1983	0.05	0.55	0.05		
20/09/1983	0.05				
20/03/1984	0.10		<0.05		
25/09/1984	<0.05		<0.05		
26/03/1985	0.10	1.10		9.20	0.50
24/09/1985	0.75	4.40		13.60	
18/03/1986	<0.05	0.90			
14/10/1986	0.20	0.70		10.00	

TABLE 7: RECORDED TOTAL PHOSPHOROUS CONCENTRATION (mg/L)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1970				0.01								
1971									1.30			
1972		0.06							0.04			
1973		0.03								0.10		
1974			0.15						<0.01			
1975		0.48								0.05		
1976		0.03								0.05		
1977		0.70								0.05		
1978		0.90	0.90							0.05		
1979		<0.05								<0.05		
1980		<0.05								<0.05		
1981		<0.05								<0.05		
1982			0.30						0.30			
1983			0.05						0.05			
1984			0.10						<0.05			
1985			0.10						0.75			
1986			<0.05							0.20		
ave		0.26	0.24	0.01					0.36	0.07		

TABLE 8: RECORDED TOTAL NITROGEN CONCENTRATION (mg/L)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1970				1.40							1.30	
1971									0.10			
1972		0.85							1.00			
1973		1.70								0.30		
1974			1.00						1.20			
1975		1.35								0.80		
1976		4.15								0.85		
1977		0.45								0.25		
1978		1.35	1.35							0.70		
1979		0.85								0.95		
1980		0.50								0.85		
1981		0.50								0.40		
1982			0.95						0.70			
1983			0.55									
1984												
1985			1.10						4.40			
1986			0.90							0.70		
ave		1.30	0.98	1.40					1.48	0.64	1.30	

TABLE 9: RECORDED INORGANIC NITROGEN CONCENTRATION (mg/L)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1970				0.20							0.30	
1971												
1972		0.10							0.20			
1973		0.20								0.30		
1974			0.40						0.30			
1975		0.05								0.25		
1976		0.05								0.10		
1977		0.05								0.15		
1978		0.10	0.10							0.20		
1979		<0.05								0.30		
1980		0.10								0.35		
1981		0.25								0.05		
1982			0.05						0.15			
1983			0.05									
1984			<0.05						<0.05			
1985												
1986												
ave		0.11	0.13	0.20					0.18	0.21		

TABLE 10: RECORDED & INTERPOLATED TOTAL PHOSPHOROUS CONCENTRATION (mg/L)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1978	0.69	0.90	0.90	0.78	0.66	0.54	0.41	0.29	0.17	0.05	0.26	0.47
1979	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1980	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1981	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1982	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
1983	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1984	0.08	0.09	0.10	0.09	0.08	0.08	0.07	0.06	0.05	0.06	0.07	0.08
1985	0.32	0.21	0.10	0.21	0.32	0.43	0.53	0.64	0.75	0.64	0.53	0.43
1986	0.11	0.08	0.05	0.07	0.09	0.11	0.14	0.16	0.18	0.20	0.17	0.14

TABLE 11: RECORDED & INTERPOLATED TOTAL NITROGEN CONCENTRATION (mg/L)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1978	1.19	1.35	1.35	1.26	1.16	1.07	0.98	0.89	0.79	0.70	0.86	1.03
1979	0.88	0.85	0.86	0.88	0.89	0.90	0.91	0.92	0.94	0.95	0.93	0.90
1980	0.59	0.50	0.54	0.59	0.63	0.67	0.72	0.76	0.81	0.85	0.76	0.68
1981	0.48	0.50	0.49	0.48	0.46	0.45	0.44	0.43	0.41	0.40	0.43	0.45
1982	0.87	0.91	0.95	0.91	0.87	0.82	0.78	0.74	0.70	0.74	0.78	0.83
1983	0.38	0.47	0.55	0.47	0.38	0.30	0.22	0.13	0.05	0.13	0.22	0.30
1984												
1985	2.20	1.65	1.10	1.65	2.20	2.75	3.30	3.85	4.40	3.85	3.30	2.75
1986	0.82	0.86	0.90	0.87	0.84	0.81	0.79	0.76	0.73	0.70	0.74	0.78

TABLE 12: RECORDED & INTERPOLATED INORGANIC NITROGEN CONCENTRATION (mg/L)

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
1978	0.12	0.10	0.10	0.11	0.13	0.14	0.16	0.17	0.19	0.20	0.18	0.15
1979	0.11	0.05	0.08	0.11	0.14	0.18	0.21	0.24	0.27	0.30	0.24	0.18
1980	0.16	0.10	0.13	0.16	0.19	0.23	0.26	0.29	0.32	0.35	0.29	0.23
1981	0.20	0.25	0.23	0.20	0.17	0.15	0.12	0.10	0.07	0.05	0.10	0.15
1982	0.08	0.07	0.05	0.07	0.08	0.10	0.12	0.13	0.15	0.13	0.12	0.10
1983	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1984	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
1985												
1986												

CHAPTER 6. ESTIMATED NUTRIENT LOADING

The nutrient discharges from Lake Richmond were estimated from the estimated monthly flows in Table 5 and estimated nutrient concentrations in Table 10,11 & 12. These estimated loadings are considered very approximate since they were derived from estimated flows and estimated nutrient concentrations which already have some inaccuracies in them. The results in Table 13,14 & 15 should only be used as a rough guide.

TABLE 13: ESTIMATED MONTHLY LOADING (kg) - TOTAL PHOSPHOROUS

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	total
1978	0	0	0	0	0	29	104	79	45	16	42	22	338
1979	0	0	0	0	0	3	14	21	15	8	2	0	64
1980	0	0	0	0	6	25	39	34	27	22	12	3	167
1981	0	0	0	0	2	8	22	26	17	11	6	2	95
1982	28	30	5	0	0	13	62	83	67	48	14	0	350
1983	0	0	0	0	0	6	16	14	8	8	8	7	67
1984	4	0	0	0	20	36	33	33	37	44	33	17	256
1985	17	0	0	0	0	37	142	271	366	305	178	55	1369
1986	0	0	0	0	0	8	43	102	122	109	64	21	469

TABLE 14: ESTIMATED MONTHLY LOADING (kg) - TOTAL NITROGEN

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	total
1978	0	0	0	0	0	59	246	240	210	221	138	48	1161
1979	0	0	0	0	0	50	261	392	286	158	41	0	1188
1980	0	0	0	0	71	342	555	511	442	374	181	42	2518
1981	0	0	0	0	15	72	190	223	143	92	54	18	806
1982	82	91	16	0	0	36	162	205	155	120	36	0	903
1983	0	0	0	0	0	37	69	38	8	21	35	39	248
1984													
1985	117	0	0	0	0	237	876	1623	2147	1829	1102	356	8287
1986	1	0	0	0	0	57	248	490	498	380	280	117	2071

TABLE 15: ESTIMATED MONTHLY LOADING (kg) - INORGANIC NITROGEN

	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	total
1978	0	0	0	0	0	8	39	46	49	63	28	7	241
1979	0	0	0	0	0	10	59	101	82	50	11	0	312
1980	0	0	0	0	22	114	198	193	175	154	68	14	937
1981	0	0	0	0	6	24	54	52	26	11	13	6	192
1982	8	7	1	0	0	4	24	37	33	22	5	0	141
1983	0	0	0	0	0	6	16	14	8	8	8	7	67
1984	2	0	0	0	12	24	25	28	37	38	24	11	201
1985													
1986													

CHAPTER 7. CONCLUSIONS

The discharges from Lake Richmond have been estimated from water levels that were recorded at the lake. The method was to derive a rating curve at the outlet drain located at the north west side of the lake. Because of the flatness of the channel slope and the dynamic nature of the drain's hydraulic characteristics, the derived rating curve and consequently the estimated discharges are considered to be approximate.

The water quality data were normally taken during the months of February, March, September and October. Straight line interpolations were used to fill in the missing data. This approximation again would be reflected in the estimates of nutrient loadings from Lake Richmond. The nutrient loading estimates are very approximate and should be used only as a rough guide.

There were too few recorded dissolved oxygen and chlorophyll data to warrant the calculations of discharge loadings of these elements.

MANGLES BAY MARINA

LAKE RICHMOND DISCHARGE AND WATER QUALITY DATA

SUPPLEMENTARY REPORT

ENGINEERING HYDROLOGY

SURFACE WATER BRANCH

WATER AUTHORITY OF W.A.

MARCH 1990

MANGLES BAY MARINA
LAKE RICHMOND DISCHARGE AND WATER QUALITY DATA
SUPPLEMENTARY REPORT

CONTENTS

1 INTRODUCTION

This supplementary study was carried out at the request of Peter Boreham after the main report was submitted to the Department of Marine and Harbours.

The aim of this study is to estimate the historic peak flow hydrographs and to derive a longer sequence of historic lake levels by using rainfall data.

The 5, 20, 50 and 100 years ARI peak monthly flowrates were calculated using frequency analysis.

2 APPROACH

Record of observed water levels for Lake Richmond is short (12 years). Two approaches to extend the water level records are:-

1) Regression analysis to derive a relationship between rainfall and lake level.

2) Water balance analysis.

Water balance analysis requires a level-storage relationship for Lake Richmond which is currently unavailable. A straight-line relationship for level and storage would have to be assumed.

Regression analysis was carried out on the monthly rainfall data. To simulate the antecedent conditions, the monthly rainfall totals from the last three months were taken into account in the analysis. A regression equation was found to fit the data well with better fit for the peak flows than the low flows. Since the low flows were of less importance to the study, the derived regression equation was adopted.

3 REGRESSION ANALYSIS

The data was fitted using method of least-squares. The regression equation will be in the form

$$Y = a_1X_1 + a_2X_2 + \ldots\ldots + C$$

where

Y is lake level

$X_1, X_2, ..$ are monthly rainfall totals, X_1 is rainfall total for month. X_2 is rainfall total for previous month and X_3 is rainfall total for month before X_2 and etc.

$a_1, a_2, ..$ are the regression coefficients

C is the regression constant

The derived regression equation is

$$\text{Lake Level} = 0.001563 * x_1 + 0.001319 * x_2 + 0.000997 * x_3 + 0.001326 * x_4 + 0.396625$$

Details of the regression analysis are shown below:-

Constant C	0.396625			
Std Err of Y est	0.138223			
R Squared	0.749286			
No. of Observations	133			
Degrees of Freedom	128			
X Coefficients, a	0.001563	0.001319	0.000997	0.001326
Std Err of Coeff	0.000231	0.000256	0.000258	0.000229

The derived R^2 value of 0.75 suggests a reasonably high level of predictability of the lake levels using rainfall data. Table 1 (Appendix I) shows the comparison of observed and predicted lake levels using the derived regression equation. Figure 1 shows the comparison graphically. The regression equation fitted the peak lake levels better than the low water levels.

The estimated lake levels were converted to flows by using the adopted rating curve. Table 2 (Appendix II) shows the results of the flows estimated using the 92 years of monthly rainfall record. The estimated flows are plotted in Figure 2.

A frequency analysis was carried out on the estimated annual maximum monthly flowrates. The results of the analysis and frequency plots are shown in Table 3 (Appendix III) and Figure 3 respectively.

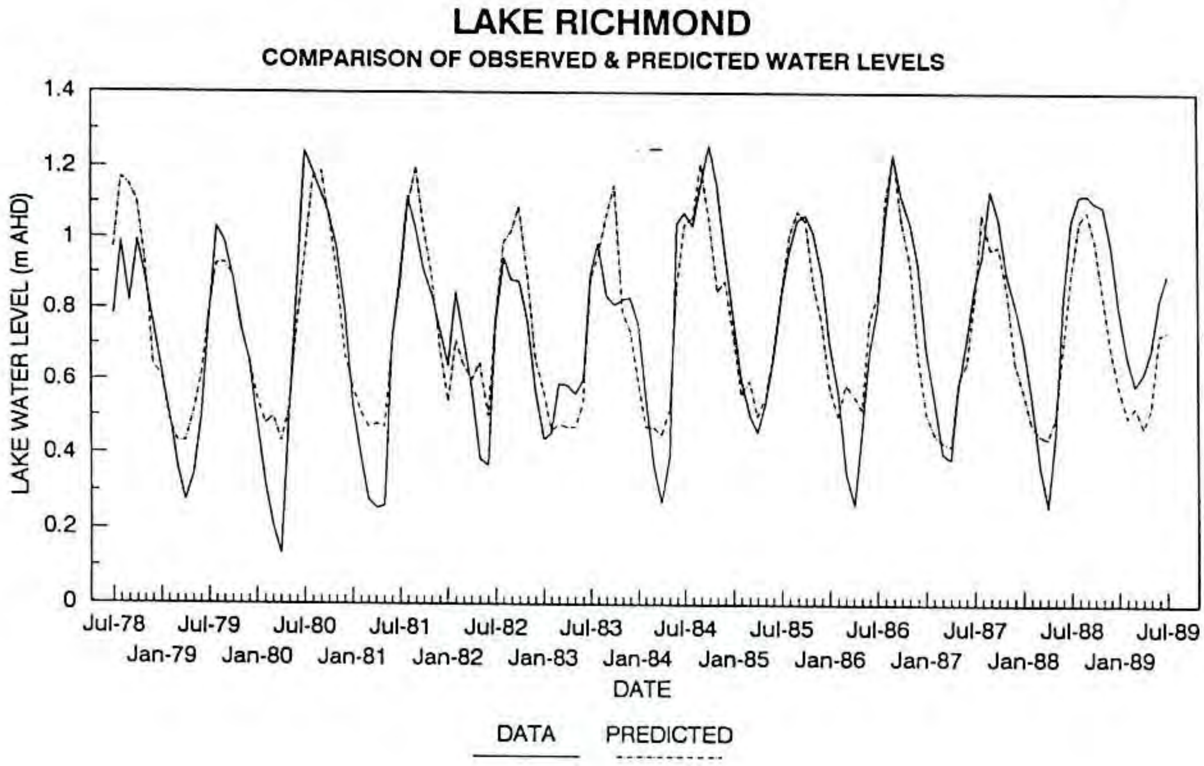
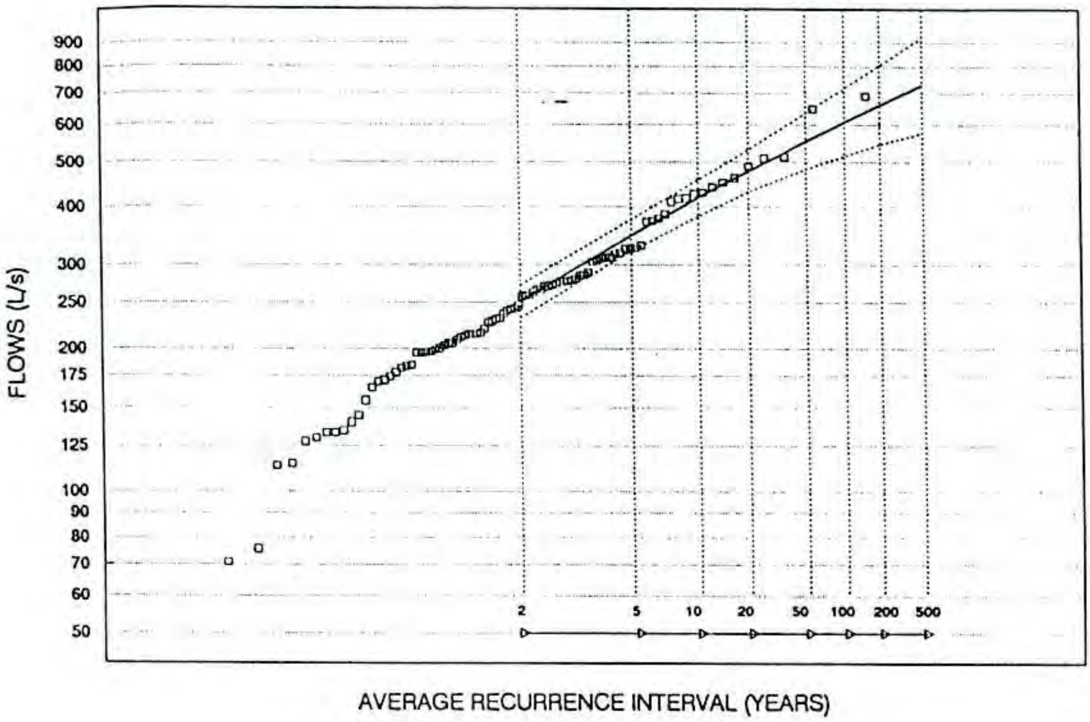


FIGURE 1: COMPARISON OF OBSERVED & PREDICTED WATER LEVELS

FREQUENCY CURVE OF FLOWS FROM LAKE RICHMOND
FITTED LOG-PEARSON TYPE III DISTRIBUTION



ARI years	95% Conf limit	Freq Curve	5% Conf limit
2	232	251	271
5	326	352	381
10	382	417	455
20	429	477	530
50	481	552	634
100	514	607	716
200	543	660	802
500	576	729	923

FIGURE 2: FREQUENCY CURVE - LAKE RICHMOND FLOWS

APPENDIX I

RESULTS OF REGRESSION ANALYSIS

TABLE 1: RESULTS OF REGRESSION ANALYSIS - MONTHLY RAINFALL AND LAKE LEVELS

CORRELATION OF CATCHMENT AVERAGE MONTHLY RAINFALL
WITH LAKE RICHMOND WATER LEVELS USING REGRESSION TECHNIQUE

	Y	X1	X2	X3	X4	
DATE	OBSERVED WATER LEVEL m AHD	CATCHMENT AVG MONTHLY RAINFALL mm NO LAG	LAG 1 MTH	LAG 2 MTH	LAG 3 MTH	PREDICTED WATER LEVEL m AHD
01/07/78	0.78	211.5	157.6	16.2	16.9	0.97
01/08/78	0.99	200.1	211.5	157.6	16.2	1.17
01/09/78	0.82	44.2	200.1	211.5	157.6	1.15
01/10/78	0.99	107.3	44.2	200.1	211.5	1.10
01/11/78	0.88	52.4	107.3	44.2	200.1	0.93
01/12/78	0.76	8.7	52.4	107.3	44.2	0.64
01/01/79	0.63	7.9	8.7	52.4	107.3	0.61
01/02/79	0.51	3.3	7.9	8.7	52.4	0.49
01/03/79	0.36	5.7	3.3	7.9	8.7	0.43
01/04/79	0.27	10.4	5.7	3.3	7.9	0.43
01/05/79	0.34	58.1	10.4	5.7	3.3	0.51
01/06/79	0.49	73.4	58.1	10.4	5.7	0.61
01/07/79	0.78	149.2	73.4	58.1	10.4	0.80
01/08/79	1.03	121.1	149.2	73.4	58.1	0.93
01/09/79	0.99	79.5	121.1	149.2	73.4	0.93
01/10/79	0.89	47.7	79.5	121.1	149.2	0.89
01/11/79	0.76	23.7	47.7	79.5	121.1	0.74
01/12/79	0.65	49.9	23.7	47.7	79.5	0.66
01/01/80	0.48	2.6	49.9	23.7	47.7	0.55
01/02/80	0.32	0.0	2.6	49.9	23.7	0.48
01/03/80	0.21	20.8	0.0	2.6	49.9	0.50
01/04/80	0.13	0.5	20.8	0.0	2.6	0.43
01/05/80	0.53	74.5	0.5	20.8	0.0	0.53
01/06/80	0.88	149.6	74.5	0.5	20.8	0.76
01/07/80	1.24	177.8	149.6	74.5	0.5	0.95
01/08/80	1.19	184.3	177.8	149.6	74.5	1.17
01/09/80	1.13	111.7	184.3	177.8	149.6	1.19
01/10/80	1.07	59.4	111.7	184.3	177.8	1.06
01/11/80	0.97	42.3	59.4	111.7	184.3	0.90
01/12/80	0.79	9.5	42.3	59.4	111.7	0.67
01/01/81	0.53	35.2	9.5	42.3	59.4	0.58
01/02/81	0.39	0.0	35.2	9.5	42.3	0.51
01/03/81	0.28	18.0	0.0	35.2	9.5	0.47
01/04/81	0.25	8.5	18.0	0.0	35.2	0.48
01/05/81	0.26	25.6	8.5	18.0	0.0	0.47
01/06/81	0.73	165.9	25.6	8.5	18.0	0.72
01/07/81	0.90	142.4	165.9	25.6	8.5	0.87
01/08/81	1.12	194.5	142.4	165.9	25.6	1.09
01/09/81	1.03	116.9	194.5	142.4	165.9	1.20
01/10/81	0.91	60.4	116.9	194.5	142.4	1.03
01/11/81	0.84	28.9	60.4	116.9	194.5	0.90
01/12/81	0.74	24.1	28.9	60.4	116.9	0.69
01/01/82	0.64	4.2	24.1	28.9	60.4	0.54
01/02/82	0.85	155.4	4.2	24.1	28.9	0.71
01/03/82	0.72	4.0	155.4	4.2	24.1	0.64
01/04/82	0.57	25.6	4.0	155.4	4.2	0.60
01/05/82	0.39	6.5	25.6	4.0	155.4	0.65
01/06/82	0.37	40.4	6.5	25.6	4.0	0.50
01/07/82	0.76	190.8	40.4	6.5	25.6	0.79
01/08/82	0.95	185.6	190.8	40.4	6.5	0.99
01/09/82	0.88	86.7	185.6	190.8	40.4	1.02
01/10/82	0.88	87.2	86.7	185.6	190.8	1.09
01/11/82	0.76	31.3	87.2	86.7	185.6	0.89
01/12/82	0.57	11.4	31.3	87.2	86.7	0.66
01/01/83	0.44	4.9	11.4	31.3	87.2	0.57
01/02/83	0.46	0.5	4.9	11.4	31.3	0.46
01/03/83	0.59	37.7	0.5	4.9	11.4	0.48
01/04/83	0.59	8.7	37.7	0.5	4.9	0.47
01/05/83	0.56	12.1	8.7	37.7	0.5	0.47
01/06/83	0.60	43.0	12.1	8.7	37.7	0.54
01/07/83	0.90	256.3	43.0	12.1	8.7	0.88
01/08/83	0.99	102.1	256.3	43.0	12.1	0.95
01/09/83	0.84	138.4	102.1	256.3	43.0	1.06
01/10/83	0.81	80.3	138.4	102.1	256.3	1.15
01/11/83	0.83	9.4	80.3	138.4	102.1	0.79
01/12/83	0.83	40.7	9.4	80.3	138.4	0.74
01/01/84	0.76	16.1	40.7	9.4	80.3	0.59
01/02/84	0.55	0.0	16.1	40.7	9.4	0.47
01/03/84	0.37	3.8	0.0	16.1	40.7	0.47
01/04/84	0.27	14.3	3.8	0.0	16.1	0.45
01/05/84	0.39	61.7	14.3	3.8	0.0	0.52
01/06/84	1.04	236.6	61.7	14.3	3.8	0.87
01/07/84	1.08	163.1	236.6	61.7	14.3	1.04
01/08/84	1.03	84.8	163.1	236.6	61.7	1.06
01/09/84	1.15	144.5	84.8	163.1	236.6	1.21
01/10/84	1.26	103.4	144.5	84.8	163.1	1.05
01/11/84	1.15	36.3	103.4	144.5	84.8	0.85
01/12/84	0.96	88.7	36.3	103.4	144.5	0.88
01/01/85	0.77	18.1	88.7	36.3	103.4	0.72
01/02/85	0.60	0.0	18.1	88.7	36.3	0.56
01/03/85	0.50	41.8	0.0	18.1	88.7	0.60
01/04/85	0.46	17.5	41.8	0.0	18.1	0.50
01/05/85	0.54	65.8	17.5	41.8	0.0	0.56

TABLE 1: contd RESULTS OF REGRESSION ANALYSIS - MONTHLY RAINFALL AND LAKE LEVELS

CORRELATION OF CATCHMENT AVERAGE MONTHLY RAINFALL
WITH LAKE RICHMOND WATER LEVELS USING REGRESSION TECHNIQUE

	Y	X1	X2	X3	X4	
DATE	OBSERVED WATER LEVEL m AHD	CATCHMENT AVG MONTHLY RAINFALL mm NO LAG	LAG 1 MTH	LAG 2 MTH	LAG 3 MTH	PREDICTED WATER LEVEL m AHD
01/06/85	0.66	77.7	65.8	17.5	41.8	0.68
01/07/85	0.84	172.5	77.7	65.8	17.5	0.86
01/08/85	0.97	138.9	172.5	77.7	65.8	1.01
01/09/85	1.05	141.3	138.9	172.5	77.7	1.08
01/10/85	1.07	66.3	141.3	138.9	172.5	1.05
01/11/85	1.02	41.0	66.3	141.3	138.9	0.87
01/12/85	0.90	32.9	41.0	66.3	141.3	0.76
01/01/86	0.70	8.6	32.9	41.0	66.3	0.58
01/02/86	0.57	3.2	8.6	32.9	41.0	0.50
01/03/86	0.35	89.2	3.2	8.6	32.9	0.59
01/04/86	0.26	19.1	89.2	3.2	8.6	0.56
01/05/86	0.46	3.2	19.1	89.2	3.2	0.52
01/06/86	0.68	150.4	3.2	19.1	89.2	0.77
01/07/86	0.81	138.7	150.4	3.2	19.1	0.84
01/08/86	1.05	240.8	138.7	150.4	3.2	1.11
01/09/86	1.23	121.3	240.8	138.7	150.4	1.24
01/10/86	1.12	47.5	121.3	240.8	138.7	1.05
01/11/86	1.05	17.5	47.5	121.3	240.8	0.93
01/12/86	0.93	25.1	17.5	47.5	121.3	0.67
01/01/87	0.69	2.3	25.1	17.5	47.5	0.51
01/02/87	0.55	1.0	2.3	25.1	17.5	0.45
01/03/87	0.40	0.0	1.0	2.3	25.1	0.43
01/04/87	0.39	14.5	0.0	1.0	2.3	0.42
01/05/87	0.58	117.1	14.5	0.0	1.0	0.60
01/06/87	0.72	52.3	117.1	14.5	0.0	0.65
01/07/87	0.86	141.7	52.3	117.1	14.5	0.82
01/08/87	0.95	181.0	141.7	52.3	117.1	1.07
01/09/87	1.14	81.0	181.0	141.7	52.3	0.97
01/10/87	1.06	67.5	81.0	181.0	141.7	0.98
01/11/87	0.89	28.5	67.5	81.0	181.0	0.85
01/12/87	0.81	26.5	28.5	67.5	81.0	0.65
01/01/88	0.71	12.0	26.5	28.5	67.5	0.57
01/02/88	0.56	0.0	12.0	26.5	28.5	0.48
01/03/88	0.37	1.0	0.0	12.0	26.5	0.45
01/04/88	0.26	14.0	1.0	0.0	12.0	0.44
01/05/88	0.45	51.0	14.0	1.0	0.0	0.50
01/06/88	0.83	139.0	51.0	14.0	1.0	0.70
01/07/88	1.05	162.0	139.0	51.0	14.0	0.90
01/08/88	1.12	151.0	162.0	139.0	51.0	1.05
01/09/88	1.13	88.0	151.0	162.0	139.0	1.08
01/10/88	1.10	72.5	88.0	151.0	162.0	0.99
01/11/88	1.09	29.5	72.5	88.0	151.0	0.83
01/12/88	0.98	37.0	29.5	72.5	88.0	0.68
01/01/89	0.80	3.5	37.0	29.5	72.5	0.58
01/02/89	0.67	17.6	3.5	37.0	29.5	0.50
01/03/89	0.59	39.2	17.6	3.5	37.0	0.53
01/04/89	0.62	1.0	39.2	17.6	3.5	0.47
01/05/89	0.69	41.8	1.0	39.2	17.6	0.53
01/06/89	0.83	145.6	41.8	1.0	39.2	0.73
01/07/89	0.90	69.7	145.6	41.8	1.0	0.74

APPENDIX II

RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING
DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
31/01/1898	14	0.419		0	
28/02/1898	2.5	0.419		0	
31/03/1898	0	0.414		0	
30/04/1898	14	0.440		0	
31/05/1898	87.4	0.555		0	
30/06/1898	179.8	0.807		53	
31/07/1898	148.6	0.972		135	
31/08/1898	168.4	1.151		246	
30/09/1898	40.1	1.068		192	
31/10/1898	114.8	0.994		147	
30/11/1898	8.4	0.824		60	
31/12/1898	3.3	0.580		0	246
31/01/1899	0.8	0.563		0	
28/02/1899	8.9	0.426		0	
31/03/1899	19.3	0.444		0	
30/04/1899	37.8	0.491		0	
31/05/1899	73.4	0.592		0	
30/06/1899	152.4	0.795		48	
31/07/1899	177.8	0.999		150	
31/08/1899	133.6	1.089		205	
30/09/1899	96.8	1.103		214	
31/10/1899	93.5	1.039		174	
30/11/1899	18.3	0.822		60	
31/12/1899	5.3	0.651		0	214
Jan-00	71.4	0.657		0	
Feb-00	0.5	0.521		0	
Mar-00	8.4	0.489		0	
Apr-00	22.4	0.538		0	
May-00	81.5	0.563		0	
Jun-00	191.3	0.837		66	
Jul-00	175.5	1.034		171	
Aug-00	174.5	1.200		278	
Sep-00	55.9	1.143		241	
Oct-00	56.6	0.965		131	
Nov-00	6.1	0.768		38	
Dec-00	13.7	0.557		0	278
Jan-01	1.3	0.498		0	
Feb-01	0	0.420		0	
Mar-01	45.5	0.487		0	
Apr-01	9.7	0.474		0	
May-01	143.3	0.679		0	
Jun-01	133.6	0.864		79	
Jul-01	139.4	0.946		120	
Aug-01	143.5	1.128		231	
Sep-01	63.2	1.001		151	
Oct-01	35.1	0.863		78	
Nov-01	12.7	0.716		13	
Dec-01	19.3	0.562		0	231
Jan-02	2.5	0.485		0	
Feb-02	1	0.438		0	
Mar-02	2	0.429		0	
Apr-02	8.1	0.416		0	
May-02	142.7	0.634		0	
Jun-02	123.2	0.788		45	
Jul-02	236.2	1.081		200	
Aug-02	27.9	1.064		189	
Sep-02	111.3	1.006		154	
Oct-02	45.5	0.956		126	
Nov-02	3.6	0.610		0	
Dec-02	10.2	0.610		0	200
Jan-03	6.4	0.484		0	
Feb-03	0	0.420		0	
Mar-03	8.9	0.430		0	
Apr-03	58.9	0.509		0	
May-03	36.8	0.541		0	
Jun-03	136.9	0.730		25	
Jul-03	173.2	0.963		130	
Aug-03	182.6	1.096		210	
Sep-03	177	1.268		324	
Oct-03	79.8	1.166		256	
Nov-03	13.2	0.941		118	
Dec-03	33.3	0.780		42	324
Jan-04	3.8	0.565		0	
Feb-04	5.1	0.460		0	
Mar-04	31.2	0.500		0	
Apr-04	39.1	0.509		0	
May-04	133.1	0.694		0	
Jun-04	218.7	0.994		147	
Jul-04	202.9	1.187		270	
Aug-04	173	1.329		371	
Sep-04	84.8	1.250		312	
Oct-04	85.9	1.084		202	
Nov-04	17.3	0.851		73	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

DATE	CATCHMENT RAINFALL mm	USING DERIVED REGRESSION EQN PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	USING ADOPTED RATING CURVE EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Dec-04	7.6	0.629		0	371
Jan-05	5.1	0.546		0	
Feb-05	8.9	0.448		0	
Mar-05	3.8	0.429		0	
Apr-05	36.6	0.474		0	
May-05	176.5	0.736		27	
Jun-05	86.1	0.806		53	
Jul-05	119.1	0.921		107	
Aug-05	57.2	0.963		130	
Sep-05	108.2	0.874		83	
Oct-05	44.2	0.823		60	
Nov-05	10.4	0.655		0	
Dec-05	6.1	0.607		0	130
Jan-06	8.6	0.487		0	
Feb-06	5.1	0.436		0	
Mar-06	11.9	0.439		0	
Apr-06	9.7	0.444		0	
May-06	128.3	0.629		0	
Jun-06	181.6	0.875		84	
Jul-06	108.2	0.946		120	
Aug-06	132.6	1.098		211	
Sep-06	111.5	1.094		209	
Oct-06	6.6	0.830		63	
Nov-06	8.1	0.705		3	
Dec-06	0	0.562		0	211
Feb-07	13.5	0.435		0	
Mar-07	0.0	0.425		0	
Apr-07	10.6	0.427		0	
May-07	24.4	0.467		0	
Jun-07	175.4	0.713		10	
Jul-07	167.4	0.928		111	
Aug-07	331.4	1.343		384	
Sep-07	123.2	1.426		460	
Oct-07	112.1	1.287		339	
Nov-07	68.9	1.214		287	
Dec-07	16.9	0.789		46	
Jan-08	1.3	0.638		0	460
Feb-08	19.1	0.536		0	
Mar-08	12.9	0.466		0	
Apr-08	7.1	0.445		0	
May-08	15.4	0.468		0	
Jun-08	148.8	0.674		0	
Jul-08	200.1	0.930		112	
Aug-08	158.5	1.077		198	
Sep-08	124.3	1.197		276	
Oct-08	60.5	1.078		198	
Nov-08	46.2	0.883		88	
Dec-08	21.1	0.716		13	
Jan-09	3.3	0.556		0	276
Feb-09	5.1	0.491		0	
Mar-09	2.5	0.439		0	
Apr-09	30.4	0.457		0	
May-09	94.2	0.593		0	
Jun-09	223.9	0.904		98	
Jul-09	255.0	1.225		294	
Aug-09	105.4	1.246		309	
Sep-09	247.0	1.473		509	
Oct-09	124.4	1.360		399	
Nov-09	70.4	1.057		185	
Dec-09	22.9	0.977		138	
Jan-10	2.0	0.665		0	509
Feb-10	10.1	0.531		0	
Mar-10	4.3	0.449		0	
Apr-10	1.3	0.417		0	
May-10	36.3	0.473		0	
Jun-10	232.3	0.815		57	
Jul-10	198.0	1.050		181	
Aug-10	203.8	1.256		316	
Sep-10	7.6	1.183		267	
Oct-10	94.5	1.020		163	
Nov-10	22.1	0.834		65	
Dec-10	18.3	0.559		0	
Jan-11	2.6	0.572		0	316
Feb-11	0.0	0.448		0	
Mar-11	1.5	0.426		0	
Apr-11	4.6	0.409		0	
May-11	80.1	0.529		0	
Jun-11	91.2	0.651		0	
Jul-11	102.6	0.763		36	
Aug-11	178.7	1.008		155	
Sep-11	84.0	0.987		143	
Oct-11	79.0	0.946		120	
Nov-11	24.3	0.860		77	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Dec-11	13.1	0.639		0	
Jan-12	22.8	0.579		0	155
Feb-12	7.6	0.484		0	
Mar-12	11.5	0.465		0	
Apr-12	0.0	0.450		0	
May-12	6.4	0.428		0	
Jun-12	109.2	0.591		0	
Jul-12	132.7	0.754		33	
Aug-12	287.4	1.138		237	
Sep-12	78.1	1.175		262	
Oct-12	140.0	1.181		266	
Nov-12	40.0	1.103		214	
Dec-12	11.0	0.710		7	
Jan-13	14.0	0.659		0	266
Feb-13	3.8	0.485		0	
Mar-13	0.8	0.431		0	
Apr-13	7.2	0.431		0	
May-13	43.8	0.480		0	
Jun-13	26.2	0.504		0	
Jul-13	264.2	0.897		95	
Aug-13	198.0	1.139		238	
Sep-13	167.6	1.218		289	
Oct-13	51.4	1.246		309	
Nov-13	60.0	0.988		144	
Dec-13	23.4	0.786		45	
Jan-14	34.8	0.610		0	309
Feb-14	0.3	0.546		0	
Mar-14	4.7	0.470		0	
Apr-14	0.8	0.451		0	
May-14	23.6	0.440		0	
Jun-14	38.7	0.495		0	
Jul-14	161.2	0.724		22	
Aug-14	107.3	0.847		71	
Sep-14	58.7	0.842		68	
Oct-14	13.2	0.815		57	
Nov-14	14.8	0.638		0	
Dec-14	49.6	0.585		0	
Jan-15	6.1	0.504		0	71
Feb-15	25.7	0.514		0	
Mar-15	64.3	0.603		0	
Apr-15	24.9	0.554		0	
May-15	78.2	0.650		0	
Jun-15	145.8	0.838		67	
Jul-15	178.9	0.979		139	
Aug-15	197.4	1.190		271	
Sep-15	120.1	1.216		288	
Oct-15	73.9	1.105		216	
Nov-15	55.1	0.962		129	
Dec-15	11.9	0.721		18	
Jan-16	7.6	0.577		0	288
Feb-16	14.7	0.515		0	
Mar-16	12.2	0.458		0	
Apr-16	0.0	0.437		0	
May-16	11.2	0.446		0	
Jun-16	88.3	0.566		0	
Jul-16	157.1	0.770		38	
Aug-16	172.9	0.977		138	
Sep-16	142.3	1.121		226	
Oct-16	4.3	0.972		135	
Nov-16	31.9	0.823		60	
Dec-16	54.0	0.716		13	
Jan-17	1.5	0.508		0	226
Feb-17	0.0	0.495		0	
Mar-17	34.8	0.524		0	
Apr-17	13.6	0.466		0	
May-17	27.1	0.492		0	
Jun-17	118.9	0.678		0	
Jul-17	205.4	0.920		107	
Aug-17	271.3	1.246		309	
Sep-17	126.2	1.314		360	
Oct-17	143.7	1.330		372	
Nov-17	64.2	1.172		260	
Dec-17	13.2	0.813		56	
Jan-18	26.3	0.710		7	372
Feb-18	1.6	0.532		0	
Mar-18	22.4	0.477		0	
Apr-18	37.7	0.522		0	
May-18	46.1	0.543		0	
Jun-18	145.6	0.752		32	
Jul-18	186.8	0.977		138	
Aug-18	76.2	0.968		133	
Sep-18	94.6	1.024		165	
Oct-18	77.0	0.965		131	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Nov-18	37.1	0.752		32	
Dec-18	15.8	0.672		0	
Jan-19	2.9	0.561		0	165
Feb-19	0.0	0.465		0	
Mar-19	0.5	0.421		0	
Apr-19	8.1	0.414		0	
May-19	21.7	0.442		0	
Jun-19	37.3	0.492		0	
Jul-19	153.1	0.717		14	
Aug-19	145.0	0.891		91	
Sep-19	114.4	0.969		133	
Oct-19	46.7	0.968		133	
Nov-19	23.6	0.801		51	
Dec-19	8.7	0.640		0	
Jan-20	3.8	0.499		0	133
Feb-20	1.6	0.444		0	
Mar-20	3.1	0.419		0	
Apr-20	19.1	0.437		0	
May-20	0.8	0.428		0	
Jun-20	129.7	0.624		0	
Jul-20	213.1	0.927		110	
Aug-20	106.1	0.974		136	
Sep-20	185.4	1.211		285	
Oct-20	32.8	1.081		200	
Nov-20	21.4	0.799		50	
Dec-20	2.6	0.707		5	
Jan-21	0.8	0.466		0	285
Feb-21	1.3	0.431		0	
Mar-21	8.9	0.416		0	
Apr-21	19.8	0.442		0	
May-21	21.8	0.467		0	
Jun-21	229.1	0.815		57	
Jul-21	167.4	1.008		155	
Aug-21	179.9	1.156		249	
Sep-21	109.5	1.276		330	
Oct-21	91.3	1.085		203	
Nov-21	50.2	0.943		119	
Dec-21	18.6	0.728		24	
Jan-22	30.3	0.640		0	330
Feb-22	6.4	0.532		0	
Mar-22	9.2	0.474		0	
Apr-22	6.6	0.466		0	
May-22	84.7	0.555		0	
Jun-22	169.4	0.792		47	
Jul-22	112.8	0.890		91	
Aug-22	176.6	1.103		214	
Sep-22	85.0	1.099		212	
Oct-22	63.0	0.933		114	
Nov-22	22.3	0.834		65	
Dec-22	22.8	0.637		0	
Jan-23	21.0	0.565		0	214
Feb-23	25.0	0.516		0	
Mar-23	0.0	0.481		0	
Apr-23	108.2	0.618		0	
May-23	48.8	0.649		0	
Jun-23	150.5	0.804		52	
Jul-23	262.4	1.197		276	
Aug-23	87.0	1.093		208	
Sep-23	73.5	1.087		204	
Oct-23	139.4	1.146		243	
Nov-23	54.5	0.854		74	
Dec-23	1.9	0.708		5	
Jan-24	11.2	0.656		0	276
Feb-24	3.6	0.491		0	
Mar-24	5.1	0.423		0	
Apr-24	5.3	0.430		0	
May-24	10.1	0.429		0	
Jun-24	132.7	0.629		0	
Jul-24	121.0	0.778		41	
Aug-24	92.2	0.846		70	
Sep-24	154.6	1.056		184	
Oct-24	72.1	0.966		132	
Nov-24	106.4	0.934		114	
Dec-24	31.2	0.863		78	
Jan-25	0.0	0.639		0	184
Feb-25	12.0	0.588		0	
Mar-25	4.6	0.461		0	
Apr-25	27.4	0.457		0	
May-25	13.8	0.475		0	
Jun-25	107.0	0.615		0	
Jul-25	188.2	0.882		87	
Aug-25	180.1	1.051		181	
Sep-25	47.9	1.039		174	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

DATE	CATCHMENT RAINFALL mm	USING DERIVED REGRESSION EQN: PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	USING ADOPTED RATING CURVE: EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Oct-25	92.0	1.033		170	
Nov-25	37.1	0.863		78	
Dec-25	5.0	0.609		0	
Jan-26	13.0	0.583		0	181
Feb-26	0.0	0.468		0	
Mar-26	14.0	0.438		0	
Apr-26	77.3	0.553		0	
May-26	174.8	0.786		45	
Jun-26	140.7	0.943		119	
Jul-26	142.9	1.082		201	
Aug-26	270.3	1.380		416	
Sep-26	111.3	1.256		316	
Oct-26	122.6	1.194		274	
Nov-26	53.7	1.112		220	
Dec-26	48.4	0.813		56	
Jan-27	0.0	0.677		0	416
Feb-27	16.8	0.542		0	
Mar-27	0.0	0.483		0	
Apr-27	53.5	0.497		0	
May-27	18.7	0.519		0	
Jun-27	123.1	0.667		0	
Jul-27	206.3	0.971		134	
Aug-27	151.8	1.053		183	
Sep-27	137.9	1.181		266	
Oct-27	63.5	1.103		214	
Nov-27	34.5	0.873		83	
Dec-27	6.6	0.699		0	
Jan-28	5.0	0.532		0	266
Feb-28	28.9	0.501		0	
Mar-28	0.5	0.449		0	
Apr-28	4.8	0.440		0	
May-28	56.1	0.529		0	
Jun-28	201.8	0.791		47	
Jul-28	117.6	0.909		101	
Aug-28	279.0	1.263		321	
Sep-28	194.1	1.453		488	
Oct-28	100.2	1.243		307	
Nov-28	47.3	1.166		256	
Dec-28	8.9	0.830		63	
Jan-29	12.0	0.607		0	488
Feb-29	4.8	0.492		0	
Mar-29	10.7	0.443		0	
Apr-29	2.0	0.435		0	
May-29	25.2	0.456		0	
Jun-29	240.8	0.822		60	
Jul-29	230.4	1.102		214	
Aug-29	116.4	1.156		249	
Sep-29	48.3	1.175		262	
Oct-29	41.9	0.947		121	
Nov-29	44.7	0.724		22	
Dec-29	17.4	0.589		0	
Jan-30	6.8	0.530		0	262
Feb-30	0.0	0.482		0	
Mar-30	1.3	0.429		0	
Apr-30	2.3	0.411		0	
May-30	56.6	0.489		0	
Jun-30	50.9	0.555		0	
Jul-30	263.4	0.935		115	
Aug-30	149.1	1.103		214	
Sep-30	122.2	1.114		221	
Oct-30	57.0	1.145		242	
Nov-30	32.2	0.842		68	
Dec-30	5.9	0.667		0	
Jan-31	24.9	0.551		0	242
Feb-31	0.0	0.478		0	
Mar-31	0.3	0.430		0	
Apr-31	13.4	0.451		0	
May-31	99.3	0.570		0	
Jun-31	133.0	0.749		31	
Jul-31	135.9	0.901		97	
Aug-31	174.5	1.113		221	
Sep-31	205.0	1.259		318	
Oct-31	110.1	1.193		273	
Nov-31	28.5	1.022		164	
Dec-31	3.5	0.821		59	
Jan-32	9.6	0.591		0	318
Feb-32	7.2	0.462		0	
Mar-32	0.0	0.420		0	
Apr-32	7.4	0.428		0	
May-32	84.8	0.548		0	
Jun-32	157.7	0.762		36	
Jul-32	149.5	0.933		114	
Aug-32	214.2	1.198		277	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Sep-32	129.4	1.240		305	
Oct-32	50.0	1.057		185	
Nov-32	85.9	1.010		157	
Dec-32	1.5	0.734		26	
Jan-33	0.8	0.552		0	305
Feb-33	5.6	0.522		0	
Mar-33	1.6	0.409		0	
Apr-33	17.8	0.433		0	
May-33	16.7	0.455		0	
Jun-33	129.4	0.641		0	
Jul-33	153.4	0.847		71	
Aug-33	91.7	0.893		93	
Sep-33	126.3	1.039		174	
Oct-33	69.1	0.966		132	
Nov-33	93.3	0.881		87	
Dec-33	0.0	0.756		34	
Jan-34	1.5	0.584		0	174
Feb-34	11.3	0.540		0	
Mar-34	3.3	0.418		0	
Apr-34	70.2	0.524		0	
May-34	16.3	0.533		0	
Jun-34	205.5	0.814		56	
Jul-34	240.5	1.153		247	
Aug-34	117.9	1.125		229	
Sep-34	130.5	1.268		324	
Oct-34	79.7	1.130		232	
Nov-34	23.1	0.824		60	
Dec-34	15.8	0.704		3	
Jan-35	1.3	0.548		0	324
Feb-35	0.0	0.445		0	
Mar-35	24.2	0.457		0	
Apr-35	0.5	0.431		0	
May-35	27.4	0.464		0	
Jun-35	68.6	0.573		0	
Jul-35	141.7	0.737		27	
Aug-35	242.1	1.067		191	
Sep-35	85.8	1.082		201	
Oct-35	95.3	1.088		205	
Nov-35	38.1	0.988		144	
Dec-35	4.1	0.662		0	
Jan-36	5.1	0.574		0	205
Feb-36	8.4	0.471		0	
Mar-36	0.0	0.418		0	
Apr-36	3.6	0.417		0	
May-36	24.0	0.450		0	
Jun-36	185.5	0.722		20	
Jul-36	243.4	1.050		181	
Aug-36	156.7	1.179		264	
Sep-36	161.1	1.344		385	
Oct-36	51.8	1.169		258	
Nov-36	23.1	0.869		81	
Dec-36	0.0	0.692		0	
Jan-37	22.0	0.523		0	385
Feb-37	0.0	0.456		0	
Mar-37	6.4	0.429		0	
Apr-37	16.3	0.460		0	
May-37	120.5	0.613		0	
Jun-37	283.0	1.023		164	
Jul-37	233.1	1.276		330	
Aug-37	54.7	1.231		298	
Sep-37	165.6	1.335		377	
Oct-37	70.9	1.090		206	
Nov-37	34.5	0.782		43	
Dec-37	12.5	0.752		32	
Jan-38	5.3	0.550		0	377
Feb-38	3.0	0.467		0	
Mar-38	2.0	0.426		0	
Apr-38	32.1	0.459		0	
May-38	50.0	0.523		0	
Jun-38	68.1	0.604		0	
Jul-38	124.1	0.773		39	
Aug-38	178.1	0.973		136	
Sep-38	155.7	1.089		205	
Oct-38	64.9	1.046		178	
Nov-38	32.7	0.925		109	
Dec-38	30.0	0.758		34	
Jan-39	4.6	0.562		0	205
Feb-39	12.3	0.495		0	
Mar-39	14.5	0.480		0	
Apr-39	1.0	0.436		0	
May-39	12.9	0.449		0	
Jun-39	129.2	0.636		0	
Jul-39	300.1	1.050		181	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Aug-39	314.0	1.429		463	
Sep-39	198.6	1.592		648	
Oct-39	4.0	1.376		413	
Nov-39	60.2	1.110		219	
Dec-39	77.2	0.864		79	
Jan-40	0.5	0.565		0	648
Feb-40	9.2	0.568		0	
Mar-40	0.8	0.513		0	
Apr-40	1.0	0.409		0	
May-40	14.3	0.433		0	
Jun-40	81.0	0.544		0	
Jul-40	119.1	0.705		3	
Aug-40	110.3	0.826		61	
Sep-40	56.7	0.857		75	
Oct-40	60.6	0.834		65	
Nov-40	45.8	0.751		32	
Dec-40	6.1	0.602		0	
Jan-41	7.4	0.542		0	75
Feb-41	0.0	0.473		0	
Mar-41	3.3	0.417		0	
Apr-41	7.3	0.422		0	
May-41	51.6	0.490		0	
Jun-41	58.6	0.568		0	
Jul-41	211.7	0.866		80	
Aug-41	199.8	1.115		222	
Sep-41	87.6	1.086		203	
Oct-41	113.4	1.169		258	
Nov-41	26.2	0.939		117	
Dec-41	17.2	0.687		0	
Jan-42	0.3	0.596		0	258
Feb-42	0.0	0.449		0	
Mar-42	0.0	0.420		0	
Apr-42	42.7	0.464		0	
May-42	69.1	0.561		0	
Jun-42	130.8	0.735		27	
Jul-42	256.0	1.095		209	
Aug-42	176.9	1.233		300	
Sep-42	121.4	1.248		310	
Oct-42	101.6	1.231		298	
Nov-42	45.6	0.958		127	
Dec-42	2.0	0.722		20	
Jan-43	3.8	0.585		0	310
Feb-43	25.4	0.504		0	
Mar-43	22.6	0.472		0	
Apr-43	84.6	0.589		0	
May-43	53.1	0.647		0	
Jun-43	67.6	0.687		0	
Jul-43	128.4	0.852		73	
Aug-43	168.9	0.968		133	
Sep-43	156.6	1.082		201	
Oct-43	97.1	1.094		209	
Nov-43	16.5	0.931		113	
Dec-43	1.3	0.725		23	
Jan-44	0.0	0.544		0	209
Feb-44	2.4	0.424		0	
Mar-44	0.0	0.402		0	
Apr-44	3.1	0.404		0	
May-44	42.0	0.470		0	
Jun-44	109.7	0.627		0	
Jul-44	91.9	0.731		25	
Aug-44	133.7	0.892		92	
Sep-44	79.8	0.935		115	
Oct-44	33.3	0.809		54	
Nov-44	18.1	0.726		24	
Dec-44	25.9	0.600		0	
Jan-45	26.6	0.535		0	115
Feb-45	2.8	0.486		0	
Mar-45	1.0	0.463		0	
Apr-45	9.1	0.450		0	
May-45	12.7	0.433		0	
Jun-45	179.4	0.704		3	
Jul-45	490.9	1.425		459	
Aug-45	109.5	1.411		446	
Sep-45	227.3	1.623		689	
Oct-45	92.4	1.601		659	
Nov-45	16.1	0.915		104	
Dec-45	38.6	0.872		83	
Jan-46	11.5	0.604		0	689
Feb-46	0.3	0.472		0	
Mar-46	0.0	0.460		0	
Apr-46	10.6	0.429		0	
May-46	70.2	0.521		0	
Jun-46	145.7	0.727		24	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Jul-46	201.4	0.988		144	
Aug-46	306.1	1.379		416	
Sep-46	95.6	1.344		385	
Oct-46	25.8	1.135		235	
Nov-46	3.6	0.938		116	
Dec-46	78.2	0.676		0	
Jan-47	9.4	0.552		0	416
Feb-47	1.0	0.493		0	
Mar-47	3.9	0.517		0	
Apr-47	6.2	0.425		0	
May-47	120.6	0.598		0	
Jun-47	230.0	0.927		110	
Jul-47	282.8	1.270		326	
Aug-47	157.3	1.405		440	
Sep-47	71.2	1.302		350	
Oct-47	80.7	1.148		244	
Nov-47	100.3	0.939		117	
Dec-47	10.0	0.719		16	
Jan-48	7.8	0.629		0	440
Feb-48	0.0	0.550		0	
Mar-48	0.3	0.418		0	
Apr-48	17.1	0.434		0	
May-48	41.0	0.484		0	
Jun-48	37.6	0.527		0	
Jul-48	186.5	0.801		51	
Aug-48	155.9	0.978		138	
Sep-48	115.0	1.018		161	
Oct-48	122.0	1.142		240	
Nov-48	30.5	0.927		110	
Dec-48	44.3	0.780		42	
Jan-49	11.9	0.666		0	240
Feb-49	2.1	0.500		0	
Mar-49	0.0	0.470		0	
Apr-49	21.7	0.448		0	
May-49	38.0	0.487		0	
Jun-49	24.8	0.507		0	
Jul-49	91.0	0.638		0	
Aug-49	198.0	0.901		97	
Sep-49	206.9	1.105		216	
Oct-49	27.7	1.031		169	
Nov-49	80.1	1.027		167	
Dec-49	29.1	0.850		72	
Jan-50	0.0	0.552		0	216
Feb-50	4.6	0.539		0	
Mar-50	3.6	0.447		0	
Apr-50	0.3	0.406		0	
May-50	4.7	0.414		0	
Jun-50	208.7	0.734		26	
Jul-50	189.6	0.973		136	
Aug-50	140.3	1.080		200	
Sep-50	100.5	1.204		280	
Oct-50	73.6	1.035		172	
Nov-50	38.4	0.840		67	
Dec-50	55.2	0.740		28	
Jan-51	11.7	0.624		0	280
Feb-51	0.0	0.518		0	
Mar-51	14.5	0.504		0	
Apr-51	2.6	0.435		0	
May-51	125.1	0.610		0	
Jun-51	78.0	0.705		3	
Jul-51	152.3	0.866		80	
Aug-51	122.2	1.032		170	
Sep-51	118.4	0.998		150	
Oct-51	35.0	0.931		113	
Nov-51	38.4	0.783		43	
Dec-51	30.5	0.687		0	
Jan-52	108.9	0.692		0	170
Feb-52	5.4	0.630		0	
Mar-52	0.0	0.553		0	
Apr-52	22.2	0.581		0	
May-52	18.8	0.462		0	
Jun-52	104.2	0.606		0	
Jul-52	227.3	0.937		116	
Aug-52	178.6	1.104		215	
Sep-52	122.2	1.188		270	
Oct-52	51.1	1.117		223	
Nov-52	53.2	0.906		99	
Dec-52	15.7	0.704		3	
Jan-53	20.8	0.571		0	270
Feb-53	1.1	0.512		0	
Mar-53	32.8	0.491		0	
Apr-53	1.3	0.471		0	
May-53	21.7	0.466		0	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Jun-53	195.4	0.775		40	
Jul-53	245.0	1.061		188	
Aug-53	111.8	1.118		224	
Sep-53	57.4	1.137		237	
Oct-53	32.2	0.959		128	
Nov-53	80.5	0.770		38	
Dec-53	27.7	0.654		0	
Jan-54	0.5	0.557		0	237
Feb-54	5.3	0.540		0	
Mar-54	1.3	0.443		0	
Apr-54	2.6	0.408		0	
May-54	25.4	0.448		0	
Jun-54	125.8	0.631		0	
Jul-54	121.2	0.781		42	
Aug-54	171.4	0.983		141	
Sep-54	140.1	1.129		231	
Oct-54	21.1	0.946		120	
Nov-54	14.0	0.813		56	
Dec-54	21.8	0.656		0	
Jan-55	4.8	0.475		0	231
Feb-55	1.3	0.445		0	
Mar-55	226.1	0.785		44	
Apr-55	0.3	0.703		2	
May-55	105.2	0.788		45	
Jun-55	96.9	0.987		143	
Jul-55	113.8	0.807		53	
Aug-55	203.1	1.100		212	
Sep-55	232.5	1.270		326	
Oct-55	59.4	1.149		245	
Nov-55	95.5	1.125		229	
Dec-55	2.8	0.894		93	
Jan-56	16.1	0.599		0	326
Feb-56	0.0	0.547		0	
Mar-56	2.5	0.420		0	
Apr-56	41.9	0.487		0	
May-56	39.7	0.516		0	
Jun-56	216.3	0.832		64	
Jul-56	206.8	1.100		212	
Aug-56	76.6	1.057		185	
Sep-56	18.9	1.020		163	
Oct-56	65.0	0.874		83	
Nov-56	31.1	0.651		0	
Dec-56	34.0	0.580		0	
Jan-57	2.3	0.562		0	212
Feb-57	5.0	0.482		0	
Mar-57	0.4	0.451		0	
Apr-57	8.5	0.418		0	
May-57	56.7	0.503		0	
Jun-57	97.7	0.633		0	
Jul-57	282.4	1.035		172	
Aug-57	59.4	1.034		171	
Sep-57	121.2	1.075		196	
Oct-57	40.9	1.054		183	
Nov-57	27.0	0.692		0	
Dec-57	0.0	0.634		0	
Jan-58	12.0	0.496		0	196
Feb-58	2.7	0.452		0	
Mar-58	0.9	0.414		0	
Apr-58	0.5	0.417		0	
May-58	15.8	0.426		0	
Jun-58	71.7	0.531		0	
Jul-58	132.4	0.714		11	
Aug-58	323.2	1.169		258	
Sep-58	69.2	1.158		251	
Oct-58	30.0	1.032		170	
Nov-58	51.4	1.014		159	
Dec-58	16.1	0.611		0	
Jan-59	7.9	0.521		0	258
Feb-59	4.6	0.498		0	
Mar-59	10.5	0.448		0	
Apr-59	4.3	0.432		0	
May-59	48.4	0.494		0	
Jun-59	60.7	0.573		0	
Jul-59	154.5	0.772		39	
Aug-59	61.9	0.822		60	
Sep-59	177.2	0.989		144	
Oct-59	32.2	0.947		121	
Nov-59	51.0	0.777		41	
Dec-59	25.0	0.770		38	
Jan-60	29.9	0.570		0	144
Feb-60	13.8	0.550		0	
Mar-60	7.7	0.490		0	
Apr-60	68.7	0.567		0	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
May-60	27.2	0.556		0	
Jun-60	148.0	0.742		29	
Jul-60	109.9	0.882		87	
Aug-60	190.7	1.023		164	
Sep-60	76.6	1.074		196	
Oct-60	55.9	0.921		107	
Nov-60	14.0	0.821		59	
Dec-60	7.2	0.584		0	
Jan-61	2.7	0.498		0	196
Feb-61	13.0	0.446		0	
Mar-61	10.1	0.442		0	
Apr-61	46.9	0.500		0	
May-61	104.0	0.648		0	
Jun-61	88.9	0.733		26	
Jul-61	181.5	0.963		130	
Aug-61	166.5	1.123		227	
Sep-61	133.9	1.124		228	
Oct-61	48.2	1.055		184	
Nov-61	17.2	0.841		68	
Dec-61	4.1	0.651		0	
Jan-62	21.8	0.517		0	228
Feb-62	0.2	0.452		0	
Mar-62	4.1	0.430		0	
Apr-62	0.2	0.431		0	
May-62	8.8	0.415		0	
Jun-62	149.1	0.647		0	
Jul-62	151.8	0.839		67	
Aug-62	168.9	1.021		163	
Sep-62	92.3	1.112		220	
Oct-62	56.6	0.976		137	
Nov-62	44.1	0.856		75	
Dec-62	32.8	0.685		0	
Jan-63	15.5	0.583		0	220
Feb-63	10.6	0.525		0	
Mar-63	9.4	0.484		0	
Apr-63	18.2	0.469		0	
May-63	70.6	0.554		0	
Jun-63	239.8	0.895		94	
Jul-63	208.4	1.133		234	
Aug-63	192.9	1.306		354	
Sep-63	191.5	1.476		512	
Oct-63	50.5	1.197		276	
Nov-63	27.2	0.952		124	
Dec-63	10.4	0.753		33	
Jan-64	0.4	0.505		0	512
Feb-64	0.0	0.444		0	
Mar-64	1.9	0.414		0	
Apr-64	15.0	0.423		0	
May-64	43.5	0.486		0	
Jun-64	35.9	0.527		0	
Jul-64	333.8	1.029		168	
Aug-64	225.6	1.283		336	
Sep-64	148.5	1.306		354	
Oct-64	72.0	1.372		409	
Nov-64	69.5	1.047		179	
Dec-64	5.0	0.765		37	
Jan-65	14.5	0.590		0	409
Feb-65	1.9	0.516		0	
Mar-65	2.2	0.423		0	
Apr-65	20.8	0.453		0	
May-65	31.5	0.478		0	
Jun-65	149.9	0.696		0	
Jul-65	159.4	0.902		97	
Aug-65	113.4	0.975		137	
Sep-65	181.0	1.187		270	
Oct-65	71.9	1.072		195	
Nov-65	96.8	0.973		136	
Dec-65	46.9	0.909		101	
Jan-66	11.0	0.667		0	270
Feb-66	0.5	0.587		0	
Mar-66	1.7	0.473		0	
Apr-66	9.1	0.428		0	
May-66	27.4	0.454		0	
Jun-66	75.5	0.562		0	
Jul-66	209.9	0.863		78	
Aug-66	166.3	1.045		178	
Sep-66	74.0	1.041		175	
Oct-66	66.8	1.043		177	
Nov-66	39.2	0.840		67	
Dec-66	1.6	0.615		0	
Jan-67	10.2	0.542		0	178
Feb-67	5.4	0.472		0	
Mar-67	10.0	0.431		0	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD (USING DERIVED REGRESSION EQN)	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s (USING ADOPTED RATING CURVE)	MAX FLOWRATE FOR YEAR L/s
Apr-67	7.1	0.440		0	
May-67	52.2	0.505		0	
Jun-67	202.8	0.803		52	
Jul-67	274.5	1.154		248	
Aug-67	220.6	1.375		412	
Sep-67	103.6	1.392		428	
Oct-67	19.9	1.148		244	
Nov-67	36.2	0.875		84	
Dec-67	13.6	0.623		0	
Jan-68	17.0	0.503		0	428
Feb-68	33.5	0.533		0	
Mar-68	1.9	0.479		0	
Apr-68	71.9	0.567		0	
May-68	95.2	0.686		0	
Jun-68	57.6	0.686		0	
Jul-68	234.1	1.029		168	
Aug-68	153.3	1.128		231	
Sep-68	122.8	1.100		212	
Oct-68	145.7	1.249		311	
Nov-68	51.0	0.994		147	
Dec-68	14.8	0.795		48	
Jan-69	0.0	0.660		0	311
Feb-69	1.5	0.481		0	
Mar-69	0.0	0.418		0	
Apr-69	16.5	0.424		0	
May-69	59.0	0.513		0	
Jun-69	99.3	0.646		0	
Jul-69	154.5	0.850		72	
Aug-69	122.4	0.969		133	
Sep-69	70.5	0.954		125	
Oct-69	9.3	0.831		63	
Nov-69	1.6	0.644		0	
Dec-69	20.2	0.533		0	
Jan-70	3.8	0.443		0	133
Feb-70	0.7	0.425		0	
Mar-70	68.2	0.535		0	
Apr-70	2.2	0.496		0	
May-70	72.9	0.582		0	
Jun-70	106.2	0.751		32	
Jul-70	314.3	1.103		214	
Aug-70	240.6	1.390		426	
Sep-70	57.3	1.257		317	
Oct-70	75.9	1.247		310	
Nov-70	45.2	0.943		119	
Dec-70	8.3	0.621		0	
Jan-71	4.6	0.560		0	426
Feb-71	7.5	0.483		0	
Mar-71	11.4	0.440		0	
Apr-71	46.8	0.498		0	
May-71	3.1	0.484		0	
Jun-71	93.1	0.608		0	
Jul-71	124.9	0.780		42	
Aug-71	146.7	0.887		90	
Sep-71	89.3	0.978		138	
Oct-71	133.1	1.034		171	
Nov-71	50.0	0.934		114	
Dec-71	15.5	0.738		28	
Jan-72	3.0	0.648		0	171
Feb-72	0.7	0.483		0	
Mar-72	1.7	0.424		0	
Apr-72	5.0	0.411		0	
May-72	19.0	0.436		0	
Jun-72	45.8	0.501		0	
Jul-72	122.9	0.675		0	
Aug-72	140.4	0.849		72	
Sep-72	131.9	0.971		134	
Oct-72	52.0	0.955		125	
Nov-72	36.6	0.840		67	
Dec-72	11.2	0.689		0	
Jan-73	1.1	0.519		0	134
Feb-73	6.3	0.468		0	
Mar-73	2.4	0.424		0	
Apr-73	1.1	0.409		0	
May-73	70.9	0.520		0	
Jun-73	103.8	0.657		0	
Jul-73	158.9	0.854		74	
Aug-73	188.1	1.098		211	
Sep-73	123.0	1.133		234	
Oct-73	151.3	1.193		273	
Nov-73	41.8	1.033		170	
Dec-73	10.8	0.782		43	
Jan-74	0.3	0.654		0	273
Feb-74	0.2	0.464		0	

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

		USING DERIVED REGRESSION EQN		USING ADOPTED RATING CURVE	
DATE	CATCHMENT RAINFALL mm	PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Mar-74	9.7	0.427		0	
Apr-74	2.7	0.414		0	
May-74	65.7	0.513		0	
Jun-74	239.0	0.872		83	
Jul-74	162.9	1.035		172	
Aug-74	273.6	1.364		402	
Sep-74	113.9	1.415		450	
Oct-74	26.2	1.076		197	
Nov-74	87.4	1.044		177	
Dec-74	18.8	0.718		15	
Jan-75	0.5	0.544		0	450
Feb-75	0.3	0.532		0	
Mar-75	0.0	0.422		0	
Apr-75	13.5	0.419		0	
May-75	22.3	0.450		0	
Jun-75	83.1	0.569		0	
Jul-75	170.1	0.812		55	
Aug-75	179.6	1.014		159	
Sep-75	90.3	1.054		183	
Oct-75	71.7	1.032		170	
Nov-75	45.2	0.890		91	
Dec-75	35.5	0.703		2	
Jan-76	0.1	0.584		0	183
Feb-76	34.5	0.546		0	
Mar-76	20.8	0.522		0	
Apr-76	0.5	0.459		0	
May-76	76.0	0.583		0	
Jun-76	80.9	0.651		0	
Jul-76	108.2	0.749		31	
Aug-76	112.1	0.896		94	
Sep-76	127.8	0.959		128	
Oct-76	61.4	0.916		105	
Nov-76	39.0	0.815		57	
Dec-76	58.9	0.771		39	
Jan-77	4.1	0.601		0	128
Feb-77	0.9	0.514		0	
Mar-77	0.2	0.480		0	
Apr-77	7.5	0.415		0	
May-77	1.3	0.410		0	
Jun-77	113.9	0.584		0	
Jul-77	85.4	0.691		0	
Aug-77	96.9	0.776		40	
Sep-77	141.1	0.981		140	
Oct-77	31.5	0.842		68	
Nov-77	57.0	0.796		49	
Dec-77	12.0	0.709		6	
Jan-78	1.2	0.513		0	140
Feb-78	4.7	0.493		0	
Mar-78	29.9	0.467		0	
Apr-78	16.9	0.469		0	
May-78	16.2	0.480		0	
Jun-78	157.6	0.721	0.487	18	
Jul-78	211.5	0.974	0.781	136	
Aug-78	200.1	1.167	0.990	257	
Sep-78	44.2	1.149	0.816	245	
Oct-78	107.3	1.103	0.994	214	
Nov-78	52.4	0.929	0.884	111	
Dec-78	8.7	0.645	0.760	0	
Jan-79	7.9	0.615	0.627	0	257
Feb-79	3.3	0.490	0.508	0	
Mar-79	5.7	0.429	0.362	0	
Apr-79	10.4	0.434	0.273	0	
May-79	58.1	0.511	0.345	0	
Jun-79	73.4	0.606	0.493	0	
Jul-79	149.2	0.798	0.783	50	
Aug-79	121.1	0.933	1.033	114	
Sep-79	79.5	0.927	0.991	110	
Oct-79	47.7	0.895	0.887	94	
Nov-79	23.7	0.736	0.758	27	
Dec-79	49.9	0.659	0.651	0	
Jan-80	2.6	0.553	0.485	0	114
Feb-80	0.0	0.481	0.315	0	
Mar-80	20.8	0.498	0.206	0	
Apr-80	0.5	0.428	0.132	0	
May-80	74.5	0.534	0.532	0	
Jun-80	149.6	0.757	0.876	34	
Jul-80	177.8	0.947	1.242	121	
Aug-80	184.3	1.167	1.188	257	
Sep-80	111.7	1.190	1.128	271	
Oct-80	59.4	1.056	1.069	184	
Nov-80	42.3	0.897	0.974	95	
Dec-80	9.5	0.674	0.791	0	
Jan-81	35.2	0.585	0.533	0	271

TABLE 2: RESULTS OF ESTIMATION OF HISTORIC LAKE LEVELS contd

ESTIMATES OF LAKE WATER LEVELS AND FLOWRATES USING DERIVED REGRESSION EQUATIONS

DATE	CATCHMENT RAINFALL mm	USING DERIVED REGRESSION EQN PRED AVG LAKE LVL FOR MNTH m AHD	OBS AVG LAKE LVL FOR MNTH m AHD	USING ADOPTED RATING CURVE EST AVG FLOWRATE FOR MNTH L/s	MAX FLOWRATE FOR YEAR L/s
Feb-81	0.0	0.509	0.387	0	
Mar-81	18.0	0.472	0.278	0	
Apr-81	8.5	0.480	0.254	0	
May-81	25.6	0.466	0.262	0	
Jun-81	165.9	0.722	0.729	20	
Jul-81	142.4	0.875	0.904	84	
Aug-81	194.5	1.088	1.120	205	
Sep-81	116.9	1.198	1.025	277	
Oct-81	60.4	1.028	0.911	167	
Nov-81	28.9	0.896	0.843	94	
Dec-81	24.1	0.688	0.742	0	
Jan-82	4.2	0.544	0.639	0	277
Feb-82	155.4	0.707	0.846	5	
Mar-82	4.0	0.644	0.716	0	
Apr-82	25.6	0.602	0.574	0	
May-82	6.5	0.651	0.386	0	
Jun-82	40.4	0.499	0.369	0	
Jul-82	190.8	0.789	0.757	46	
Aug-82	185.6	0.987	0.945	143	
Sep-82	86.7	1.021	0.880	163	
Oct-82	87.2	1.085	0.877	203	
Nov-82	31.3	0.893	0.762	93	
Dec-82	11.4	0.658	0.569	0	
Jan-83	4.9	0.566	0.437	0	203
Feb-83	0.5	0.457	0.456	0	
Mar-83	37.7	0.476	0.590	0	
Apr-83	8.7	0.467	0.587	0	
May-83	12.1	0.465	0.562	0	
Jun-83	43.0	0.538	0.601	0	
Jul-83	256.3	0.877	0.898	85	
Aug-83	102.1	0.953	0.988	124	
Sep-83	138.4	1.060	0.838	187	
Oct-83	80.3	1.146	0.811	243	
Nov-83	9.4	0.791	0.827	47	
Dec-83	40.7	0.736	0.833	27	
Jan-84	16.1	0.591	0.757	0	243
Feb-84	0.0	0.471	0.552	0	
Mar-84	3.8	0.473	0.366	0	
Apr-84	14.3	0.445	0.270	0	
May-84	61.7	0.516	0.392	0	
Jun-84	236.6	0.867	1.043	80	
Jul-84	163.1	1.044	1.075	177	
Aug-84	84.8	1.062	1.034	188	
Sep-84	144.5	1.211	1.152	285	
Oct-84	103.4	1.050	1.260	181	
Nov-84	36.3	0.846	1.154	70	
Dec-84	88.7	0.878	0.962	85	
Jan-85	18.1	0.715	0.774	12	285
Feb-85	0.0	0.557	0.604	0	
Mar-85	41.8	0.598	0.505	0	
Apr-85	17.5	0.503	0.457	0	
May-85	65.8	0.564	0.540	0	
Jun-85	77.7	0.678	0.656	0	
Jul-85	172.5	0.857	0.838	75	
Aug-85	138.9	1.006	0.966	154	
Sep-85	141.3	1.076	1.054	197	
Oct-85	66.3	1.054	1.070	183	
Nov-85	41.0	0.873	1.018	83	
Dec-85	32.9	0.756	0.900	34	
Jan-86	8.6	0.582	0.700	0	197
Feb-86	3.2	0.500	0.570	0	
Mar-86	89.2	0.592	0.350	0	
Apr-86	19.1	0.559	0.265	0	
May-86	3.2	0.520	0.461	0	
Jun-86	150.4	0.773	0.678	39	
Jul-86	138.7	0.840	0.809	67	
Aug-86	240.8	1.110	1.052	219	
Sep-86	121.3	1.242	1.235	306	
Oct-86	47.5	1.055	1.121	184	
Nov-86	17.5	0.927	1.048	110	
Dec-86	25.1	0.667	0.930	0	
Jan-87	2.3	0.514	0.688	0	306
Feb-87	1.0	0.449	0.547	0	
Mar-87	0.0	0.434	0.401	0	
Apr-87	14.5	0.423	0.386	0	
May-87	117.1	0.600	0.580	0	
Jun-87	52.3	0.647	0.716	0	
Jul-87	141.7	0.823	0.864	60	
Aug-87	181.0	1.074	0.950	196	
Sep-87	81.0	0.972	1.139	135	
Oct-87	67.5	0.977	1.058	138	
Nov-87	28.5	0.851	0.894	73	
Dec-87	26.5	0.650	0.815	0	

TABLE 3: FREQUENCY ANALYSIS OF PEAK FLOWRATES

STATISTICAL RESULTS FOR X = LOG(Y)

n = 92

mean	2.39170
std. devn.	.18241
sum x	220.03640
sum x**2	529.28900
sum x**3	1280.25200
sum (x-mean)**3	-.13233

coefficient of skewness, G = -.2449

std. error of est. for G = .25134

OUTLIER IDENTIFICATION

high outlier threshold = 777.66470
low outlier threshold = 61.63039

LOG-NORMAL DISTRIBUTION : RESULTS

REC.INT	PROB EXC	95% CONF	VALUE	5% CONF	LINEAR X PLOT POS.
2.00	50.0000	227.99	246.43	266.37	.00000
5.00	20.0000	322.62	350.99	381.85	.84146
10.00	10.0000	382.42	422.24	466.19	1.28173
20.00	5.0000	435.58	491.78	555.23	1.64521
50.00	2.0000	498.41	583.96	684.18	2.05419
100.00	1.0000	541.40	654.63	791.54	2.32679
200.00	.5000	581.66	727.11	908.93	2.57624
500.00	.2000	631.35	825.45	1079.21	2.87851

LOG-PEARSON TYPE III DISTRIBUTION : RESULTS

REC.INT	PROB EXC	95% CONF	VALUE	5% CONF	LINEAR X PLOT POS.
2.00	50.0000	231.84	250.68	271.05	.00000
5.00	20.0000	325.71	352.37	381.21	.84146
10.00	10.0000	381.72	416.98	455.49	1.28173
20.00	5.0000	428.95	476.95	530.31	1.64521
50.00	2.0000	481.00	552.07	633.64	2.05419
100.00	1.0000	514.11	606.65	715.85	2.32679
200.00	.5000	543.13	660.10	802.26	2.57624
500.00	.2000	576.12	729.29	923.19	2.87851

Appendix 6.

Expected Impact of the Mangles Bay Marina on
Seagrass Communities in Cockburn Sound.

EXPECTED IMPACT OF THE MANGLES BAY MARINA ON SEAGRASS COMMUNITIES IN COCKBURN SOUND

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1. INTRODUCTION

The following report is intended to be read as an update and supplement to Hillman's (1985) report on the impact of the proposed Rockingham Marina on seagrass communities in Cockburn Sound. Unnecessary repetition of the information has therefore been avoided.

2. SEAGRASSES

2.1 Present status

A study in 1984/85 of water quality and seagrass distribution in Cockburn Sound found that seagrass dieback had halted and that there were signs that the seagrass was recovering in some areas (Hillman, 1986). This was attributed to several years of reduced nitrogen loading and the associated improvement in water quality, which in turn led to a reduction of the heavy epiphytic growth responsible for the original seagrass dieback. An identical water quality study carried out in 1986/87 found, however, that water quality had declined since the 1984/85 study, although it remained an improvement over conditions during the 1976-79 study (Hillman and Bastyan, 1988). No study was carried out on seagrass distribution at this time.

The seagrass mapping exercise carried out during November 1989 for the purposes of this report disclosed that although the main areas of seagrass meadow on Southern Flats and in the waters off the Rockingham shore have remained healthy and unchanged since 1985 (see Figures 1 and 2), there was definite evidence that the eastern fringe of the Southern Flats meadows has been receding. An area classified in 1985 as "patchy, deteriorating seagrass with mussels and fibre" (Figure 2) was almost entirely devoid of seagrass cover in November 1989 (Figure 2). It was also found that seagrasses on the eastern and southern fringes of

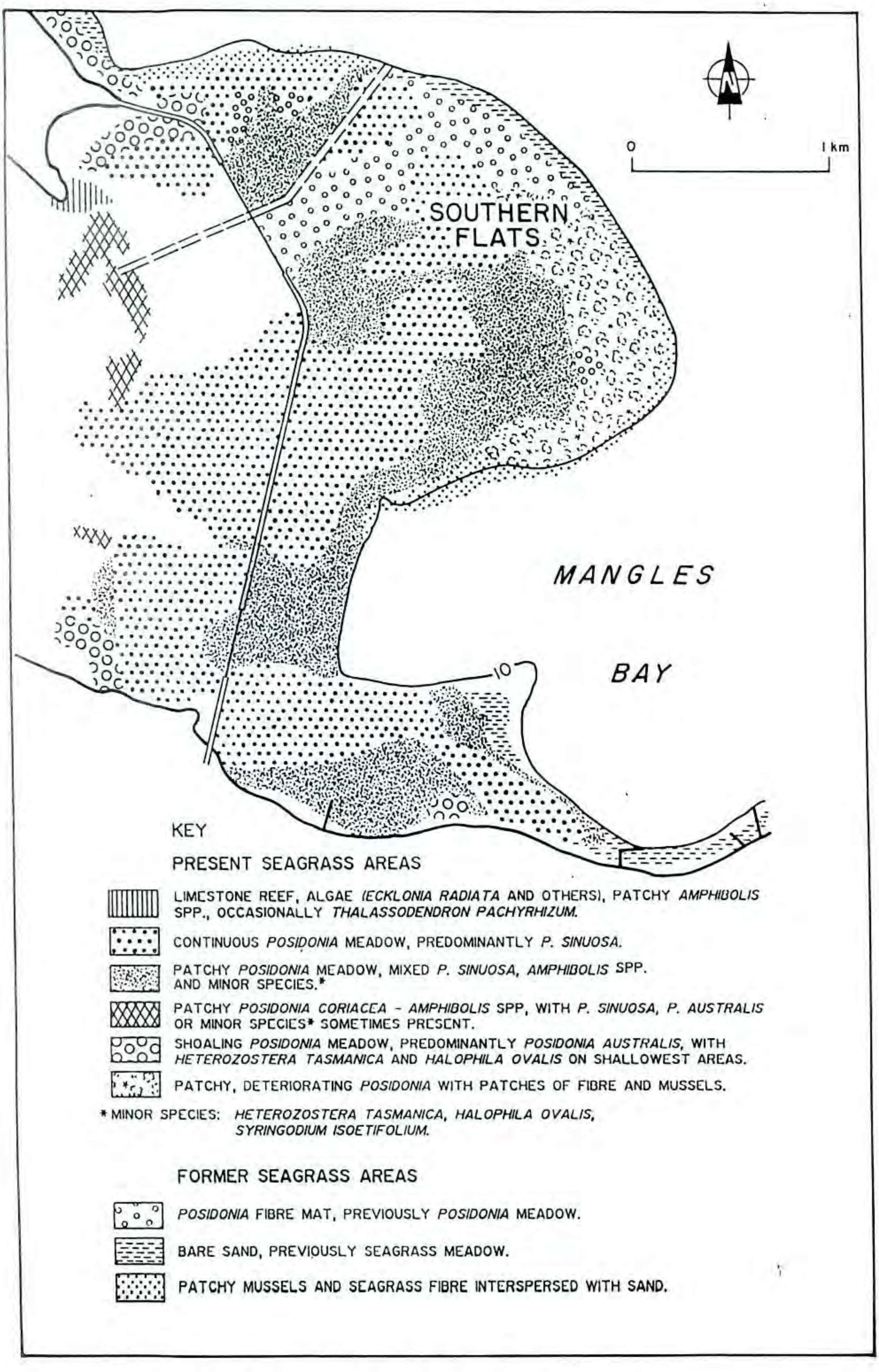

Fig. 1 SEAGRASS MANGLES BAY 1985

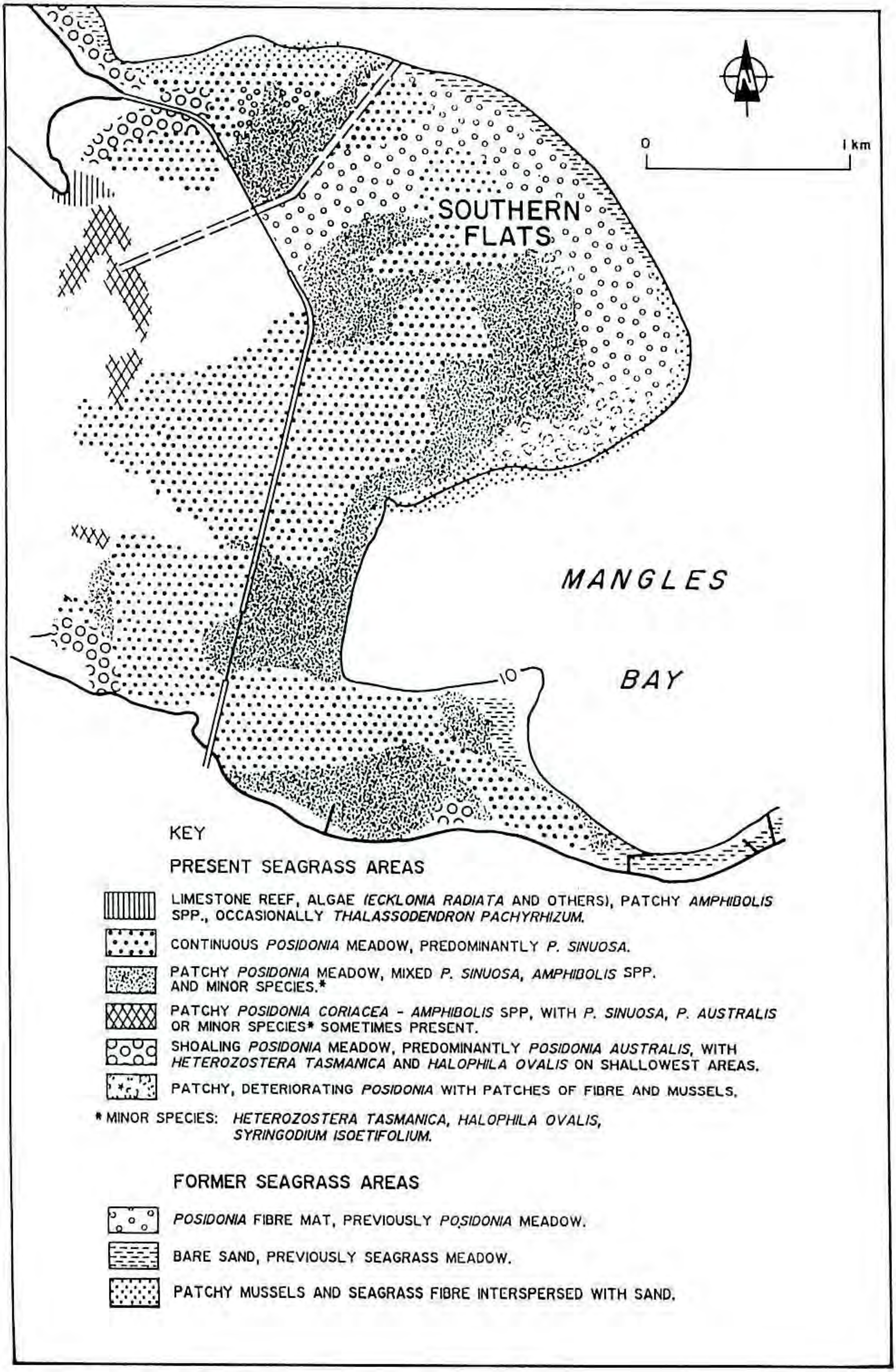

Fig. 2 SEAGRASS MANGLES BAY 1989

Southern Flats were heavily epiphytised, and those in the main boat mooring area off the Rockingham shore were in poor condition (low percentage cover, and leaves were lying flat and covered with a thick epiphytic scum).

2.2 Detailed examination of the proposed marina site, November 1989

The proposed marina site is presently occupied by 20ha of dense healthy seagrass and 5ha of patchy, unhealthy seagrass (the latter in the boat mooring area), the main species being *Posidonia sinuosa* and *P. australis*. The proposed approach channel will pass over a further hectare of healthy seagrass meadow, assuming a channel width of 70m. The seagrasses extend from just below extreme low water mark to a depth of approximately 5m (relative to AHD), but almost all of the seagrass is overlain by 1-2m of water (relative to AHD). *P. sinuosa* is the main species, and small species such as *Halophila ovalis* and *Heterozostera tasmanica* also occur infrequently. Within the 20ha of healthy seagrass meadow there are two major interruptions to continuous cover, both being old scars associated with the scything action of the mooring chains of two large barges. The patchiness of seagrass cover within the boat mooring area is also largely due to the scything action of boat mooring chains.

3. ENVIRONMENTAL IMPACT OF SITE DEVELOPMENT

3.1 Loss of seagrass within the proposed site

The proposed development of the study area will remove 26ha of seagrass, comprising 21ha of healthy *Posidonia* meadow and 5ha of patchy *Posidonia* meadow. The seagrass is unlikely to reestablish within the marina part of the proposed development due to shading by jetties and moored boats and to increased water turbidity associated with boating activity. *Posidonia* may eventually reestablish in the approach channel providing the dredged depth is less than 6m (the current depth limit of seagrasses at the southern end of Cockburn Sound), but will only do so slowly and will only offset the total seagrass loss by 1ha. The loss of seagrass could be offset to a further degree by relocating boats moored east of the proposed site to within the marina, thus allowing the relevant area of patchy meadow a chance to increase seagrass cover.

In view of the severe seagrass dieback already experienced in Cockburn Sound, a further loss of 26ha is undesirable. The loss of 26ha represents 1.5% of the remaining seagrass beds in the Sound, and whilst this can not be viewed as a serious threat to the existing ecology, it is unfortunate that 21ha of the healthiest seagrass in the southern half of the Sound will be lost at a time when there is evidence to suggest that the fringes of the Southern Flats meadows are receding and therefore that water quality in that part of the Sound maybe deteriorating.

3.2 The effects of site development on nearby seagrass meadows

(i) Nutrient release from sediments and seagrasses

Based on Hillman's (1985) original estimates, it is not anticipated that nutrient release from sediments dredged during site development will cause excessive phytoplankton or macroalgal growth. Nor should it be necessary to remove the seagrass from the area designated for commercial and residential development since cover in this area is very patchy and the level of nutrient release would be low. However the seagrass growing in the area designated for mooring pens and "future development" (immediately adjacent to the causeway) is dense healthy meadow, and if left to decay within the site or onshore may result in sufficient nutrient release to cause algal blooms. It is therefore recommended that seagrass cover be removed from this area and disposed of on land.

(ii) Increased water turbidity

Dredging associated with the proposed site development is anticipated to take 3-6 months, and during this time , under certain wind and tidal conditions, the dredging plume may move over the Southern Flats seagrass beds. Given the duration of the dredging and the fact that most of the seagrass beds on Southern Flats are in shallow water, it is unlikely that the seagrass will suffer any long-term deleterious effects from increased water turbidity, although there will be some loss of plant production in the short-term. Loss of plant production could be minimized by taking steps to contain the dredging plume and by carrying out dredging operations over autumn and winter, when plant growth is slow anyway.

(iii) Deoxygenation of water and release of toxic substances

The degree of localized deoxygenation of water and release of toxic substances during dredging operations should be minor and is not expected to harm the biota of areas adjacent to the proposed development, providing dredge spoil is not dumped in the water column.

(iv) Sediment deposition

Given the size of the proposed development, only seagrasses on the eastern edge of the site will experience a degree of smothering likely to cause small-scale losses. Eventually the seagrass should reestablish to within 0.5-1.0m of the eastern edge of the eastern breakwater, and to just below extreme low water mark off the beach adjacent to the area designated for hotel and chalet construction. The settling out of dredging plume sediments is unlikely to harm the Southern Flats seagrass meadows.

3. POST-CONSTRUCTION EFFECTS

The major post-construction causes for concern will be water and sediment quality within the marina and nutrient-enriched runoff from the proposed commercial and residential areas. Within the marina, water quality and sediments may be affected by the accumulation and decay of algae and seagrass drift material, uncontrolled release of boat sewage, fuel spills and the build-up of hydrocarbons and heavy metals, all of which have the potential to cause reduced seagrass growth in nearby meadows and to harm the associated biota. There is also the possibility of fertilizer application resulting in nutrient-rich runoff from the gardens and grounds in the commercial and residential area, in turn causing algal blooms and epiphyte proliferation in nearby seagrass meadows. It is therefore essential that regular monitoring of nutrient and contaminant levels in the waters and sediments within and adjacent to the marina be carried out , so that appropriate action can be taken if increases are detected. In addition, both the design of the marina and facilities and the maintenance and upkeep of the grounds should be carried out to minimize any loss of contaminants. In particular, boat maintenance practices, rubbish collection and the application of fertilizers should be strictly controlled - in the latter case as little fertilizer as possible should be used, and then only the slow-release types of fertilizer.

4. CONCLUSIONS AND RECOMMENDATIONS

(i). The proposed development will result in the loss of 26ha of seagrass, 21ha of which is the healthiest stand of *Posidonia* in the southern half of Cockburn Sound. This represents 1.5% of present seagrass meadows, and whilst the loss should not seriously affect the existing ecology of the Sound it is nonetheless undesirable, particularly at a time when the eastern fringe of the Southern Flats meadows appear to be receding.

(ii) Seagrasses are unlikely to reestablish in the marina but may eventually recolonise the approach channel. Losses may be offset to some degree if boats presently moored adjacent to the proposed site are relocated within the marina.

(iii) Adjacent seagrass beds will suffer no long-term deleterious effects, although plant production will decline during site development. These effects can be minimised by containing the dredge plume, carrying out dredging during autumn and winter, and disposing of seagrass removed from the areas of dense meadow on land.

(iv) The design of the marina and its associated facilities should minimise addition of and accumulation of contaminants, and the maintenance and upkeep of grounds should be carried out in such a way as to minimise the input of contaminants to the waters of the Sound.

(v) Regular monitoring of contaminant levels in the sediments and water of the marina and adjacent areas should be carried out to enable corrective measures to be taken if increases are detected.

5. ACKNOWLEDGEMENTS

We would like to thank Professor Arthur McComb for his assistance in editing this manuscript.

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Appendix 7.

An Archaeological Survey of a Proposed Marina Development at Mangles Bay, Rockingham.

AN ARCHAEOLOGICAL SURVEY OF A PROPOSED MARINA DEVELOPMENT AT MANGLES BAY ROCKINGHAM

by

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NOVEMBER, 1989

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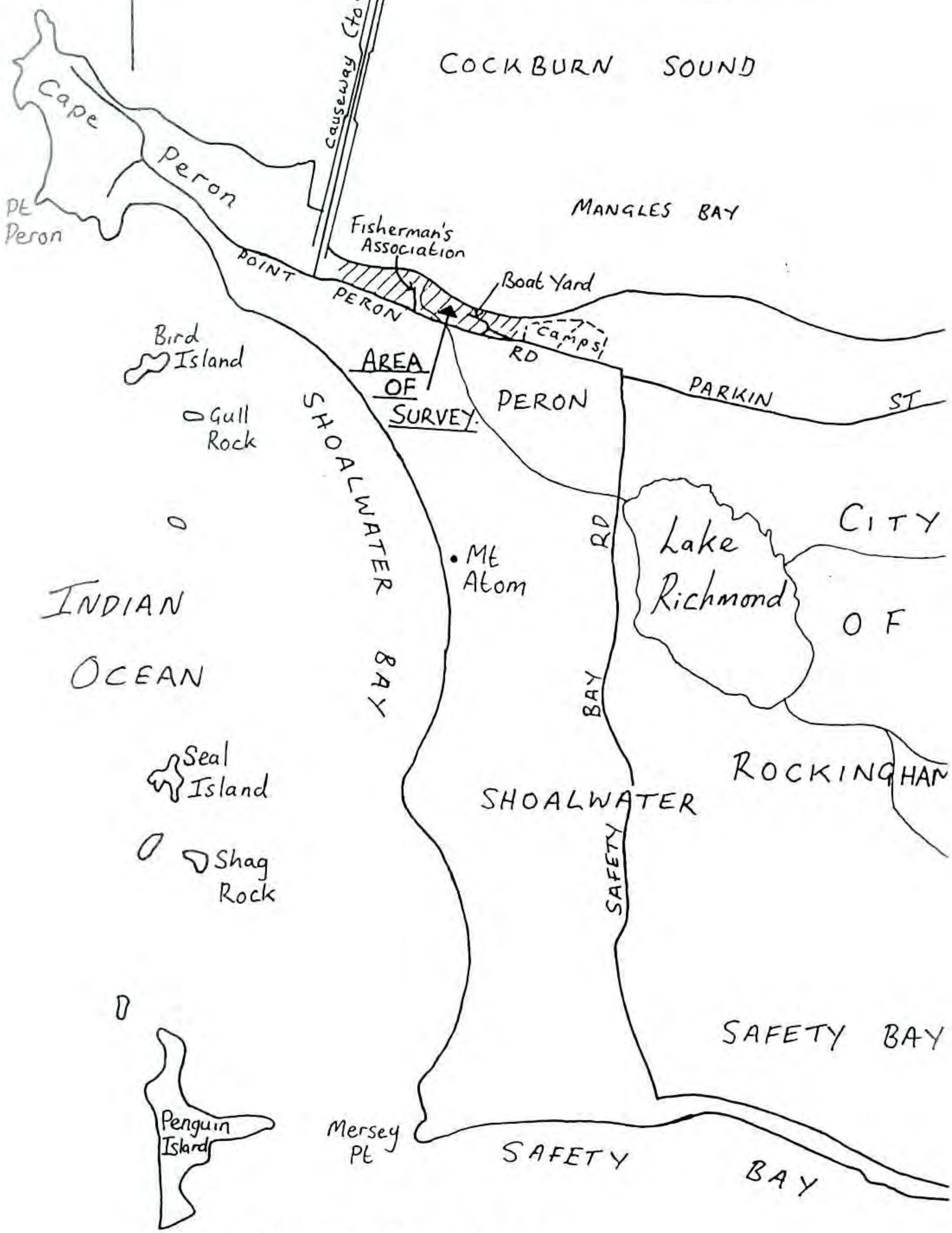
1. INTRODUCTION

In November 1989, McDonald, Hales and Associates was commissioned by the Department of Marine and Harbours, Western Australia, to conduct an archaeological investigation of a proposed Marina Development in Mangles Bay, Rockingham.

The area concerned is a narrow strip of coastline, approximately 0.5km long, to the east of Cape Peron, due north of Point Peron Road (see map).

No sites of significance, as defined by Section 5 of the Western Australian Aboriginal Heritage Act 1972-80, were located in the survey area.

LOCATION MAP OF SURVEY AREA, MANGLES BAY, ROCKINGHAM.



SCALE 1 : 20,000

2. LOCAL ENVIRONMENT AND LAND INTEGRITY

The Shire of Rockingham, where Mangles Bay is located, is an extensive region. The majority of this Shire is currently undeveloped with residential development centred in the Shoalwater-Rockingham-Safety Bay area plus recreation clusters along the coastline.

Geology

Rockingham lies within the Swan Coastal Plain which forms part of the Perth Basin (Wilde and Low, 1978). The base rock of Yilgarn block, visible on the Darling Scarp, lies beneath Phanerozoic sedimentary deposits on the plain (Biggs et al, 1980).

The Swan Coastal Plain is further divided into varying geomorphic zones including the Quindalup Dune System, where this part of Rockingham is situated. This Dunal System is made up of young and mobile calcareous sands, occurring as beach ridges and parabolic dunes which partly overlie older aeolian limestone (Cottesloe limestone) (McArthur and Bettenay, 1960).

The above dunal formation contrasts with the older and more stable dune systems to the east, the Karrakatta Sands and the Bassendean Sands. The Karrakatta Sands zone contains a chain of permanent lakes parallel to the coast in depressions between the limestone ridges. The even older Bassendean Sands zone contains interdunal swamps and lakes along its eastern edge towards the foothills of the Darling Range.

Due to the high permeability of the calcareous sands of the Quindalup Dune System, surface drainage features are usually rare. However, Lake Richmond is a relatively large area of non-saline water, approximately 1km south-east of the survey area.

Vegetation

Almost half of the area surveyed was bare sanded shoreline, exposed to tidal fluctuations. Behind this strip lay a higher area of acacia scrub including Acacia rostellifera and native grasses.

Such coastal vegetation is very vulnerable to fire and grazing as can be witnessed by Rottnest Island. Devegetation set coastal dunes in motion thousands of years before European settlement (Hallam, 1975) in certain areas of the south-west.

Climate

The Swan Coastal Plain has what is described as a warm Mediterranean Climate (Beard, 1982), with 5-6 dry months.

Wetter conditions prevailed pre-40,000 B.P. up until the Terminal Pleistocene with greater fluctuations during the late Pleistocene and the Holocene. Such fluctuations would have caused concomitant changes in vegetation zones, but these are thought to be minor.

A change of greater significance for this area occurred around 6,000 B.P. with a sea-level rise of 140m to its present-day level. This sea-level rise inundated large areas of coastline cutting off such land as Garden Island and Rottnest Island and covering possible chert sources, a seemingly highly desirable rock for Aboriginal tool production, off Mandurah to the south (Glover, 1975).

3. REGIONAL ARCHAEOLOGY

A search of the site files found only 2 sites have been previously recorded within a 5km radius of the survey area; S00178, Rockingham stone arrangement and S01956, Safety Bay burial. A further 2 sites are recorded for Garden Island S02097 and S02098; these, however, are simply 2 chert flakes and 1 quartz flake and are of minimal use for research purposes.

No systematic survey has been carried out in the Shire of Rockingham area, a fact that needs rectifying if hypotheses about past Aboriginal lifestyles and habitation patterns are to be drawn.

Hallam (1987) suggests that, from the distribution of known sites in the Swan Coastal Plain, past Aboriginal habitation concentrated around the lakes and swamps of the coastal sandplain and in the alluvial and scarpfoot zones utilizing the abundant resources in such areas, with minimal usage of littoral and upland resources.

However, when other factors are taken into consideration, such assumptions appear less certain. For instance, it is known that the uplands were fired to improve accessibility and increase game numbers in the Jarrah forest and, therefore, lack of sites could be a function of poor preservation, visibility and lack of research in such areas, rather than reflecting a true usage pattern.

Similarly, the use of littoral resources may too be underestimated. The Quindalup dunes are young and mobile and may have obscured or eroded sites away. However, pre-6,000 B.P. coastal areas, such as Mangles Bay, would not have been truly littoral due to the rise in sea-level after this time.

Before 6,000 B.P. Eocene chert for tools would have been traded from west to east (Pearce, 1977). After this time trade would have been from east to west using rock sources of mylonite etc. from the Darling Scarp. The use of different raw materials requires a change in flaking technology; the change in trading patterns may have altered social relationships; the loss of land from inundation would have caused stress on remaining resources and possibly brought different groups into conflict with the push of landless coastal groups.

Therefore it can be seen that along this coastal strip at least, lack of recorded sites may be a true reflection of usage patterns. Pre-6,000 B.P., sites may have been concentrated off the coast utilizing littoral resources and chert sources off Mandurah (this requires further research).

Post-6,000 B.P. sites may have concentrated further east utilizing the lakes and swamplands such as Lake Cooloongup, Lake Walyungup and possibly Lake Richmond which would reflect the land usage pattern further north in better researched areas such as Thompsons Lake and Bibra Lake.

Ethnohistorical Data

The Swan River Colony was established in 1829 concentrating upon the alluvial flats of the Swan River, as the best prospective farmland.

For travel and new settlements, the white settlers depended upon what Hammond (1933) refers to as "the pads of natives" which occurred throughout the south-west and were similar to and just as plain as cattle pads, connecting water sources.

Hammond lists one of these pads as running from Perth along the north bank of the river to North Fremantle, then to Bibra Lake, through Rockingham to Mandurah, and then up both sides of the Murray River.

It was the similarity in land-use patterns which caused the masking and eventual obliteration of much of traditional Aboriginal ways of life.

Hammond, who was in close contact with Aborigines from the 1860's onwards, also spoke of the custom of "old time natives" to visit their places of birth and stay at them for as long as resources would allow. Rockingham is mentioned as one such place where the food supply could support a large number of people and, consequently, had a large number of births.

This fact is not, as yet, reflected in the archaeological evidence due to the lack of research. It is probable that large numbers of sites may be associated with the wetlands systems in this area.

An occurrence that <u>is</u> recorded from geological evidence and was passed down via oral traditions in Aboriginal legend is observed by G.F. Moore in 1884, "The natives have a tradition that Rottnest, Carnac and Garden Island, once formed part of the mainland.... the ground split asunder with a great noise, and the sea rushed in between...".

4. SURVEY METHODS

Examination of the survey area was carried out on foot, covering as much land as possible due to its small size.

100% of the bare sanded shoreline was investigated, as there was full visibility. Approximately 60% of the vegetated dunal strip was surveyed, some grassier areas having a reduced visibility of 10%.

Two areas have already been semi-developed and are, therefore, highly disturbed; the Fisherman's Association and a boat yard. A drainage channel from Lake Richmond was also closely inspected along its course through the survey area, but this too had been artificially banked.

Approximately 80% of the whole area was surveyed.

5. CULTURAL MATERIAL

No archaeological sites, such as artefact scatters, fish-traps or shell middens, or isolated finds were located in the survey area.

6. DISCUSSIONS AND RECOMMENDATIONS

Due to the high percentage of coverage in this survey, it is not likely that any archaeological evidence could have been overlooked.

Lack of archaeological sites in such an area may be due to the poor preservation on the Quindalup Dunes. However, from the previous discussion on resource locations to the east and west of this area in varying periods, it is unlikely that this area could have been the focus of substantial prehistoric occupation.

It is recommended that the Department of Marine and Harbours may proceed with plans for the Marina Development in Mangles Bay, Rockingham.

The obligations of the developer to report any archaeological material, should this be encountered during the development, is outlined under Section 15 of the Western Australian Aboriginal Heritage Act, 1972-80. (See Appendix).

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APPENDIX

Obligations Relating to Sites

Under the Aboriginal Heritage Act

1972 - 1980

"Report of Findings

Any person who has knowledge of the existence of anything in the nature of Aboriginal burial grounds, symbols or objects of sacred, ritual or ceremonial significance, cave or rock paintings or engravings, stone structures or arranged stones, carved trees, or of any place or thing to which this act applies or to which this act might reasonably be suspected to apply shall report its existence to the Trustees, or to a police officer, unless he has reasonable cause to believe the existence of the thing or place in question to be already known to the Trustees.

Excavation of Aboriginal Sites

(1) Subject to Section 18, the right to excavate or to remove anything from an Aboriginal site is reserved to the Trustees.

(2) The Trustees may authorise the entry upon and excavation of an Aboriginal site and the examination or removal of anything on or under the site in such a manner and subject to the such conditions as they may direct.

Offences Relating to Aboriginal Sites

A person who -

(a) excavates, destroys, damages, conceals or in any way alters any Aboriginal site; or

(b) in any way alters, damages, removes, destroys, conceals, or who deals with in a manner not sanctioned by relevant custom, or assumes the possession, custody, or control of, any object on or under an Aboriginal site, commits an offence unless he is acting with the authorisation of the Trustees under Section 16 or the consent of the Minister under Section 18.

Consent to Certain Uses

(1) For the purposes of this section, the expression "the owner of any land" includes a lessee from the Crown, and the holder of any mining tenement or mining privilege, or of any right or privilege under the Petroleum Act 1967, in relation to land.

(2) Where the owner of any land gives to the Trustees notice in writing that he requires to use the land for a purpose which, unless the Minister gives his consent under this section, would be likely to result in a breach of Section 17 in respect of any Aboriginal site that might be on the land, the Trustees shall, as soon as they are reasonably able, form an opinion as to whether there is any Aboriginal site on the land, evaluate the importance and significance of any such site, and submit the notice to the Minister together with their recommendation in writing as to whether or not the Minister should consent to the use of the land for that purpose, and where applicable, the extent to which and the conditions upon which his consent should be given.

(3) Where the Trustees submit a notice to the Minister under subsection (2) of this section he shall consider their recommendation and having regard to the general interest of the community shall either -

(a) Consent to the use of the land the subject of the notice, or a specified part of the land, for the purpose required, subject to such conditions, if any, as he may specify; or

(b) wholly decline to consent to the use of the land the subject of the notice for the purpose required,

and shall forthwith inform the owner in writing of his decision.

(4) Where the owner of any land has given to the Trustees notice pursuant to subsection (2) of this section and the Trustees have not submitted it with their recommendation to the Minister in accordance with that subsection the Minister may require the Trustee to do so within a specified time, or may require the Trustees to take such other action as the Minister considers necessary in order to expedite the matter, and the Trustees shall comply with any such requirement.

(5) Where the owner of any land is aggrieved by a decision of the Minister made under subsection (3) of this Section he may, within the time and in the manner prescribed by rules of court, appeal from the decision of the Minister to the Supreme Court which may hear and determine the appeal.

(6) In determining an appeal under subsection (5) of this section the Judge hearing the appeal may confirm or vary the decision of the Minister against which the appeal is made or quash the decision and substitute his own decision which shall have effect as if it were the decision of the Minister, and may sake such an order as to the costs of the appeal as he sees fit.

(7) Where the owner of the land gives notices to the Trustees under subsection (2) of this Section, the Trustees may, if they are satisfied that it is practicable do to so, direct the removal of any object to which this Act applies from the land to a place of safe custody.

(8) Where consent has been given under this section to a person to use any land for a particular purpose nothing done by on behalf of that person pursuant to, and in accordance with any conditions attached to, the consent constitutes an offence against this Act."

Appendix 8.

Report on an Ethnographic Survey of the
Mangles Bay Marina Development
(including Supplementary Report).

REPORT ON AN ETHNOGRAPHIC SURVEY OF THE MANGLES BAY MARINA DEVELOPMENT

TO
DEPARTMENT OF MARINE AND HARBOURS

BY
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DECEMBER 1989

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RESEARCH BRIEF

McDonald Hales and Associates were commissioned by the Department of Marine and Harbours to conduct a survey of Aboriginal sites at Mangles Bay,Rockingham.

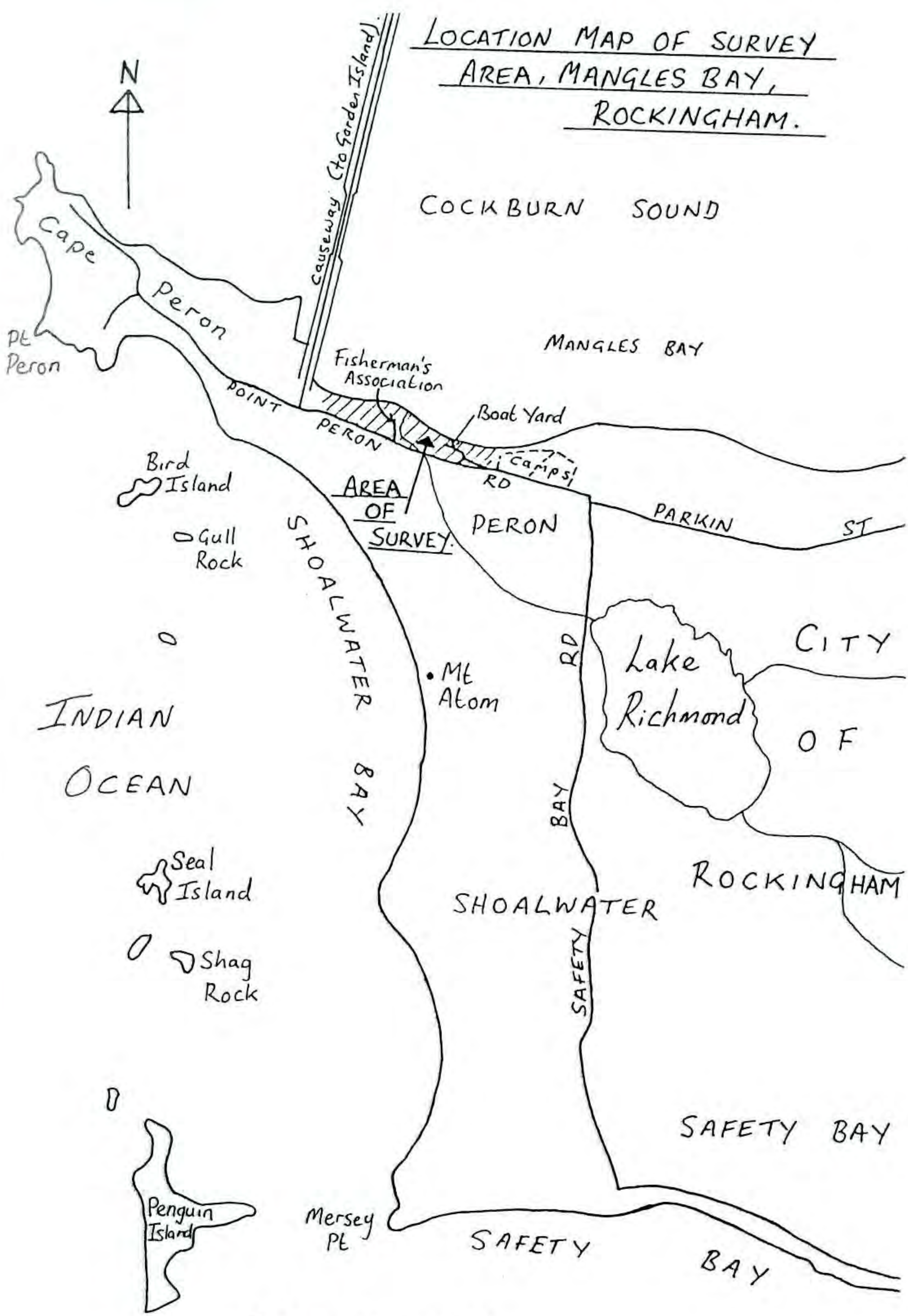
FINDINGS

The ethnographic survey uncovered the existence of a hitherto unrecorded mythological site concentrated at Rotary Park and the car park opposite but involving the Mangles Bay beach from the causeway up to the car park beyond Palm Beach.

RECOMMENDATIONS

There is no objection to the Marina development,but our informant recommends that the mythological site be recognized and signposted.

LOCATION MAP OF SURVEY AREA, MANGLES BAY, ROCKINGHAM.



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METHODS

The survey took place on December 4th,5th with the assistance of Ken Colbung and a field assistant.

It consisted of the followed procedures:

1.Archival research

2.Physical examination of the area video and audio-taped interview with Ken Colbung.

3.Still photographs.

4.Closer mapping of the site.

Preliminary research involved a review of the existing data on Mangles Bay in the sites register and other reports.This was followed by a field trip with the main aboriginal informant for this area and a further visit to provide more detailed observation and recording of the mythological site.Other informants were not accessible, one informant used in previous reports was too old and sick to help,others were not available or had moved out of the area.

ARCHIVAL RESEARCH

Archival research revealed no known ethnographic sites in the proposed development area.Nearest ethnological sites were located at Mandurah Road Trees,East Rockingham Cemetery,Chalk Hill Camps and Thomas Oval and Sloans Reserve (see Baines 1984 and O'Connor et al 1985).(The archeological data is contained in the accompanying report).

ETHNOGRAPHIC BACKGROUND

The south west of western Australia was occupied by the *Nyungar* Aboriginal people at the time of initial colonization.The area around Perth was associated with the *Whadjug* sub-group (Berndt 1979:82).The *Whadjug*,like other coastal Nyungars has matrilineal moieties and exogamous clans.These named clans had totemic associations.Ritual affiliations came via an individual's father and there were probably local patrilineal decent groups,focussed on specific totemic sites in defined country (ibid.).

Within the *Whadjug* there were identifiable group territories at contact.For example the Helena area is recorded as the land of *Binan* under the leadership of Yagan (Makin 1970;McNair and Rumley 1981) but these European influenced territorial and patrilineal categories tend to conceal the reality of overlapping ritual and social relations and reciprocal usage rights which linked these people.

The land was owned by all *Nyungar* but each family looked after their own areas.

Colonization decimated the *Nyungar* and disrupted social patterns and relations with the land.Policies of forced exclusion,restrictions of movement and labour broke traditional links with country and sites.

Such colonial policies continued until the recent past and are part of the social history of the Mangles Bay region.Aborigines are no longer allowed to camp there.

This part of the coastline and bush was in regular use by Aboriginal people until the recent past,it is an important mythological site and an area of whale feasting.During the course of my investigation of the beach we found a *Nyungar* grinding stone confirming their presence in this area.

The Myth

The direct translation of the story,which explains the mythological significance of the Mangles Bay beach and the lake at Rotary Park,is found in Appendix A.The beach from the causeway to the car park opposite Rotary Park and the Park itself are all significantly associated with this creation myth which explains the formation of Garden Island,Carnac Island and Rottnest, it also explains the formation of the Lake, the creation of the emu and why whales regularly beach themselves on this coastline.

CONCLUSIONS AND RECOMMENDATIONS

There seem to be no strong objections to a development in the Bay.It is suggested that the Shire,in co-operation with the Dept. of Marine and Harbours,put up a board at Rotary park telling the story of the creation of the local topography and the creation of the Emu,encouraging respect for Aboriginal traditions in this area.

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APPENDIX A

HOW THE EMU WAS CREATED

Told by Ken Colbung

The crocodile came up there,the first bit here is where the crocodile came in and then after that is where the whale came,they called it *mammun*.The crocodile came in where the pine trees are and there there was a little bit of a swamp, then there is a bigger bit beyond.That is where he sat down. He came down the beach and his bottom was here and his feet were here like that.This island here is Garden Island then Carnac island then Rottnest well they call that Rottnest *Wadjemup* see.Rottnest is there that's one bit of his tail, there's Carnac and this one here's Garden Island goin like this over the causeway goin like this ,that's the three islands that's the three bits of the tail.

The story goes that every time the whale used to come from the south down Albany way and it was goin north and these three countries here,one this Nyungar's country here from Albany,Esperance right up there going to Eneabba, Geraldton like that,then the whale used to come through here like that to Lake Moore and this was all water like that that's made one island and that island comin up here from Geraldton through to Shark Bay like that Port Hedland 90 Mile Beach that's another island there,that island this way that's the Kimberley island there.That one was *mammun-* the whale, this one(the second)was the shark and that one was the crocodile.They used come up like that shark and he'll go round like this swimmin around all up that north like,round the Philippines and all that area, Philippines,New Guinea .On one side of the whale was the shark on the other side was the crocodile,they used to flap their tails against the side of the whale making a sound like the waves going over the reef and the fish used to come,because where the reef was was all their food and the whale would open his mouth wide to catch the fish and as he closed his mouth fish would escape and give food to the shark and the crocodile.After they would come back from visiting around like that and the whale would go home.The shark and the crocodile escortin him.

Well one time there wasn't much food.One time they come up like that and they had no fish.It was a poor harvest,drought in the ocean.And they come home and they was all hungry.They usually go home and store up that stuff for the whale so he can live in that *nyittin* time down there, so he can live under the ice.Anyhow these two coming along past this place when they come to the Ambrolhos islands like that,he(the shark) started arguing:

"What you doin?" the shark said to the crocodile,"You making love to that whale,you loving(caressing) him or something."

"Oh,no I'm not."

"Yes,you getting all the fish,I'm getting nothing."

"Alright we'll swap places,at the back so he won't see."

So they are still going along and the shark getting real wild cos he's still getting nothing.

"You telling him like this you know(caressing him) to tell him that you want all of it your side."

They keep going then, the shark keep going behind him,snuck up behind him.When they got up to Two Rocks,what we call Two Rocks,just between Wanneroo and Yanchep,when they got up there,that's where all the animals come,birds,kangaroos and rats.They all came to that Two Rocks,And they also had that *yonga*-the kangaroo and *bibulyong*-the scrub turkey and they saw this big fight like that,big noise they was making,fighting,that crocodile and that shark.Anyhow they went on and the shark was biting that crocodile on the tail.They was making a big song like that.They went on and the shark started to biting the crocodile on the tail and throwing him up and chucking him like that.The first bit he caught off,he chucked it like that it was *Wajemup* Rottnest like that,the next one he grabbed him and took another big bite and pushed him over like that and made this one here Garden island like that,so when this one was made he got nothing ,he can't swim cos his tail gone so he dog paddle like this,dog paddled,come in and he sat down,got a big lake here and a small one near the pine trees,made a big dent in the ground,He sat down and didn't know what to do.

He said:"I got to go back to the Kimberleys see.
"Oh dear."
He's crying poor fellow,noone didn't know him cos they all up that side.

"I gotta get going." and he left here and want to Fremantle that's where that Derbal Yaragan that Swan river.
"I'll move in here into the river."

That Waugal,that rainbow serpent came out:
"Hey,Hey come on you can"t come in here."

"Why?"

"Look at all them big teeth.You will eat all them little people.Here they frightened of you.They said you gotta go."

"Can't I just stop here one night?"

"No,no you gotta go."

He chased him off then right up that way past Scarborough to Wanneroo into Yanchep up there to Two Rocks where that kangaroo was waiting there and that scrub turkey(*Yongandiviel*) that's what that two Rocks is named after and they standing there and they said:"What do you want?"

"Please can I come and stay there for the night,I gotta get back to the Kimberleys?"

They said;"We don't know,you look savage,you are a horrible big monster and you want to come and frighten all these birds and animals like that."

"I don't want to do that ."he said"look I'm sorry for everything,that shark bit my tail off."

"All right we"ll be sorry for you and they went to talk to the rest of the animals.
They said :"We'll let him in."

"No ."they're frightened.

These two were the leaders :"You know we gotta do something all right,all right we'll make an agreement,you promise you won't jump into the trees to sleep,you promise you won't swim on the water and you promise you'll only eat this grass seed here and we'll give you this one tree like the emu berry tree no other animal can have it only you."
And he said:"All right .
"You can come here and you can sleep in this cave right."

He was just going to get up and:
"I'm embarrassed." he said:"Look I got no clothes.I"m a bit shy gettin up in front of all those animals like that and *bibulyon* said:

"I'll help you."and he took off his shirt like that,"And I'll put this on you,that'll save you,like that.So he got his *buga* and he put him down like that."Oh." he said he put him round.
"Now," he said,"you're protected like that,see you got my feathers,there you can get up all right."

"Thankyou."he said like that.Then he got up and started to walk off.He had some clothes now,he was decent and he started to walk off,and he went up that track,up one place and all the blood came out of him and the next place he went to,another lake,where all the marrow went from him.Then he went to sleep in the cave.Then he was in the cave sleeping and he had a big dream in the cave like that, he was that tired, and lay down and he is dreaming about what these animals said to him and he is thinking with a big head like this.
"Oh then ," he said his neck stretched out like this and his head grew smaller and he had a lovely nice slender neck like this see and he was thinking all that thankyou to that *bubulyong* for giving him that *buga* like this.
"Now," he said that's them lovely feathers, so he got them and when the shark was grabbing his tail and snapping his tail he stretched his legs out and his legs grew slender and slim and he is thinking,"Now look at me now I'm a good length.And he came round like that.I'm happy now they made me beautiful,like this.I'm a beautiful bird.

That's how we got the emu and that's how these islands got to be here.They are the tail of the crocodile.He camped over there and those two little bits of swamp by the pine(his feet) and the big one behind(Rotary Park) there where he sat down,that's his place where the water come off him and made that pool.That's how they got this place here now and this side.Always *mammun* the whale come in looking for him see and when he come in here looking for him see and when he come to these beaches in there and he dies like that cos he can't find his old friend so he lies down here.

SUPPLEMENTARY REPORT

of an

ETHNOGRAPHIC SURVEY FOR ABORIGINAL SITES

MANGLES BAY, ROCKINGHAM

Prepared for

THE DEPARTMENT OF MARINE AND HARBOURS

by

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FEBRUARY 1990

Supplementary Report on Mangles Bay

The Aboriginal Cultural Material Committee (ACMC) at its last meeting requested that the location of a site(s) referred to in our report be clarified and marked on a map. A map is attached to this supplementary report. The Committee also requested interpretation of the myth recorded by B. Machin during the abovementioned survey and comment on the significance of the myth. Prior to doing so I wish to comment on a number of methodological issues.

Methodological Note

First, the researcher endeavored to locate a number of informants knowledgeable about the site. A number of contacts were made with a representative of the Medina Aboriginal Cultural Group. The representative identified persons who might be knowledgeable about the survey area. However, following inquires in the local community, he informed the researcher that the key informant used in other surveys was now too old and incapacitated to be involved in the study. He also noted that another potential informant, a son of the abovementioned informant, was a heavy drinker and could not therefore be used in the survey. Others, who might have been helpful, he reported, had moved out of the area and their present addresses were unknown to the association.

Mr. K. Colbung was the only informant who could be located with knowledge of the area. Mr. Colbung has reported that he acquired knowledge of the site and the mythology, and therefore the right to speak for sites in the area, from relations who belonged to the *Hill River Mob*. The *run* of the *Hill River Mob* included the coastal strip from Hill River (near Jurien Bay) to Rockingham, in addition to other coastal areas to the north and south of these points.

The myth narrated by Mr. Colbung was recorded by the researcher using both audio and audio-visual recording equipment. Copies can be made available for inspection.

The Significance of the Site

Further discussions were held with Mr. Colbung to clarify the issue of the site's significance. He reports that the site is a mythological but **not** a sacred site. Mr. Colbung reported that the site no longer has any sacred, ritual or ceremonial usage associated with it. In other words, the site has lost its religious significance. The analogy Mr. Colung used was a church which had been de-consecrated.

The site while being of significance for the informant is not a sacred site as defined by Section 5 (b) of the Aboriginal Heritage Act 1972-1980 and Section 39 (3) of the Act is not a key issue in its evaluation. Any difficulties in regard to the evaluation of the significance of the site may be more to do with the Act than with Nyungar cultural evaluations.

The ethnographic significance of the site could be recognised, in the view of Mr. Colbuug, by the erection of an information plaque at Rotary Park.

Interpretation of the Myth

The ACMC's concerns about the interpretation of the myth seem to imply a concern about its authenticity. From discussions with the informant and staff of the Department, this concern would seem to relate to the following factors:

1) the consistency of the myth with others told by the informant himself and other Nyungars,

2) the nature of some of the elements in the myth (e.g., a crocodile and New Guinea).

With regard to the issue of consistency, Mr. Colbung maintains that there is no contradiction between this myth and others he was told about the area and in particular Rottnest.

However, even if there were inconsistencies, this would not undermine the authenticity of the myth. Mythology does not have to be consistent in either folk or anthropological terms to be authentic. There are numerous examples in Aboriginal Australia and other cultures of inconsistent and indeed competing creation myths for the same sites, myths relating to social and cultural practices and so on.

Sutton (1988 'Myth as history, history as myth' in Keen (ed.) *Being Black*), for example, notes cases where versions of particular myths were publicly debated and used to negotiate politically desired ends. B. Machin found inconsistencies in myths relating to healing rituals in Sri Lanka, not only between competing groups of priests/healers but also within the same group. In fact these contradictions were a central feature of the mythological system (personal communication). The Bible, contains major inconsistencies regarding the life and works of Christ. A notable example, in view of the recent celebration of Christmas, is in the Nativity story. Two of the four Gospels do not even mention the Nativity, the other two provide very contradictory accounts (See Warner 1976 *Alone of All Her Sex*, see also Wilson 1984 *Jesus: The Evidence*). In these and other cases inconsistencies are not necessarily an issue in accepting the myth as authentic. Indeed, as Propp (1972 'Transformations in Fairy Tales' in Maranda (ed.) *Mythology*) notes transformations - inconsistencies - are an integral part of mythical systems.

The second issue, concerns the introduction of elements into the myth that are not considered to be traditional. One is the presence of a crocodile. Another, is the mentioned parts of Australian outside what was traditionally Nyungar country and worse, other countries such as New Guinea and the Phillipnes. This concern seems to be based on the principle that "everybody knows" that there are not crocodiles around Perth and that Nyungars could not have known about these far off places and therefore they could not be constituents of the a 'real' Nyungar myth.

This criticism would seem to be based on, on the one hand, a fundamental misunderstanding of the nature of myth, and on the other, a denial that Nyungars still have a mythological system and a belief that Nyungar tradition ended with colonisation.

Myth, as Maranda (*Mythology* 1972:8)) argues "consists of an reorganising traditional components in the face of new circumstances or, correlatively, in reorganising new, imported components, in the light of tradition". The informant, Mr. Colbung, reported that he was telling the myth in a modern idiom. He thus used the term crocodile to refer to an aquatic monster. This creature was like the Waugal but inhabited the sea and was known by another name.

It is interesting to note that Francis Armstrong reported in 1836 that his informants described the Waugal as an aquatic monster. He said that his informants described the creature as resembling what he thought was an alligator, i.e., it was crocodilian like. Both sea and freshwater Waugals were referred to by his informants.

The introduction of new components to this Nyungar myth is no different to the appearance of Ned Kelly and Captain Cook in Gurindji myth or Captain Cook and other Europeans in other Aboriginal myths (see Maddock 1988 "Myth, history and a sense of oneself" in Beckett (ed.) *Past and Present*). Biblical myths have also been superimposed on Aboriginal myth. For example, Noah's Ark was recorded as part of a myth by Kolig in the Kimberely and the death and resurrection of Jesus was found in a myth as occurring a Nambucca heads in NSW (Sutton *op. cit.*:256).

The presence of these new components does not undermine the authenticity of the myth narrated by Mr. Colbung. They do show, however, that Nyungar mythology is alive and well.

Conclusions

The authenticity of the myth told by the informant can not be questioned on the basis of the presence of new or non-traditional components or presumed inconsistencies with other myths about the area. The myth is as authentic as any myth in any other cultural system. The myth was acquired by the informant from kin who had associations with the area.

The site, according to the informant, while mythological is not sacred.

The development should therefore be permitted to proceed.

Appendix 9.

Predictions of the Hydrodynamic Effects of a Proposed Marina
Near Rockingham, Cockburn Sound

Predictions of the Hydrodynamic Effects of a Proposed Marina Near Rockingham, Cockburn Sound

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Report OMR-16/31
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1 Introduction

This report describes the results of a modelling study into the hydrodynamic effects of a proposed marina, sited at the southern end of Cockburn Sound, WA. The work was commissioned by the Department of Marine and Harbours, Western Australia.

The model is of the two-dimensional vertically-averaged type with the inclusion of nonlinear advection, friction and volume conservation terms in the controlling equations (Hunter, 1989). The model was driven by the combined effects of a tidal flow through the channel at the site of the Trestle Bridge (i.e. the channel in the breakwater indicated in Figures 1 to 18) and surface wind stress. In all, sixteen runs of the model were implemented, covering a range of these driving forces.

2 Model Details

The bathymetry for the models was digitised onto a 50m x 50m grid from charts 434–1–1 (supplied by the Department of Marine and Harbours, WA) and AUS 117 (Hydrographic Service, RAN). Two configurations were considered, corresponding to the topography before and after construction of the proposed marina (as indicated on chart 347–7–1, supplied by the Department of Marine and Harbours, WA). Since the flow inside the marina is not the subject of this study, and since the entrance channel to the marina is small, the marina was modelled as if there were a barrier across the entrance. The bathymetries of the two configurations are shown in Figures 1 and 2.The model boundaries extend from 376,475E to 379,025E and from 6,428,075N to 6,429,725N.

Relevant parameters are :

Coriolis parameter : .00007786 s^{-1}

Bottom drag coefficient : .0025

Background current velocity in friction law : .1 ms^{-1} (for current speeds below this value, a linear bottom friction law is used; for higher current speeds, a quadratic law is used – see Hunter, 1989)

Horizontal coefficient of eddy viscosity : 1 m^2s^{-1}

Wind stress law :

$$C_A = (.75 + .067W) \times 10^{-3}, \quad 4 \text{ ms}^{-1} < W < 21 \text{ ms}^{-1} \qquad (1)$$

where C_A is the surface drag coefficient and W is the wind speed (Garratt, 1977)

Ratio densities of air and water : .00117

Tidal flow under Trestle Bridge : ± 250 m^3s^{-1} (a typical value derived from observations, Hunter and Hearn, 1985)

Wind speeds and directions : 0 or 5 ms^{-1} at 90°, 225° or 315° (grid, from). These winds are deemed typical of the Cockburn Sound region.

The currents in the vicinity of the Trestle Bridge are predominantly tidal, with magnitudes of around 0.3 ms^{-1} (compared with wind-driven currents, which are typically 0.05 to 0.1 ms^{-1}). We may estimate the relative importance of flow accelerations due to temporal and spatial variations by considering the following ratio of terms in the hydrodynamic equation :

$$\frac{(\text{time} - \text{derivative term})}{(\text{space} - \text{derivative term})} = \frac{\frac{\partial u}{\partial t}}{\frac{\partial u^2}{\partial x}} \approx \frac{L}{uT} \qquad (2)$$

where u is one component of the current velocity, x and t are spatial and temporal coordinates, respectively, and L and T are characteristic spatial and temporal scales, respectively. In this instance, $u \approx 0.3 \text{ ms}^{-1}$, $L \approx 1500$ m and $T \approx 24$ hrs $= 86400$ s. Hence

$$\frac{(\text{time} - \text{derivative term})}{(\text{space} - \text{derivative term})} \approx \frac{L}{uT} \approx 0.06 \qquad (3)$$

indicating that the time-derivative term is rather small. Hence in all simulations, **the model was run to steady state, under conditions of constant forcing.**

The various model runs are summarised in Table 1.

Since the current velocity field in South Channel and Cockburn Sound is not well known, the lateral boundary conditions of the model are somewhat arbitrary. In the present case, the normal velocities at the open boundaries are prescribed to have magnitudes of :

.041 ms^{-1} for boundary points to the west of the Trestle Bridge (i.e. in South Channel)

.0066 ms^{-1} for boundary points to the east of the Trestle Bridge (i.e. in Cockburn Sound)

These values ensure that the magnitude of the flow under the Trestle Bridge is **250 m^3s^{-1}**. The prescribed velocity at the open boundaries **is hence independent of the imposed wind stress.**

Due to the necessary uncertainty in the open boundary conditions, **the model predictions should be viewed with caution in the vicinity of the open boundaries.**

RUN	CONFIGURATION	FLOW (cu m/s, +ve towards east)	WIND SPEED (m/s)	WIND DIRECTION (deg., grid, from)
1	Marina absent	250	0	-
2	"	250	5	90 (E)
3	"	250	5	225 (SW)
4	"	250	5	315 (NW)
5	"	-250	0	-
6	"	-250	5	90 (E)
7	"	-250	5	225 (SW)
8	"	-250	5	315 (NW)
9	Marina present	250	0	-
10	"	250	5	90 (E)
11	"	250	5	225 (SW)
12	"	250	5	315 (NW)
13	"	-250	0	-
14	"	-250	5	90 (E)
15	"	-250	5	225 (SW)
16	"	-250	5	315 (NW)

Table 1 Model Runs

3 Model Predictions

The model was run for a period of 56 hours (equivalent to about five e-folding decay times) after which time a steady state was deemed to have been reached (it is estimated that the results are within about 0.7% of the true steady-state values). The velocity fields for the 16 runs, summarised in Table 1, are shown in Figures 3 to 18. It is evident that the wind-induced currents are rather insignificant compared with those associated with the tidal flow under the Trestle Bridge.

4 References

Garratt, J.R., 1977. Review of drag coefficients over oceans and continents, *Monthly Weather Review*, **105**, 915–929.

Hunter, J.R., 1989. User manual for numerical hydrodynamic models of marine systems and associated plotting package, CSIRO Division of Oceanography, Hobart, Report OMR-14/00.

Hunter, J.R. and Hearn, C.J., 1985. Physical oceanography and meteorology of the Rockingham Marina Site, and predicted physical impacts of the marina, in *Rockingham Marina, Public Environmental Report*, Volume 2, Appendix 2, John Holland Group.

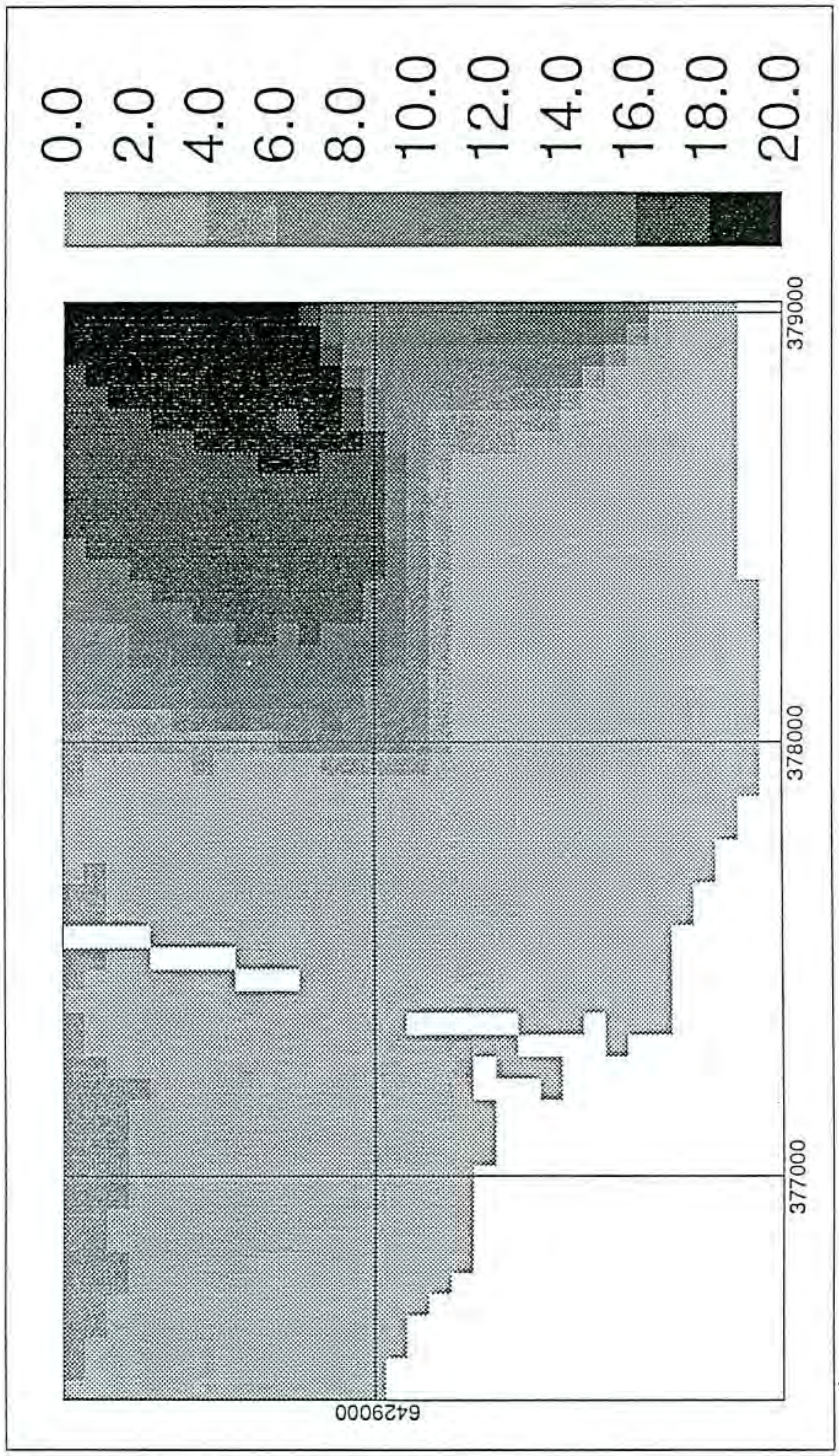

Figure 1 Bathymetry (metres) prior to construction of the marina

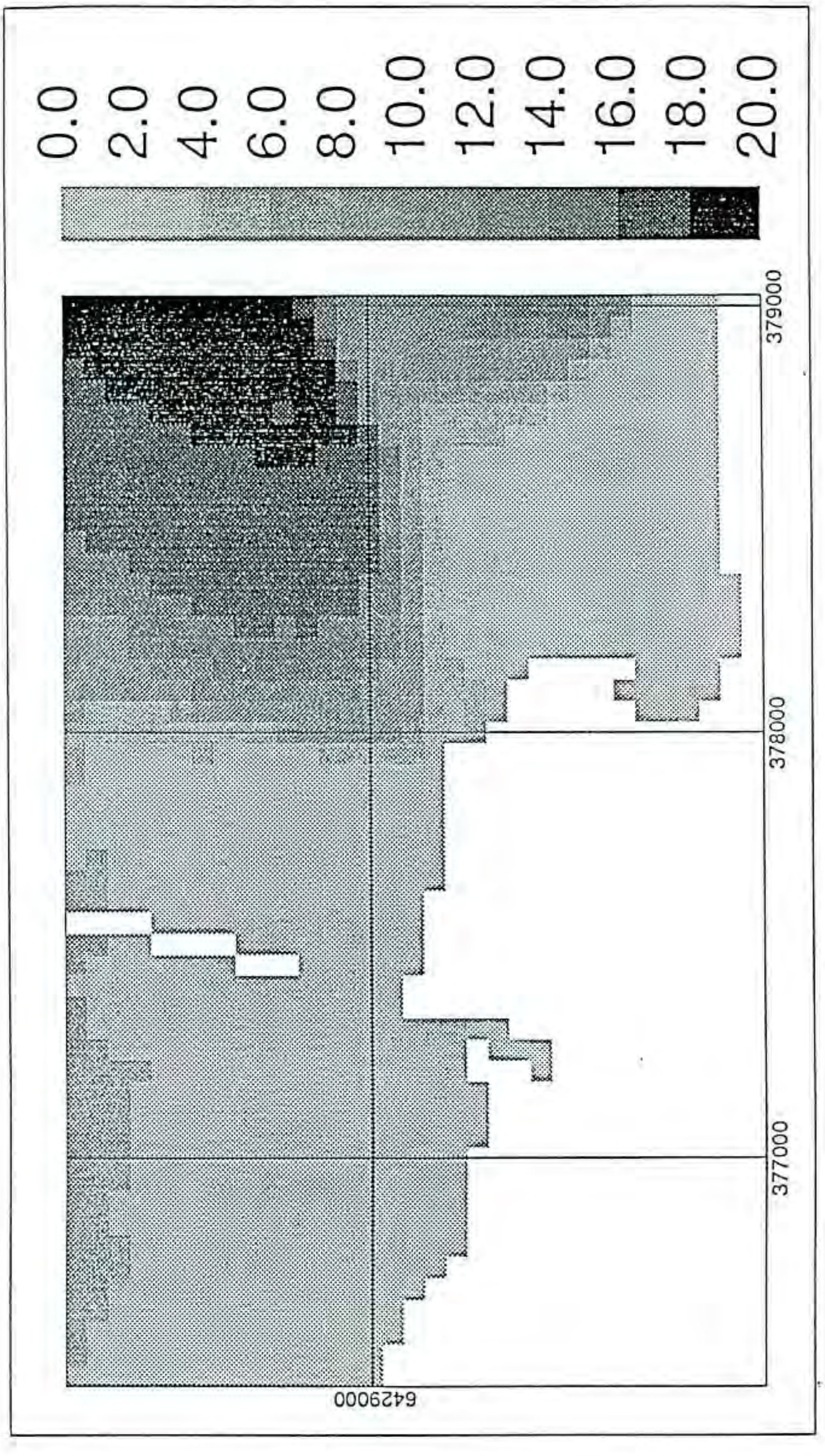

Figure 2 Bathymetry (metres) after construction of the marina

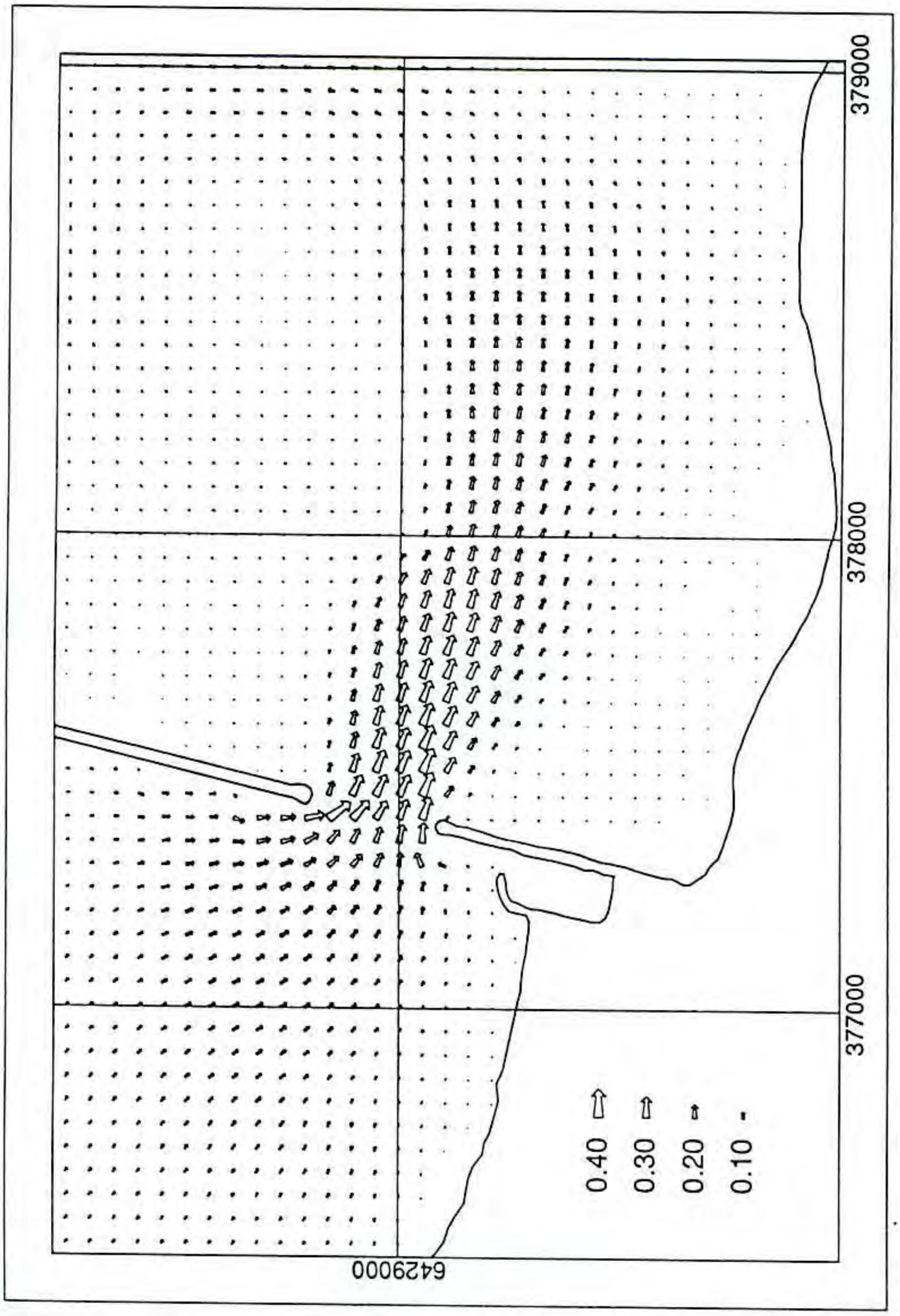

Figure 3 Currents (ms^{-1}). Run 1. Marina absent. Tidal flow : 250 m^3s^{-1}. No wind.

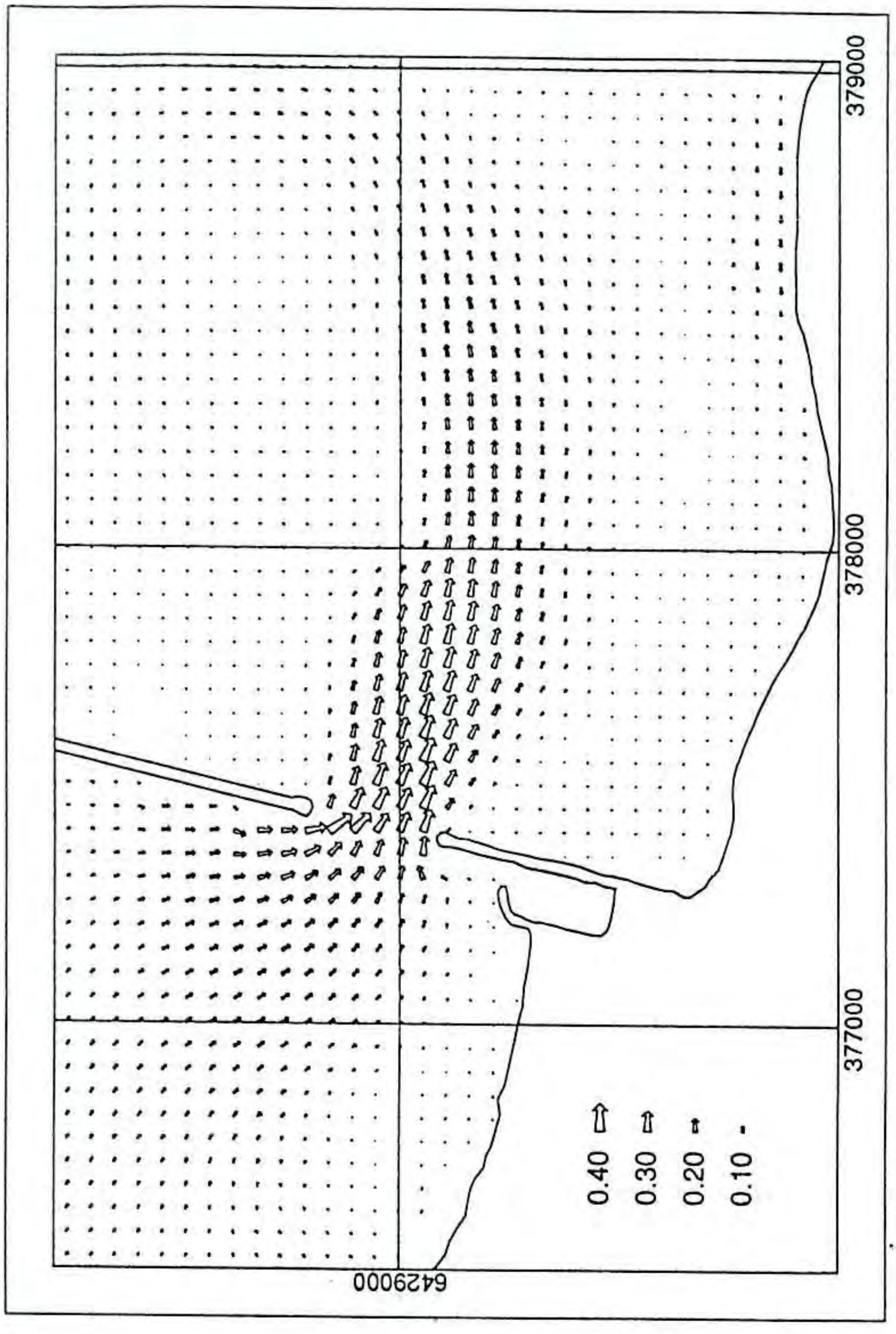

Figure 4 Currents (ms^{-1}). Run 2. Marina absent. Tidal flow : 250 m^3s^{-1}. Wind : 5 ms^{-1} from 90° (east).

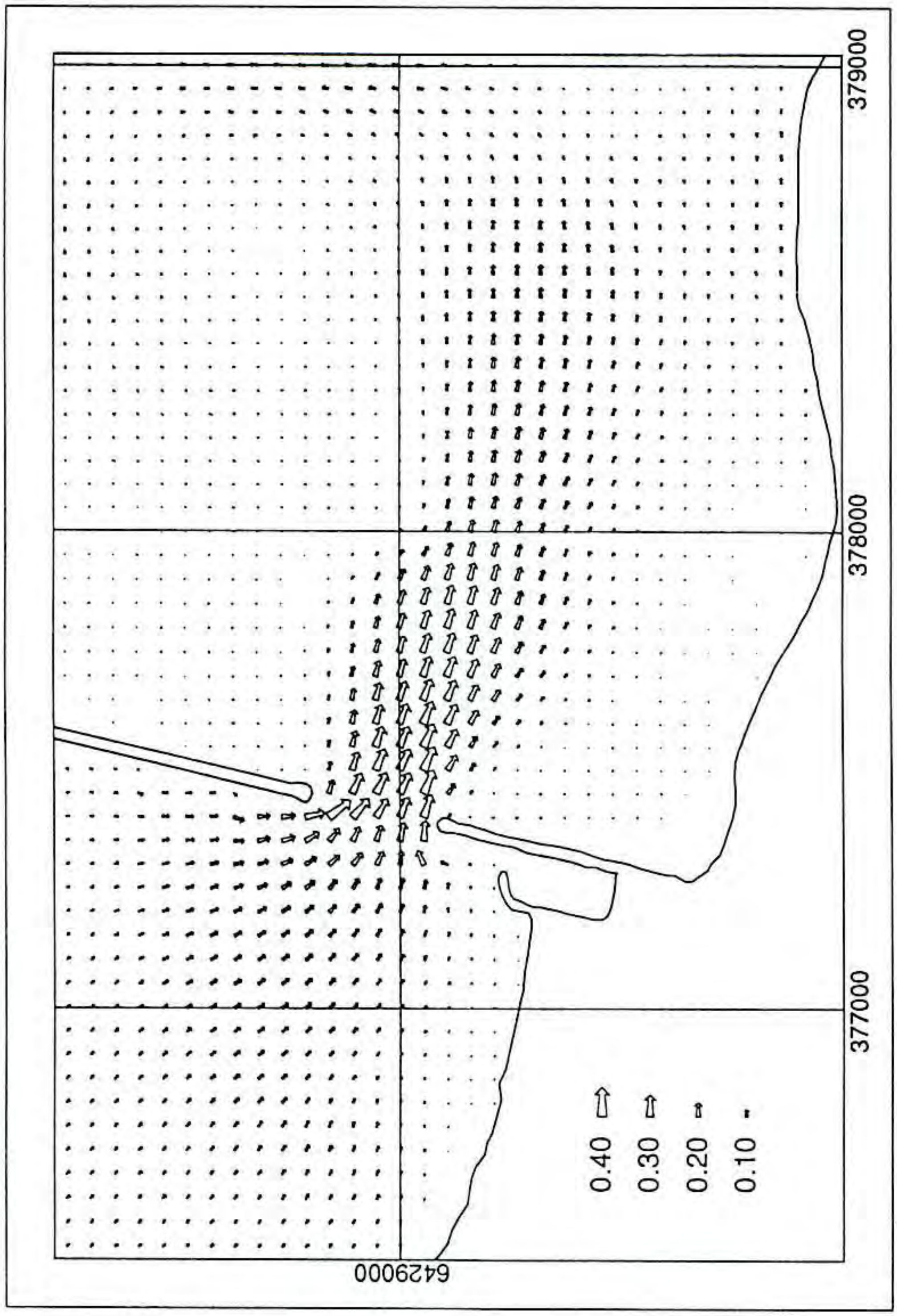

Figure 5 Currents (ms^{-1}). Run 3. Marina absent. Tidal flow : 250 m^3s^{-1}. Wind : 5 ms^{-1} from 225° (southwest).

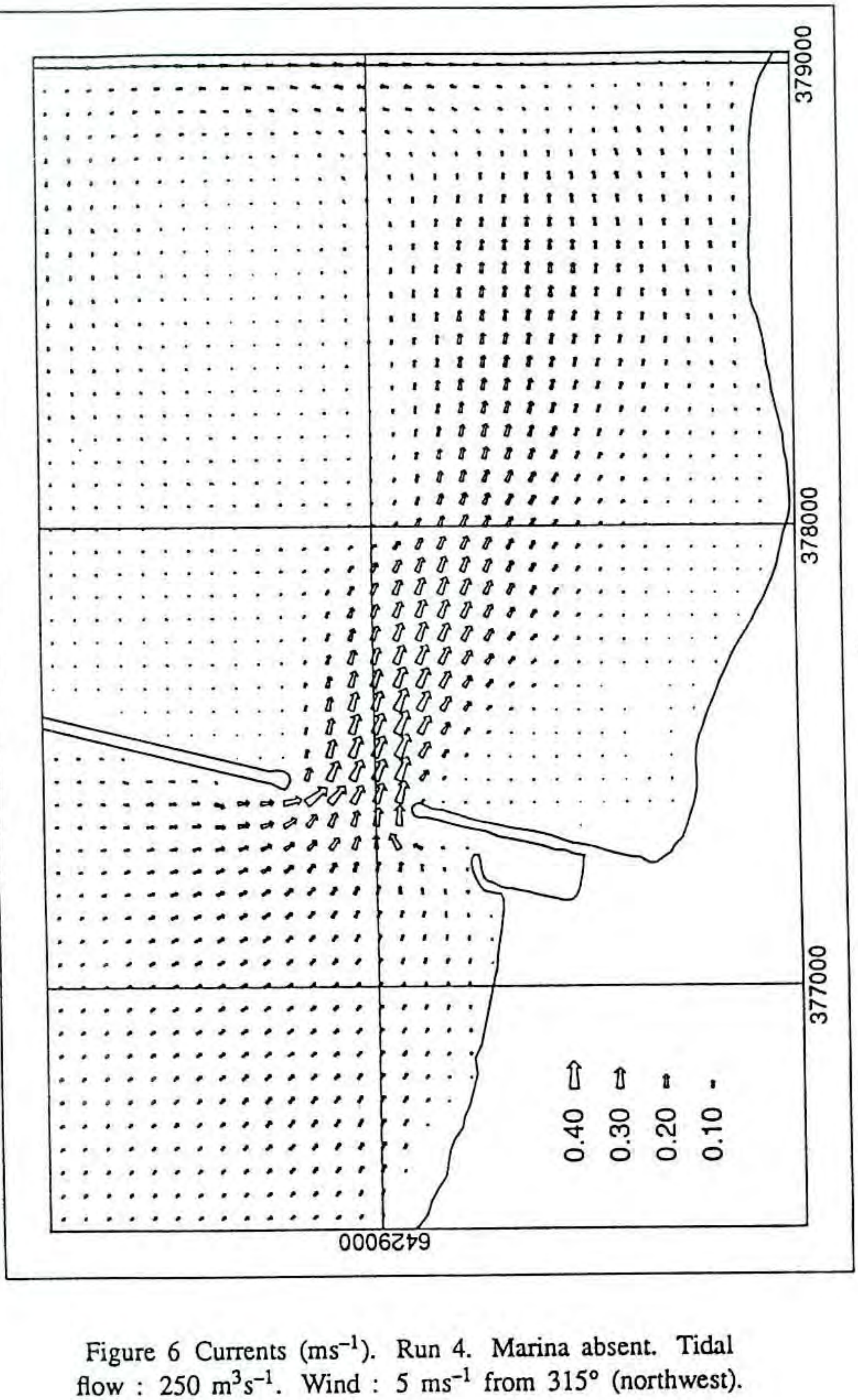

Figure 6 Currents (ms^{-1}). Run 4. Marina absent. Tidal flow : 250 m^3s^{-1}. Wind : 5 ms^{-1} from 315° (northwest).

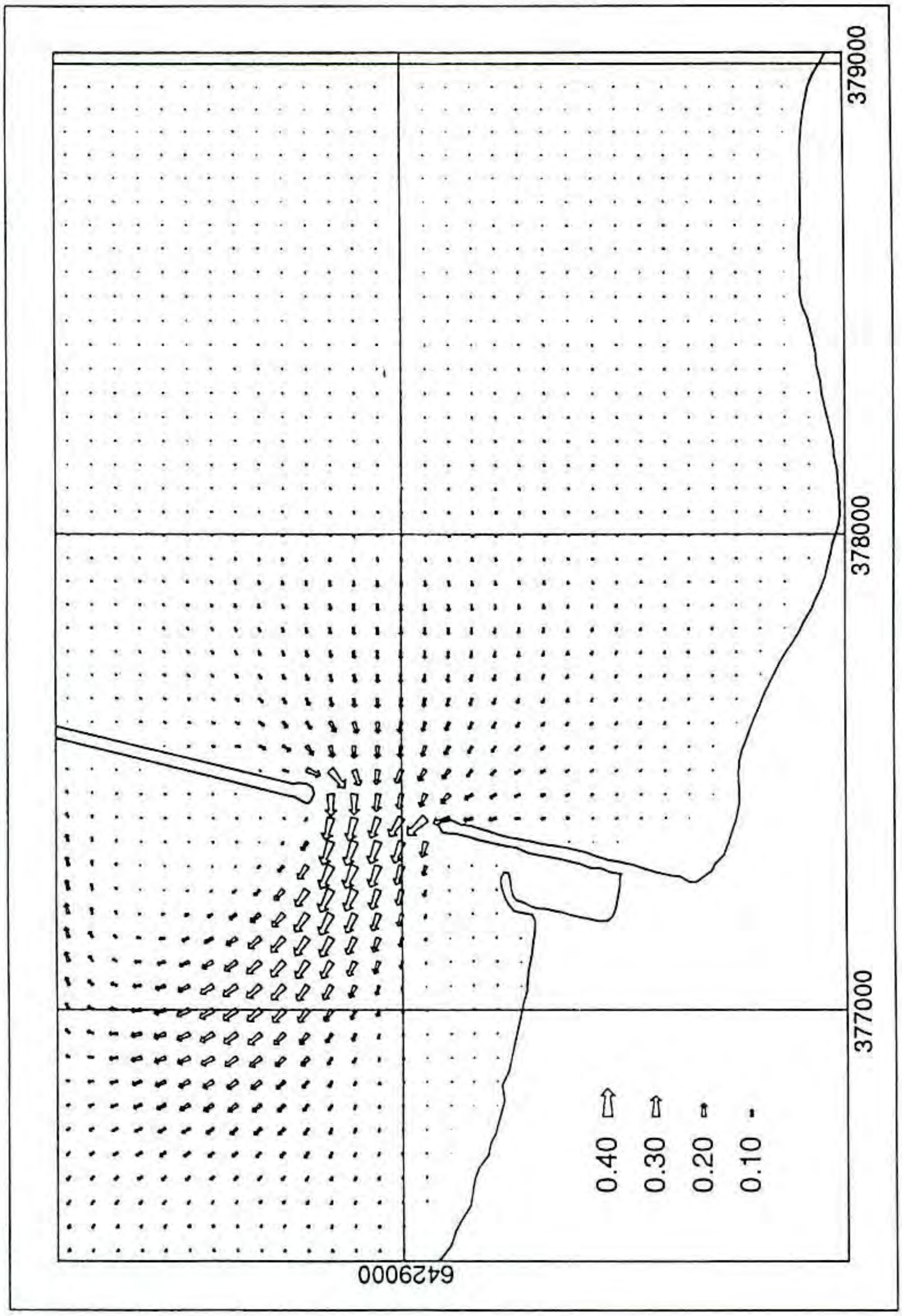

Figure 7 Currents (ms^{-1}). Run 5. Marina absent. Tidal flow : $-250\ m^3s^{-1}$. No wind.

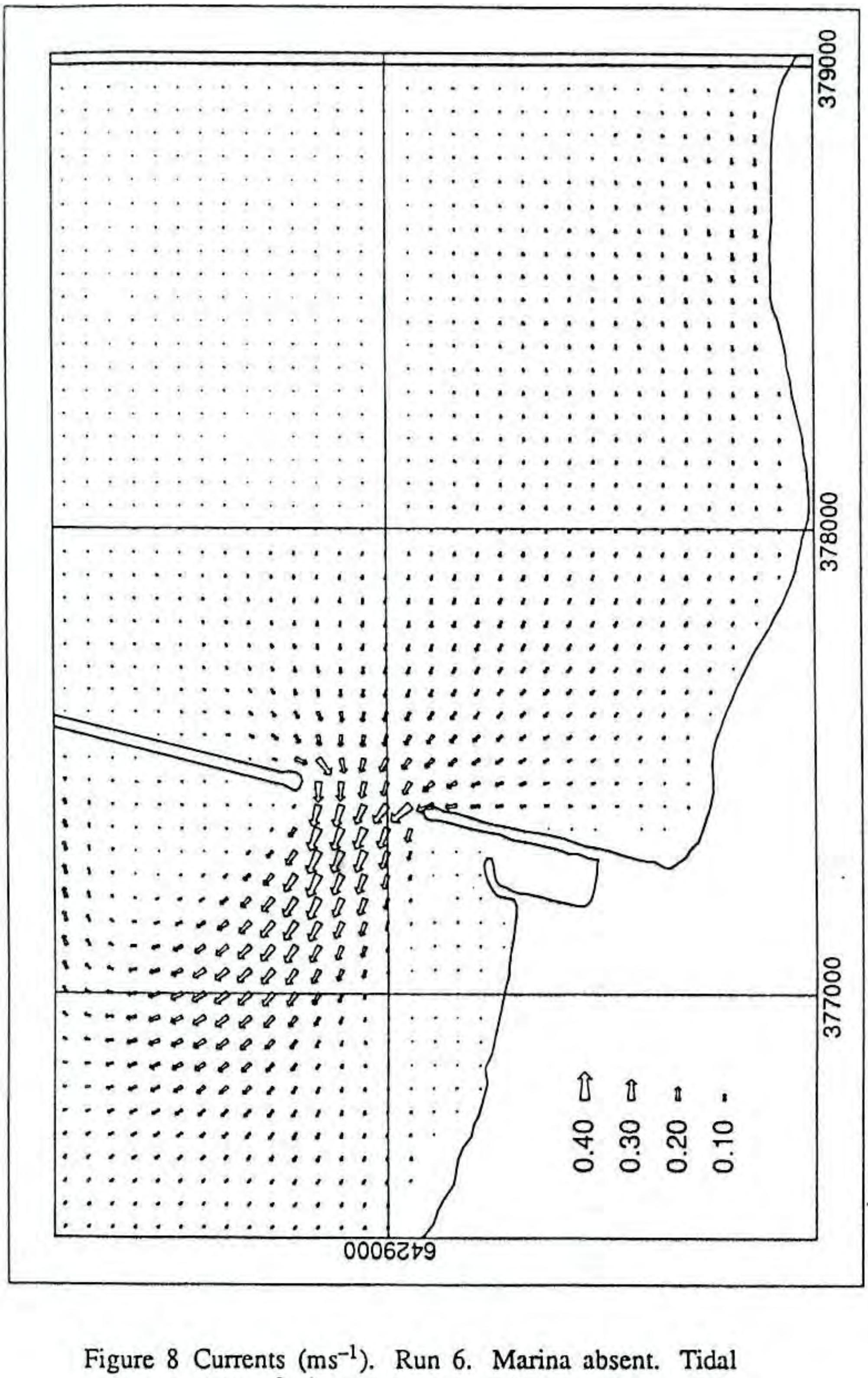

Figure 8 Currents (ms^{-1}). Run 6. Marina absent. Tidal flow : -250 m^3s^{-1}. Wind : 5 ms^{-1} from 90° (east).

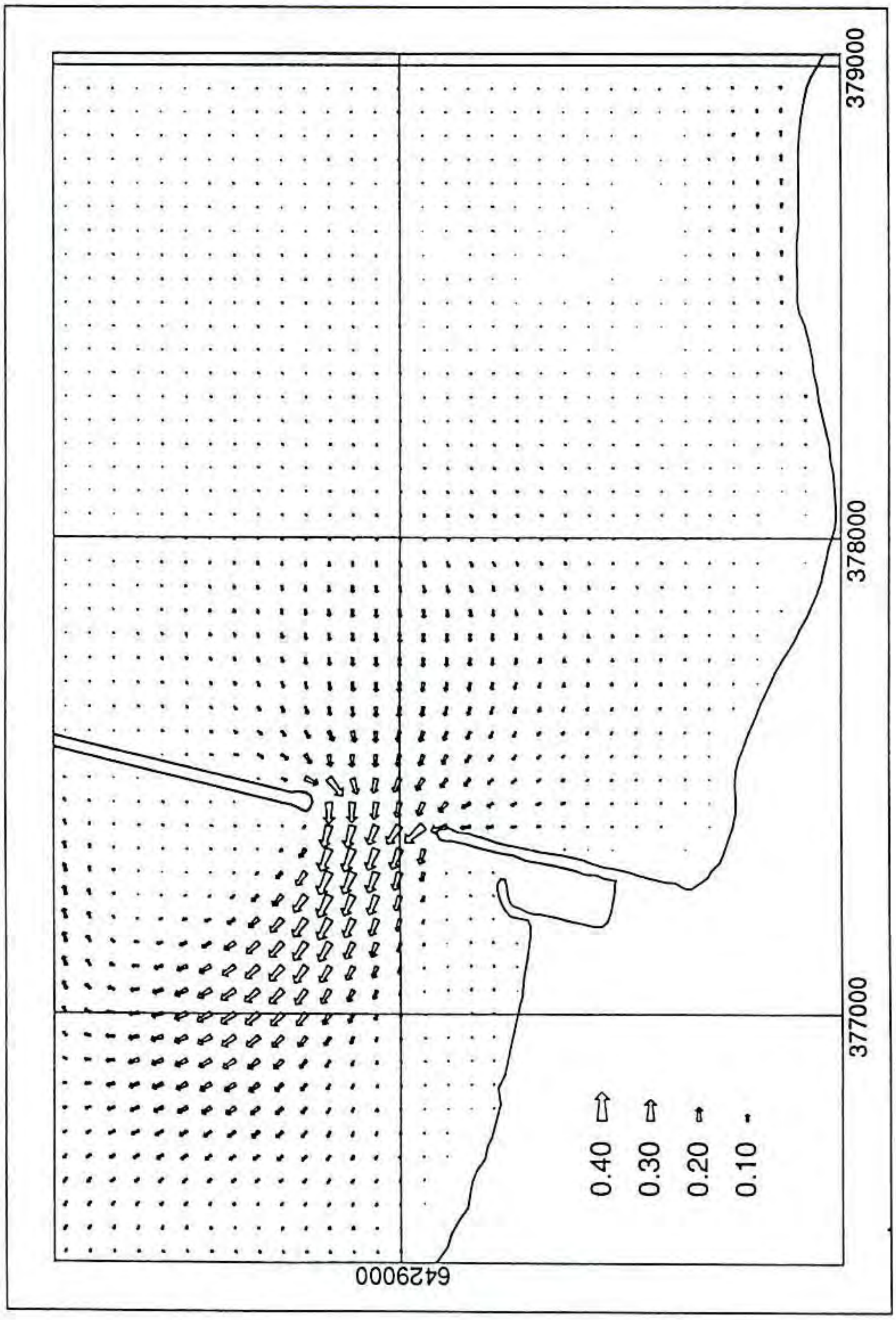

Figure 9 Currents (ms^{-1}). Run 7. Marina absent. Tidal flow : $-250\ m^3s^{-1}$. Wind : 5 ms^{-1} from 225° (southwest).

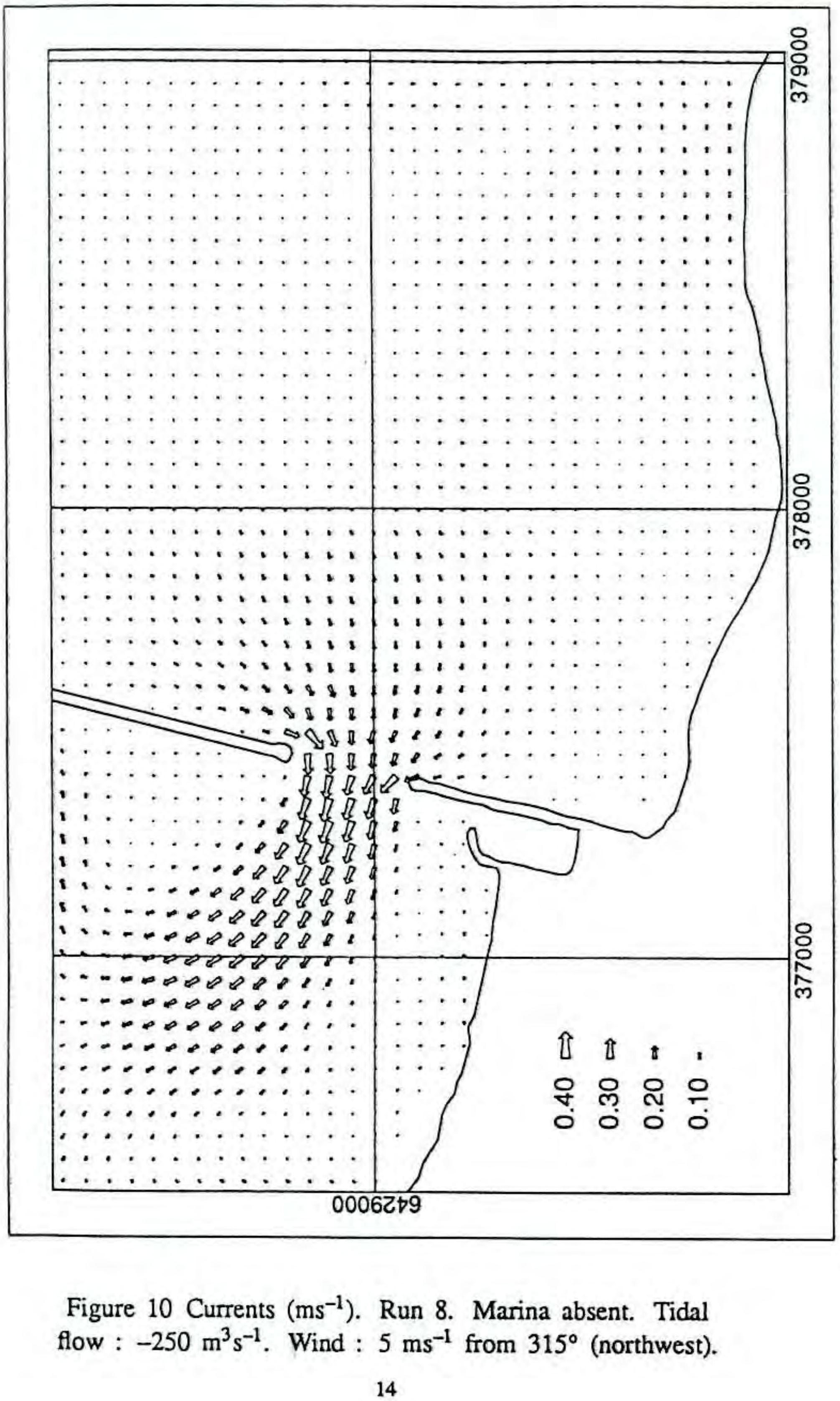

Figure 10 Currents (ms^{-1}). Run 8. Marina absent. Tidal flow : $-250\ m^3s^{-1}$. Wind : $5\ ms^{-1}$ from 315° (northwest).

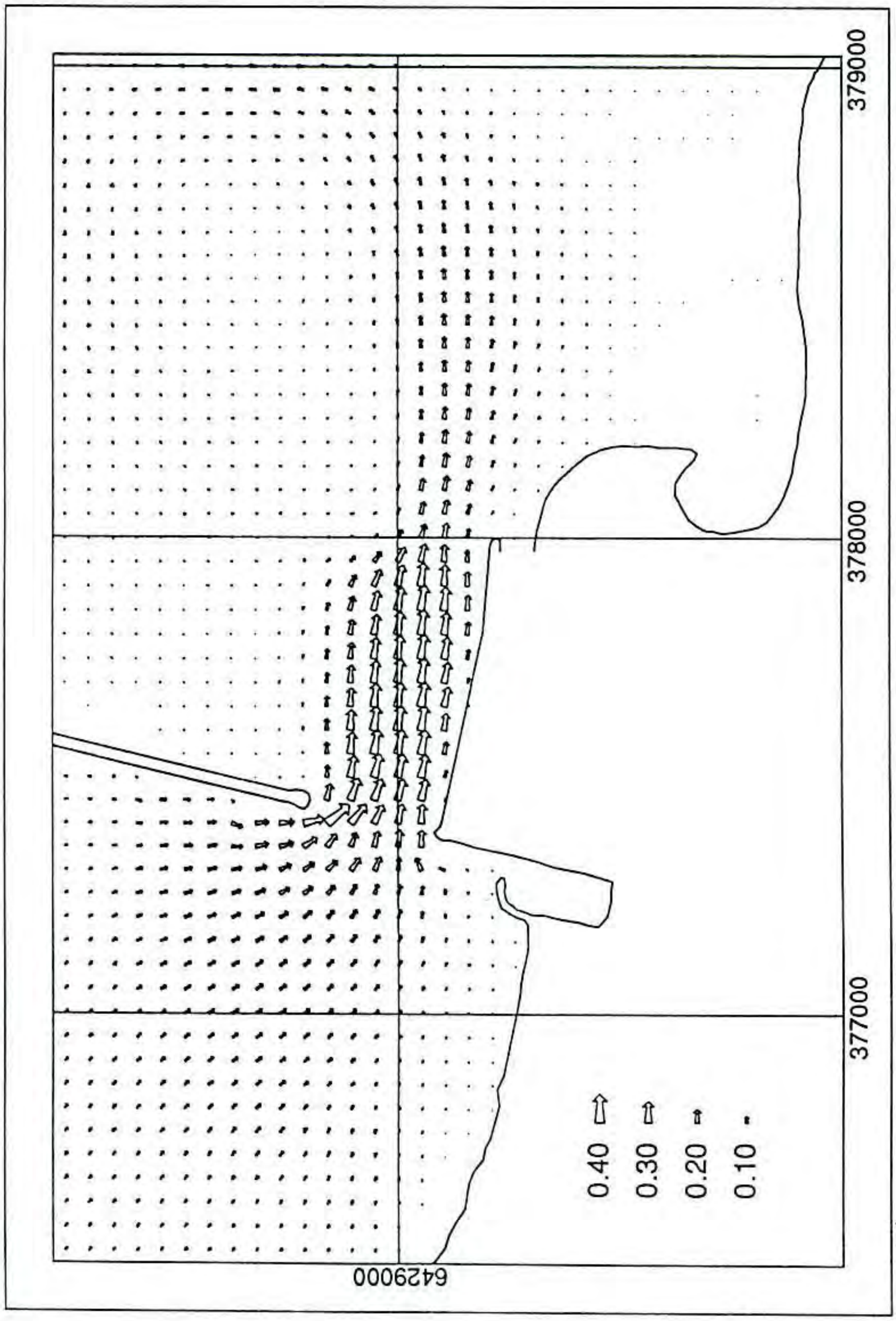

Figure 11 Currents (ms^{-1}). Run 9. Marina present. Tidal flow : 250 m^3s^{-1}. No wind.

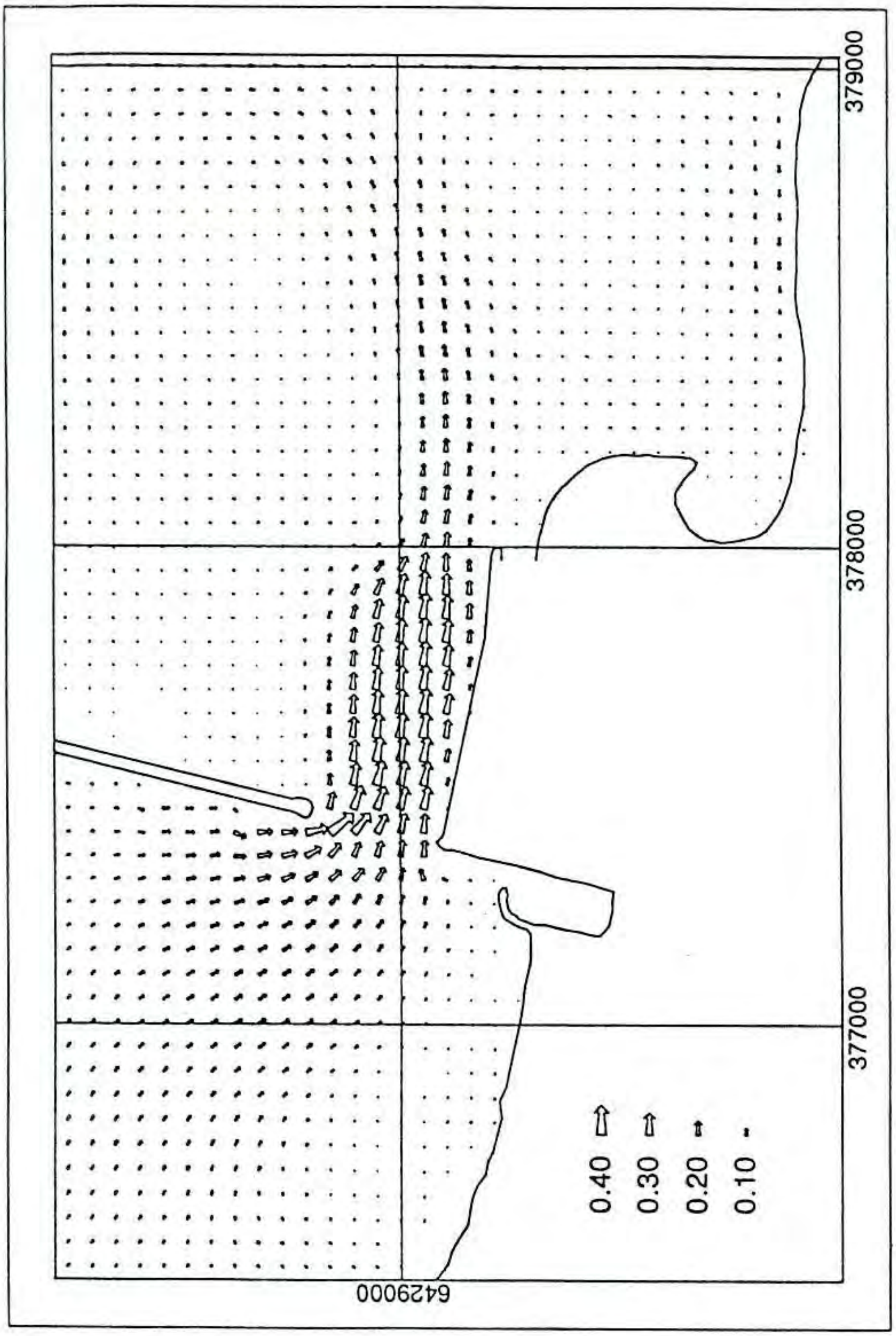

Figure 12 Currents (ms^{-1}). Run 10. Marina present.
Tidal flow : 250 m^3s^{-1}. Wind : 5 ms^{-1} from 90° (east).

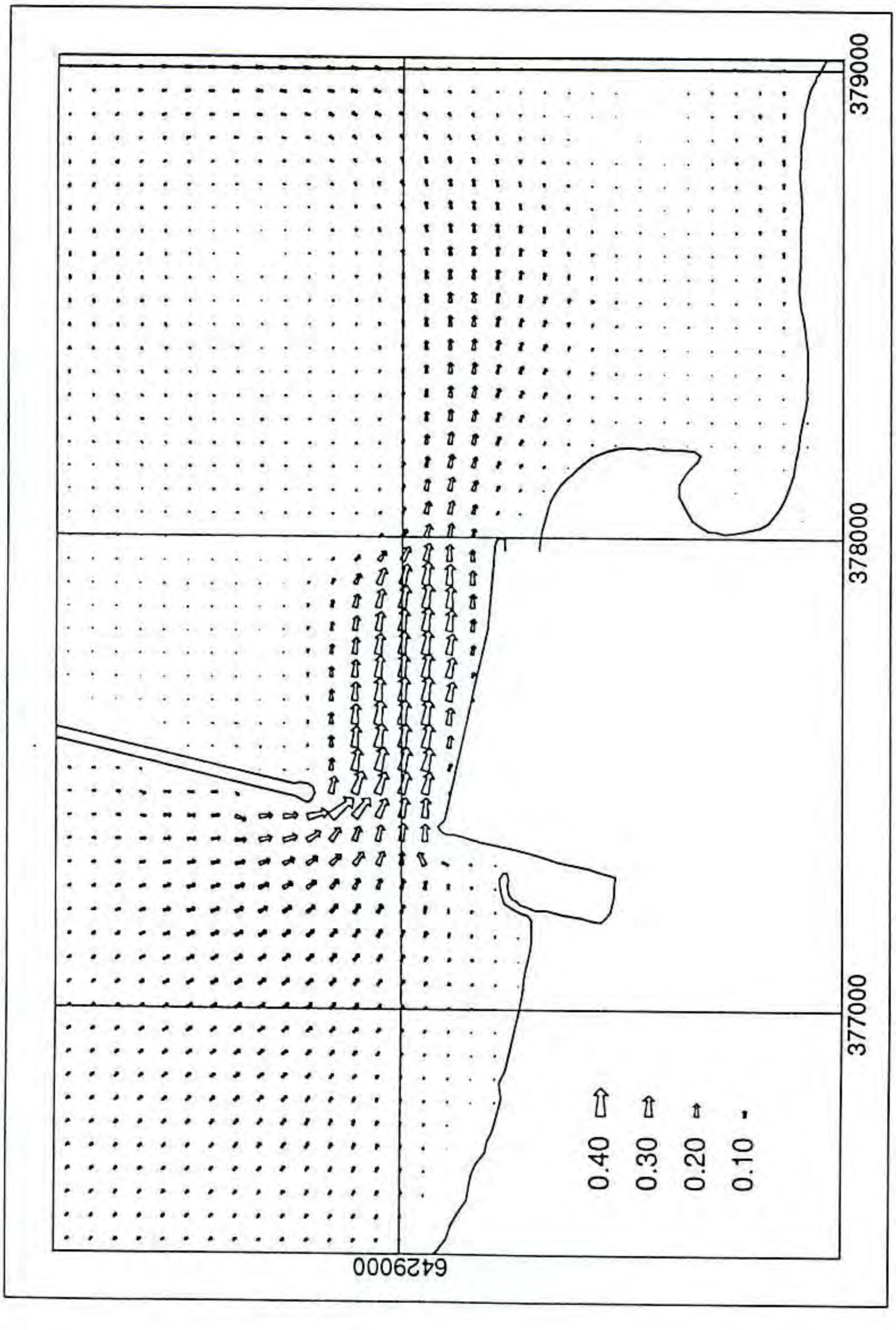

Figure 13 Currents (ms^{-1}). Run 11. Marina present. Tidal flow : 250 m^3s^{-1}. Wind : 5 ms^{-1} from 225° (southwest).

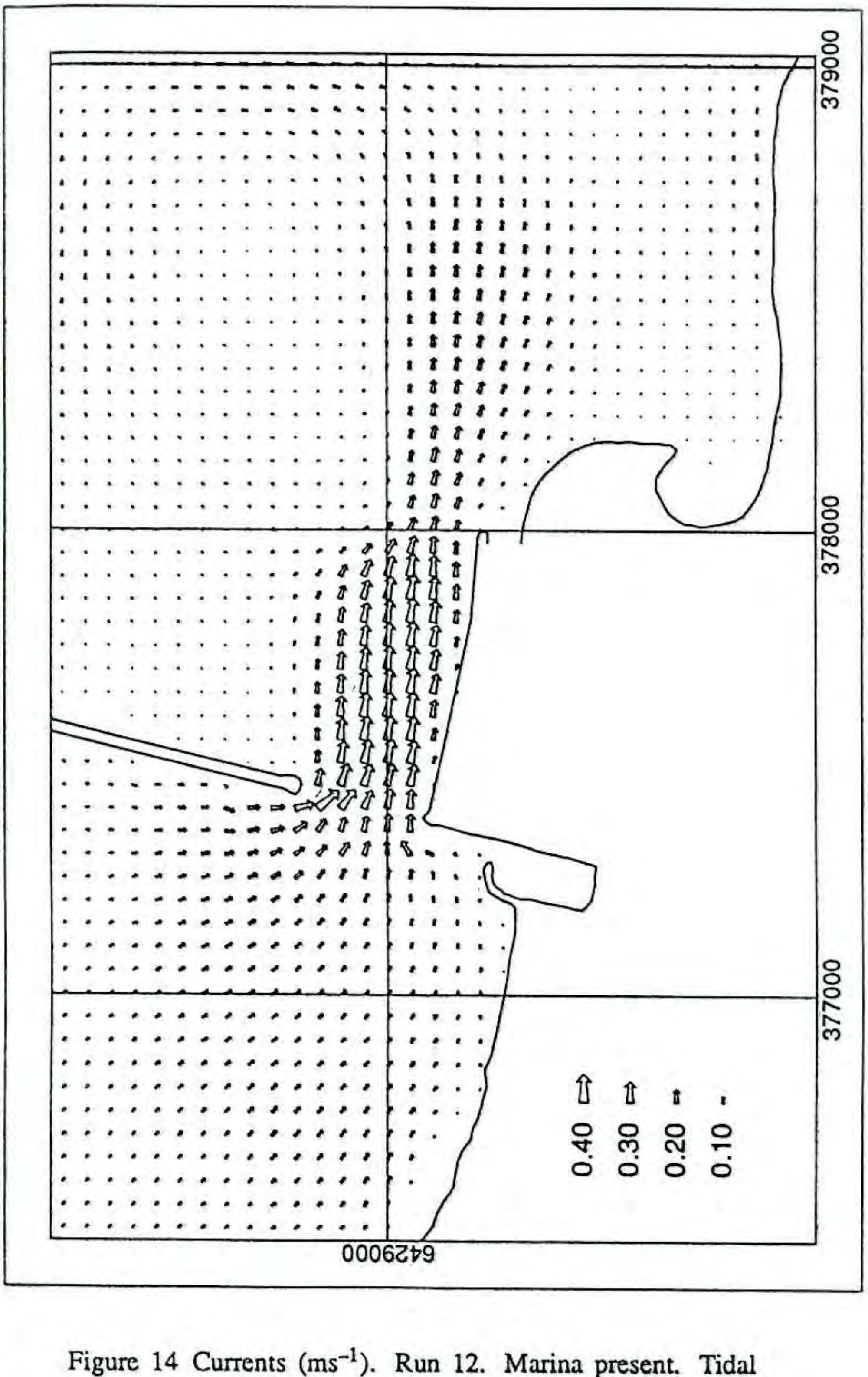

Figure 14 Currents (ms^{-1}). Run 12. Marina present. Tidal flow : 250 m^3s^{-1}. Wind : 5 ms^{-1} from 315° (northwest).

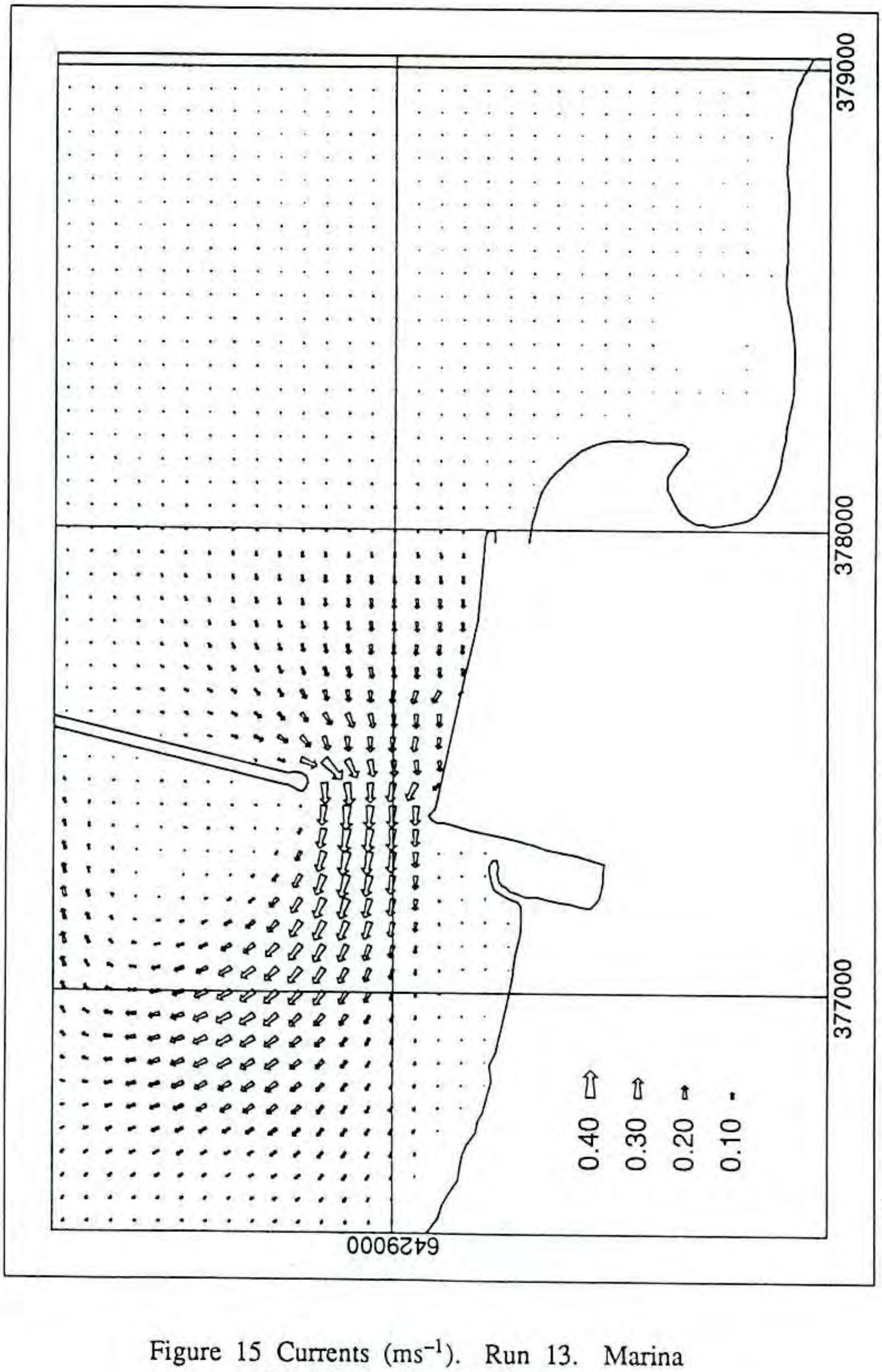

Figure 15 Currents (ms^{-1}). Run 13. Marina present. Tidal flow : -250 m^3s^{-1}. No wind.

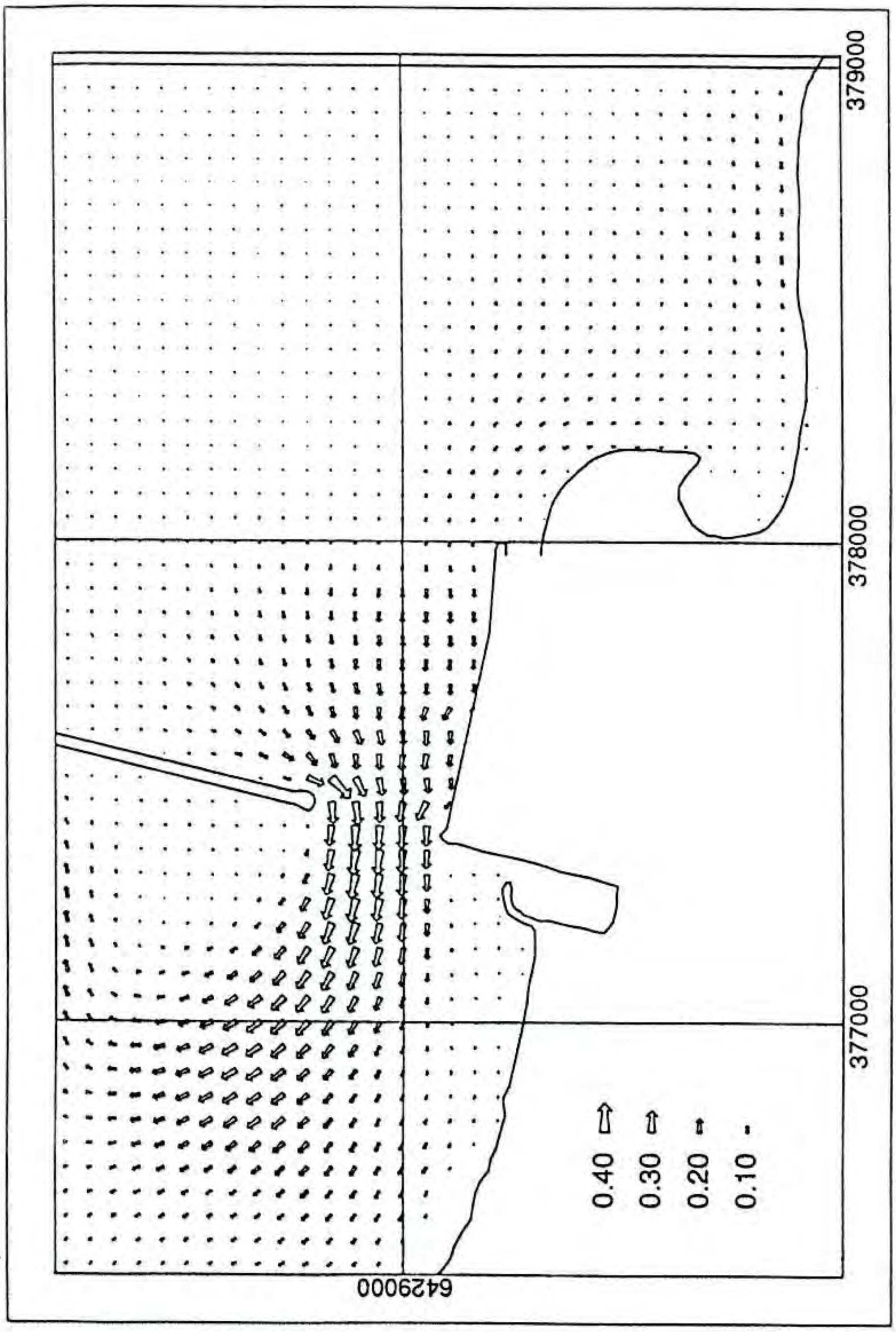

Figure 16 Currents (ms^{-1}). Run 14. Marina present. Tidal flow : $-250\ m^3s^{-1}$. Wind : 5 ms^{-1} from 90° (east).

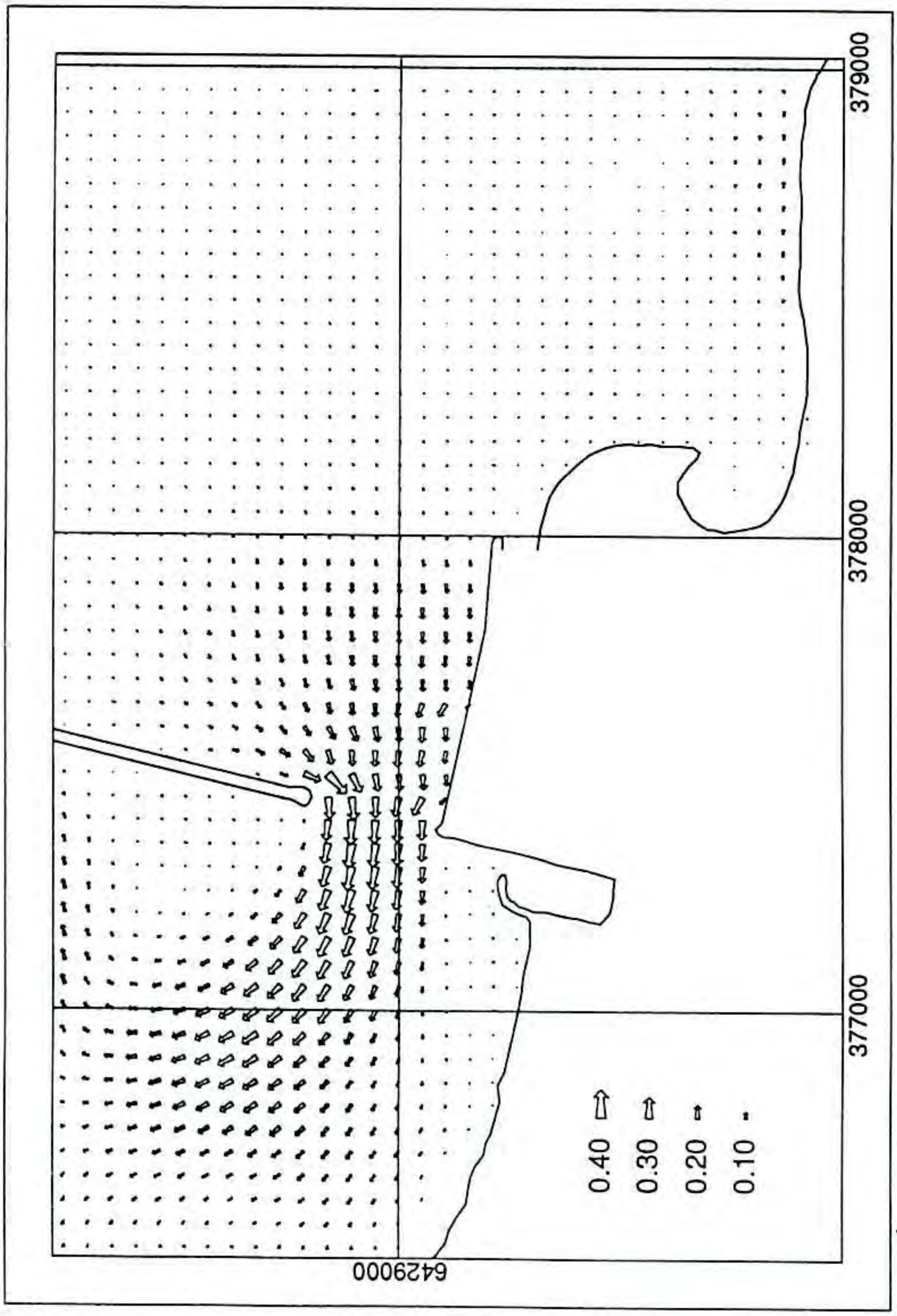

Figure 17 Currents (ms^{-1}). Run 15. Marina present. Tidal flow : $-250\ m^3s^{-1}$. Wind : 5 ms^{-1} from 225° (southwest).

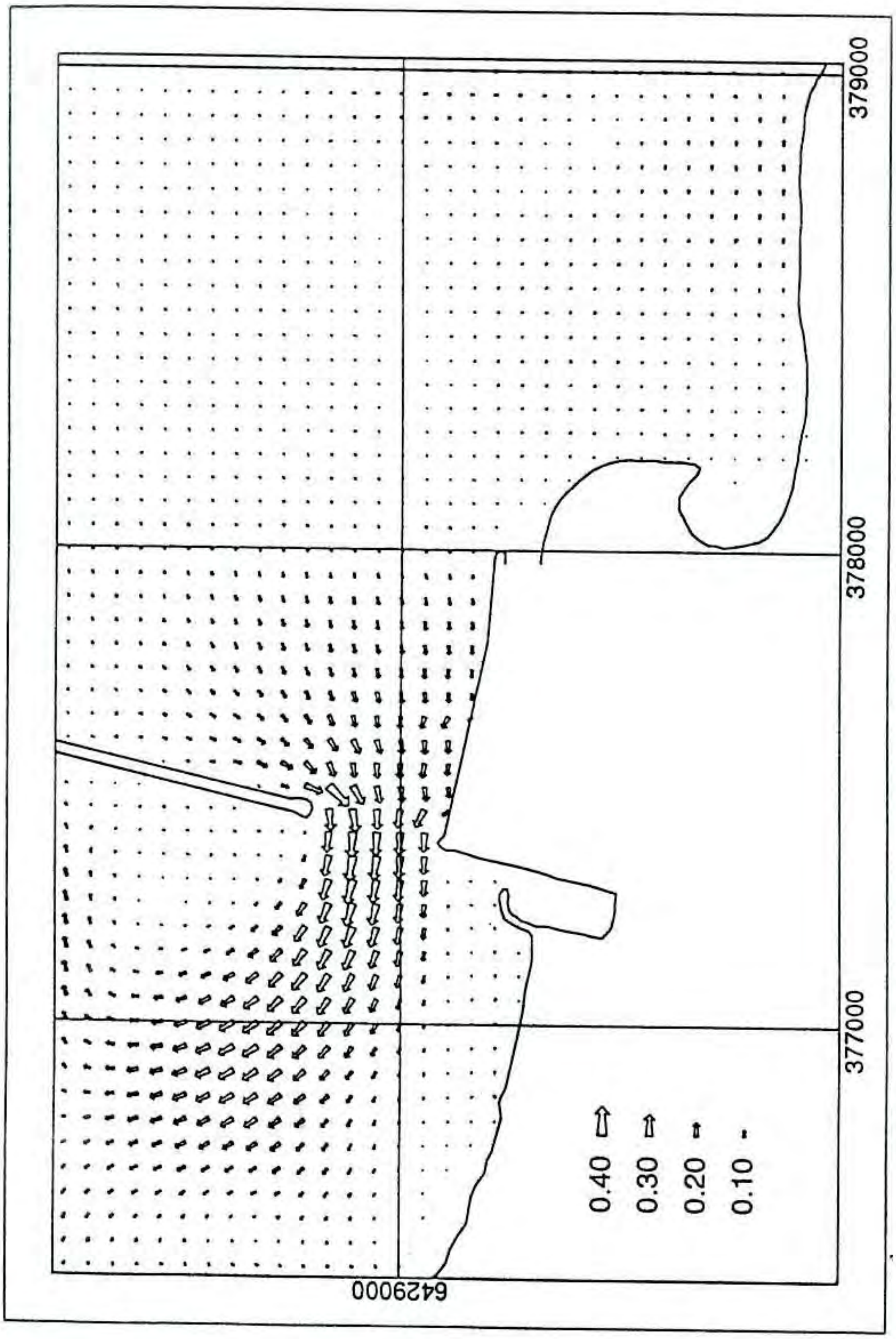

Figure 18 Currents (ms^{-1}). Run 16. Marina present. Tidal flow : $-250\ m^3s^{-1}$. Wind : 5 ms^{-1} from 315° (northwest).

Appendix 10.

Proposed Marine and Harbour Complex, The Causeway - Rockingham, Initial Acoustical Survey.

Our ref.0152-89148

PROPOSED MARINE HARBOUR AND COMPLEX

THE CAUSEWAY - ROCKINGHAM

INITIAL ACOUSTICAL SURVEY

INTRODUCTION

This study relates to noise emission and resultant impact to the surrounding environment for the proposed boat marina as shown on concept plan No. SK9 of February 1990. In addition to this detailed facility layout we have reviewed proposed road layouts of the general area.

The items to be addressed in this study are:

1. Road Traffic
2. Boat noise levels
3. Construction Activity Noise

Items 1 and 2 will address existing noise levels where applicable and compare these to future predictions in consideration of changes estimated to be brought about by the proposed marina. Item 3 will make general statements and recommendations at this stage, limited by the knowledge of construction programme and procedures, and for example, the location of quarry sites.

DATA

Road traffic data was obtained from Main Roads Department (MRD) by way of traffic flow summaries for the relevant roads in the vicinity. As no predictions for future traffic flows were available which included the proposed marina and related road modifications, we have used road traffic flow data obtained from the Hillary's Marina in the first half of 1988. The traffic flow averages from the Hillary's data has been added to the current road data and/or redistributed to other roads where this has been considered relevant.

After some discussion, it was considered that the Marine and Harbour Vessel MV "VIGILANT" would be representative of higher noise levels from large vessels to be catered for in this facility, and therefore, noise levels were measured at the engine exhaust outlet of this vessel to be used as the sound power level (PWL) basis in a computer modelling programme.

Existing ambient noise levels were also measured in the vicinity; Location 1 on the Esplanade near the corner of Hymus St, and Location 2 adjacent to the Causeway entrance at Point Peron Road. Both these locationsare shown on the attached plan SK-1. These measurements were to be used for subsequent comparison of both road traffic noise predictions adjusted to these points, and boat noise levels plotted as noise contours emanating from vessels departing the harbour.

UTILIZATION OF DATA

Road traffic flow counts were used in calculations from the MRD endorsed "UK Dept of Environment, Welsh Study" to obtain basic sound levels, defined at 10m from the centreline of traffic flow, which
were then extrapolated to the previously identified measurement points shown on the attached plan SK-1 .

It is noted from the most recent concept plan that Point Peron Road has been terminated, and we have therefore allocated the Hillary's Marina main access road traffic flows to the new controlled access highway. We have also made the following assumptions at this stage to facilitate a basis for calculation:

PARKIN ST:	Existing flow plus 75% Hillary's main access.
SAFETY BAY RD:	Existing flow plus existing Pt Peron Rd flow plus 75% Hillary's main access.
HYMUS RD:	Normal increase; note no access to Marina.

The sound pressure levels measured at 100 mm from the MV "VIGILANT" engine exhaust outlet have been adjusted to sound power levels (PWL's) and used in the E.P.A. endorsed Environmental Noise Model (E.N.M).

The basis for boat noise levels has been two vessels leaving the marina in the dredged channel and applying full power. The resulting contours are shown on SK-2 which also make some general allowance for buildings which will form various sections of the complex. No specific details of building construction have been included at this stage, only a general height allowance of 6 metres.

It is also relevant to note that activities associated with these buildings have not been considered at this early stage and will be a consideration for each building on its own merits at the appropriate stage of development.

RESULTS & GENERAL DISCUSSION

1. Road Traffic

Increases in noise levels due to increases in traffic flow have been calculated in accordance with Section 1 of the UK Welsh Traffic Study. A mean traffic speed of 60 kph has been used with a 2% "heavy vehicle" content, with the exception of Hymus St., where there is no "heavy vehicle" allowance and the traffic speed is 50 KPH.

The following table summarises calculated existing noise levels and those predicted in accordance with the previously detailed increases and redistribution.

	dBA L_{10} 18 hour	
	EXISTING	PREDICTED
Hymus Street	57*	58*
Point Peron Road	62*	Becomes cul-de-sac
Parkin Street	64*	68*
Safety Bay Road	65*	69*
New Access Highway	-	68*
Location 1	57#	58#
Location 2	62*	subject to proposed new access highway
Safety Bay Rd at corner of Lake Street	65#	69#

* Basic noise levels at 10 metres distance from the nearside carriageway edge as defined in the Welsh Study.

\# Calculated overall level to nearest residential boundary or location noted.

As can be seen from the above, the largest increases are 4 dBA on Parkin Street, Safety Bay Road and Safety Bay Road at the intersection with Lake Street. The overall calculated level at Location 1 is the same as the level due to the local traffic on Hymus Street, as the distance attenuation and barrier effect of houses is such that increases on Parkin Street, Safety Bay Road and the new access highway are insignificant at this location.

It is important to note that these predictions are in terms of L_{10} over 18 hours and that a 17 minute L_{10} measured between 1215 and 1245 residents at Location 1 was 59 dBA, which compares favourably with the calculated values and shows there to be no significant difference.

The location at the corner of Safety Bay Road and Lake Street was targetted in order to show a "worst case" influence from traffic not only by way of increases on existing roads but also due to the new proposed highway.

2. Boat Noise Levels

The resulting E.N.M. predicted noise contours on attached plan SK-2 shows that the nearest residences on Hymus Street are just on, but mostly outside the 45 dBA contour due to two motor vessels leaving the harbour at full power. In view of the intermittency and existing measured noise levels of L_{90} 46 dBA and L_{10} 59 dBA, there is very little impact to the existing residential areas, which do not benefit from any barrier attenuation from breakwater or other proposed construction. These predictions have been made for the "worst case" wind condition of the wind blowing from the noise source (vessels leaving the marina) to the residences at 5m/sec.

Some areas of the proposed development show lower predicted noise levels due to the barrier effect from breakwaters, buildings, etc. and these can be related directly from the noise contour plan SK-2.

3. Construction Activity Noise

Until quarry sites and corresponding haulage routes are known there can be no precise statement made in regard to the related noise impact.

Similarly, for construction activities such as pile driving and heavy equipment operation, no meaningful statements can be made until construction methods and schedules and types of equipment to be used are known.

We have discussed both these aspects with E.P.A. at this stage and informally resolved that as more details become available, discussions should be initiated with the E.P.A. with a view to making the necessary application for a Licence during construction; if it can be established that construction activity noise may cause some inconvenience to the surrounding areas or those along haulage transport routes. If a Licence is necessary, then it is anticipated that any restrictions placed would be by way of operating time constraints.

CONCLUSION

The subject study has shown there to be no significant influence on the existing environment due to activities associated with the proposed marina.

It must be considered that road traffic flow and related noise will increase in the area independent of the marina project, as there are large areas of residential development in the region generally.

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27 April 1990

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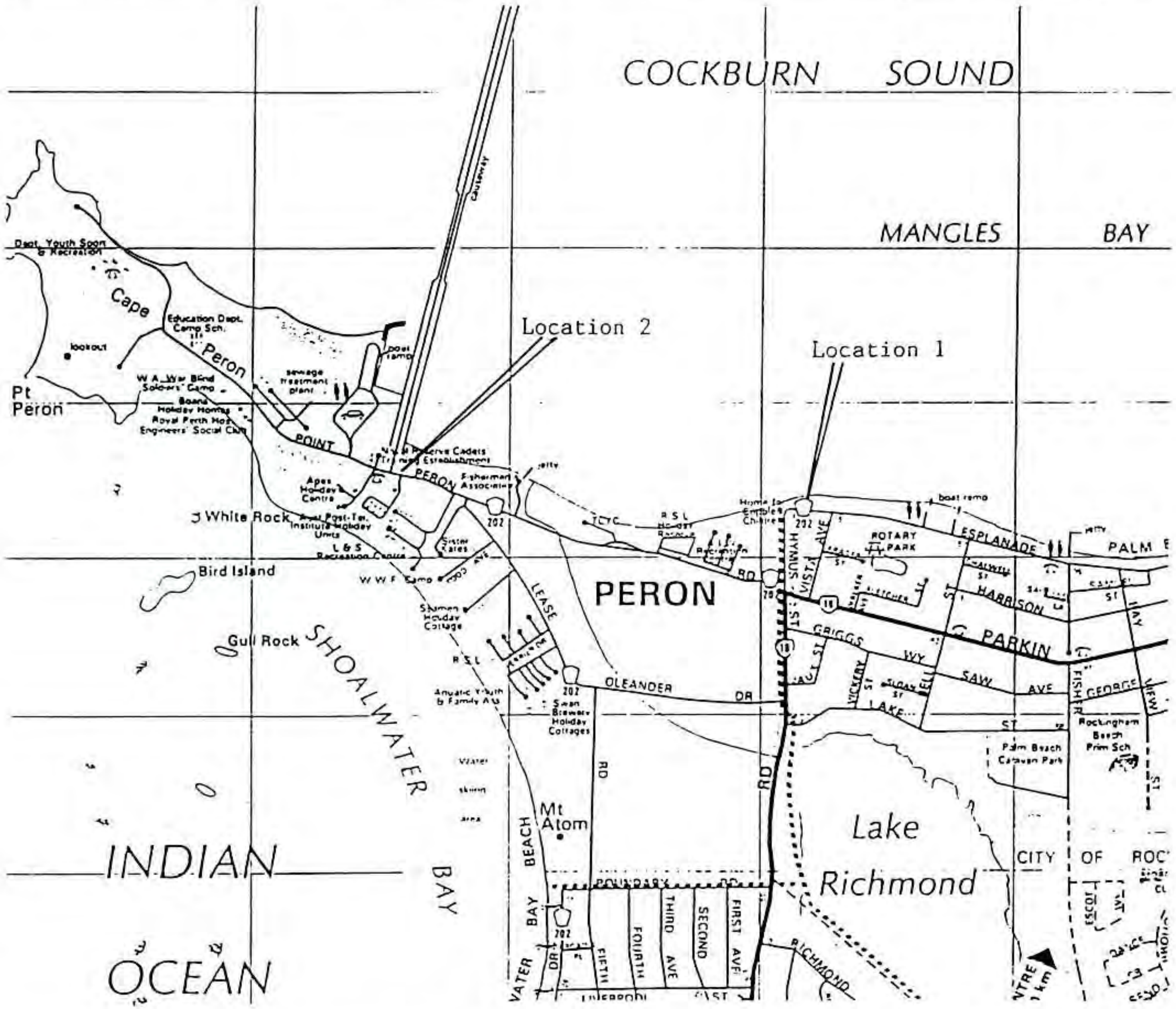
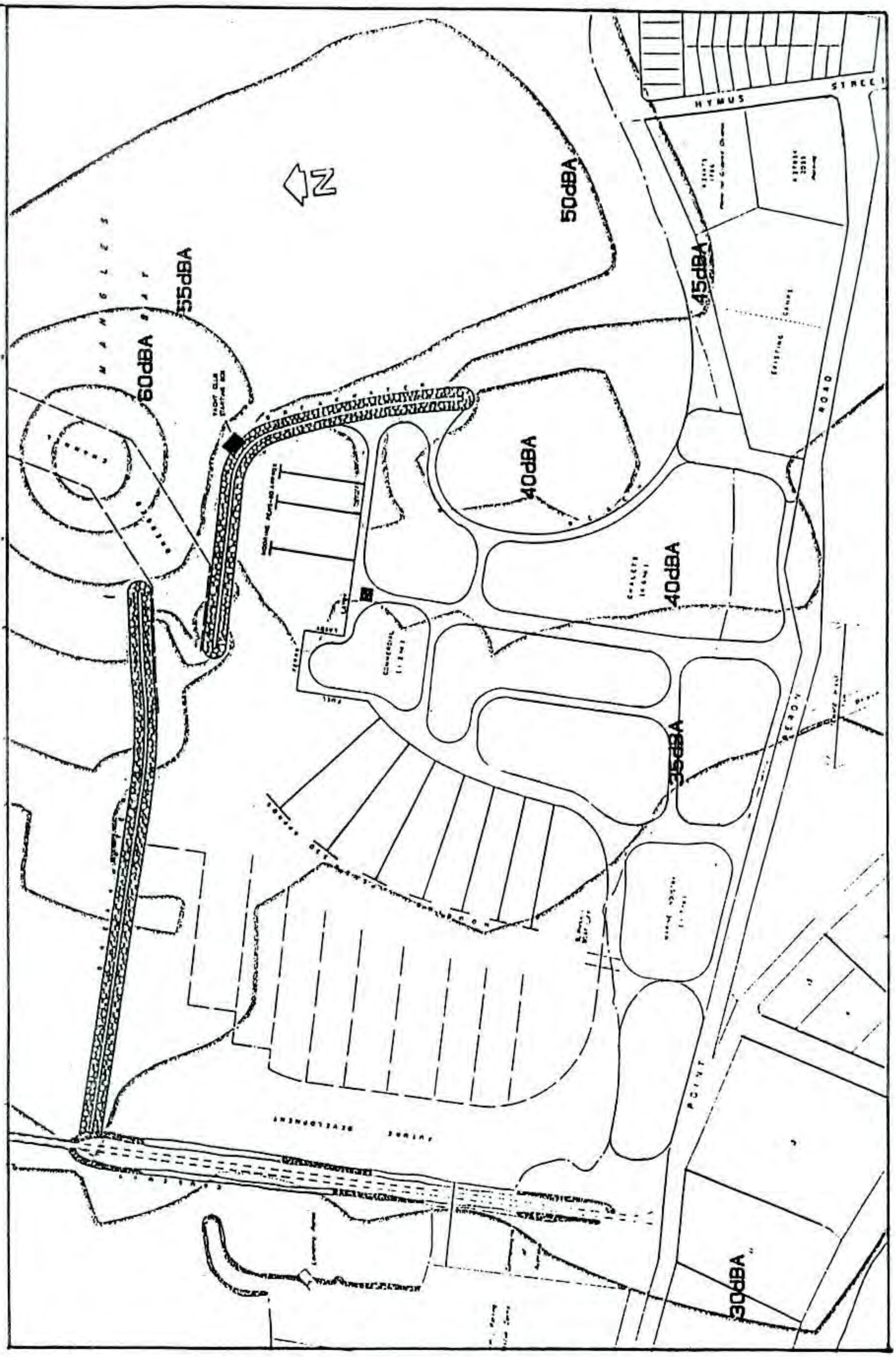
Proposed Marina and Harbour Complex
The Causeway - Rockingham
Measurement Locations

April 1990

SK-1





SCHEMATIC DRAWING - NOT TO SCALE

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Proposed Marina and Harbour Complex
The Causeway - Rockingham

Vessel Noise Level Contours
SK-2

Appendix 11.

Tidal Flushing Analysis for the Proposed Mangles Bay Marina

Tidal Flushing Analysis
for the proposed Mangles Bay Marina

Department of Marine and Harbours

Western Australia

The tide is indisputably a major forcing parameter responsible for flushing a semi-enclosed body of water, and the tidal prism method is a means by which a tidal flushing rate can be predicted. An estimate of the tidal flushing rate for a marina proposal sited in Mangles Bay, Cockburn Sound was determined using the tidal prism method. The method assumes that a marina is flushed exclusively by tidal fluctuations where the pollutant mass removed on an ebb tide does not return on the following flood tide. It is also assumed that point source pollutants are evenly distributed throughout the marina in less than one tidal cycle.

The tidal range applicable to this investigation was obtained from tide data measured at the Port of Fremantle. The Mean Low Low Water (MLLW) and Mean High High Water (MHHW) levels are 0.53 metres Chart Datum (mCD) and 0.94 mCD respectively, with a Mean Sea Level (MSL) at 0.72 mCD. (pers. comm. - D. Wallace, DMH Survey and Cartographic Services).

The flushing rate calculations were based on the single entrance marina platform shown on Marine and Harbours drawing number 347-7-1. Although this layout does not reflect the final design, it does represent the worst case scenario in terms of flushing. Water volumes within the marina at Mean Low Low Water (MLLW) and at Mean High High Water (MHHW) were calculated using a measured surface area of 285,990 m^2 and a dredged basin depth of RL -4.2 mAHD which is 4.16 m below MLS (RL -0.04 mAHD).

Sea Level	Dredged Basin Depth	Total Volume
MHHW	4.38m	919,773m^3
MSL	4.16m	856,855m^3
MLLW	3.97m	802,517m^3

TABLE 1: Water volumes within Marina at various water levels.

The tidal flushing rate for the proposed marina was calculated using equation 1, where n is the number of tidal cycles, M_o is the initial mass of pollutants, and M_n is the mass of pollutants remaining in the marina after n cycles.

$$n = [\log (M_n/M_o)] [\log (V_{LW}/V_{HW})]-1 \tag{1}$$

For Mangles Bay, the number of tidal cycles n is equivalent to a number of days since the tides at this location are predominantly diurnal.

The constant mass ratio (M_n/M_o) curves shown in Figure 1 represent solutions to Eq. (1) as a function of a variable volume ratio (V_{LW}/V_{HW}). Given a predetermined volume ratio, Figure 1 can be used to determine the number of tidal cycles required to dilute an initial pollutant concentration to a predefined value.

The time scale which describes an exponentially decaying system such as the flushing of a marina is defined to be the e-folding time or the time required for an initial concentration (M_n/M_o = 1.0) to fall below a value of 1/e, where e = $\ln^{-1}$ (1). In other words, the tidal flushing time of a marina can be defined as the time required for tidal fluctuations to dilute an initial normalised pollutant mass concentration (M_n/M_o = 1.0) to a value of 0.37.

The volume ratio (V_{LW}/V_{RH}) for the proposed Mangles Bay Marina is approximately 0.87. Using the flushing time criteria established above, Figure 1 yields a *tidal flushing time* equal to 7 days, however, this is a predicted flushing time which does not incorporate the beneficial effects of wind induced circulations, multiple entrances and density currents.

Experience at Hillarys Boat Harbour has shown that the combined contribution to flushing by secondary influences such as density currents and atmospheric forcing can reduce a predicted *tidal flushing time* by as much as 50% (Schwartz and Imberger, 1988). The size of the proposed Mangles Bay Marina is of the same order as Hillarys Boat Harbour, and the potential flushing benefits from secondary forcing parameters is also similar. An actual flushing time can therefore be expected to be significantly lower than the predicted *flushing time* of 7 days.

A second marina entrance is planned near the causeway. This will further improve flushing by allowing the existing wind and tidal driven flows under the low level bridge crossing in the causeway to circulate through the marina. Numerical modelling results for a similar sized marina at the same location indicated that a four-fold reduction in the flushing time could be expected by introducing a second entrance (John Holland Group, 1985).

Unlike the contribution to flushing by tidal motions, the individual contributions to flushing by the aforementioned secondary influences is difficult to quantify because of their intermittent behaviour. However, empirical estimates of their combines contribution can be made based on previous investigations. In this case, it is feasible to assume that the predicted *tidal flushing time* of 7 days is conservative, and as a result of secondary influences the actual flushing time could be in the order of 1 to 2 days.

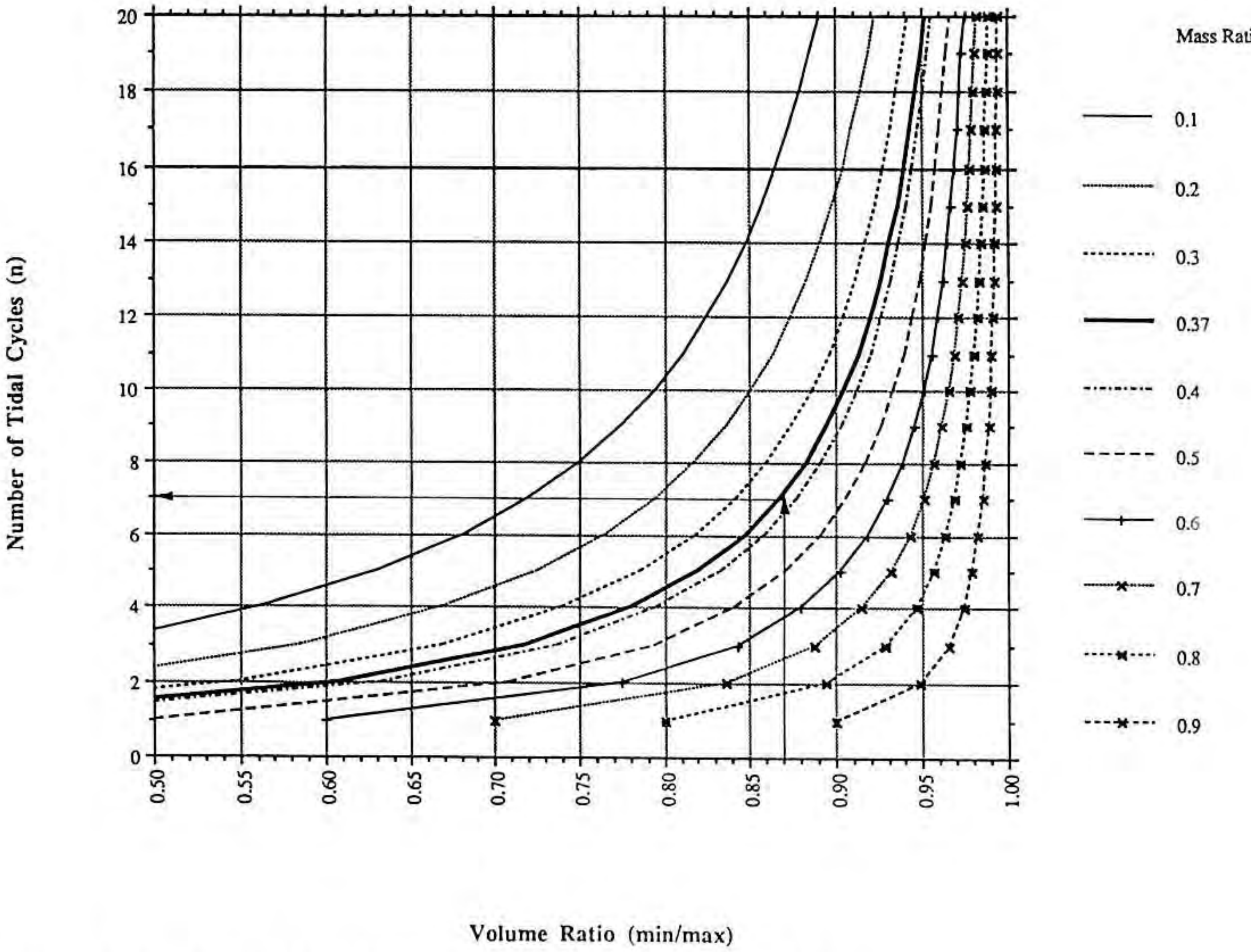

Fig. 1 MASS RATIO TIDAL FLUSHING CURVES

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Appendix 12.

The Implications of Contaminant Loading and Flushing
for
The Proposed Mangles Bay Marina

Halpern
Glick
Maunsell

THE IMPLICATIONS OF CONTAMINANT LOADING AND FLUSHING FOR THE PROPOSED MANGLES BAY MARINA

for

DEPARTMENT OF MARINE & HARBOURS

Report - E9129

June 1991

IMPLICATIONS OF CONTAMINANT LOADING & FLUSHING FOR THE PROPOSED MANGLES BAY MARINA

LIST OF CONTENTS

1. INTRODUCTION/BACKGROUND

1.1 Scope of work

This short report has been commissioned by the Department of Marine and Harbours as input to a Public Environmental Report (PER) for the proposed Mangles Bay Marina. This report was intended to provide discussion relating to the expected nutrient budget for the marina and resultant environmental implications. The report does not aim to cover all environmental implications of the marina construction or operation, these broader considerations form part of discussion within other sections of the PER.

1.2 Marinas and Water Quality

Various contaminants enter the coastal waters of Cockburn Sound each day. Both soluble and particulate pollutants reach the marine environment via surface water drainage, groundwater seepage, airborne fallout, water discharged from industrial outlets and pollution resulting from recreational activities. Such pollutants include:

- nutrients;
- metals;
- pesticides;
- hydrocarbons; and
- various synthetic compounds.

Coastal systems have a certain capacity to deal with such pollution through dispersal, adsorption or decomposition. The Western Australian Environmental Protection Authority has defined this degree as a systems' "assimilative capacity", or its capacity to adsorb waste without long term damage.

The "dispersal" component of assimilative capacity is particularly relevant to marina developments. If a coastal development reduces the dispersal capacity of the receiving environment (through reduced flushing) then the assimilative capacity of the localised area may similarly be reduced.

Reduced dispersion may cause accumulation of particulate material and increased sedimentation or gradual build-up of pollutants that would otherwise be spread and diluted far-afield. An example of such build-up would be the accumulation of heavy metals in sediments of a poorly flushed area, relative to a well flushed system.

Poor dispersal and distribution may also allow biological reductions in water quality to compound. When growth-stimulating nutrients enter enclosed waters they are diluted somewhat proportional to the degree of dispersion. At low levels of dispersion relatively high concentrations of nutrients may be available for algae (phytoplankton) growth. This may then lead to further water quality difficulties associated with reduced light penetration, disagreeable odours, detrital carbon loading, dissolved oxygen stress and reduced species diversity, all of which reduce the beneficial use values of the system.

Possible reductions in water quality associated with marina developments may also affect surrounding waters. Large phytoplankton populations generated within the marina precinct will be dispersed, over some time period, to the surrounding waters. Depending on the concentration of these plankton in the water column they will reduce light penetration. This in turn may impact on existing benthic communities which rely on light for their survival, such as seagrass meadows. Furthermore phytoplankton populations generated within an enclosed area may impact on adjacent areas as nutrient and carbon cycling patterns change from increased levels of detrital fallout to nearby zones.

The potential environmental impacts of the proposed Mangles Bay Marina depend on characteristics of the marina and its immediate environment, both of which are discussed in more detail in subsequent sections.

1.3 Water Quality in Cockburn Sound

Cockburn Sound is widely recognised as a eutrophic (detrimentally enriched) environment which has suffered from excessive contaminant loading for several decades (DCE 1979).

Historically, excessive nutrient loadings have been seen as a primary source of reduced water quality in Cockburn Sound. Summer phytoplankton blooms have, in the past, resulted in:

- a reduction in water quality for recreation;
- toxic contamination of shellfish;
- deoxygenation and fish deaths;
- increased turbidity and epiphytic algal growth, both of which have led to seagrass death.

Nitrogen is believed to be the growth-limiting nutrient in Cockburn Sound during summer, with temperature and light limitation during winter. It is generally accepted that increases in nitrogen input to Cockburn Sound will lead to larger summer phytoplankton blooms. Nitrogen enters the waters of Cockburn Sound from industrial discharge, surface drainage, groundwater intrusion and atmospheric fixation (Figures 2.1 and 2.2).

Other contaminants of concern that accumulate in Cockburn Sound include metals, hydrocarbons and microbiological levels. Metals may accumulate in ecological compartments to toxic levels, shellfish deaths in Cockburn Sound have been attributed to metal pollution. Hydrocarbons may taint fish and shellfish flesh and reduce the commercial viability of Cockburn Sound stocks. Microbiological parameters are of concern primarily for public health reasons. Shellfish contaminated by high faecal coliform and Salmonella levels have been found within the Sound, though these have largely been associated with wastewater and abattoir effluent.

While all types of contaminants are of concern in the general ecological context, nutrient loadings and metal accumulations are of particular importance to the Mangles Bay Marina development. The following discussion will concentrate largely on these two parameters.

2. CONTAMINANT LOADING AND FLUSHING

2.1 Phytoplankton Growth

As identified in the preceding section, nutrient inputs to Cockburn Sound are of concern due to their potential to promote algal growth, both phytoplankton in the water column and attached (epiphytic) algae. While nutrients entering a water column may find their way into various pools or system compartments (Figures 2.1 and 2.2) they are rapidly available to algae.

Under optimal conditions the ready availability of dissolved nutrients gives rise to rapid phytoplankton growth rates. As shown in Table 1 the doubling time for aquatic algae (marine and freshwater examples) may be as low as a few hours.

TABLE 1
EXAMPLE ALGAE GROWTH RATES UNDER FAVOURABLE CONDITIONS
(from Jorgensen 1979)

ALGA	DOUBLING TIME
Amphidinium	8.8 hours*
Anabaena	10.6 hours*
Microcystis	2.0 hours*
Asterionella	9.6 hours*
Ceratium	82.8 hours*
Chaetoceros	33.0 hours
Chlorella	8.0 hours*
Coscinodiscus	29.0 hours
Ditylum	15.0 hours
Isochrysis	30.2 hours*
Monodus	24.3 hours*
Navicula	3.0 days
Nitzschia	1.5 doublings/day
Phaeodactylum	13.0 hours
Platymonas	30.0 hours
Skeletonema	13.0 hours
Thalassiosira	15.0 hours
Trichodesmium	17.7 hours

* under saturating light conditions

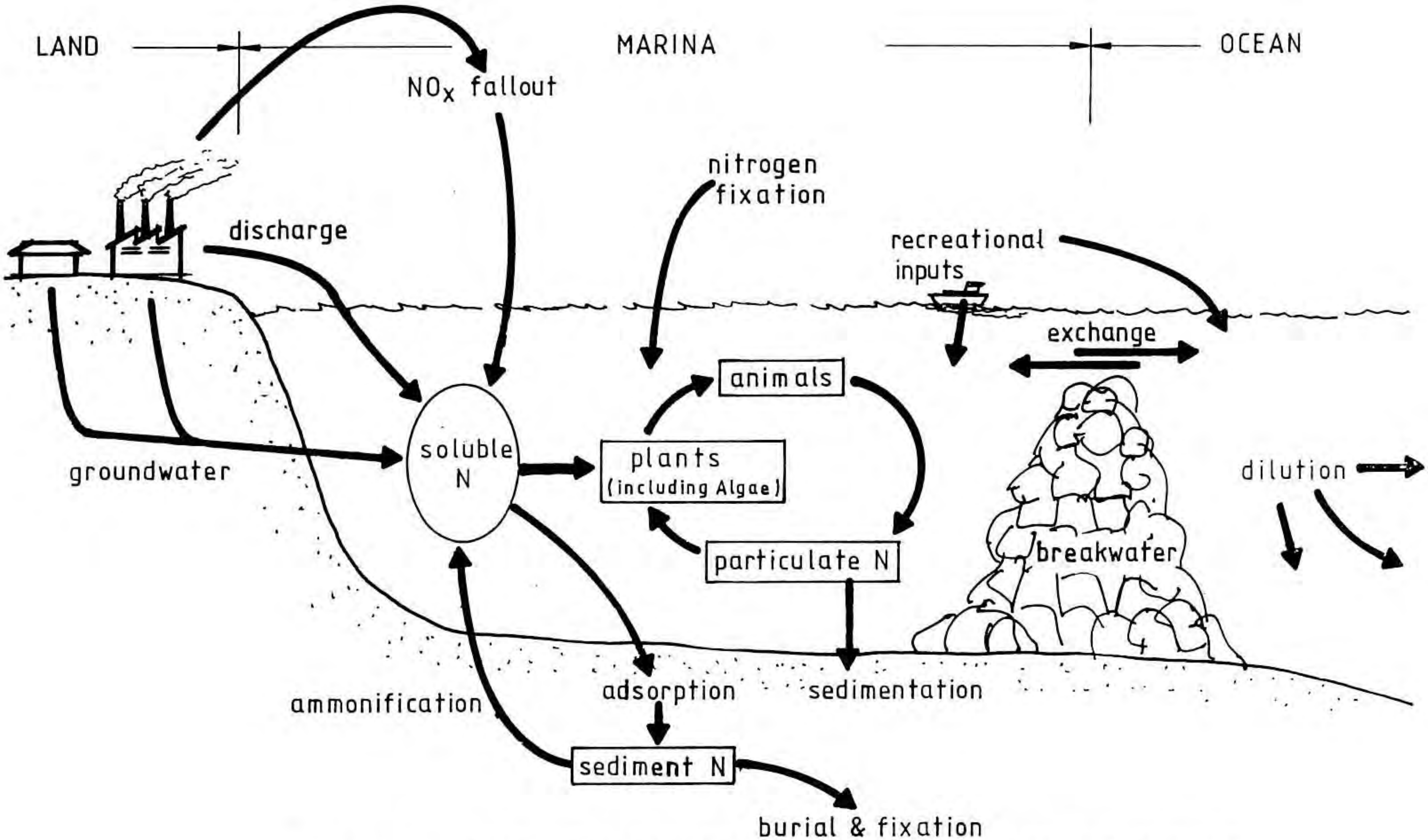

Figure 2.1 SCHEMATIC REPRESENTATION OF NITROGEN (N) CYCLING WITHIN A MARINA ENCLOSURE

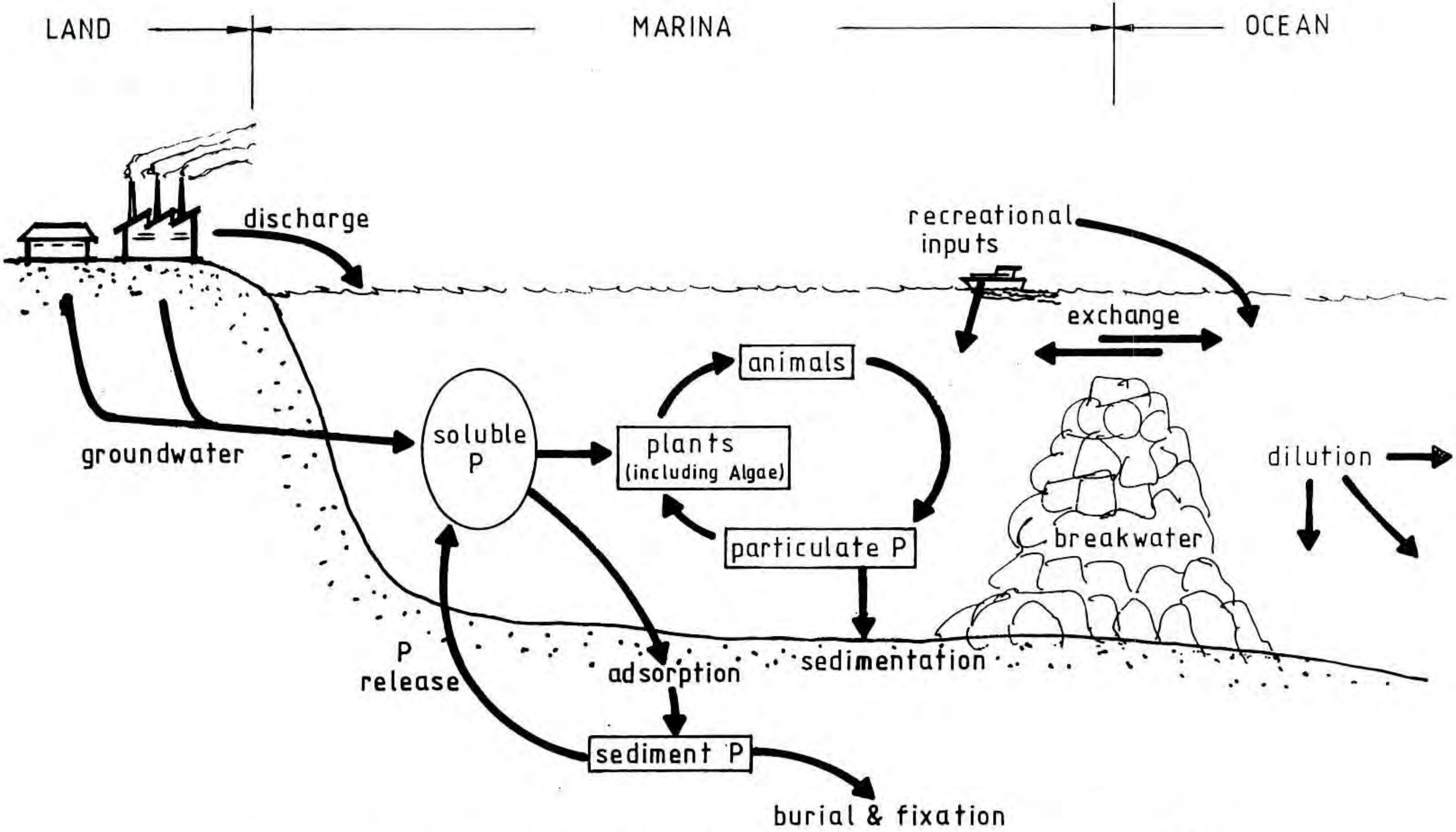

Figure 2.2 SCHEMATIC REPRESENTATION OF PHOSPHORUS (P) CYCLING WITHIN A MARINA ENCLOSURE

While specific doubling times may vary, a general approximation of around one doubling per day is given by Jorgensen (1979) for marine phytoplankton.

The ability of phytoplankton populations to increase in any waterbody relies on the ready availability of light, nutrients and other essential elements within an acceptable temperature regime. Circulation in a waterbody may act to restrict the availability of both light and nutrients. Rapid flushing and dilution of incoming nutrients may effectively reduce the concentration of nutrients available to a phytoplankton population for growth, this is perhaps most markedly applicable to the case where nutrients are supplied from a discreet point source (such as a drainage or industrial outfall). Given the rapid growth potential of phytoplankton it is likely that limitation by nutrient dispersal would require exchange periods in the order of hours to a few days.

Artificial circulation to provide light limitation provides a water quality management tool in various Australian waterbodies. This is usually carried out in lake systems and involves vigorous mixing by artificially induced destratification. Mixing beyond a light limiting compensation depth is unlikely to be applicable to a marina, however, frequent flushing exchange within a marina may provide a useful mechanism to aid in the prevention of scum forming algae growth at the water surface. Again it is reasonable to expect a rapid exchange period (hours to a few days) would be required.

The ability of phytoplankton to rapidly reach nuisance concentrations in a waterbody represents only a potential for growth. To realise this potential the phytoplankton require adequate light, temperature, nutrients and trace elements.

2.2 Nutrient Loading

Algal blooms within the general Cockburn Sound area and in the Mangles Bay locality have been noticed since as early as 1973-74, particularly in the eastern and southern areas of Cockburn Sound (DCE 1979). While precise identification of nitrogen loading to Cockburn Sound is still being finalised, some general estimates may be made. Based on existing licence conditions for major point sources discharging nitrogen-rich waste to Cockburn Sound and estimated groundwater loadings, total nitrogen (TN) loading to the Sound is likely to be between 600 and 1,000 tonnes per year (EPA pers. comm., GSWA pers. comm.). Over a surface area of 10,050ha this equates to between $6.0g/m^2/yr$ and $9.9g/m^2/yr$.

The exact impacts and implications of a given nutrient loading will vary with different aquatic systems, which has lead to the development of assimilative capacity estimates on a localised basis. Various attempts have, however, been made to estimate generalised acceptable nutrient loadings. These have typically been based on comparative observations in selected waterbodies throughout the world, with measurable nutrient inputs and definable environmental consequences.

One such study undertaken by Jaworski (1981) on estuarine and coastal systems examined the environmental implications of external phosphorus loadings varying from $0.04g/m^2$/year to $190g/m^2$/year and nitrogen loading variations of $1.0g/m^3$/year to $750g/m^2$/year. The study concluded, among other things, that in phosphorus limited systems a "permissible" phosphorus loading of $0.75g/m^2$/year was appropriate and that at phosphorus loadings less than $1.0g/m^2$/year excessive eutrophic conditions would not prevail. While the findings were much less definitive for nitrogen limited systems it was concluded that as nitrogen limitation was assumed to occur at N/P ratios below 16, an approximate permissible nitrogen loading could be set at $5.4g/m^2$/year.

These findings are consistent with the earlier estimates for loading to Cockburn Sound. As a nutrient enriched waterbody, with resultant biological water quality problems, it receives loading exceeding the tentative permissible estimate of $5.4g/m^2/yr$ N.

While rigorous estimations of the likely impacts of nutrient loading require consideration of various hydrodynamic components, a marina does represent a partially enclosed waterbody that will receive a definable nutrient loading.

The proposed Mangles Bay Marina represents a sediment surface area of 286,000m^2. Contributions to the nutrient input of the water within this system will include:

- the Lake Richmond drain;
- groundwater influx;
- sediment nutrient release;
- airborne inputs;
- recreational inputs.

Nutrient load measurements for the Lake Richmond discharge drain have been carried out by WAWA (1990). These estimates are based largely on monthly nitrogen concentration measurements and estimated discharge volumes. The likely degree of uncertainty in these measurements is acceptable within the broad scale estimates used in this marina evaluation. The estimated total nitrogen loading to the proposed marina site from the Richmond Drain may be gauged from Table 2.

TABLE 2
ESTIMATED MONTHLY LOADING (kg)
TOTAL NITROGEN

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1978	0	0	0	0	0	59	246	240	210	221	138	48	1161
1979	0	0	0	0	0	50	261	392	286	158	41	0	1188
1980	0	0	0	0	71	342	555	511	442	374	181	42	2518
1981	0	0	0	0	15	72	190	223	143	92	54	18	806
1982	82	91	16	0	0	36	162	205	155	120	36	0	903
1983	0	0	0	0	0	37	69	38	8	21	35	39	248
1984													
1985	117	0	0	0	0	237	876	1623	2147	1829	1102	356	8287
1986	1	0	0	0	0	57	248	490	498	380	280	117	2071

(WAWA 1990)

Based on this information the maximum yearly loading is 8,287kg N with an average yearly loading of 2,036kg N.

The Geological Survey of Western Australia (GSWA) is currently completing estimates for the nutrient contribution made by groundwater influx to Cockburn Sound. The nutrient input to any given locality along the coast may be expected to vary with the location of individual point sources and localised strata characteristics. Nevertheless generalised approximations may be derived for the coastline adjoining Cockburn Sound. Current estimates derived by the GSWA for groundwater loading to Cockburn Sound are:

200kgTN/yr/km of coast;
5kgTP/yr/km of coast.

The total length of coastline (existing and filled areas) enclosed by the proposed marina would be approximately 1km, thus contributing about 200kg of total nitrogen per year.

While the contribution to total water column nitrogen loading made by sediment release, was not included in the permissible estimate of Jaworski (1981), it may be a significant consideration. No measurements of net nutrient release from the sediments of Mangles Bay have been carried out, though data are available from nearshore coastal sediments off Mandurah. In this instance coastal sediments typically release up to 1.0mgTN/m^2/day (anaerobic conditions) (Lukatelich pers. comm.). Over the surface area of the proposed marina this would result in a loading of approximately 112kg per year to the water column.

No estimates are available for the contribution made by airborne or recreational inputs into the proposed marina area. Given appropriate management strategies it is likely that recreational inputs will be insignificant relative to those described earlier (AEC 1988). Airborne inputs remain an uncertainty, however, it must be noted that while such contribution undoubtedly consumes a component of assimilative capacity, it has not been considered in the derivation of the proposed 5.4g/m^3/day permissible level discussed earlier.

Combining the inputs described above reveals a total loading to the proposed marina of:

Lake Richmond Drain (max.)		8,287kg/yr
Groundwater input		200kg/yr
Sediment release		112kg/yr
Airborne/recreational input		?
	Total	>8,599kg/yr

Over the 286,000m^2 seabed area of the proposed marina this equates to approximately 30g/m^2/yr.

With or without the sediment release component, the expected loading to the proposed marina is considerably greater than the tentative 5.4g/m^2/yr permissible level and the 6-9.9g/m^2/yr loading currently experienced by the enriched waters of Cockburn Sound. Applying the average yearly loading from the Lake Richmond Drain (2,036kg N) rather than the maximum yearly loading (8,287kg N) the unit area loading is reduced to 8.0g/m^2/yr. While this loading exceeds the proposed permissible level, it is within the loading range experienced by Cockburn Sound as a whole. When considering "downstream" environmental impacts it is, however, inappropriate to look at average values. If a year of exceptionally high loading results in habitat destruction then such exceptional loading must be the limiting consideration.

By far the main contributor to the expected marina loading is the Lake Richmond Drain (up to 28.97g/m^2/yr). If this component were to be removed from the marina loading estimate, the resultant loading would be well less than both the proposed permissible limit and the unit loading to Cockburn Sound.

2.3 Metal Contamination

Perhaps most notorious of metal contaminants in marine environments are residues from anti-fouling treatments, of which the most commonly used has been tributyl tin (TBT). "Evidence from field studies and trials on shellfish (such as oysters) around the world have shown conclusively that TBT is harmful, even at extremely low concentrations. Many of the reported incidences of TBT contamination have occurred in marinas, enclosed or semi-enclosed embayments, estuaries and around slipways and boat maintenance yards, that is, in areas of restricted flushing with a high concentration of vessels using TBT" (EPA 1990).

Under regulations in place for the use of organotin anti-fouling agents in Western Australia, it is unlikely that excessive loading of TBT would result from operation of the proposed marina. The area in which it is proposed to build the marina (Mangles Bay) does, however, already contain relatively high concentrations of TBT in both sediments and mussels (314ngTBT/g mussel and 159ngTBT/g sediment). Depending on the chemical nature of the element in question and its surroundings, resuspension of sediment material (eg during dredging) may either aid release of the element to the water column or promote stripping of dissolved portions of the element from the water column. Little information is available on the likelihood of TBT release and dispersion as a result of dredging TBT enriched sediments. The potential for far reaching impacts may warrant closer examination of the fate of sediment-base TBT when resuspended.

Very little information is available on the relative contributions made by the various sources to other metal loadings into Cockburn Sound. It is, however, likely that most contaminant loadings will be somewhat proportional to nutrient loading, given the high proportion of nutrient loading entering via the Lake Richmond Drain.

3. ENVIRONMENTAL IMPLICATIONS

3.1 Within the Marina

The high nutrient loading likely within the marina precinct could reasonably be expected to result in eutrophic conditions (given maximum yearly nitrogen loading from the Lake Richmond Drain), unless rapid water exchange could be achieved (hours to a few days). Rapid flushing would act to inhibit phytoplankton growth mainly through nutrient dispersal and dilution with oceanic water.

The likelihood of eutrophic water quality within the marina could readily be reduced through a reduction in total nitrogen loading entering the marina. Elimination of nitrogen loading entering via the Lake Richmond Drain would reduce expected areal loading to well below "background" Cockburn Sound loadings and proposed permissible loadings.

Given the very high proportion of total nitrogen loading expected to be provided by the lake Richmond Drain, elimination of this input to the marina precinct would appear most desirable. Coupling of this nutrient removal with rapid flushing should maintain water quality to that of surrounding waters.

3.2 Outside the Marina Precinct

There are two main avenues by which the Mangles Bay proposal may impact on environmental compartments outside the immediate marina area:

- contaminant distribution during construction, and
- dispersal of phytoplankton populations generated within the marina.

In the former case contamination may spread from spillages or plumes leaving dredging or breakwater construction areas. While some impacts may be minimised by appropriate management and/or contingency strategies, the possibility for redistribution of sediment-bound contaminants remains one uncertainty. Under aerobic conditions nutrients bound by the dredged sediments will remain bound, indeed the resuspension of dredged sediment is likely to act as a nutrient stripping agent in the water column

(McAuliffe 1991). It is unknown what impact the resuspension of TBT-rich sediments will have on adjacent ecological compartments. A limited experimental programme may clarify this matter. Furthermore, as most of the TBT is likely to be bound in the upper layer of sediment a detailed dredging strategy may be able to minimise the potential for undesirable impact far-afield.

In the second case (dispersal of phytoplankton) work conducted by the EPA in the Cockburn Sound (Masini et al. 1990; Pearce 1990) has demonstrated a direct relationship between average daily nitrogen load and chlorophyll ‘a’ concentration and theoretical maximum depth of seagrass survival (Figure 3.1). In the case of the proposed marina and its expected high nitrogen loading, chlorophyll ‘a’ generated within the marina (as phytoplankton) may critically reduce the amount of light available to adjoining seagrass meadows, depending on the degree of dispersion outside the marina entrance and the chlorophyll ‘a’ concentrations being dispersed.

The relationships shown in Figure 3.1 have been drawn solely from the light attenuation properties of water column particles, water quality sampling in Cockburn Sound and the productivity responses of seagrasses to differing light intensities. The relationships do not include considerations other than water column light attenuation, such as increased detrital carbon loading, increased oxygen demand or accelerated epiphytic growth. The relationships of Figure 3.1 serve to highlight the sensitivity of seagrass meadows to nutrient loading without the added effects described above. In the case of Cockburn Sound seagrass communities it is conceivable to expect that the most productive period is during summer following a carbon-deficient winter period. Early summer phytoplankton blooms could effectively extend the winter-like light regime and detrimentally impact on the restoration of a yearly carbon blanace afforded by high summer light levels.

The tentative 5.4mg/m^2/yr permissible loading level proposed by Jaworski (1981) has been derived from system-wide impacts noted in American coastal environments. This value includes a diverse range of effects resulting from nutrient loading and any synergistic considerations.

While prediction of the likely outcome of marina development within Cockburn Sound would be based largely on speculation and limited contaminant loading estimates it appears appropriate to conclude that:

- the seagrass communities of Cockburn Sound are sensitive to light availability or effective extension of the winter period and nutrient loading;

- that the tentative permissible loading level of 5.4mg/m^2/yr is a reasonable starting point for consideration when attempting to predict likely outcomes from nitrogen loading.

With rapid flushing and low nitrogen loading to the marina (Lake Richmond Drain diversion) the potential for impact on regional seagrass meadows would be minimal. With high nutrient loading to the marina and moderate flushing (several days for exchange) the potential for loss of seagrass outside the marina is increased considerably. Under these conditions it would be appropriate to further define likely chlorophyll 'a' concentrations within the marina and the potential for dispersion and/or further seagrass loss.

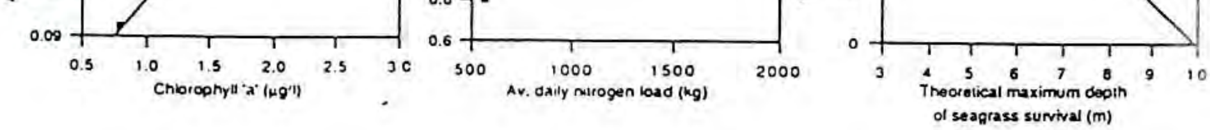

FIGURE 3.1: RELATIONSHIPS DERIVED FROM LONG TERM AVERAGES OF SYSTEM WIDE DATA COLLECTED IN COCKBURN SOUND DURING SUMMER (Pearce 1990)

4. CONCLUSIONS

(i) The dependence of Cockburn Sound seagrass communities on light attenuation, water column chlorophyll 'a' and nitrogen loading is well established.

(ii) The proposed marina will receive extremely high nitrogen loading relative to the wider Cockburn Sound area and tentative permissible levels, due largely to loading from the Lake Richmond Drain.

(iii) Diversion of the Lake Richmond Drain to a well flushed adjoining area of Cockburn Sound would minimise the likelihood of damage to adjoining seagrass meadows from phytoplankton growth within the marina basin, given a particular flushing regime.

(iv) To reliably predict the potential for impact on adjoining seagrass areas with Lake Richmond drainage discharge to the marina and a flushing time something less than seven days, it is necessary to further define likely chlorophyll 'a' concentrations within the marina and the potential for dispersion outside the marina mouth.

(v) Minimisation of the likelihood of redistribution of sediment-bound contaminants from dredging operations requires a containment oriented dredging strategy and/or a limited experimental dissolution evaluation.

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