

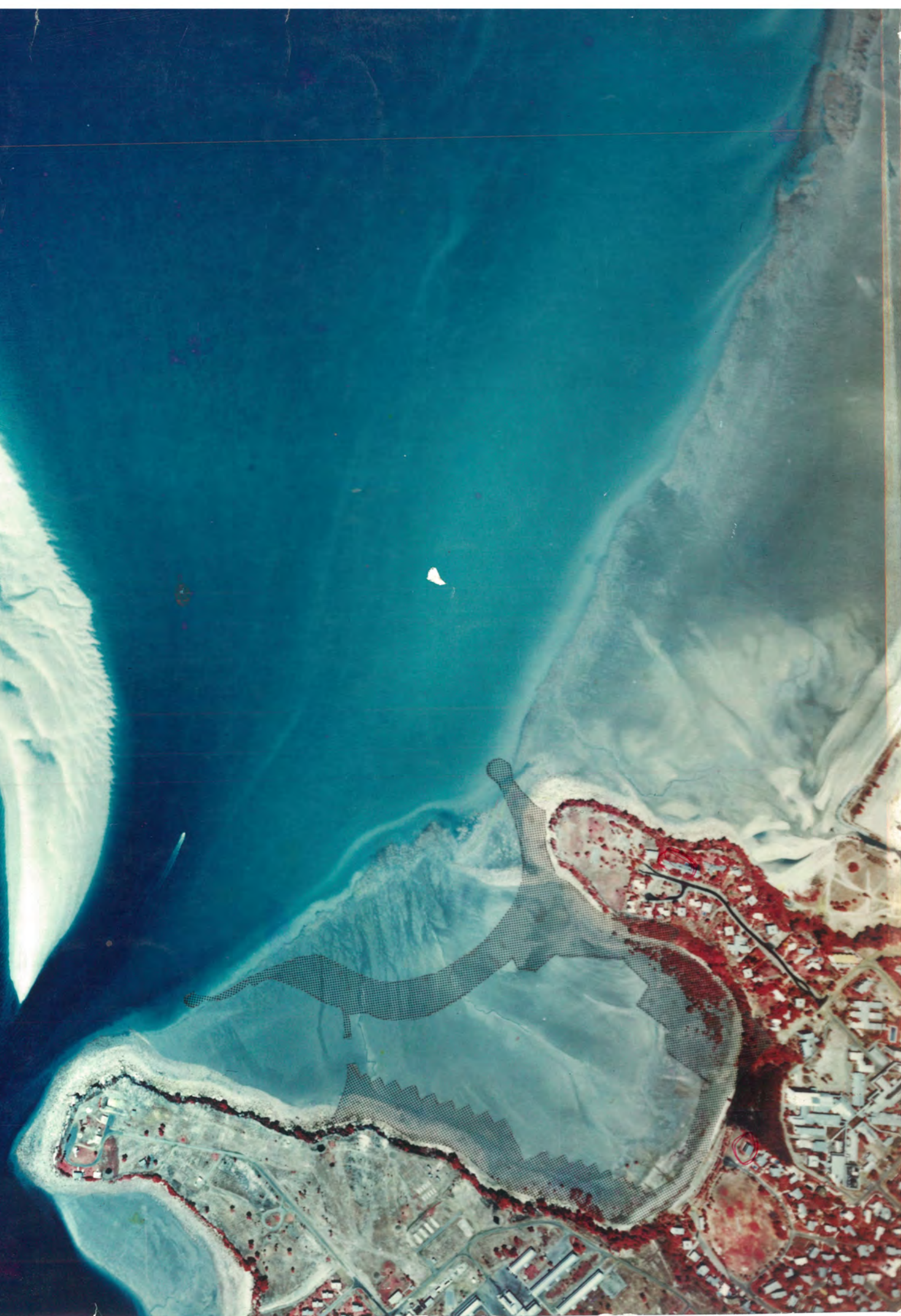
DARWIN MARINA ESTATE

**DRAFT ENVIRONMENTAL IMPACT STATEMENT
AND PLANNING STUDY — VOLUME ONE**

JAN. 1987



87/0055M



Mike Bugler
Environment Unit
C.C.N.T.

DARWIN MARINA ESTATE
CULLEN COVE MARINA

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STATEMENT & PLANNING STUDY**

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SUMMARY

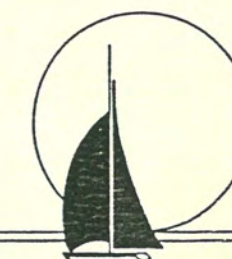
THIS REPORT HAS BEEN PREPARED TO OUTLINE THE DESIGN IDEAS FOR DARWIN'S FIRST RESIDENTIAL MARINA. DETAILED ENVIRONMENTAL AND ENGINEERING STUDIES HAVE BEEN UNDERTAKEN TO PROVE THE CONCEPT. THESE STUDIES ARE PROVIDED IN THIS REPORT TOGETHER WITH APPENDICES AND PRESENT BACK UP INFORMATION.

for
Darwin Marina Estates Pty Ltd
17 Lindsay Street, Darwin
P.O. Box 1641, Darwin, N.T.

prepared by
Vos Woodhead Planning Group &
Woodhead Australia: Architects

Riedel & Byrne
Consulting Engineers Pty. Ltd.

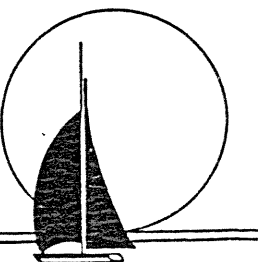
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SECTION I

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1.1 OBJECTIVES OF THE PROPOSAL

This proposal sets out to construct a Marina with associated waterfront residential, commercial and resort hotel facilities at Cullen Beach, Darwin. The proposal will provide a long awaited facility for Darwin and capitalise on one of Australia's most extensive harbour systems.

The City of Darwin is situated on a harbour larger than Sydney Harbour. However, for most of its coastline it is remarkably inaccessible due to the large tidal ranges, extensive shallow and mangrove areas. During the wet season the lack of suitable and safe anchorages for the majority of boats requires their removal from the water for safe storage. This difficulty has resulted in the lack of boating activity in the wet season for both pleasure craft and commercial operations.

This Marina proposal will provide the boating community of Darwin with a facility allowing year round safe mooring and access to the harbour. The Marina will be shared by both private pleasure craft as well as commercially operated charter boats. A ferry terminal will be incorporated within the design to cater for the many commercial craft operators. The provision of this terminal will provide a potential for the future extension of this service to other points of interest in Darwin harbour.

It is proposed to develop residential housing, commercial and tourist facilities. The combination of these developments attached to the marina will provide a lifestyle not available in Darwin at present while at the same time making the project economically viable by their mutually supportive nature.

The opportunity to live by the water and have a boat moored at one's doorstep with convenient all year access is the design principal of the scheme and creates the basis of a new lifestyle in Darwin.

Not only will Darwin's lifestyle be improved, but the opportunity for a whole range of new commercial activities will see a considerable spinoff to the Territory's growing economy.

1.2 BACKGROUND OF PROPONENTS

Darwin Marina Estate Pty. Limited is a company set up to develop the project. The three principals are Hans Vos, Gary Hunt and Graeme Townes, giving the firm a broad base of expertise and experience in planning, architecture and engineering. When the project proceeds, consultants will be commissioned to carry out the detailed design and documentation with the three principals controlling the work.

The backgrounds, expertise and experience of the three principals is as follows:

Hans Vos

Hans Vos has resided in Darwin since 1962. Initially spending several years with the Northern Territory Administration Town Planning Section.

In 1975, after Cyclone Tracy, he entered private practice and the partnership of Stapledon Vos Pty. Limited was formed. This era produced many award winning buildings within Darwin. In 1981, the partnership was dissolved and Hans Vos formed his own practice, Hans Vos Planning Consultants Pty. Limited.

In 1986, Hans Vos merged his practice with Woodhead Australia - Architects, becoming a Director of Woodhead Australia - Architects.

In 1986, Hans Vos was awarded The Tracy Award by the Royal Australian Institute of Architects (N.T. Chapter) for architectural excellence.

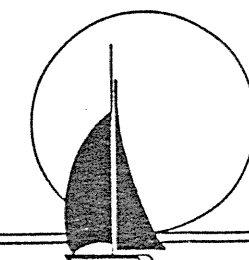
In his own right or in partnership, Hans Vos was also awarded The Tracy Award in 1979, 1980, 1981, 1983, and the National Sir Zelman Cowen Award in 1983 for the Territory Insurance Office Headquarters, Darwin. The T.I.O. Headquarters also won the National Energy Award for the year 1983.

Project experience includes:-

Initial evaluation of the Palmerston suburbs
Long term development of Cox Peninsula, Darwin - Provisional design brief.
500 Lot residential subdivision, Karama, Darwin Long term development of the Diocese of Sanderson for the Catholic Diocese of Darwin - Brief and reports
Lee Point Tourist resort, Darwin 1983 \$7 million
T.I.O. Headquarters, Darwin 1982 \$4.5 million
Museum and Art Gallery, Darwin 1978 \$5.7 million
Casuarina Shopping Village 1985 \$8.5 million

Current Projects include:-

Multi-storey office development, Darwin \$25 million
Ellis Beach holiday resort and Marina, Queensland \$35 million
Multi-storey library building for University College of the Northern Territory \$4 million
Darwin High School - Restoration of Vestey's water tank \$2 million



Gary Hunt

Qualifications:

Bachelor of Architecture, Melbourne University 1973
Associate of the Royal Australian Institute of Architects
Registered Architect, Northern Territory Architects Board
Deputy Chairman, Northern Territory Town Planning Appeals Committee
Chairman, CSIRO Northern Territory Advisory Committee
Member, CSIRO Advisory Council, Canberra

Gary Hunt has resided in the Northern Territory since 1973. Initially as an architect with the Department of Construction and later with the Darwin Reconstruction Commission as Architect/Planner.

In 1976, Gary Hunt became an Architect/Director of Woodhead Australia - Architects, a position he currently holds. Woodhead Australia have offices in Darwin, Alice Springs, Adelaide, Port Douglas and Perth.

Project Experience:

Gary Hunt has had a major involvement in many projects of a varied nature. The more significant projects are as follows:

Reconstruction of Darwin after Cyclone Tracy, including major projects such as Berrimah Gaol, 1300 house contract, replanning urban infra-structure etc.
Northlakes Development, Marrara
Darwin Golf Club, Clubhouse and golf course.
Desert Spring Development, Alice Springs (300 house lots, townhouses, Sheraton Hotel site etc.)
Consultants for Todd Street Mall, Alice Springs 70 room hostel, Yulara
Police station, Yulara
Numerous projects for Conservation Commission
Westpac Bank, Alice Springs

Current Projects:

Port Douglas Resort Development with Quintex, which includes a Marina, golf course, resort hotel, condominiums, townhouses and historic village and railway station.
Mauritius Reunion Islands, a \$200 million premium resort development which includes a Marina, resort hotels, condominiums, townhouses and golf courses.

John Graeme Townes

Qualifications:

Bachelor of Science Institute (Technology)
Member of Institution of Engineers
Member of Association of Consulting Engineers
Member of Building Referees Board
Member of Course Advisory Committee, Darwin
Institute of Technology

Graeme is a Director of W.L. Meinhardt and Partners, a firm of Consulting Engineers with offices throughout Australia and S.E. Asia. Graeme has managed the Darwin office of the firm since 1976, and during this time has been responsible for all of the work carried out by that office.

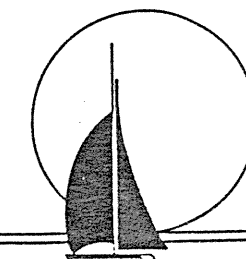
Project experience includes:-

The Museum, Darwin
Art Gallery, Darwin
Darwin Plaza Building
Marrakai Apartments
Lower Courts and Registrar Generals Building
Northlakes Country Club Estate
Darwin High School Gymnasium
(Vesteys Tank)
Casuarina Village Shopping Centre
5km x 225ø Rising Main from Leanyer Sewerage
Treatment Plant to Marrara Sports Complex
Katherine East High & Primary Schools

Graeme has also been involved with Hans Vos in the development of their own two storey office building in Lindsay Street, a six storey office development in Lindsay Street on behalf of the N.T. Government and they are about to commence a two storey office development in Shepherd Street.

SUMMARY

The ability and resources of the three principals of Darwin Marina Estates in many successful projects within the Northern Territory and interstate, have shown a proven track record of commercially successful and award winning projects.



1-3 BACKGROUND TO THE PROPOSAL

Site Selection

The idea of a marina for Darwin is not new. Marinas and associated residential proposals in other locations have been considered in Darwin over the last decade. At present none have commenced principally due to high costs and a lack of suitable sites.

Cullen Beach had not previously been considered for a marina. Investigations undertaken to date show that it is practical to construct a marina and residential development in this area. The marina feasibility is supported by the ability to construct significant residential components plus services infrastructure into the project, which are the principal source of funding.

Location Close to Darwin CBD

The proximity of the site to the Darwin central business district together with some of Darwin's major tourist and recreational facilities such as Diamond Beach Casino, Mindil beach, the Gardens Ovals and the Botanical Gardens will further enhance the social and economic fabric of the Darwin city region through the diversification of activities in the area.

Scale and Format of the proposal

The natural terrain of Cullen Beach and the method of reclamation within the Bay has resulted in a proposal which sets a balance between developable land area and water area available for marina facilities.

The rugged cliff faces flanking either side of Cullen Beach set the backdrop for the development. The proposal attempts to site as much of the development as possible in a close and intimate relationship with the water.

Direct access to deep water and the inherent safety of the site, protected by a man made break-water which is in turn protected by a significant sand bar. The steep terrain of Myilly and Larrakeyah Points produce a site with all the necessary ingredients.

The chosen site has undergone a number of design refinements since conception and with detailed engineering studies now undertaken the site proves to be the most appropriate.

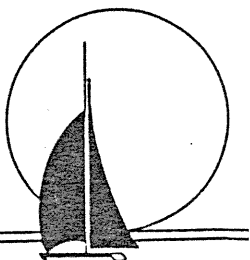
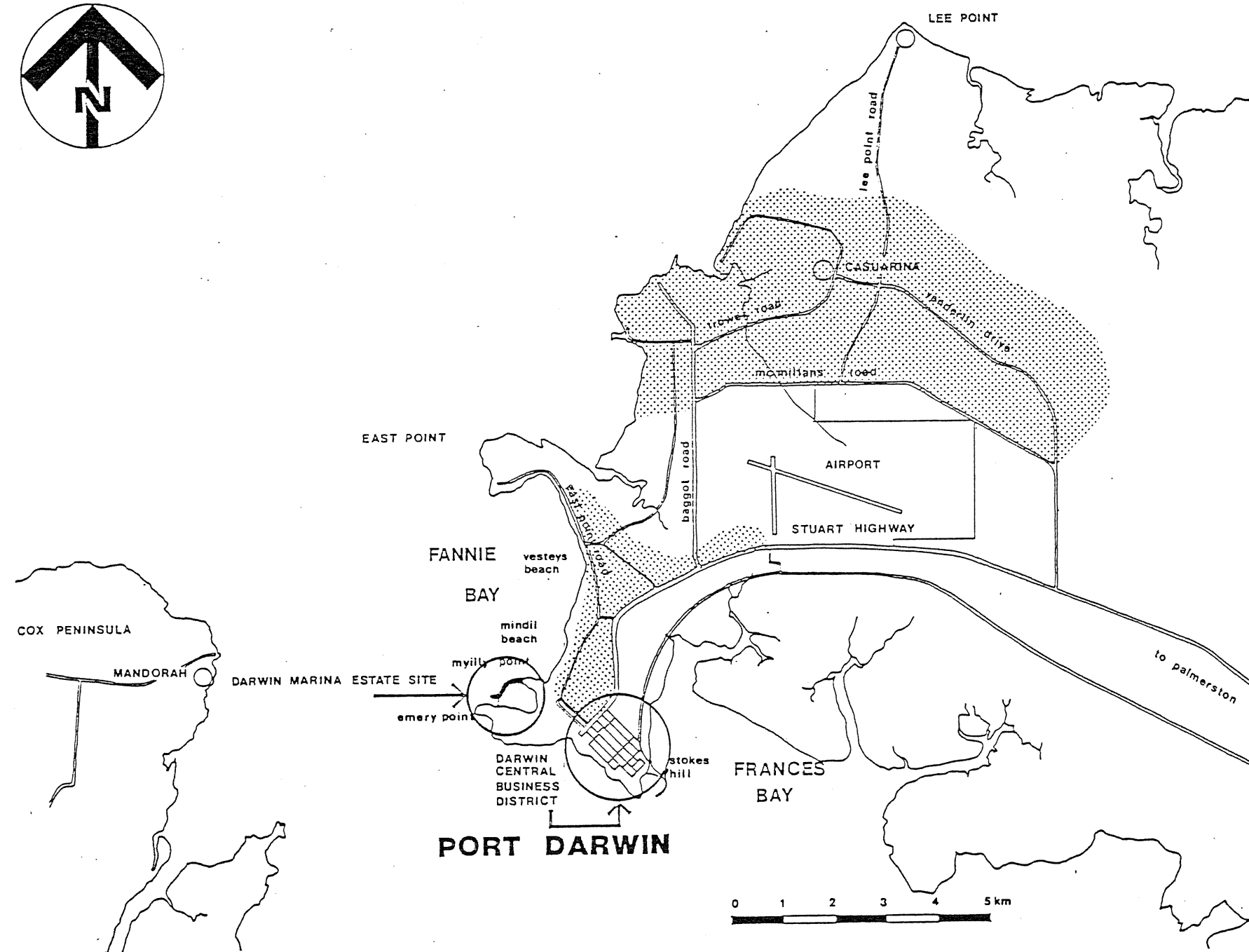
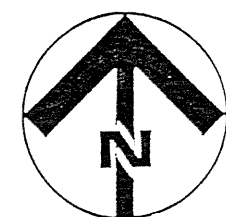
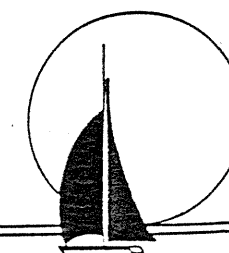


fig 1.1



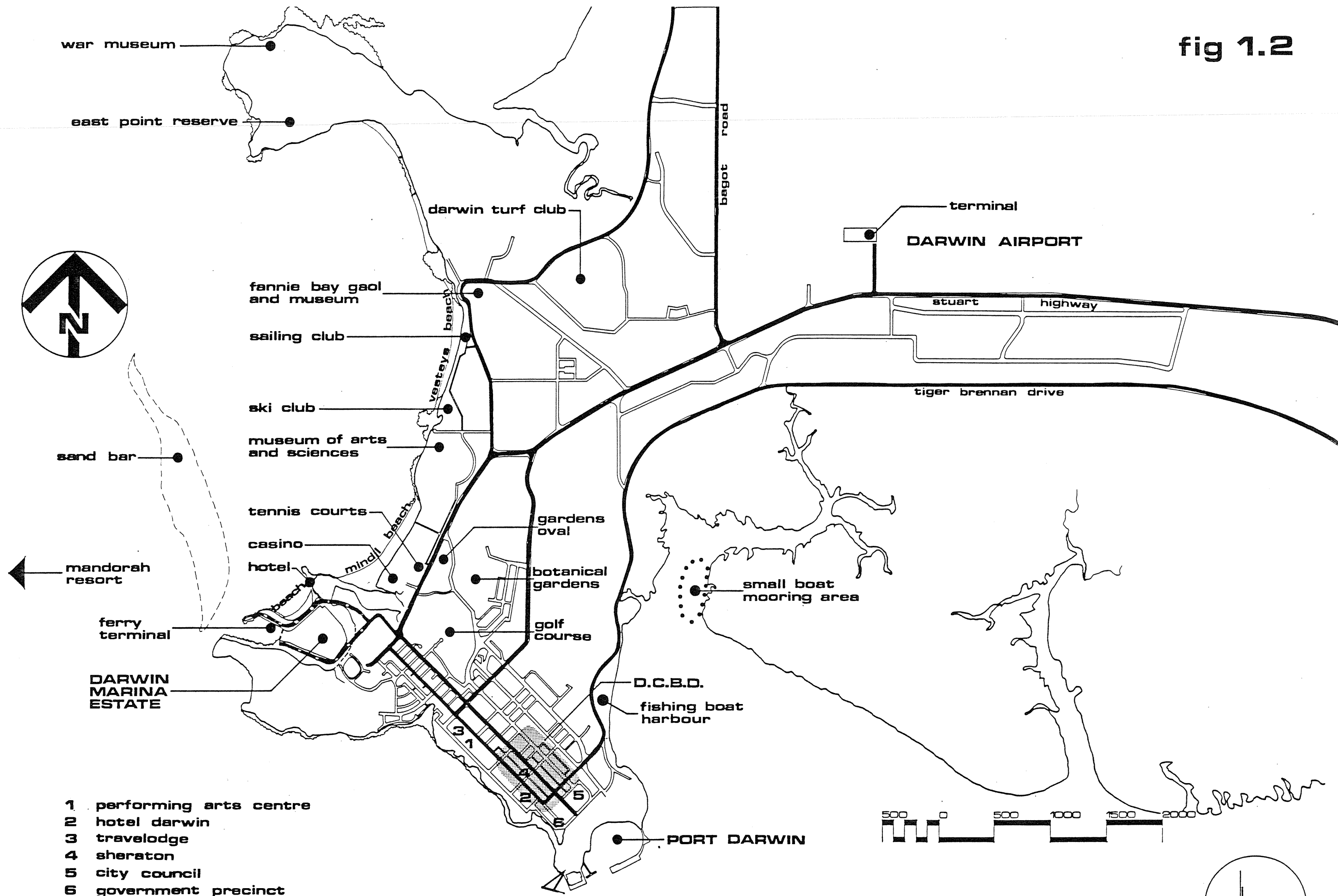
- between Myilly Point and Emery Point
- 2 kilometers from the centre of the Darwin central business district
- western aspect toward Darwin harbour and the deep water navigation channel approaches to the Stokes Hill wharf and Frances Bay
- the closest point on the Darwin shoreline to access the Cox Peninsular through Mandorah

site and location



DARWIN MARINA ESTATE

fig 1.2



locality plan

DARWIN MARINA ESTATE

1.4 ALTERNATIVE SITES

Over the past 15 years there have been a number of attempts to provide marina facilities for Darwin.

The following is a summary of past proposals' locations

- | | |
|----------------------------|---|
| 1. Rapid Creek | 4. Doctors Gully |
| 2. Ludmilla Creek | 5. Sadgrove Creek |
| 3. Vestey's beach proposal | 6. Palmerston and old Quarantine station. |

Rapid Creek and Ludmilla Creek have North Westerly aspects which has monsoon weather exposure as well as very shallow water entrance requiring long dredging entrance channels.

The proposals also required large-scale mangrove removal, with the possible affect of de-stabilising the sites and rendering them more susceptible to damage resulting from storm surge.

Vesteys Beach Proposal This proposal was put to the public and rejected.

Doctors Gully Originally considered by the Darwin Reconstruction Commission and rejected as having limited land for shore based activity and poor access by vehicular traffic.

Sadgroves Creek Access has been provided to the creek via landing ramps and moorings have now been placed. The area is isolated and does not have the quality to support major tourist infrastructure and residential opportunities.

Palmerston and Old Quarantine Station Considered to be too far from the centre of activity and main harbour. This area will become more popular with the growth of Palmerston.

Cullen Cove Marina and Resort Hotel

The Cullen Cove Marina is well situated environmentally, the site has limited mangrove distribution and will require minor dredging only.

The Marina is also well situated in the context of the surrounding land use. The proximity of existing facilities such as the Casino, Botanical Gardens, golf course, tennis courts and the closeness of the Darwin central business district is such that the resort hotel and marina will complement and enhance the locality generally.

As stated elsewhere in this report the resort hotel complements the marina. The marina infrastructure facilitates the building of the resort hotel.

The new Beach with the proposed sea wasp net, sailing and restaurant facilities will main- tain the identity of the resort hotel as catering for the family group, thereby satisfying a specific need, without competing with the recently completed Darwin hotel.

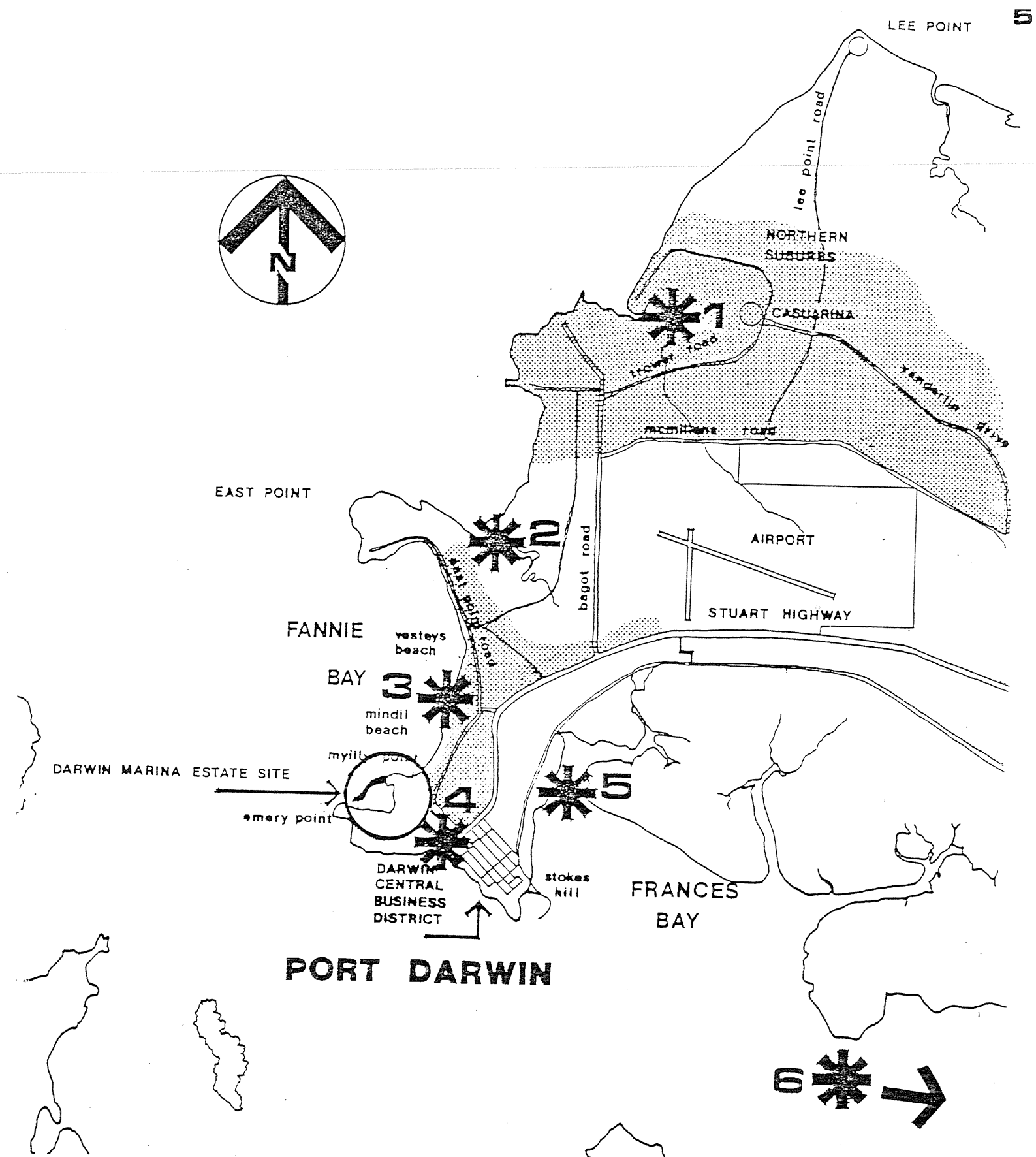
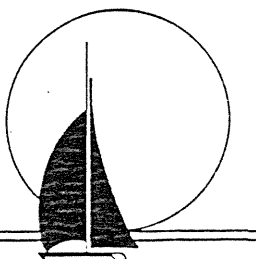


fig. 1.3 ALTERNATIVE SITES



1.5 EXISTING ENVIROMENTAL CONDITIONS

1.5.1 NATURAL LAND ENVIRONMENT

The existing vegetation within the survey area is composed of a combination of:

- a) endemic communities and species.
- b) introduced native and exotic species.

The former includes:

- 1) Mangroves - a relatively small but purely endemic community.
- 2) Foreshore and cliff community dominated by endemic species (black wattle, rock fig, native hibiscus, paperbark) with considerable weed infestation.
- 3) Headland community - only mature milkwood trees remain of the original community.

The latter introduced vegetation is predominantly exotic vegetation mostly throughout residential development. (African Mahogany, Poinciana, coconuts and frangipani). Notable native species planted include Ghost gum, Beauty leaf and Casuarinas.

The existing vegetation is typical for this landscape in the Darwin region. More extensive stands of mangroves occur towards Nightcliff and Casuarina whilst remnant milkwoods are evident on all rocky headlands from Port Darwin to East point.

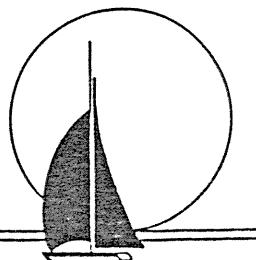
The precinct area generally has an underlay of sedimentary rock formation of calcareous claystone and sandstone which has generally produced, with organic deposits, a shallow stony clay soil.

Under existing conditions, these formations are relatively stable, accepting the natural erosion of the rock formation by wind and water movements to produce the cliff-face typical of Darwin's ocean foreshores.

Most important for the retardation of this natural erosion is the retention of existing vegetation along the cliff-faces and cliff top edges.

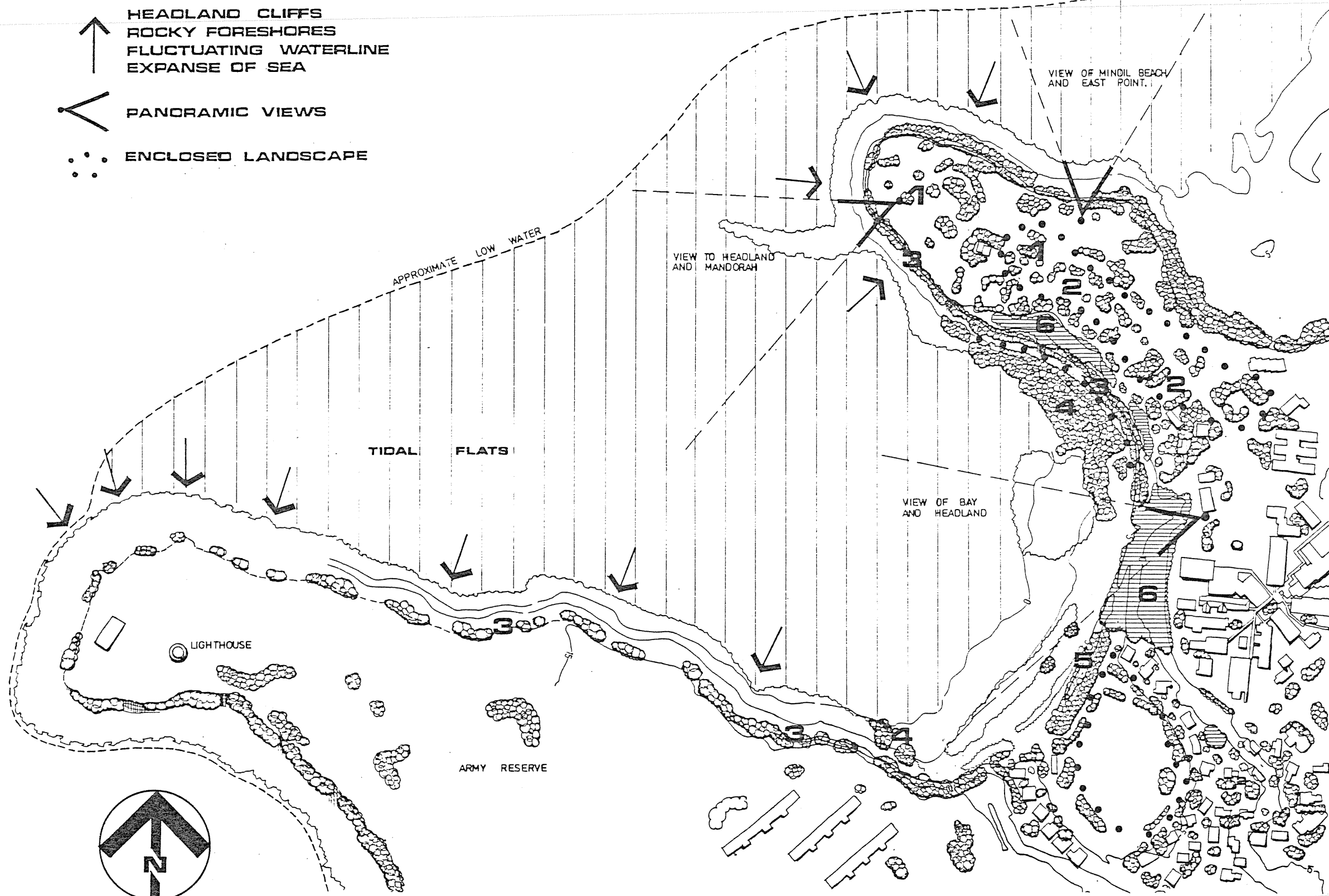
The generally extensive vegetation coverage restricts soil erosion to a minimum.

For location of the existing vegetation species refer figure 1.4.

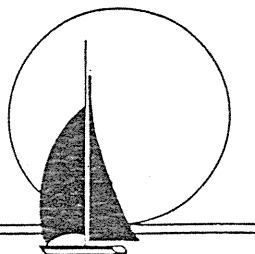


VISUAL FEATURES

VEGETATION



existing land
environment



1.5.2 GEOTECHNICAL ASPECTS

As part of the Cullen Cove Marina Study, 1984, Coffey and Partners Pty Ltd carried out preliminary geotechnical investigations within the Cullen Beach locality of Fannie Bay.

The initial preliminary investigation consisted of a seismic refraction and hand auger borehole survey. The results were not encouraging and most of the geotechnical assessment was based on 25 Dynamic Cone Penetrometer tests and visual examination of the site.

From this initial preliminary investigation it was found that surface sediments in the bay were mainly very loose, fine grained silty sand. It was noted that this material often exhibited a tendency to liquify when disturbed in water.

It was assumed that refusal in the penetrometer tests occurred on phyllite and not a very stiff to hard clay or very dense sand. Previous investigations around the Darwin coastline have indicated that often a deposit of soft marine clay overlies the phyllite bedrock. The penetrometer results indicate a soft soil layer immediately above the phyllite and for the purpose of this present study it will be assumed to be a soft clay material. The results of the penetrometer tests are shown on Figure 2.1 Volume two.

From Coffey and Partners' work a general description of the material within the Cullen Beach locality is shown in figure 1.5, existing land environment and also presented in Volume 2, section 2.1.

A more detailed geotechnical site investigation will be necessary prior to the start of detailed design. The scope of this investigation will cover:-

- . A survey of subsurface conditions utilising existing information, core drilling and sampling and in situ vane shear testing and probing.
- . The evaluation of a suitable construction method for the construction of the beach causeway and breakwater, taking into consideration long term settlement of the embankments and the requirement for a relatively impermeable causeway and foundation.
- . The assessment of the driveability of piler and sheet piles for the civil works associated with the ferry terminal, water level control gates and marina based on the engineering properties of the surface sediments and underlying phyllite.
- . The evaluation of the dredgeability and suitability of the materials within the inner and outer harbour basins for use as general land fill.
- . Engineering assessment of the material sources for construction of the new public, the breakwater and groyne.
- . Analysis of the slope stability for the retaining walls or slopes adjacent to the marina area.

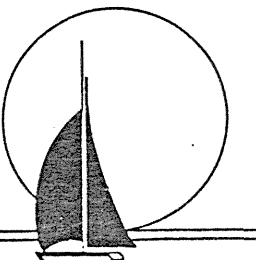
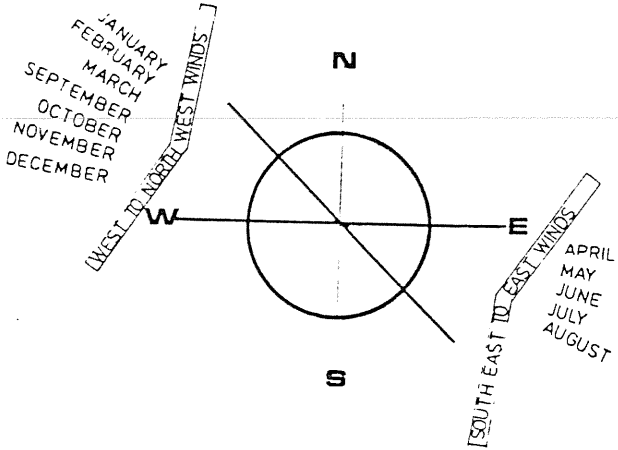


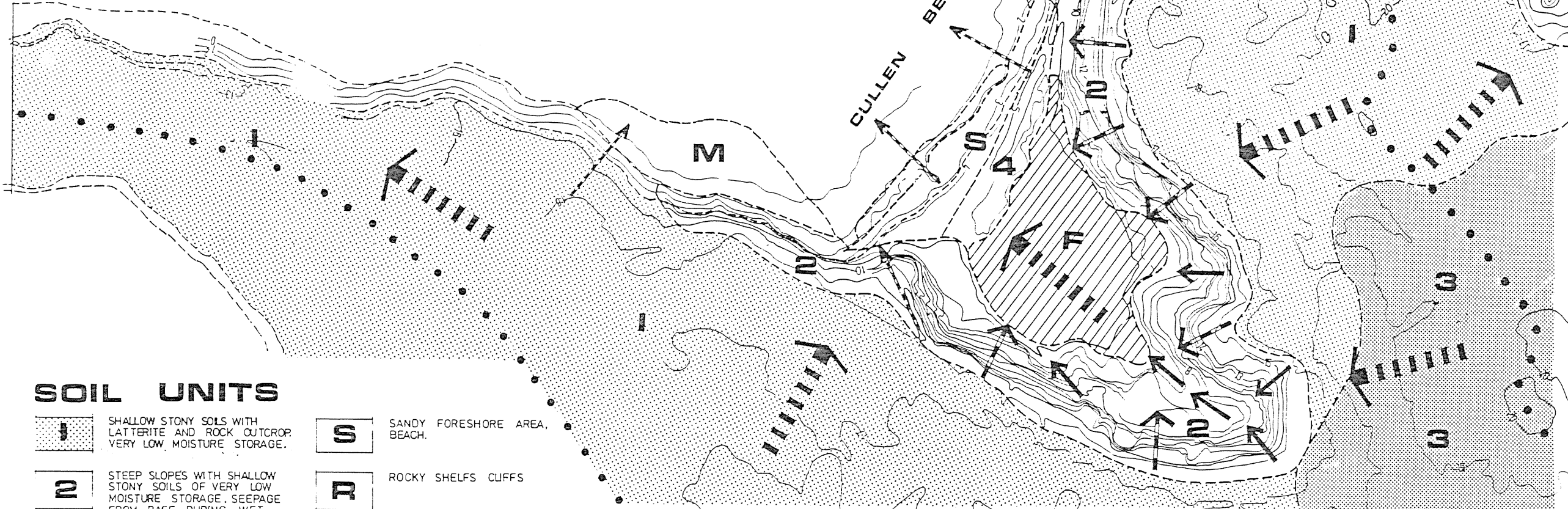
fig 1.5

PREDOMINANT WINDS

Refer Vol.2 Section 2.2
for detailed description



FANNIE BAY



SOIL UNITS

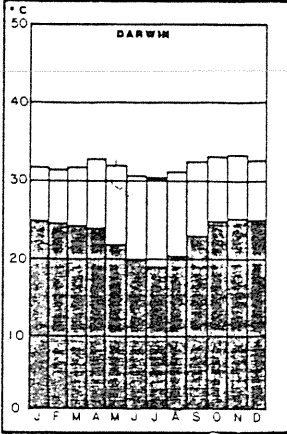
- | | | | |
|----------|---|----------|-------------------------------|
| 1 | SHALLOW STONY SOILS WITH LATTERITE AND ROCK OUTCROP. VERY LOW MOISTURE STORAGE. | S | SANDY FORESHORE AREA, BEACH. |
| 2 | STEEP SLOPES WITH SHALLOW STONY SOILS OF VERY LOW MOISTURE STORAGE. SEEPAGE FROM BASE DURING WET. | R | ROCKY SHELF'S CLIFFS |
| 3 | MODERATELY DEEP GRAVELLY RED AND YELLOW EARTHS SOME LATTERITE MODERATE MOSTURE STORAGE. | | UNKNOWN FILLED SOILS |
| 4 | STABLE SAND DUNES WITH ORGANIC SANDY SOILS. | M | MARINE MUD, TIDALLY INUNDATED |

REFERENCE: LAND RESOURCES OF THE DARWIN SUBURBAN AREA.

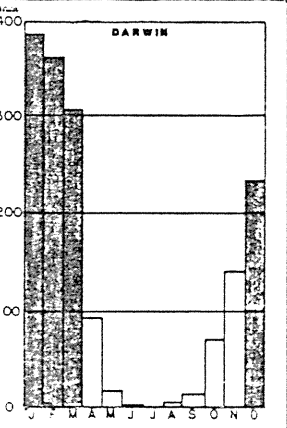
GEOLOGY

- | | | |
|----------|------------------|--|
| MESOZOIC | LOWER CRETACEOUS | BATHURST ISLAND FORMATION |
| | | DARWIN MEMBER |
| | | CALCAREOUS CLAYSTONE MINOR SILTSTONE AND FINE GRAINED SANDSTONE. |

TEMPERATURE STATISTICS



RAINFALL STATISTICS



DRAINAGE

- DIRECTION OF DISPERSED, SLOW MOVING SURFACE FLOW
- DISPERSED FAST MOVING SURFACE FLOW
- CONCENTRATED FAST MOVING SURFACE FLOW
- PIPED OR CHANNELLED OUTFALLS
- WATERSHED, EDGE OF CATCHMENT

existing land environment

1.5.3 WINDS

The wind provides the input of energy to create waves which ultimately shape the coast, the wind climate in the vicinity of the marina is therefore of importance because of its effect on local wave conditions and coastal processes.

These waves also determine the optimum layout of breakwaters and the useability of the marina entrance.

The predominance of the northwesterly winds can be readily seen in the form of wind roses graphically displayed in figure 2.2 and 2.3, Volume two of this report.

1.5.4 TIDAL CURRENTS

Currents flow along this section of the coastline with the rise and fall of the tides. During the September 1986 spring and neap tide conditions a current meter was used in the vicinity of Cullen Beach, Fannie Bay, to establish tidal current velocities and directions at various depths during flood and ebb tides. This information is tabulated in Appendix A, Volume two of this report. Figure 2.4 Volume two, shows peak tidal velocities for spring tides.

There are a number of important aspects of the local current regime that were identified as a result of the above monitoring exercise carried out by Riedel and Byrne, Consulting Engineers Pty Ltd, they include the following:-

- . The tidal currents in the vicinity of Fannie Bay are primarily confined between an offshore sand bar and the coastline.
- . There is little penetration of currents into Cullen Beach.
- . A deep channel has been scoured between the southern tip of the sand bar and Emery Point.
- . A north-south tidal current flows through this channel for all states of the tide.

1.5.5 WATER LEVELS

The tide at Darwin is semi-diurnal, the tide water level will vary with the astronomical tide. In addition to this astronomical tide the water level can increase due to storm surge, wave set up and surf beat.

These aspects have been examined in a detailed study commissioned by the Northern Territory Department of Lands. The results are presented by Lawson & Treloar, 1982; and Blain, Bremner & Williams, 1983. The findings of this study have been adopted when determining design water levels for the various components of the proposed development.

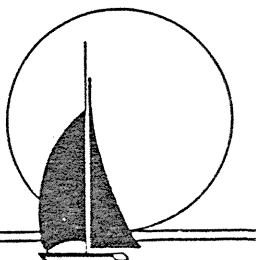
For surge plus tide effects alone, the study recommends 1 in 100 year and 1 in 1000 year water levels in Fannie Bay of RL +8.5m C.D. and RL +9.5m C.D. respectively. To this level must be added the effects of wave set-up and surf beat.

Wave set-up is a local increase in water level due to breaking waves pushing water up against a coastline. Surf beat comprises irregular oscillations of the nearshore water level with periods of the order of several minutes.

The above study evaluated the combined wave set-up and surf beat effects to be 1.0m in Fannie Bay for a 100 year event.

Therefore, 100 year design water levels for the proposed development are:

- . Storm surge plus tide RL +8.5m C.D.
- . Storm surge plus tide,
wave set-up and surf
beat RL +9.5m C.D.



1.5.6 WAVE CLIMATE

Wave climate is an integral requirement in the design of marine structures. In order to study the coastal processes, a detailed knowledge of the nearshore, directional wave climate is required. Consideration must be given to both the ambient climate and that during extreme events such as cyclones. Storm waves are less frequent but because of their intensity are of significance with respect to coastal processes and the design of marine structures. Ambient waves are milder, but in view of their frequency, are also a significant factor in determining coastal processes. Volume two, section 2.5 details the study investigated by Riedel and Byrne, Consulting Engineers Pty Ltd. The study includes wave climate, wave hindcasts, Hindcast Swell wave climate, wave transformation, seabed friction, transformed wave climate, nearshore sea wave climate, nearshore local sea wave climate, nearshore swell wave climate and storm wave climate.

The results of the above study were used to:-

- . Determine a stable beach profile and alignment for the new beach.
- . To determine the initial design of the entrance breakwater and the groyne.
- . To determine navigability of the entrance to the outer harbour.
- . To determine the breakwater armour.
- . To determine any effect the development might have on the wave climate at Mindil Beach.

1.5.7 COASTAL PROCESSES

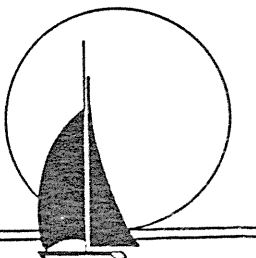
Examination of aerial photographic records extending back as far as 1945 have provided evidence of some sediment movement from north to south in Fannie Bay. The amount of longshore movement is estimated to be quite small because of the absence of large amounts of accretion against the headland extending out to Myilly Point and various boat ramps along the beach. Even moderate amounts of sediment moving along the beach would result in a substantial accumulation of sediment against the Myilly Point headland.

Section 2.6, Volume two, describes the techniques used to mathematically estimate littoral drift, the results are presented in figure 7.2, Volume two.

There are two mechanisms which can cause a loss of beach sediment from the Vestey's and Mindil Beach system. One is an offshore movement of sediment by storm waves. This sediment is subsequently influenced by the tidal currents and carried toward Emery Point and hence lost to the beaches. The other mechanism occurs when the creeks which cross the beaches flow strongly. The flow can carry some sediment offshore and again into the influence of the tidal currents.

The main features of the sediment movement patterns in Fannie Bay are as follows:-

- . There is a small net littoral drift along Vestey's and Mindil Beaches from North to South.
- . During storms, waves move sediment offshore from the beaches into the influence of the tidal currents.
- . Sediment is subsequently moved by the strong flood tidal currents towards Emery Point.
- . Ebb tide currents move sediment from the harbour upstream of Emery Point, and deposit it on the offshore sand bar located north of Emery Point.



1.5.8 SAND BAR

Bathymetric surveys incorporating the Fannie Bay sand bar have been carried out as far back as 1938. An analysis of surveys carried out since 1938 indicate the sand bar is increasing at the rate of approximately 50,000m³ a year.

In order to identify the source of supply to the sand bar sediment samples were taken from several locations on the sand bar and cover a range of depths. Samples were also taken from Vestey's and Mindil Beaches.

From the samples taken, it was found that the sand bar has a high shell content, as distinct from the Fannie Bay Beaches, indicating that a high proportion of the material in this bar comes from Darwin Harbour rather than the areas adjacent to the development. Section 2.7 Volume two, discusses the material make up of the sand bar in more detail.

The main features of the sediment movement patterns in Fannie Bay are as follows:-

- . There is a small net littoral drift along Vestey's and Mindil beaches from North to South.
- . During storms, waves move sediment offshore from the beaches into the influence of the tidal currents.
- . Sediment is subsequently moved by the strong flood tidal currents towards Emery Point.
- . Ebb tide currents move sediment from the harbour upstream of Emery Point, and deposit it on the offshore sand bar located north of Emery Point.
- . The sand bar has a high shell content, as distinct from the Fannie Bay beaches, indicating that a high proportion of the material in this bar comes from Darwin Harbour rather than the areas adjacent to the development.
- . The sand bar is increasing at a rate of approximately 50,000 m³/year.

A computer analysis of the transformation of waves from Timor Sea through Beagle Gulf to the proposed site in Port Darwin indicates that there is very little penetration of swell waves. Considerable protection is afforded by Cox Peninsula to the west and Melville and Bathurst Islands to the north. The sand bar off Emery Point also shelters the site from large waves by causing them to break on the bar rather than propagate into Cullen Bay.

The biggest waves which can reach the site are those generated by high winds such as might be associated with a severe cyclone crossing Beagle Gulf. This combination of high local winds and increased water depths would result in waves of approximately 3.3m in height arriving in water immediately offshore of the proposed breakwater.

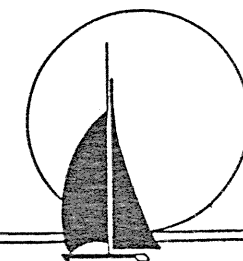
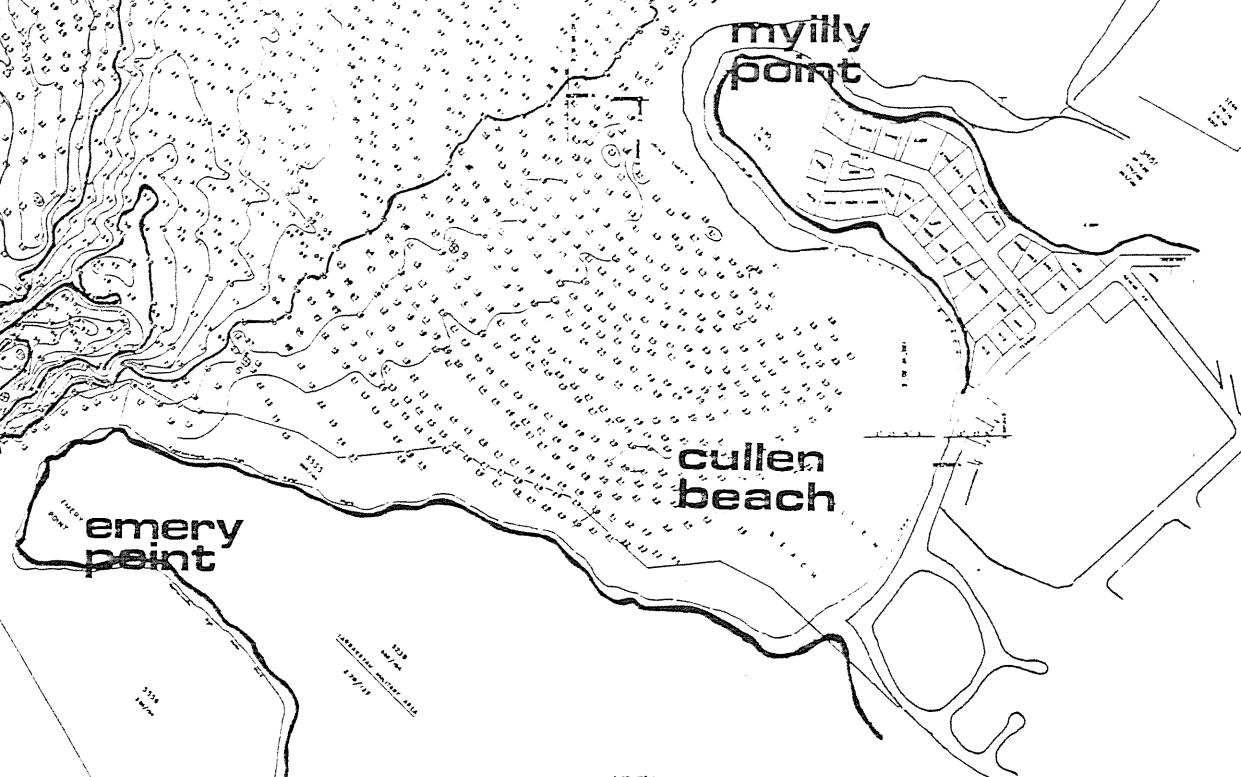


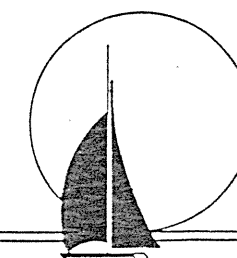
fig.1-6

Bathymetric Survey reproduced
from information supplied by
Mapping and Hydrographic Surveys,
refer to appendix A, volume 2 of
the Report.



existing
underwater contours

DARWIN MARINA ESTATE



1.5.9 SOCIAL AND "BUILT" ENVIRONMENTS

Social Environment

Cullen Beach and Kahlín Oval is essentially a residential suburb lining the slopes of the hillside overlooking Kahlín Oval and Cullen Beach.

The residential areas of Larrakeyah line the slopes overlooking Kahlín oval and Cullen Beach, traditionally this area was and remains one of Darwin's more exclusive residential areas.

The appeal of this area derives from its close proximity to the central business district, the cul-de-sac nature of the suburb which offers no through roads, the generous recreation fields, water views as well as less quantifiable but desirable socio-economic aspects that derive from the local population.

Cullen Beach does not offer any significant amenity to either the local residents or to any other user groups. The principle social area is therefore Kahlín Oval. This oval is owned and maintained by the Darwin City Council and is available to any group from the community and booked through the Parks and Gardens Department. Enquiries with this department revealed that substantial improvements were made to the oval's facilities in recent years by both the Council and private sporting groups. The main use of this oval is by Northern Territory Cricket Association club and club matches. During the dry season, the oval is booked consistently every day of the week. The wet season has not been successfully booked and last season 1984-85 no bookings were taken during the wet.

Community groups with interests in this area are the Larrakeyah Scout Group whose premises are located on Temira Crescent. This group would benefit by the development of a marina. The scout recreational activities could be enlarged to encompass sailing, beach training, swimming, including life saving training and general adventure style activities.

Areas of Cultural Significance

There are two areas close to Cullen Beach which are of cultural significance. These concern:

- (i) Aboriginal Sacred Sites
- (ii) Architectural Heritage Sites

i) Aboriginal Sacred Sites

Enquiries with the Aboriginal Sacred Sites Authority showed that there are three known sacred sites on top of Emery Point within the area occupied by the Army Reserve. In about 1975 discussions were held between the Army and the Aboriginal traditional owners when a claim was made on the whole of Emery Point. The issue was resolved through the negotiation of access rights for Aboriginals to these sites through the Army reserve.

These sites will not affect the marina development as they are not within the area of the development proposal.

The Aboriginal Sacred Sites are located on the zoning plan, Fig. 1.7.

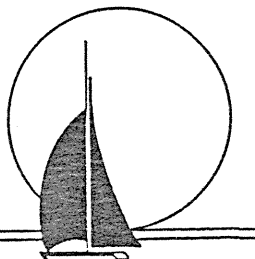
ii) Architectural Heritage Sites

The principle area of interest in this category is the Kahlín Triangle Precinct which contains several historic houses including Audit House.

Audit House is owned by the National Trust of Australia and leased to the present tenants on a life time lease. The house and gardens have been fully restored by the National Trust and the house and gardens are listed on the register of the national heritage estate.

There are three other houses within the Kahlín Triangle of interest to the National Trust. Two of them are owned by the Commonwealth Government who retain responsibility for them and their further protection under the Heritage Conservation Act.

The Northern Territory National Trust Association is actively involved in the preservation of these houses. The houses are not within the marina site and will not be affected by the proposal.



1.5.10 EXISTING AESTHETIC CLIMATE

The existing social and "built" climate of residential and recreational facilities will be enhanced with the development of the marina. The existing Kahlín Oval residential area borders and will have access to the marina foreshore, ensuring the continuation of the existing environment and the improvement of access to the waters edge. The existing cul-de-sacs to the oval perimeter road are outside the marina development and will remain, thereby continuing the present restriction of through traffic.

Myilly Point overlooks the marina development, the sparse residential development existing on the north side of Myilly Point will not be adversely affected by the construction or the existence of the marina.

Larrakeyah and Emery Point also overlook the marina development and will not be adversely affected by the construction or the existence of the marina.

The surrounding residential area and the new university will benefit as a result of the facilities to be provided within the marina development. Cullen Beach will provide swimming facilities that at present do not exist for local residents and the raising of the finished ground level adjacent to Kahlín Oval will provide storm surge protection for the adjacent existing housing.

1.5.11 EXISTING ZONING

The current zoning easements are shown on the zoning plan on the following page, figure 1.7. Much of the land bordering the marina perimeter is set aside for special use. The Kahlín Oval and Darwin CBD, consists of residential, both low and high density, with pockets of land zoned for tourist and business development.

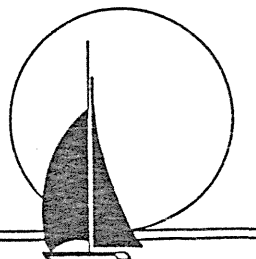
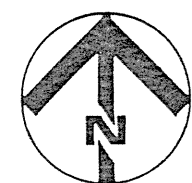


fig 1-7

- LEGEND
- RESIDENTIAL
R1 - Detached Dwellings
R2 - Attached Dwellings
R4 - Flats up to 8 Stories
- BUSINESS
B1 - Central Business
B2 - Local Business
B4 - Central Development
B5 - Tourist Business
- OPEN SPACE
O1 - Open Space
O2 - Organised Recreation
- SPECIAL PURPOSES
S1 - Special Purposes
- SPECIAL PLANNING
INSTRUMENT ZONE
SP - As determined by the
Special Planning Instrument
-  ABORIGINAL
SACRED SITE



sand bar

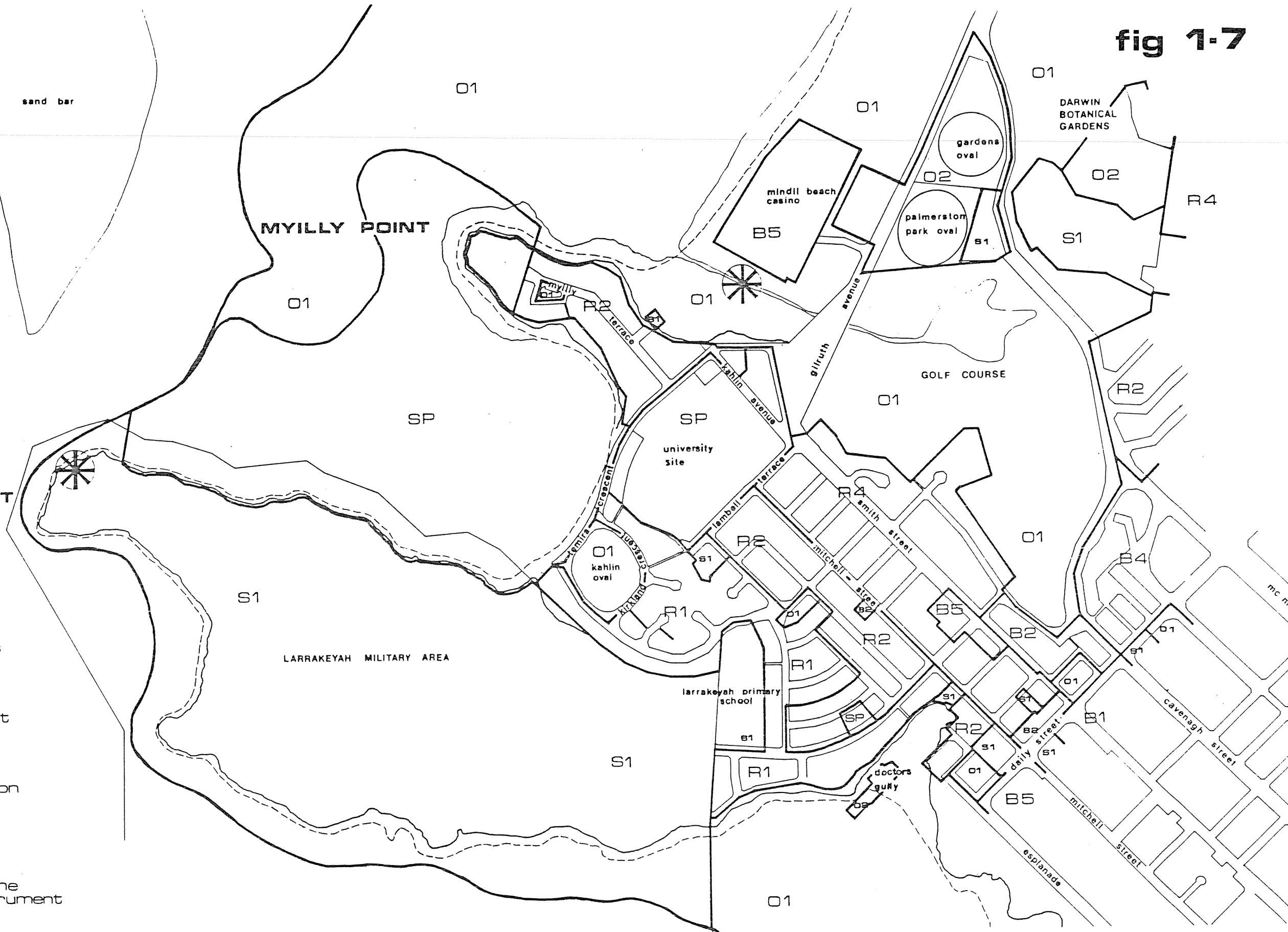
MYILLY POINT

EMERY POINT

LARRAKEYAH MILITARY AREA

zoning plan

DARWIN MARINA ESTATE



SECTION II

SECTION II

PROPOSAL AND ENVIROMENTAL SAFEGUARDS

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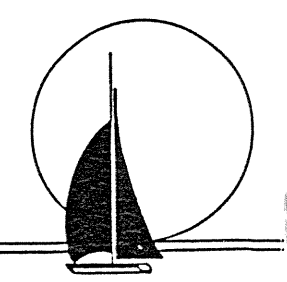
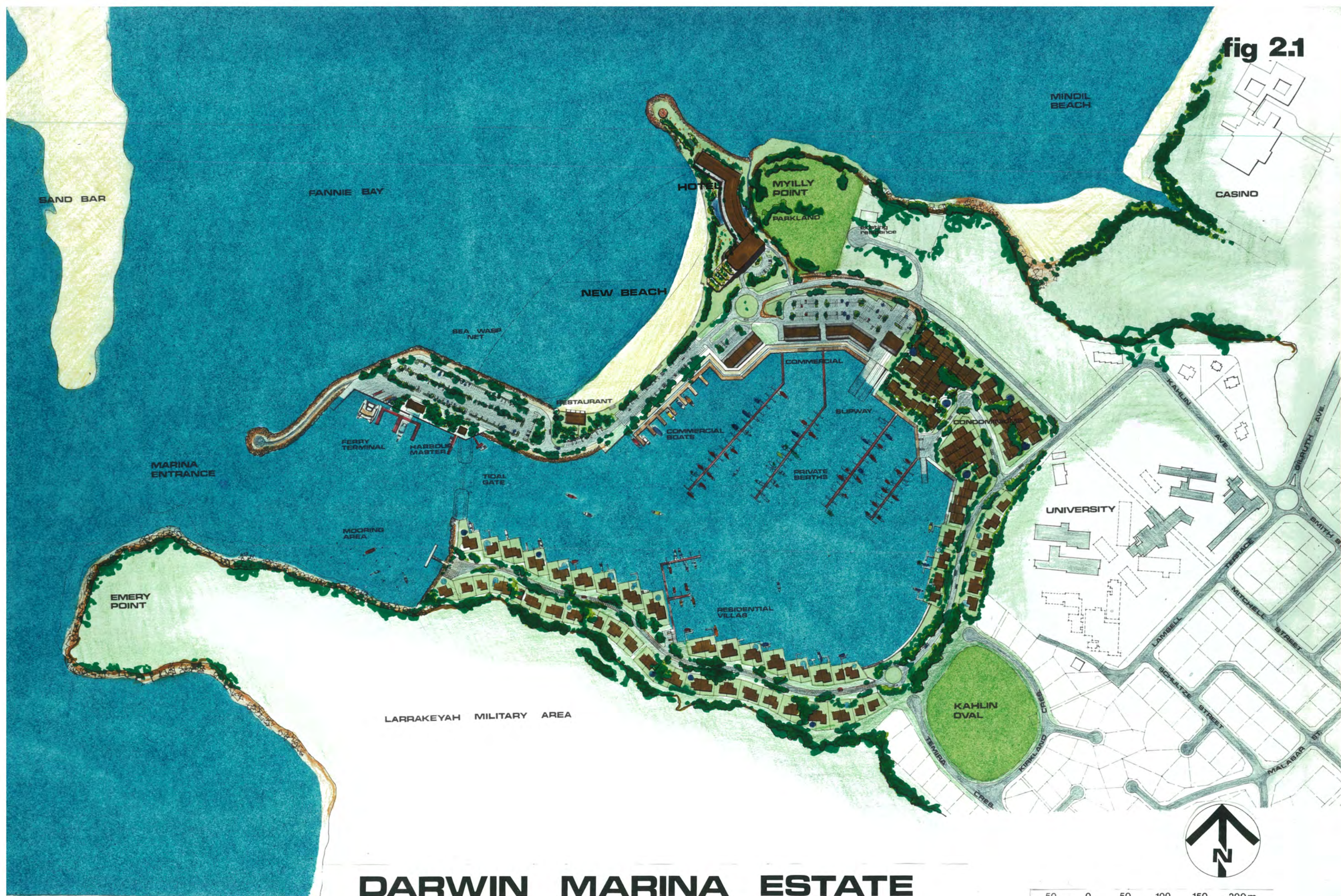


fig 2.1



DARWIN MARINA ESTATE
JAN 1987

2-1 PROPOSAL DESCRIPTION

GENERAL

It is proposed to develop a harbour with surrounding residential blocks, a hotel and restaurant and a commercial retail area. Figure 2.2 shows the general layout of the proposed development. A barrier approximately 1.0km long will be required to protect the marina and the surrounding development from ocean waves. Approximately one half the length of the barrier will be formed by a beach and the other half by a conventional breakwater.

A system of weirs and gates is planned to control the water level within an inner harbour such that it would be tidal above RL +3.75m Chart Datum but not allowed to fall below this level. This inner harbour basin would be dredged to an average level of RK +1.0m Chart Datum and consequently always have approximately 2.75m depth of water. Access to the ocean would be provided for about 60% of the time.

Within the basin mooring facilities for both leisure and commercial vessels will be provided. Sufficient space is available for a 300 berth marina. The number of berths initially provided would be smaller and be expanded on demand.

An outer harbour and channel would be dredged to RL -3.0m C.D. to allow access at all stages of the tide for vessels with draught up to 2.5m. This outer harbour would provide shelter to vessels awaiting suitable tide conditions to enter the inner harbour.

A ferry terminal and a public boat launching facility will also be incorporated within the outer harbour.

2.1.1 NEW PUBLIC BEACH

A new beach is proposed to form a barrier to protect the marina from the ocean waves. The beach will form a pocket beach between two headlands, as shown on the facilities plan item 10. The existing headland at Myilly Point would be extended and a breakwater would be constructed to constrain the southwest end of the beach and to extend the barrier further south.

An analysis of stable beach alignments using the mathematical modelling techniques described in Volume two, section 2.5 was undertaken for this beach.

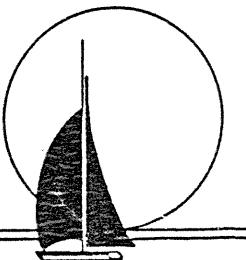
From the mathematical modelling techniques it was found that a beach having a bearing of 219° at its toe would have negligible net longshore transport.

Using mathematical modelling techniques it was also possible to establish a beach profile, refer Volume 2, figure 3.2. Existing beach slopes on Mindil and Vestey's Beaches are similar and confirm the results.

Armour on the groyne forming the northern boundary to the beach will be extended to form a seawall in front of the planned hotel complex. This will provide a defence against erosion during a very severe cyclone. To maintain the marina water level at 3.75m above Chart Datum, the "beach section" must prevent water flowing to the ocean during periods when the tide is lower. In order to achieve this, phyllite, quarry scalplings or other readily available suitable material will be needed to form an impermeable barrier beneath the beach to form a dam. This material will also be extended to form the cove of the breakwater.

It is anticipated that sand for the surface of the beach will be dredged from the offshore sand bar. In order to limit the amount required, the bulk of the "beach section" will be made from general fill.

The above is discussed in greater detail in Volume two, section 3.2.



2.1.2 BREAKWATER AND GROYPE

A groyne will be constructed as an extension of Myilly Point to contain the sand at the northern end of the beach. A groyne length of approximately 125m will be required.

At the southern edge a breakwater similarly prevents loss of sand from the beach but serves primarily to provide wave protection to the inner harbour entrance and a safe haven and mooring area for vessels awaiting suitable tide conditions to enter the inner harbour.

The entrance to the outer harbour is approximately 150m wide, which under all conditions except those associated with cyclones will ensure the significant wave height in the navigation channel through the tidal gates would be limited to 0.4m. This would not present a hazard to vessels negotiating the channel.

Because of the protection afforded by the offshore sand bank, it has been possible to utilize armour protection which should be available from local Darwin quarries.

Refer to Volume two, section 3.3 for a detailed description of the breakwater and Groyne.

2.1.3 WATER LEVEL CONTROL GATES

An important feature of the proposed development is the water level control system. The water level for the marina would be controlled by the level of the gates and weir section shown on appendix D and Figure 3.3 Volume two. The gates would be kept open for navigation when the tide level was greater than 3.75m above Chart Datum. They would be closed on a falling tide of 3.75m and re-opened when the next flood tide reached 3.75m. In this way, at low tides, the marina basin would always have a minimum depth of approximately 2.75m.

The weir section adjacent to the gates would not contribute to the flow area at the water level at which the gates would be opened and closed. The water flowing into or out of the marina at that time would flow only through the gate area. The maximum water velocity through the open gates is dependent upon:

- . area of gates
- . water area of marina at +3.75m C.D.
- . rate of change of tide

In order to keep the current less than 1.5 kts to 2.0 kts, gates totalling 30m in width are proposed for the marina entrance.

The gates would be of two types, four narrow side gates for controlling water current velocities and a single central gate for navigation purposes. It is proposed that this gate would be approximately 10.0m wide. The gates would be operated manually or hydraulically.

At higher tides, navigation would be possible over the weir section as well as through the gates. However it is considered desirable to restrict all but the smallest vessels to the navigation channel to prevent accidents due to boats beaching on the weir.



2.1.4 INTERNAL WALLS

There will be essentially two types of wall within the inner and outer harbours:

- . rock revetment, which in some locations would have a boardwalk above it to allow pedestrian access along the harbour edge.
- . vertical walling, to provide deep mooring immediately adjacent to the inner harbour edge.

Rock Revetment

Rock armouring of the revetments against cyclone wave attack is discussed in detail in Volume two, section 3.4.

The profile of the rock revetment is designed to allow the front face to slump under wave action to a more stable alignment, as shown in Volume two, figure 3.4.

Virtually all material won from local quarries can be used on the development, resulting in economic quarrying operations.

Vertical Wall

Vertical walls will be provided around the perimeter of the inner harbour basin to facilitate easy access to berths and other marina facilities.

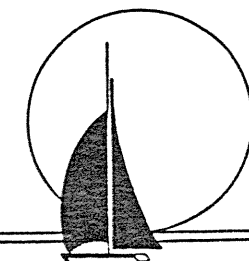
There are a number of wall types which could be used for this purpose and include sheetpiling, concrete diaphragm walls and concrete L-units. The selection of wall type would be made at the detailed design stage when the results of more detailed soil investigations are known.

2.1.5 MARINA AND COMMERCIAL BERTHS

Due to the high tidal range within the harbour, fixed level pier and wharf structures will not be suitable. Floating pontoons secured by piles will provide access to berths for all tide levels. Access to the pontoons will be via sloping ramps hinged on land and designed for a maximum grade of approximately 1:5 at low tide.

Several types of pontoon units are available as propriety items. While they will probably be suitable for the smaller leisure craft, pontoons for the larger commercial vessels and ferries will need to be purpose made.

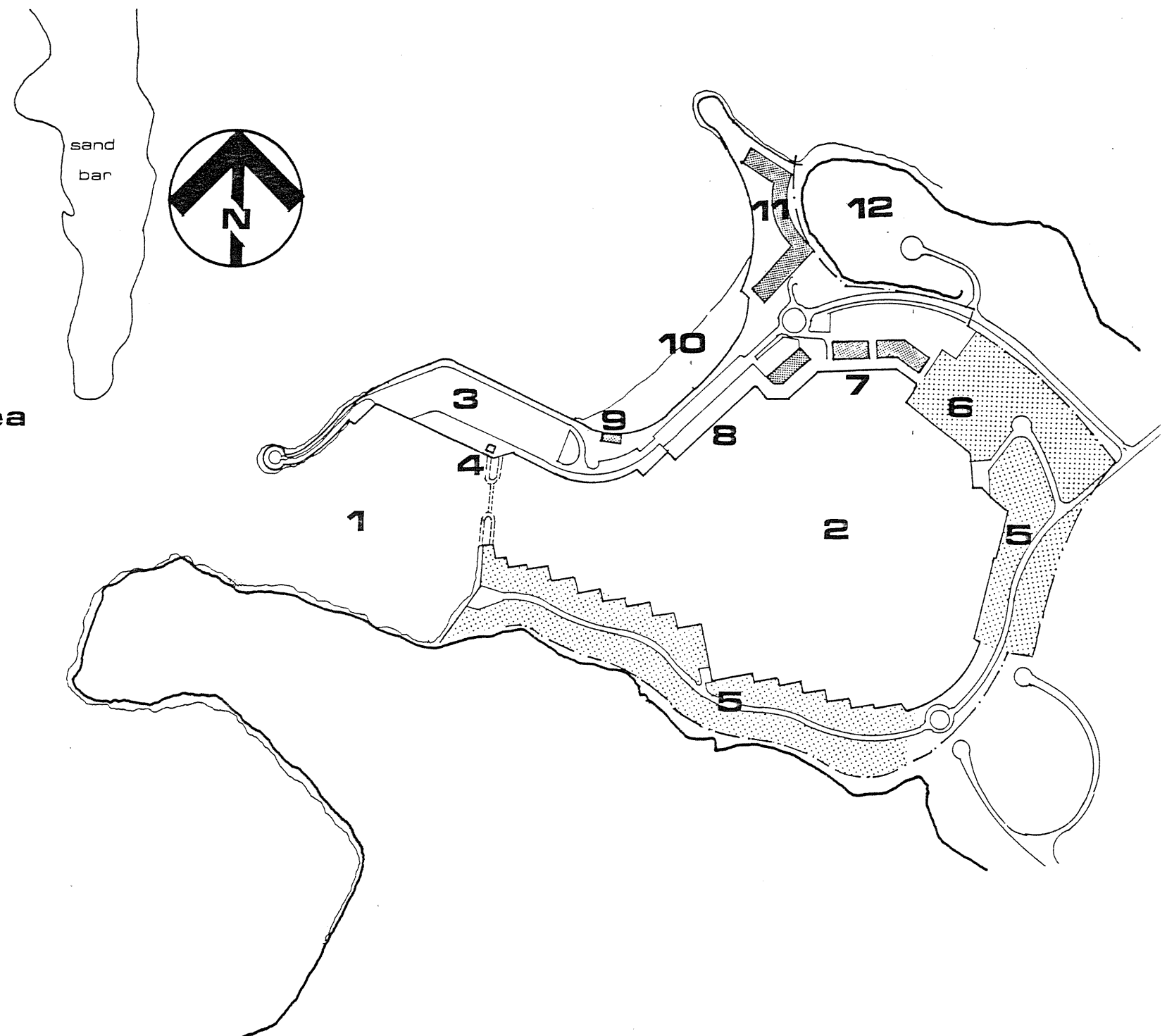
For location of the components and facilities of the Marina development refer figure 2.2.



MARINA DEVELOPMENT

Legend

- 1 outer harbour
- 2 inner harbour
- 3 public boating terminal & parking area
- 4 harbour master
- 5 residential
- 6 medium density residential
- 7 commercial development
- 8 commercial & charter boats
- 9 restaurant
- 10 public beach
- 11 resort hotel
- 12 myilly point reserve



facilities plan

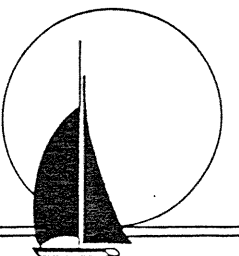
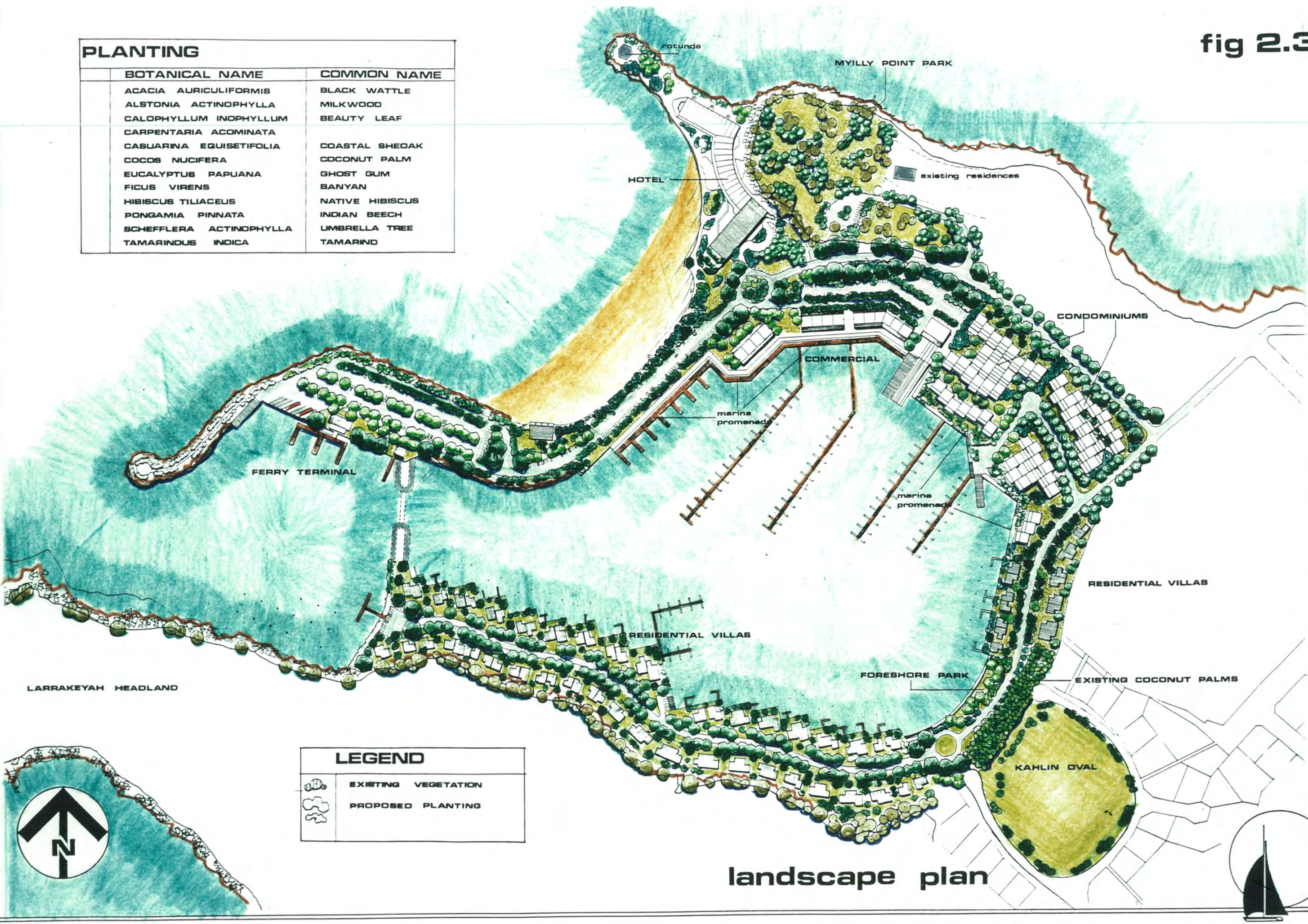


fig 2.3

PLANTING		
	BOTANICAL NAME	COMMON NAME
	ACACIA AURICULIFORMIS	BLACK WATTLE
	ALSTONIA ACTINOPHYLLA	MILKWOOD
	CALOPHYLLUM INOPHYLLUM	BEAUTY LEAF
	CARPENTARIA ACOMINATA	
	CASUARINA EQUISETIFOLIA	COASTAL SHEOAK
	COCOS NUCIFERA	COCONUT PALM
	EUCALYPTUS PAPUANA	GHOST GUM
	FICUS VIRENS	BANYAN
	HIBISCUS TILIACEUS	NATIVE HIBISCUS
	PONGAMIA PINNATA	INDIAN BEECH
	SCHEFFLERA ACTINOPHYLLA	UMBRELLA TREE
	TAMARINDUS INDICA	TAMARIND

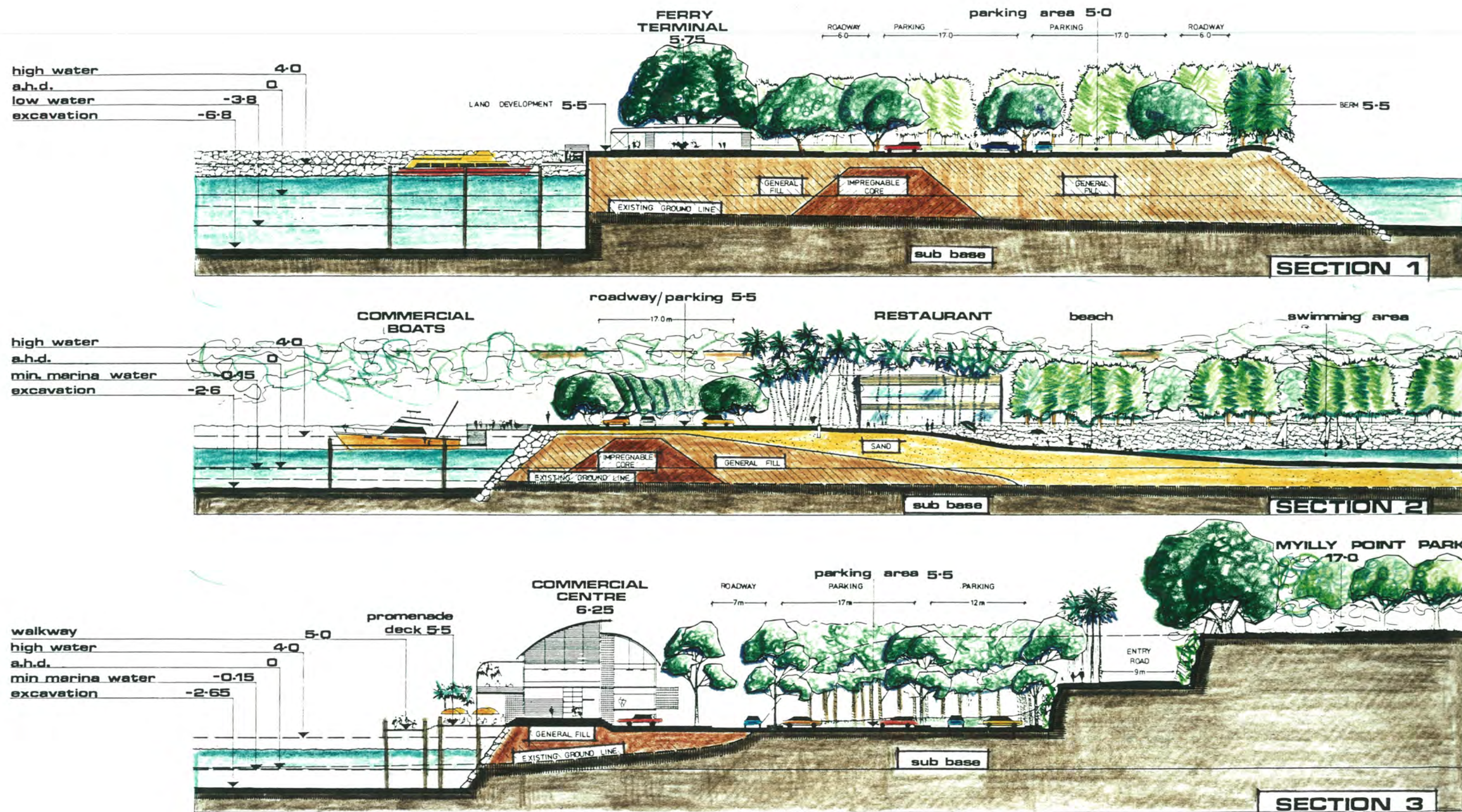


LEGEND	
	EXISTING VEGETATION
	PROPOSED PLANTING

landscape plan

DARWIN MARINA ESTATE

fig 2.5

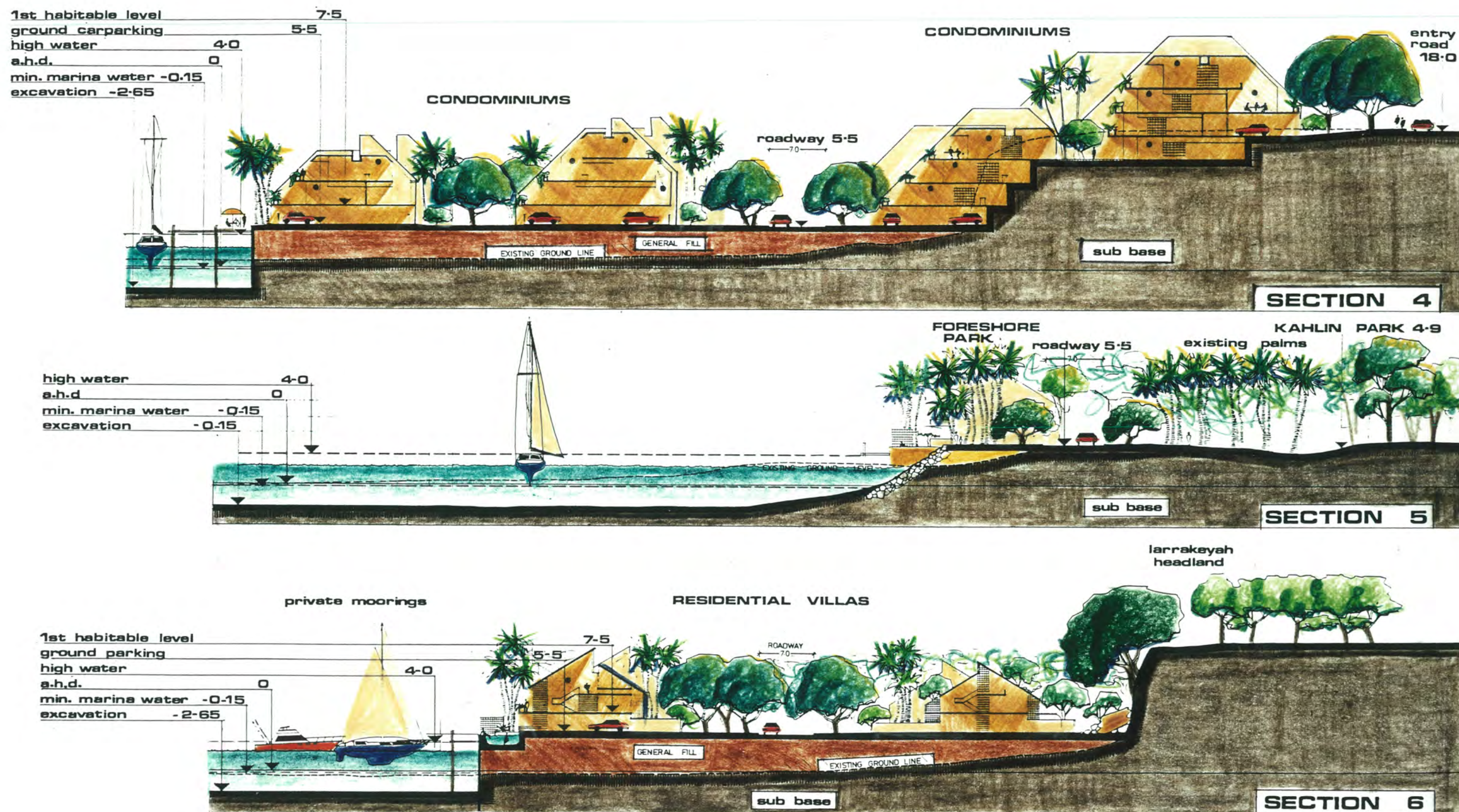


illustrative sections

DARWIN MARINA ESTATE



fig 2.6

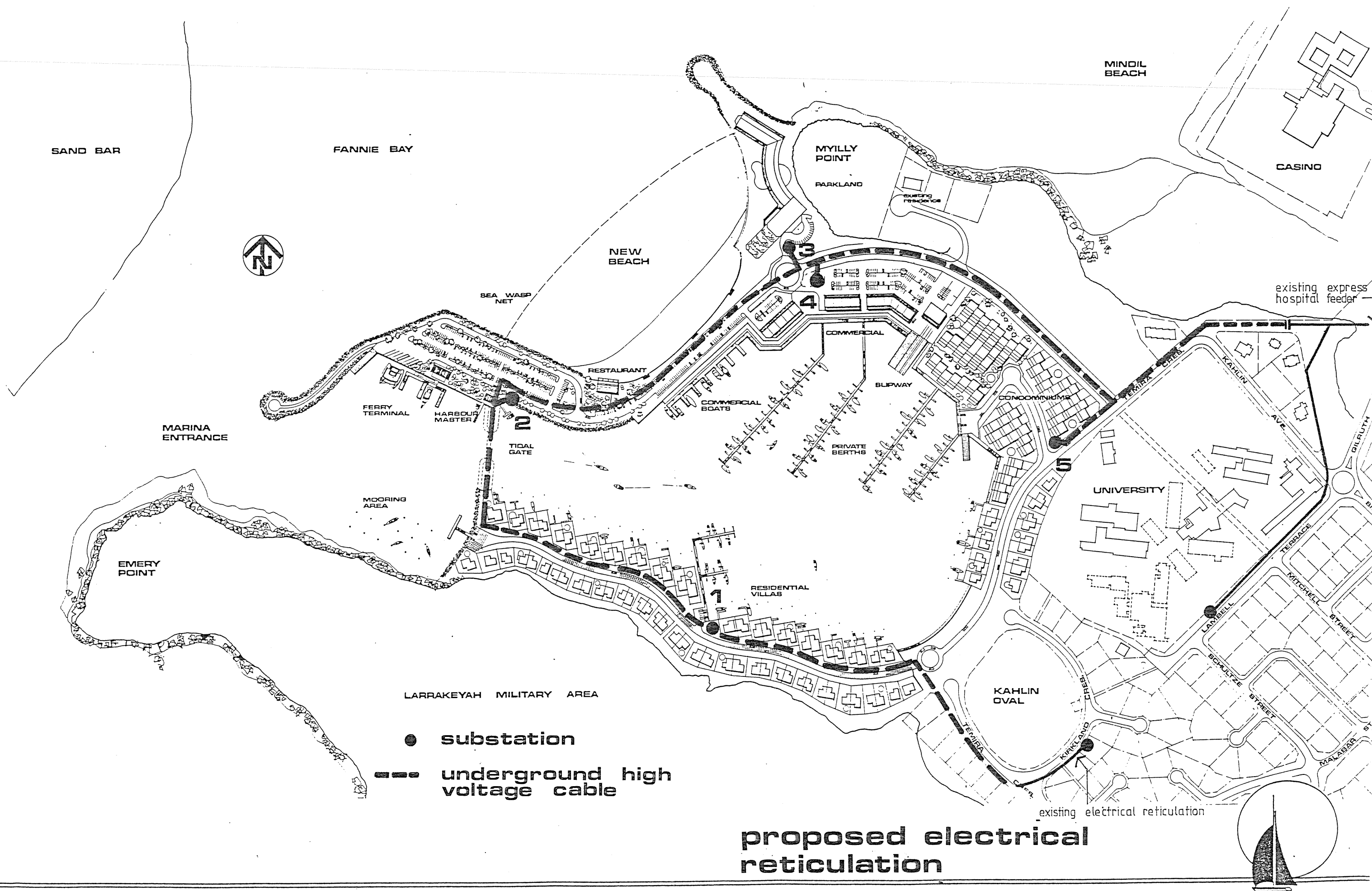


illustrative sections

DARWIN MARINA ESTATE



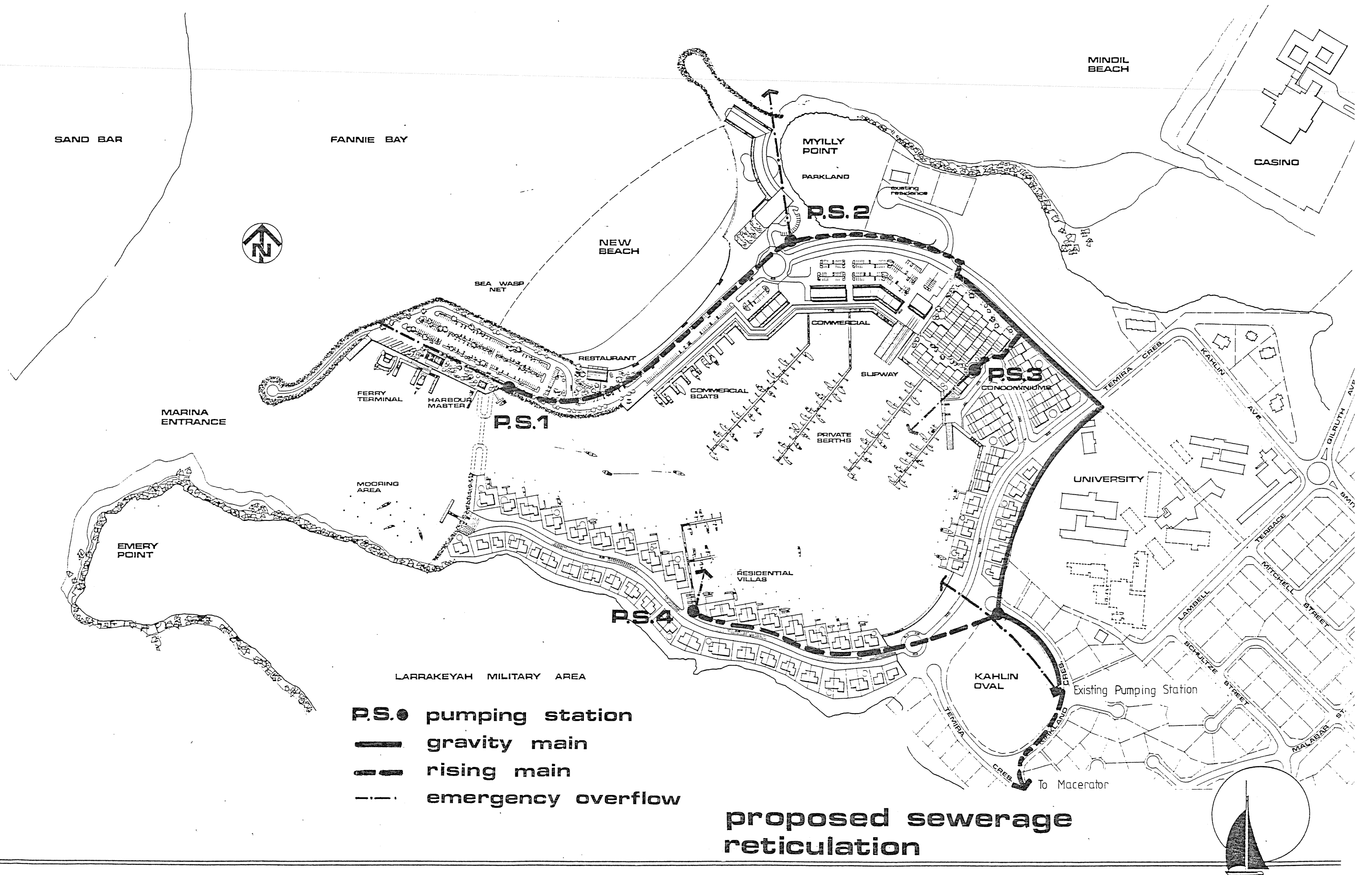
fig. 2-7



proposed electrical
reticulation

DARWIN MARINA ESTATE

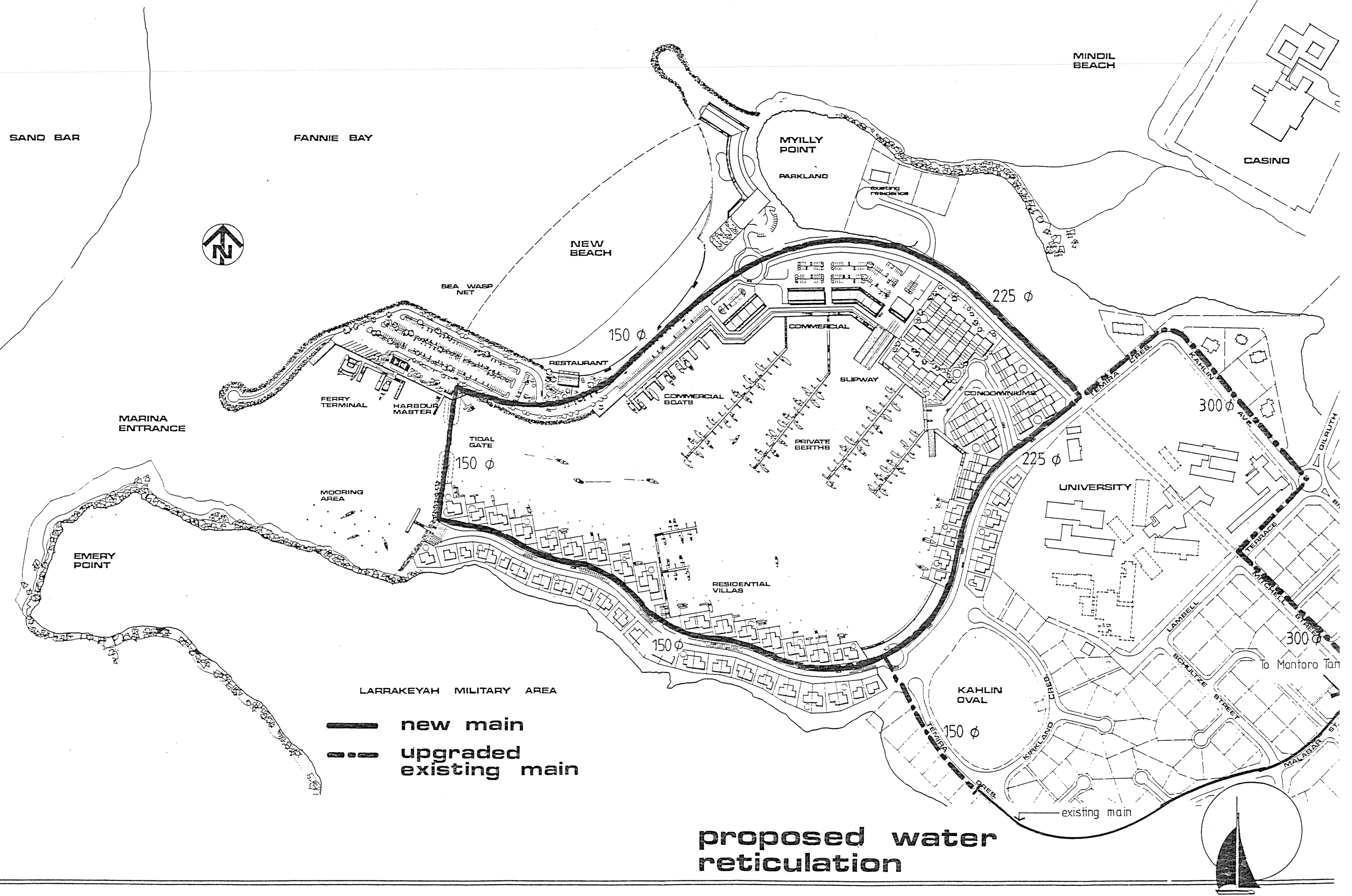
fig. 2-8



proposed sewerage
reticulation

DARWIN MARINA ESTATE

fig. 2.9



2.3 CONSTRUCTION

2.3.1 MAJOR MARINE ENGINEERING COMPONENTS

The major marine engineering components of the development are:-

- . Excavation/Backfilling to form harbour Basins and adjacent reclamation.
- . Dredging/formation of Beach.
- . Breakwater
- . Weir and Tidal Gates
- . Internal Walls
- . Mooring Facilities and Boat Ramps.

It is anticipated that the harbour basins will be excavated by land based plant working within bunds. The bunds will prevent the discharge of turbid water into Fannie Bay. The entrance channel to the harbour basin will be excavated by dredges as the water is too deep for land based plant.

Approximately 750,000m³ of material is required to be excavated to form the minor and outer harbours.

The fill obtained from the harbour excavation will be blended as necessary with shore based fill and used as general fill elsewhere on the development.

The new beach to be formed at the western extreme of the development will use sand obtained from the existing sand bar adjacent to Emery Point.

Approximately 200,000m³ of sand will be required. It is anticipated that a cutter section dredge will be used with sufficient capacity to pump the sand directly to the beach. In order to limit the amount of sand required, the bulk of the "beach section" will be made from general fill.

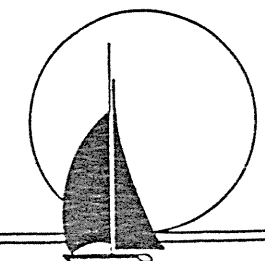
The breakwaters will be constructed from land based materials obtained in local quarries. It is anticipated that they will be the first item to be constructed on the site as they will act as temporary bunds for the excavation works.

The weir and gate structure is an essential component of the development as it will enable the marina to have permanent wet moorings.

The structure will be constructed within a temporary cofferdam mid-way through the harbour excavation works.

Internal walls will be a combination of vertical walls, revetments and boardwalks over revetments. Simple commonly used structures are proposed.

Moorings are proposed for public yachts, charter and game fishing vessels and ferries. The inner harbour has sufficient space for 300 wet berths. The number of berths provided would initially be less and the number would then be increased according to demand. Floating pontoons are proposed for all vessels. Standard "off the shelf" units are proposed for the inner harbour but specially constructed robust pontoons would be required for the ferry terminal and the game fishing and charter vessels. Access to the pontoon will be by sloping ramps hinged on land. Two lane boat ramps are provided in both the inner and outer harbour. The ramp in the inner harbour will be tidal. Construction techniques, excavation/backfilling and general civil works are described in detail in section 3.7, Volume two.



2.3.2 CONSTRUCTION WORK FORCE

The project construction work force and can be broken down into 3 categories

1. Civil construction
2. Marine dredging
3. Building construction

In all three cases it is not necessary for on site accommodation. There are no areas of specified expertise which might require imported labour, therefore where possible the contractor will be instructed to employ local labour.

Civil Construction

Plant and machinery normally used for civil construction would be used in this event. Except for some large earth moving machines which would be stationed on site and operating to move large quantities of material the remainder of plant operation would be similar to any other land subdivision exercise. Construction times would be limited to the legal hours allowed set by civil law.

Marine dredging and construction

This has been discussed briefly at section 2.5.1. Dredging will not be a great employer and its water based machinery is distant from the actual marina basin and in particular the existing residential areas of Kahlin.

Pile driving as also discussed in 2.5.1 can be a noise source. Jet piling with hollow concrete spun piles using high pressure water ejected through the base of the pile and pressed into the ground will be used where ever practical.

Other marine components such as floating berths are proprietary items bolted together and floated into place.

Building Construction

This phase will not commence until the land development is completed in approximately 12 months and will be the largest employer.

The major building and civil works components are:

Civil and Land Development (including Ferry Terminal)	\$28 million
Residential	\$19.5 million
Condominiums	\$14 million
Commercial Facilities	\$6 million
Resort Hotel	\$28 million
Landscaping & Marina Berths	\$4.5 million
Approx. Total Construction	\$100 million

A work force of 350-450 would be engaged for 2-3 years. Because it comprises of a whole range of separate buildings, a large number of separate contractors can become involved. The economic impact will be very positive for the Darwin construction industry.

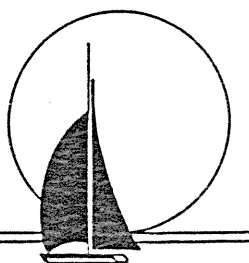
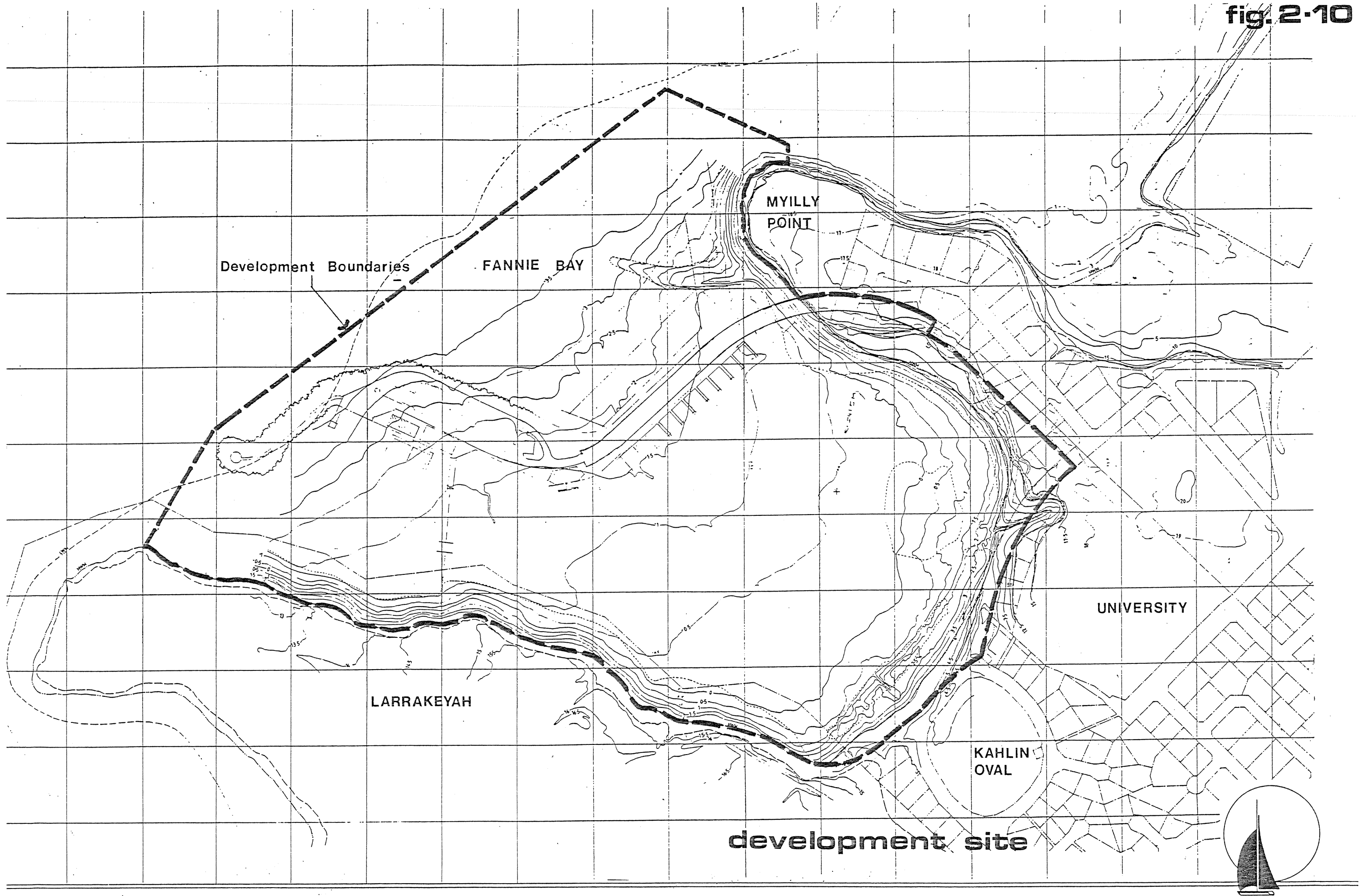


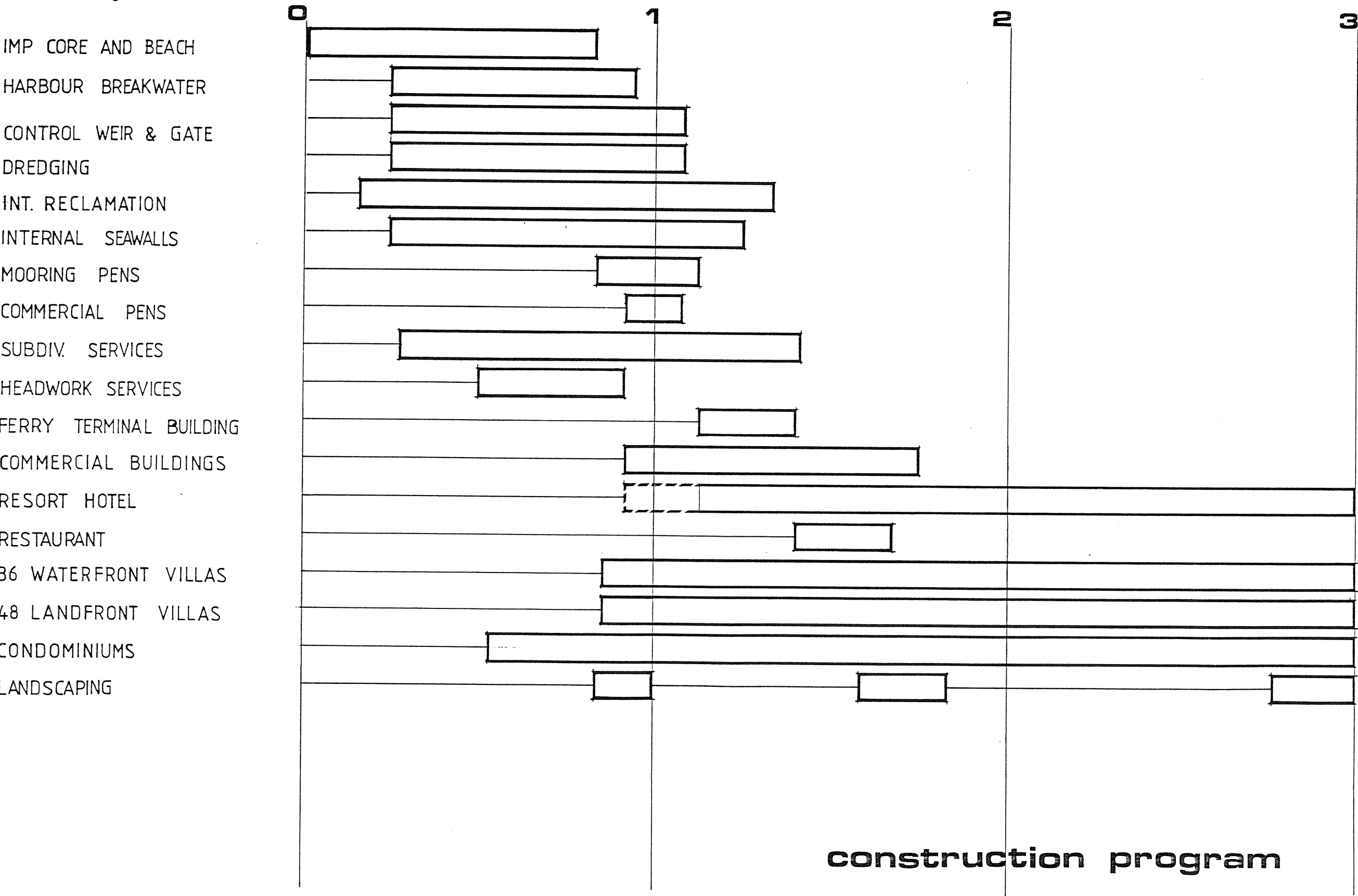
fig. 2-10



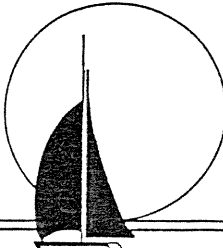
DARWIN MARINA ESTATE

fig 2-11

Activity



construction program



2.3.3 VISUAL APPEARANCE (During construction)

During construction the visual appearance will have the following effects.

Myilly Point - The main areas of construction are at the southern base of Myilly Point and will not be seen by residents of the sparsely populated Myilly Point residential area.

University Site - Construction of the main components of the marina can be seen from this site. The construction is about 500m distant from the proposed science block.

Kahlin Residents - The large landscaped grove of palm trees and beach vegetation will reduce the visual impact and glimpses of the construction will be seen by the residents. The northern Kahlin residents would see the Larrakeyah residential construction whilst the Southern Kahlin area will see the activities toward Myilly point. Generally, little of the construction activity will be seen from the residential housing surrounding Kahlin Oval.

Larrakeyah - The residential construction at the base of Larrakeyah reserve would not be visible to residents of the military reserve. Most residents are confined to the eastern and southern ends of the reserve. The activity at Myilly Point would be visible if residents frequented the Northern edges of the reserve. The recently constructed patrol boat base would have produced a much greater effect on the environment of the base.

2.3.4 PERMANENT EMPLOYMENT CREATED

A major construction project such as the marina will create major employment opportunities for local companies, skilled tradesmen and the labour force generally, not only in the construction industry but also the supporting service industry.

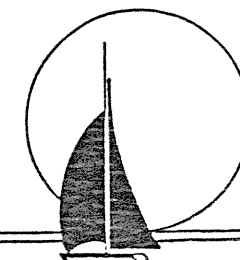
Future employment opportunities will also exist in commercial, hotel, service and marine management, following the completion of construction. It is predicted that approximately 120 full time employment positions will be created for the ongoing management and servicing of the hotel, commercial and marine facilities. The corresponding spinoff into support service industries will greatly enlarge the number of full time job opportunities for local companies.

2.3.5 MANAGEMENT (During Construction)

Operational construction management would lie with the Darwin Marina Estates P/L Project Manager. The Project Manager would call construction packages and contracts with successful tenderers would be entered into. At all times the performance, behaviour and activity will be the responsibility of the Project Manager who will ensure that all laws and statute codes of practices to Australian Standards are stringently adhered to.

Contractual obligations shall include controls over the contractors to ensure that construction noise, dust, traffic management, water pollution and any other factor influencing the existing environment is kept to a minimum.

Refer to section 2.5 for a more detailed explanation of the potential environmental impact.



2-4 MYILLY POINT HOTEL

The need to provide a Northern breakwater to contain and protect the beach has produced a site which lends itself most suitably to a resort hotel. The hotel suits part of the total infrastructure catering for tourists and providing for their recreational needs with the marinas commercial and water activities. The resort has direct access to the beach by way of steps from its garden terrace and would provide a type and level of accommodation not available in Darwin at present, 180 rooms would be provided. A sensitive architectural solution ensuring the massing and size of the development does not overpower the site and ensure a moulding into the vegetation will be created. The existing cliff face will not be disturbed and apart from clearing the base rubble additional landscaping will ensure a sensitive marriage between the building and its environment. The Northern wing of the building has a totally open undercroft and occupies only one level of accommodation suites.

The site would be serviced as a normal lot with power, sewer and water as part of the land development, as shown in 2.2 - Infrastructure Requirements.

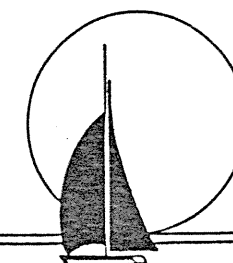
No unusual construction methods are required and access to the site would be by normal road access being provided with the development.

Visual Appearance - The drawings at appendix H and J show the visual appearance. This is also outlined on the model and it can be seen that the majority of the building is below the cliff face with its roofs angled to the eye view line to reduce the impact from the cliff top. The materials chosen will be light to blend with the colours of the porcellenite rock of the cliff.

The Southern entrance wing is 5 levels high and its resultant roof is no higher in elevation than the existing residence on Myilly Point.

Landscaped and water gardens will be a feature of the hotel with swimming pools and outdoor decks stepping down to the beach.

Construction Phase - will be similar as described in 2.3, the construction is not of a heavy nature. Most of the building is low level residential type and the 5 level wing would be of reinforced concrete construction.



2.5 ASSESSMENT OF POTENTIAL ENVIRONMENTAL IMPACT

2.5.1 Tidal Currents

The development is to be located within the coastal compartment of Fannie Bay, between Emery and Myilly Points. There is very little flow of tidal currents into and out of Cullen Bay so that the development will have only a very minor effect on the water circulation patterns in the vicinity. The main body of tidal flow is seaward of Emery and Myilly Points.

In order to minimize any effects on the existing tidal currents, the seaward extent of the development has primarily been limited to a line joining Emery and Myilly Points.

The groyne extending Myilly Point will however extend into the main tidal flow but its effect would be such as to cause only a small localised increase in tidal flow velocities. The maximum loss in cross section area available for tidal discharge would be approximately 10%. A similar increase in velocities immediately offshore of the groyne would result. This small increase in velocity is not expected to result in anything other than minimal changes to the bathymetry immediately offshore of the groyne.

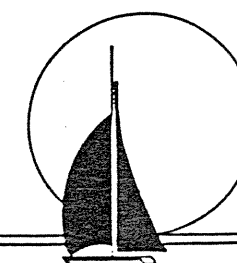
2.5.2 Water Levels

As discussed in section 2.4, Volume two, the design water levels during cyclones for the various components of the proposed development have been selected based on the findings of the "Greater Darwin Surge Study" and are as follows:-

- . For surge plus tide effects RL +8.5m C.D.
- . For surge plus tide, wave
set-up and surf beats effects RL +9.5m C.D.

The design water level for wave set-up and surf beat effects of RL +9.5m C.D. were used to determine the design of the new beach. The minimum design level of RL +9.5m C.D. has also been established for all construction of buildings in the development.

Design waves for the structural design of the breakwater are non-breaking waves (refer Section 2.5.2, Volume two consequently there is no wave set-up or surf beat to increase the water level on the face of the breakwater over and above that due to surge and tide alone. The water level used for breakwater design has therefore been taken at RL +8.5m C.D.



2.5.3 Wave Climate

Under normal conditions, vessels negotiating the entrance to the outer harbour are not expected to experience any difficulties. For more than 90% of the time the significant wave height would be not more than 0.5m. During the more severe storms that may be expected once or twice a year, the significant wave heights are less than 1.0m. during such storms, waves penetrating the outer harbour will have wave heights less than 0.4m at the water level control gates and will therefore not present a hazard to vessels entering the inner harbour.

The proposed groyne and breakwater in the marina development will not affect the wave climate at the nearby Mindil and Vestey's beaches, since the development will be confined to within a line joining Emery and Myilly Points.

The dredging of 200,000m² of sand in a 450m long slice from the south west edge of the sand bar will have negligible effect on the wave climate. This is fully explained with supporting wave climate tables and refraction coefficients in Volume two of this report by Riedel and Byrne, Consulting Engineers Pty Ltd.

It is established that dredging of up to 400,000m² of sand from the sand bar will have negligible effect on the Mindil Beach wave climate.

2.5.4 Coastal Processes

The coastal processes at work in this part of Fannie Bay are governed by the interaction of the strong tidal currents and the inshore wave climate. As discussed in Volume two, sections 4.1 and 4.3, the development in Cullen Bay will have no effect upon either of these two components or the existing Mindil and Vestey's beaches.

Cullen Bay does not contribute any significant material to the local sediment movement patterns (refer Volume two, section 2.6). There is little supply of Cullen Bay sediment to the accreting sand bar.

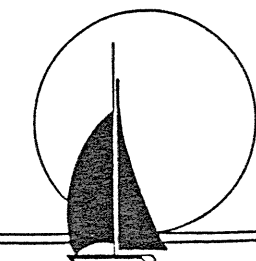
It is proposed to dredge material from the southwest edge of the offshore bar to provide sand for the new beach. Mathematical modelling techniques (described in Volume two, section 2.6) were used to determine what effect this might have on nearby Mindil Beach.

Figure 4.1, Volume two, show the results of the modelling and indicate that provided the material is removed as a slice from the seaward side of the sand bar, no change to the wave climate or longshore sediment transport will result. No realignment or loss of beach sand from Mindil Beach will therefore result as a consequence of removing sand from the bar.

The removal of a slice from the sand bar will in no way jeopardise its existence. The bar is growing significantly each year and the material removed will quickly be replaced.

In summary, therefore the impact of the marina construction on the coastal processes within the area is expected to be minimal due to the following:

- . The development is contained within a closed coastal compartment and will have no influence on sediment paths elsewhere.
- . The development is restricted behind the line between two headlands and therefore has minimal effect on tidal streams.
- . Beach material removed from the sand bar will be quickly replaced from natural sources without any deleterious effects on adjoining areas.



2.5.5 Water Quality

Water quality within the marina must be such that the following beneficial uses would not be adversely affected:

- . Occasional human immersion and wading
- . Boating
- . Adjacent development
- . Passive recreation (which can be affected by odour, insects, rubbish).

In assessing the water quality of the proposed development, several factors must be considered. They are:

- . quality of source water
- . nutrient and pollutant inputs
- . water mixing and exchange

These aspects are examined in this section.

Source Water

The source water for the marina is that in Port Darwin. This water is suitable for the four beneficial uses listed above since the area is frequently used by locals and visitors for recreational activities including:

- . boating
- . fishing
- . wading and swimming
- . picknicking

It is therefore concluded that the source water is of a high standard.

Nutrient and Pollutant Inputs

The proposed development would not lead to nutrients and pollutants entering the marina or adjacent waters provided the development has the following features to handle and dispose of any materials that would adversely affect the water quality:

- . deep sewerage
- . household and garden rubbish disposal in appropriate refuse sites.

In addition, on board living within the marina is restricted to short periods for visiting vessels only and all vessels will be required to have holding tanks for waste.

Water Mixing and Exchange

There are a number of mechanisms that can cause water to mix and circulate in a harbour system. These include winds, water level variations, boat traffic and density currents. In the proposed development, winds and water level variations would be the more important factors.

Winds

Winds would have two significant effects on the marina: they would cause waves that would prouce some vertical mixing of the water body and they also set up drift currents. The alignment of the marina takes full benefit of prevailing winds from the south-east through to the north-east.

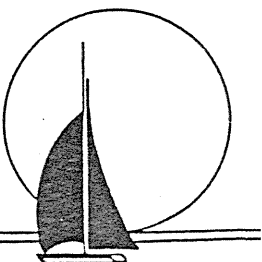
Tidal Exchange

The typical tidal range during one day is about 3.7m. The inner harbour basin would have a tidal prism ratio of about 0.42 for the normal daily tidal range and normal operation of the water level control gates. This means that about 42% of the water in the harbour at high tide would flow out of the harbour by the low tide.

Conclusions

The water quality in the marina will not adversely affect the beneficial uses of the water body and adjacent waters, provided the necessary precautions are taken.

The nutrient and pollutant inflow will not be significant and there would be substantial flushing and water circulation caused by tides and winds.



2.5.6 Siltation

The sheltered waters of the harbour will provide an opportunity for any fine sediment in suspension to settle to the bottom.

The amount which will drop out of suspension will determine how frequently maintenance dredging operations need to be carried out to maintain the design depth in the basin. The siltation rate will depend upon a number of factors:

- . Density and size of the suspended particles
- . Plan area of the basin
- . Tidal range

For a detailed description of water quality, water samples and grading analyses, refer to Volume two.

2.5.7 Construction Phase

The marine components of the development which will have an effect on the environment are:-

- . Importation of fill and Armour Rocks
- . Marina Excavation Works
- . Sand Dredging Works
- . Vertical Walls and Mooring Piles.
- . Maintenance dredging.

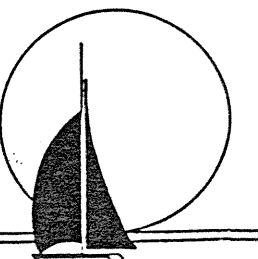
It will be necessary to import a considerable quantity of fill and armour rocks onto the site. This will result in an increase in truck traffic between the site and local quarries. The effect of this traffic increase can be controlled by the selection of specific routes, strict speed restrictions and fixed work hours. Damage to roads that may be caused by this traffic would be repaired at regular intervals.

It is anticipated that the marina excavation works will have little impact on the local populace. The construction plant will remain on the site during the construction program. Some noise is inevitable but should not be excessive provided machine silencers are maintained in good order. The Project Manager will ensure the any contract awarded for this work will clearly state that all plant and equipment will be fitted with effective silencers.

Bunding during excavations will prevent turbid water from entering Fannie Bay. Short-term discolouration will occur when the channel is excavated between the outer harbour and deep water. However this is unlikely to be anymore severe than the turbidity experienced in the waters of Port Darwin during the wet season.

Minimal noise and water discolouration will occur during sand dredging and placement operations. Samples of sand taken from the sand bar indicate that it has a low fines content.

Pile driving works required for vertical walls and mooring piles has the potential to cause considerable noise, however purpose made 'quiet' hammers are available and would be used. The Project Management will also ensure that the noise level emanating from the pile driving work will not exceed the noise levels tabulated in the appropriate Australian Standards Association noise suppression regulations. A strict time schedule for piling works would be enforced to ensure pile driving work occurs during daylight hours only, 6 days a week, excluding Sundays. This clause will form part of the contractual obligations imposed on the successful contractor.



2.5.8 OPERATIONAL PHASE

Environmental Effects

The marina is to be located within the coastal compartment of Fannie Bay, between Emery and Myilly Points. There is very little flow of tidal currents into and out of the Cullen Beach vicinity so that the development will have only a very minor effect on the water circulation patterns in the vicinity. The extension of Myilly Point with the construction of a groin will reduce the available flow area for tidal currents flowing between the coastline and the offshore sand bar only slightly (by approximately 10%). The subsequent increase in flow velocity will be a localised effect and not sufficient to cause any scouring of the adjacent sand bar.

The removal of sand from the offshore sand bar does not effect the wave climate on the northern Vesteys and Mindil Beaches. Therefore the coastal processes at work on these beaches will not be affected by the development.

Cullen Bay does not contribute any significant material to the local sediment movement patterns except during severe storms when some of the fine surface sediments are removed from the bay by wave action and subsequently washed into Port Darwin by the tidal currents. There is no direct supply of Cullen Bay sediment to the accreting sand bar.

The loss of material to the coastal system by the construction of a marina within Cullen Bay would therefore be minimal and have no effect on the sand bar formation.

The barrier provided by the breakwater and beach will prevent waves entering the marina during storms. All marina facilities such as moorings, access jetties and fender systems will be designed to accommodate vessels at the increased water levels due to storm surge.

Water quality within the marina would deteriorate if the amount of nutrient entering the water created a demand for oxygen greater than could be supplied by the water body. Two aspects are therefore important: the first that the nutrient inflow must be kept low; the second that available oxygen must be maintained by adequate water exchange with the ocean.

Appropriate measures will be taken into control the input of contaminants to marina waters and are discussed in Section 2.6.1.

There are a number of mechanisms that can cause water to mix and circulate in a waterway system. These include winds, water level variations, boat traffic and density currents. In the proposed development, winds and water level variations would be the more important factors.

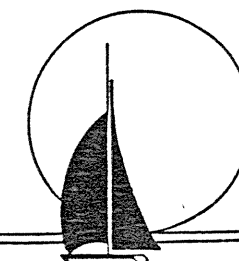
The alignment of the marina has been chosen to take full benefit of the prevailing winds from the south-east quadrant.

The typical tidal range at Darwin during one day is about 4.2 m which is sufficient to ensure substantial exchange between the water in the marina and that in the ocean.

At present Cullen Beach has limited recreational opportunities due to the nature of the surface sediments and the fact that most of the bay is left dry at low tides.

The perceived benefits of the development are as follows:-

- . Safe anchorage. The design of the marina basin and its entrance channel will provide access to a safe anchorage for craft with a draft up to 2.75m thereby catering for a broad range of boat types and sizes. The anchorage will also provide most of the facilities required of a modern marina complex. The marina will not only offer shelter to locally based leisure craft but will provide a base for commercial vessels.
- . Permanent Moorings. The harbour will provide a variety of mooring facilities which will enhance the recreational activities of people in the Darwin region.
- . Boat Ramps. This development will provide safe all weather, maintenance free boat ramps which will significantly enhance existing boat launching facilities.
- . Ferry Terminal. The layout of the marina can easily incorporate a ferry terminal which will improve public access along the Darwin foreshore.



2.5.9 MANAGEMENT STRUCTURE

Marina Management

Harbour Master: Management of the marina harbour will be the responsibility of a full time professional Harbour Master and staff.

It is intended the Harbour Master will have the authority and training to co-ordinate and initiate safety, environmental conditions and procedure for accidents which may occur, within the Marina. He would also be given the authority to control behaviour of the permanent and visiting users.

In keeping with the high standard expected of a premium marina complex, the Harbour Master will control and police the use of the inner and outer harbours to ensure that both commercial and leisure craft comply with regulations governing the use and maintenance of the marina.

Living aboard boats will be strictly limited to short periods for visiting vessels only and all vessels will be required to have holding tanks for waste and be required to discharge through the marina pumpout system.

The Harbour Master will ensure that boats are correctly moored and in a tidy state. The Harbour Master will also be responsible for the prevention of floating debris in the harbour.

Speed limits and undue wave motions will also be strictly enforced and guarded against.

Specific matters which may arise:

a) Fire

Fire protection in the form of hydrants and hose reels will be provided throughout the subdivision and on the berths. There are strict codes and rules which apply to both land development, floating marinas and berths, all these will be strictly adhered to, ensuring safe and efficient fire control.

b) Spillage - fuel, oil and other

Accidental discharge of fuel into the marina will, in most cases flush automatically with the great volumes of water changes due to Darwin's large tides. In the event of major discharge, absorbent material, containment procedures and/or dissolving agents and detergents will be used to remove the spillage from the marina. The Harbour Master's tender will be equipped to undertake these incidents.

c) Sewerage & Waste

No marina toilets or waste from moored boats will discharge into the marina basin. The craft will seal their sea cocks and tankage on board which can be pumped out at certain locations within the development. Direct connection to pump-out ports for larger boats will also be provided. This trend is becoming mandatory overseas and provision for this facility will be made.

d) Failure of Tidal Gate

The tidal gates will be both mechanically and manually operated. History has shown that similar systems operating in tidal areas of northern Europe and similar places, have a low level of failure.

In the event of a gate failing to close due to an object floating through the gate and being trapped, the water level is able to drop to the gate base approx. 2m below the marina design level. If the obstruction was small it may not drain the basin for the short period the tide is below the design level. However if the obstruction was serious and allowed the basin to drain, the water levels at the entrance and commercial berths would retain approx. 1.5meters of water. This should be sufficient for most craft to settle on the bottom with minimal effects. The areas closer to Kahlin Oval could dry and these craft generally smaller, would simply settle on the bottom as they do in Fannie Bay outside the Darwin sailing club at this time.

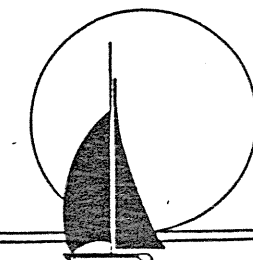
Commercial and Residential Management

The management of the commercial and residential areas will be the responsibility of a management body consisting of Darwin Marina Estate land owners and commercial owners.

This body will have responsibility and maintenance of standards both environmentally and aesthetically.

Individual building designs will be vetted by the management body to ensure that compliance with overall design philosophy of the precinct is maintained. Restrictive covenants, such as those used at Northlakes and Desert Springs Country Club Estate, will ensure legal control over the approved range of building materials, fences, out buildings etc to guarantee a high standard of construction.

Individual lot freehold ownership will be no different to any other subdivision in Darwin. The individual will be responsible for payment of council rates, sewer and water rates, however, an extra rate will be levied on each block and user to fund ongoing maintenance of marina, tide gate, Harbour Master management etc, again to maintain the high standard expected of a premium marina complex.



2.6 ENVIRONMENTAL SAFEGUARDS

2.6.1 MARINA AND RELATED ASPECTS - SUMMARY AND CONCLUSIONS

The tidal current regime in the vicinity of the development has been identified and is discussed in detail in Volume two of this report. The major feature is that there is no significant flow of tidal currents into Cullen Bay, the main body of flow is offshore to the Emery and Myilly Point headlands.

In order to minimize any effect on existing tidal currents and coastal processes the seaward extent of the development will be confined to a line joining Emery and Myilly Point. The groin extending Myilly Point will encroach into the main tidal flow but its effect will be such as to cause only a small localised increase in flood tide flow velocities.

A beach is to be constructed to form part of the barrier protecting the marine from ocean waves. It is proposed to dredge material from the offshore sand bar to provide sand for the surface of the beach.

It is further proposed that this material would be removed as a 50m wide, slice from the southwest edge of the bar for the following reasons:-

- . Removal of material from the southern end of the bar ensures that there will be no effect to the wave conditions and sediment movement on the northern Vestey and Mindil Beaches.
- . The seaward edge of the bar extends to a greater depth than the landward edge, so the required volume of sand can be removed in a relatively thin sliver.
- . This thin sliver will not reduce the width of the bar to such an extent that it cannot still provide protection at the site from large waves.
- . Natural accretion rates indicate that the sand bar would replenish the material dredged from it over a period of approximately 5 years.

To cater for the high tidal range, floating berths would be used to provide moorings in the marina. These berths would be moored with piles.

Water quality in the marina can be expected to be high provided the input of nutrients and pollutants to marina waters is controlled. The surrounding development would have features to handle and dispose of any materials that would adversely affect the water quality, such as sewerage household and garden rubbish disposal. No permanent onboard living will be permitted within the public marina.

Sewerage pump outstations will be provided for visiting yachtsmen and some of the commercial berths.

Management and maintenance of the marina, including the water body, will include the following:

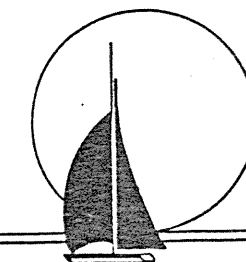
- . removal of floating debris
- . maintenance of the breakwaters and beach for such period as may be agreed between the proponent and the appropriate Government agency.
- . Maintenance of the marina basin and entrance channel to the design depths.
- . ensuring compliance with the appropriate water quality standards, including adoption of any remedial measures necessary to meet such standards.

The maintenance of water quality will primarily be achieved through minimising the entry of pollutants and pathogenic organisms into the marina waters.

Due to the large tidal range of 5.5m (spring) to 1.9m (neaps) the exchange of marina and ocean waters will be adequate to prevent serious decline in the quality of the marina waters. Despite this, discharge of litter, hydrocarbons and sewerage into the marina will be prohibited. Waste disposal facilities such as garbage bins and sewerage toilets will be provided around the marina.

Responsibility for the environmental monitoring and management programme will be with the marina operator. The operator will be responsible for the day-to-day maintenance, monitoring and long-term management.

There would appear to be no coastal or marine engineering reason why the development should not proceed.



2.6.2 CONTROLS TO REDUCE OR ELIMINATE POTENTIAL ENVIRONMENTAL IMPACTS

DURING CONSTRUCTION

The Darwin Marina Estates Project Manager will be responsible for maintaining and applying controls initiated to reduce or eliminate potential environmental impacts.

Where necessary controls will be inserted in the negotiated contracts and will form part of the contractual obligations of the selected contractor.

The construction of the marina components of the development that will have an effect on the environment are:-

- . Importation of fill and armour rock
- . Marina excavation works
- . Sand dredging works
- . Vertical walls
- . Maintenance dredging

The following controls and/or methods to reduce the environmental impact will be as follows:

Importation of Fill and Armour Rock

The importation of the above materials onto the site will result in a considerable increase in truck traffic in the area. To minimise the effect that this traffic will have on the local populace, it is suggested that specific haul routes be nominated and strict speed restrictions be enforced.

A detailed survey of road conditions on the nominated routes would be undertaken prior to the start of the development construction. Any damage caused to the roads by the construction traffic would be repaired on a regular basis.

Marina Excavation Works

It is not anticipated that the marina excavation works will have a major impact on the local environment. All construction plant will remain on the site during the entire works. To ensure low noise levels it will be clearly stated in any contracts awarded for this work that all plant and equipment must be fitted with effective silencers.

The formation of bunds around areas being excavated will prevent turbid water from entering Fannie Bay. Short term discoloration will occur when the channel is excavated between the outer harbour and deep water. However this is unlikely to be anymore severe than the turbidity experienced in the waters of Port Darwin during the wet season.

Sand Dredging Works

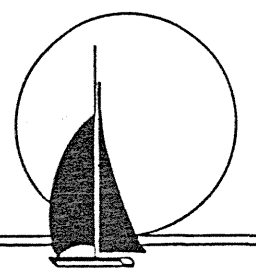
Minimal noise and water discoloration will occur during sand dredging and placement operations. Sediment from the Cullen Beach locality does not contribute any significant material to the local sediment movement patterns.

Vertical Walls

There will be some noise associated with the pile driving works, however every means available including limitations on working hours will be enforced by contractual obligations and the Project Manager to reduce the noise level to a minimum. Refer to section 2.5.7.

Maintenance Dredging

Results of tests on the sediment in the locality of the marina harbour suggest that the harbour basin would experience siltation rates less than 0.01m/year, requiring maintenance dredging at intervals in excess of 15-20 years.



OPERATIONAL PHASE

General

Due to the minimal flow of tidal currents into and out of the Cullen Beach there will be very minor effects on the water circulation patterns in the vicinity.

The extension of Myilly Point with the construction of a groin will reduce the available flow area for tidal currents flowing between the coastline and the offshore sand bar by approximately 10%. The subsequent increase in flow velocity will be a localised effect and not sufficient to cause any scouring of the adjacent sand bar.

The wave climate on the northern Vestey's and Mindil Beaches will not be affected by the removal of sand from the offshore sand bar.

There is no direct supply of Cullen Beach sediment to the accreting sand bar. Therefore, construction of the marina will have no effect on the sand bar formation.

The alignment of the marina takes full benefit of the prevailing winds from the south-east quadrant. The 4.2m tidal range is sufficient to ensure substantial exchange of water between the marina and ocean.

The existing limited recreation facilities of Cullen Beach due to the surface sediments and low tide conditions will cease to exist and will be replaced with the following perceived benefits:

- . Safe Anchorage
- . Permanent Moorings
- . Boat Ramps
- . Ferry Terminal
- . Recreational Facilities for Youth Groups
- . A New Family Beach

Marina Management

A full time professional Harbour Master will have the authority to control the marina harbour environment.

The Harbour Master will ensure that all vessels comply with the regulations governing the use and maintenance of the marina. In particular, he will ensure that:

- . Vessels do not discharge waste into the marina basin.
- . That living on board moored vessels will be restricted to short periods for visiting vessels only.
- . Speed limits and undue wave motions will be strictly enforced.
- . Precautions are taken to contain and remove spillage of fuel, oil and other accidental discharges should they occur.
- . Strict fire protection precautions are taken.

Commercial and Residential Management

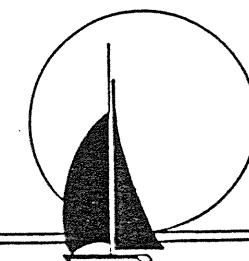
The management of the commercial and residential areas will be the responsibility of a management body consisting of Darwin Marina Estate land owners and commercial owners.

This body will have responsibility and maintenance of standards both environmentally and aesthetically.

A rate will be levied on each block and user to fund ongoing maintenance of marina, tide gate, Harbour Master management etc, again to maintain the high standard expected of a premium marina complex.

Services

Permanent services such as electrical power, sewerage, water and stormwater reticulation, will all comply with the standards laid down by the relevant authorities.



2.7 VISUAL APPEARANCE (ON COMPLETION)

General

The visual appearance on completion will be one of low key buildings sculptured to suit the land contours and sited amongst a landscaped setting.

Access to the waterfront will be maintained in the public areas and except for Cullen Beach, car parking will be situated behind public buildings ensuring no cross flow occurs between vehicular and pedestrian traffic.

The Marina complex will be overlooked by Myilly Point Park. Extensive landscaping to Myilly Point Park along with the enhanced view below will encourage greater use of this public facility. The new Cullen Beach in its cove-like setting will be an added attraction for families with young children.

Residential Areas

The two groups of residential villas, separated by the foreshore park, are positioned on the South and South East side of Kahlin Oval, allowing uninterrupted views of the main body of the Marina.

The residential villas south of the Marina are set below the Larrakeyah Headland, the front villas overlooking the waters edge.

The residential villas along the South East side of the Marina are set below the proposed university, again with the front villas overlooking the waters edge.

The condominiums are grouped generally North East of the Marina overlooking the private mooring berths.

The condominiums will follow the land contours and step down to the waters edge.

Resort Hotel

The resort hotel is situated at the end of Myilly Point, below the Myilly Point Park. The design is such that access is provided under the connecting spine between the two spurs of the hotel to the Myilly Point cliff face behind, this area is to be landscaped with water features, enhancing the natural vegetation that exists on the cliff face. The spine maintains a low profile, supporting one level of resort apartments over. The East end of the spine will contain five levels of resort apartments, each level steps back effectively reducing the building mass and allowing a large open deck at each level to overlook the Cullen Beach and Marina. Refer appendix H and J.

Commercial Development

The commercial development consists of low level two storey structures adjacent to the timber boardwalks of the Marina with adequate parking to the rear.

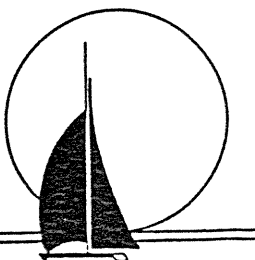
The building style with its sail form like roofs will continue the general nautical theme and harmonise with the human scale maintained throughout the Marina.

Headland

The visual appearance from Darwin Harbour is designed to blend and appear as an extension of the natural land.

The man made breakwater with the new Cullen Beach and protecting rock headlands will appear as an extension of the existing environment.

The significant landscaping and tree planting will ensure that the harsh materials used on the rocky headland soften the visual impact to the total project.



SECTION III
APPENDIX

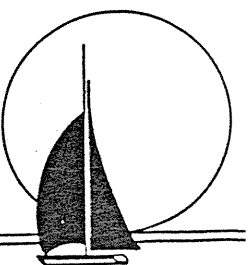


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Part 2 Geographic Elements

Department of the Northern Territory
Land Conservation Section
Land Resources of the Darwin Suburban Area
Soils and Geological Map

Hearne, D.A.
Trees for Darwin and Northern Australia
Australian Government Publication Service,
Canberra 1975



WOODHEAD AUSTRALIA - ARCHITECTS

Woodhead Australia - Architects is one of the largest and most technologically advanced Architectural firms in Australia with offices in Darwin, Adelaide, Port Douglas, Perth and Alice Springs. It comprises a total staff of some 140 persons operating in a supportive manner between offices for the various fields of expertise required for any specific project.

The Darwin Company has recently been strengthened by the merger of Hunt Giles Woodhead Pty. Limited with Hans Vos Planning Consultants Pty. Limited to form a Professional group of Architects, Planners, and Designers employing some 32 people in their Darwin office.

This firm is a natural selection for the provision of professional design and Architectural and Planning Services for this project because of their possession of the following skills and abilities required for a project of this nature:-

- . Detailed knowledge of the site and project requirements
- . Existing conceptual, design approach developed and accepted by the community for the Marina Development
- . Previous experience in the design and development of coastal residential/resort developments such as under construction or completed in Port Douglas and South Australia
- . Offices already established in Darwin for over 25 yrs
- . Established good relations with the various authorities having jurisdiction over the development
- . Experience in tropical Architecture developed by the Principals and staff who are permanent residents in Darwin
- . Available strong local resources of the company
- . Financial capacity to carry out the project
- . Experience in working with major financial and corporate groups in the development work of this nature and an understanding of the aims and expectations
- . Experience and ability to co-ordinate and direct the wide range of specialist consultants who will be required for the design and documentation of marine structures, building structures, and all essential services (sewer, water, stormwater, electrical, communications, mechanical, etc)
- . Detailed appreciation and understanding of the environmental requirements and sensitivities of the area involved
- . In-house qualified specialists in Landscape Architecture with local knowledge of plant types and tropical landscaping design
- . Experience in Construction and Contract Administration procedures
- . Ability to draw on experienced and specialist staff from other offices at short notice when work peaks and demands require strict timetables to be fulfilled.

The Darwin Office is advanced in its application of the latest technology and computerised for its functions involving word-processing, specification writing, project control, cash-flow management and forecasting and normal business administration tasks.

RIEDEL & BYRNE PTY. LIMITED

Riedel & Byrne Consulting Engineers Pty. Ltd. is an Australian consulting practise specialising in all aspects of coastal and marine civil engineering and presently maintains offices in Perth, Melbourne, Brisbane and the Kingdom of Tonga.

The firm specialises in studies of the interaction between coastal and offshore processes and man-made structures. Its members have a sound theoretical understanding and wide practical experience, including a number of major projects in the Darwin area. One of the principal areas in which the firm is involved is that of marinas and boat harbours.

Riedel & Byrne offer a comprehensive service in the management of coastal engineering works from the project feasibility through the environmental enquiry phase to detailed design and construction supervision.

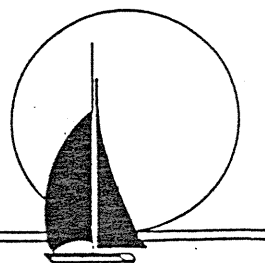
MAPPING & HYDROGRAPHIC SURVEYS

Mapping & Hydrographic Surveys is a wholly owned Queensland firm of consulting surveyors with a special interest in projects associated with the marine environment.

Mapping & Hydrographic Surveys offers a comprehensive service for both onshore and offshore survey requirements specialising in precision navigation, bathymetry, high resolution marine seismic profiling, side scan sonar searching, current flow and tidal studies, temperature, salinity/water sampling.

The finalisation of the firm's transition to computerisation by means of software developed for their integrated hydrographic survey capabilities is of a particular note. This greatly enhances the efficiency and precision of onboard field data acquisition thereby reducing time consuming procedures.

Mapping & Hydrographic Surveys operates throughout Australia and the near Pacific region.



TIDAL LEVELS

0.1 % _____ 1 in 1000 YEAR STORM WATER LEVEL

1.0 % _____ 1 in 100 YEAR STORM WATER LEVEL

H.A.T. _____ HIGHEST ASTRONOMICAL TIDE

M.H.W.S. _____ MEAN HIGH WATER SPRINGS
(average of spring tide levels)

M.H.W.N. _____ MEAN HIGH WATER NEAPS
(average of neap tide levels)

M.L.W.N. _____ MEAN LOW WATER NEAPS
(average of neap tide levels)

M.L.W.S. _____ MEAN LOW WATER SPRINGS
(average of spring tide levels)

L.A.T. _____ LOWEST ASTRONOMICAL TIDE

A.H.D. _____ AUSTRALIAN HEIGHT DATUM
A constant level based on several mean sea
levels throughout Australia and given a benchmark of
0.00 at Darwin.

C.D. _____ CHART DATUM (DARWIN)
zero on the Darwin Tide Gauge,
9.73m below NTA BM 70/14

0.1 % storm tide

1.0 % storm tide

H.A.T.

M.H.W.S.

M.H.W.N.

M.L.W.N.

M.L.W.S.

L.A.T.

A.H.D.

C.D.

+5.4

+9.5

+4.4

+8.5

+3.8

+7.9

+2.8

+6.9

+1.0

+5.1

+0.00

+4.1

Exclusive to
wave set-up
and run-up.

Aust. Height datum (A.H.D.)

-0.9

+3.2

-2.7

+1.4

Darwin Town datum (D.T.D.)

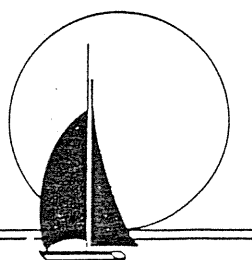
-4.0

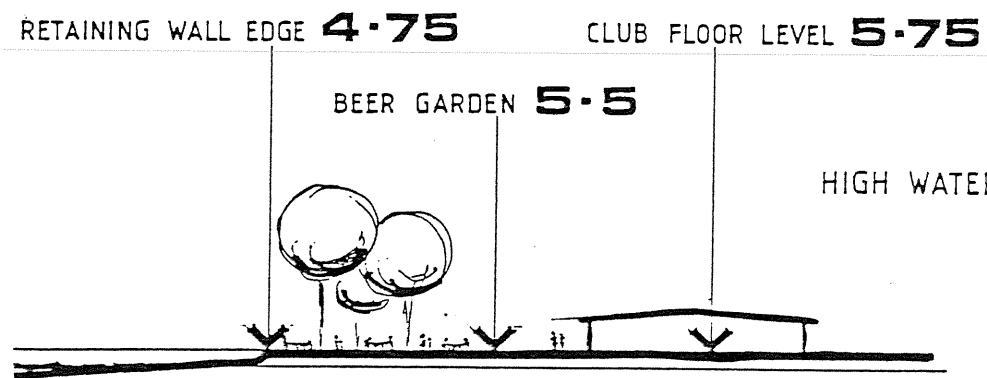
+0.1

0.00 Chart datum (C.D.)

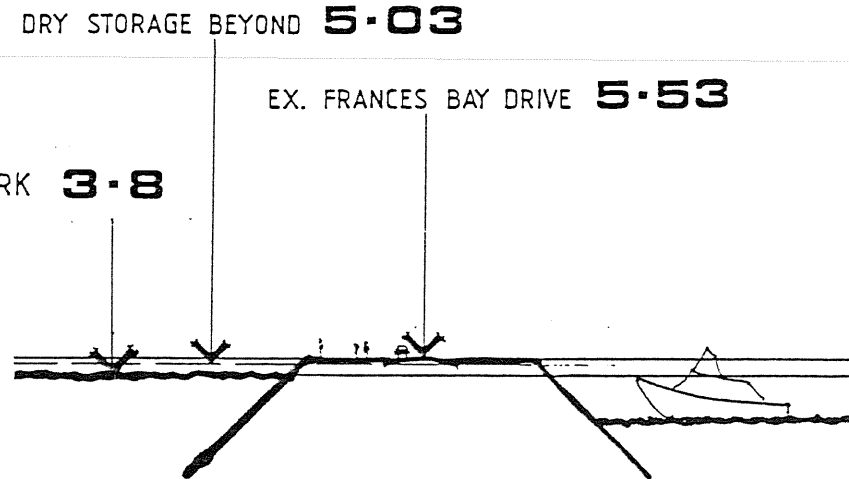
tidal information

DARWIN MARINA ESTATE

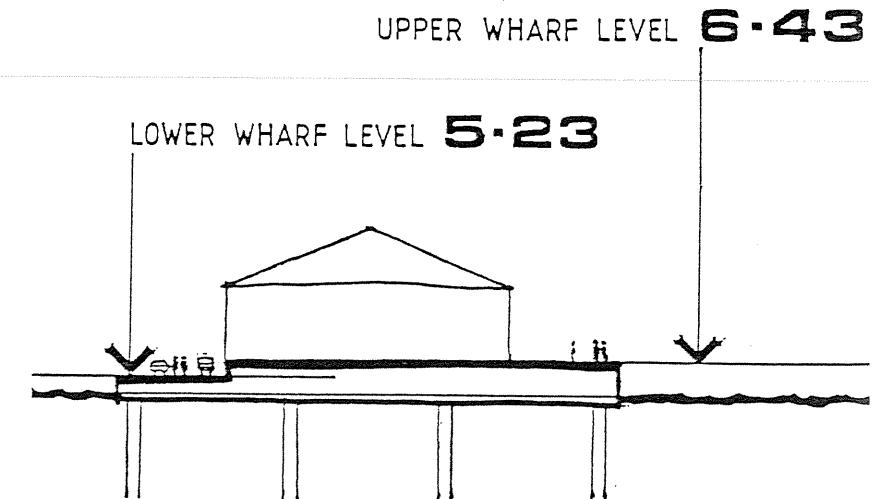




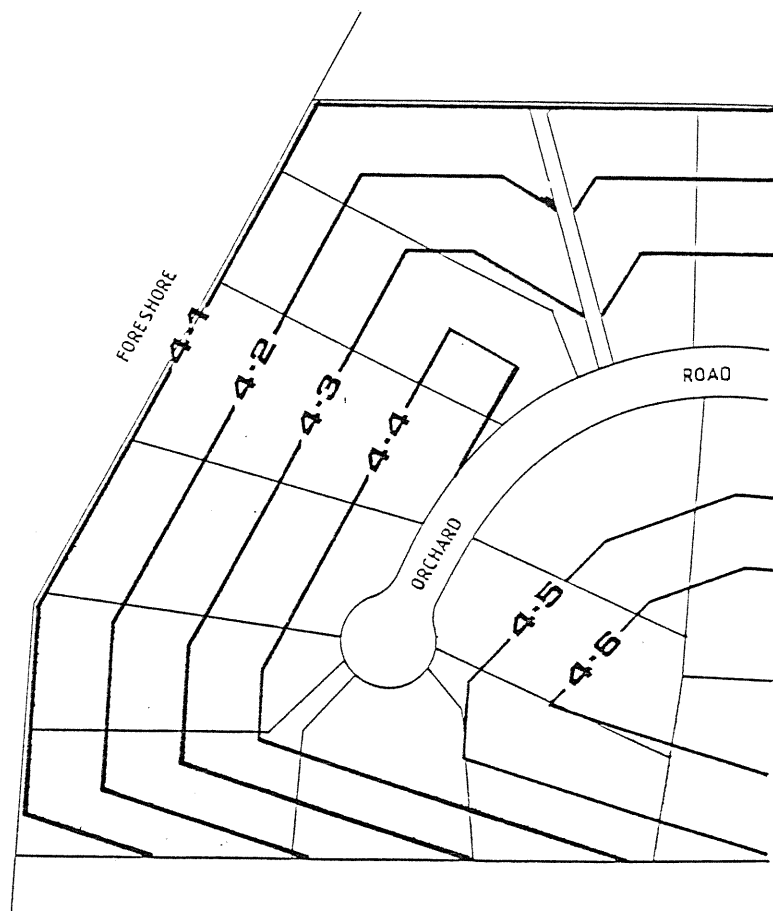
DARWIN SAILING CLUB
INFORMATION OBTAINED
FROM ORTHOPHOTO



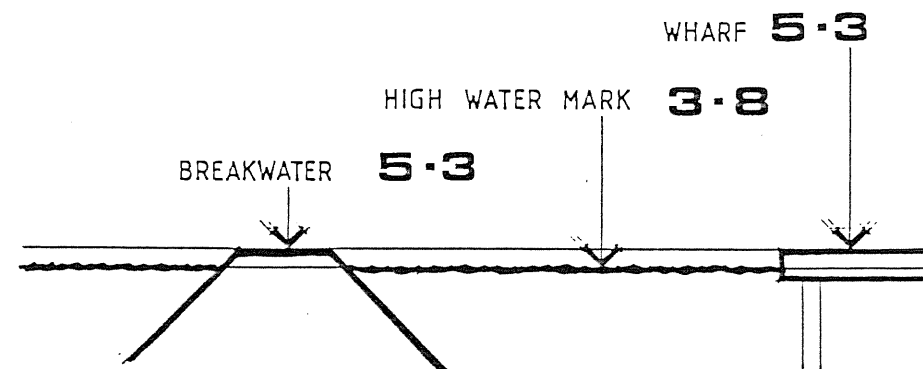
FRANCES BAY MARINA
INFORMATION SUPPLIED BY
DARWIN PORT AUTHORITY



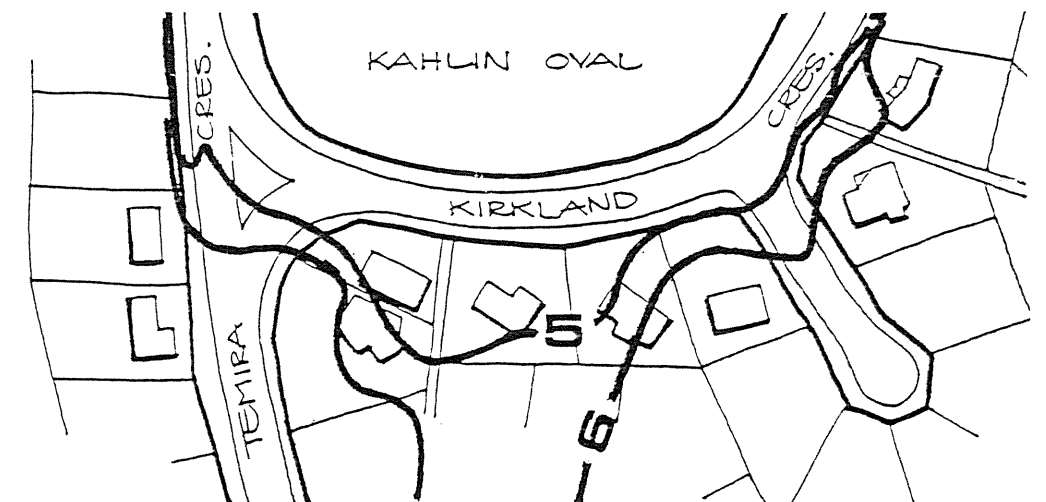
STOKES HILL WHARF
INFORMATION SUPPLIED BY
DARWIN PORT AUTHORITY



ORCHARD PARK ESTATE
INFORMATION SUPPLIED BY
VAUGHAN HOSKING PTY. LTD.
LEVELS SHOWN ARE NEW FINISHED LEVELS



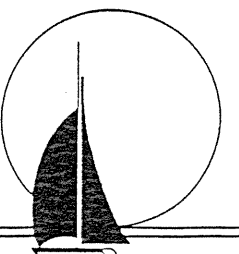
PATROL BOAT BASE
INFORMATION SUPPLIED BY
RIEDEL & BYRNE PTY. LTD.

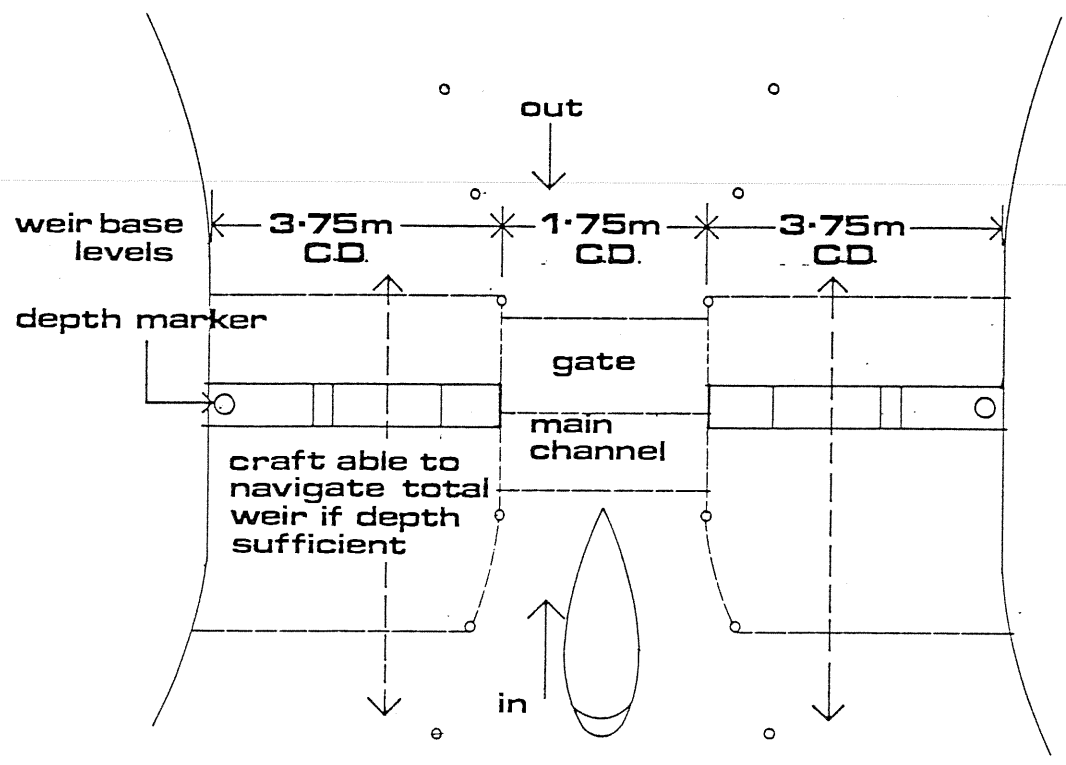


KAHLIN OVAL RESIDENTIAL
INFORMATION OBTAINED
FROM ORTHOPHOTO

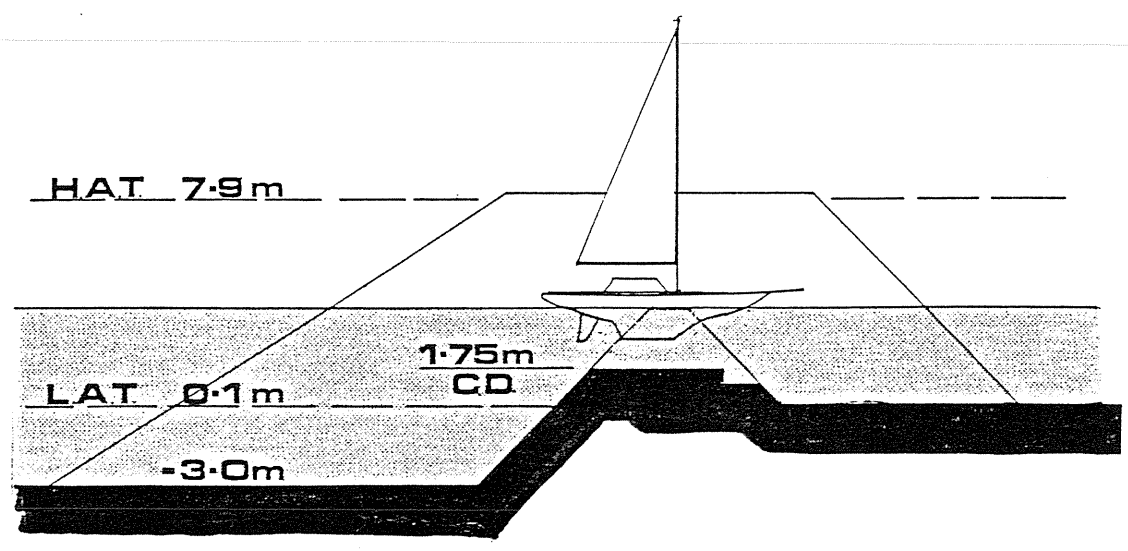
comparison of levels with existing facilities

ALL LEVELS SHOWN ARE A.H.D.

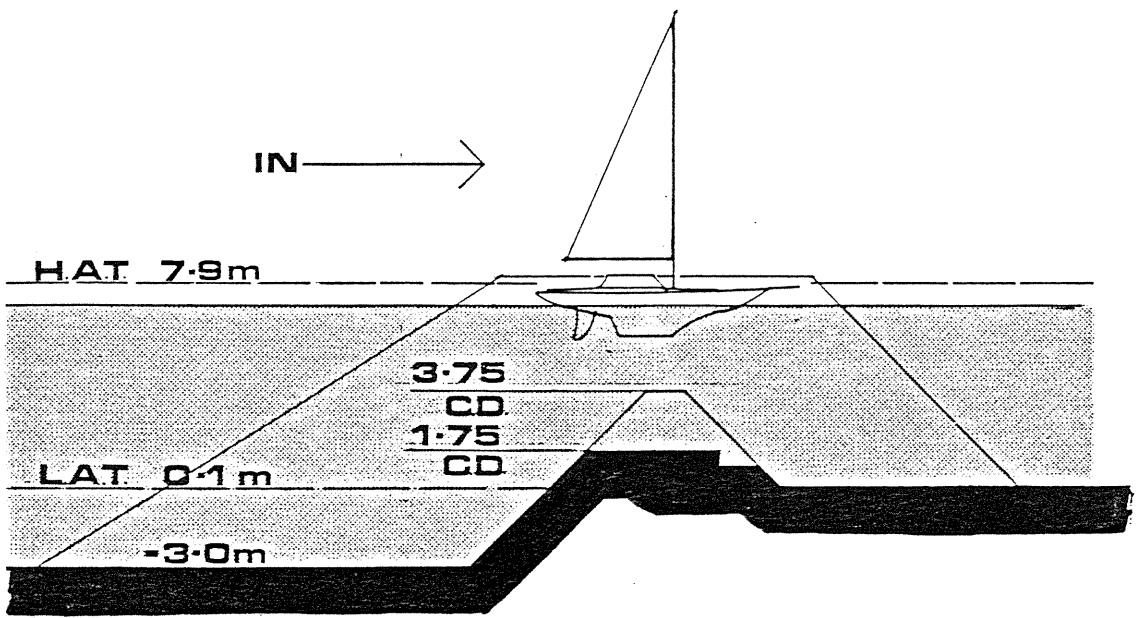




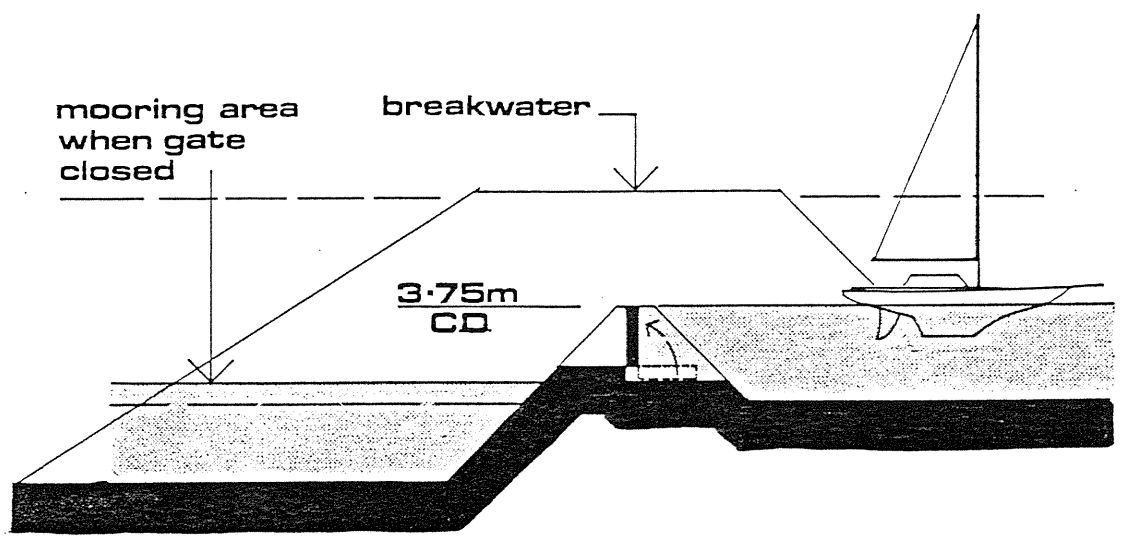
TIDAL GATE PLAN



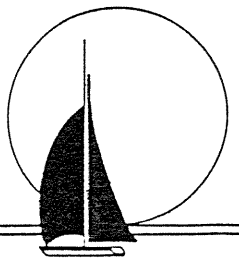
2. MID TIDE access thru gate just prior to closing at 3.75m



1. HIGH TIDE full access over total weir

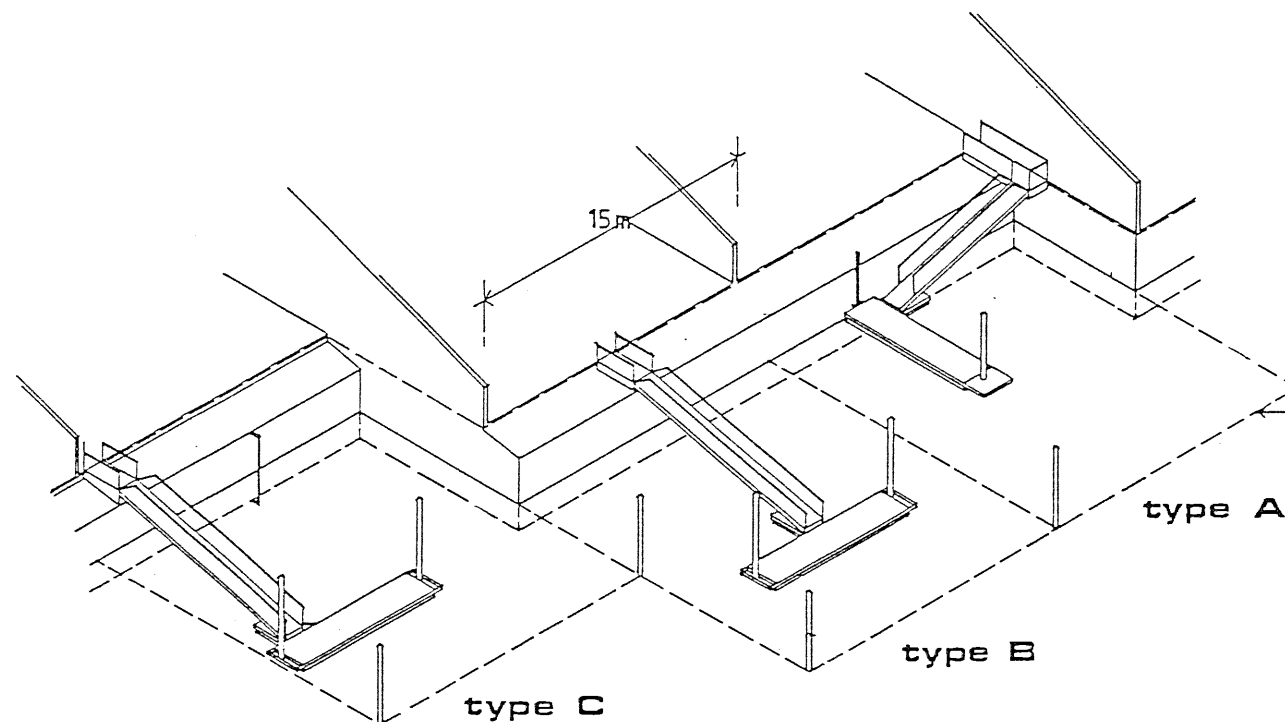
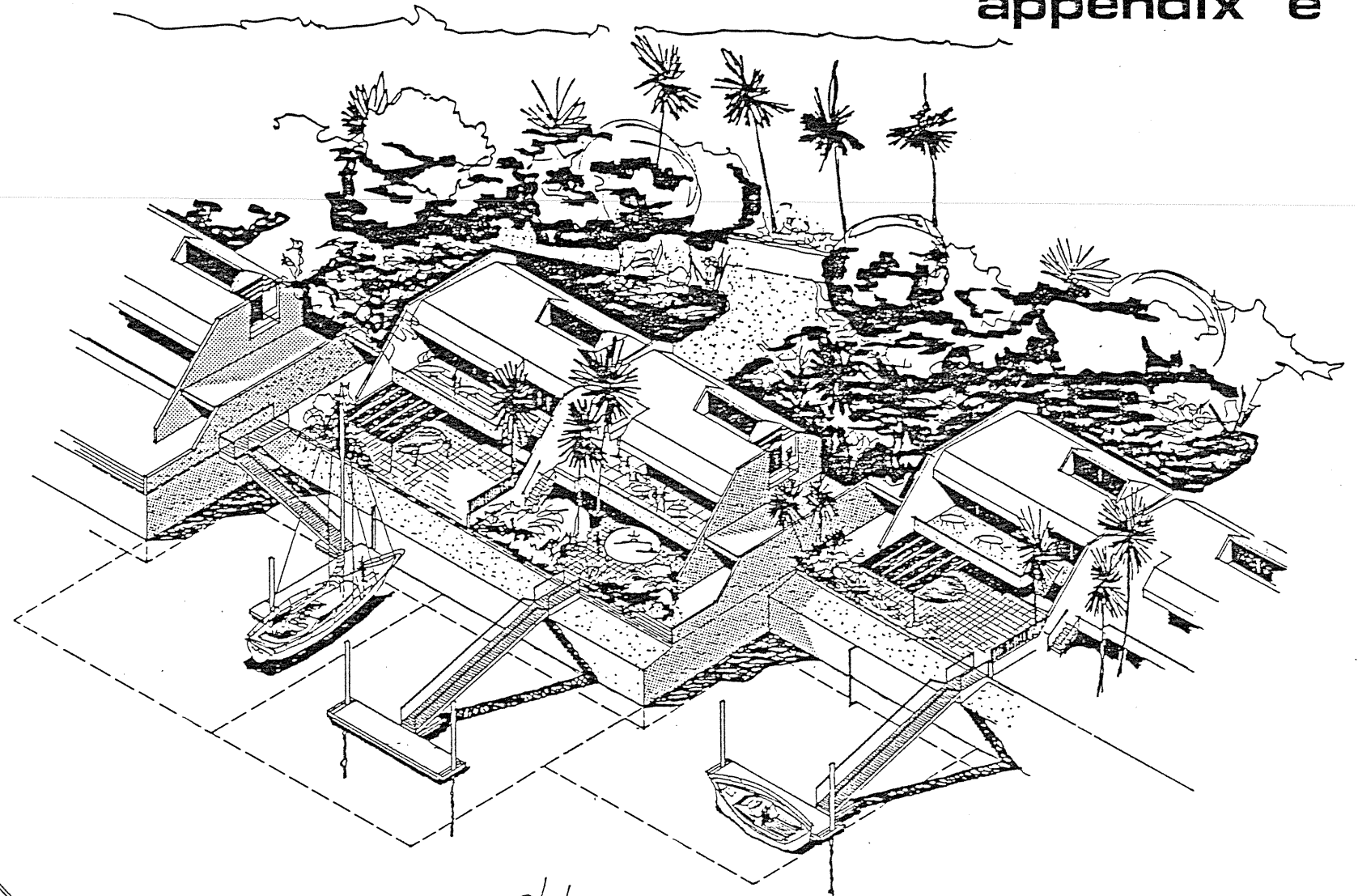


3. LOW TIDE gate closed



PRIVATE JETTIES

Concrete floating pontoons to allow for the tidal range within the inner harbour are proposed, connected by ramps hinged on land to allow for tidal movement.

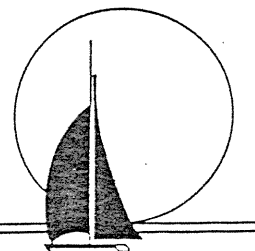


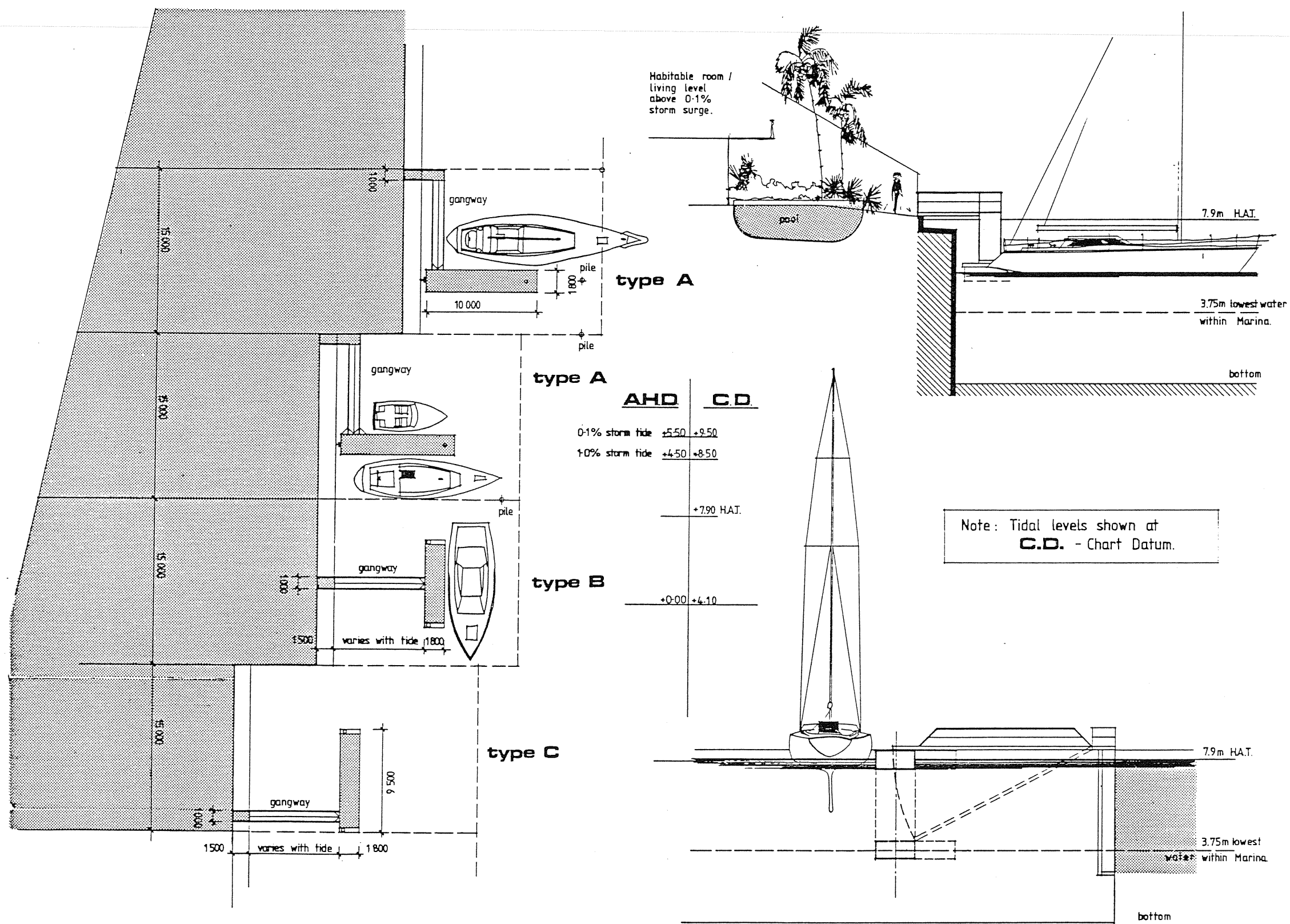
Denotes area of exclusive water front to the residential blocks.

(PONTOONS) JETTIES

Floating Type A, B and C private jetties illustrate the possible configuration of ramps and floating pontoons to suit boat size and/or preference

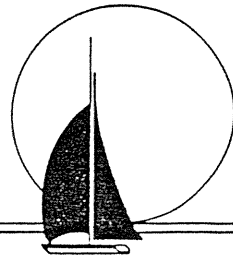
private jetty configurations
Shown at mid marina tide level.

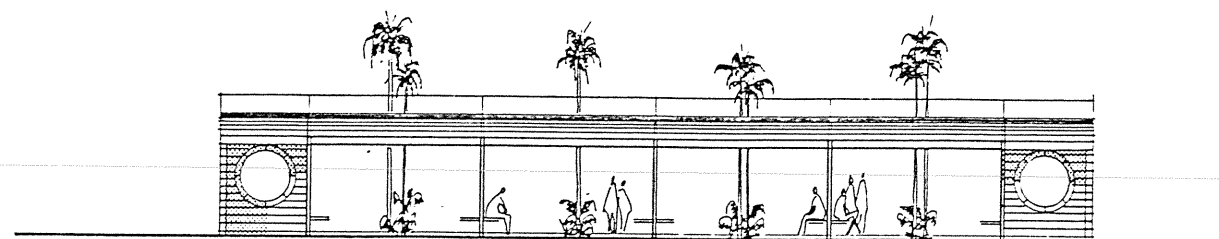




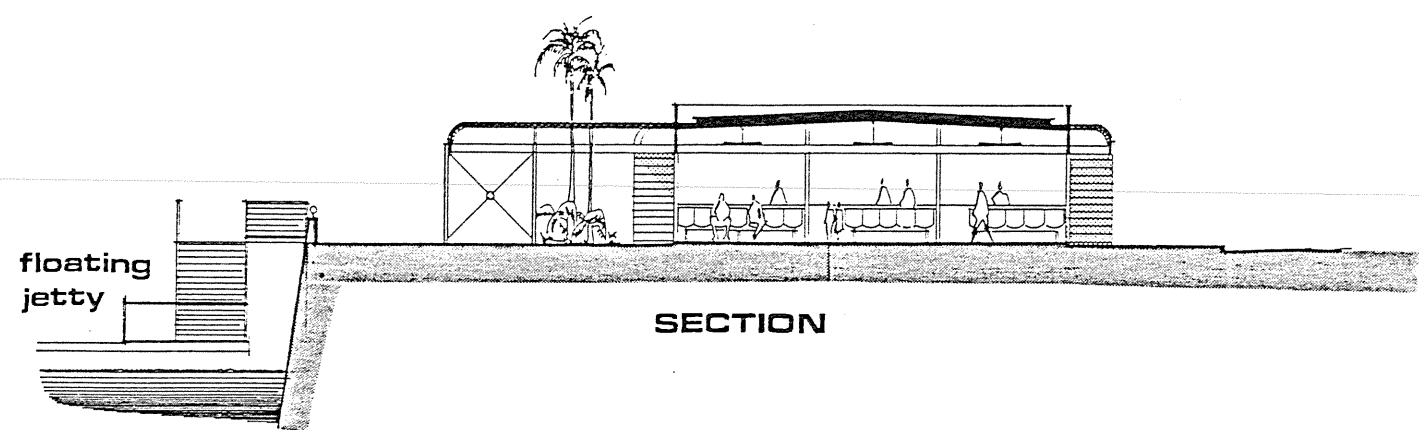
private berth details

DARWIN MARINA ESTATE

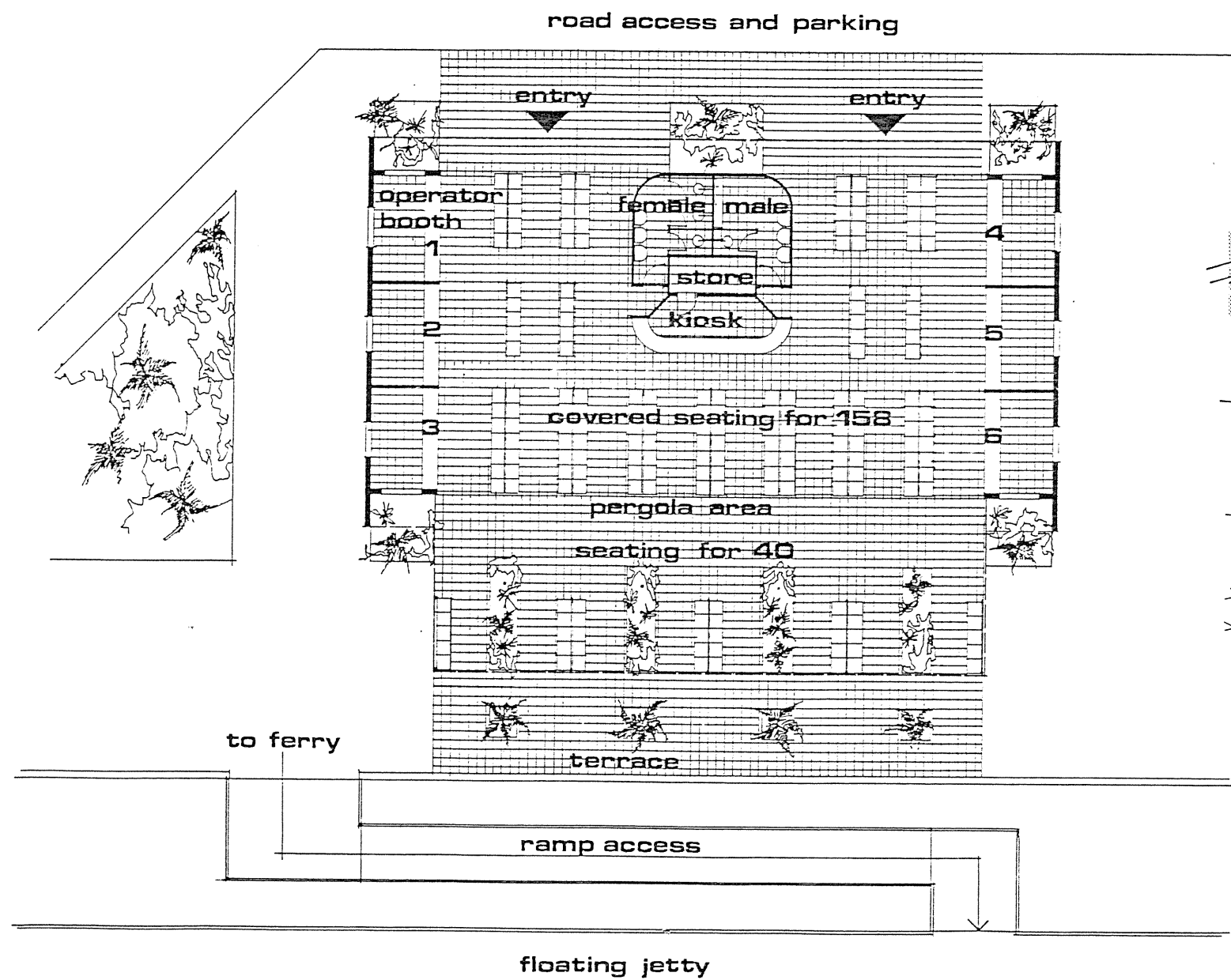




ELEVATION

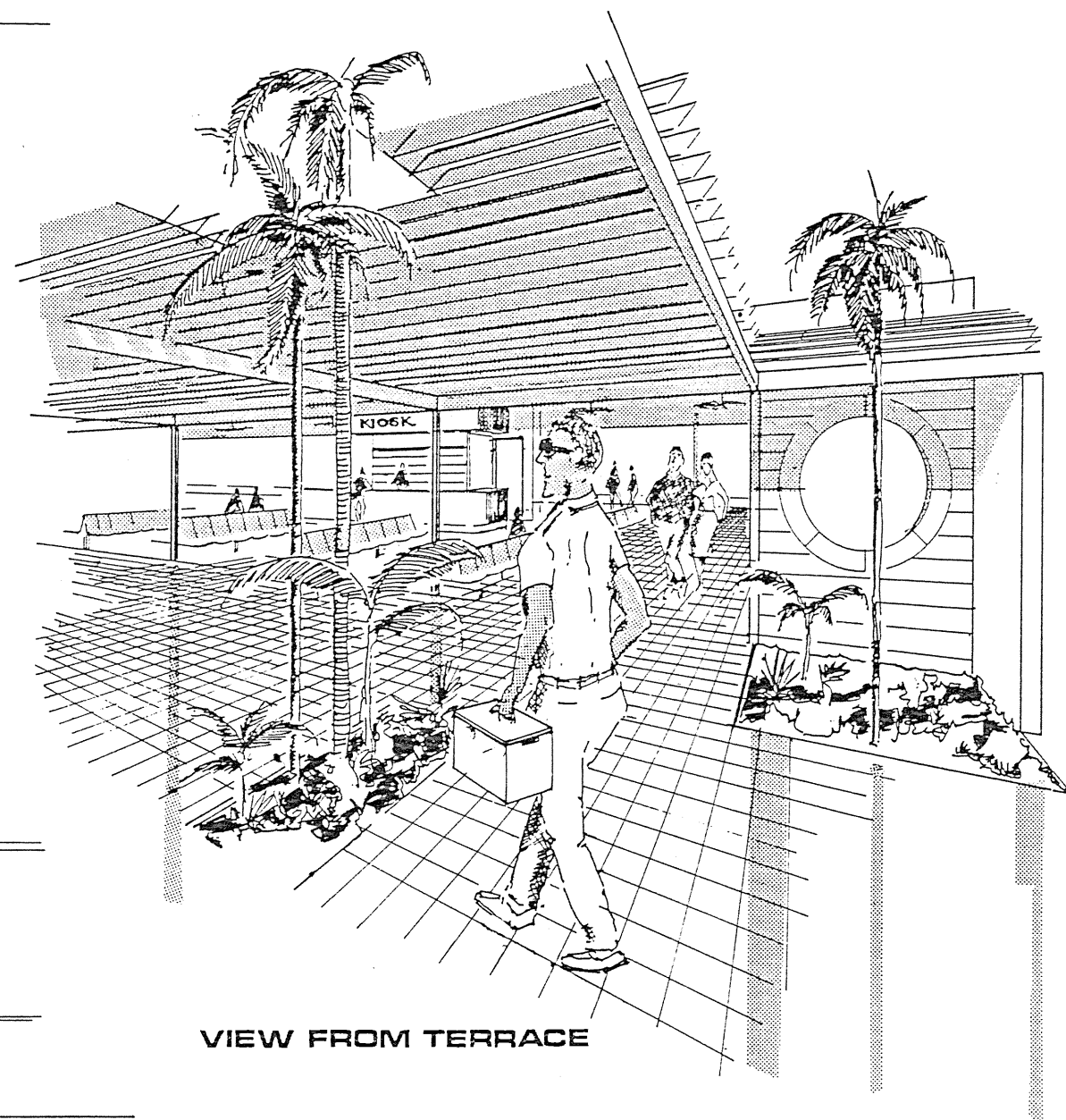


SECTION



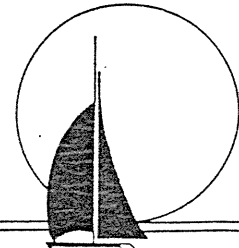
PLAN

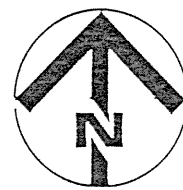
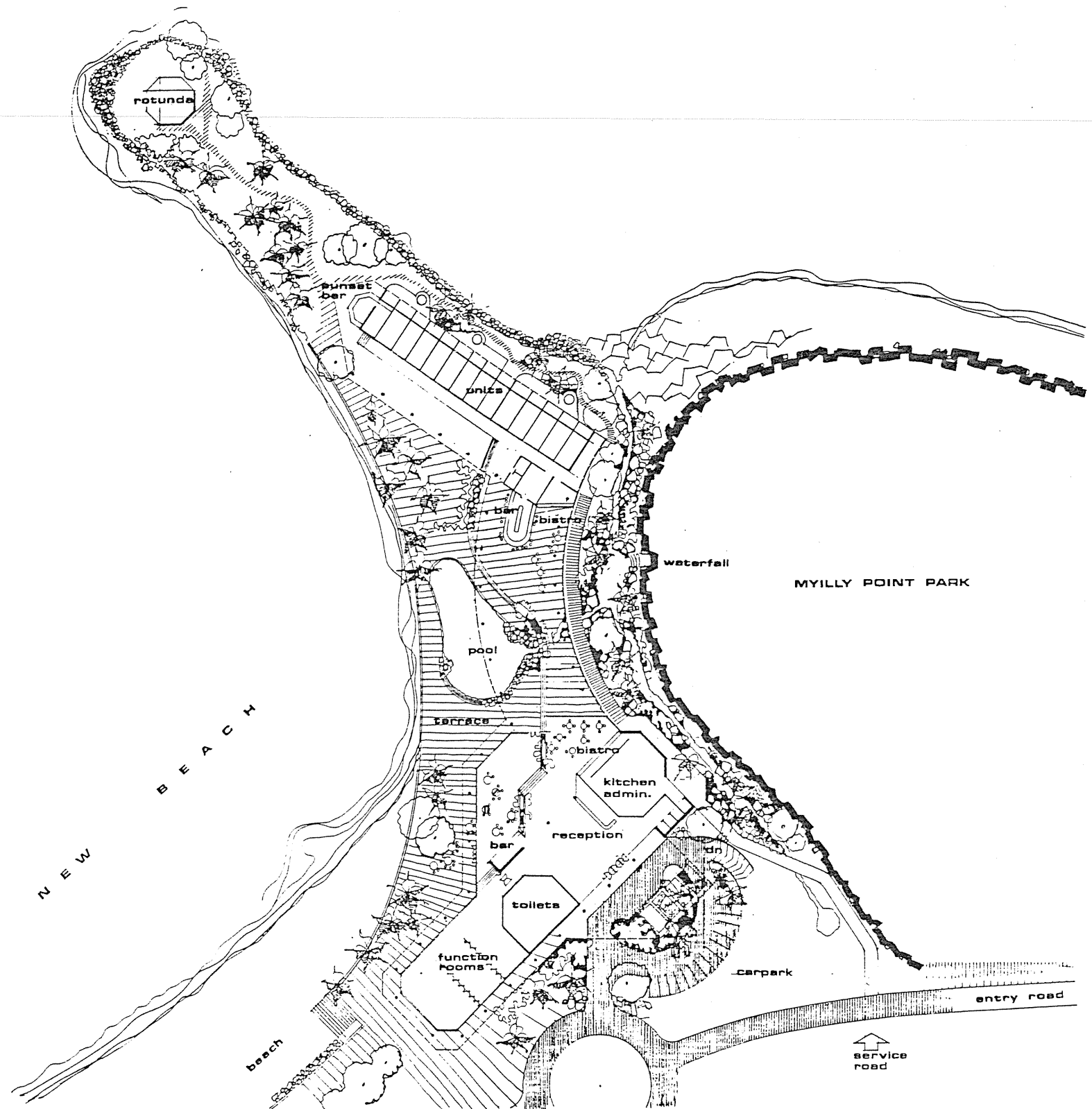
0 1 2 3 4 5 10 meters



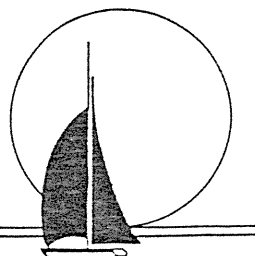
VIEW FROM TERRACE

ferry terminal

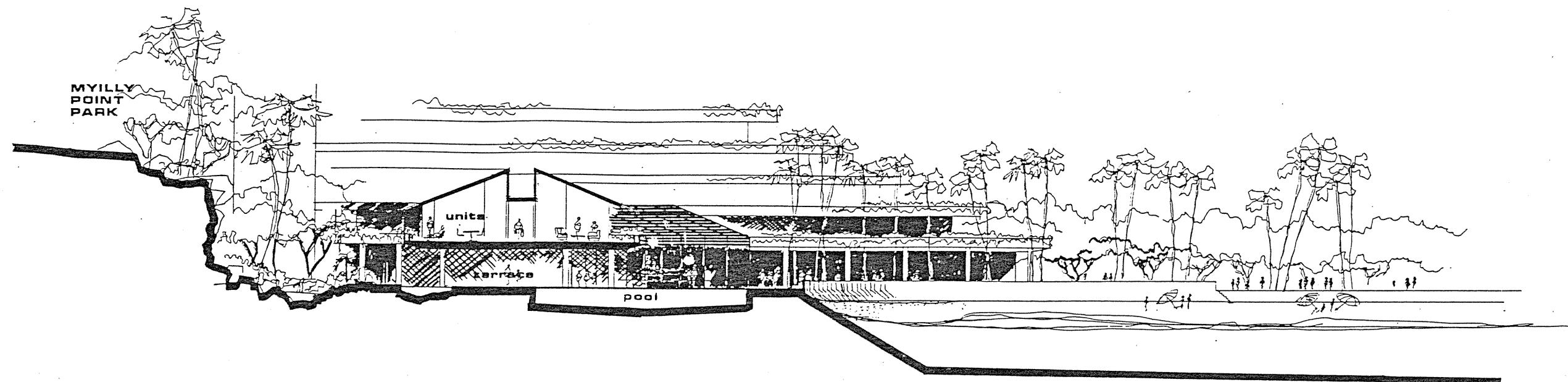




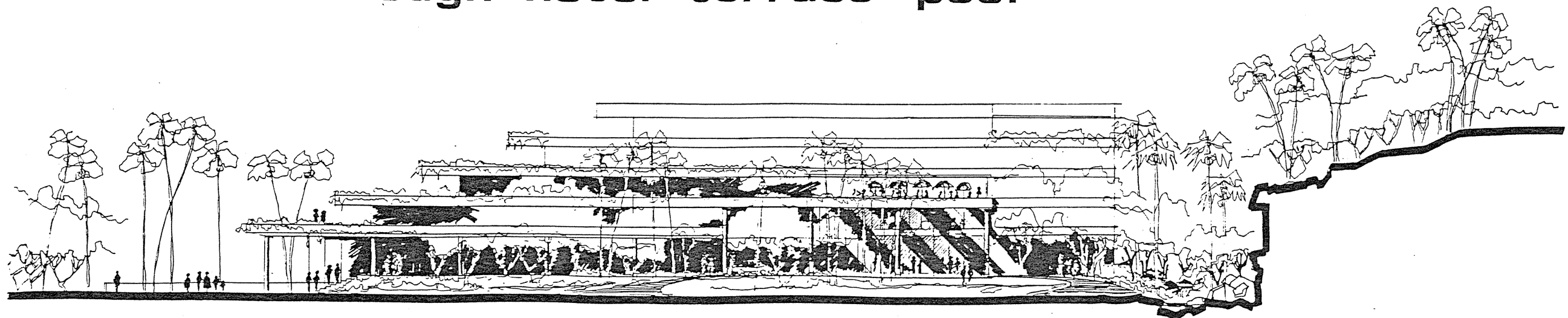
hotel - terrace level



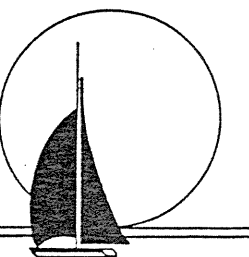
DARWIN MARINA ESTATE



section through hotel terrace - pool



hotel elevation from marina



2.2 INFRASTRUCTURE REQUIREMENTS

Permanent Facilities

Figure

ELECTRICAL RETICULATION

2.7

SEWER RETICULATION

2.8

WATER RETICULATION AND
STORMWATER

2.9

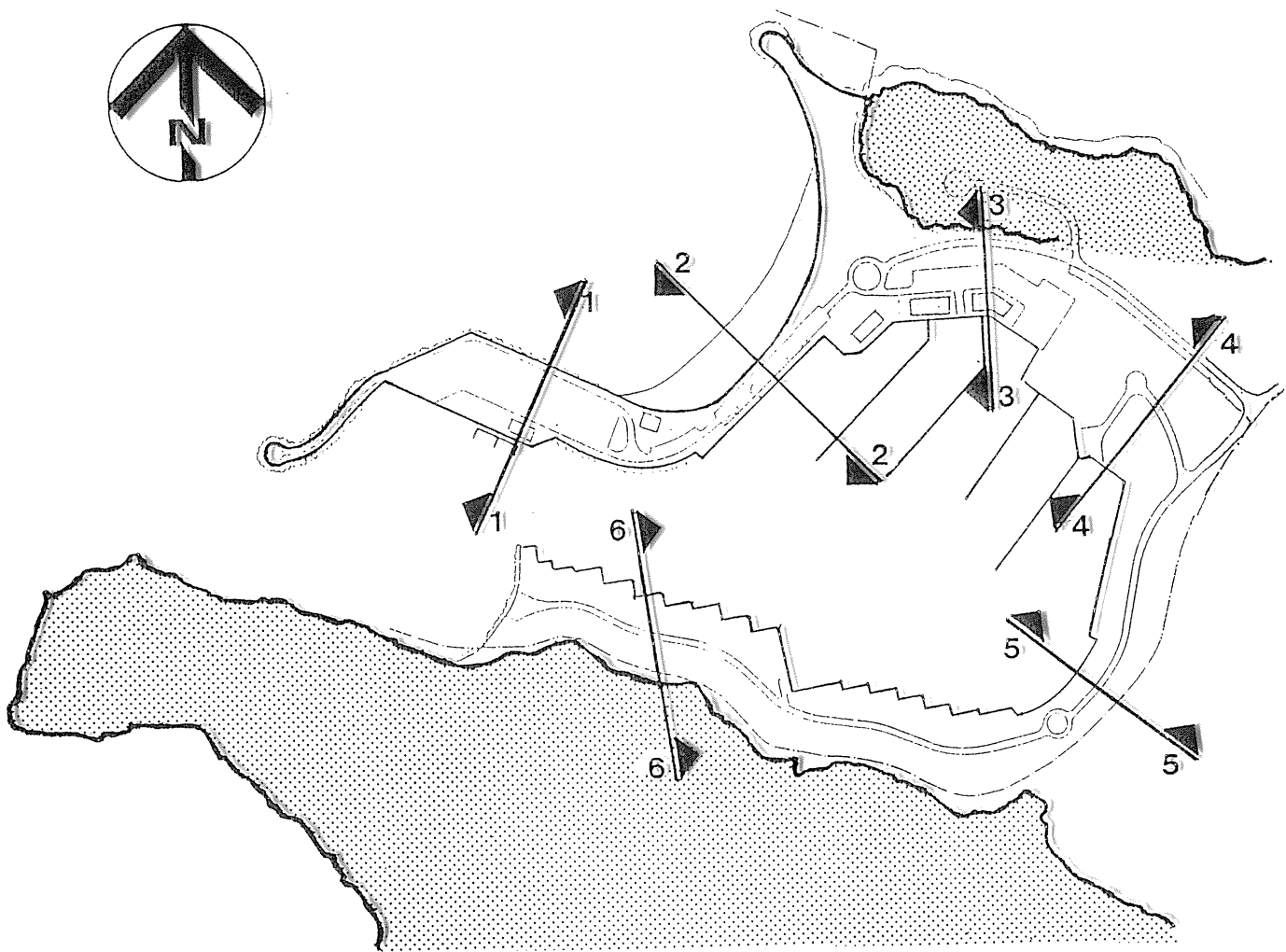
WATER RETICULATION

The estate will be served by an extension of the existing water reticulation system based upon the Montoro elevated water reservoir. The Water Authority has accepted the watermain layout shown, and has suggested the following:

1. From corner of Kirkland Crescent and Temira Crescent upgrade existing main in Temira Crescent to 150 ϕ
2. From corner of Smith Street and Lambell Terrace upgrade existing main along Kahlin Avenue to 300 ϕ
3. Provide underground reticulation within road reserve as shown on drawings with connection across tidal gate.
4. Investigate upgrading of water main from corner of Smith Street and Lambell Terrace back to Montoro Tank.

STORMWATER

The stormwater from the existing Kahlin catchment discharges into Cullen Bay via two main outfalls and several minor out falls. It is proposed to allow all storm -water to discharge into the marina waters as the marina waters can overflow to the sea at all times, regardless of tide level. The existing outfalls will be incorporated in any sea walls during construction. Stormwater disposal from new reclaimed areas will be via underground pipes where appropriate, discharging to the marina waters.



SECTION LOCATION PLAN

Fig 2-2 FACILITIES PLAN

1 OUTER HARBOUR

The entrance to the Marina and public ferry terminal is dredged out to -3.0 CD. The Harbour will provide 100% access to craft which draw 2.5 metres at lowest of tides. A temporary mooring area is provided at the eastern side for craft requiring to wait for the tidal gates to open and gain access to the main marina facility.

2 MARINA HARBOUR

Craft enter the marina harbour through the tidal control gates. These gates will be open approximately 60% of the time. The gates will be held open and provide 100% access. Maintained water depths will be approximately 2.75m deep throughout the inner harbour. These depths are quite adequate for most pleasure craft. The marina system will be the floating type held by piles. The marina basin provides for both private residential berths and public berthing facilities.

3 PUBLIC BOATING TERMINAL AND PARKING AREA

At the landward end of the breakwater protecting the outer harbour, a parking area providing for approximately 300 cars and 8 coaches, will be built. A shelter building with public conveniences will be situated adjacent to the floating wharfs for the comfort of waiting passengers.

The car park will be heavily landscaped and reduce the impact of the pavement and parked vehicles. The details of the ferry terminal building are shown on appendix 'G'.

4 HARBOUR MASTER

To maintain control and police the water areas and oversee the control gates, the Harbour Master is located at the head of the tide control weir where access is provided to both basins. This position may also be suitable for the water police to station a craft. Visitors entering the marina for the first time would report to the Harbour Master to be shown the facilities of the marina, and allocation of a berth. The Harbour Master would also be responsible generally for conduct of boat operations and use of marina berths.

5 RESIDENTIAL

Residential blocks have been designed to provide direct access to the waterfront with their private floating berths adjacent to the site.

Residential sites which are road fronted on the second line have their own marina complex dedicated to their sites.

The southern residential area against Larrakeyah Point will have restricted access to provide both security and privacy. The road pavement will be interlocking brick type paving with special attention to kerbs footpaths and landscaping.

Land will be sold with stringent covenants to control the appearance and quality of the buildings in keeping with the concept of providing a co-ordinated development.

6 MEDIUM DENSITY RESIDENTIAL

R4 Medium density strata titled residential sites are provided in 3 large blocks.

These sites all have their dedicated water frontages and marina facilities.

The development envisages a Mediterranean style condominium development stepping up the existing cliff face with heavily landscaped terraces built on this land.

SEWER RETICULATION

The Kahlin area is presently serviced by a gravity system and a pumping station located in Kahlin Oval. After discussions with the Water Authority, the proposed sewerage system will be as shown on the drawing and as outlined below:

1. The ferry terminal and the restaurant will gravity feed to Pump Station No. 1. This pump station will deliver to Pump Station No. 2 near the hotel. The overflow from Pump Station No. 1 will discharge to the harbour. Pump Station No. 1 will have two pumps, one on standby.
2. Pump Station No. 2 will collect discharge from the hotel, the commercial area and Pump Station No. 1. It will discharge into the gravity main on Myilly Point. Pump Station No. 1. will have an overflow to the groin at the end of Myilly Point. It will have two pumps, one on standby.
3. Pump Station No. 3 will collect discharge from the condominiums and will discharge into the gravity main. Two pumps (one on standby) will be provided and emergency power generation will be provided.
4. Pump Station No. 4 will collect discharge from the residential villas and will discharge into the gravity main. Two pumps will be provided, one on standby.
5. A gravity main will run from Myilly Point to the existing pump station in Kahlin Oval. This existing pump station will have new submersible pumps installed to increase capacity.
6. The rising main from Kahlin Oval to the Larrakeyah macerator will be upgraded.
7. The macerator at Larrakeyah is currently at its capacity and will need to be upgraded.

As outlined elsewhere in this report, the waters within the marina will be partially replaced twice every day, with the sea wall being over-topped by between 1.5 and 4 metres of water, so that, at worst, there is a change of a third of the water within the marina every twelve hours. Each of the pump stations will be provided with 100% standby capacity, consisting of a spare, installed pump.

7 COMMERCIAL DEVELOPMENT

Fronted by timber board walks and floating berths the commercial blocks will provide for all the boatowners needs, such as food, materials and victualing, Chandleries, yacht brokerage, tourist operation and the like would be catered for in this area.

A "Fishermens Wharf" style restaurant and souvenir shops will all be included with the development.

A small slipway will be included/provided to attend to the simple below the waterline jobs such as skin fitting, propellor gland and regular maintenance. Anti-fouling and minor repair and paint jobs would be undertaken. No activities such as boat building, sandblasting or any other nuisance industry will be allowed. Francis Bay has these facilities and for major work and dry storage, boats will need to use Frances Bay.

8 COMMERCIAL AND CHARTER BOATS

Provision for approximately 15 berths for up to 20m maximum length charter boats such as flying bridge fishing boats, charter boats and small harbour cruisers will be provided at a floating pontoon wharf against a timber board walk which will allow these craft to be accessed directly from the road and parking areas. Their offices will be within the commercial area at location 7.

9 RESTAURANT

A high quality licensed restaurant to be located overlooking the new beach is planned. The massing and size of the restaurant structure will be designed to ensure that the restaurant will not dominate the new beach. It is proposed that the restaurant cater for the demand of beach users with a ground level medium fast food outlet. The upper level deck of the restaurant overlooking the western bay and sunset, will provide a-la-carte facilities.

10 PUBLIC BEACH

The two heads of the breakwater design create a pocket public beach adjacent to the main road system which has public parking areas provided to both sides of the road.

The possibility of providing a stinger net between the headlands gives Darwin city a swimming beach usable all year round, similar to the facility recently installed in Nightcliff. It is expected that this facility would also be very popular with tourists in city accommodation.

11 RESORT HOTEL

A low rise mid-market resort hotel is provided at the end of Myilly Point. The hotel has direct access to the beaches and is set at the base of Myilly Point clear of the cliffs to maintain the existing vegetation and cliff appearance.

The hotel is designed to fill a need for a type and level of tourist hotel accommodation that at present is not available in Darwin. The hotel will therefore compliment rather than compete with existing hotels.

The hotel also compliments the marina. The marina infrastructure allows the building of the hotel, internal facilities such as the new Cullen Beach, the sailing facilities, restaurant and commercial facilities ensure that the hotel with its serviced apartments will predominately cater for family groups.

12 MYILLY POINT PARK

Myilly Point is outside this development, however there is a close public relationship with the park. The park therefore features in these plans to co-ordinate the access and landscaping potential.

Project : Darwin Marina Estate
Report : Draft Environmental Impact
Statement and Planning Study
Volume 2 - Coastal Engineering Study
Client : Vos Woodhead Planning Group
Date : January, 1987
Status : Final



87/0055AW

Riedel & Byrne Consulting Engineers Pty. Ltd.
396 Rokeby Road
SUBIACO W.A. 6008

January 1987

87/0055

1. INTRODUCTION

This report has been prepared for Hans Vos Planning Consultants. It details the results of a study into the coastal and marine civil engineering aspects of Darwin Marina Estate.

Darwin Marina Estate is a proposed marina and housing development which will be constructed in Cullen Bay in the Port of Darwin. The location is shown in Figures 1.1 and 1.2.

The report was commissioned to investigate the coastal engineering aspects of the development including:

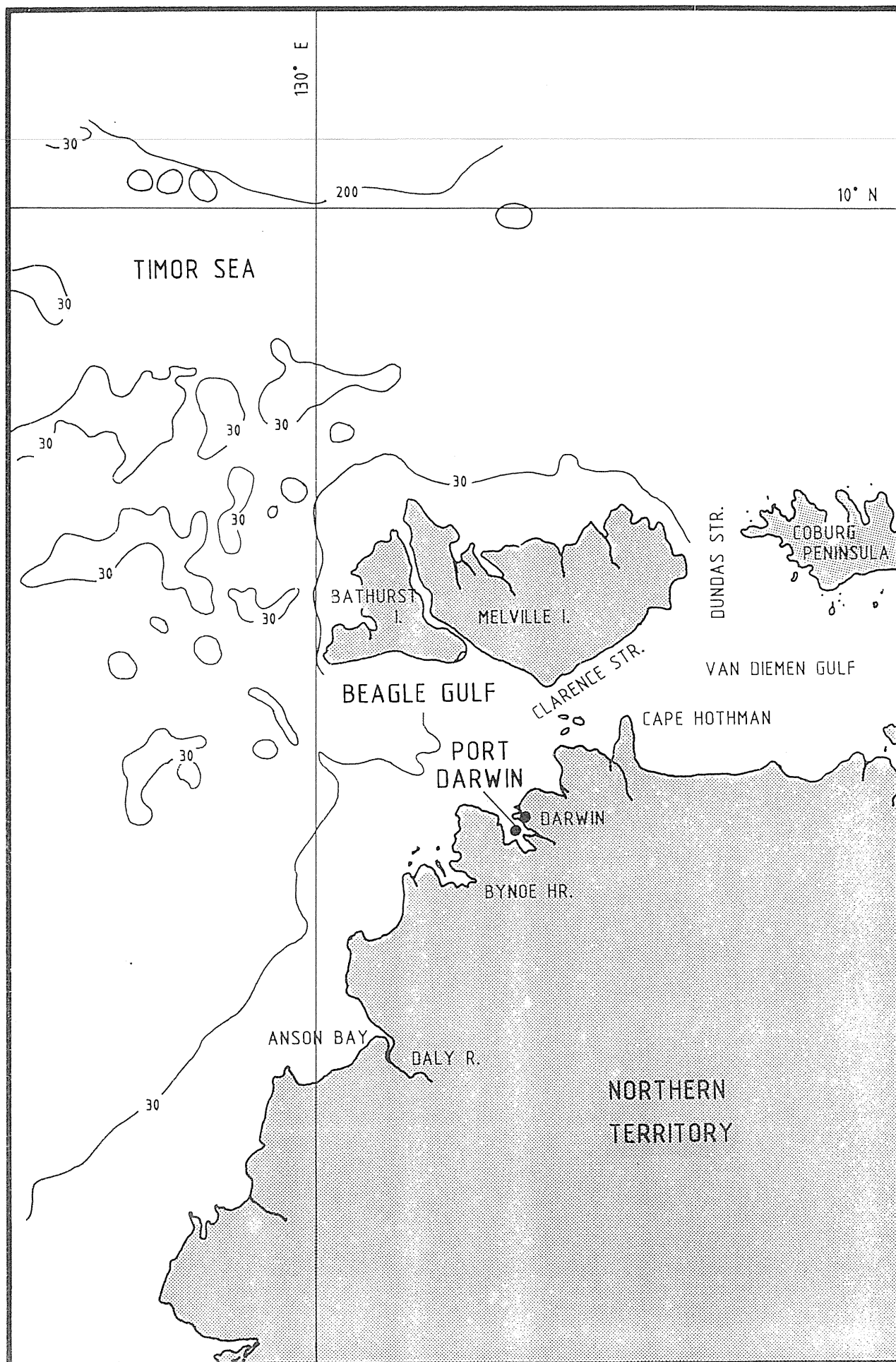
- . Winds
- . Tidal Currents
- . Waves
- . Coastal Processes
- . Construction Methods and Techniques.

Where possible existing data has been used. It has been necessary however, in order to accurately determine the wave climate at the site, and to determine coastal processes, to prepare a detailed hindcast of waves and to transform them to the site.

A detailed tidal current measuring and hydrographic survey programme was also undertaken as part of the study.

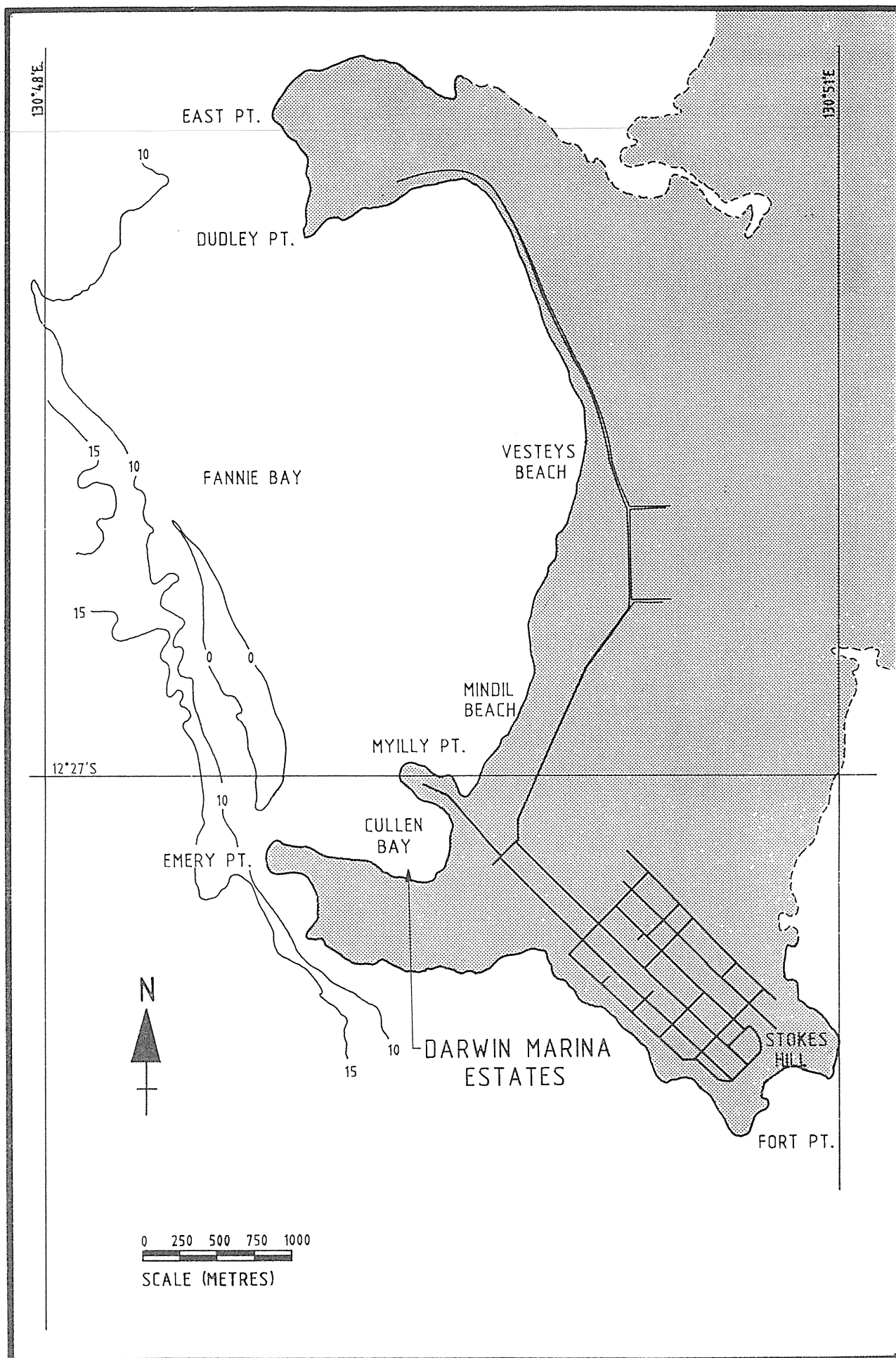
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1. INTRODUCTION
 2. EXISTING ENVIRONMENTAL CONDITIONS
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 - 2.2 Winds
 - 2.3 Tidal Currents
 - 2.4 Water Levels
 - 2.5 Wave Climate
 - 2.5.1 Ambient Wave Climate
 - 2.5.2 Storm Wave Climate
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 3. PROPOSED DEVELOPMENT
 - 3.1 General
 - 3.2 Beach
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 - 3.4 Water Level Control Gates
 - 3.5 Internal Walls
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 4. ENVIRONMENTAL IMPACT ASSESSMENT
 - 4.1 Tidal Currents
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 - 4.7 Construction Operations
 5. SUMMARY AND CONCLUSIONS
 6. REFERENCES
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- APPENDIX A Tidal Current Measurements
 - APPENDIX B Hindcast & Wave Transformation



LOCALITY PLAN

Figure 1.1



SITE LOCATION

Figure 1.2

2. EXISTING ENVIRONMENTAL CONDITIONS

2.1 Geotechnical Aspects

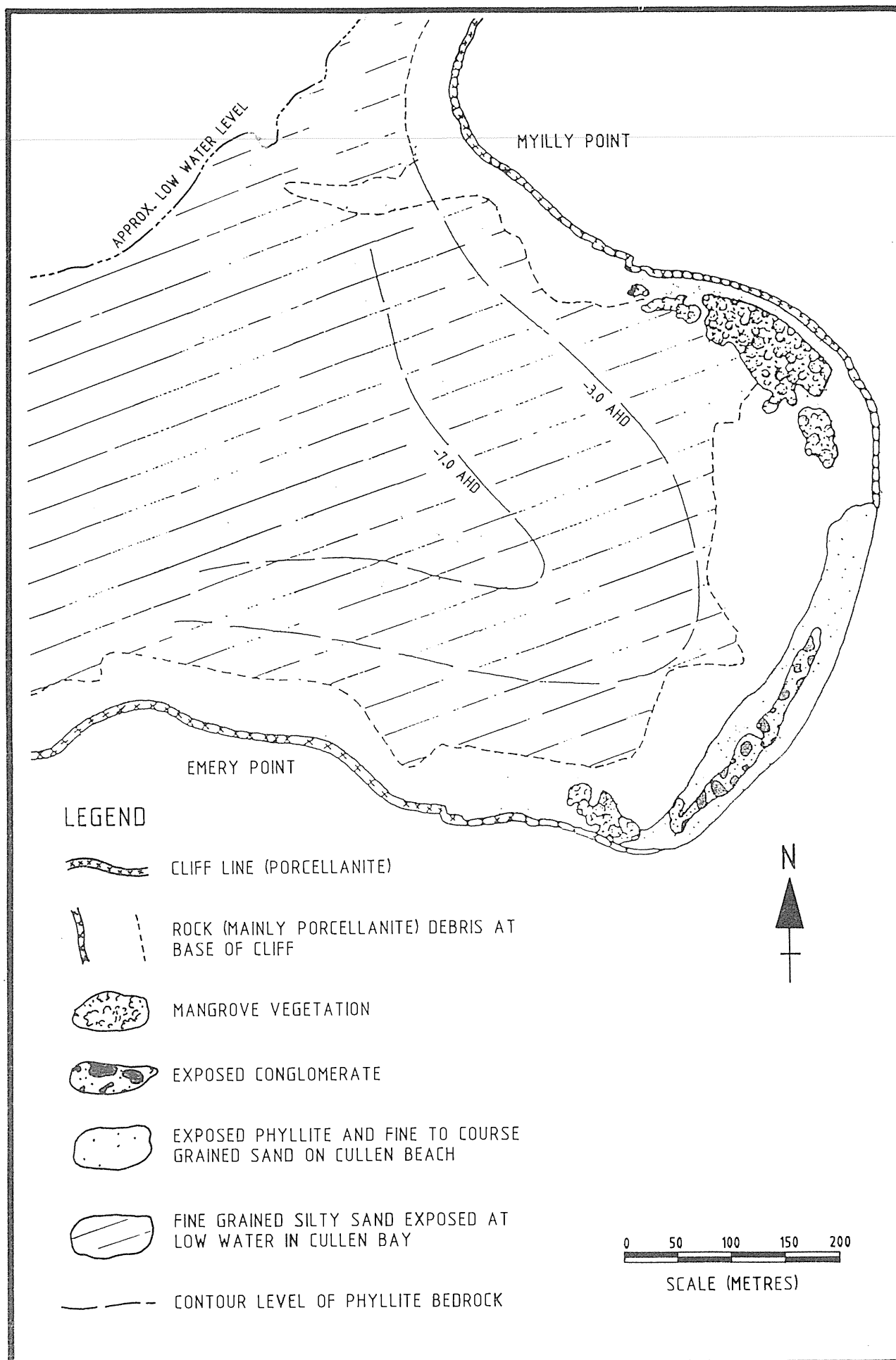
As part of the Cullen Bay Marina Study, 1984, Coffey and Partners Pty. Ltd. carried out preliminary geotechnical investigations in Cullen Bay. Although a seismic refraction survey and hand auger boreholes were attempted, the results were not encouraging and most of the geotechnical assessment was based on 25 Dynamic Cone Penetrometer tests and visual examination of the site.

The surface sediments in the bay were found to be mainly very loose, fine grained silty sand. It was noted that this material often exhibited a tendency to liquify when disturbed in water.

It was assumed that refusal in the penetrometer tests occurred on phyllite and not a very stiff to hard clay or very dense sand. Previous investigations around the Darwin coastline have indicated that often a deposit of soft marine clay overlies the phyllite bedrock. The penetrometer results indicate a soft soil layer immediately above the phyllite and for the purpose of this present study it will be assumed to be a soft clay material. The results of the penetrometer tests are shown on Figure 2.1.

From Coffey and Partners' work a general description of the materials in Cullen Bay is as follows:

- . Headlands extending to Emery and Myilly Points are composed of porcellanite rock and there is some porcellanite rock debris at the base of the cliffs.
- . Surface sediments within the bay are very loose, fine grained silty sands.
- . There is a bedrock of phyllite within the bay. Its approximate level is shown on Figure 2.1.



PHYLLITE LEVELS IN CULLEN BAY

Figure 2.1

- . There is a layer of soft marine clay overlying the phyllite bedrock.
-

Prior to the start of detailed design it will be necessary to undertake a more detailed geotechnical investigation at the site.

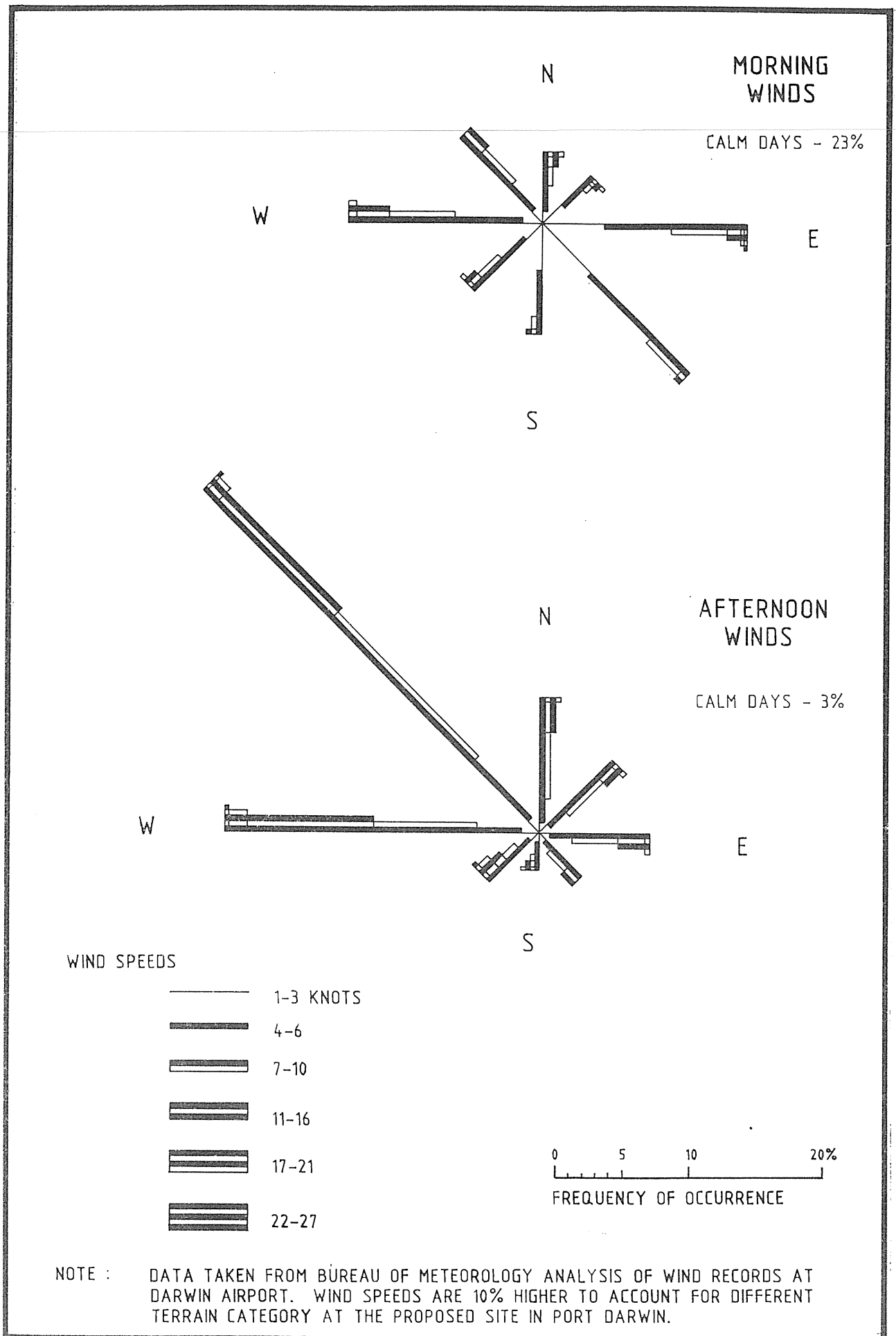
The scope of this investigation would be as follows:

- . Determination of subsurface conditions within the extent of the development utilising existing information in addition to drilling, sampling, in situ vane shear testing and probing.
- . Evaluation of a suitable method for construction of the beach causeway and breakwater with due consideration of long term settlement of the embankments and the requirement for a relatively impermeable causeway and foundation.
- . Assessment of the driveability of piles and sheet piles within the location of the ferry terminal, water level control gates and marina based on the engineering properties of the surface sediments and underlying phyllite.
- . Evaluation of both the dredgeability of the materials within the inner and outer harbour basins and the suitability of these materials for use as general land fill.
- . Engineering assessment of the material sources for construction of the public beach, the breakwater and groyne.
- . Analyses of the slope stability for the retaining walls or slopes adjacent to the marina area.

2.2 Winds

The wind climate in the vicinity of the marina is of importance because of its effect on local wave conditions and coastal processes.

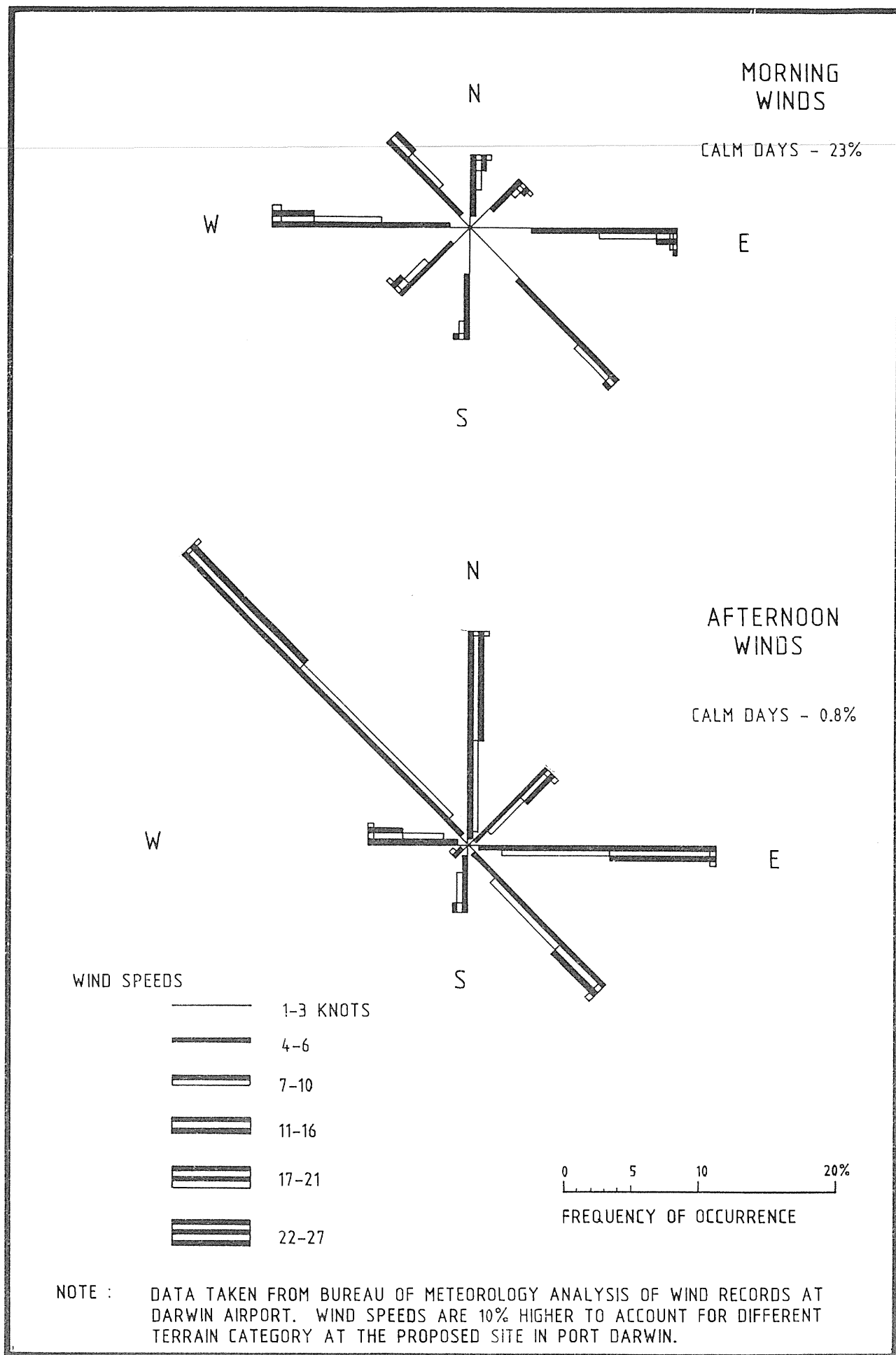
The wind provides the input of energy to create waves which ultimately shape the coast. These waves also determine the optimum layout of breakwaters and the useability of the marina entrance.



WIND FREQUENCY DISTRIBUTION

NOVEMBER - APRIL

Figure 2.2



WIND FREQUENCY DISTRIBUTION

MAY - OCTOBER

Figure 2.3

A frequency analysis has been carried out for winds recorded at Darwin airport. Consideration has been given to the difference in terrain categories at the airport and at the proposed site. The record does not contain winds associated with Cyclone Tracy, since this event would not represent normal operational conditions in Port Darwin.

The data is presented on Figures 2.2 and 2.3 in the form of wind roses.

The predominance of northwesterly winds can be readily seen.

2.3 Tidal Currents

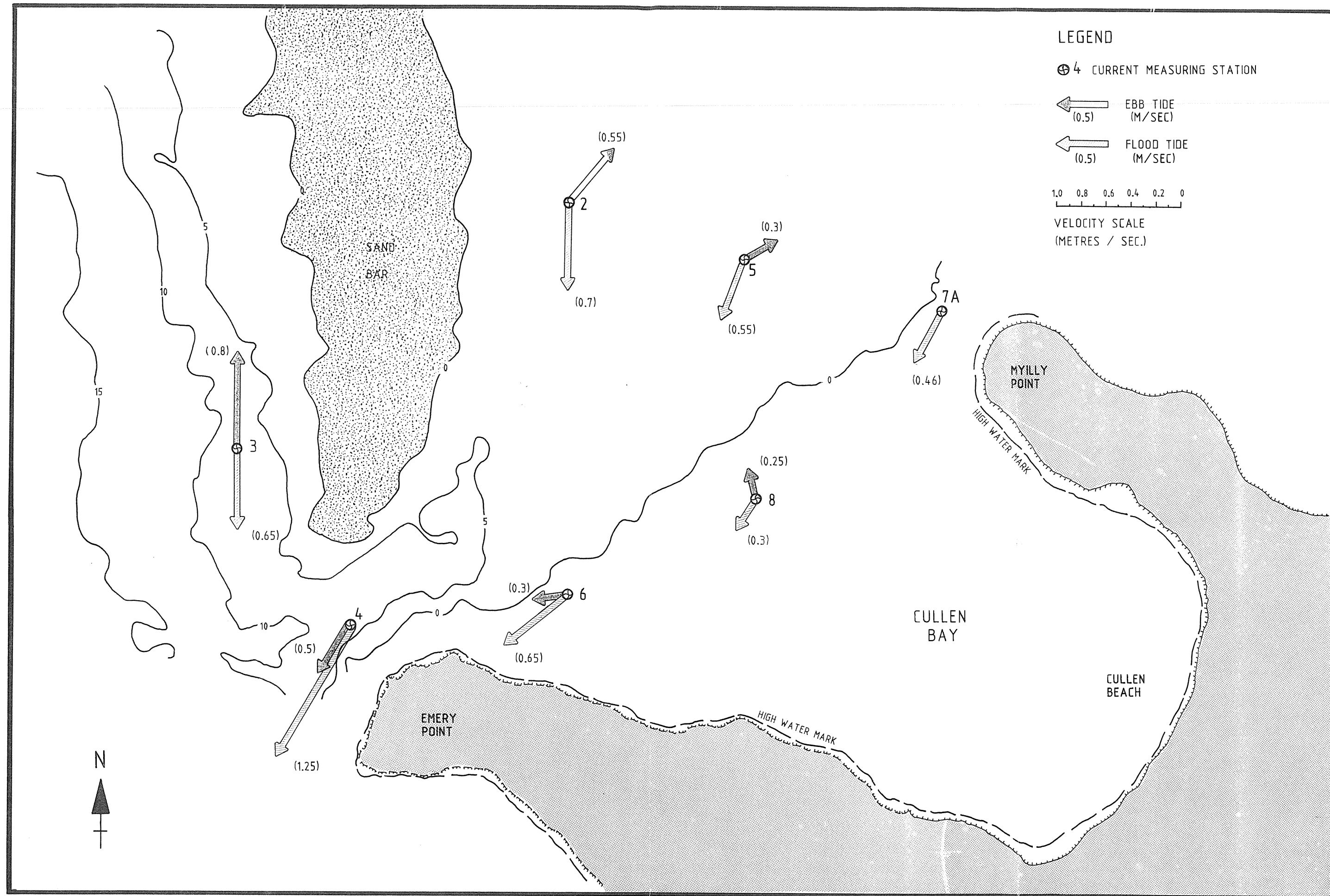
As the water level rises and falls with the tides, currents flow along this section of coastline.

A current measuring exercise was undertaken during both spring and neap tidal conditions in September 1986. A current meter was used at seven stations in the vicinity of Cullen Bay to determine tidal current velocities and directions at various depths during flood and ebb tides.

The detailed results are presented in Appendix A. Figure 2.4 shows the peak tidal velocities at each location for spring tides.

There are a number of important aspects of the local current regime which were identified as a result of the monitoring exercise:

- . During most tide cycles the crest of an offshore sand bar is above low water level. Subsequent ebb and flood tidal flows are confined between the sand bar and the coastline until the tide level submerges the bar.
- . The main body of tidal flow is seaward of the headlands of Emery Point and Myilly Point and primarily confined by the offshore bar.
- . There is little penetration of currents into Cullen Bay.
- . A deep channel has been scoured between the southern tip of the sand bar and Emery Point.



PEAK SPRING TIDAL
FLOW VELOCITIES

Figure 2.4

- . A north to south tidal current flows through this channel for all states of the tide (ie. for both ebb and flood tides).
- . The alignment of the sand bar causes the inflowing flood tide to converge, and consequently increase in velocity, as it flows between the sand bar and Emery Point.
- . Peak spring tide flows result in an average velocity of approx 1.25 m/sec in the channel during a flood tide. This velocity has scoured a stable channel profile.

2.4 Water Levels

The tide at Darwin is semi-diurnal with:

- . Highest Astronomical Tide = 7.9m above Chart Datum
- . Mean High Water Springs = 6.9m above Chart Datum
- . Mean High Water Neaps = 5.1m above Chart Datum
- . Mean Sea Level = 4.1m above Chart Datum
- . Mean Low Water Neaps = 3.2m above Chart Datum
- . Mean Low Water Springs = 1.4m above Chart Datum
- . Lowest Astronomical Tide = 0.1m above Chart Datum

In addition to this astronomical tide the water level can increase due to storm surge, wave set-up and surf beat.

These aspects have been examined in a detailed study commissioned by the Northern Territory Department of Lands. The results are presented by Lawson & Treloar, 1982; and Blain, Bremner & Williams, 1983. The findings of this study have been adopted when determining design water levels for the various components of the proposed development.

For surge plus tide effects alone, the study recommends 1 in 100 year and 1 in 1000 year water levels in Fannie Bay of RL +8.5m C.D. and RL +9.5m C.D. respectively. To this level must be added the effects of wave set-up and surf beat.

Wave set-up is a local increase in water level due to breaking waves pushing water up against a coastline. Surf beat comprises irregular

oscillations of the nearshore water level with periods of the order of several minutes.

The above study evaluated the combined wave set-up and surf beat effects to be 1.0m in Fannie Bay for a 100 year event.

Therefore, 100 year design water levels for the proposed development are:

- | | |
|--|---------------|
| • Storm surge plus tide | RL +8.5m C.D. |
| • Storm surge plus tide, wave set-up and surf beat | RL +9.5m C.D. |

2.5 Wave Climate

In order to study the coastal processes, a detailed knowledge of the nearshore, directional wave climate is required. Consideration must be given to both the ambient climate and that during extreme events such as cyclones. Storm waves are less frequent but because of their intensity are of significance with respect to coastal processes and the design of marine structures. Ambient waves are milder, but in view of their frequency, are also a significant factor in determining coastal processes.

The offshore wave climate was determined for both conditions using techniques described below and the deepwater directional wave climate transformed to the proposed site by consideration of:

- refraction
- diffraction
- shoaling
- attenuation due to seabed friction
- wave breaking
- regeneration due to following wind

The nearshore directional wave climate was then used as input to longshore sediment transport calculations to determine stable beach alignments and also for the design of the entrance breakwater and the groyne.

2.5.1 Ambient Wave Climate

Wave Hindcasts

For convenience, waves are often considered in two broad categories:

- . Swell waves which are generated over distant fetches and have travelled out of their generation area. Swell waves typically have long periods.
- . Sea waves which are locally generated, and typically have short periods.

The wave hindcast was undertaken by Oceanroutes (Australia) Pty. Ltd. using techniques which have been verified at other sites. At these sites, the hindcast wave heights were generally within 10% of the measured wave heights, refer McCormack et al, 1985.

The details of the wave hindcasting technique are given in Appendix B.

The wave hindcasts were in general based on wind fields obtained from :

- . synoptic charts
- . ship reports
- . satellite imagery
- . wind records

Sea waves can be generated solely within Port Darwin as well as in Beagle Gulf and the nearby Timor Sea. These waves are affected by refraction, diffraction, shoaling, breaking and seabed friction as they travel across the reef and shoals to the shore.

The hindcast of sea waves was done every 3 hours using the techniques outlined in CERC, 1984.

Wave activity varies seasonally and from year to year. To obtain meaningful results concerning the wave climate, the hindcast must cover a full year that is typical of annual wave conditions. The year from October 1981 to September 1982 was selected as being a suitable year to represent typical wave conditions.

Swell wave conditions were hindcast at 6-hourly intervals throughout the 12 month period, whilst the sea wave conditions were hindcast at 3-hourly intervals. Results of the hindcast are given in Appendix B.

Locations at which waves were hindcast are shown on Figure 2.5 and are as follows:-

- Site 1 : for hindcast of swell waves
- Site 2 : for hindcast of sea waves generated in Beagle Gulf
- Site 3 : for hindcast of sea waves generated in Port Darwin

Hindcast Swell Wave Climate

The swell wave hindcast site was located in the Timor Sea at the entrance to Beagle Gulf, in a water depth of typically about 60m. In this depth of water, the waves have not been significantly affected by refraction, shoaling and seabed friction and the hindcast represents the deepwater wave climate.

The hindcast often involved waves arriving at the hindcast site from several distant storms. To avoid the problems of combining the waves from various individual storms to give a single resultant wave train at the site, the swell hindcast was separated into two parts covering swell from the :

- south-west sector
- north-west sector

The hindcast swell wave climate is summarised in Table 2.1. The values in the Table represent the percentage occurrences of given wave height - wave direction combinations, these results having been derived from the more detailed tables presented in Appendix B. The results indicate a relatively mild wave climate, with the significant wave heights in excess of 1.5m occurring less than 2% of the time.

Maximum significant wave heights up to 2.5m were hindcast with corresponding peak periods in the range of 7 - 11 seconds, the dominant wave direction being west-southwest to west-northwest.

HINDCAST SHELL WAVE CLIMATE.

Location: Entrance to Beagle Gulf.
Wave Type: Swell.
Date: Oct. 1981 to Sept. 1982.

Wave period range: 5 s - 14 s.

The results presented are percentage occurrences.

Height (m)	Direction (deg)							
	202.5	225.0	247.5	270.0	292.5	315.0	337.5	360.0
.0 - .5	.00	1.58	36.30	15.27	.27	.00	.00	.14
.5 - 1.0	.07	.21	16.71	6.58	.27	.00	.14	.27
1.0 - 1.5	.00	.07	1.10	.75	.89	.00	.21	.07
1.5 - 2.0	.07	.07	.34	.68	.27	.00	.00	.00
2.0 - 2.5	.07	.00	.00	.27	.00	.00	.00	.00

HINDCAST DEEP WATER SEA WAVE CLIMATE.

Location: Entrance to Port Darwin.
Wave Type: Sea waves generated within Beagle Gulf.
Date: Oct. 1981 to Sept. 1982.

Wave period range: 1 s - 5 s.

The results presented are percentage occurrences.

Height (m)	Direction (deg)							
	247.5	270.0	292.5	315.0	337.5	360.0	22.5	45.0
.0 - .2	.72	1.82	.82	.51	1.34	2.81	1.06	.86
.2 - .4	.58	2.19	1.82	.68	2.77	3.22	1.34	.48
.4 - .6	.07	1.44	1.13	.10	1.95	1.71	.55	.55
.6 - .8	.17	1.61	1.16	.00	.41	.38	.17	.14
.8 - 1.0	.03	.55	.34	.00	.10	.21	.07	.03
1.0 - 1.2	.00	.31	.24	.00	.03	.03	.00	.00
1.2 - 1.4	.00	.03	.00	.00	.03	.00	.00	.00
1.4 - 1.6	.00	.03	.00	.00	.00	.03	.00	.00

HINDCAST SHALLOW WATER SEA WAVE CLIMATE

Location: Approx. 300 m north of Emery Point.
Wave Type: Sea waves generated within Port Darwin.
Date: Oct. 1981 to Sept. 1982.

Wave period range: 1 s - 4 s.

The results presented are percentage occurrences.

Height (m)	Direction (deg)					
	247.5	270.0	292.5	315.0	337.5	360.0
.0 - .2	1.03	2.43	.62	.31	1.13	5.86
.2 - .4	.55	5.31	3.25	.86	4.18	2.53
.4 - .6	.03	.27	1.54	.14	1.30	.03
.6 - .8	.00	.00	.10	.00	.03	.00

HINDCAST WAVE CLIMATE

Table 2.1

Hindcast Sea Wave Climates

i) Beagle Gulf

A site near the entrance to Port Darwin was used as the hindcasting site for sea waves generated within Beagle Gulf and adjoining areas in the Timor Sea (refer Figure 2.5). The water depth at the site was approximately 20m. The results for the 12 months of hindcast sea wave conditions are shown in Table 2.1.

The most severe waves at the hindcast site were generally from the west and west-northwest directions, due primarily to the almost unlimited fetch available in these directions. Maximum significant wave heights were up to 1.5m, with corresponding peak periods of 4 – 5 seconds.

ii) Port Darwin

The sea waves generated locally within Port Darwin were hindcast using measured wind data, for a site located approximately 300m north of Emery Point at the southern tip of the offshore sand bank (refer Figure 2.5). The water depth at the site was about 5m.

The summary table for the 12 months of hindcast wave conditions is given in Table 2.1. The predominant wave directions at the site are west-northwest to north-northwest, reflecting the increased fetch distances available in these directions. Maximum significant wave heights were up to 0.8m, with peak periods of 3 – 4 seconds.

Wave Transformation

Refraction, Diffraction and Shoaling

As waves move from deep water to shallower water they are altered by refraction and shoaling and in some cases by diffraction. A calculation scheme based on that developed by Abernathy and Gilbert (1975) was used to calculate the effect of refraction, diffraction and shoaling. The original program was further developed by Treloar and Abernathy (1977) and still further refinements have been subsequently made.

The reasons for using this program are:

- . The input format allows an easy variation of grid sizes in the computational scheme. Grid sizes of 25m, 50m, 100m, 200m, 400m, 800m, 1,600m, 3,200m and 6,400m were used for this study. This allowed the seabed bathymetry to be described in detail wherever it was required.
- . It is based on a reverse ray refraction technique which tends to eliminate wave caustics which can occur with forward ray refraction schemes.
- . Wave refraction is calculated on a spectral basis whereby the spreads in wave periods and directions that occur in nature are taken into account.
- . The standard output obtained from the refraction calculations are in a convenient form for sediment transport calculations.

The refraction technique used is described in detail in Appendix B.

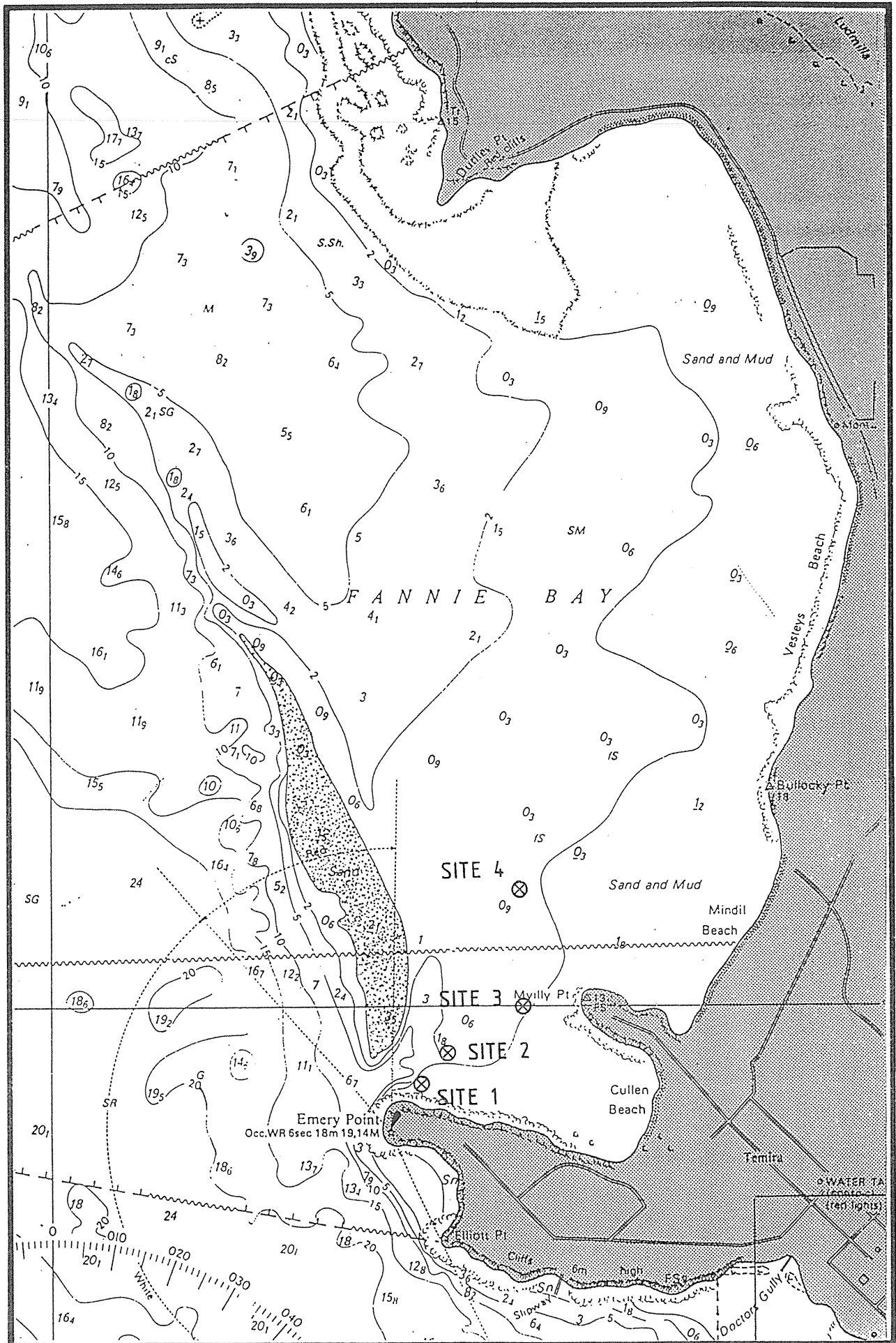
Four locations in the vicinity of the development were selected as refraction origins for which inshore wave climates were determined. Their locations are shown in Figure 2.6.

Site 1 : Located at the entrance to the outer harbour. The inshore wave climate at this site has been used to determine navigability of the entrance.

Site 2 : Located immediately offshore of the breakwater head. The results of the wave transformation has been used to design the breakwater armour.

Site 3 : Located offshore of the proposed beach. The inshore wave climate at site 3 was used to determine a stable beach profile and alignment.

Site 4 : Located offshore of Mindil Beach to the north of the proposed site. This site will be used to determine any effect the development might have on the wave climate at Mindil Beach.



REFRACTION SITES

Figure 2.6

The proposed development will utilize material dredged from the Fannie Bay sand bar. Hence the transformation of waves to the area was done for both pre-developed and developed conditions.

Seabed Friction

Wave attenuation by seabed friction is often overlooked whereas its effect can be quite significant, particularly where there are reefs or seagrass meadows or where the sand bed may be rippled. The existence of ripples depends on the sand grain size, wave characteristics and water depth.

The methods used to calculate the attenuation due to friction have been adopted from Riedel, Kamphuis and Brebner (1972), Kamphuis (1975), Nielsen (1977) and Hsiao and Shemdin (1978). In brief, the seabed is schematized in segments to which are assigned:

- water depth
- sand grain size
- seagrass roughness if seagrass is present
- reef roughness where reef is present.

For every possible combination of wave direction, height and period calculations are performed to determine:

- whether ripples are likely to exist
- the effective roughness of the seabed
- the wave height attenuation
- whether wave breaking would occur and if so assigns a reformed wave height.

The wave height attenuation by seabed friction depends upon many variables:

- wave travel path
- nature of the seabed
- wave height over the individual segments used in the calculations; the variations due to refraction and shoaling are taken into account
- wave period
- water depth
- wave regeneration by a following wind.

Transformed Wave Climate

The nearshore directional wave climate at the proposed marina site and adjacent beaches was determined by considering the effects of wave refraction, diffraction, shoaling and attenuation due to bottom friction on the three separate hindcast wave climates. The results obtained by transforming the hindcast wave climates in this way are discussed below.

Nearshore Sea Wave Climate

A refraction analysis was undertaken for waves generated within Beagle Gulf and nearby Timor Sea. The combined effects of refraction, diffraction and shoaling on the wave height as the waves propagate from the entrance to Port Darwin through to Sites 3 and 4 was determined. The resulting wave coefficients are shown in Appendix B.

The results indicate for example that, at Site 4 offshore of Mindil Beach, the wave coefficient for a 5 second wave with an offshore direction of 270° is 0.46. The combined effect of refraction, shoaling and diffraction is therefore to reduce a 1.0m wave height offshore to 0.46m at Site 4. This wave would have an inshore direction of 301° .

The nearshore wave climate obtained by transforming the hindcast sea wave climate to Site 4 is presented in Table 2.2. The wave climate represents existing conditions on Mindil Beach, prior to any development taking place in Cullen Bay. The results are presented in greater detail in Appendix B. The results indicate that the sea waves generated in Beagle Gulf have a height of 1.0m or less once they have propagated to Mindil Beach. The predominant wave direction offshore of the beach is 300° to 310° (with 360° representing North).

Nearshore Local Sea Wave Climate

The sea waves generated within Port Darwin were hindcast at a site close to Cullen Bay, with the result that the transformation of the waves to the marina site and adjacent Mindil Beach had little effect on the hindcast conditions.

INSHORE SEA WAVE CLIMATE

Location: Site 4 (pre-development).
Wave Type: Sea waves generated within Port Darwin.
Date: Oct. 1981 to Sept. 1982.

Wave period range: 2 s - 4 s.

The results presented are percentage occurrences.

Height (m)	Direction (deg)										
	250.0	260.0	270.0	280.0	290.0	300.0	310.0	320.0	330.0	340.0	350.0
.0 - .2	1.06	.92	.51	.99	.24	.31	1.03	1.27	1.85	2.47	3.29
.2 - .4	.55	.62	.24	3.39	2.77	.51	4.90	1.23	.10	.00	.00
.4 - .6	.03	.07	.00	1.40	1.54	.00	.24	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.03	.10	.03	.00	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Site 4 (pre-development).
Wave Type: Sea waves generated within Beagle Gulf.
Date: Oct. 1981 to Sept. 1982.

Wave period range: 2 s - 5 s.

The results presented are percentage occurrences.

Height (m)	Direction (deg)						
	290.0	300.0	310.0	320.0	330.0	340.0	350.0
.0 - .2	.00	4.79	1.68	8.25	5.03	1.40	.00
.2 - .4	.00	2.09	5.96	2.33	.00	.00	.00
.4 - .6	.00	.72	3.70	.00	.00	.00	.00
.6 - .8	.00	.10	1.03	.00	.00	.00	.00
.8 - 1.0	.00	.03	.14	.00	.00	.00	.00

SEA WAVE CLIMATES AT MINDIL BEACH

Table 2.2

Results of the transformation are presented in Appendix B. The wave climate at Site 4 for sea waves generated locally within Port Darwin is also presented on Table 2.2. Maximum significant wave heights are in the range of 0.6 to 0.8m with directions of 280° to 300°.

Nearshore Swell Wave Climate

The proposed marina site is largely protected from the swell in the Timor Sea by the Cox Peninsula to the west and Bathurst and Melville Islands to the north. Wave energy which does enter Beagle Gulf is dissipated by the shallow water and offshore shoals in Port Darwin through the effects of bottom friction and wave breaking.

The combined effects of wave refraction, shoaling, diffraction and attenuation due to bottom friction reduce the wave heights at the development site to less than 10% of the corresponding hindcast height in the Timor Sea, resulting in maximum significant swell wave heights at the marina site of less than 0.2m. The ambient swell wave component of the total wave climate at the proposed site is therefore small compared to the sea wave climate and has an insignificant effect on sediment transport rates and on the maximum wave height used for structural design purposes.

2.5.2 Storm Wave Climate

The effect of cyclone waves on the coastline around Darwin has been the subject of considerable studies, particularly since the devastation caused by Cyclone Tracey in 1974. The "Greater Darwin Storm Surge Study" commissioned by the Northern Territory Department of Land investigated the effects of various cyclones on such aspects as storm surge, wave set-up and wave heights on the foreshore in the greater Darwin region.

Results of the study into the maximum significant wave heights along the coastline are presented in Part 2 of the above report and indicate that maximum significant wave heights up to 6.5m can occur at the entrance to Port Darwin under very severe cyclone conditions.

For the purpose of determining the maximum significant wave height at the proposed development site, a range of wave heights up to a maximum of 6.5m and having all possible combinations of offshore direction and wave period were transformed to the site using the mathematical techniques described previously.

The results of the transformation show that the maximum significant wave height immediately offshore of the proposed breakwater will be 3.3m. Considerable protection is afforded by the offshore sand bar which causes larger waves to break. This wave height has been used to design the armouring on the breakwater.

2.6 Coastal Processes

Aerial photographic records extend back as far as 1945. Examination of these photographs has provided evidence of some sediment movement from north to south in Fannie Bay. The main indicators were the shape and location of the sand across the creek outlet at the southern end of Mindil Beach and the small accretion of sand on the northern side of a boat ramp on Vesteys Beach. However, the amount of longshore movement is estimated to be quite small because of the absence of large amounts of accretion against the headland extending out to Myilly Point and various boat ramps along the beaches. Even moderate amounts of sediment moving along the beach would result in a substantial accumulation of sediment against the Myilly Point headland.

A technique has been developed to mathematically estimate littoral drift taking into account wave height and the wave direction, at the point of breaking, relative to the shoreline. The method used is the C.E.R.C. formula as described in the Shore Protection Manual (1984).

Traditionally the mathematical techniques have been very coarse and at best have been able to provide accuracy only within an order of magnitude. More recently, refinements to the technique have been possible as result of more accurate directional wave information and more precise techniques for wave transformation into shallow water.

It is now possible to sequentially calculate sediment transport every three hours for a twelve month period and although it must still be considered an approximate method it is considerably more accurate than it has been in the past.

Calculations have been performed at three (3) locations along the coast opposite the proposed site and also at Mindil Beach. At each site careful study was required of the offshore features such as reefs and in particular the offshore sand bar.

The results are presented in Figure 2.7 and show that there is only a very small net littoral drift on the beaches.

Results of the mathematical modelling and the analysis of aerial photographic records are consistent with each other and with the findings of previous reports on coastal processes in the area.

There are two mechanisms that cause a loss of sediment to the Vesteys and Mindil Beach system:

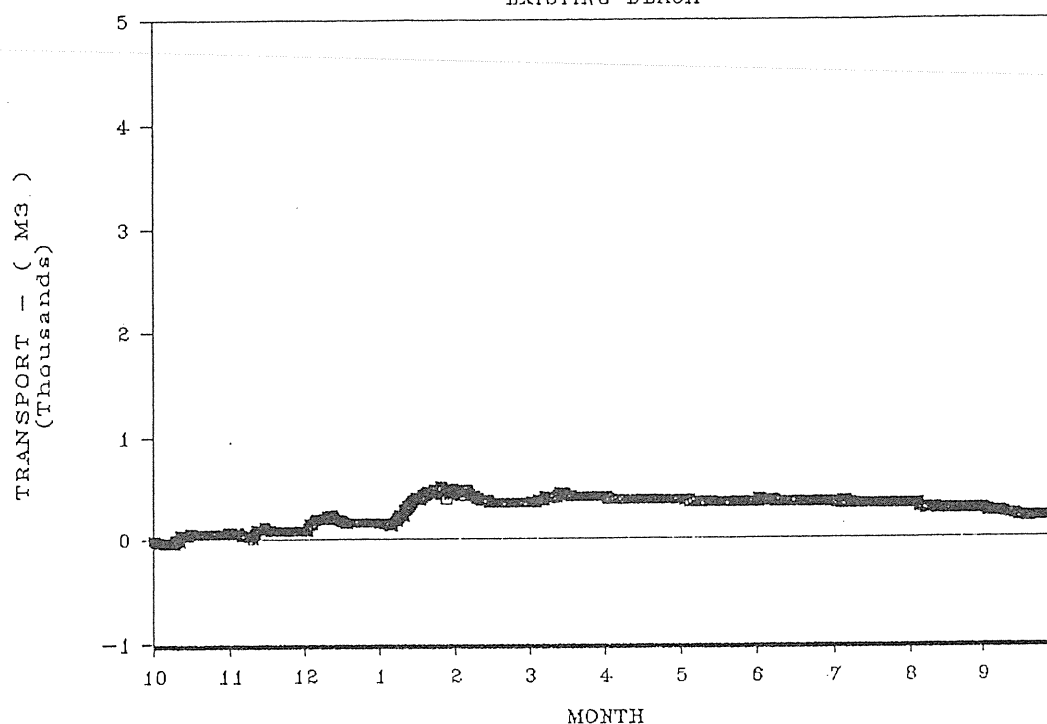
- . The first is an offshore movement of sediment by storm waves. This offshore movement transports the sediment into an area of Fannie Bay where it can be influenced by strong flood tide currents and moved towards Emery Point. This sediment is subsequently lost to the beaches.
- . The second is when the creeks which cross the beaches flow strongly and carry some sediment offshore and again into the influence of the flood tide currents.

The aerial photographs show that there is some very limited erosion of the beaches over the 40 years of record. This is consistent with a gradual movement of sand by tidal streams as described above.

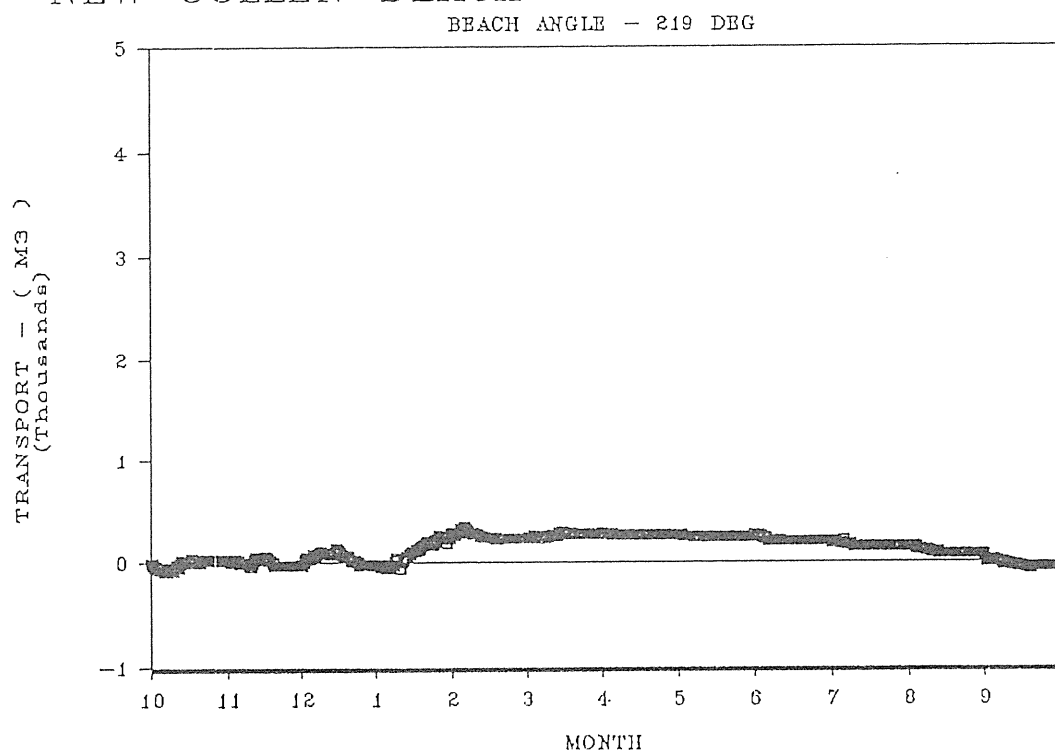
The likely sediment movement patterns in Fannie Bay are shown on Figure 2.8. The main features are :

- . A small net littoral drift along Vesteys and Mindil Beaches from north to south.

MINDIL BEACH -- SEDIMENT TRANSPORT

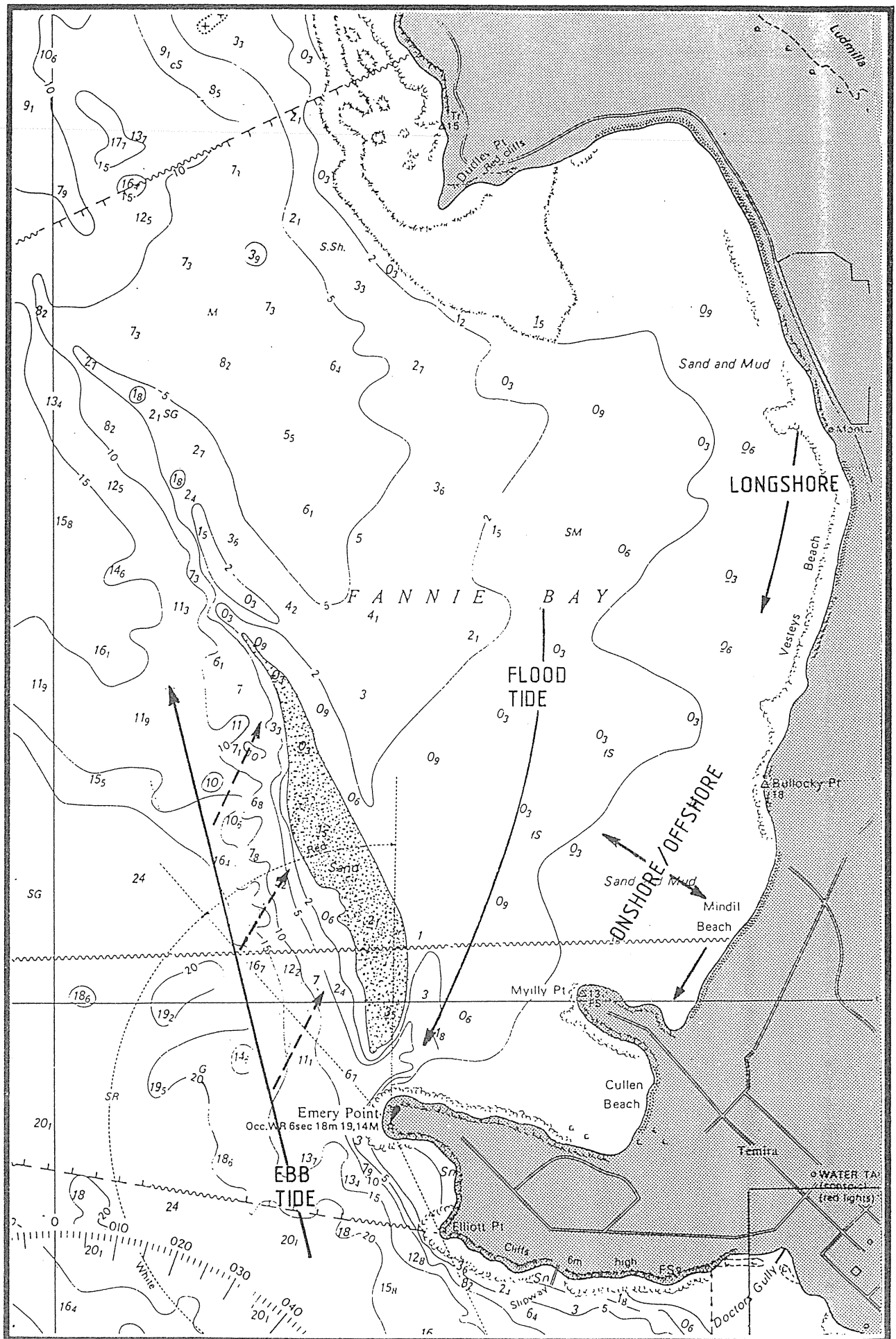


NEW CULLEN BEACH -- SEDIMENT TRANSPORT



LONGSHORE SEDIMENT TRANSPORT

Figure 2.7



SEDIMENT MOVEMENT PATTERNS
FANNIE BAY

Figure 2.8

- . Offshore movement of sediment from the beaches, placing sediment where it can be influenced by the strong flood tide currents.
- . Sediment moved by flood tide currents past Emery Point and into Port Darwin.
- . Ebb tide currents move sediment from within the harbour (south of Emery Point) and deposit some on the offshore sand bar north of Emery Point.

2.7 Sand Bar

Bathymetric surveys incorporating the Fannie Bay sand bar have been carried out as far back as 1938. An analysis of surveys done in 1938, 1970 and 1986 indicate the sand bar is accreting at a rate of approximately $50,000\text{m}^3/\text{yr}$. In order to identify the source of supply to the sand bar sediment samples were taken from several locations on the bar and over a range of depths. Samples were also taken from Vestey's and Mindil Beaches.

Material forming the sand bar consists of sand and shellgrit while those on the beaches of Fannie Bay are primarily fine sand.

Closer examination indicates that the coarser materials on the sand bar are the broken down shell fragments of organisms that inhabit the intertidal and subtidal zones of rocky shorelines. There is also evidence of siliclastic material which has been formed by the gradual breakdown of rock. None of the grain components in the sand bar have derived from a tidal flat or mangrove environment.

Within the various distinct environments of Port Darwin there are rocky shore areas which can sustain extensive habitats of intertidal marine organisms. The strong currents within Port Darwin result in continuous and substantial removal of these organisms. It is possible that the interaction between the strong ebb current from the harbour and the flow out of Fannie Bay has resulted in the deposition on the Fannie Bay sand bar.

In summary, an examination of sediment taken from the Fannie Bay sand bar and the inshore beaches has established the following:

- . Sediments comprising the sand bar and those on the inshore Fannie Bay beaches are from two quite distinct origins.
- . There is little exchange of sediment between the sand bar and the inshore beaches.
- . There is a continuous strong supply of sediment to the bar resulting in its steady growth.

3. PROPOSED DEVELOPMENT

3.1 General

It is proposed to develop a harbour with surrounding residential blocks, a hotel and restaurant and a commercial retail area. Figure 3.1 shows the general layout of the proposed development. A barrier approximately 1.0km long will be required to protect the marina and the surrounding development from ocean waves. Approximately one half the length of the barrier will be formed by a beach and the other half by a conventional breakwater.

A system of weirs and gates is planned to control the water level within an inner harbour such that it would be tidal above RL +3.75m Chart Datum but not allowed to fall below this level. This inner harbour basin would be dredged to an average level of RL +1.0m Chart Datum and consequently always have approximately 2.75m depth of water. Access to the ocean would be provided for about 60% of the time.

Within the basin mooring facilities for both leisure and commercial vessels will be provided. Sufficient space is available for a 300 berth marina. The number of berths initially provided would be smaller and be expanded on demand.

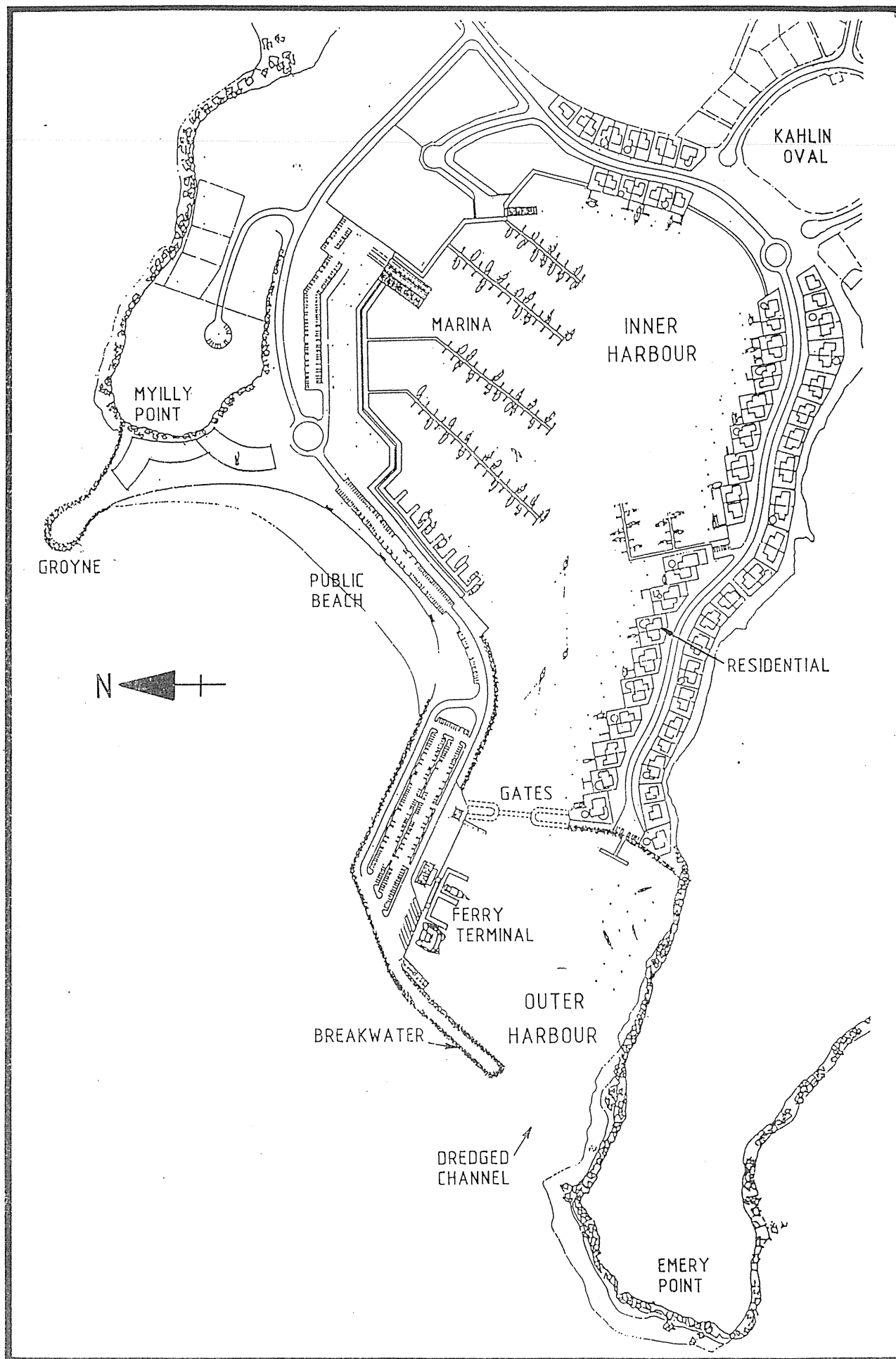
An outer harbour and channel would be dredged to RL -3.0m C.D. to allow access at all stages of the tide for vessels with draught up to 2.5m. This outer harbour would provide shelter to vessels awaiting suitable tide conditions to enter the inner harbour.

A ferry terminal and a public boat launching facility will also be incorporated within the outer harbour.

3.2 Beach

A barrier is needed to protect the marina from the ocean waves. It is proposed to do this in part by forming a pocket beach between two headlands. As shown on Figure 3.1, the existing headland at Myilly Point would be extended and a breakwater would be constructed to constrain the southwest end of the beach and to extend the barrier further south.

An analysis of stable beach alignments using the mathematical modelling techniques described in Section 2.5 was undertaken for this beach.



GENERAL LAYOUT
OF DEVELOPMENT

Figure 3.1

Over a year of typical wave conditions it was found that a beach having a bearing of 219° at its toe would have negligible net longshore transport. As the ambient conditions vary throughout the year there would be some rotation and realignment of the beach about this bearing, hence the need to contain the beach within the two artificial headlands.

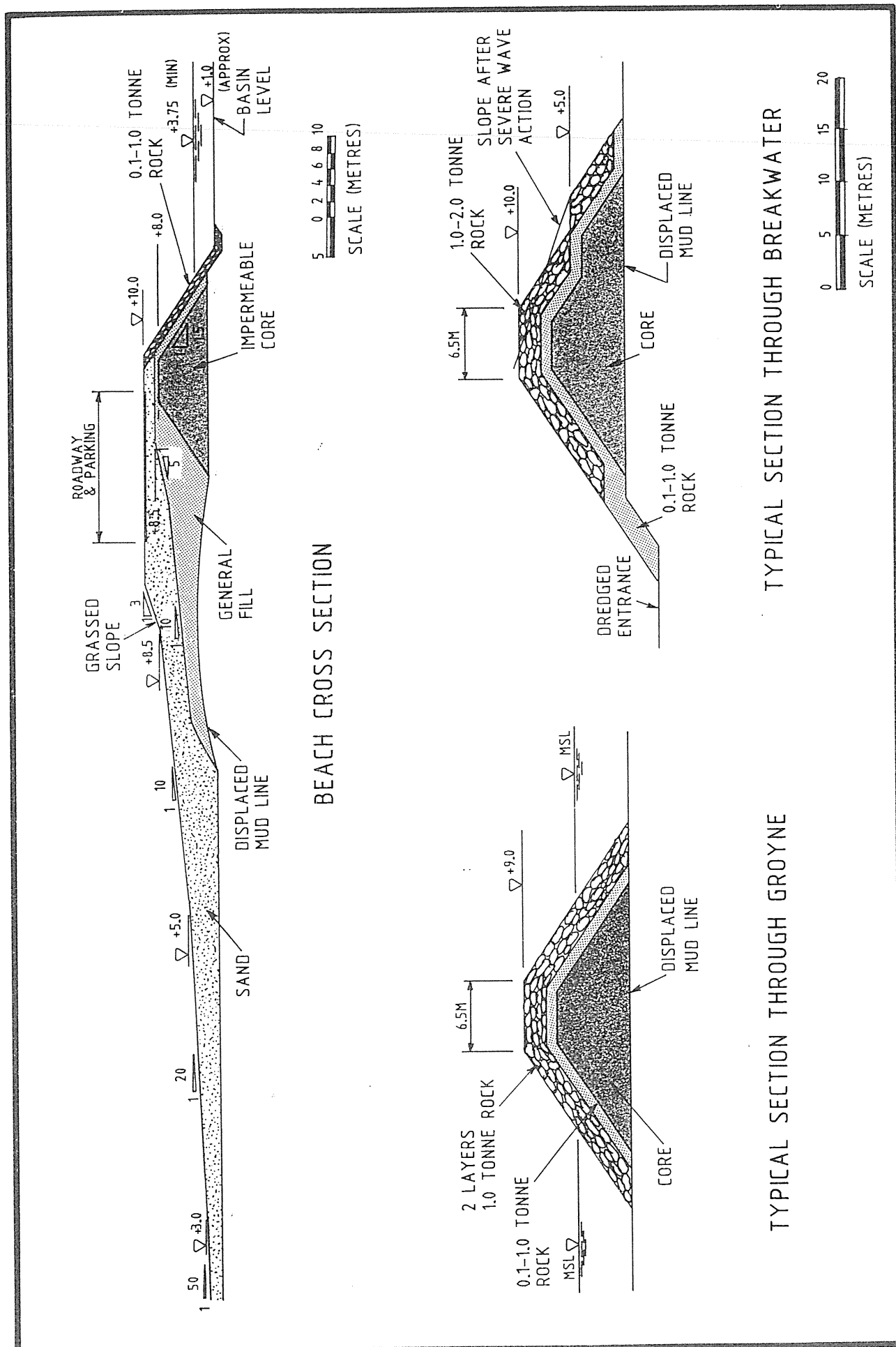
During some storms there would be a loss of sand from the beach as the waves move it offshore. This sand may return to the beach but it is likely that the flood tide currents would subsequently move some of the sand away from the area and it would be lost from the beach. It may be necessary from time to time to replenish the beach, however the extent of the replenishment works is not expected to be significant.

The beach profile shown on Figure 3.2 is that which would be formed by ambient wave conditions and has been determined by mathematical modelling techniques developed by Swart (1974). Existing beach slopes on Mindil and Vestey's Beaches are similar and confirm the results.

As discussed, storm waves will move sediment from the beach and deposit it offshore. This removal is particularly severe during cyclones when the increased water levels allow the larger waves access to the higher parts of the beach not normally accessible to wave action. For this reason it will be necessary to ensure that buildings and other permanent facilities are sufficiently set back beyond the influence of any beach recession. A set back distance of 25m will be required except where the structures are provided with additional erosion protection, such as seawalls.

A hotel complex is planned behind the northern end of the beach. Armour on the groyne forming the northern boundary to the beach will be extended to form a seawall in front of the hotel. This will provide a defence against erosion during a very severe cyclone.

It is proposed to maintain the marina water level at 3.75m above Chart Datum. Therefore the "beach section" must prevent water flowing to the ocean during periods when the tide is lower. In order to achieve this, an impermeable section will be built beneath the beach and act as a dam, refer Figure 3.2. This will be built from phyllite, quarry scalplings or other readily available suitable material and be extended to form the core of the breakwater.



DETAILS OF BEACH,
BREAKWATER & GROUYNE

Figure 3.2

It is anticipated that sand for the surface of the beach will be dredged from the offshore sand bar. In order to limit the amount required, the bulk of the "beach section" will be made from general fill.

When the beach is constructed on the very loose, silty sand material in Cullen Bay it is likely that the insitu material will be displaced. The construction of breakwaters in Darwin Harbour has shown that with suitable construction techniques, mud displacement can be undertaken with satisfactory results.

3.3 Breakwater and Groyne

A groyne will be constructed as an extension of Myilly Point to contain the sand at the northern end of the beach. A groyne length of approximately 125m will be required.

At the southern edge a breakwater similarly prevents loss of sand from the beach but serves primarily to provide wave protection to the inner harbour entrance and a safe haven and mooring area for vessels awaiting suitable tide conditions to enter the inner harbour.

The entrance to the outer harbour is approximately 150m wide, which under all conditions except those associated with cyclones will ensure the significant wave height in the navigation channel through the tidal gates would be limited to 0.4m. This would not present a hazard to vessels negotiating the channel.

Because of the protection afforded by the offshore sand bank, it has been possible to utilize armour protection which should be available from local Darwin quarries.

Typical sections through the breakwater and groyne are shown on Figure 3.2. The breakwater has been designed to adjust its shape under the action of cyclone waves. A greater than normal thickness of armour has been provided on the seaward face to allow the constructed slope to realign to a more stable, flatter slope under storm wave action.

Physical modelling will be undertaken at the detailed design stage to optimise the breakwater design.

The consequence of the above design approach is that construction costs are considerably reduced without any reduction in wave penetration. However, permanent road access along the crest of the breakwater will not necessarily be maintained.

3.4 Water Level Control Gates

An important feature of the proposed development is the water level control system. The water level for the marina would be controlled by the level of the gates and weir section shown on Figure 3.3. The gates would be kept open for navigation when the tide level was greater than 3.75m above Chart Datum. They would be closed on a falling tide of 3.75m and re-opened when the next flood tide reached 3.75m. In this way, at low tides, the marina basin would always have a minimum depth of approximately 2.75m.

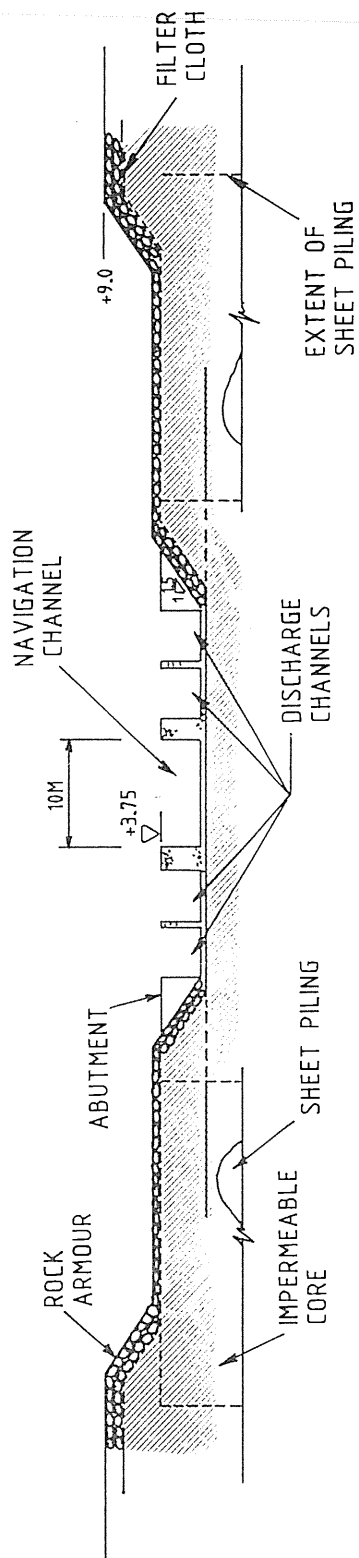
The weir section adjacent to the gates would not contribute to the flow area at the water level at which the gates would be opened and closed. The water flowing into or out of the marina at that time would flow only through the gate area. The maximum water velocity through the open gates is dependent upon :

- . area of gates
- . water area of marina at +3.75m C.D.
- . rate of change of tide.

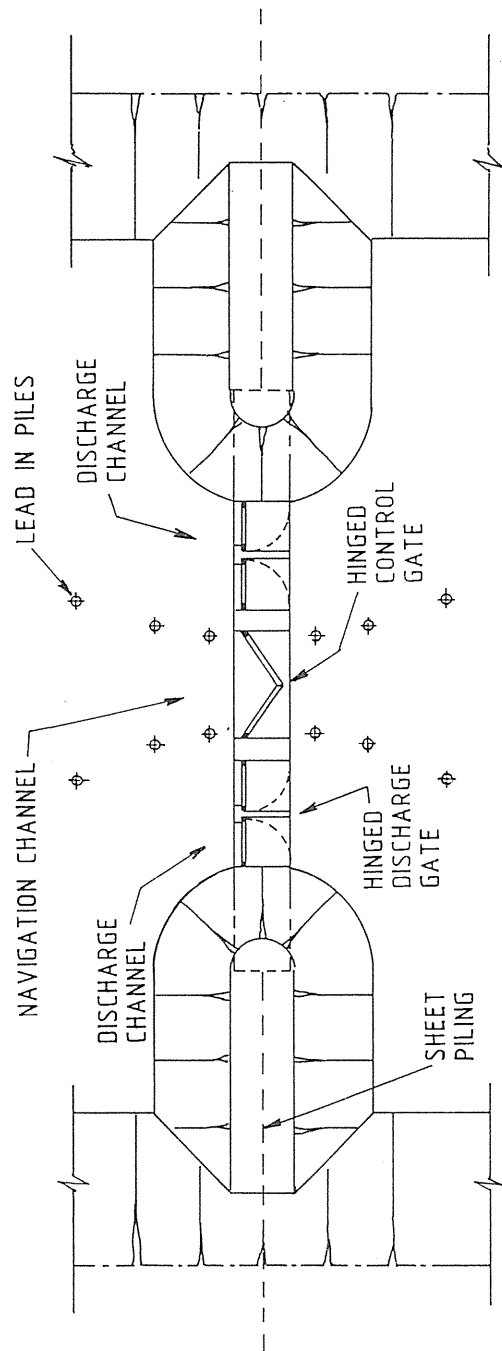
In order to keep the current less than 1.5 kts to 2.0 kts, gates totalling 30m in width are proposed for the marina entrance.

The gates would be of two types, four narrow side gates for controlling water current velocities and a single central gate for navigation purposes. It is proposed that this gate would be approximately 10.0m wide. The gates would be operated manually or hydraulically.

At higher tides, navigation would be possible over the weir section as well as through the gates. However it is considered desirable to restrict all but the smallest vessels to the navigation channel to prevent accidents due to boats beaching on the weir.



ELEVATION



PLAN

WATER LEVEL CONTROL GATES

Figure 3.3

3.5 Internal Walls

There will be essentially two types of wall within the inner and outer harbours:

- . rock revetment, which in some locations would have a boardwalk above it to allow pedestrian access along the harbour edge.
- . Vertical walling, to provide deep mooring immediately adjacent to the inner harbour edge.

Rock Revetment

The waters of the inner harbour will be significantly protected from ocean waves, the only major wave action being that caused by boat traffic. As a result, the armouring of the internal revetments will not require large rock sizes. Virtually all material won from local quarries can be used on the development, resulting in economic quarrying operations.

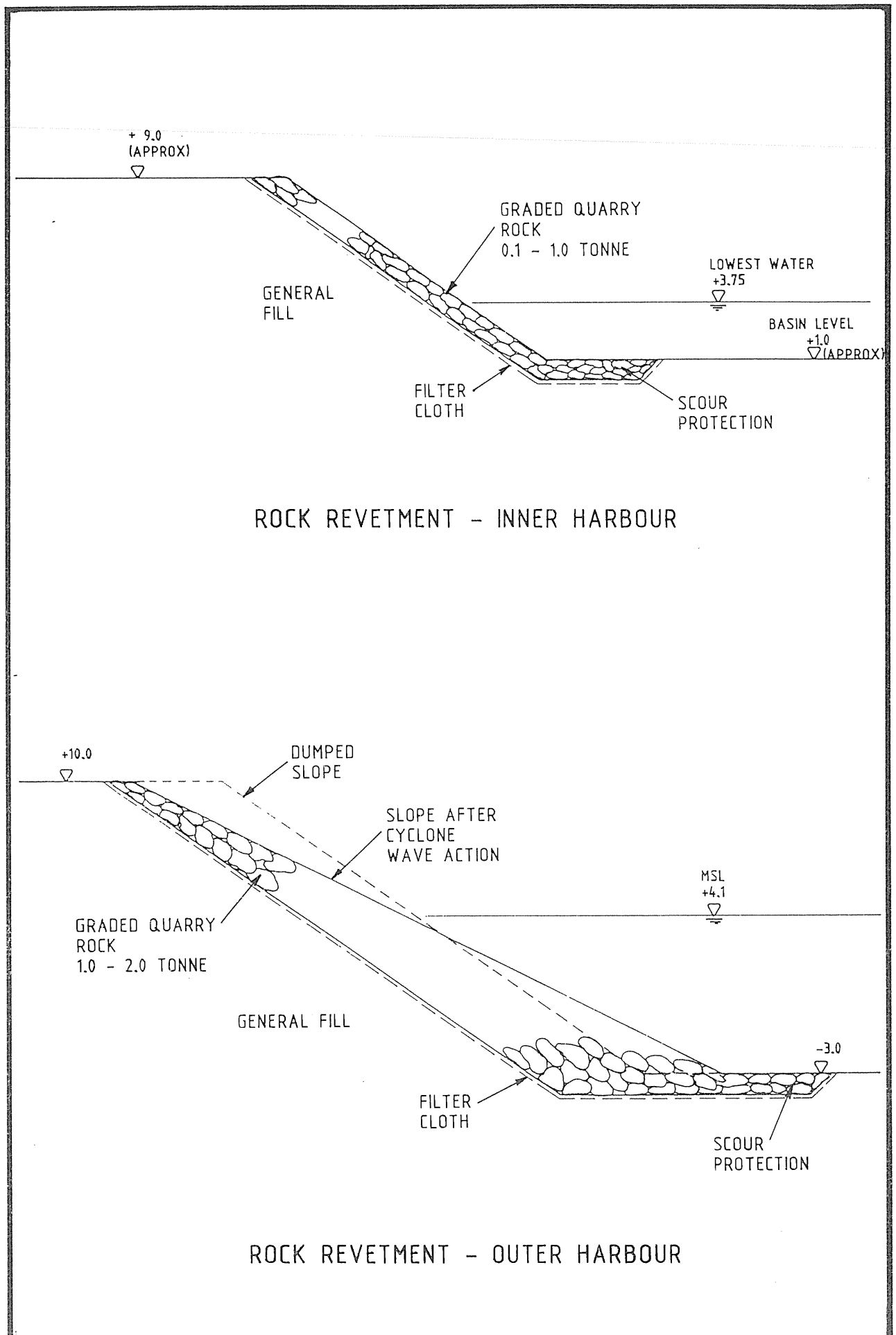
As shown on Figure 3.4 the revetment will consist of quarried rock placed at a stable slope. A filter cloth will separate the rocks from the underlying material to prevent leaching of fines from beneath the rock.

The revetment in the outer harbour immediately opposite the entrance will require 1.0 – 2.0 tonne rock to be placed on its slope. This revetment is exposed to cyclone wave attack and must afford protection to adjacent residential developments. As shown on Figure 3.4, sufficient rock will be placed to allow the front face to slump under wave action to a more stable alignment.

Vertical Wall

To facilitate easy access to berths and other marina facilities, vertical walls will be provided at various locations around the perimeter of the inner harbour basin. These walls must retain a height of approximately 8m.

There are a number of wall types which could be used for this purpose and include sheetpiling, concrete diaphragm walls and concrete L-units. The selection of wall type would be made at the detailed design stage when the results of more detailed soil investigations are known.



INTERNAL WALL TYPES

Figure 3.4

3.6 Marina & Commercial Berths

Due to the high tidal range within the harbour, fixed level pier and wharf structures will not be suitable. Floating pontoons secured by piles will provide access to berths for all tide levels. Access to the pontoons will be via sloping ramps hinged on land and designed for a maximum grade of approximately 1:5 at low tide.

Several types of pontoon units are available as propriety items. While they will probably be suitable for the smaller leisure craft, pontoons for the larger commercial vessels and ferries will need to be purpose made.

3.7 Construction Techniques

The major marine engineering components of the development are:

- . Excavation/Backfilling to form harbour basins and adjacent reclamation
- . Dredging/Formation of beach area
- . Construction of Breakwaters
- . Construction of Weir and Tidal Gates
- . Construction of Internal Walls (vertical, boardwalks and revetments)
- . Installation of Mooring Facilities and Boat Ramps

The method of construction will to some extent depend on the techniques employed by the Contractor, who is nominated to undertake the work and also the nature of the material on the site. Where appropriate therefore alternative construction techniques are described. It is anticipated that these works would take between 1.5 and 2 years to complete.

Excavation/Backfilling within the Marina

Approximately 750,000m³ of material is required to be excavated to form the inner and outer harbours.

The existing information on this material indicates that it is loose fine silt which will require blending with other material before it can be used as general fill elsewhere on the development.

The basic methods that could be utilised to undertake this work are either a cutter suction dredge or land based excavation equipment working from bunds.

Land based equipment would probably start at the shore and work seawards. The first stage of the operation being the construction of an impermeable bund from Myilly Point to Emery Point along the line of the core beneath the beach crest and then across the weir. The fill would be trucked to the reclamation site and tipped within bunds and then blended with shore based fill. The outer harbour and channel would then be excavated, probably using a floating cutter suction dredge.

If all of the work was undertaken by dredge alone, the overall procedure would probably be the same. The dredge would be floated in on a high tide into a pre-formed moat. The surrounding bund would be used to retain water in the inner harbour to allow the dredge to excavate to the correct level.

Dredging/Formation of the Beach

It is proposed to form a beach as part of the development using 3 sand obtained from the existing offshore sandbar. Approximately 200,000m³ of sand will be required. The most feasible method of obtaining this sand would be by dredging. It is anticipated that a small cutter suction dredge would be mobilized with sufficient capacity to pump the sand directly to the beach where it would hydraulically compact as the water drained away.

Breakwater and Groyne

The breakwater core will form the bund for the basin excavation works. It will therefore be one of the first items to be constructed. The core within the breakwater and that within the groyne will be constructed using land based fill transported to the site by truck. It will be dumped in layers to ensure good compaction as it must be impervious to water. Armour rock placement would progress in conjunction with the formation of the core. Armour rocks will be obtained from local quarries.

Water Level Control Structures

The weir and tidal gate structure between the outer and inner harbours is an essential component of the harbour as it will provide permanent wet moorings within the inner harbour. The weir structure will comprise a conventional breakwater with a central sheet pile cut-off wall. The gate structure will be a reinforced concrete structure with flood gates and will probably require piled foundations.

It is anticipated that the structure would be constructed inside a temporary cofferdam. At that time there would be a bund across the harbour entrance limiting the tidal range inside the harbour. The sheet piling works within the weir are simple and could be driven from the weir crest at a number of periods during the construction of the development.

Internal Walls, Revetments and Boardwalks

All the proposed internal treatments are simple and commonly used. Their construction techniques are not therefore discussed in detail. It is probable that both the excavation and construction of the walls will be done in the dry using land based equipment.

Mooring Facilities and Boat Ramps

Due to the high tidal range at the site, fixed pier structures will not be suitable. Floating pontoons will be adopted, moored with piles or a system of anchors. Access to the pontoons will be provided by sloping ramps hinged on land and designed with a maximum grade of approximately 1:5 at low water.

Provision within the inner harbour has been made for berths suitable for commercial charter and fishing vessels. Space for a ferry terminal has been incorporated in the outer harbour. Floating pontoons will be utilized at these locations. Pontoons used to provide berths for commercial vessels will be purpose made units, whereas those for the smaller leisure boats are likely to be proprietary items. These items will be assembled on land and floated into position.

A two lane tidal boat ramp is provided within the inner harbour and a non-tidal ramp within the outer harbour. The ramps will be constructed with a non slip surface and will extend sufficiently to provide 1.0m water depth at lowest tides. They will be at a grade of 1:8 to allow easy launching and retrieval of trailerable boats.

4. ENVIRONMENTAL IMPACT ASSESSMENT

4.1 Tidal Currents

The development is to be located within the coastal compartment of Cullen Bay, between Emery and Myilly Points. There is very little flow of tidal currents into and out of Cullen Bay so that the development will have only a very minor effect on the water circulation patterns in the vicinity. The main body of tidal flow is seaward of Emery and Myilly Points.

In order to minimize any effects on the existing tidal currents, the seaward extent of the development has primarily been limited to a line joining Emery and Myilly Points.

The groyne extending Myilly Point will however extend into the main tidal flow but its effect would be such as to cause only a small localised increase in tidal flow velocities. The maximum loss in cross section area available for tidal discharge would be approximately 10%. A similar increase in velocities immediately offshore of the groyne would result. This small increase in velocity is not expected to result in anything other than minimal changes to the bathymetry immediately offshore of the groyne.

4.2 Water Levels

As discussed in Section 2.4, the design water levels during cyclones for the various components of the proposed development have been selected based on the findings of the "Greater Darwin Storm Surge Study" and are as follows:

- | | |
|--|---------------|
| . For surge plus tide effects | RL +8.5m C.D. |
| . For surge plus tide, wave set-ups and
surf beat effects | RL +9.5m C.D. |

Incorporation of both wave set-up and surf beat effects into the design water level of RL +9.5m C.D. is applicable locations to conditions where breaking waves push water ahead of them and the higher water levels occur for only a short period of time due to the surf beat component. Design of the beach has taken these effects into account. The minimum level for construction of all buildings in the development has been established at RL +9.5m C.D.

Design waves for the structural design of the breakwater are non-breaking waves (refer Section 2.5.2) consequently there is no wave set-up or surf beat to increase the water level on the face of the breakwater over and above that due to surge and tide alone. The water level used for breakwater design has therefore been taken at RL +8.5m C.D.

4.3 Wave Climate

Under normal wave conditions, vessels negotiating the entrance to the outer harbour are not expected to experience any difficulties. Reference to Table 4.1 indicates that the significant wave height at the entrance would be less than 0.5m for more than 90% of the time. Even during the more severe storms which can be expected once or twice a year, the significant wave heights are less than 1.0m. During such storms, waves penetrating the outer harbour will have wave heights less than 0.4m at the water level control gates and will therefore not present a hazard to vessels entering the inner harbour.

During severe cyclones, the combination of increased water levels and higher waves will cause some overtopping of the breakwater. As a result, it may be necessary for some ferries to seek shelter within the inner harbour.

The proposed groyne and breakwater in the marina development will not affect the wave climate at the nearby Mindil and Vestey's beaches, since the development will be confined to within a line joining Emery and Myilly Points.

Dredging of sand from the bar will remove approximately 200,000m³ of material which will be subsequently used as fill on the beach. It is proposed that this material will be removed as a 50m wide, 450m long slice from the southwest edge of the bar. Because the seaward edge of the bar extends to a greater depth than the landward edge, the required volume of sand can be removed in a relatively thin sliver, thereby retaining the overall form of the bar.

In fact up to 400,000m³ of sand can be removed from this slice and still retain the bar form. This can be achieved by extending the dredging down the full depth of the seaward edge of the bar, by extending it along the

INSHORE SEA WAVE CLIMATE

Wave Type: Combined sea wave climate.
Date: Oct. 1981 to Sept. 1982.

The results presented are percentage occurrences.

		Height (m)	Direction (deg)								
			270.0	280.0	290.0	300.0	310.0	320.0	330.0	340.0	350.0
SITE 1	.0 - .2	.00	2.53	1.27	.10	.21	.24	3.77	7.23	.51	
	.2 - .4	.00	.58	2.05	.27	1.82	2.29	4.08	1.06	.00	
	.4 - .6	.00	.00	.65	.00	.48	3.63	3.80	.07	.00	
	.6 - .8	.00	.00	.00	.00	.03	1.85	.55	.00	.00	
	.8 - 1.0	.00	.00	.00	.00	.00	.17	.63	.00	.00	

INSHORE WAVE CLIMATES

Table 4.1

length of the bar, or by a combination of both. The dredging will however be restricted to the removal of a 50m wide slice.

To determine what affect this removal of sand might have on nearby Mindil Beach, the transformation of the hindcast wave climate was undertaken for both existing and dredged sand bar conditions. The wave climate tables presented in Appendix B for both these conditions indicate that dredging of up to 400,000m³ from the sand bar will have negligible effect on the wave climate. Reference to the refraction coefficients in Appendix B also indicates that the wave coefficients for the dominant wave directions differ by less than 2% for post and pre-developed conditions.

4.4 Coastal Processes

The coastal processes at work in this part of Fannie Bay are governed by the interaction of the strong tidal currents and the inshore wave climate. As previously discussed (Sections 4.1 and 4.3), the development in Cullen Bay will have no effect upon either of these two components or the existing Mindil and Vestey's beaches.

Cullen Bay does not contribute any significant material to the local sediment movement patterns (refer Section 2.6). There is little supply of Cullen Bay sediment to the accreting sand bar.

It is proposed to dredge material from the southwest edge of the offshore bar to provide sand for the new beach. Mathematical modelling techniques (described in Section 2.6) were used to determine what effect this might have on nearby Mindil Beach.

Appendix B shows the results of the modelling and indicate that provided the material is removed as a slice from the seaward side of the sand bar, no change to the wave climate or longshore sediment transport will result. No realignment or loss of beach sand from Mindil Beach will therefore result as a consequence of removing sand from the bar.

The removal of a slice from the sand bar as shown in Figure 4.1 will in no way jeopardise its existence. The bar is growing significantly each year and the material removed will quickly be replaced.

In summary, therefore the impact of the marina construction on the coastal processes within the area is expected to be minimal due to the following:

- The development is contained within a closed coastal compartment and will have no influence on sediment paths elsewhere.
- The development is restricted behind the line between two headlands and therefore has minimal effect on tidal streams.
- Beach material removed from the sand bar will be quickly replaced from natural sources without any deleterious effects on adjoining areas.

4.5 Water Quality

Water quality within the marina must be such that the following beneficial uses would not be adversely affected:

- Occasional human immersion and wading
- Boating
- Adjacent development
- Passive recreation (which can be affected by odour, insects, rubbish).

In assessing the water quality of the proposed development, several factors must be considered. They are:

- quality of source water
- nutrient and pollutant inputs
- water mixing and exchange

These aspects are examined in this section.

Source Water

The source water for the marina is that in Port Darwin. This water is suitable for the four beneficial uses listed above since the area is frequently used by locals and visitors for recreational activities including:

- . boating
- . fishing
- . wading and swimming
- . picknicking

It is therefore concluded that the source water is of a high standard.

Nutrient and Pollutant Inputs

The proposed development would not lead to nutrients and pollutants entering the marina or adjacent waters provided the development has the following features to handle and dispose of any materials that would adversely affect the water quality:

- . deep sewerage
- . household and garden rubbish disposal in appropriate refuse sites.

In addition, no on board living should be allowed within the marina unless sewage disposal facilities are provided at berths.

Water Mixing and Exchange

There are a number of mechanisms that can cause water to mix and circulate in a harbour system. These include winds, water level variations, boat traffic and density currents. In the proposed development, winds and water level variations would be the more important factors.

Winds

Winds would have two significant effects on the marina: they would cause waves that would produce some vertical mixing of the water body and they also set up drift currents. The alignment of the marina takes full benefit of prevailing winds from the south-east through to the north-east.

Tidal Exchange

The typical tidal range during one day is about 3.7m. The inner harbour basin would have a tidal prism ratio of about 0.42 for the normal daily

tidal range and normal operation of the water level control gates. This means that about 42% of the water in the harbour at high tide would flow out of the harbour by the low tide.

The shape of the basin can affect the degree of mixing and water exchange (one extreme being for the source water to merely flow in and out without mixing and exchange). The exchange is gauged by a factor called the flushing efficiency. Application of techniques developed by Nece et al, 1976 and Falconer, 1980 indicate that the inner harbour would have good flushing efficiency and a tidal exchange coefficient of about 0.4 to 0.5. This means that during each normal tidal cycle, the marina would have about 40% to 50% of its volume replaced by water from the ocean. Opening of the weir gates will increase this exchange to approximately 70%

Conclusions

The water quality in the marina will not adversely affect the beneficial uses of the water body and adjacent waters, provided the necessary precautions are taken.

The nutrient and pollutant inflow will not be significant and there would be substantial flushing and water circulation caused by tides and winds.

4.6 Siltation

The sheltered waters of the harbour will provide an opportunity for any fine sediment in suspension to settle to the bottom.

The amount which will drop out of suspension will determine how frequently maintenance dredging operations need to be carried out to maintain the design depth in the basin. The siltation rate will depend upon a number of factors:

- . Density and size of the suspended particles
- . Plan area of the basin
- . Tidal range

Water samples were taken from Cullen Bay and adjacent waters and suspended sediment concentrations determined by filtering out the samples and measuring the oven dried weight retained.

In addition, grading analyses were carried out to determine the distribution of suspended particle size. This enabled consideration to be given to the variation in fall velocity expected of the various suspended particle sizes. These settling velocities were then used in conjunction with tidal exchange and retention times to determine the volume of sediment which would fall out of suspension.

The results indicate that the harbour basin would experience siltation rates less than 0.01m/yr, requiring maintenance dredging at intervals in excess of 15-20 years.

4.7 Construction Operations

The marine components of the development which will have an effect on the environment are:

- . Importation of fill and armour rock
- . Marina excavation works
- . Sand dredging works
- . Vertical walls
- . Maintenance dredging

It is anticipated that, due to the fine nature of the material to be excavated in the harbours, considerable quantities of shore based granular fill may have to be imported onto the site for blending purposes. This material would be obtained at local quarries. All armour rock for the breakwater, groyne and revetments will also have to be supplied from local quarries.

The importation of the above materials onto the site will result in a considerable increase in truck traffic in the area. To minimise the effect that this traffic will have on the local populace, it is suggested that specific haul routes be nominated and strict speed restrictions be enforced.

A detailed survey of road conditions on the nominated routes would be

undertaken prior to the start of the development construction. Any damage caused to the roads by the construction traffic would be repaired on a regular basis at the cost of the developer.

It is not anticipated that the marina excavation works will have a major impact on the local environment. All construction plant will remain on the site during the entire works. To ensure low noise levels it will be clearly stated in any contracts awarded for this work that all plant and equipment must be fitted with effective silencers.

The formation of bunds around areas being excavated will prevent turbid water from entering Fannie Bay. Short term discoloration will occur when the channel is excavated between the outer harbour and deep water. However this is unlikely to be anymore severe than the turbidity experienced in the waters of Port Darwin during the wet season.

Minimal noise and water discoloration will occur during sand dredging and placement operations. Samples of sand taken from the sand bar indicate that it has a low fines content.

Pile driving works for vertical wall and boat moorings, will probably be done using diesel hammers. There will be some noise associated with this activity, however the duration of such works will be limited.

Maintenance dredging of the marina is anticipated to be required after a considerable period. During this dredging works, there may be some temporary disruption to boat traffic in the marina.

5. SUMMARY AND CONCLUSIONS

This report examines the various coastal and marine engineering aspects of the proposed development. The work is briefly summarised as follows:

- . The oceanographic and meteorological conditions are suitable for a development of the type proposed.
- . The geotechnical conditions at the site have been assessed, however a more detailed site investigation will be undertaken prior to detailed design.
- . In view of the water levels expected during a 1 in 100 year cyclone, buildings with first floor levels at or around RL +9.5m C.D. can be expected to suffer inundation. The buildings should be designed to structurally accommodate the wave forces.
- . Permanent wet moorings will be provided in the inner harbour by the operation of a system of water level control gates and weirs to maintain a minimum water level of RL +3.75m C.D.
- . An outer harbour will be dredged to allow shelter for vessels awaiting suitable tide conditions to enter the inner harbour.
- . The coastal processes at work in Fannie Bay are influenced primarily by the tidal current regime. There is very little penetration of currents into Cullen Bay. The proposed development is located almost entirely within the coastal compartment of Cullen Bay and will therefore have only minimal effect on the current patterns in Fannie Bay.
- . The sediments within Cullen Bay comprise fine grained silty sand overlying phyllite bedrock. These fine sediments do not contribute any significant material to the coastal processes. Their loss from the system with the construction of the development in Cullen Bay will not affect the coastal processes in Fannie Bay, in particular the supply of sand to the sand bar.

- Removal of sand from the Fannie Bay sand bar for use as fill within the development will have no effect on the neighbouring Mindil and Vestey's beaches provided:
 - the quantity removed is limited to approximately 400,000m³
 - dredging is confined to a 50m wide strip taken from the southwestern edge of the bar.
- The sand bar is accreting at a rate of approximately 50,000m³/year.
- The protection afforded by the offshore sand bar makes it possible to utilize armour for the breakwater and groyne which is available from local quarries.
- All other construction will be localised and the excavation of harbour basins will probably be carried out by land based equipment in the dry. Dredging operations will be done with minimal disruption to leisure boat traffic.
- The water quality within the sheltered waters of the development will be high given the large tidal exchange.
- There would appear to be no coastal or marine engineering reason why the development should not proceed.

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DARWIN MARINA ESTATE

TIDAL CURRENT MEASUREMENTS

APPENDIX A

- Introduction
- Current Measuring Locations
- Current Measurement Results

INTRODUCTION

In September 1986 a current measuring exercise was carried out in conjunction with a bathymetric survey of the waters adjacent to the proposed development site.

The purpose of the exercise was to identify the tidal current regime in the area so that the development could be designed to have minimum effect on existing current patterns.

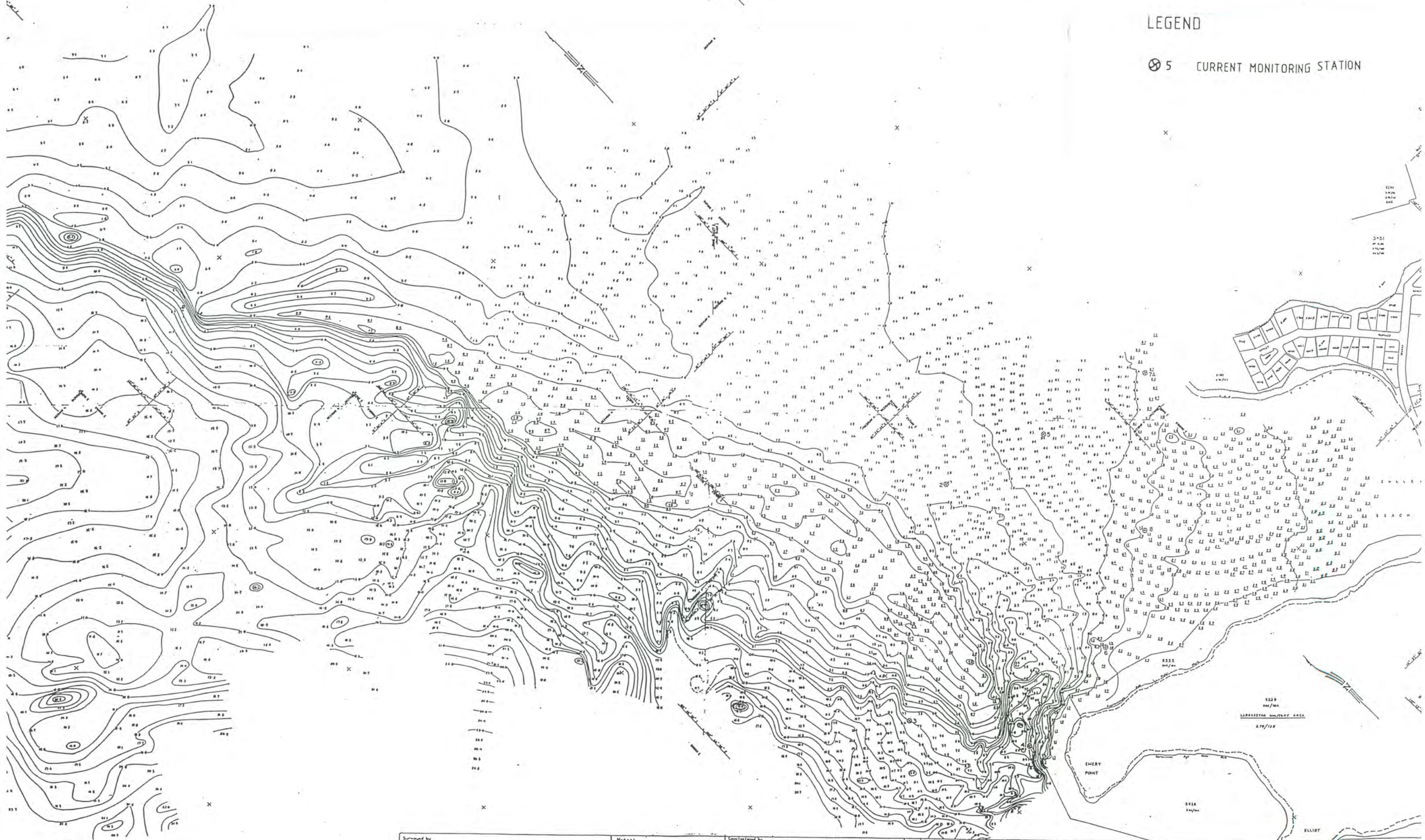
The velocity profile was determined over the full depth of water at up to seven locations in the vicinity of the site. Measurements of current velocity and direction were taken for ebb and flood tides during both Spring and Neap tides.

APPENDIX A

Current Monitoring Locations

LEGEND

⊗ 5 CURRENT MONITORING STATION



Surveyed by MAPPING & HYDROGRAPHIC SURVEYS BRISBANE		Notes:		Commissioned by MRS YOS planning consultants pty. ltd. 170 RCE 141 DARWIN ph. 1401 817222		Vertical Datum L.V.D. Based on DARWIN STRONGIDGE		Horizontal Datum R.M.G. Zone 52 ENCHY POINT HTS 221 817746.8196 847515.8184 FUNCTIONARY HTS 224 818178.8286 847515.8184 TOWER 21 HTS 221 817746.8202 847515.8184		Scale: 1:2500	
Drawn by <i>[Signature]</i>		Date 10/11/88		Sheet 1 of 1		Surveyed M.H.S.		Drafted M.H.S.		Projected J.M.S.	

DARWIN MARINA DEVELOPMENT
BATHYMETRIC SURVEY
HYDROGRAPHIC INVESTIGATIONS CULLEN BEACH SITE

APPENDIX A

Current Monitoring Results

DARWIN MARINA ESTATE

TIDAL MONITORING SURVEY

By
MAPPING & HYDROGRAPHIC SURVEYS

CURRENT METERING RECORDS

DATE 8-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1625	2	1.90 " "	3.8 " "	3.2 1.5 0.5	+0.68 +0.67 +0.70	190 190 180	10 knot..NE small chop
1635	5	2.1 "	2.7 "	2.2 0.5	+0.48 +0.49	200 210	
1644	6	2.4 " "	4.8 " "	4.3 2.0 0.5	+0.39 +0.55 +0.57	230 230 230	
1704	4A	2.9 " "	13.5 " "	13.0 6.5 0.5	+1.0 +1.02 +1.05	210 210 205	
1720	3	3.25 " "	13.2 " "	12.7 6.5 0.5	+0.45 +0.61 +0.61	180 155 160	

CURRENT METERING RECORDS

DATE 8-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
735	2	3.60 " "	5.3 " "	4.7 2.3 0.5	+0.56 +0.64 +0.65	185 190 190	10 knot NE small chop
745	5	3.90 " "	4.5 " "	4.0 2.0 0.5	+0.45 +0.50 +0.55	190/200 210 200	
753	7	4.10 " "	4.5 " "	4.0 0.5	+0.34 +0.46	220 205	
802	6	4.30 " "	6.9 " "	6.2 3.0 0.5	+0.53 +0.63 +0.67	230 230/240 220	
313	4A	4.60 " "	14.5 " "	14.0 7.0 0.5	+1.16 +1.25 +1.24	210 210 200	
330	3	5.00 " "	14.2 " "	13.7 7.0 0.5	+0.53 +0.60 +0.64	170 170 180	10 knot NE small chop

CURRENT METERING RECORDS

DATE 8-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1843	2	5.30 " "	7.2 " "	6.7 3.5 0.5	+0.53 +0.63 +0.64	200 200 200	
1852	5	5.54 " "	6.4 " "	5.8 3.0 0.5	+0.31 +0.49 +0.48	210 200 200	
1900	6	5.74 " "	8.0 " "	7.5 4.0 0.5	+0.28 +0.48 +0.53	240 230 230	
1912	4A	6.00 " "	13.0 " "	12.5 6.5 0.5	+0.86 +0.87 +0.90	230 220 220	10 knot NE small chop
1940	3	6.45 " "	15.6 " "	15.0 7.5 0.5	+0.21 +0.37 +0.41	160 180 180	

CURRENT METERING RECORDS

DATE 8-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1955	2	6.60 " "	8.5 " "	8.0 4.0 0.5	+0.29 +0.34 +0.33	210 190 190	
2005	5	6.70 " "	7.3 " "	6.5 3.0 0.5	+0.19 +0.17 +0.21	210 200 200/210	
2017	6	6.75 " "	8.7 " "	8.0 4.0 0.5	+0.25 +0.21 +0.14	220 220 260/270	10 knot NE small chop
2030	4A	6.84 " "	11.5 " "	11.0 5.5 0.5	+0.15 +0.13 +0.27	- 260 250	

CURRENT METERING RECORDS

DATE	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
0805	2	6.75 " "	8.5 " "	8.0 4.0 0.5	+0.15 +0.20 +0.22	180 200 190	10 knot NE small chop
0815	5	6.80 " "	7.5 " "	7.0 3.5 0.5	+0.08 +0.09 +0.11	180 210 200	
0825	7A	6.80 " "	6.8 " "	6.0 3.0 0.5	+0.11 - +0.11	340 120 130	
0835	8	6.85 " "	4.7 " "	4.2 0.5	+0.11 +0.12	80 120	4 sec. swell waves - no wind height 0.3 to 0.5 metres
0850	6	6.85 " "	6.2 " "	5.6 0.5	- -0.18	100? 90	10 knot NE small chop - position changed
0906	4	6.8 " "	18.1 " "	17.5 9.0 0.5	-0.25 -0.49 -0.36	140/180 70/75 50	
0935	3	6.55 " "	17.0 " "	16.5 8.0 0.5	-0.39 -0.62 -0.80	10 340/360 350/360	

CURRENT METERING RECORDS

DATE 9-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
0950	2	6.35 " "	8.0 " "	7.5 4.0 0.5	-0.38 -0.47 -0.56	50 40 40	
1000	5	6.20 " "	6.7 " "	6.2 3.5 0.5	-0.26 -0.30 -0.28	80 80 60	10 knot NE small chop
1008	7A	6.00 " "	6.0 " "	5.5 3.0 0.5	-0.16 - -	270 - -	
1015	8	5.85 " "	3.9 " "	3.4 0.5	- -0.08	230 190	
1025	6	5.60 "	5.1 "	4.5 0.5	-0.20 -0.28	260 260	
1035	4	5.4 " "	15.0 " "	14.5 7.0 0.5	- -0.16 -0.20	260 260 270	10 knot NE small shop
1045	3	5.15 " "	14.5 " "	14.0 7.0 0.5	-0.27 -0.53 -0.50	360 360 355	

CURRENT METERING RECORDS

DATE 9-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1129	2	3.95 " "	5.5 " "	5.0 2.5 0.5	-0.12 - -0.06	180 90 90	
1137	5	3.75 " "	4.5 " "	4.0 0.5	-0.26 -	360 150	
1145	7A	3.55 " "	3.5 " "	3.0 0.5	-0.13 -0.10	290 240	
1152	8	3.30	1.8	1.0	-0.24	350	10 knot NE small chop
1158	6	3.20 " "	2.7 " "	2.0 0.5	-0.22 -0.24	260 250	
1206	4	3.10 " "	13.0 " "	12.5 6.5 0.5	-0.27 -0.38 -0.39	240 240 240	
1217	3	2.80 " "	12.1 " "	11.5 6.0 0.5	- -0.22 -0.22	70 60 100	

CURRENT METERING RECORDS

DATE 9-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1232	2	2.50 "	4.1 "	3.5 0.5	-0.14 -0.15	210 200	
1239	5	2.35 "	2.9 "	2.5 0.5	-0.19 -0.20	240 230	
1246	7A	2.07	2.1	1.0	-0.17	230	10 knot NE small chop
1439	4	0.90 " "	13.0 " "	12.5 6.0 0.5	-0.50 -0.36 -0.28	200 220 230	
1514	3	0.75 " "	10.0 " "	9.5 5.0 0.5	+0.08 +0.11 +0.13	140 140 140	

CURRENT METERING RECORDS

DATE 9-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1537	2	0.80 "	2.6 "	2.0 0.5	+0.39 +0.44	200 200	
1549	5	0.90	1.5	0.7	+0.18	210	
1626	4	1.30 " "	12.5 " "	12.0 6.0 0.5	+0.45 +0.71 +0.77	230 220 220	
1641	3	1.50 " "	10.0 " "	9.5 5.0 0.5	+0.40 +0.54 +0.60	170 150 170	10 knot NE small chop

CURRENT METERING RECORDS

DATE 9-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1703	2	2.00 "	3.8 "	3.0 0.5	+0.56 +0.72	190 190	
1711	5	2.20	2.7	1.5	+0.38	200	
1722	4	2.50 " "	12.5 " "	12.0 6.0 0.5	+1.00 +1.11 +1.05	210 210 210	
1732	3	2.70 " "	11.5 " "	11.0 5.5 0.5	+0.40 +0.50 +0.64	160 170 170	

CURRENT METERING RECORDS

DATE 9-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1744	2	3.00 "	4.5 "	4.0 0.5	+0.51 +0.66	180 190	10 knots NE small chop
1752	5	3.20 "	3.7 "	3.0 0.5	+0.39 +0.45	210 210	
1803	7A	3.50 "	3.8 "	3.0 0.5	+0.44 +0.45	210 210	
1811	8	3.50	2.5	1.5	+0.30	220	
1820	6	3.60	3.2	1.5	+0.45	240	
1839	4	4.30 " "	12.8 " "	12.0 6.0 0.5	+1.03 +1.28 +1.17	210 200 200	
1852	3	4.65 " "	13.4 " "	12.8 6.5 0.5	+0.27 +0.50 +0.53	170 180 190	10 knots NE small chop

CURRENT METERING RECORDS

DATE 9-9-86

SPRING CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1910	2	5.05 " "	6.9 " "	6.0 3.5 0.5	+0.45 +0.59 +0.60	200 190 200	
1921	5	5.30 " "	5.8 " "	5.0 3.0 0.5	+0.26 +0.48 +0.48	210 210 210	
1936	7A	5.55 " "	5.8 " "	5.0 3.0 0.5	+0.34 +0.38 +0.35	200 210 220	
1948	8	5.80 " "	4.0 " "	3.5 0.5	+0.23 +0.31	200 210	
1958	6	5.90 " "	5.5 " "	5.0 2.7 0.5	+0.28 +0.39 +0.20	230 240 240	10 knot NE small chop
2012	4	6.10 " "	15.0 " "	14.5 7.5 0.5	+0.52 +0.79 +0.81	200 210 210	
2027	3	6.30 " "	15.0 " "	14.5 7.5 0.5	+0.24 +0.31 +0.34	170 180 190	

CURRENT METERING RECORDS

NEAP CONDITIONS

DATE 13-9-86

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1646	2	4.00 " "	5.6 " "	5.0 2.5 0.5	+0.08 +0.14 +0.16	190 210 200	5 knots NE small chop
1700	5	4.00 "	4.5 "	4.0 0.5	+0.11 +0.13	NIL 220	
1713	7A	4.05 "	3.8 "	3.3 0.5	+0.11 +0.14	230 220	
1722	8	4.05 "	3.3 "	2.8 0.5	+0.08 +0.12	230 230	
1730	6	4.10 "	3.8 "	3.3 0.5	+0.16 +0.12	240 260	
1736	4	4.10 " "	13.8 " "	13.3 6.5 0.5	+0.21 +0.24 +0.29	200 240 170	
1752	3	4.20 " "	13.1 " "	12.5 6.5 0.5	+0.09 +0.19 +0.17	160 180 180	

CURRENT METERING RECORDS

DATE 13-9-86 NEAP CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
0812	2	4.20 " "	5.8 " "	5.3 2.5 0.5	+0.12 +0.14 +0.15	200 200 170	8 knot NE small chop
0817	5	4.20 "	4.7 "	4.0 0.5	+0.12 +0.16	230 200	
0826	7A	4.30 "	4.2 "	3.7 0.5	+0.10 +0.15	250 200	
0835	8	4.30 "	3.2 "	2.7 0.5	+0.09 +0.13	210 210	
0842	6	4.30 "	3.6 "	3.0 0.5	+0.20 +0.15	270 240	
0849	4	4.30 " "	13.7 " "	13.0 6.5 0.5	+0.10 +0.22 +0.25	210 230 200	
0900	3	4.35 " "	13.1 " "	12.5 6.5 0.5	+0.07 +0.10 +0.15	130 190 200	

CURRENT METERING RECORDS

NEAP CONDITIONS

DATE 13-9-86

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
0913	2	4.40 " "	6.0 " "	5.5 3.0 0.5	+0.07 +0.14 +0.15	180 190 170	10 knot NE small chop
0927	5	4.45 " "	5.0 " "	4.5 0.5	+0.11 +0.12	220 200	
0936	7A	4.45 " "	4.3 " "	3.8 0.5	+0.07 +0.13	230 190	
0946	8	4.50 " "	3.5 " "	3.0 0.5	+0.09 +0.12	210 230	
0955	6	4.50 " "	3.7 " "	3.0 0.5	+0.11 +0.14	260 270	
1026	4	4.55 " "	14.1 " "	13.5 7.0 0.5	+0.07 +0.13 +0.21	200 130 120	
1036	3	4.55 " "	13.3 " "	12.7 6.5 0.5	+0.06 +0.06 +0.13	180 240 200	

CURRENT METERING RECORDS

DATE 13-9-86

NEAP CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1049	2	4.60 " "	6.3 " "	5.8 3.0 0.5	+0.06 +0.09 +0.11	230 220 190	10 knots NE small chop
1059	5	4.60 " "	5.0 " "	4.5 0.5	+0.06 +0.09	290 180	
1105	7A	4.60 " "	4.6 " "	4.0 0.5	+0.06 +0.12	260 180	
1119	8	4.60 " "	3.6 " "	3.0 0.5	- +0.09	220 180	
1126	6	4.60 " "	3.7 " "	3.0 0.5	+0.09 +0.06	170 200	
1140	4	4.60 " "	12.1 " "	11.5 5.5 0.5	+0.13 +0.06 +0.07	310 210 120	
1212	3	4.50 " "	13.3 " "	12.7 6.5 0.5	+0.09 +0.17 +0.17	340 340 310	

CURRENT METERING RECORDS

DATE 13-9-86

NEAP CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1259	2	4.30 " "	5.9 " "	5.4 3.0 0.5	-0.20 -0.24 -0.18	280 300 290	5 knot NE
1306	5	4.30 " "	4.7 " "	4.0 0.5	-0.10 -0.17	300 290	
1314	7A	4.20 " "	4.1 " "	3.5 0.5	-0.06 -0.15	320 310	
1322	8	4.20 " "	3.1 " "	2.5 0.5	-0.06 -0.06	350 200	
1330	6	4.10 " "	3.2 " "	2.7 0.5	-0.06 -0.08	200 80	
1337	4	4.05 " "	10.3 " "	9.8 5.0 0.5	-0.12 -0.10 -0.14	70 60 70	
349	3	4.00 " "	12.6 " "	12.0 6.0 0.5	-0.08 -0.17 -0.26	310 340 350	

CURRENT METERING RECORDS

NEAP CONDITIONS

DATE 13-9-86

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+) flood (-) ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1403	2	3.90 " "	5.6 " "	5.0 3.0 0.5	-0.08 -0.19 -0.10	310 290 290	12 knot NE small chop
1415	5	3.80 "	4.2 "	3.7 0.5	-0.06 -0.09	340 350	
1424	7A	3.70 "	3.6 "	3.0 0.5	-0.08 -0.08	160 210	
1435	8	3.60 "	2.6 "	2.0 0.5	-0.09 -0.09	260 250	
1444	6	3.55 "	2.6 "	2.0 0.5	-0.16 -0.10	320 300	
1452	4	3.50 " "	10.6 " "	10.0 5.0 0.5	-0.10 -0.17 -0.14	280 200 230	
1503	3	3.45 " "	11.7 " "	11.0 5.5 0.5	-0.10 - -0.10	80 NIL 280	

CURRENT METERING RECORDS

NEAP CONDITIONS

DATE 13-9-86

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
1515	2	3.40 "	5.1 "	4.5 1.0	- -0.05	NIL 190	12 knot NE small chop
1524	5	3.35 "	3.8 "	3.3 0.5	-0.06 -0.08	230 280	
1533	7A	3.30	3.2	1.5	-0.10	300	
1553	8	3.20	2.2	1.0	-0.09	280	
1600	6	3.15	2.2	1.0	-0.12	220	
1607	4	3.10 " "	10.8 " "	9.3 4.5 0.5	-0.14 -0.26 -0.22	240 240 270	
1617	3	3.05 " "	11.2 " "	10.7 5.5 0.5	-0.08 -0.10 -0.23	NIL 340 190	

CURRENT METERING RECORDS

NEAP CONDITIONS

DATE 13-9-86

IME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
639	2	2.90 "	4.5 "	4.0 0.5	-0.08 -0.10	350? NIL	5 knot NE remnant chop
648	5	2.80 "	3.3 "	2.8 0.5	-0.08 -0.08	NIL NIL	
656	7A	2.75	2.6	1.0	-0.11	300	
704	8.	2.75	2.0	1.0	-0.10	340	
709	6	2.70	1.7	0.8	-0.08	20	
715	4	2.65 " "	7.6 " "	7.0 3.5 0.5	-0.10 -0.11 -0.10	200 220? 230	
727	3	2.60 " "	10.3 " "	9.8 5.0 0.5	-0.07 - -0.11	290 NIL NIL	

CURRENT METERING RECORDS

DATE 13-9-86 NEAP CONDITIONS

TIME	STATION	TIDE HEIGHT L.W.D. (m)	DEPTH TO BOTTOM (m)	DEPTH BELOW SURFACE (m)	CURRENT VELOCITY (+)flood (-)ebb (m/s)	DIRECTION (degrees) (mag.)	REMARKS
822	2	2.30 "	3.9 "	3.4 0.5	-0.11 -0.20	300 160	10 knot NW
825	5	2.30	2.8	1.4	-0.13	220	
834	7A	2.25	2.2	1.0	-0.15	230	
840	8	2.25	1.5	0.7	-0.11	250	
847	6	2.20	1.5	0.7	-0.11	270	
859	4	2.20 " "	10.0 " "	9.5 5.0 0.5	-0.06 -0.26 -0.30	210 240 230	
911	3	2.20 " "	10.2 " "	9.7 5.0 0.5	+0.16 +0.16 +0.22	160 200 190	

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.W.D.

number	PMG co-ords	time lag	range ratio
1	690480.0 8620400.0	0.000	1.0000

date	time	raw	adj
	0600	6.41	0.00
	0630	6.80	0.00
	0700	7.08	0.00
	0730	7.17	0.00
	0800	7.06	0.00
	0830	6.74	0.00
	0900	6.20	0.00
	0930	5.38	0.00
	1000	4.50	0.00
	1030	3.70	0.00
	1100	2.95	0.00
	1130	2.30	0.00
	1200	1.86	0.00
	1230	1.52	0.00
	1300	1.32	0.00
	1330	1.20	0.00
	1400	1.24	0.00
	1430	1.48	0.00
	1500	1.90	0.00
	1530	2.50	0.00
	1600	3.32	0.00
	1630	4.02	0.00
	1700	4.88	0.00
	1730	5.56	0.00
	1800	6.10	0.00
	1830	6.50	0.00
	1900	6.78	0.00
	1930	6.86	0.00
	2000	6.78	0.00
	2030	6.50	0.00
	2100	6.00	0.00
	2130	5.30	0.00
	2200	4.40	0.00
	2230	3.70	0.00
	2300	2.92	0.00
	2330	2.30	0.00
7:9:86	0000	1.84	0.00
	0030	1.44	0.00
	0100	1.20	0.00
	0130	1.04	0.00
	0200	1.05	0.00
	0230	1.22	0.00
	0300	1.70	0.00
	0330	2.30	0.00
	0400	3.00	0.00
	0430	3.85	0.00
	0500	4.62	0.00
	0530	5.46	0.00
	0600	6.02	0.00
	0630	6.58	0.00
	0700	6.94	0.00
	0730	7.14	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.U.D.

number	RM co-ords	time lag	range ratio
1	690480.0 8620400.0	0.000	1.0000

date	time	raw	adj
	0800	7.18	0.00
	0830	7.00	0.00
	0900	6.58	0.00
	0930	6.00	0.00
	1000	5.10	0.00
	1030	4.30	0.00
	1100	3.50	0.00
	1130	2.70	0.00
	1200	2.08	0.00
	1230	1.64	0.00
	1300	1.30	0.00
	1330	1.04	0.00
	1400	.91	0.00
	1430	.94	0.00
	1500	1.20	0.00
	1530	1.68	0.00
	1600	2.30	0.00
	1630	3.10	0.00
	1700	3.90	0.00
	1730	4.70	0.00
	1800	5.40	0.00
	1830	6.00	0.00
	1900	6.48	0.00
	1930	6.80	0.00
	2000	6.93	0.00
	2030	6.90	0.00
	2100	6.65	0.00
	2130	6.20	0.00
	2200	5.50	0.00
	2230	4.82	0.00
	2300	4.04	0.00
	2330	3.24	0.00
8:9:86	0000	2.50	0.00
	0030	2.08	0.00
	0100	1.72	0.00
	0130	1.46	0.00
	0200	1.32	0.00
	0230	1.30	0.00
	0300	1.46	0.00
	0330	1.84	0.00
	0400	2.47	0.00
	0430	3.10	0.00
	0500	3.84	0.00
	0530	4.64	0.00
	0600	5.56	0.00
	0630	6.00	0.00
	0700	6.52	0.00
	0730	6.92	0.00
	0800	7.09	0.00
	0830	7.12	0.00
	0900	6.92	0.00
	0930	6.50	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.L.O.

number	FIG	co-ords	time lag	range ratio
1	690480.0	8620400.0	0.000	1.0000

date	time	raw	adj
	1000	5.80	-0.00
	1030	5.00	0.00
	1100	4.10	0.00
	1130	3.24	0.00
	1200	2.50	0.00
	1230	2.00	0.00
	1300	1.50	0.00
	1330	1.14	0.00
	1400	.90	0.00
	1430	.74	0.00
	1500	.79	0.00
	1530	1.00	0.00
	1600	1.44	0.00
	1630	2.00	0.00
	1700	2.76	0.00
	1730	3.50	0.00
	1800	4.30	0.00
	1830	5.00	0.00
	1900	5.74	0.00
	1930	6.34	0.00
	2000	6.66	0.00
	2030	6.84	0.00
	2100	6.87	0.00
	2130	6.70	0.00
	2200	6.30	0.00
	2230	5.70	0.00
	2300	5.00	0.00
	2330	4.10	0.00
9:9:86	0000	3.32	0.00
	0030	2.76	0.00
	0100	2.30	0.00
	0130	2.02	0.00
	0200	1.80	0.00
	0230	1.67	0.00
	0300	1.68	0.00
	0330	1.84	0.00
	0400	2.18	0.00
	0430	2.80	0.00
	0500	3.44	0.00
	0530	4.05	0.00
	0600	4.82	0.00
	0630	5.45	0.00
	0700	6.00	0.00
	0730	6.45	0.00
	0800	6.70	0.00
	0830	6.86	0.00
	0900	6.87	0.00
	0930	6.65	0.00
	1000	6.20	0.00
	1030	5.50	0.00
	1100	4.80	0.00
	1130	3.95	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.W.D.

number	AMG	co-ords	time lag	range ratio
1	690480.0	8620400.0	0.000	1.0000

date	time	raw	adj
	1200	3.14	0.00
	1230	2.50	0.00
	1300	2.00	0.00
	1330	1.56	0.00
	1400	1.22	0.00
	1430	.93	0.00
	1500	.74	0.00
	1530	.76	0.00
	1600	.96	0.00
	1630	1.40	0.00
	1700	2.00	0.00
	1730	2.66	0.00
	1800	3.40	0.00
	1830	4.10	0.00
	1900	4.85	0.00
	1930	5.46	0.00
	2000	5.96	0.00
	2030	6.36	0.00
	2100	6.56	0.00
	2130	6.62	0.00
	2200	6.50	0.00
	2230	6.16	0.00
	2300	5.60	0.00
	2330	5.00	0.00
10:9:86	0000	4.20	0.00
	0030	3.60	0.00
	0100	3.10	0.00
	0130	2.70	0.00
	0200	2.40	0.00
	0230	2.34	0.00
	0300	2.20	0.00
	0330	2.20	0.00
	0400	2.44	0.00
	0430	2.60	0.00
	0500	3.00	0.00
	0530	3.60	0.00
	0600	4.30	0.00
	0630	4.90	0.00
	0700	5.30	0.00
	0730	5.80	0.00
	0800	6.20	0.00
	0830	6.40	0.00
	0900	6.48	0.00
	0930	6.46	0.00
	1000	6.20	0.00
	1030	5.70	0.00
	1100	5.00	0.00
	1130	4.50	0.00
	1200	3.65	0.00
	1230	3.00	0.00
	1300	2.56	0.00
	1330	2.16	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.V.D.

number	RTG co-ords	time lag	range ratio
1	690480.0 8620400.0	0.000	1.0000

date	time	raw	adj
	1400	1.70	-0.00
	1430	1.40	0.00
	1500	1.10	0.00
	1530	.96	0.00
	1600	.92	0.00
	1630	1.00	0.00
	1700	1.30	0.00
	1730	1.70	0.00
	1800	2.35	0.00
	1830	3.02	0.00
	1900	3.70	0.00
	1930	4.40	0.00
	2000	5.00	0.00
	2030	5.50	0.00
	2100	5.80	0.00
	2130	6.10	0.00
	2200	6.24	0.00
	2230	6.22	0.00
	2300	6.00	0.00
	2330	5.60	0.00
11:9:86	0000	5.00	0.00
	0030	4.58	0.00
	0100	4.00	0.00
	0130	3.56	0.00
	0200	3.20	0.00
	0230	3.00	0.00
	0300	2.86	0.00
	0330	2.80	0.00
	0400	2.82	0.00
	0430	2.90	0.00
	0500	3.10	0.00
	0530	3.46	0.00
	0600	3.86	0.00
	0630	4.30	0.00
	0700	4.70	0.00
	0730	4.85	0.00
	0800	5.50	0.00
	0830	5.78	0.00
	0900	5.92	0.00
	0930	5.97	0.00
	1000	5.88	0.00
	1030	5.64	0.00
	1100	5.30	0.00
	1130	4.80	0.00
	1200	4.30	0.00
	1230	3.70	0.00
	1300	3.20	0.00
	1330	2.76	0.00
	1400	2.30	0.00
	1430	2.06	0.00
	1500	1.80	0.00
	1530	1.60	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.W.D.

number	PMG co-ords	time lag	range ratio
1	690480.0 8620400.0	0.000	1.0000

date	time	raw	adj
	1600	1.40	-0.00
	1630	1.32	0.00
	1700	1.30	0.00
	1730	1.50	0.00
	1800	1.70	0.00
	1830	2.20	0.00
	1900	2.80	0.00
	1930	3.30	0.00
	2000	3.80	0.00
	2030	4.40	0.00
	2100	4.80	0.00
	2130	5.08	0.00
	2200	5.40	0.00
	2230	5.62	0.00
	2300	5.73	0.00
	2330	5.69	0.00
12:9:86	0000	5.50	0.00
	0030	5.13	0.00
	0100	4.80	0.00
	0130	4.48	0.00
	0200	4.10	0.00
	0230	3.80	0.00
	0300	3.60	0.00
	0330	3.50	0.00
	0400	3.44	0.00
	0430	3.43	0.00
	0500	3.46	0.00
	0530	3.54	0.00
	0600	3.70	0.00
	0630	3.94	0.00
	0700	4.24	0.00
	0730	4.56	0.00
	0800	4.83	0.00
	0830	5.00	0.00
	0900	5.16	0.00
	0930	5.25	0.00
	1000	5.28	0.00
	1030	5.22	0.00
	1100	5.10	0.00
	1130	4.92	0.00
	1200	4.59	0.00
	1230	4.20	0.00
	1300	3.80	0.00
	1330	3.40	0.00
	1400	3.10	0.00
	1430	2.80	0.00
	1500	2.60	0.00
	1530	2.40	0.00
	1600	2.20	0.00
	1630	2.00	0.00
	1700	1.86	0.00
	1730	1.78	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.U.D.

number	PMG co-ords	time lag	range ratio
1	690480.0 8620400.0	0.000	1.0000

date	time	raw	adj
	1800	1.80	-0.00
	1830	1.93	0.00
	1900	2.20	0.00
	1930	2.54	0.00
	2000	2.90	0.00
	2030	3.30	0.00
	2100	3.66	0.00
	2130	4.00	0.00
	2200	4.38	0.00
	2230	4.70	0.00
	2300	5.00	0.00
	2330	5.14	0.00
15:9:86	0000	5.25	0.00
	0030	5.28	0.00
	0100	5.20	0.00
	0130	5.08	0.00
	0200	4.89	0.00
	0230	4.72	0.00
	0300	4.54	0.00
	0330	4.40	0.00
	0400	4.28	0.00
	0430	4.18	0.00
	0500	4.08	0.00
	0530	4.02	0.00
	0600	3.99	0.00
	0630	3.98	0.00
	0700	4.01	0.00
	0730	4.08	0.00
	0800	4.18	0.00
	0830	4.28	0.00
	0900	4.36	0.00
	0930	4.44	0.00
	1000	4.52	0.00
	1030	4.57	0.00
	1100	4.60	0.00
	1130	4.60	0.00
	1200	4.56	0.00
	1230	4.44	0.00
	1300	4.30	0.00
	1330	4.10	0.00
	1400	3.88	0.00
	1430	3.67	0.00
	1500	3.48	0.00
	1530	3.32	0.00
	1600	3.14	0.00
	1630	3.00	0.00
	1700	2.78	0.00
	1730	2.58	0.00
	1800	2.40	0.00
	1830	2.26	0.00
	1900	2.19	0.00
	1930	2.18	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.W.D.

number	MAG co-ords		time lag	range ratio
1	690490.0	8620400.0	0.000	1.0000

date	time	raw	adj
	2000	2.24	0.00
	2030	2.38	0.00
	2100	2.60	0.00
	2130	2.84	0.00
	2200	3.12	0.00
	2230	3.42	0.00
	2300	3.74	0.00
	2330	4.06	0.00
14:9:86	0000	4.40	0.00
	0030	4.69	0.00
	0100	4.91	0.00
	0130	5.10	0.00
	0200	5.22	0.00
	0230	5.27	0.00
	0300	5.28	0.00
	0330	5.24	0.00
	0400	5.16	0.00
	0430	5.00	0.00
	0500	4.85	0.00
	0530	4.66	0.00
	0600	4.46	0.00
	0630	4.26	0.00
	0700	4.12	0.00
	0730	4.00	0.00
	0800	3.90	0.00
	0830	3.84	0.00
	0900	3.80	0.00
	0930	3.77	0.00
	1000	3.76	0.00
	1030	3.78	0.00
	1100	3.84	0.00
	1130	3.95	0.00
	1200	4.06	0.00
	1230	4.18	0.00
	1300	4.28	0.00
	1330	4.35	0.00
	1400	4.38	0.00
	1430	4.38	0.00
	1500	4.30	0.00
	1530	4.20	0.00
	1600	4.04	0.00
	1630	3.85	0.00
	1700	3.60	0.00
	1730	3.36	0.00
	1800	3.10	0.00
	1830	2.86	0.00
	1900	2.64	0.00
	1930	2.40	0.00
	2000	2.24	0.00
	2030	2.10	0.00
	2100	2.04	0.00
	2130	2.03	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Garwin Standard Gauge	0.00	L.W.O.

number	RMG co-ords	time lag	range ratio
1	690400.0 8620400.0	0.000	1.0000

date	time	raw	adj
	2200	2.12	-0.00
	2230	2.30	0.00
	2300	2.58	0.00
	2330	2.95	0.00
15:9:86	0000	3.36	0.00
	0030	3.72	0.00
	0100	4.14	0.00
	0130	4.52	0.00
	0200	4.87	0.00
	0230	5.17	0.00
	0300	5.44	0.00
	0330	5.60	0.00
	0400	5.72	0.00
	0430	5.75	0.00
	0500	5.70	0.00
	0530	5.54	0.00
	0600	5.28	0.00
	0630	5.00	0.00
	0700	4.64	0.00
	0730	4.34	0.00
	0800	4.02	0.00
	0830	3.78	0.00
	0900	3.56	0.00
	0930	3.39	0.00
	1000	3.26	0.00
	1030	3.19	0.00
	1100	3.17	0.00
	1130	3.23	0.00
	1200	3.37	0.00
	1230	3.56	0.00
	1300	3.82	0.00
	1330	4.10	0.00
	1400	4.37	0.00
	1430	4.60	0.00
	1500	4.80	0.00
	1530	4.90	0.00
	1600	4.94	0.00
	1630	4.89	0.00
	1700	4.74	0.00
	1730	4.48	0.00
	1800	4.15	0.00
	1830	3.80	0.00
	1900	3.40	0.00
	1930	3.00	0.00
	2000	2.66	0.00
	2030	2.32	0.00
	2100	2.10	0.00
	2130	1.88	0.00
	2200	1.73	0.00
	2230	1.65	0.00
	2300	1.67	0.00
	2330	1.81	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.W.D.

number	FMG co-ords	time lag	range ratio
1	690480.0 8620400.0	0.000	1.0000

date	time	raw	adj
16:9:86	0000	2.12	0.00
	0030	2.50	0.00
	0100	3.00	0.00
	0130	3.55	0.00
	0200	4.09	0.00
	0230	4.65	0.00
	0300	5.14	0.00
	0330	5.55	0.00
	0400	5.88	0.00
	0430	6.12	0.00
	0500	6.26	0.00
	0530	6.27	0.00
	0600	6.13	0.00
	0630	5.86	0.00
	0700	5.44	0.00
	0730	5.00	0.00
	0800	4.42	0.00
	0830	3.96	0.00
	0900	3.53	0.00
	0930	3.20	0.00
	1000	2.90	0.00
	1030	2.68	0.00
	1100	2.55	0.00
	1130	2.48	0.00
	1200	2.53	0.00
	1230	2.70	0.00
	1300	2.96	0.00
	1330	3.34	0.00
	1400	3.80	0.00
	1430	4.30	0.00
	1500	4.77	0.00
	1530	5.14	0.00
	1600	5.44	0.00
	1630	5.62	0.00
	1700	5.70	0.00
	1730	5.63	0.00
	1800	5.40	0.00
	1830	5.00	0.00
	1900	4.60	0.00
	1930	4.06	0.00
	2000	3.51	0.00
	2030	2.97	0.00
	2100	2.58	0.00
	2130	2.04	0.00
	2200	1.72	0.00
	2230	1.49	0.00
	2300	1.34	0.00
	2330	1.28	0.00
17:9:86	0000	1.34	0.00
	0030	1.56	0.00
	0100	1.94	0.00
	0130	2.50	0.00

number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.W.O.

number	PMG co-ords	time lag	range ratio
1	690400.0 8620400.0	0.000	1.0000

date	time	raw	adj
	0200	3.12	0.00
	0230	3.80	0.00
	0300	4.58	0.00
	0330	5.17	0.00
	0400	5.68	0.00
	0430	6.11	0.00
	0500	6.46	0.00
	0530	6.64	0.00
	0600	6.69	0.00
	0630	6.59	0.00
	0700	6.30	0.00
	0730	5.80	0.00
	0800	5.15	0.00
	0830	4.44	0.00
	0900	3.80	0.00
	0930	3.24	0.00
	1000	2.76	0.00
	1030	2.39	0.00
	1100	2.16	0.00
	1130	1.99	0.00
	1200	1.90	0.00
	1230	1.93	0.00
	1300	2.10	0.00
	1330	2.50	0.00
	1400	2.96	0.00
	1430	3.55	0.00
	1500	4.20	0.00
	1530	4.84	0.00
	1600	5.38	0.00
	1630	5.80	0.00
	1700	6.10	0.00
	1730	6.29	0.00
	1800	6.31	0.00
	1830	6.16	0.00
	1900	5.82	0.00
	1930	5.28	0.00
	2000	4.64	0.00
	2030	3.96	0.00
	2100	3.32	0.00
	2130	2.65	0.00
	2200	2.40	0.00
	2230	1.73	0.00
	2300	1.42	0.00
	2330	1.19	0.00
18:9:86	0000	1.07	0.00
	0030	1.10	0.00
	0100	1.28	0.00
	0130	1.66	0.00
	0200	2.22	0.00
	0230	2.90	0.00
	0300	3.74	0.00
	0330	4.44	0.00

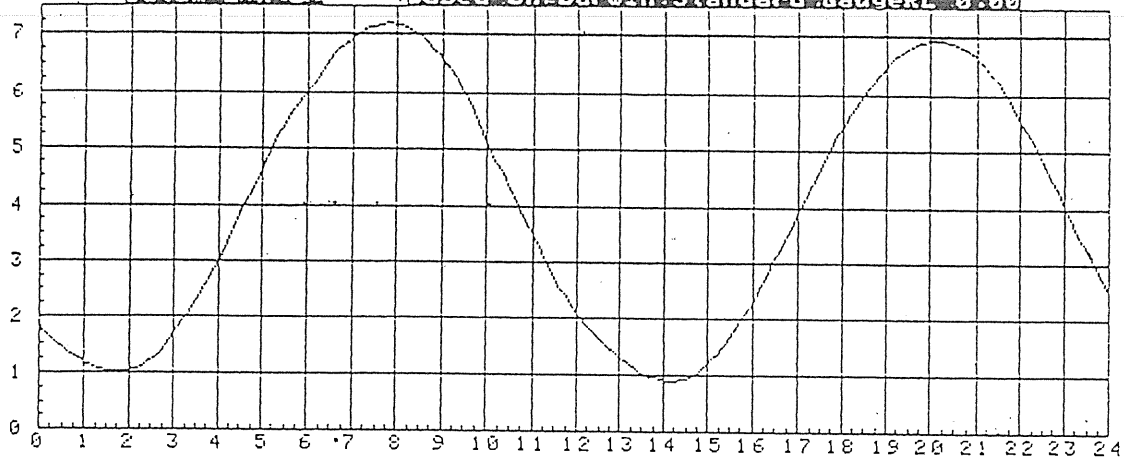
number	gauge	based on	RL	datum
1	Fort Hill Wharf	Darwin Standard Gauge	0.00	L.W.D.

number	AMS co-ords	time lag	range ratio
1	690480.0 8620400.0	0.000	1.0000

date	time	raw	adj
	0400	5.14	-0.00
	0430	5.80	0.00
	0500	6.28	0.00
	0530	6.68	0.00
	0600	6.92	0.00
	0630	7.02	0.00
	0700	6.94	0.00
	0730	6.66	0.00
	0800	6.15	0.00
	0830	5.40	0.00
	0900	4.55	0.00
	0930	3.82	0.00
	1000	3.10	0.00
	1030	2.50	0.00
	1100	2.08	0.00
	1130	1.76	0.00
	1200	1.54	0.00
	1230	1.42	0.00
	1300	1.41	0.00
	1330	1.60	0.00
	1400	1.96	0.00
	1430	2.50	0.00
	1500	3.22	0.00
	1530	4.00	0.00
	1600	4.74	0.00
	1630	5.42	0.00
	1700	5.93	0.00
	1730	6.35	0.00
	1800	6.62	0.00
	1830	6.72	0.00
	1900	6.68	0.00
	1930	6.40	0.00
	2000	5.90	0.00
	2030	5.18	0.00
	2100	4.36	0.00
	2130	3.63	0.00
	2200	2.92	0.00
	2230	2.32	0.00
	2300	1.84	0.00
	2330	1.48	0.00
19:9:86	0000	1.18	0.00
	0030	1.04	0.00
	0100	1.01	0.00
	0130	1.20	0.00
	0200	1.54	0.00
	0230	2.12	0.00
	0300	2.83	0.00
	0330	3.62	0.00
	0400	4.45	0.00
	0430	5.22	0.00
	0500	5.86	0.00
	0530	6.40	0.00

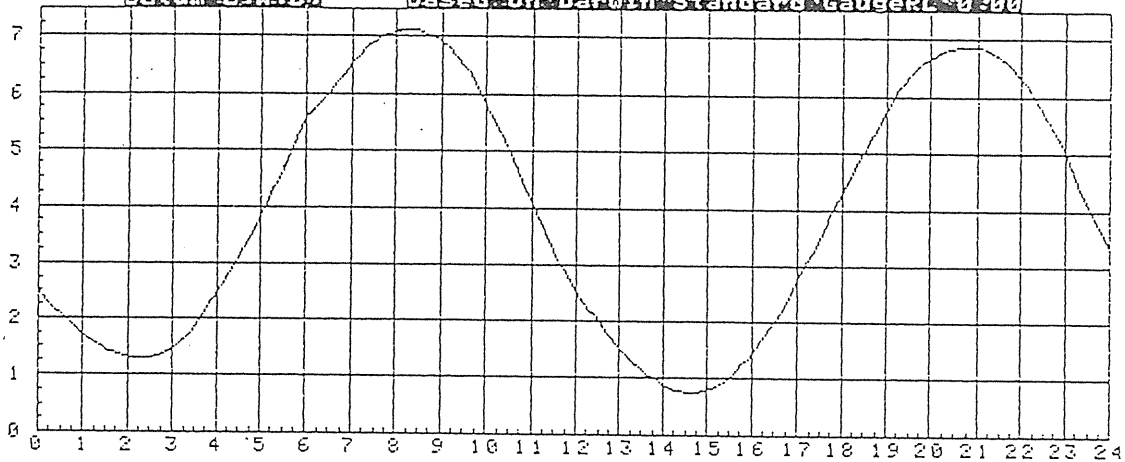
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Datum L.W.D. Based on Darwin Standard GaugeRL 0.00



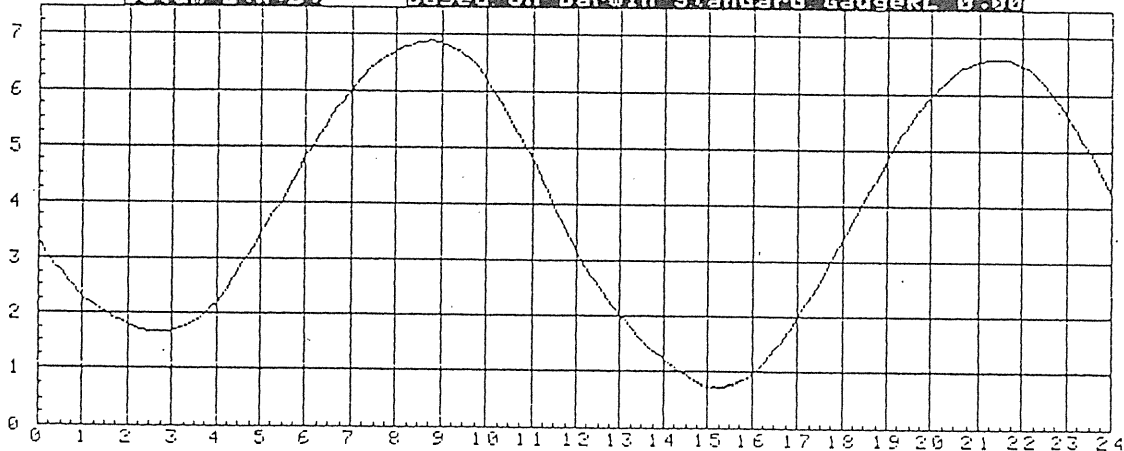
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Datum L.W.D. Based on Darwin Standard GaugeRL 0.00



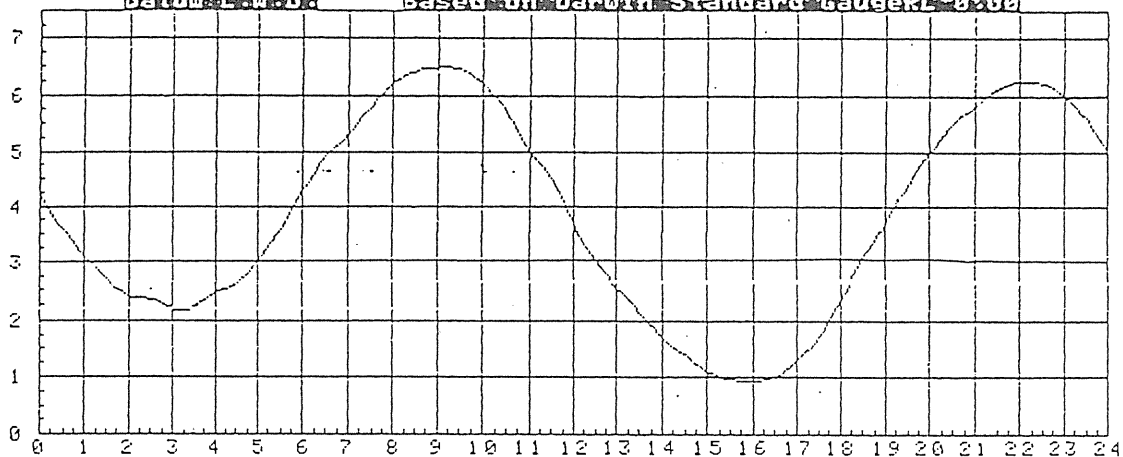
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Datum L.W.D. Based on Darwin Standard GaugeRL 0.00



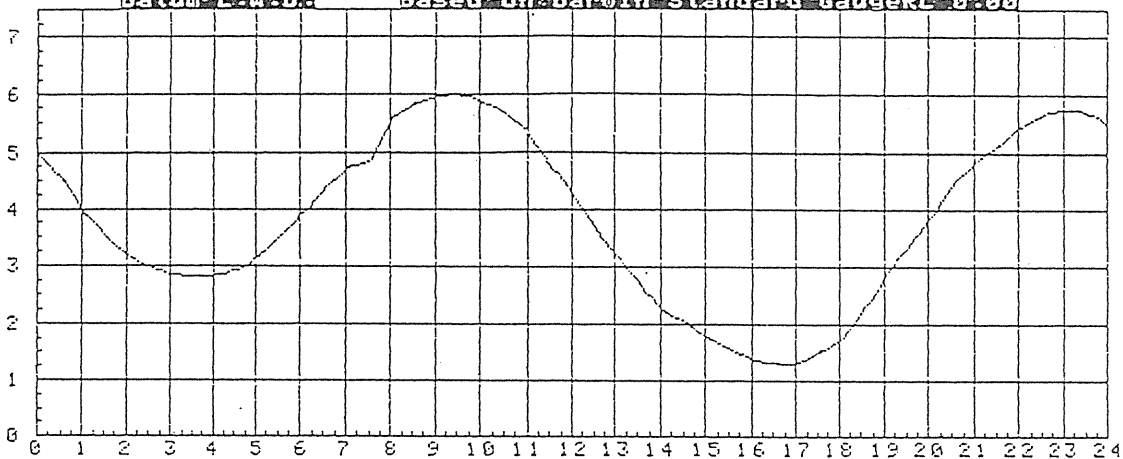
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Datum: L.M.D. Based on Darwin Standard Gauge RL: 0.00



Gauge Location: Fort Hill Wharf Date: 11:9:86

Datum: L.M.D. Based on Darwin Standard Gauge RL: 0.00



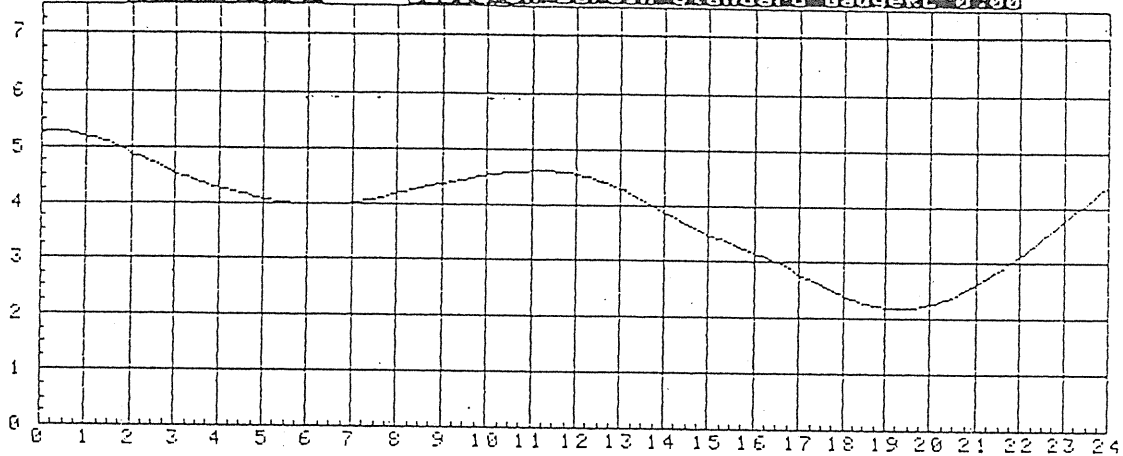
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Datum: L.M.D. Based on Darwin Standard Gauge RL: 0.00



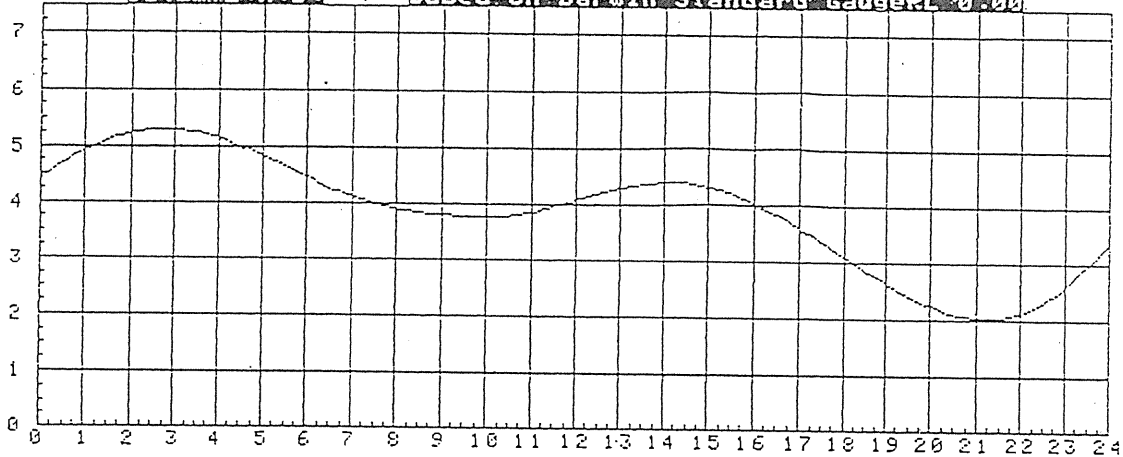
Gauge Location Fort Hill Wharf Date 13:9:86

Datum L.M.D. Based on Darwin Standard Gauge RL 0.00



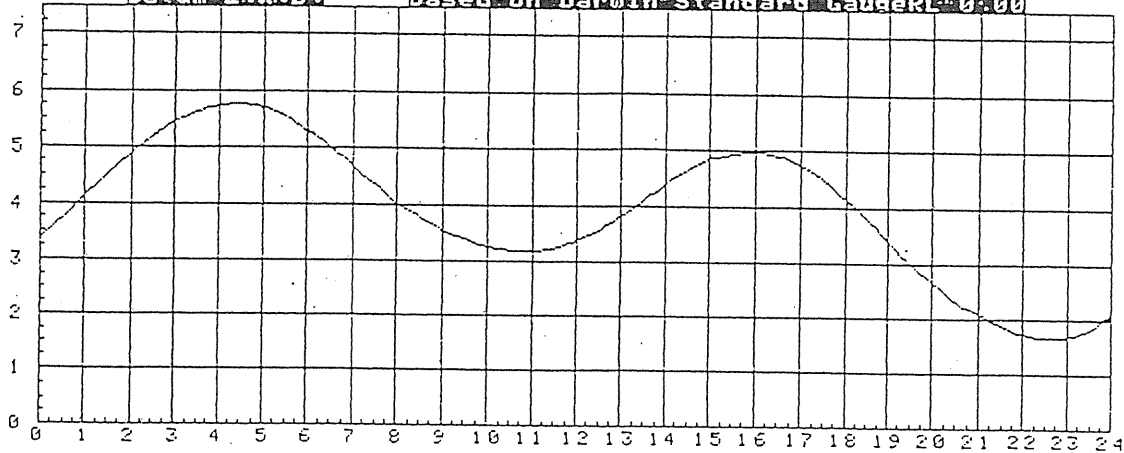
Gauge Location Fort Hill Wharf Date 14:9:86

Datum L.M.D. Based on Darwin Standard Gauge RL 0.00



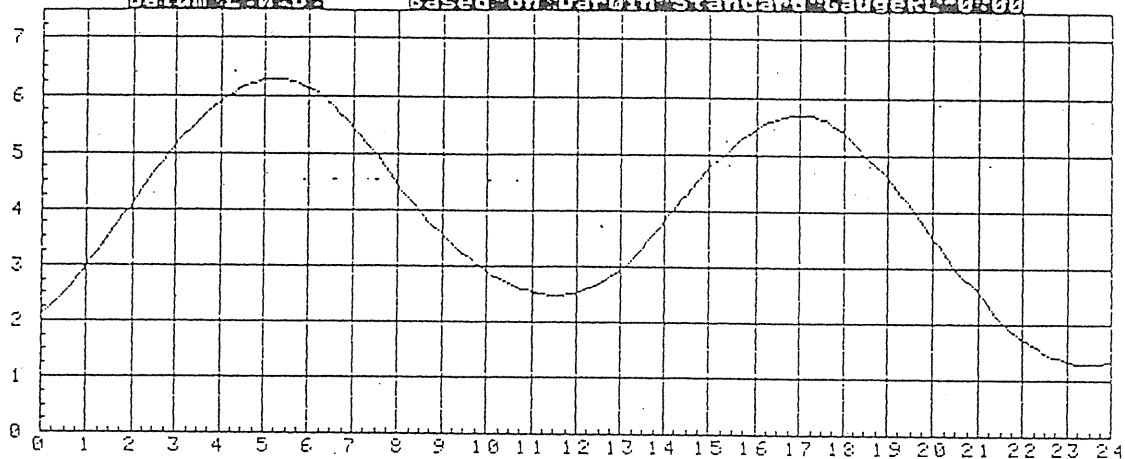
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Datum L.M.D. Based on Darwin Standard Gauge RL 0.00



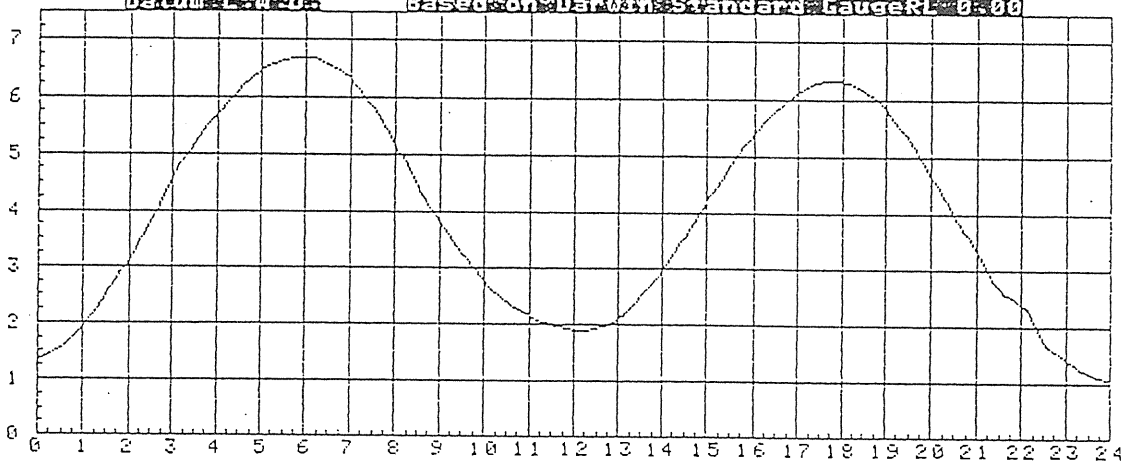
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Datum: L.H.D. Based on Darwin Standard Gauge RL: 0.00



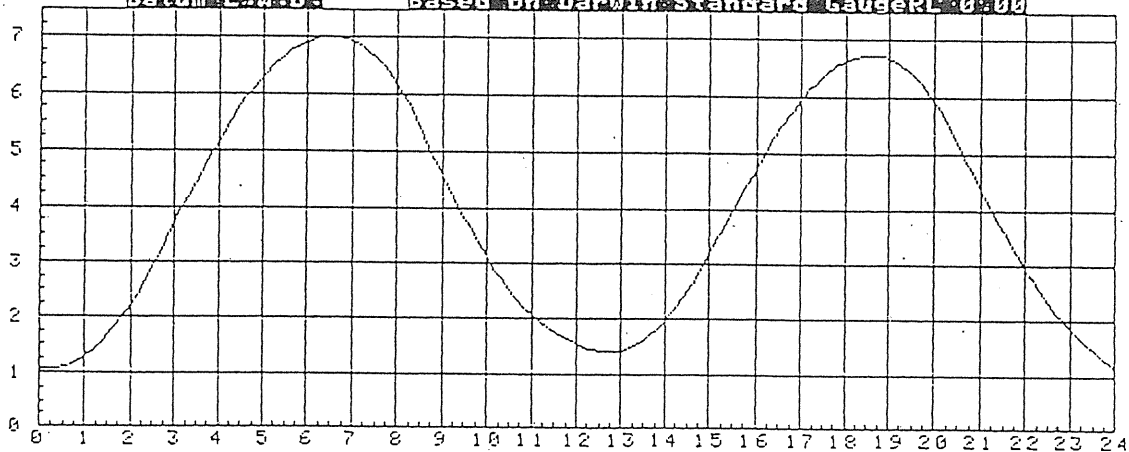
Gauge Location: Fort Hill Wharf Date: 17:9:86

Datum: L.H.D. Based on Darwin Standard Gauge RL: 0.00



Gauge Location: Fort Hill Wharf Date: 18:9:86

Datum: L.H.D. Based on Darwin Standard Gauge RL: 0.00



DARWIN MARINA ESTATE

HINDCAST AND WAVE TRANSFORMATION

APPENDIX B

- Wind and Wave Hindcast Technique
- Wind and Wave Hindcast Results
- Reverse Ray Refraction Technique
- Wave Attenuation by Seabed Friction
- Refraction Grid
- Refraction Tables
- Wave Transformation Results
- Sediment Transport Results

APPENDIX B

Wind and Wave Hindcast Technique

OCEANROUTES' Wind and Wave
Hindcast Technique

1.0 INTRODUCTION

A brief description follows of the techniques that are used by OCEANROUTES' marine meteorologists in determining the wind and wave conditions that are likely to have occurred at a given location at specific times in the past.

The "manufactured" data base is a set of observations at the required frequency consisting of entries which include date/time, wind direction and speed, sea wave height and period, and swell wave heights, periods and directions. A further step can be to combine the sea and swell values to provide significant wave heights (H_S) and average zero crossing periods (T_Z).

The data contained in a manufactured data base can be compared with measured observations if they exist for the site in order to establish any bias that may exist in the data set. This bias may be the result of limitations in the original Mean Sea Level charts and in the techniques described below, and in the measured data.

From a regular set of data, joint frequency occurrences of the various parameters can be developed. Further manipulation of the data can provide estimates of extreme values and return periods.

2. DATA SOURCES

The primary data source for constructing a data base is the set of Mean Sea Level (MSL) synoptic analyses which include the site and the oceanic areas from which distant swell may arrive at the site. The MSL analyses are isobaric chart, that is, the contours depict lines of equal atmospheric pressure corrected to mean sea level. These analyses are constructed at regular intervals from observations of weather parameters noted at stations on land and at ships at sea. Supplementary information for the analysis of the MSL charts is obtained from the upper air by radiosonde, pilot balloons and observations from aircraft. The interpretation of the observational data is also aided by analysis of the cloud imagery obtained by means of geostationary or polar orbiting satellites.

Throughout the world the MSL synoptic analyses are usually prepared at 6-hourly intervals. In the Australian region the analyses are these days available at 3-hourly intervals. Incorporation of smaller scale features and coastal effects is consequently readily achieved.

OCEANROUTES' uses Bureau of Meteorology MSL and upper air synoptic charts from 1975 on for database work of this kind, as these are available at 3-hourly intervals.

The techniques used for determining the various parameters in the data base are now described.

3. WINDS

Winds in the data base are derived from the historical MSL charts, using known relationships between isobaric spacing (pressure gradients) and wind speed.

For synoptic situations where the isobars are parallel and straight and the pressure field is not moving, the basic relationship between the pressure field and the resultant wind is given by the formula:

$$V_g = \alpha (f^{-1}) \frac{dp}{dn}$$

where V_g is the wind speed, known in this special case as the geostrophic wind speed, α is the specific volume of air ($=(\text{density})^{-1}$) f is the Coriolis parameter ($= 1.4584 \times 10^{-4} \sin \phi \text{ rad sec}^{-1}$, where ϕ is the latitude), and $\frac{dp}{dn}$ is the pressure gradient normal to the isobars.

To determine the effective wind at sea level, corrections must be applied to the geostrophic wind to make allowances for surface friction, thermal stability of the atmosphere, curvature of the isobars and movement of the pressure field. In many cases the relevant parameters necessary to calculate these corrections are unknown. In these cases a simplified relationship is used:

$$V_s = 0.72 V_g$$

where V_s is the effective surface wind speed (Dexter, 1980).

Wind directions are also related to the isobaric pattern. The geostrophic wind flows parallel to the isobars. However, frictional effects result in a turning of the airflow towards the region of lower pressure. The amount of turning is considered to be about 10° to 15° over the open ocean. This is accommodated subjectively in the analysis by the meteorologist.

4.0 WAVE GENERATION AND PROPAGATION

The theory and techniques of wave generation and propagation used routinely by OCEANROUTES in forecasting and hindcasting tasks are current and up-to-date. They have been developed by Pierson, Newman and James (1960), Bretschneider (1970) and others and have been collated in the "Handbook of Wave Analysis and Forecasting" World Meteorological Organisation (1976), especially Part 1 Chapter 3 and Part 11, Chapters 1, 2 and 3.

The general concepts of wave generation and propagation are now described.

4.1 Wave Accretion

Waves are first formed by the pushing and dragging effects of turbulent air motion over water. Growth of the waves continues in the same direction as the wind until there is equilibrium between the wave generating force of the wind and energy dissipation through internal friction and air resistance. At this time the waves are fully developed.

Important factors which limit wave growth to less than full development are the duration of the constant wind and fetch length over which it is blowing.

The surface of the sea generally has a confused appearance owing to the presence of many different groups of waves becoming superimposed as the groups move with different speeds and directions. This combination of characteristics of the different wave groups can be determined and is called the wave or sea spectrum.

4.2 Computation of Wind Waves

To enable ocean wave parameters to be computed from known properties of the wind field, in particular wind velocity, its duration and its fetch, many studies have been undertaken. The results of such studies are usually empirical, based on as many observations as can be gathered. Typical of these results expressed in graphical form are that developed by Bretschneider (1970) and that published by the World Meteorological Organisation (1976), (Figure 1), which relate wave heights and periods to wind speed, duration and fetch length. Figure 1 assumes that the waves are formed in deep water and that there were no waves initially.

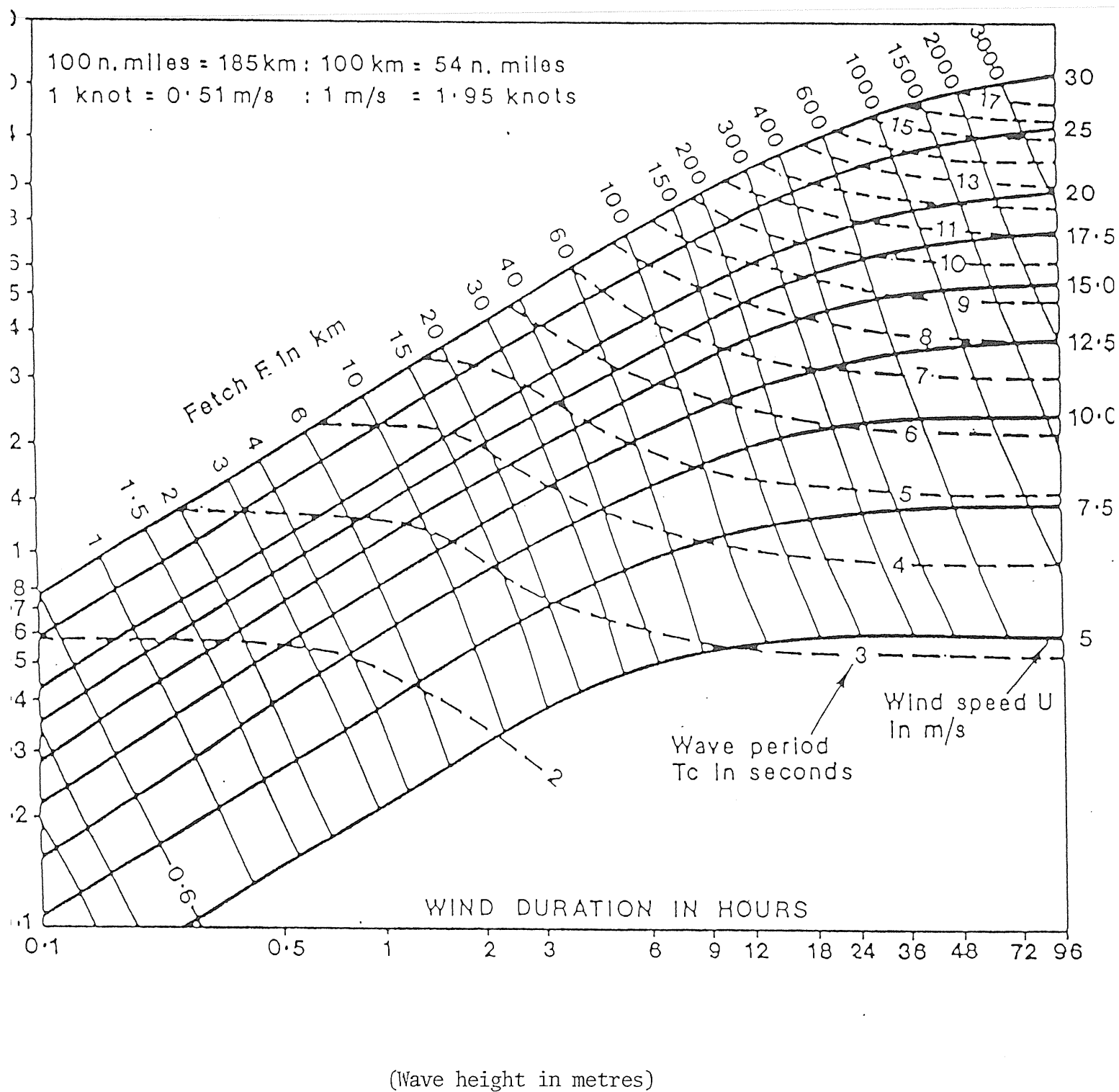


Figure 1 : WAVE FORECASTING DIAGRAM

The first step in computing waves is to determine the fetch and its duration, i.e. the area of sea surface over which the wind is blowing at constant speed from a constant direction and the time for which it persists. Fetch boundaries are generally limited physically by coastlines, and analytically by fanning out of isobars on a chart, by meteorological fronts, or by changes in curvature of the isobars.

Successive wind analyses may indicate that the fetch area is moving. The wave analysis must then be modified to take account of this effect. OCEANROUTES uses techniques based on the various "filters" described in Pierson, Neuman and James (1970) pp 127-135 and in World Meteorological Organisation (1976) Part 1 3.1.3.

Since the wind speed, duration and fetch length are known, the maximum significant wave height is calculated using a mathematical formulation of Figure 1. The energy spectrum is then determined by using the formulation of the JONSWAP spectrum (HASSELMANN 1973):

$$S(f) = a g^2 (2\pi)^{-4} f^{-5} \exp \left\{ -\frac{5}{4} \left(\frac{f}{f_p} \right)^{-4} \right\} \exp \left\{ \frac{-(f - f_p)^2}{2 \sigma^2 f_m^2} \right\}$$

with σ having two values:

$$\sigma_a = 0.07 \text{ for } f \leq f_p$$

$$\sigma_b = 0.09 \text{ for } f < f_p$$

and where $S(f)$ is the energy density

f is the frequency

f_p is the frequency at maximum energy
density (peak frequency)

v is a peak enhancement factor

a is 0.01 for wind speeds of 20 to 50 kts
and for fetches which are not too short.

One important wave frequency that is required is f_p (peak frequency) which is obtained from the Kruseman Model as:

$$f_p = (0.055/H_{m0})^{1/2}$$

Figure 2 shows a COMPARISON between the JONSWAP and KRUSEMAN models.

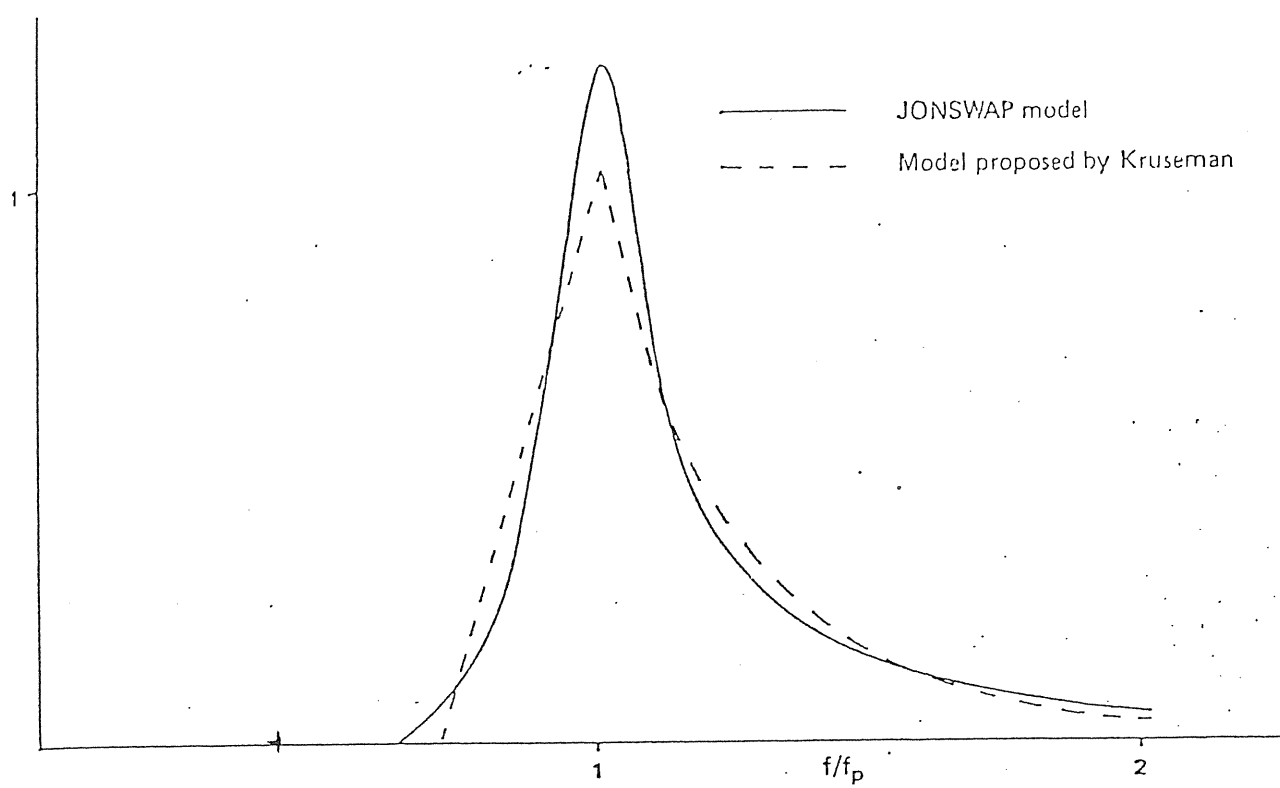


Figure 2 : A COMPARISON BETWEEN THE JONSWAP AND KRUSEMAN MODELS

4.3 Shallow Water Waves

The waves discussed so far were assumed to be in deep water. However water depth affects wave generation and wave heights will be smaller and wave periods shorter if waves are being generated in shallow water rather than deep water. Generally water depths of less than 15m are considered shallow and water depths greater than 90m are considered deep water. Water depth 15–90m are considered transitional.

In shallow or transitional depths the method used to calculate wave height and period is based on successive approximations in which energy is added due to the wind and subtracted due to bottom friction and percolation. The amount of energy lost is governed by the wave period and the following formulae are used for determining the wave height and period:

$$\frac{gH}{U_A^2} = 0.283 \tanh \left[0.530 \left(\frac{gd}{U_A^2} \right)^{3/4} \right] \tanh \left\{ \frac{0.00565 \left(\frac{gF}{U_A^2} \right)^{1/2}}{\tanh \left[0.530 \left(\frac{gd}{U_A^2} \right)^{3/4} \right]} \right\}$$

$$\frac{gT}{U_A} = 7.54 \tanh \left[0.833 \left(\frac{gd}{U_A^2} \right)^{3/8} \right] \tanh \left\{ \frac{0.0379 \left(\frac{gF}{U_A^2} \right)^{1/3}}{\tanh \left[0.833 \left(\frac{gd}{U_A^2} \right)^{3/8} \right]} \right\}$$

where H is the significant wave height

T is the significant wave period

F is the fetch length

d is the water depth

U is the wind stress factor

(Coastal Engineering Research Centre, 1984)

4.4 Swell Waves

So far the waves discussed are waves that are growing or maintained in height by the existing wind that is, the so-called wind waves or sea.

When sea waves become separated from the wind which generated them, they become known as swell. The separation may be the result of the waves moving beyond the fetch area, or of significant changes in the wind direction or speed, thereby creating a different fetch area. As soon as the swell waves are separated from the generating wind they begin to lose energy through the resistance of the water to being set in motion by the waves. Since a direct relationship exists between the amount of energy a wave possesses and its height, as swell waves lose energy their height decreases accordingly.

Two other important mechanisms also cause swell wave characteristics to change. These are known as angular spreading and dispersion.

Angular spreading is the lateral extension of sea waves as they move out of a fetch. It results from the slight natural variations in wind direction within the fetch. The wave energy is propagated mainly in the predominant direction of the wind, decreasing at deviant directions and reaching zero at directions perpendicular to the predominant one. It is generally assumed that the wave energy in different directions is distributed according to:

$$\cos^2 (Q - Q_0)$$

where Q_0 is the predominant direction of the sea and Q is the direction of the wave component under consideration.

Swell waves originating from different points and times along the down wind edge of the fetch may affect the observation point being monitored. A certain fraction of the original energy determined by the $\cos^2(Q - Q_0)$ energy distribution is propagated to the observing site along each direction. The energy arriving at the site is the sum of all these factors expressed as a percentage in diagrammatic form are shown in Figure 3.

Dispersion is the separation of the waves into their component parts owing to the different wave groups possessing different frequencies and hence velocities. Those with greater velocities out-distance the others. Hence swell from distant fetches possesses a much narrower range of frequencies than sea waves.

However, swell from nearby fetches may possess a broad spectrum as longer period waves from the rear of the fetch may be present at the site at the same time as lower period waves originating from near the front of the fetch.

In summary, waves generated in a fetch which arrive at the site at any future time have periods limited to those determined by the dispersion process while their heights are decreased by the spreading factor.

4.5 Calculation of Parameters of Significant Waves

Waves from different originating fetches whether nearby or distant may be simultaneously present at the site. These are combined using the formulae:

$$H_s = (H_1^2 + H_2^2)^{1/2}$$
$$\text{and } T_z = \frac{H_1^2 + H_2^2}{H_1^2/T_1^2 + H_2^2/T_2^2}^{1/2}$$

in an iterative manner (Hogben and Miller, 1980). H is the resultant significant wave height, and T is the zero crossing period.

These values are the forecast wave heights and periods at a deepwater site.

The primary direction of the propagated waves is taken as that component contributing the maximum proportion to H_S . A secondary direction may also be specified from the direction of the next highest contribution.

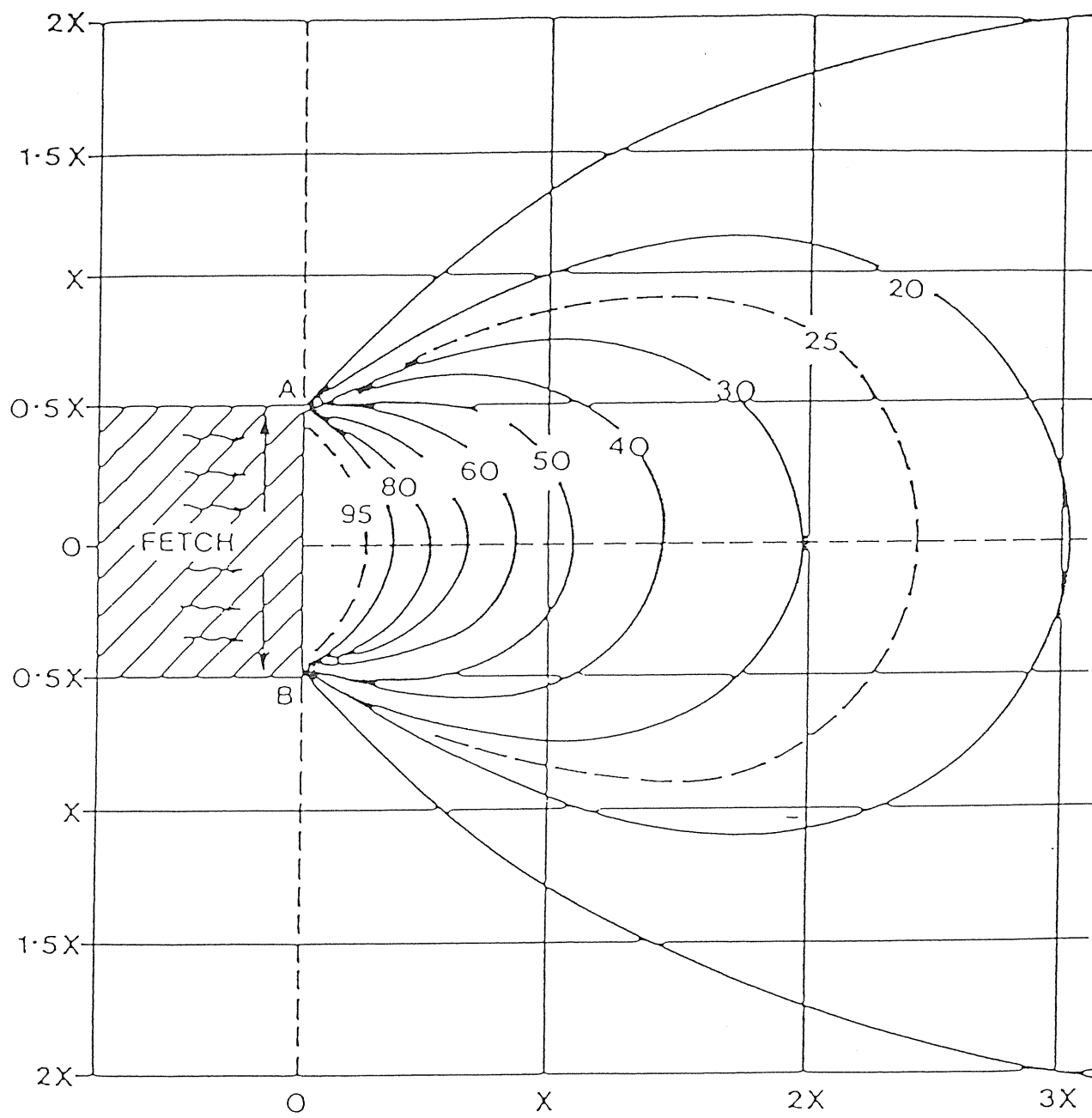


Figure 3 : ANGULAR SPREADING FACTORS FOR SWELL ENERGY IN PER CENT

5. ASSUMPTIONS AND LIMITATIONS (WINDS AND WAVES)

The main assumption made in the technique for determining the wind speeds and directions is that the precise corrections for the geostrophic flow caused by surface roughness, thermal stability, curvature of the isobars and movement of the pressure field are unknown and a simplified relationship is used. An average cross-isobar flow is also assumed.

The most noteworthy limitation to this technique for determining winds is that the winds with low velocities e.g. less than about 8kt, will probably be systematically overestimated. This will result in an overestimate of the associated sea heights.

The chief assumption made in the techniques for wave generation and propagation include simplified concepts of:

- (i) the shape and size of the particular fetch area;
- (ii) the location and movement of the fetch area relative to the site;
- (iii) the distribution of the wind through the fetch area;
- (iv) the determination of the duration of each event or part of it.

Other assumptions are contained in the adoption of the particular wave forecasting diagram (Figure 1), the Jonswap model spectrum, and the formulation of the angular spreading factor and the dispersion process.

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APPENDIX B

Wind and Wave Hindcast Results

HINDCAST DEEPWATER SEA WAVE CLIMATE

Location: Entrance to Port Darwin.
Wave Type: Sea generated in Beagle Gulf.
Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 247.5 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .3	.65	.00	.00	.00
.3 - .6	.00	.27	.00	.00
.6 - .9	.00	.07	.10	.00
.9 - 1.2	.00	.00	.03	.00
1.2 - 1.5	.00	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .3	2.33	.00	.00	.00
.3 - .6	.00	2.29	.00	.00
.6 - .9	.00	.21	1.75	.00
.9 - 1.2	.00	.00	.38	.14
1.2 - 1.5	.00	.00	.00	.07

Wave Direction: 292.5 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .3	1.47	.00	.00	.00
.3 - .6	.00	1.95	.00	.00
.6 - .9	.00	.31	1.10	.00
.9 - 1.2	.00	.00	.31	.03
1.2 - 1.5	.00	.00	.00	.00

Wave Direction: 315.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .3	.86	.00	.00	.00
.3 - .6	.00	.31	.00	.00
.6 - .9	.00	.00	.00	.00
.9 - 1.2	.00	.00	.00	.00
1.2 - 1.5	.00	.00	.00	.00

Wave Direction: 337.5 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .3	2.23	.03	.00	.00
.3 - .6	.00	3.39	.00	.00
.6 - .9	.00	.07	.41	.00
.9 - 1.2	.00	.00	.07	.00
1.2 - 1.5	.00	.00	.00	.03

Wave Direction: 360.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .3	4.18	.03	.00	.00
.3 - .6	.00	2.71	.00	.00
.6 - .9	.00	.03	.55	.00
.9 - 1.2	.00	.00	.00	.03
1.2 - 1.5	.00	.00	.00	.03

Wave Direction: 22.5 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .3	1.61	.00	.00	.00
.3 - .6	.00	.96	.00	.00
.6 - .9	.00	.03	.21	.00
.9 - 1.2	.00	.00	.00	.00
1.2 - 1.5	.00	.00	.00	.00

Wave Direction: 45.0 deg.

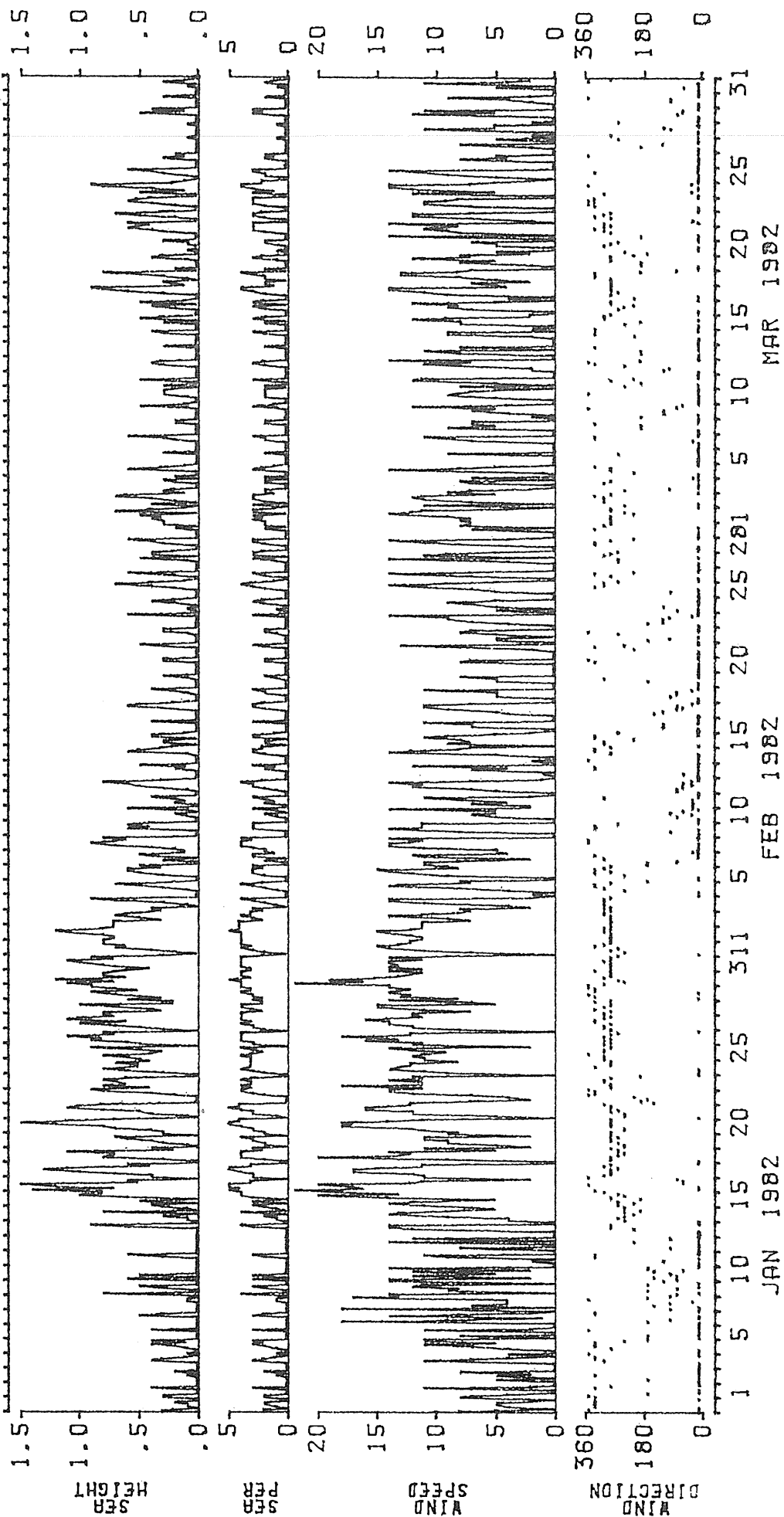
Height (m)	Period (s)			
	2	3	4	5
.0 - .3	.79	.00	.00	.00
.3 - .6	.00	.72	.00	.00
.6 - .9	.00	.07	.10	.00
.9 - 1.2	.00	.00	.00	.00
1.2 - 1.5	.00	.00	.00	.00

The figure consists of four vertically stacked time-series plots sharing a common x-axis representing time from October 1, 1981, to December 31, 1981. The x-axis is marked with dates at 5-day intervals (1, 5, 10, 15, 20, 25, 30, 31) for each month.

- Top Plot (Sea Height):** The y-axis is labeled "SEA HEIGHT" and ranges from 0.0 to 1.5. The plot shows a highly variable signal with frequent peaks and troughs, indicating significant fluctuations in sea level.
- Second Plot (Sea Pressure):** The y-axis is labeled "SEA PRESS" and ranges from 0 to 5. The signal is highly variable, with many sharp peaks reaching values between 1 and 5.
- Third Plot (Wind Speed):** The y-axis is labeled "WIND SPEED" and ranges from 0 to 20. The plot shows frequent spikes, with many values reaching between 10 and 20.
- Bottom Plot (Wind Direction):** The y-axis is labeled "WIND DIRECTION" and ranges from 0 to 360. The plot shows a signal that fluctuates between 0 and 360 degrees, with some periods of relative stability and others of rapid change.

PLOTTED: 27 DEC 1986

SITE: ENTRANCE TO PORT DARWIN - JAN 1982 TO MAR 1982



PLOTTED: 27 DEC 1986

This meteorological chart displays four data series for station 311 over a period from April 1 to June 30, 1982. The data is presented in four vertically stacked panels sharing a common horizontal time axis.

- Top Panel (Sea Height):** The y-axis ranges from 0 to 1.5. The data is shown as a series of vertical spikes, indicating fluctuations in sea height over time.
- Second Panel (Sea Per):** The y-axis ranges from 0 to 5. The data is shown as a series of vertical spikes, representing another variable related to sea conditions.
- Third Panel (Wind Speed):** The y-axis ranges from 0 to 20. The data is shown as a series of vertical spikes, representing the speed of the wind.
- Bottom Panel (Wind Direction):** The y-axis ranges from 0 to 360. The data is shown as a series of vertical spikes, representing the direction of the wind.

The horizontal axis at the bottom is labeled with dates: APR 1, 5, 10, 15, 20, 25, 30, MAY 10, 15, 20, 25, 30, JUN 10, 15, 20, 25, 30, 1982.

PLOTTED: 27 DEC 1986

The figure consists of four vertically stacked time-series plots sharing a common x-axis representing time from July 1, 1982, to September 30, 1982. The x-axis is marked with dates at 5-day intervals (1, 5, 10, 15, 20, 25, 30) for each month.

- Top Plot (Sea Height):** The y-axis ranges from 0.0 to 1.5. The data is shown as a highly oscillatory signal, likely representing tidal cycles, with peaks reaching approximately 1.2 and troughs near 0.0.
- Second Plot (TSSR):** The y-axis ranges from 0 to 5. The signal is also highly oscillatory, with values fluctuating between 0 and 5 throughout the period.
- Third Plot (Wind Speed):** The y-axis ranges from 0 to 20. The data shows frequent spikes, with several peaks reaching between 15 and 20.
- Bottom Plot (Wind Direction):** The y-axis ranges from 0 to 360. The data is plotted as a series of dots, showing a general trend that starts near 0, rises to a peak around 180 in late July, and then fluctuates between 0 and 180 through September.

HINDCAST LOCAL SEA WAVE CLIMATE

Location: Approx. 300 m north of Emery Point.
 Wave Type: Sea waves generated within Port Darwin.
 Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 247.5 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.03	.00	.00
.2 - .4	.55	.00	.00
.4 - .6	.00	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	2.43	.00	.00
.2 - .4	2.91	2.40	.00
.4 - .6	.00	.27	.00
.6 - .8	.00	.00	.00

Wave Direction: 292.5 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.62	.00	.00
.2 - .4	.55	2.71	.00
.4 - .6	.00	1.54	.00
.6 - .8	.00	.07	.03

Wave Direction: 315.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.31	.00	.00
.2 - .4	.24	.62	.00
.4 - .6	.00	.14	.00
.6 - .8	.00	.00	.00

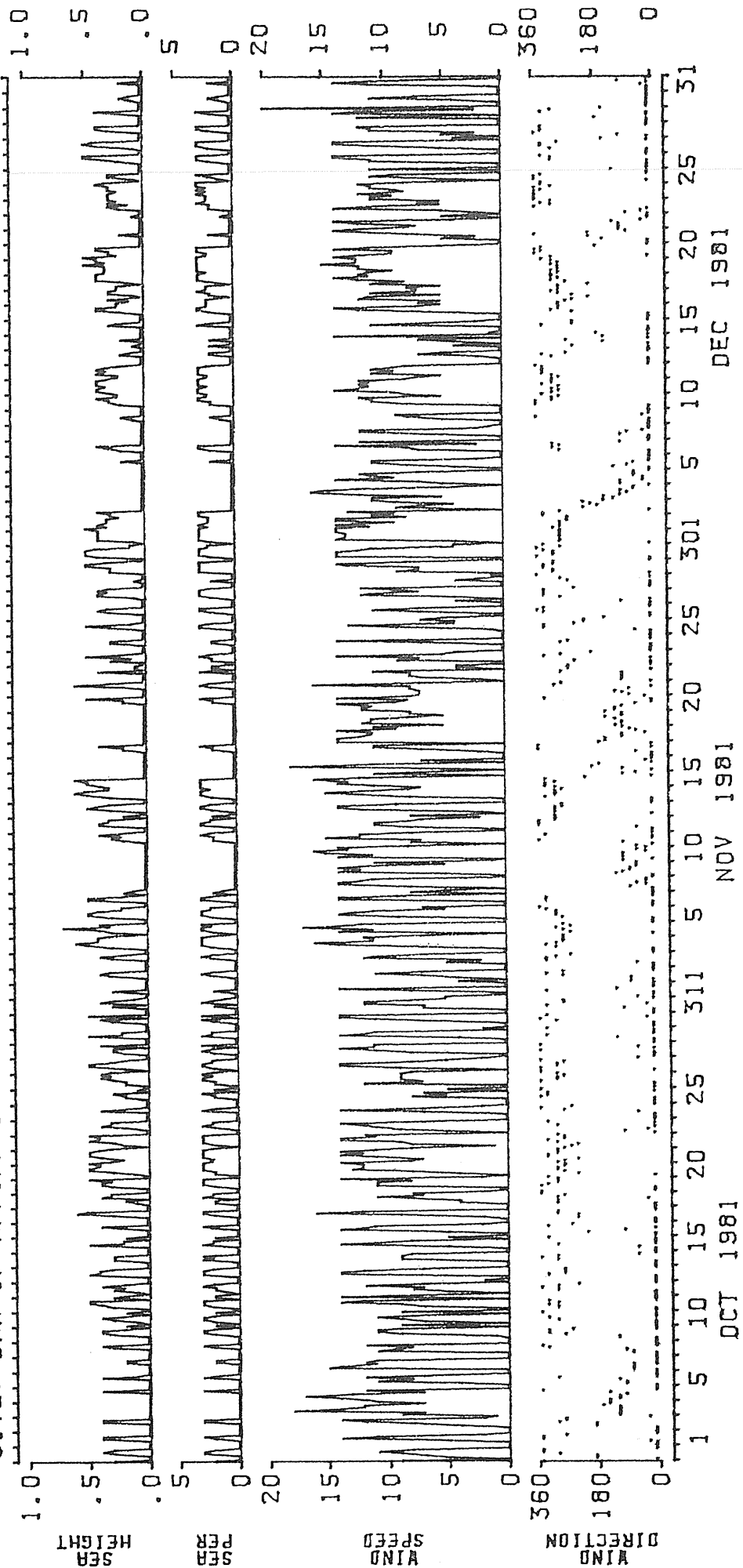
Wave Direction: 337.5 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.10	.00	.00
.2 - .4	.72	3.46	.00
.4 - .6	.00	1.30	.00
.6 - .8	.00	.00	.03

Wave Direction: 360.0 deg.

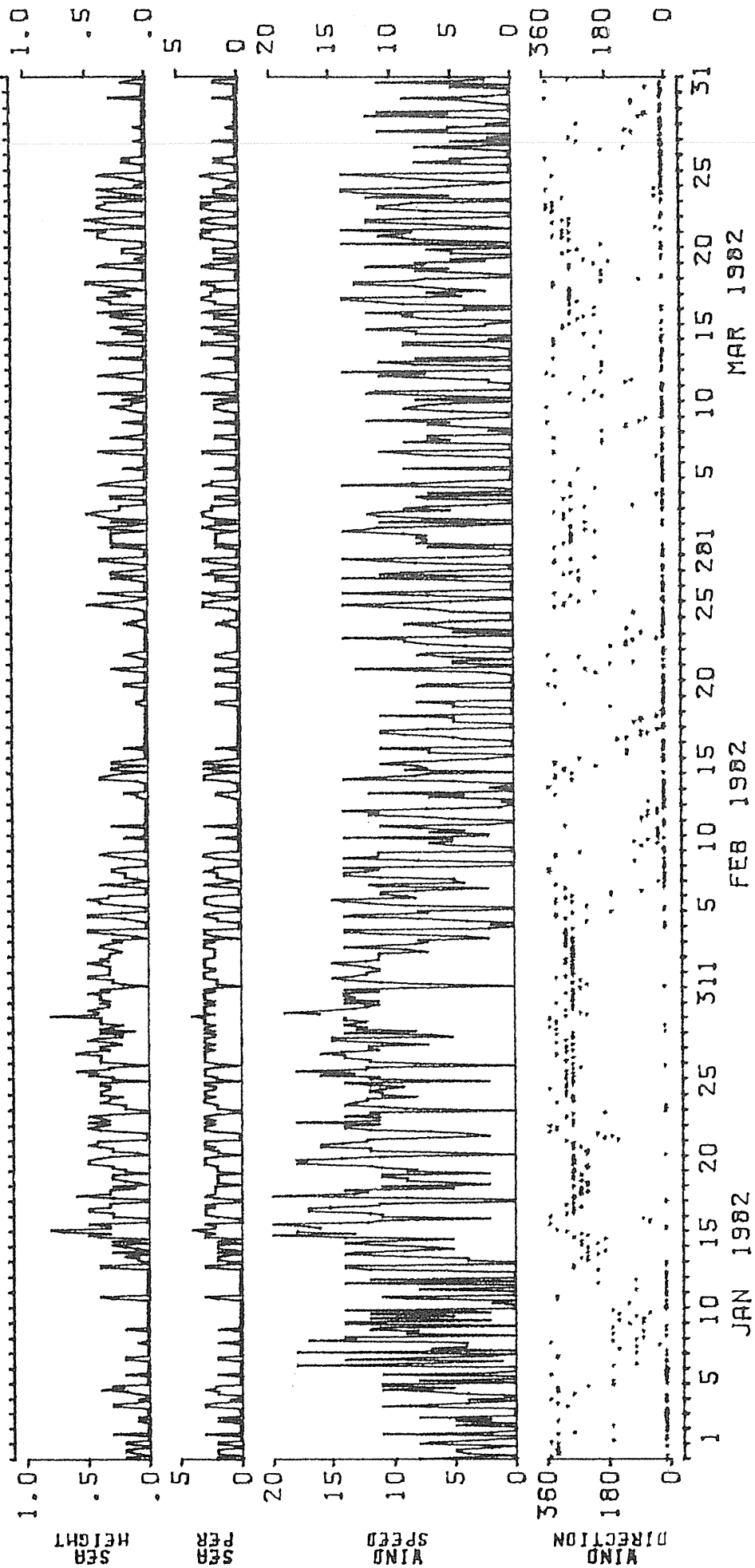
Height (m)	Period (s)		
	2	3	4
.0 - .2	4.93	.00	.00
.2 - .4	1.85	.68	.00
.4 - .6	.00	.03	.00
.6 - .8	.00	.00	.00

SITE: DARWIN MARINA OCT 1981 TO DEC 1981



PLOTTED: 19 DEC 1986

SITE: DARWIN MARINA JAN 1982 TO MAR 1982



PLOTTED: 26 DEC 1986

The chart displays four meteorological parameters over time (April 1 to June 30, 1982):

- SEA HEIGHT:** Y-axis scale 0.0 to 1.0. The plot shows a series of small, frequent fluctuations, mostly between 0.0 and 0.5.
- SEA PRESSURE:** Y-axis scale 0 to 5. The plot shows a series of small, frequent fluctuations, mostly between 0 and 2.
- WIND SPEED:** Y-axis scale 0 to 20. The plot shows a series of small, frequent fluctuations, mostly between 0 and 10.
- WIND DIRECTION:** Y-axis scale 0 to 360. The plot shows a series of small, frequent fluctuations, mostly between 0 and 180.

The X-axis for all panels represents time, with major ticks every 5 days (1, 5, 10, 15, 20, 25, 30) and labels for APR 1982 and MAY 1982.

PLOTTED: 26 DEC 1986

[illegible]

PLOTTED: 26 DEC 1986

HINDCAST DEEPWATER SWELL WAVE CLIMATE

Location: Entrance to Beagle Gulf.
Wave Type: Swell.
Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 202.5 deg.

Height (m)	Period (s)									
	5	6	7	8	9	10	11	12	13	14
.0 - .5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
.5 - 1.0	.07	.00	.00	.00	.00	.00	.00	.00	.00	.00
1.0 - 1.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
1.5 - 2.0	.00	.00	.00	.00	.00	.07	.00	.00	.00	.00
2.0 - 2.5	.00	.00	.07	.00	.00	.00	.00	.00	.00	.00

Wave Direction: 225.0 deg.

Height (m)	Period (s)									
	5	6	7	8	9	10	11	12	13	14
.0 - .5	.00	.41	.48	.41	.21	.07	.00	.00	.00	.00
.5 - 1.0	.07	.07	.00	.07	.00	.00	.00	.00	.00	.00
1.0 - 1.5	.00	.07	.00	.00	.00	.00	.00	.00	.00	.00
1.5 - 2.0	.00	.07	.00	.00	.00	.00	.00	.00	.00	.00
2.0 - 2.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Wave Direction: 247.5 deg.

Height (m)	Period (s)									
	5	6	7	8	9	10	11	12	13	14
.0 - .5	1.85	7.74	8.36	5.82	4.04	2.60	2.53	1.51	1.16	.68
.5 - 1.0	.21	.89	3.01	6.44	4.32	1.58	.21	.07	.00	.00
1.0 - 1.5	.00	.21	.21	.21	.41	.07	.00	.00	.00	.00
1.5 - 2.0	.00	.00	.07	.14	.07	.07	.00	.00	.00	.00
2.0 - 2.5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)									
	5	6	7	8	9	10	11	12	13	14
.0 - .5	2.33	5.27	2.88	1.92	1.10	.68	.48	.34	.21	.07
.5 - 1.0	.68	1.78	2.33	1.30	.34	.14	.00	.00	.00	.00
1.0 - 1.5	.00	.27	.14	.21	.07	.07	.00	.00	.00	.00
1.5 - 2.0	.00	.00	.34	.14	.07	.07	.07	.00	.00	.00
2.0 - 2.5	.00	.00	.07	.07	.07	.00	.07	.00	.00	.00

APPENDIX B

Wave Attenuation by Seabed Friction

LAWSON AND TRELOAR PTY. LTD.

WAVE REFRACTION USING REVERSE RAY TECHNIQUE

1. INTRODUCTION

The generally accepted method of wave refraction studies for coastal engineering investigations is to project parallel rays (orthogonals) from offshore deepwater towards some chosen area of coastline. If these rays have an initial spacing of b_0 , and this spacing becomes b in shallow water, then refraction coefficient, K_r , is simply defined as

$$K_r = \frac{b_0^2}{b^2} \quad (1)$$

This technique is suitable for simple locations where there are no abrupt bathymetric changes. However, in these instances, ray paths are quite complex and one may have a refraction diagram such as that shown in Figure 1. These rays began in deep water and were initially parallel and equidistant. The deep water origin is not shown, but it is obvious that interpretation is difficult, if not impossible. Even where ray paths have not crossed, a large gradient in inshore ray spacing can make it difficult to interpret the results and obtain reliable estimates of refraction coefficients. The result depends upon the chosen values of b_0 . Thus one can see that general refraction results for a length of coastline can be obtained in this way, but there is virtually no detail at any particular point.

At this stage it is important to ask one-self, "What is my purpose in carrying out a wave refraction study?" If the answer be to eventually use these results to obtain inshore wave climate from offshore wave data, then it is obvious, refer to Figure 1, that the forward ray technique is generally inadequate. By wave climate we here mean wave-height exceedance and wave direction information. A large amount of wave data is collated in terms of T_z , average zero crossing period. Forward ray projection, using monochromatic wave periods, does not facilitate the use of these data and requires "adaption" from the more realistic condition. Further, offshore waves virtually never occur with a single direction. Thus it is desirable to use a technique which can take this aspect into account in a physically acceptable manner. This work has the objective of describing a technique which overcomes most of these problems. It is one which was originally developed at the Hydraulics Research Station Wallingford, England, and has been further developed by Lawson and Treloar Pty. Ltd.

2. REVERSE RAY TECHNIQUE

The H.R.S. program, RAYTRK, calculates orthogonal paths using the basic refraction initial value equation

$$d\alpha/ds = -1/C \, dC/dn$$

where α is ray bearing

s is distance along the ray

n is the inward normal direction

The seabed is schematised on a grid of equilateral triangles contained within zones which are parallelograms. Within each zone all triangles are of the same size, but the triangle size may vary among the zones. In this way it is possible to develop the seabed in some detail where necessary, yet be economical in deeper water where data points can be further apart.

An inshore location is chosen and fans of rays are projected from there to deep water with wave periods of say 4, 6, 8, 10, 12 and 14 seconds. The inshore orthogonal bearings, θ , are generated at intervals of $d\theta$, which may range from less than 1 degree to 5 degrees, depending upon the site and the window to deep water. The results of this are a series of θ - Θ plots (in theory only, as they are never in fact drawn), where Θ is the offshore orthogonal bearing. The required result, then, of the ray calculation procedure is the θ - Θ relationship for each ray. Figure 2A shows one such plot. It will be seen that θ can be multi-valued for some Θ values as in this example. These areas exhibit the effect of caustics, which in effect are those events in the forward ray technique where neighbouring rays cross. In such a case the logical conclusion from equation (1) would be that K_r tends towards infinity. However, we know that this is not so and that wave diffraction causes a lateral transfer of wave energy so that the total spectral energy remains constant. Refraction and diffraction are not independent phenomena.

The next step is to make the reasonable proposal that an offshore frequency direction spectrum can be assumed to be made up of the linear product of the separate frequency and direction spectra. The form of these can be freely chosen, but the modified Moskowitz spectrum and Gaussian distribution are usually chosen for the frequency and direction spectra respectively. This follows the work of Abernethy and Gilbert, (1975). Thus,

$$S(f, \theta) = S_1(f) \cdot S_2(\theta) \quad (2)$$

$$\text{where } S_1(f) = (H_s^2 u^{-5}) / 4\pi f z \exp(-u^2 / \pi) \quad (3)$$

$$S_2(\theta) = 1/\sigma\sqrt{2\pi} \exp(-(\mu-\sigma)^2 / 2\sigma^2) \quad (4)$$

where μ is mean offshore direction
 σ is the standard deviation in wave direction
 f is wave frequency
 $u = f/f_z$
 $f_z = 1/T_z$

At the present stage the choice of σ is somewhat arbitrary. A value of 10 degrees provides stable results when one has parallel offshore contours, but a value of 40 degrees has been obtained from ocean wave measurements carried out by Cartwright, Longuet-Higgins and Smith, (1963). It is believed that σ will depend on the site and will have its own statistical distribution. A value of 40 degrees is generally used, but if insight into the effect of a narrower direction spectrum is desired, a smaller σ value should be tried.

Figures 2A-C show the essential steps in the method. Suppose that from an inshore location a fan of wave orthogonals has been projected out to deep water for some chosen frequency, f_1 , and their directions plotted as the θ - θ curve of Figure 2A. A set of such curves at several frequencies will contain the full description of the refracting effect of the seabed topography between A and the ocean.

Figure 2B on the other hand depicts the "climatic" input to the problem: this is a spectrum shown as the contoured surface of $S(f, \theta)$, the more familiar one dimensional components being indicated on the axes. The shape of the spectrum is decided by the choice of equations (3) and (4). Its position in the f - θ plane depends upon the choice of T_z and μ . H_s can be assigned an arbitrary value since we follow usual practice in neglecting non-linear effects and so making K_r independent of H_s .

The spectrum at A that results from combining the deep water spectrum of Figure 2B with the refracting properties of Figure 2A is constructed in Figure 2C as a set of contours on the f, θ plane. Its method of construction is thus: for any point f_1, θ_1 of Figure 2C the conjugate value of θ_1 is found by reference to Figure 2A. The point f_1, θ_1 is located in Figure 2B and its ordinant, $S(f_1, \theta_1)$, read there. This value is transferred directly to the location f_1, θ_1 in Figure 2C, after adjustment according to the equation

$$S(f, \theta) = (C_g \cdot C_o) / (C_g \cdot C) \cdot S(f, \theta) \quad (5)$$

Equation (5) was first presented by Longuet-Higgins (1957) in wave number space and its derivation can be summarised as follows. Consider (in the context of conventional forward

projected wave rays) a small element of wave energy which in deep water is contained between two rays at spacing b_0 , and which is distributed over small ranges of frequency and direction, df and $d\theta$. At A the ray separation is b and the corresponding ranges of frequency and direction will be df and $d\theta$. Equating energy fluxes we have

$$S(f, \theta) \cdot df \cdot d\theta \cdot C_{g0} \cdot b_0 = S(f, \theta) \cdot df \cdot d\theta \cdot C_g \cdot b \quad (6)$$

which, by introducing $K_r = b_0/b$ and substituting

$$K_r^2 = (C_0/C) \cdot d\theta/d\theta$$

a relationship developed by Dorrestein (1960), produces the form shown in equation (5).

Calculation of the inshore root-mean-square wave-height is then simply given by

$$H_{r.m.s.}^2 = 8 \iint S(f, \theta) \cdot df \cdot d\theta \quad (7)$$

The inshore mean wave direction is given by

$$\theta_m = \left(\iint \theta S(f, \theta) \cdot df \cdot d\theta \right) / \left(\iint S(f, \theta) \cdot df \cdot d\theta \right) \quad (8)$$

The inshore zero crossing period can also be determined from

$$T_z^2 = \left(\iint S(f, \theta) \cdot df \cdot d\theta \right) / \left(\iint f^2 S(f, \theta) \cdot df \cdot d\theta \right) \quad (9)$$

The equations are evaluated numerically. Note that equation (9) demonstrates the change in T_z as refraction occurs. This aspect can not be obtained from the forward ray technique.

The method is quite versatile and is applicable where one has islands which intercept some orthogonals and severely refract others. Figure 3A-B shows an idealized example of such a bed area and the resulting θ - θ diagram. The important aspect is the discontinuity in θ which will appear in the inshore spectrum as a break or depression, i.e. there will be two humps of energy. Wave diffraction would of course mean that the spectrum is not discontinuous, but due account of the islands effect should be taken.

Table 1 is an example of the results obtained from this method. The first block is an array of wave coefficients arranged in columns for directions and rows for zero crossing period. Note that this method does not obtain separate refraction and shoaling coefficients, as shoaling coefficient and T_z are not directly related. However, each spectral ordinant is

correctly transformed. If it be desired, wave coefficients at each of the monochromatic periods can be determined, each of these being averaged over the direction spectrum.

3 CALCULATION OF INSHORE WAVE CLIMATE

Wave-height statistics generally fall into four areas. These are

- (1) Short term statistical distribution - Rayleigh Distribution
- (2) Long term wave-height exceedance statistics - Log-normal or Weibull Distributions.
- (3) Storm Duration-Return Interval studies.
- (4) Wave group statistics.

This study is concerned with the first two of these, the first in an implicit sense and the second directly. Where adequate data are available they are collated in a form whereby it is divided into groups, each referred to by an offshore direction and period. This means that all wave observations falling within a 22.5 degree sector are assigned to the central direction and all observations within a 1 second zero crossing period band are assigned to the central period. Thus it is possible to prepare the data in the form shown in Figure 4. In that figure, p_1 , is the probability that the particular offshore direction-period event will occur. The plot then shows the conditional probability of wave height exceedance. The data are usually drawn up in terms of H_s . Thus one has a number of such plots, one for each direction-period case. Each is completely described by choosing two pairs of wave-height and probability points, including p_1 , and given that the distribution is log-normal.

In order to calculate inshore wave-height exceedance statistics, one first selects a list of wave-heights. Then, taking the smallest, say H_1 , it is divided by the wave coefficient for the first direction period condition to determine the offshore wave-height, H_{o1} , necessary to generate that inshore wave-height. The wave-height exceedance plot is then entered at H_{o1} on the vertical axis and the conditional probability p_2 determined. The product $p_1 \cdot p_2$ then provides the partial probability of H_1 being exceeded. By repeating this process for all offshore conditions and summing all partial probabilities, the total probability of H_1 being exceeded will be produced. The procedure is then repeated for each choice of H_1 . The total wave-height exceedance plot can then be determined by calculating successive probabilities of exceedance.

It should be noted that the breaking wave-height limitation is not included. If a particular design probability be chosen, then this wave-height can be matched to a water level taking into account the change in inshore wave-height with change in water level. The effects of bed friction can be included by calculating wave conditions at a number of locations between deep water and the shoreline. This is necessary because turbulent flow energy dissipation depends upon wave-height itself and the wave height must be included in each calculation of K_f , the friction coefficient.

A further calculation may be performed and this is the weighted mean inshore wave direction. Based on the premise that wave energy is a more relevant parameter than wave-height in many situations, H_e , the effective wave-height is calculated as

$$H_e^2 = \int H^2 p(H) dH$$

where $p(H)$ is the log-normal distribution.

Then, following from the general sediment transport equations in which, Q , rate of transport, is described by

$$Q \propto H^2 T \quad \text{i.e. wave power}$$

one determines weighting factors E_o thus

$$E_o = p_1(T_z, \mu) \cdot T_z \cdot H_e^2 \quad \text{for each } T_z - \mu \text{ pair}$$

Thus Q can be written further

$$Q \propto E_o \cdot K_w^2 \quad \text{for each } T_z - \mu \text{ pair}$$

Thus the total average sediment transport can be obtained by summing these Q values over all $T_z - \mu$ pairs. Note that this procedure should not be used as presented for sediment transport as no account of threshold velocities has been included. The E_o and K_w values can then be used to calculate the weighted mean inshore direction. This mean direction is also useful for offshore berth investigations.

Additionally it is possible to divide the inshore directions up into sectors for studies involving ship movement. Diffraction effects can also be included by further analysis.

The processes presented above have been well tested and are believed to provide the most reliable inshore wave-height information, which is in a form which is readily used in further studies. Although the method has been presented in terms of T_z many aspects can be used in a monochromatic period study or use can be made of other period parameters.

WAVE CLIMATE STUDY

LOCATION

INSHORE WAVE CONDITIONS FOR POSITION *
DIRECTION STANDARD DEVIATION 40.0

WAVE COEFFICIENTS

ZERO		DIRECTION					
CROSSING	225.0	247.5	270.0	292.5	315.0	337.5	360.0
PERIOD							
4.5	0.49	0.57	0.59	0.56	0.48	0.38	0.28
5.5	0.43	0.51	0.54	0.52	0.47	0.39	0.30
6.5	0.40	0.47	0.50	0.50	0.47	0.42	0.35
7.5	0.39	0.45	0.48	0.49	0.48	0.47	0.44
8.5	0.39	0.44	0.47	0.48	0.50	0.51	0.50
9.5	0.39	0.44	0.46	0.48	0.50	0.53	0.53
10.5	0.40	0.45	0.46	0.47	0.51	0.54	0.55
11.5	0.40	0.45	0.46	0.47	0.51	0.55	0.56
12.5	0.40	0.45	0.46	0.47	0.51	0.55	0.56

INSHORE DIRECTIONS							
4.5	251.37	254.81	258.71	262.74	266.36	269.04	270.64
5.5	250.83	253.63	256.94	260.41	263.37	265.24	266.00
6.5	249.87	252.19	255.09	258.20	260.70	261.97	262.15
7.5	248.56	250.43	253.02	256.03	258.40	259.46	259.56
8.5	247.49	248.99	251.31	254.32	256.87	258.11	258.45
9.5	246.97	248.24	250.38	253.41	256.12	257.55	258.05
10.5	246.72	247.88	249.92	252.95	255.77	257.30	257.89
11.5	246.60	247.70	249.68	252.70	255.58	257.17	257.81
12.5	246.53	247.60	249.54	252.56	255.47	257.10	257.77

WEIGHTED MEAN INSHORE ORTHOGONAL DIRECTION 259.03

TABLE POSITION * - TIDE + 1.8M I.S.L.W.

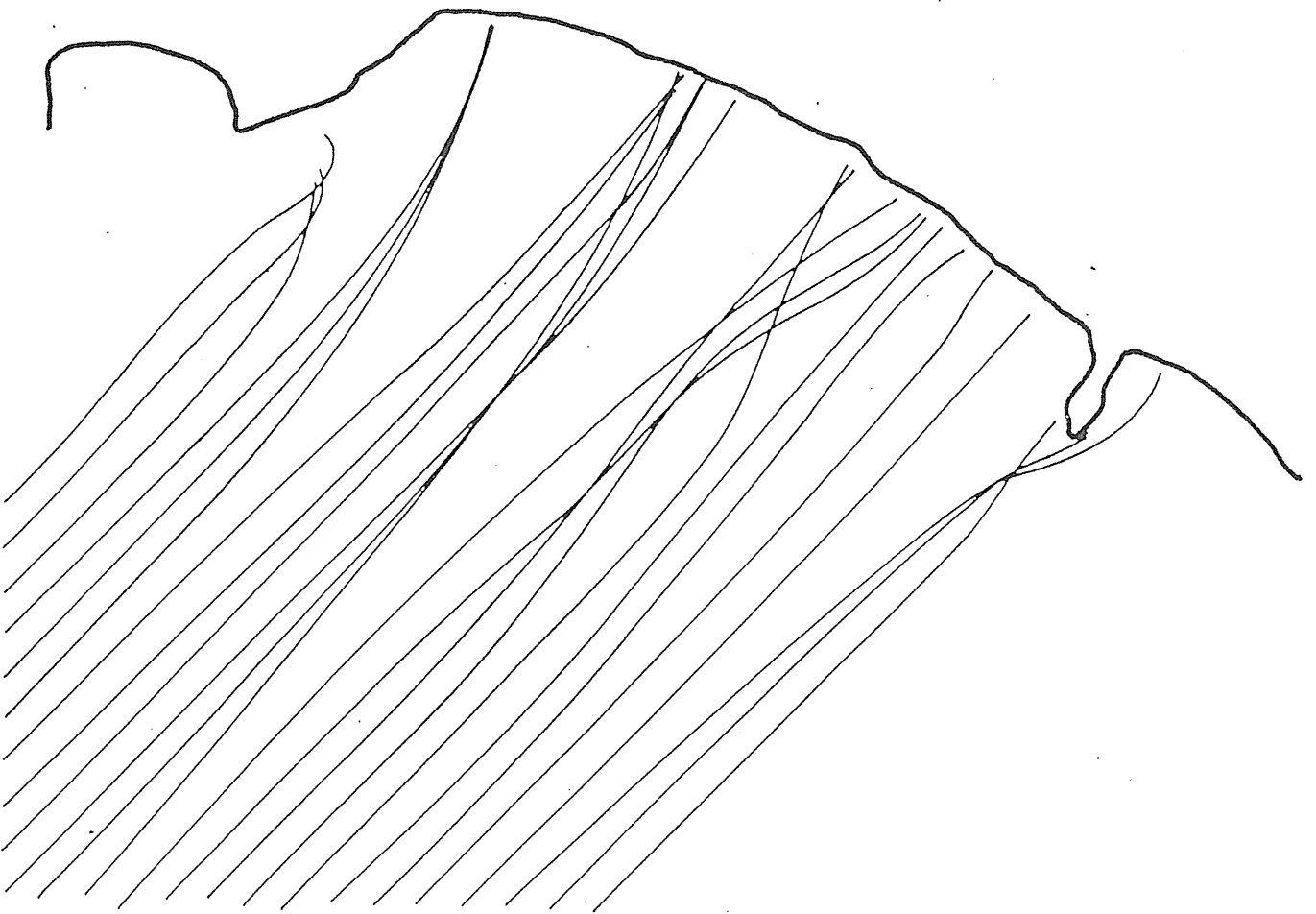
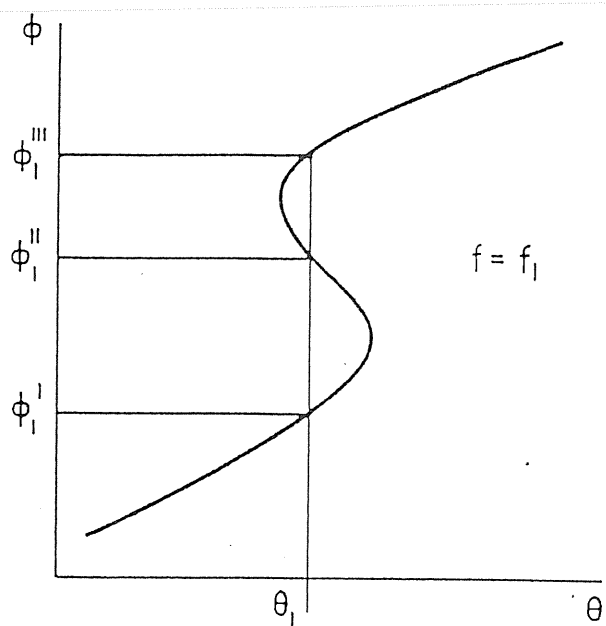
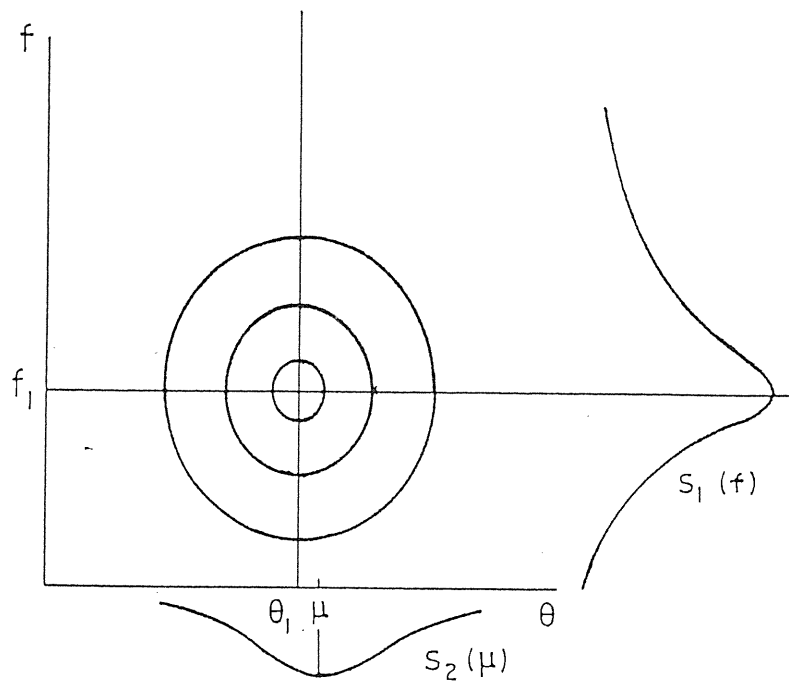


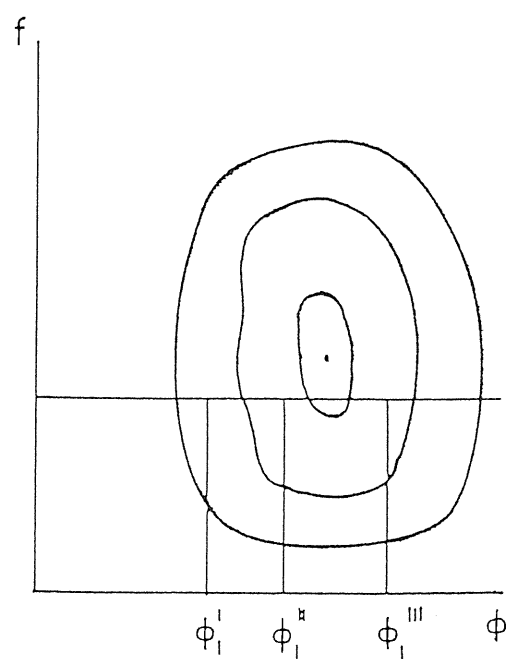
FIGURE 1: FORWARD PROJECTED RAYS



(a)

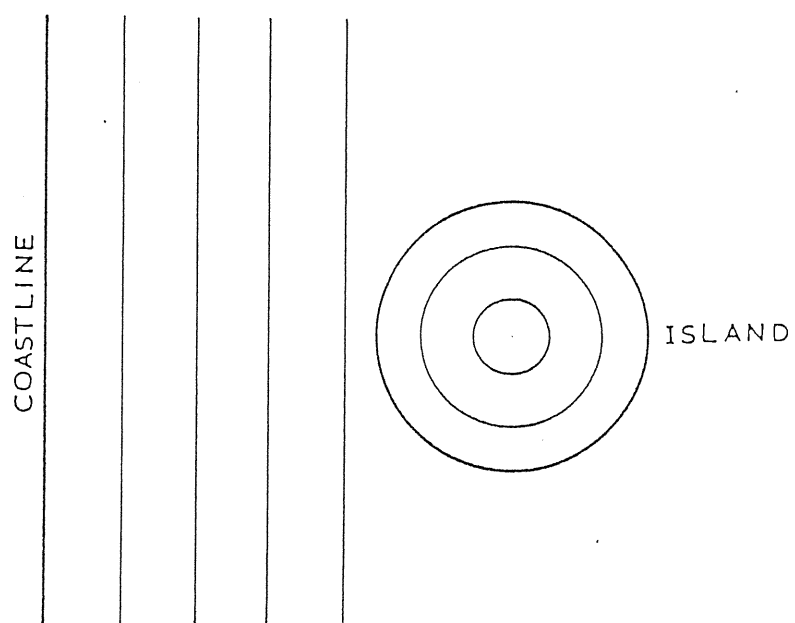


(b)

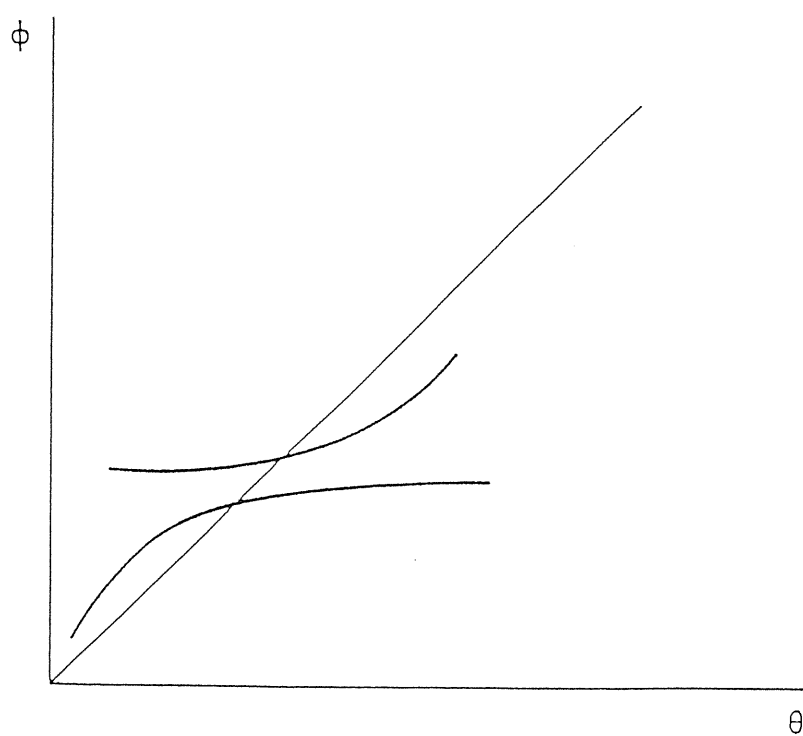


(c)

FIGURE 2.



(a)



(b)

FIGURE 3.

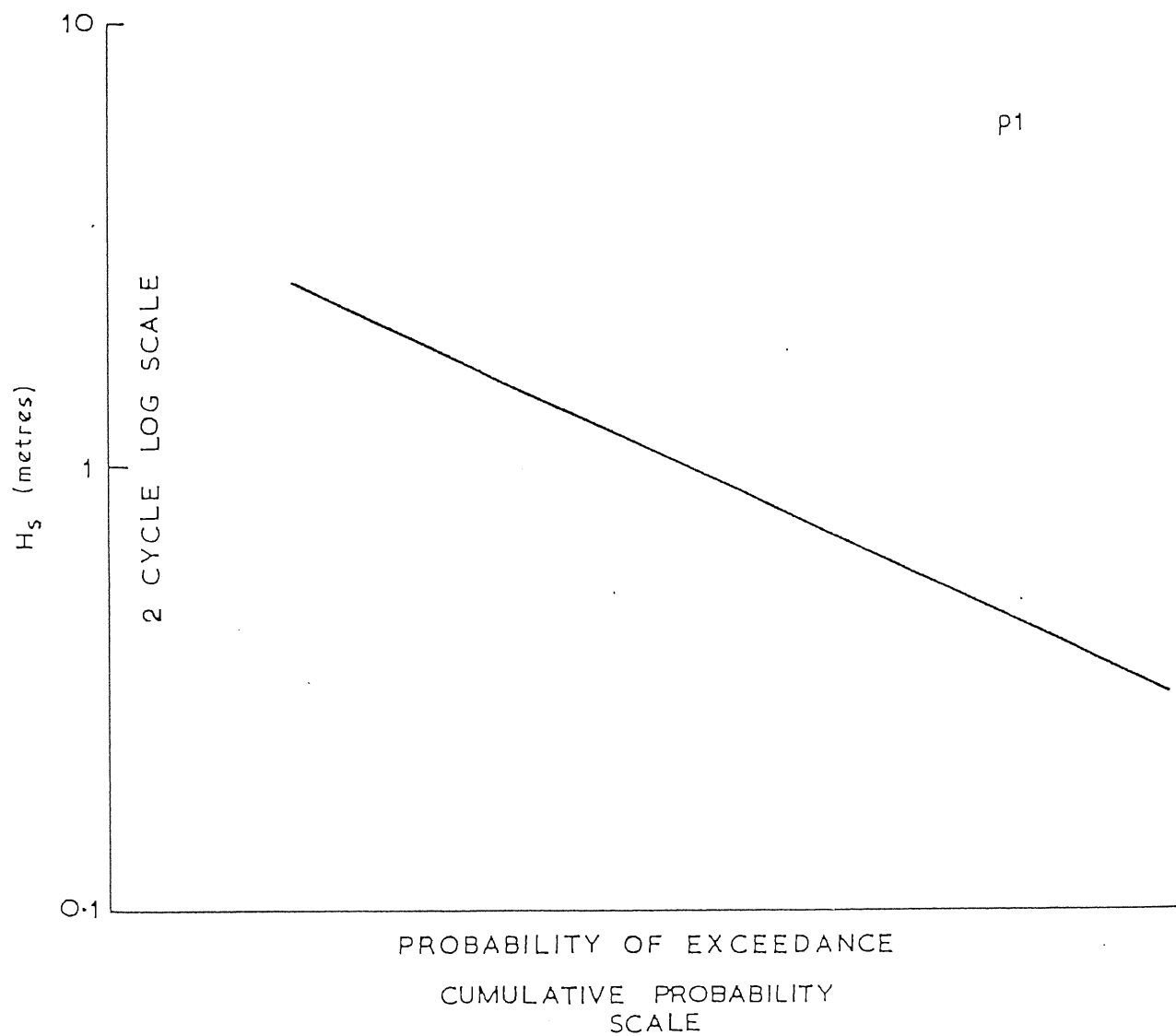


FIGURE 4.

APPENDIX B

Reverse Ray Refraction Technique

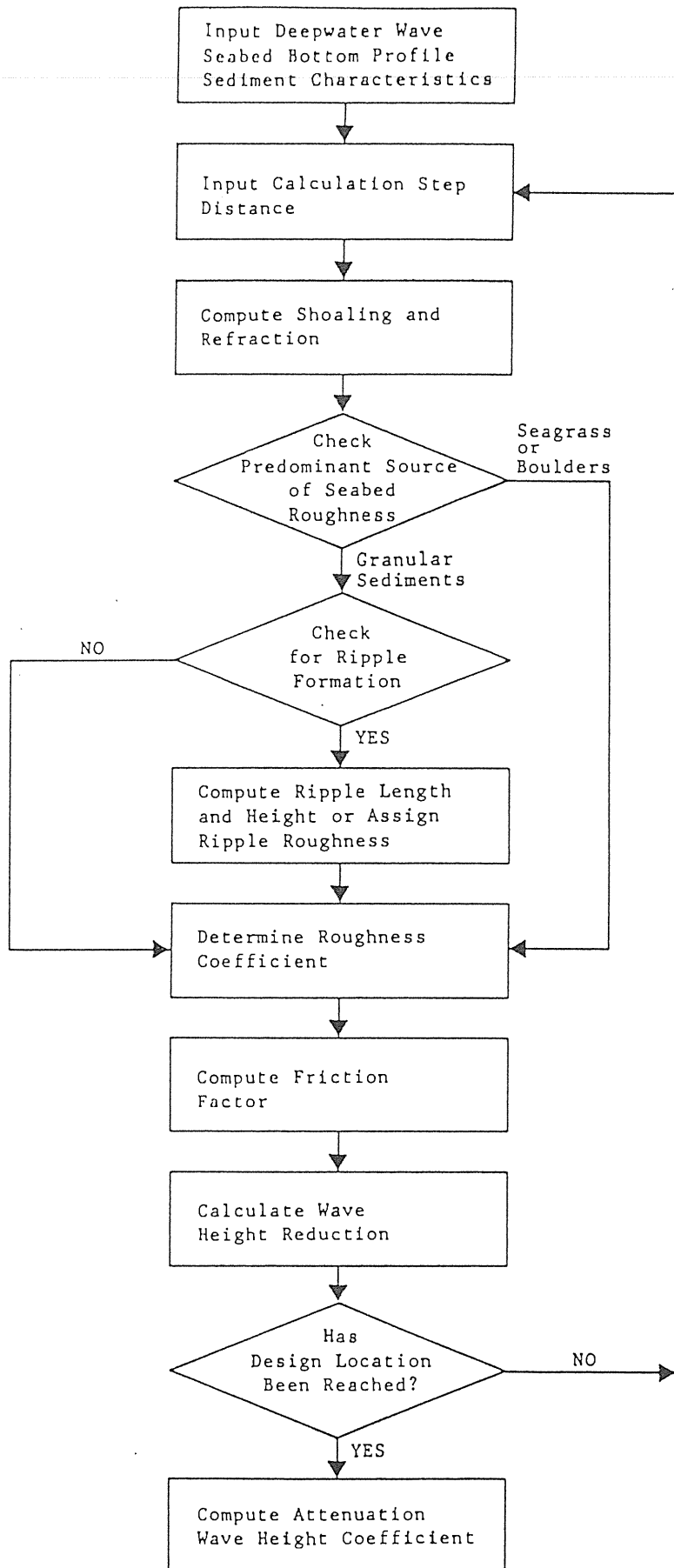
TECHNIQUE

Wave attenuation due to friction at the seabed is calculated using a computer program the flow chart for which is shown overleaf.

The calculational procedure involves :

- . inputting water depth and wave refraction and shoaling coefficients for each offshore direction radiating from the site of interest out to deep water. This is done as a series of discrete steps along the radial. The step length is variable and depends primarily on the rate of change of the seabed slope.
- . for the first step for each nominated deepwater wave height period and direction the shoaling and refraction coefficients are retrieved from the computer memory.
- . the type of seabed is assessed. If the seabed is granular it will form either a plane bed or a rippled bed depending on the wave characteristics, the seabed material and the water depth. If the seabed has seagrass, boulder, or other surface materials these will control the roughness. At other sites where the seabed is granular, the formation of ripples are checked and a roughness coefficient determined.
- . from the roughness coefficient a friction factor is computed and the wave height reduction calculated for that computational step.
- . the procedure is then repeated for the next computational step.
- . wave generation due to onshore winds is included in each computational step.

Typically it has been found that up to 10 computational steps from deepwater to shallow water are required.



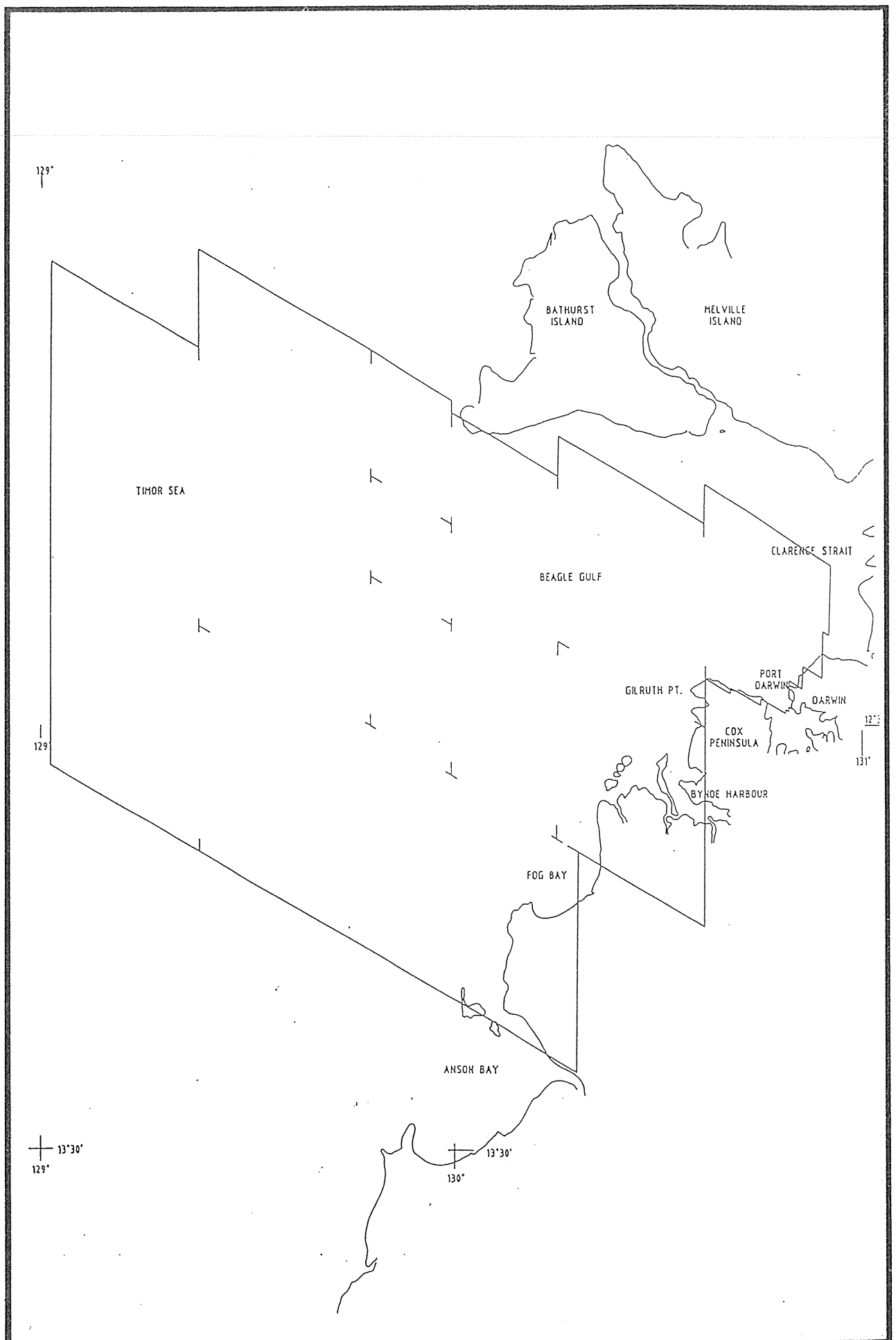
FLOW CHART

Source references describing the mathematics, reasearch and other literature upon which these calculations are based are :

- . Riedel, H.P., Kamphius, J.W. and Brebner, A. (1972). "Measurement of Bed Shear Stress under Waves". Proc. 13th Int. Coastal Engineering Conference, Vancouver.
- . Kamphius, J.W. (1975) "Friction Factor under Oscillatory Waves". Proc. ASCE, 101, WW2, 135 - 144.
- . Hsiao, S.V., and Shemdin, O.H. (1978) "Bottom Dissipation in Finite - Depth Water Waves", Proc. 16th International Coastal Engineering Conference Hamburg.

APPENDIX B

Refraction Grid



REFRACTION GRID

APPENDIX B

Refraction Tables

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 1 (post-development).
 Water Depth at Site: 8.5 m
 Wave Type: Local sea generated within Port Darwin.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	.21	.19	.16	.21
230.0	.30	.28	.23	.26
240.0	.41	.37	.31	.34
250.0	.52	.48	.40	.42
260.0	.63	.58	.49	.50
270.0	.73	.68	.59	.59
280.0	.82	.77	.67	.67
290.0	.88	.84	.75	.74
300.0	.93	.89	.81	.80
310.0	.95	.92	.86	.86
320.0	.95	.93	.89	.90
330.0	.93	.91	.90	.92
340.0	.87	.87	.89	.91
350.0	.80	.80	.84	.86
360.0	.70	.71	.77	.78
10.0	.58	.60	.68	.67

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	275	276	280	281
230.0	276	278	281	283
240.0	279	280	283	285
250.0	281	282	285	287
260.0	284	286	288	290
270.0	288	289	292	294
280.0	293	294	296	299
290.0	299	300	302	305
300.0	305	306	308	311
310.0	312	312	314	317
320.0	318	319	320	323
330.0	325	325	326	327
340.0	331	330	330	330
350.0	336	334	333	333
360.0	341	337	335	334
10.0	345	340	336	334

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 2 (post-development).
 Water Depth at Site: 8.0 m
 Wave Type: Local sea generated within Port Darwin.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	.33	.32	.28	.27
230.0	.45	.44	.38	.36
240.0	.58	.56	.49	.46
250.0	.70	.68	.61	.56
260.0	.80	.79	.73	.68
270.0	.88	.87	.83	.79
280.0	.94	.93	.90	.88
290.0	.97	.96	.95	.95
300.0	.98	.98	.97	.99
310.0	.98	.97	.96	1.00
320.0	.96	.94	.93	.98
330.0	.92	.90	.88	.93
340.0	.86	.83	.81	.86
350.0	.77	.74	.72	.77
360.0	.67	.63	.61	.66
10.0	.56	.51	.50	.54

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	262	261	260	257
230.0	264	264	263	260
240.0	267	265	266	264
250.0	270	270	270	269
260.0	274	274	274	273
270.0	280	279	279	278
280.0	286	285	284	283
290.0	293	292	290	287
300.0	301	299	296	293
310.0	309	307	302	298
320.0	316	314	309	304
330.0	323	321	316	310
340.0	329	326	321	314
350.0	335	331	325	318
360.0	340	335	329	321
10.0	344	338	331	324

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 3 (post-development).
 Water Depth at Site: 6.2 m
 Wave Type: Local sea generated within Port Darwin.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	.45	.46	.44	.45
230.0	.57	.58	.56	.57
240.0	.69	.70	.68	.69
250.0	.79	.80	.78	.79
260.0	.87	.88	.86	.88
270.0	.92	.93	.91	.93
280.0	.96	.96	.94	.96
290.0	.97	.97	.95	.97
300.0	.97	.96	.94	.97
310.0	.95	.94	.92	.94
320.0	.91	.89	.87	.90
330.0	.85	.82	.80	.84
340.0	.77	.73	.71	.76
350.0	.67	.62	.61	.66
360.0	.56	.51	.50	.56
10.0	.46	.40	.39	.45

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	254	254	255	254
230.0	257	256	257	257
240.0	260	260	260	259
250.0	264	264	263	263
260.0	270	269	268	267
270.0	276	275	274	273
280.0	283	282	281	279
290.0	291	290	289	286
300.0	299	298	296	293
310.0	306	305	303	300
320.0	313	311	309	305
330.0	319	317	314	310
340.0	325	322	318	313
350.0	331	326	322	315
360.0	337	330	325	317
10.0	343	335	328	318

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 4 (post-development).
 Water Depth at Site: 6.2 m
 Wave Type: Local sea generated within Port Darwin.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	.64	.68	.69	.73
230.0	.74	.78	.79	.81
240.0	.83	.86	.86	.88
250.0	.89	.91	.91	.94
260.0	.93	.95	.94	.97
270.0	.96	.96	.96	.98
280.0	.97	.97	.95	.98
290.0	.96	.96	.94	.96
300.0	.94	.93	.90	.92
310.0	.90	.88	.85	.87
320.0	.84	.80	.77	.80
330.0	.75	.71	.67	.71
340.0	.66	.60	.56	.62
350.0	.56	.48	.44	.51
360.0	.47	.38	.33	.41
10.0	.39	.29	.24	.32

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	241	241	241	242
230.0	246	245	246	247
240.0	251	250	251	252
250.0	257	257	257	258
260.0	265	264	264	265
270.0	272	272	272	272
280.0	281	280	280	279
290.0	288	288	288	286
300.0	296	295	295	294
310.0	303	301	301	300
320.0	309	307	306	305
330.0	315	312	310	309
340.0	322	316	314	312
350.0	329	321	316	313
360.0	337	327	319	313
10.0	345	335	323	313

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 4 (pre-development).
 Water Depth at Site: 6.2 m
 Wave Type: Local sea generated within Port Darwin.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	.64	.67	.69	.73
230.0	.74	.78	.79	.83
240.0	.82	.86	.86	.90
250.0	.89	.91	.91	.94
260.0	.93	.95	.94	.97
270.0	.96	.96	.95	.98
280.0	.97	.97	.95	.97
290.0	.96	.95	.93	.95
300.0	.94	.92	.90	.91
310.0	.90	.87	.85	.86
320.0	.83	.80	.77	.80
330.0	.75	.70	.67	.71
340.0	.65	.59	.56	.62
350.0	.55	.47	.44	.52
360.0	.46	.37	.33	.41
10.0	.38	.28	.23	.32

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)			
	2.0	3.0	4.0	5.0
220.0	242	241	242	243
230.0	246	245	246	247
240.0	251	251	251	252
250.0	257	257	257	257
260.0	265	264	264	264
270.0	272	272	272	272
280.0	281	280	280	279
290.0	288	288	288	287
300.0	296	295	295	294
310.0	302	301	301	301
320.0	309	306	306	306
330.0	315	311	310	309
340.0	321	316	313	312
350.0	329	321	316	313
360.0	337	327	319	314
10.0	346	335	322	313

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 1 (post-development).
 Water Depth at Site: 8.5 m
 Wave Type: Sea waves generated within Beagle Gulf.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	.13	.12	.09	.10	.15
250.0	.21	.19	.15	.16	.22
260.0	.31	.28	.23	.25	.32
270.0	.42	.40	.34	.35	.43
280.0	.55	.52	.47	.48	.56
290.0	.66	.65	.61	.62	.70
300.0	.76	.75	.75	.75	.82
310.0	.82	.83	.86	.86	.90
320.0	.84	.87	.92	.92	.95
330.0	.82	.85	.93	.93	.93
340.0	.75	.79	.89	.88	.87
350.0	.65	.69	.79	.79	.77
360.0	.53	.57	.66	.67	.65
10.0	.41	.44	.51	.54	.54
20.0	.29	.31	.37	.41	.44
30.0	.20	.21	.25	.31	.35
40.0	.12	.13	.16	.23	.28

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	301	302	305	307	313
250.0	303	304	308	310	315
260.0	304	306	311	313	317
270.0	306	308	313	316	318
280.0	308	310	316	318	320
290.0	310	313	319	320	322
300.0	313	316	322	323	323
310.0	316	319	324	325	325
320.0	319	322	327	326	326
330.0	323	325	329	328	327
340.0	326	328	331	330	328
350.0	328	330	332	331	329
360.0	331	332	333	332	330
10.0	333	333	334	333	331
20.0	334	334	335	334	332
30.0	336	335	335	334	332
40.0	337	336	336	334	332

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 2 (post-development).
 Water Depth at Site: 8.0 m
 Wave Type: Sea waves generated in Beagle Gulf.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	.14	.16	.20	.21	.26
250.0	.22	.24	.30	.31	.35
260.0	.32	.35	.42	.43	.45
270.0	.43	.47	.55	.55	.57
280.0	.56	.60	.68	.68	.69
290.0	.67	.71	.78	.78	.80
300.0	.77	.80	.86	.86	.88
310.0	.83	.85	.91	.91	.94
320.0	.84	.86	.91	.91	.95
330.0	.81	.83	.87	.88	.92
340.0	.74	.76	.80	.81	.87
350.0	.64	.65	.69	.72	.78
360.0	.52	.53	.57	.60	.68
10.0	.40	.41	.44	.48	.57
20.0	.29	.29	.32	.37	.46
30.0	.19	.19	.21	.27	.36
40.0	.12	.12	.14	.19	.27

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	301	297	293	292	292
250.0	302	298	294	293	294
260.0	304	300	295	294	295
270.0	305	301	296	296	298
280.0	308	304	298	297	300
290.0	310	306	300	300	301
300.0	313	309	303	303	303
310.0	316	313	308	306	305
320.0	319	317	312	310	307
330.0	322	320	316	314	309
340.0	325	323	320	317	310
350.0	328	326	323	320	311
360.0	330	329	325	322	312
10.0	332	331	328	323	312
20.0	334	332	329	324	311
30.0	336	333	330	324	310
40.0	337	334	331	324	308

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 3 (post-development).
 Water Depth at Site: 6.2 m
 Wave Type: Sea waves generated in Beagle Gulf.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	.15	.14	.12	.14	.20
250.0	.23	.22	.19	.21	.27
260.0	.34	.32	.29	.30	.36
270.0	.46	.44	.40	.41	.47
280.0	.58	.56	.52	.53	.59
290.0	.69	.67	.63	.64	.70
300.0	.78	.76	.72	.73	.80
310.0	.83	.81	.77	.79	.86
320.0	.84	.81	.77	.79	.88
330.0	.80	.77	.73	.76	.87
340.0	.72	.69	.65	.68	.82
350.0	.61	.59	.55	.58	.74
360.0	.49	.47	.43	.47	.66
10.0	.37	.35	.32	.36	.57
20.0	.26	.24	.22	.27	.48
30.0	.17	.16	.14	.20	.39
40.0	.11	.10	.09	.14	.30

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	299	300	304	307	306
250.0	300	301	305	307	305
260.0	302	303	306	307	304
270.0	304	304	307	307	303
280.0	306	306	308	307	303
290.0	308	309	309	308	302
300.0	311	311	311	309	302
310.0	314	314	312	310	302
320.0	318	316	314	311	301
330.0	321	319	316	312	301
340.0	324	322	318	313	301
350.0	326	324	319	314	300
360.0	329	326	321	316	299
10.0	331	328	322	317	298
20.0	332	329	323	318	298
30.0	334	331	324	318	299
40.0	335	332	325	319	302

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 4 (post-development).
 Water Depth at Site: 6.2 m
 Wave Type: Sea waves generated in Beagle Gulf.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	.16	.15	.14	.18	.28
250.0	.25	.24	.21	.26	.36
260.0	.35	.34	.31	.35	.45
270.0	.47	.46	.42	.45	.55
280.0	.59	.57	.53	.55	.64
290.0	.69	.67	.63	.64	.72
300.0	.76	.74	.70	.71	.78
310.0	.78	.76	.73	.73	.80
320.0	.76	.73	.71	.71	.79
330.0	.70	.67	.64	.65	.75
340.0	.60	.57	.55	.57	.69
350.0	.49	.45	.43	.48	.61
360.0	.38	.34	.32	.39	.54
10.0	.28	.24	.23	.32	.47
20.0	.19	.16	.15	.27	.41
30.0	.12	.10	.10	.23	.35
40.0	.07	.06	.06	.19	.29

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	298	298	300	297	292
250.0	299	299	301	298	292
260.0	300	301	303	299	293
270.0	302	302	304	301	295
280.0	304	304	305	303	296
290.0	306	306	307	305	298
300.0	308	308	308	307	300
310.0	310	310	310	308	302
320.0	313	312	312	310	303
330.0	316	314	313	312	304
340.0	318	316	315	313	305
350.0	321	318	316	314	305
360.0	324	320	318	314	305
10.0	326	322	319	314	306
20.0	329	324	319	313	308
30.0	332	326	319	313	309
40.0	334	329	318	313	310

WAVE COEFFICIENTS AND INSHORE DIRECTIONS

Inshore Location: Site 4 (pre-development).
 Water Depth at Site: 6.2 m
 Wave Type: Sea waves generated in Beagle Gulf.

The wave coefficients allow for refraction, diffraction and shoaling,
 but do NOT allow for friction and wave regeneration.

WAVE COEFFICIENTS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	.16	.16	.15	.19	.31
250.0	.25	.24	.23	.27	.38
260.0	.35	.34	.32	.36	.46
270.0	.47	.46	.43	.46	.55
280.0	.59	.57	.54	.56	.64
290.0	.69	.67	.64	.65	.71
300.0	.75	.73	.70	.71	.75
310.0	.78	.76	.73	.73	.76
320.0	.76	.73	.71	.70	.74
330.0	.69	.66	.64	.64	.68
340.0	.60	.57	.54	.56	.61
350.0	.49	.45	.43	.46	.53
360.0	.38	.34	.32	.38	.47
10.0	.27	.24	.22	.31	.42
20.0	.19	.16	.15	.27	.38
30.0	.12	.10	.10	.23	.34
40.0	.07	.06	.07	.20	.29

INSHORE DIRECTIONS

Offshore Direction (deg.)	Peak Period (s)				
	2.0	3.0	4.0	5.0	6.0
240.0	298	298	299	295	290
250.0	299	299	301	297	292
260.0	300	301	302	299	295
270.0	302	302	304	301	297
280.0	304	304	305	303	299
290.0	306	306	307	305	302
300.0	308	308	309	307	304
310.0	310	310	310	309	307
320.0	313	312	312	311	309
330.0	315	314	313	313	311
340.0	318	316	315	314	312
350.0	321	318	316	315	312
360.0	324	320	318	315	312
10.0	326	322	319	314	311
20.0	329	324	319	312	311
30.0	332	326	319	311	310
40.0	334	329	317	311	310

APPENDIX B

Wave Transformation Results

Inshore deep sea wave climates
at all sites, for waves generated
in Beagle Gulf.

INSHORE SEA WAVE CLIMATE

Location: Inshore Site 1, (post-development).
Wave Type: Sea waves generated within Beagle Gulf.
Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.82	.34	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.05	1.10	.41	.00
.2 - .4	1.20	1.54	.03	.07
.4 - .6	.00	.07	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.75	.00	.00	.00
.2 - .4	1.75	.92	1.47	.00
.4 - .6	.03	1.40	1.16	.14
.6 - .8	.00	.03	.55	.03
.8 - 1.0	.00	.00	.03	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	6.82	1.40	.17	.00
.2 - .4	.48	3.90	.48	.03
.4 - .6	.00	1.51	.62	.03
.6 - .8	.00	.00	.00	.03
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.57	2.57	.45	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Inshore Site 2 (post-development).
Wave Type: Sea waves generated in Beagle Gulf.
Date: Oct. 1981 to Sept. 1982.

The results presented are percentage occurrences.

Wave Direction: 290.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.00	.00	.14	.00
.2 - .4	.00	.00	.27	.00
.4 - .6	.00	.00	.03	.07
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.82	.72	.00	.00
.2 - .4	.00	1.95	.00	.00
.4 - .6	.00	.17	1.64	.00
.6 - .8	.00	.00	1.51	.14
.8 - 1.0	.00	.00	.07	.03

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.05	.00	.00	.00
.2 - .4	1.20	.55	.00	.00
.4 - .6	.00	1.68	.00	.03
.6 - .8	.00	.03	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.75	.00	.00	.00
.2 - .4	1.75	2.12	.38	.03
.4 - .6	.03	1.64	.31	.03
.6 - .8	.00	.03	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	6.82	1.85	.68	.00
.2 - .4	.48	1.92	.34	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.57	2.12	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Inshore site 3, (post-development).
 Wave Type: Sea waves generated within Beagle Gulf.
 Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.36	.82	.14	.00
.2 - .4	.00	.03	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.03	.00	.14	.00
.2 - .4	1.61	1.88	.68	.07
.4 - .6	.00	2.29	1.75	.00
.6 - .8	.00	.07	.75	.10
.8 - 1.0	.00	.00	.21	.10
1.0 - 1.2	.00	.00	.00	.03

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.68	.03	.21	.00
.2 - .4	1.95	3.70	.41	.00
.4 - .6	.00	1.20	.48	.03
.6 - .8	.00	.03	.14	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	6.99	3.25	.48	.00
.2 - .4	.00	.79	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.44	.17	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Inshore Site 4, (post-development).
Wave Type: Sea waves generated within Beagle Gulf.
Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.84	.82	.14	.00
.2 - .4	.41	1.34	.31	.03
.4 - .6	.00	.68	.00	.03
.6 - .8	.00	.00	.00	.10
.8 - 1.0	.00	.00	.00	.03

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.96	.03	.38	.00
.2 - .4	1.85	3.87	.41	.03
.4 - .6	.00	1.44	2.40	.00
.6 - .8	.00	.03	.82	.03
.8 - 1.0	.00	.00	.07	.07

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	5.00	2.74	.55	.00
.2 - .4	.82	1.27	.31	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.80	1.23	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.92	.48	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Inshore Site 4, (pre-development).
Wave Type: Sea waves generated within Beagle Gulf.
Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.84	.82	.14	.00
.2 - .4	.41	1.34	.31	.03
.4 - .6	.00	.68	.00	.03
.6 - .8	.00	.00	.00	.10
.8 - 1.0	.00	.00	.00	.03

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.16	.03	.48	.00
.2 - .4	1.64	3.87	.41	.03
.4 - .6	.00	1.44	2.26	.00
.6 - .8	.00	.03	.96	.03
.8 - 1.0	.00	.00	.07	.07

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	5.00	2.74	.51	.00
.2 - .4	.82	1.27	.24	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.80	1.23	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.92	.48	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Inshore local sea wave climates
at all sites, for waves generated
within Port Darwin.

INSHORE LOCAL SEA WAVE CLIMATE

Location: Inshore Site 1, (post-development).
 Wave Type: Sea waves generated within Port Darwin.
 Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 280.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	3.15	.03	.00
.2 - .4	.03	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.68	.00	.00
.2 - .4	2.26	2.64	.00
.4 - .6	.00	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.24	.00	.00
.2 - .4	.10	.41	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.38	.00	.00
.2 - .4	.45	3.66	.00
.4 - .6	.00	.24	.03
.6 - .8	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.03	.00	.00
.2 - .4	.72	4.28	.00
.4 - .6	.00	.10	.00
.6 - .8	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.38	.00	.00
.2 - .4	.27	1.85	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.03

Wave Direction: 340.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	2.88	.00	.00
.2 - .4	1.54	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 350.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	3.29	.00	.00
.2 - .4	.00	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

INSHORE LOCAL SEA WAVE CLIMATE

Location: Inshore Site 2 (post-development).
 Wave Type: Sea waves generated within Port Darwin.
 Date: Oct. 1981 to Sept. 1982.

The results presented are percentage occurrences.

Wave Direction: 260.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.21	.00	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.29	.00	.00	.00
.2 - .4	.68	.07	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.51	.00	.00	.00
.2 - .4	.24	2.36	.00	.00
.4 - .6	.00	.27	.00	.00
.6 - .8	.00	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.40	.00	.00	.00
.2 - .4	2.12	.38	.00	.00
.4 - .6	.00	.03	.00	.00
.6 - .8	.00	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.38	.00	.00	.00
.2 - .4	.45	2.33	.00	.00
.4 - .6	.00	1.58	.03	.00
.6 - .8	.00	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.00	.00	.00	.00
.2 - .4	.00	.72	.00	.00
.4 - .6	.00	.03	.00	.00
.6 - .8	.00	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.03	.00	.00	.00
.2 - .4	.72	3.56	.00	.00
.4 - .6	.00	.07	.00	.00
.6 - .8	.00	.00	.03	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.44	.10	.00	.00
.2 - .4	1.16	1.75	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	5.72	.00	.00	.00
.2 - .4	.03	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00

INSHORE LOCAL SEA WAVE CLIMATE

Location: Inshore Site 3, (post-development).
 Wave Type: Sea waves generated within Port Darwin.
 Date: Oct. 1981 to Sept. 1992.

The values given in the tables are percentage occurrences.

Wave Direction: 260.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.23	.00	.00
.2 - .4	.55	.03	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.75	.00	.00
.2 - .4	.65	.03	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.64	.00	.00
.2 - .4	2.29	2.36	.00
.4 - .6	.00	.27	.00
.6 - .8	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.24	.00	.00
.2 - .4	.10	.38	.00
.4 - .6	.00	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.31	.00	.00
.2 - .4	.51	2.33	.00
.4 - .6	.00	1.58	.00
.6 - .8	.00	.00	.03

Wave Direction: 310.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.31	.00	.00
.2 - .4	.24	.62	.00
.4 - .6	.00	.14	.00
.6 - .8	.00	.00	.03

Wave Direction: 320.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.72	.10	.00
.2 - .4	.48	3.73	.00
.4 - .6	.00	.92	.00
.6 - .8	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.40	.00	.00
.2 - .4	1.20	.68	.00
.4 - .6	.00	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	5.72	.00	.00
.2 - .4	.03	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

INSHORE LOCAL SEA WAVE CLIMATE

Location: Inshore Site 4, (post-development).
 Wave Type: Sea waves generated within Port Darwin.
 Date: Oct 1981 to Sept. 1982

The values given in the tables are percentage occurrences.

Wave Direction: 250.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.06	.00	.00
.2 - .4	.55	.00	.00
.4 - .6	.00	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 260.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.92	.00	.00
.2 - .4	.62	.00	.00
.4 - .6	.03	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.51	.00	.00
.2 - .4	.24	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.99	.00	.00
.2 - .4	2.19	1.20	.00
.4 - .6	.00	1.40	.00
.6 - .8	.00	.03	.00

Wave Direction: 230.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.24	.00	.00
.2 - .4	.10	2.02	.00
.4 - .6	.00	2.19	.00
.6 - .8	.00	.10	.03

Wave Direction: 300.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.31	.00	.00
.2 - .4	.51	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.31	.00	.00
.2 - .4	.24	4.18	.00
.4 - .6	.00	.21	.03
.6 - .8	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.23	.34	.00
.2 - .4	.62	1.51	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.85	.00	.00
.2 - .4	.10	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	2.47	.00	.00
.2 - .4	.00	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 350.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	3.23	.00	.00
.2 - .4	.00	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

INSHORE LOCAL SEA WAVE CLIMATE

Location: Inshore Site 4, (pre-development).
Wave type: Sea waves generated within Port Darwin.
Date: Oct. 1981 to Sept. 1982.

The values given in the tables are percentage occurrences.

Wave Direction: 250.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.05	.00	.00
.2 - .4	.55	.00	.00
.4 - .6	.00	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 260.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.92	.00	.00
.2 - .4	.62	.00	.00
.4 - .6	.03	.03	.00
.6 - .8	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.51	.00	.00
.2 - .4	.24	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.99	.00	.00
.2 - .4	2.19	1.20	.00
.4 - .6	.00	1.40	.00
.6 - .8	.00	.03	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.24	.00	.00
.2 - .4	.10	2.67	.00
.4 - .6	.00	1.54	.00
.6 - .8	.00	.10	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.31	.00	.00
.2 - .4	.51	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.03

Wave Direction: 310.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.03	.00	.00
.2 - .4	.72	4.18	.00
.4 - .6	.00	.21	.03
.6 - .8	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	.58	.68	.00
.2 - .4	.07	1.16	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	1.85	.00	.00
.2 - .4	.10	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	2.47	.00	.00
.2 - .4	.00	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Wave Direction: 350.0 deg.

Height (m)	Period (s)		
	2	3	4
.0 - .2	3.29	.00	.00
.2 - .4	.00	.00	.00
.4 - .6	.00	.00	.00
.6 - .8	.00	.00	.00

Inshore total sea wave climates
at all sites, obtained by
combining local sea and deep sea
wave climates.

INSHORE SEA WAVE CLIMATE

Location: Site 1 (post-development).
Wave Type: Combined sea wave climate.
Date: Oct. 1981 to Sept. 1982.

Wave period range: 2 s - 5 s.

The results presented are percentage occurrences.

Wave Direction: 280.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.53	.00	.00	.00
.2 - .4	.55	.03	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.27	.00	.00	.00
.2 - .4	1.78	.27	.00	.00
.4 - .6	.00	.65	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.10	.00	.00	.00
.2 - .4	.24	.03	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.21	.00	.00	.00
.2 - .4	1.10	.50	.00	.00
.4 - .6	.14	.34	.00	.00
.6 - .8	.00	.03	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.24	.00	.00	.00
.2 - .4	1.61	.21	.48	.00
.4 - .6	.62	1.64	1.34	.03
.6 - .8	.00	.58	1.13	.14
.8 - 1.0	.00	.00	.17	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.74	.86	.17	.00
.2 - .4	1.27	2.36	.41	.03
.4 - .6	.00	3.18	.62	.00
.6 - .8	.00	.45	.07	.03
.8 - 1.0	.00	.00	.03	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	4.21	2.57	.45	.00
.2 - .4	1.06	.00	.00	.00
.4 - .6	.07	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

Wave Direction: 350.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.51	.00	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Site 2 (post-development).
 Wave Type: Combined sea wave climate.
 Date: Oct. 1981 to Sept. 1982.

Wave period range: 2 s - 5 s.

The results presented are percentage occurrences.

Wave Direction: 260.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.21	.00	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.12	.00	.00	.00
.2 - .4	.51	.03	.00	.00
.4 - .6	.03	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.45	.00	.00	.00
.2 - .4	.27	.00	.00	.00
.4 - .6	.00	.89	.00	.00
.6 - .8	.00	.03	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.48	.00	.00	.00
.2 - .4	2.19	.10	.14	.00
.4 - .6	.21	.07	.14	.07
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.10	.00	.00	.00
.2 - .4	.41	.21	.00	.00
.4 - .6	.00	.41	.79	.00
.6 - .8	.00	.00	1.71	.03
.8 - 1.0	.00	.00	.65	.14
1.0 - 1.2	.00	.00	.03	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.10	.00	.00	.00
.2 - .4	.17	.03	.00	.00
.4 - .6	.38	1.68	.00	.00
.6 - .8	.00	.68	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.24	.00	.00	.00
.2 - .4	1.61	.07	.03	.03
.4 - .6	.55	2.74	.55	.03
.6 - .8	.00	.41	.07	.00
.8 - 1.0	.00	.00	.03	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.05	1.30	.68	.00
.2 - .4	2.09	2.43	.34	.00
.4 - .6	.07	.65	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	4.42	2.12	.00	.00
.2 - .4	.27	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Site 3 (post-development).
 Wave Type: Combined sea wave climate.
 Date: 01.1.1981 to Sept. 1982.

Wave period range: 2 s - 5 s.

The results presented are percentage occurrences.

Wave Direction: 260.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.23	.00	.00	.00
.2 - .4	.55	.03	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.51	.00	.00	.00
.2 - .4	.79	.00	.00	.00
.4 - .6	.03	.03	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.79	.00	.00	.00
.2 - .4	1.99	.00	.00	.00
.4 - .6	.21	.10	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.03	.00	.00	.00
.2 - .4	.31	.10	.00	.00
.4 - .6	.00	.17	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.10	.00	.00	.00
.2 - .4	.31	.14	.00	.00
.4 - .6	.10	.10	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.10	.00	.00	.00
.2 - .4	.55	.10	.00	.00
.4 - .6	.38	2.67	1.06	.03
.6 - .8	.00	.92	1.47	.03
.8 - 1.0	.00	.00	.65	.17
1.0 - 1.2	.00	.00	.03	.03
1.2 - 1.4	.00	.00	.03	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.38	.00	.21	.00
.2 - .4	1.47	1.30	.34	.00
.4 - .6	.21	3.36	.21	.03
.6 - .8	.00	.48	.41	.00
.8 - 1.0	.00	.03	.07	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	4.55	3.12	.48	.00
.2 - .4	1.13	1.13	.00	.00
.4 - .6	.03	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.29	.17	.00	.00
.2 - .4	.14	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Site 4 (post-development).
 Wave Type: Combined sea wave climate.
 Date: Oct. 1981 to Sept. 1982.

Wave period range: 2 s - 5 s.

The results presented are percentage occurrences.

Wave Direction: 250.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.06	.00	.00	.00
.2 - .4	.35	.00	.00	.00
.4 - .6	.00	.03	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 260.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.68	.00	.00	.00
.2 - .4	.75	.00	.00	.00
.4 - .6	.07	.03	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.34	.00	.00	.00
.2 - .4	.38	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.21	.00	.00	.00
.2 - .4	1.82	.00	.00	.00
.4 - .6	.00	.31	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.03	.00	.00	.00
.2 - .4	.31	.31	.00	.00
.4 - .6	.00	.41	.00	.00
.6 - .8	.00	.03	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.14	.00	.00	.00
.2 - .4	.51	.07	.00	.00
.4 - .6	.00	.92	.03	.03
.6 - .8	.00	.45	.00	.00
.8 - 1.0	.00	.00	.00	.14
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.27	.00	.38	.00
.2 - .4	.72	1.58	.00	.03
.4 - .6	.41	2.74	1.06	.00
.6 - .8	.00	1.23	1.88	.03
.8 - 1.0	.00	.00	.62	.03
1.0 - 1.2	.00	.00	.10	.03
1.2 - 1.4	.00	.00	.03	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.58	1.92	.51	.00
.2 - .4	1.16	2.02	.21	.00
.4 - .6	.00	.24	.14	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.84	1.23	.00	.00
.2 - .4	.55	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.40	.48	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 350.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.51	.00	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

INSHORE SEA WAVE CLIMATE

Location: Site 4 (pre-development).
Wave Type: Combined sea wave climate.
Date: Oct. 1981 to Sept. 1982.

Wave period range: 2 s - 5 s.

The results presented are percentage occurrences.

Wave Direction: 250.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.06	.00	.00	.00
.2 - .4	.55	.00	.00	.00
.4 - .6	.00	.03	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 260.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.68	.00	.00	.00
.2 - .4	.75	.00	.00	.00
.4 - .6	.07	.03	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 270.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.34	.00	.00	.00
.2 - .4	.38	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 280.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.21	.00	.00	.00
.2 - .4	1.82	.00	.00	.00
.4 - .6	.00	.31	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 290.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.03	.00	.00	.00
.2 - .4	.31	.31	.00	.00
.4 - .6	.00	.31	.00	.00
.6 - .8	.00	.03	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 300.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.14	.00	.00	.00
.2 - .4	.51	.07	.00	.00
.4 - .6	.00	.32	.03	.03
.6 - .8	.00	.45	.00	.00
.8 - 1.0	.00	.00	.00	.10
1.0 - 1.2	.00	.00	.00	.03
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 310.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.58	.00	.48	.00
.2 - .4	1.30	1.37	.00	.03
.4 - .6	.41	2.81	1.06	.00
.6 - .8	.00	1.23	1.35	.03
.8 - 1.0	.00	.00	.65	.03
1.0 - 1.2	.00	.00	.10	.03
1.2 - 1.4	.00	.00	.03	.00

Wave Direction: 320.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	1.27	1.92	.41	.00
.2 - .4	.86	1.99	.71	.00
.4 - .6	.00	.24	.14	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 330.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	3.84	1.23	.00	.00
.2 - .4	.55	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 340.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	2.40	.48	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

Wave Direction: 350.0 deg.

Height (m)	Period (s)			
	2	3	4	5
.0 - .2	.51	.00	.00	.00
.2 - .4	.00	.00	.00	.00
.4 - .6	.00	.00	.00	.00
.6 - .8	.00	.00	.00	.00
.8 - 1.0	.00	.00	.00	.00
1.0 - 1.2	.00	.00	.00	.00
1.2 - 1.4	.00	.00	.00	.00

APPENDIX B

Sediment Transport Results

SUMMARY OF SEDIMENT TRANSPORT CALCULATION

Location: Cullen Beach (post-development).
 Beach angle: 219 deg.
 Wave types: i) Deep sea: sea generated in Beagle Gulf.
 ii) Local sea: sea generated in Port Darwin.
 Period: Oct. 1981 to Sept. 1982.

The sediment transport was calculated for each three-hour period of the 12 months of hindcast wave conditions. The results obtained throughout the year for each of the individual offshore wave directions were summed to yield the following results:

Hindcast Offshore Wave Direction (deg.)	Sediment Transport due to Deep Sea (cubic metres)	Sediment Transport due to Local Sea (cubic metres)	Nett Sediment Transport (cubic metres)
230	0	3	3
240	1	22	23
260	7	115	122
270	1	36	37
280	109	707	816
290	1	70	71
300	-161	462	301
320	-81	-19	-100
330	-354	-192	-546
340	-114	-113	-227
350	-210	-194	-404
360	-34	-42	-76
10	-28	-17	-45
20	-17	0	-17
30	-2	0	-2
Pos. (northward) trans:	119	1415	1373
Neg. (southward) trans:	-1001	-577	-1417
Nett sediment transport:	-882	838	-44

SUMMARY OF SEDIMENT TRANSPORT CALCULATION

Location: Mindil Beach (pre-development).
 Beach angle: 214 deg.
 Wave types: i) Deep sea: sea generated in Beagle Gulf.
 ii) Local sea: sea generated in Port Darwin.
 Period: Oct. 1981 to Sept. 1982.

The sediment transport was calculated for each three-hour period of the 12 months of hindcast wave conditions. The results obtained throughout the year for each of the individual offshore wave directions were summed to yield the following results:

Hindcast Offshore Wave Direction (deg.)	Sediment Transport due to Deep Sea (cubic metres)	Sediment Transport due to Local Sea (cubic metres)	Nett Sediment Transport (cubic metres)
230	0	5	5
240	1	34	35
250	0	1	1
260	2	149	151
270	1	39	40
280	-25	762	737
290	-7	75	68
300	-438	497	59
320	-85	-17	-102
330	-228	-138	-366
340	-41	-67	-108
350	-88	-110	-198
360	-35	-29	-64
10	-17	-11	-28
20	-3	0	-3
30	-2	0	-2
Pos. (northward) trans:	4	1562	1096
Neg. (southward) trans:	-969	-372	-871
Nett sediment transport:	-965	1190	225

SUMMARY OF SEDIMENT TRANSPORT CALCULATION

Location: Mindil Beach (post-development).
 Beach angle: 214 deg.
 Wave types: i) Deep sea: sea generated in Beagle Gulf.
 ii) Local sea: sea generated in Port Darwin.
 Period: Oct. 1981 to Sept. 1982.

The sediment transport was calculated for each three-hour period of the 12 months of hindcast wave conditions. The results obtained throughout the year for each of the individual offshore wave directions were summed to yield the following results:

Hindcast Offshore Wave Direction (deg.)	Sediment Transport due to Deep Sea (cubic metres)	Sediment Transport due to Local Sea (cubic metres)	Nett Sediment Transport (cubic metres)
230	0	5	5
240	1	35	36
250	0	1	1
260	2	152	154
270	1	39	40
280	-29	762	733
290	-7	76	69
300	-426	508	82
320	-86	-19	-105
330	-232	-149	-381
340	-41	-72	-113
350	-88	-119	-207
360	-35	-28	-63
10	-18	-12	-30
20	-3	0	-3
30	-2	0	-2
Pos. (northward) trans:	4	1578	1120
Neg. (southward) trans:	-967	-399	-904
Nett sediment transport:	-963	1179	216