

WESTPORT PROJECT

DELTA HOLDINGS PTY LTD

Report and Recommendations
by the
Environmental Protection Authority

Environmental Protection Authority
Western Australia
Bulletin 281 May 1987

WESTPORT PROJECT
DELTA HOLDINGS PTY LTD

Report and Recommendations
by the
Environmental Protection Authority

Environmental Protection Authority
PERTH WESTERN AUSTRALIA

Bulletin No. 281

May 1987

ISBN 0 7309 1620 0
ISSN 0156-2983

CONTENTS

	Page
1. SUMMARY AND RECOMMENDATIONS	1
2. BACKGROUND	4
3. THE PROPOSAL	4
3.1 DESCRIPTION	4
3.2 ALTERNATIVES	5
3.3 BENEFITS AND DISBENEFITS	5
3.4 RESPONSIBILITIES	6
4. ENVIRONMENTAL IMPACTS.	6
4.1 SEDIMENT TRANSPORT/SHORELINE STABILITY	6
4.2 GROUNDWATER RESOURCE	7
4.3 HARBOUR WATER QUALITY.	8
4.4 COASTAL MANAGEMENT	10
4.5 SEAGRASS LOSS	11
4.6 EROSION.	11
4.7 NOISE AND TRAFFIC	11
5. ENVIRONMENTAL MANAGEMENT AND MONITORING	11
6. SUBMISSIONS RECEIVED	13
6.1 ABORIGINAL SITES	14
6.2 UNEXPLODED ORDNANCE	14
6.3 PLANNING ISSUES	14
6.3.1 LOSS OF ACCESS ALONG BEACH	14
6.3.2 MANAGEMENT FUNDING	14
6.3.3 DEVELOPMENT PROPOSAL DETAILS	14
7. CONCLUSIONS	14

APPENDICES

1. SUMMARY AND RECOMMENDATIONS

Westport is a proposal by Delta Holdings Pty Ltd (the proponent) to transform 262 ha of land into a major residential development focussed on an artificial waterbody. The project area partly fronts Warnbro Sound, 7 kms south of Rockingham (see Figure 1).

The project would be constructed in stages over the next 10-15 years. Stage 1, which was not included as a part of this proposal and has been implemented already, involved establishment of 163 dry lots in the northeast corner of the property. Stage 2 would involve establishment of the first 91 waterfront lots, which in turn would involve excavation of part of the waterways system (the harbour) and construction of the entrance channel to Warnbro Sound. Before construction of Stage 2 could commence, amendments to the Metropolitan Region Scheme and the Shire of Rockingham Town Planning Scheme, to allow for such a development, would be necessary.

Construction of further stages, which would include completion of the harbour and construction of related building lots, the marina and other facilities, would be undertaken as demand dictated.

An Environmental Review and Management Programme was prepared by the proponent under guidelines issued by the EPA and subsequently released for public review for a period of ten weeks and four days, ending on Wednesday, 8 April, 1987.

The EPA has assessed the environmental aspects of the project from the ERMP, public and Government agency comments on the ERMP, the proponent's response to those comments, and the Authority's own investigations including independent expert advice.

The Authority considers that the main potential environmental impact of the project would be deterioration of water quality in the harbour. However, it is of the opinion that measures can be taken to resolve this problem including redesign of the harbour basin and entrance channel. Other impacts associated with the project are considered by the Authority to be either acceptable or manageable.

RECOMMENDATION 1

The EPA recommends that the Westport project would be environmentally acceptable and could proceed, subject to:

- . the proponent's commitments in the ERMP (listed in Appendix D of this report); and
- . the EPA's Recommendations in this Assessment Report.

RECOMMENDATION 2

The EPA recommends that the legal Agreement to be negotiated for the project between the proponent, the State and the Shire of Rockingham should reflect the commitment by the proponent to bypass sand across the harbour entrance and renourish if necessary, sand lost from the system, from an external source. This commitment should include maintaining the harbour entrance to a nominated depth.

RECOMMENDATION 3

The EPA recommends that additional refinement and detailed design should be carried out for the proposed breakwater and sand bypass system. The objective should be the minimisation of potential coastal erosion effects as well as the objectives in Recommendation 7. The EPA further recommends that the redistribution of sand from either mechanical bypassing or derived from renourishment from external sources be undertaken in such a manner that will minimise any potential coastal erosion which may otherwise result from the project. This will involve a re-assessment of the implications for sediment movement and shoreline stability.

The results of the additional refinement and detailed design, plus the reassessment of consequential implications for sediment movement should be submitted to the EPA before construction.

RECOMMENDATION 4

The EPA recommends that the proponent should commence a groundwater monitoring programme which would enable it to assess the impacts of construction on groundwater. The programme should be commenced as soon as practicable. The objectives for monitoring should include:

- . establishing the existing groundwater regime of the locality within 750 m of the waterbody;
- . utilising the staging of construction to establish the manner by which groundwater in the locality changes as a result of construction; and
- . establishing the extent to which existing and future property owners' groundwater resource would be altered by project construction.

The results of the programme should be submitted to the EPA after 1 year.

RECOMMENDATION 5

The EPA recommends that the proponent should be obliged to either demonstrate, through the monitoring programme (RECOMMENDATION 4), that the project will not affect groundwater resources of existing private property owners (especially present and future owners of Stage 1) or guarantee groundwater supply to those affected. The proponent should consult the Water Authority of Western Australia for that Authority to determine the quantity of potable water that should be supplied to affected users. The objectives for this commitment should be that:

- . existing private property owners' groundwater resource rights should be protected;
- . the groundwater resource of State-owned land, including both coastal reserves and Port Kennedy, should be protected; and
- . groundwater rights should be protected in a legally-enforceable manner.

RECOMMENDATION 6

The EPA recommends that further refinement of harbour and entrance channel design (in conjunction with RECOMMENDATION 3) should be undertaken by the proponent in order to improve the flushing characteristics and consequential

water quality of the harbour to the satisfaction of the EPA and the Department of Marine and Harbours. The main objective for re-design should be to minimise flushing time for the harbour. The proponent should abide by the Guideilnes for Development of Canal Estates, 1984 in re-designing the harbour and entrance channel. As part of the res-design, the depths of the two main north-south canals should differ by approximately 0.5 m.

RECOMMENDATION 7

The EPA recommends that the proponent should set as objectives for water quality in the harbour, those criteria contained in Schedules 1 (Direct Contact Recreation) and 16 (Navigation and Shipping) of the EPA's water quality criteria (Department of Conservation and Environmental-Bulletin 103). Water quality monitoring for the project should include:

- . measurement of physical, biological and chemical parameters, within the harbour as well as a control outside the harbour, appropriate to meeting Schedules 1 and 16 of the water quality criteria. Details should be discussed in advance with the EPA and be based on guidelines presented in Appendix C of this Report;
- . management strategies developed for implementation in the event of criteria not being met, particularly in the case of algal blooms and accidental spillages;
- . contingency planning to include funding commitment and resources; and
- . monitoring and management having particular regard to nutrients, oil and fuel, wastes from boats, anti-fouling paints, rubbish and suspended solids.

RECOMMENDATION 8

The EPA recommends that, in the event that problems with water quality do arise in Stage 2 of the project, the proponent should re-assess harbour design criteria for future stages to make provision for engineering solutions to water quality problems including, but not confined to, widening the entrance channel, constructing a second entrance channel and pumping. These provisions should be taken into account before detailed design and construction phases commence.

RECOMMENDATION 9

The EPA recommends that approvals for further stages beyond Stage 2, as defined in Section 5.6.1 of the ERMP, should be made conditional upon the EPA being assured of the proponent's satisfactory performance in the environmental management of Stage 2.

RECOMMENDATION 10

The EPA recommends that a condition of approval should be preparation by the proponent of an environmental monitoring programme to the satisfaction of the EPA prior to commencement of construction.

Commitment by the proponent to implement the programme should be reflected in the Agreement being negotiated between the proponent, the State and the Shire of Rockingham.

The commitments made in the ERMP (listed in Appendix D) regarding establishing a monitoring programme, and Recommendations made in this Report regarding monitoring should be included in the programme.

The frequency of reporting on monitoring should be to the satisfaction of the EPA but should include at least the commitment to reporting on an annual basis for the first five years as well as immediate reporting of any unforeseen or extraordinary event that adversely affects environmental conditions within or adjacent to the project site arising as a result of the project.

The proponent should demonstrate how the monitoring results will affect management practices for present and future stages.

2. BACKGROUND

In August, 1984 the proponent, Delta Holdings Pty Ltd, submitted a Notice of Intent outlining a development proposal for an area of land approximately 7 kms south of Rockingham. At this stage, the proponent sought approval in principle for development of approximately 300 ha of urban-zoned land to produce:

- . 1000 waterfront lots
- . 1400 normal lots
- . marina for 400 boat pens
- . commercial sites.

Following presentation of a revised Notice of Intent to the EPA in January 1985, preparation by the proponent of an Environmental Review and Management Programme (ERMP) commenced. The ERMP was prepared under guidelines prepared by the EPA and released for public review for a period of ten weeks and four days, ending on 8 April 1987.

Following consideration of the public and Government agency submissions, the proponent's response to them and the EPA's own investigations, the Authority has prepared this Assessment Report.

3. THE PROPOSAL

3.1 DESCRIPTION

The Westport proposal envisages development of approximately 262 ha of land as an inland harbour-based project. The harbour would provide the focus for a public marina, boat launching ramps, commercial and retail outlets, service and infrastructure facilities and the ultimate development of some 1450 residential lots and 900 medium density residential sites staged over the next 10-15 years (see Figure 1).

The first stage has involved establishment of 163 dry lots in the northeast corner of the property. Stage 2 involves excavation of part of the harbour, construction of the entrance channel to Warnbro Sound and establishment of the first 91 waterfront lots. Before construction of Stage 2 could commence amendments to the Metropolitan Region Scheme and Shire of Rockingham Town Planning Scheme would be required. The former would result in designation of

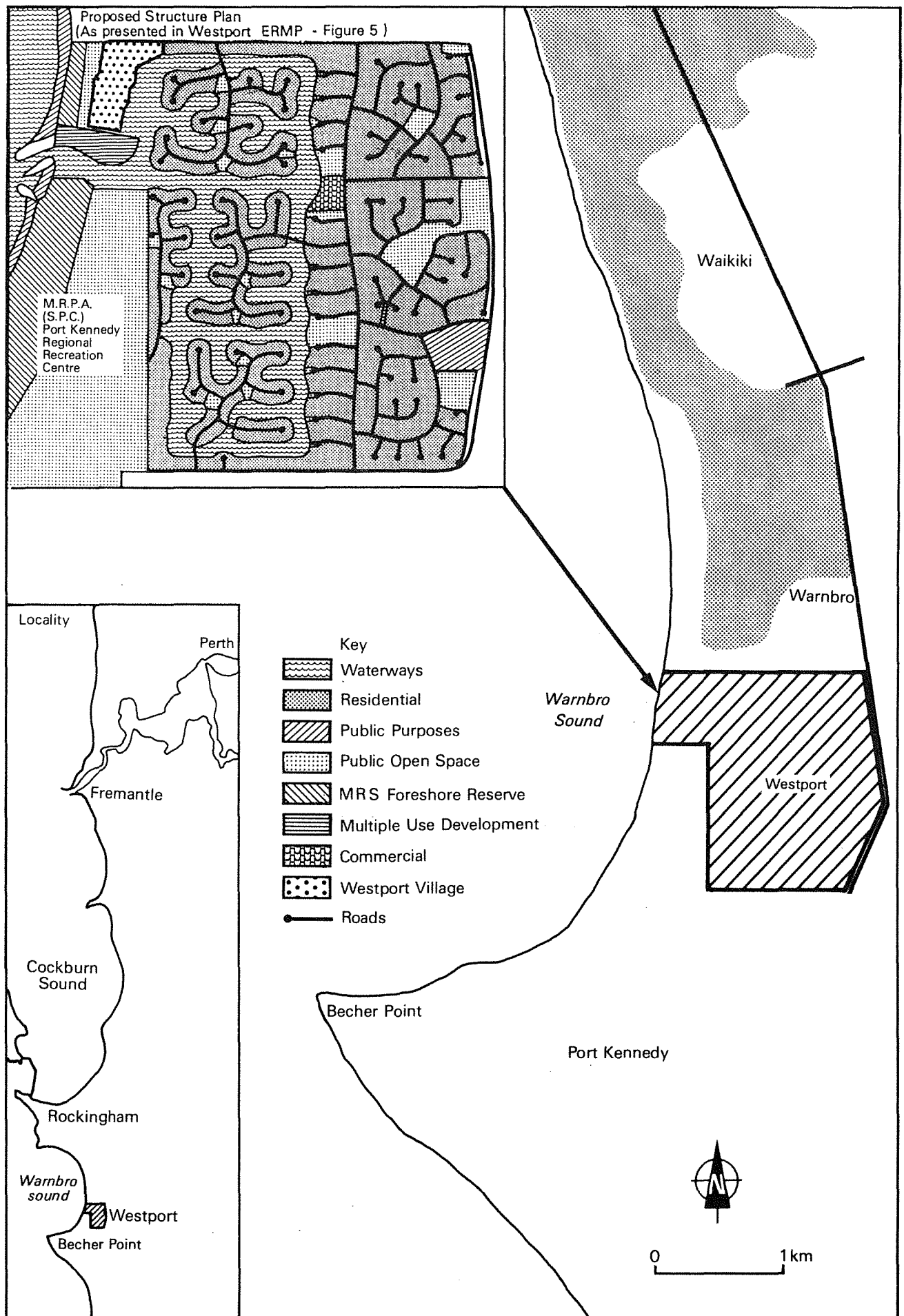


FIGURE 1 Westport Project - location

a waterways reservation over the area of land proposed for development, while the latter would result in designation of the area as a canal zone.

3.2 ALTERNATIVES

The proponent considered the likely attraction of the beaches between Cockburn Sound and Mandurah in selecting a suitable harbour development site. A range of criteria were used for evaluating alternative sites in this area. The selected site was preferred by the proponent because of its closeness to the development front, and in terms of its availability, zoning and technical criteria. Alternative designs were assessed with main emphases given to the local wind climate (to maximise internal circulation) and the presence of the adjacent proposed Port Kennedy Development site.

A "no build" option was not examined by the proponent because of the attributes and potential which it believes this site holds.

3.3 BENEFITS AND DISBENEFITS

The benefits of the proposal proceeding have been identified in the ERMP as:

- . an opportunity for local residents to live near, and have access to quiescent waters and Warnbro Sound;
- . an alternative residential landscape that contrasts with the otherwise flat Rockingham Plain;
- . protected mooring and public launching facilities for the boating community;
- . increased public access to the coast and waters of Warnbro Sound and the adjacent ocean;
- . an alternative destination for metropolitan boat owners to Rottnest;
- . tourist destination for residents of metropolitan Perth;
- . a management presence on the coastal dunes;
- . a new focus for water-oriented activities in the Rockingham area;
- . improved public access to an area which is presently undeveloped and largely inaccessible;
- . the potential to develop resort accommodation for country holiday makers who desire a waterfront site with access to supporting marina facilities.

The disbenefits of the proposal proceeding have been identified in the ERMP as:

- . increased noise and dust levels in the immediate area during construction;
- . increased recreational pressure on the fishing grounds in the area;

- . loss of approximately 1 ha of seagrass immediately adjacent to the breakwaters;
- . a possible minor decline in water quality in Warnbro Sound due to the presence of increased human activity and associated boating activity;
- . interruption of continuous access along the beach;
- . potential to disrupt local coastal processes which could lead to changes in shoreline position;
- . aquifer under 50 ha of SPC land at the north tip of Port Kennedy invaded by salt water.

3.4 RESPONSIBILITIES

In order to set out the respective responsibilities of the proponent, the State and the Shire of Rockingham, a legal Agreement is being negotiated between the parties. The EPA understands that it is not proposed to ratify the Agreement in Parliament. The EPA has not had an opportunity to provide comments on the draft Agreement.

4. ENVIRONMENTAL IMPACTS

4.1 SEDIMENT TRANSPORT/SHORELINE STABILITY

The ERMP states that the proposal may have the following potential impacts on sediment transport/shoreline stability:

- . erosion of beaches and dunes around Warnbro Sound;
- . loss of sediment from the littoral transport system into the Warnbro Sound basin, which may exacerbate erosion problems;
- . wind erosion associated with increased sand deposition adjacent to breakwaters and with recontouring of dunes following construction of breakwaters.

The EPA is cognisant that there are conflicting views on the existing sediment transport regime in Warnbro Sound and on likely future changes in sediment transport and shoreline stability in the vicinity of the project site which would result from the proposal proceeding.

Consequently, the EPA sought an independent review of this issue from Associate Professor Richard Silvester of the University of Western Australia. The Authority notes its conclusions, which support the contention in the ERMP that the breakwaters would not be likely to have a significant effect on the current shoreline of Warnbro Sound. Associate Professor Silvester's review is included as an appendix to this Report (Appendix A).

The EPA considers that, as there remains some risk to shoreline stability as a result of the proposal proceeding, the sediment transport system should be carefully monitored, and that certain breakwater design and management measures should be undertaken in order to maintain shoreline stability.

More specifically, the EPA considers that the breakwater design would need to provide sufficient sand storage facility, that any excess in net sand transport should be bypassed artificially to nourish the downdrift beach and that sand lost from the active beach/bar system either inland or offshore should be minimised.

The ERMP gives a commitment that sand bypassing will be undertaken and that sand import will occur as required. However, the Authority considers that this commitment should be reflected in the legal Agreement to be negotiated between the proponent, the State and the Shire of Rockingham as contained in Recommendation 2.

RECOMMENDATION 2

The EPA recommends that the legal Agreement to be negotiated for the project between the proponent, the State and the Shire of Rockingham should reflect the commitment by the proponent to bypass sand across the harbour entrance and renourish if necessary, sand lost from the system, from an external source. This commitment should include maintaining the harbour entrance to a nominated depth.

RECOMMENDATION 3

The EPA recommends that additional refinement and detailed design should be carried out for the proposed breakwaters and sand bypass system. The objective should be the minimisation of potential coastal erosion effects as well as the objectives in Recommendation 7. The EPA further recommends that the redistribution of sand from either mechanical bypassing or derived from renourishment from external sources be undertaken in such a manner which will minimise any potential coastal erosion which may otherwise result from the project. This will involve a re-assessment of the implications for sediment movement and shoreline stability.

The results of the additional refinement and detailed design, plus the re-assessment of consequential implications for sediment movement should be submitted to the EPA before construction.

The Authority notes the proponents commitment to monitor shoreline position following construction.

4.2 GROUNDWATER RESOURCE

The ERMP states that excavation of waterways and connection to the ocean would result in movement of the salt water interface to about 250m east of the eastern shore of the harbour and lowering of groundwater levels in areas surrounding the harbour.

The Authority considers that, while the impacts of the development on the groundwater system are generally appropriately addressed in the ERMP, there are areas of uncertainty and it is essential that an adequate monitoring system be established which will identify any undesirable impacts as soon as possible so that corrective or preventative action can be taken as necessary.

In the ERMP, the proponent makes a commitment to construct 12 observation bores into the Safety Bay aquifer and the upper part of the Rockingham aquifer, including slotting seven of these against the entire saturated section of the Safety Bay aquifer. However, advice received by the EPA suggests that this monitoring strategy should be modified. The Geological Survey of Western Australia would need to be consulted to determine the required modifications.

The ERMP recognises that the project would result in salinisation of the Safety Bay aquifer beneath a small portion of State Planning Commission land

at Port Kennedy and reduce groundwater availability to some extent outside the project site.

The EPA considers that the staging of construction of the harbour would provide a valuable means of determining the effect of previous stages so that further measures can be taken to minimise impacts on the groundwater regime.

RECOMMENDATION 4

The EPA recommends that the proponent should commence a groundwater monitoring programme which would enable it to assess the impacts of construction on groundwater. The programme should be commenced as soon as practicable. The objectives for monitoring should include:

- . establishing the existing groundwater regime for the locality within 750 m of the waterbody;
- . utilising the staging of construction to establish the manner by which groundwater in the locality changes as a result of construction; and
- . establishing the extent to which existing and future property owners' groundwater resource would be altered by project construction.

The results of the programme should be submitted to the EPA after one year.

RECOMMENDATION 5

The EPA recommends that the proponent be obliged to either demonstrate through the monitoring programme (Recommendation 4) that the project will not affect groundwater resources of existing private property (especially owners and future owners of Stage 1) or guarantee groundwater supply to those affected. The proponent should consult the Water Authority of Western Australia for that Authority to determine the quantity of potable water that should be supplied to affected users. The objectives for this commitment should be that:

- . existing private property owners' groundwater resource rights should be protected;
- . the groundwater resource of State-owned land, including both coastal reserves and Port Kennedy, should be protected; and
- . groundwater rights should be protected in a legally-enforceable manner.

4.3 HARBOUR WATER QUALITY

The EPA considers that the major potential environmental impact associated with the project would be deterioration of water quality within the harbour. As the Authority had not obtained conclusive evidence on water quality implications in the ERMP nor in the subsequent review period, it sought independent advice on this aspect from Dr John Hunter of Curtin University of Technology. As that advice forms the basis for the main conclusions on this proposal and for particular Recommendations in this Report, it is included as an appendix to this Report (Appendix B).

The EPA considers that flushing time and nutrient enrichment (and the consequent nuisance of algal blooms) are two main factors which together

determine the water quality regime of canal estates such as Westport. The Authority concurs with advice it has received that an appropriate approach to take in designing an artificial harbour basin should be to concentrate on flushing and exchange characteristics of the harbour. The rationale for this is that the lower the flushing time the lower the risk of algal blooms.

The EPA notes advice that the flushing time derived from tidal flushing as predicted in the ERMP (7 days) could be inadequate to prevent algal blooms, as a consequence of unforeseen nutrient loads to the harbour. The Authority considers that the proponent should set as an objective for flushing frequency of the harbour the time constant for algal growth, which typically is a few days.

The Authority understands that the harbour design could improve flushing time if the following modifications were made:

- . the two main north-south canals were dredged to different depths, the difference being in the vicinity of 0.5m; and
- . the exchange at the entrance was improved.

However, the Authority considers that the proponent should undertake additional investigations into this matter and report back to the EPA.

RECOMMENDATION 6

The EPA recommends that further refinement of harbour and entrance channel design (in conjunction with Recommendation 3) should be undertaken by the proponent in order to improve the flushing characteristics and consequential water quality of the harbour to the satisfaction of the EPA and the Department of Marine and Harbours. The main objective for redesign should be to minimise flushing time for the harbour. The proponent should abide by the Guidelines for Development of Canal Estates, 1984 in re-designing the harbour and entrance channel. As part of the re-design, the depths of the two main north-south canals should differ by approximately 0.5 m.

During construction the main impact on water quality would be from increased turbidity which should produce a short-term impact on marine biota. This is acceptable as a once-only effect. Also, connection of the various stages of the harbour should result in increased turbidity within the harbour.

During the operational phase there is potential for water quality problems to emerge in the harbour without proper management. The ERMP stated that the quality of water inside the harbour is difficult to predict. However, it nominated as an objective, maintenance of water quality to criteria contained in Schedules 2, 4, 5, 7(2) and 16 of the EPA's water quality criteria (Department of Conservation and Environment - Bulletin 103) which allow for:

- . harvesting of aquatic life (excluding molluscs) for food and non-edible uses;
- . passage of fish and other aquatic life;
- . maintenance of the Warnbro Sound aquatic ecosystem;

. navigation and shipping; and

to some extent criteria contained in Schedule 1 (Direct Contact Recreation).

Bathing in the harbour is likely to occur, particularly considering the proposed density of urban development around it. Hence, the EPA is concerned that the proponent has set as an objective maintenance of only some of the criteria for water quality under Schedule 1. The Authority considers that it would be more appropriate for the proponent to either achieve water quality criteria objectives for Schedules 1 (Direct Contact Recreation) and 16 (Navigation and Shipping) of the EPA's water quality criteria or provide management to ensure that no bathing occurs.

The ERMP makes a commitment to implement a water quality monitoring programme and to take specific action to alleviate any problems should they arise. However, the Authority questions the adequacy of silt/oil traps for filtering stormwater runoff into the harbour. Some form of detention basin and other filtering mechanisms may be necessary.

RECOMMENDATION 7

The EPA recommends that the proponent should set as objectives for water quality in the harbour, those criteria contained in Schedules 1 (Direct Contact Recreation) and 16 (Navigation and Shipping) of the EPA's water quality criteria (Department of Conservation and Environment - Bulletin 103). Water quality monitoring for the project should include:

- . measurement of physical, biological and chemical parameters, within the harbour as well a control outside the harbour, appropriate to meeting Schedules 1 and 16 of the water quality criteria. Details should be discussed in advance with the EPA and be based on guidelines in Appendix C of this Report;
- . management strategies developed for implementation in the event of criteria not being met, particularly in the case of algal blooms and accidental spillages;
- . contingency planning to include funding commitment and resources; and
- . monitoring and management having particular regard to nutrients, oil and fuel, wastes from boats, anti-fouling paints, rubbish and suspended solids.

RECOMMENDATION 8

The EPA recommends that, in the event that problems with water quality do arise in Stage 2 of the project, the proponent should reassess harbour design criteria for future stages to make provision for engineering solutions to water quality problems including, but not confined to, widening the entrance channel, constructing a second entrance channel and pumping. These provisions should be taken into account before detailed design and construction phases commence.

4.4 COASTAL MANAGEMENT

The ERMP states that during the construction phase the frontal dunes would be recontoured and revegetated. The proponent intends to transfer 125m of

foreshore land to the Shire of Rockingham as a foreshore reserve following rehabilitation and development. The EPA accepts this reserve width.

The issue of preparation of a coastal management plan has been raised and the Authority has asked the State Planning Commission to address the matter.

4.5 SEAGRASS LOSS

The ERMP states that construction of breakwaters is expected to result in direct destruction of approximately 1.5ha of seagrass, which represents less than 0.1% of the total seagrass meadow fringing the Warnbro Sound. Seasonal accretion and erosion pattern would result in alternative burying and scouring of the bottom, making recolonisation by seagrass unlikely. Redesign of the harbour entrance channel would result in further seagrass loss.

However, the EPA considers that the dimension of seagrass loss as result of the project is acceptable on a regional scale.

The proponent has made a commitment to monitor seagrass changes during construction and operation of the project.

4.6 EROSION

The project involves clearing of vegetation and major earthworks that have the potential to cause erosion. The proponent has made a commitment to seek advice relating to earthmoving works and stabilisation from the Commissioner for Soil Conservation. The specific requirements of the Commissioner for Soil Conservation would need to be met.

4.7 NOISE AND TRAFFIC

During the construction phase, earthmoving equipment, trucks and other vehicles would increase traffic and noise levels in the area.

Before any construction commences, the proponent would need to discuss with the Shire of Rockingham the question of noise levels and the hours of operation of equipment so that disturbance to residents in the locality may be minimised.

5. ENVIRONMENTAL MANAGEMENT AND MONITORING

The overall acceptability of a project like Westport will be influenced by:

- . the degree to which anticipated environmental impacts can be managed;
and
- . a demonstrated capacity for implementation of the necessary management initiatives.

As indicated in the preceding chapter, the impacts likely as a consequence of the proposal proceeding could generally be regarded as acceptable, subject to appropriate management.

Demonstration of the capacity for implementation of the required management initiatives would involve:

- . identification of the responsibilities of the respective management agencies and acceptance of those responsibilities;
- . definition of clear, legally-enforceable mechanisms to ensure implementation of the management measures;
- . identification of the resources required for management and clear commitments to allocation of those resources (including contingency funding);
- . initiation of a monitoring programme and incorporation of the results obtained in the management strategies implemented;
- . submission of periodic reports as specified to the appropriate authorities; and
- . implementation of all approved management conditions and commitments.

The EPA considers that, as far as environmental management is concerned, the project is essentially a private facility and that the user-pays philosophy should apply. The Authority also considers that approval for further stages of the project beyond Stage 2, as defined in Section 5.6.1 of the ERMP, should be made conditional upon the proponent's satisfactory performance in the environmental management of Stage 2.

The EPA considers it important that any unforeseen or extraordinary occurrence that adversely affects environmental conditions within or adjacent to the project site and which arises as a result of the project should be reported as soon as practicable after its occurrence.

RECOMMENDATION 9

The EPA recommends that approvals for further stages beyond Stage 2, as defined in Section 5.6.1 of the ERMP, should be made conditional upon the EPA being assured of the proponent's satisfactory performance in the environmental management of Stage 2.

RECOMMENDATION 10

The EPA recommends that, a condition of approval should be the preparation by the proponent of an environmental monitoring programme to the satisfaction of the EPA prior to commencement of construction.

Commitment by the proponent to implement the programme should be reflected in the Agreement being negotiated between the proponent, the State and the Shire of Rockingham.

The commitments made in the ERMP (listed in Appendix D) regarding establishing a monitoring programme, and Recommendations made in this Report regarding monitoring should be included in the programme.

The frequency of reporting on monitoring should be to the satisfaction of the EPA but should include at least the commitment to reporting on an annual basis for the first five years as well as immediate reporting of any unforeseen or extraordinary event that adversely affects environmental conditions within or adjacent to the project site arising as result of the project.

The proponent should demonstrate how the monitoring results will affect management practices for present and future stages.

The proponent has recognised that baseline monitoring work needs to commence prior to excavation of the harbour basin and connection of the harbour to the ocean.

Responsibility for implementing the monitoring programme and reporting regularly on results rests with the proponent. However, it would be appropriate for the proponent to liaise with relevant Government agencies including the EPA, the Department of Marine and Harbours, the State Planning Commission and the Shire of Rockingham on matters relating to implementation of the programme.

The Authority considers that monitoring in conjunction with the staging of construction of the project provides a valuable means of determining changes to the design, construction and management of future stages which would enhance environmental conditions.

The EPA notes the commitment by the proponent to report details of results of the programme on a regular basis to various Government agencies including the EPA and agrees with the suggestion by the proponent that the monitoring and management programme should be reviewed annually. At the end of the first five years following commencement of construction a report detailing a major review of the monitoring and management programme should be prepared and presented to the EPA. That review should draw on data collected and management undertaken during the full five year period.

The EPA considers that the legal Agreement to be negotiated between the proponent, the State and the Shire of Rockingham is an appropriate mechanism to ensure that environmental monitoring and management requirements are implemented, provided that it includes all commitments made by the proponent in the ERMP, and the Recommendations and other requirements included in this Assessment Report.

6. SUBMISSIONS RECEIVED

Public review of the project closed on 8 April 1987. A total of 32 submissions was received: 24 from the public and 8 from Government agencies. The Authority would like to record here its appreciation of all persons and organisations who made submissions.

The major issues raised in public and Government submissions are summarised in Appendix E. The proponent's response to major issues raised in submissions is presented in Appendix F.

The EPA has considered the issues raised in the submissions during its assessment of the project and, in many instances, the matters have been incorporated in the recommendations made (either directly or through the underlying rationale).

Several issues that were raised in submissions from Government agencies which are beyond the EPA's specific brief and which have not been dealt with elsewhere in this Assessment Report are presented below (Sections 6.1 - 6.3). The EPA is not making any judgement as to how the proponent should respond to these matters. Accordingly, they should be negotiated between the proponent and the relevant State and local Government agencies as indicated below.

6.1 ABORIGINAL SITES

No Aboriginal Sites have been registered from the project site. Reporting of any site discoveries to the Western Australian Museum's Department of Aboriginal Sites has been suggested. The provisions of the Aboriginal Heritage Act would need to be complied with.

6.2 UNEXPLODED ORDNANCE

The proposed Westport project development area covers the central part, known as the Primary Impact Area, of a former artillery range at Warnbro. A search for unexploded ordnance has been conducted in the former range area in accordance with guidelines agreed by Commonwealth and State Governments. Clearance of unexploded ordnance to a depth of 3m has been completed.

As excavation of the harbour basin to depths approaching 4m is proposed and as there is the possibility that further unexploded ordnance would be found during excavation and other works, a programme of progressive searching and clearing would need to be negotiated with the State Emergency Service and the Department of Defence.

6.3 PLANNING ISSUES

6.3.1 LOSS OF ACCESS ALONG BEACH

Loss of access along the Warnbro beachfront as a result of construction of the harbour entrance channel is a key issue. However, the EPA considers that this matter would best be resolved by negotiation between the proponent, the State Planning Commission and the Shire of Rockingham. The Authority has asked the State Planning Commission to address this issue.

6.3.2 MANAGEMENT FUNDING

Some concern has been expressed regarding proposals by the proponent to generate funds for management through the local authority's rating system. That matter would best be resolved by negotiation between the proponent, the State Planning Commission, the Department of Local Government and the Shire of Rockingham.

6.3.3 DEVELOPMENT PROPOSAL DETAILS

The ERMP indicates some details of development in terms of location, design and density which cannot be assumed to be acceptable even though the project has been found to be generally environmental acceptable. The proponent would need to liaise with the State Planning Commission and the Shire of Rockingham. State Planning Commission approval would need to be obtained for any works to be carried out on its land.

7. CONCLUSIONS

The Authority considers that the major potential environmental impact associated with the project would be deterioration of water quality within the harbour. However, it believes that this matter could be resolved by taking steps to redesign the harbour basin and entrance channel.

Other potential environmental impacts associated with the project are considered by the EPA to be either acceptable or manageable. Accordingly, the Authority has recommended that, as a condition of approval, monitoring

should be carried out by the proponent which covers such aspects as harbour water quality, sediment transport and groundwater, and that the proponent be committed to implementation of the monitoring programme through the legal Agreement being negotiated with the State and the Shire of Rockingham.

The EPA is of the view that the general community should be protected from having to meet the environmental costs of the project should the proponent default or the proposal proves uneconomical. This is consistent with similar projects such as the Secret Harbour Project and the Mindarie Keys Project.

The Authority has concluded that the project could proceed subject to the proponent implementing commitments made in the ERMP (listed in Appendix D) and the Recommendations in this Assessment Report.

ENVIRONMENTAL REVIEW
AND
MANAGEMENT PROGRAMME
FOR
WESTPORT, Vols I & II Nov. 1986
REVIEW OF FINDINGS

Submitted by

Associate Professor RICHARD SILVESTER

MAY 1987

ENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMME

FOR

WESTPORT, Vols I & II Nov. 1986

Submitted by

DELTA HOLDINGS PTY. LTD.

to the

ENVIRONMENTAL PROTECTION AUTHORITY

B.P. House, 1 Mount St, Perth 6000

REVIEW OF FINDINGS

Submitted by

Associate Professor RICHARD SILVESTER

Department of Civil Engineering

University of Western Australia

Nedlands, W.A. 6009

MAY 1987

TERM OF REFERENCE

In a letter form Dr R.A. Field, Director, Evaluation Division of the Environmental Protection Authority, dated April 14, with Ref 212/81 MK:lb, the following information was requested:

- the adequacy of the information presented in support of the conclusions drawn;
- the adequacy of assessment of the nature and scale of coastal processes and the sediment transport regime in Warnbro Sound;
- the adequacy of discussion, assessment and predictions of sediment transport and shoreline stability in the vicinity of the Westport site, based on the three approaches taken:
 - (1). qualitative assessment based on sediment transport model
 - (2). mathematical assessment based on wave hindcasting
 - (3). results of measurement at experimental groyne
- the analysis of likely impacts on coastal processes, sediment transport and shoreline stability arising from the project;
- any other matters which you feel may be relevant.

Where you disagree with the findings of the ERMP,
could you please briefly indicate why, and provide alternative estimates.

SYNOPSIS

In deriving a deepwater wave climate it seems preferable to use the Sea and Swell charts available, with data collected at sea over some 50 years, rather than hindcast waves from wind systems close to the coast over one year, as has been done for this report. Although such information is qualitative in respect to height the repetitive directions of waves is most important in assessment of sediment movement. When computing wave components in a region sheltered by reefs or islands the reflection and breaking of waves over submerged reefs must be accurately assessed, plus the direction and heights of diffracting waves passing through gaps or around extremities of the reefs or islands. On all these counts the present submission is distinctly lacking in accuracy.

In shoreline process the removal of the beach berm offshore during storms and its subsequent replacement by swell waves is paramount. The intensity of storm waves on any section of coast determines the size and location of the bar and the width of the berm. In the case of more sheltered beaches that are accreting, a platform will be constructed whose width varies with the size of the storm waves, which correlates with that of the beach berm. Where reefs exist the oblique reflection of persistent swell waves can transport large volumes along the coast without it approaching beaches leeward of them. In this report, long term changes in wave climate are invoked for historic changes in the coastline whereas these are probably due to collapses in sections of reef that have altered wave conditions in their lee. Conflicting views are expressed on the longshore drift around Becher Point and along the circular periphery of Warnbro Sound. Although an experimental groyne was employed to monitor longshore drift its existence for only 12 months provide a distorted view, due to the large fluctuations that can occur annually. The use of calcium carbonate content of sand to ascertain long-term transport rates has too many variables to achieve this goal. Blown sand has had and will continue to have some influence on the sediment budget. The need to predict and include changes over 100's of years is both impractical and unwarranted.

Changes in the coastal periphery in the Warnbro Sound area have been substantial over the past 6000 years but has been minimal for the last 10 or so decades. The greatest changes, and those likely in the future, are due to collapse in sections of reef, which could alter the wave climate both within the Sound and south of Becher Point. However, the viewpoint expressed in the submission that growth and change in the present

shoreline can be expected is very questionable. Local variations in beach lines can be expected at Becher Point and the Safety Bay area but these have no connection with transport along the main body of Warnbro Sound. A comparison of the Sound with Jurien Bay has many deficiencies. The influence of the Westport northern breakwater in deflecting sand over the platform could be minimised, as also the possible scouring along its length by swell waves arriving at it obliquely.

Wave diffraction within Warnbro Sound has been discounted by all consultants whereas the Reviewer believes it to be paramount in the historic shaping of the shoreline and in the present shoreline processes. It explains the paucity in longshore transport due to the normal approach of all major deepwater waves, whilst waves generated within the Sound can effect annual movements in both directions, these being minimal. The distribution of heights of diffracted storm waves from various directions and their influence on platform and beach berm widths points to the predominance of such waves from the W to SW directions.

In summary the Report is lacking in wave climate assessment, examination of the shoreline process involved and the static nature of the current shoreline. The effect of the Westport development will be minimal for reasons other than those expressed.

TABLE OF CONTENTS

	Page
TERM OF REFERENCE	2
SYNOPSIS	3
TABLE OF CONTENTS	5
LIST OF FIGURES	6
LIST OF TABLES	7
 1	
INTRODUCTION	8
1.1 Wave Climate, 8	
1.2 Shoreline Processes, 12	
1.3 Longshore Transport, 15	
1.4 Limestone Reefs, 18	
1.5 Cuspate Forelands, 19	
1.6 Wave Diffraction, 21	
 2	
APPLICATIONS TO WARNBRO SOUND	23
2.1 Wave Climate, 23	
2.2 Shoreline Processes, 26	
2.3 Longshore Transport, 26	
2.4 Limestone Reefs, 27	
2.5 Cuspate Forelands, 27	
2.6 Wave Transmission Through Reef, 28	
 3	
THE ERMP REPORT	32
3.1 Wave Climate, 32	
3.2 Longshore Transport, 37	
3.3 Coastal Periphery Changes, 42	
3.4 Influence of Breakwaters, 49	
 4	
CANAL SYSTEM	51
4.1 Set-Up due to Winds, 51	
4.2 Sand Movement, 52	
 5	
REFERENCES	53

LIST OF FIGURES

<u>Figure</u>	<u>Page</u>
1 Plan of Warnbro Sound from a recent hydrographic survey published by Harbour and Marine Department of W.A.	11
2 Hydraulic flow pattern for A : swell conditions and B : storm conditions.	13
3 Storm beach profile showing offshore bar.	14
4 Shoreline processes in forming a spit.	17
5 Progressive elongation and rounding of a natural spit.	17
6 Wave propagation in shallow zone of an island or reef structure.	19
7 Wave patterns within a gap of breakwater or reef.	20
8 Beach formation in the lee of offshore breakwaters.	21
9 Definition sketch of waves entering a breakwater gap.	22
10 Parameters of wave diffraction through a breakwater gap.	22
11 Variables in wave transmission over a submerged reef.	29
12 Progressive development of Becher Point.	46
13 Wave pattern assumed by Searle (5) inside a reef gap.	47
14 Plan of canals showing possible zones of erosion and accretion.	52

LIST OF TABLES

<u>Table</u>	<u>Page</u>
I Average number of storms over 15 years	9
II Percentage average winds based upon $U^4 \propto H^2$ for fully arisen sea conditions	9
III Percentages of average Sea and Swell	10
IV Energies (H^2T^2) of waves generated within Warnbro Sound	25
V Diffraction coefficient K at various angles α from centreline of entering wave orthogonals	28
VI Maximum values of h/L_0 to produce wave breaking over a reef	29
VII Reflection, transmission and energy loss coefficients over a submerged reef	30
VIII Computed coefficients and directions by RB for waves arriving at the Westport site	36

INTRODUCTION

Before a study of longshore drift can be made on any segment of coast it is first necessary to determine the wave climate for the area. This comprises locally generated waves by winds generally considered within a square of 5° latitude and longitude, plus swell arriving within the same area of ocean. To this should be added information on the general paths followed by cyclones, be they tropical or extra tropical in character. Where the section of coast is partially protected by offshore islands or reefs these deepwater waves may be diffracted and so reduced in height before arriving at the beach. Within such confines locally generated waves may still play their part without such diffraction. Although more modest in energy due to the shorter fetches they can arrive with very little refraction and hence generate significant longshore currents within the narrow band of the surf zone.

The shoreline processes comprise two significant sets of waves, those of storm character and those of swell from distant generating areas. Storm waves arrive over a wide fan of directions whereas swell has a persistent direction, since storm waves in any ocean are repetitive from one decade to another. It is direction of swell waves, particularly in the weeks just after a storm, that dictates the direction of nett sediment movement along the coast.

The formation of limestone on a coast can play a significant part in the formation of beaches between these features which become headlands or offshore reefs. The longshore transport of sediment is interrupted thus forming cells between which material may or may not migrate.

Where an island or offshore reef occurs on a coast the waves are diffracted behind them which then proceed into the shadow zone from both ends. The concentric circles of wave crests centred on these extremities force sediment into the centre line axis of the island or reef where a shoal is developed which may be accompanied by a protrusion of the beach line. Where this does not reach the island or reef structure it is called a "cusplate foreland" but where it does the feature is termed a "tombolo". These can be observed the world over and are particularly significant along the coast under study.

1.1 Wave Climate

The Reviewer (1) has made a detailed study of the ocean waves around the coastlines of Australia, having divided it into segments of 5° latitude or longitude, equivalent to shoreline lengths of about 550 kms. One such section covers the coast

from Cape Leeuwin to north of Perth, for which the following data were gathered for deep water wave conditions.

Table I Average number of storms over 15 years

Summer	22
Autumn	34
Winter	42
Spring	22
TOTAL	120
Annual	8

It is seen from Table I that on average 8 storms arrived on the coast each year which can of course fluctuated from 4 to 12. As will be seen later, these can make the annual longshore drift vary by some 300% as the bulk of it travels just after each cyclone sequence.

The local wind conditions can generate waves both in the open ocean and in enclosed waters behind islands and reefs. Those in the winter and spring will add to the effect of the swell during those periods in influencing the direction of longshore drift. As seen in Table II these are concentrated in W, SW, and S directions, or littoral drift towards the north. The cyclonic winds are equally maxima in these three directions.

Table II Percentage average winds based upon $U^4 \propto H^2$
for fully arisen sea conditions

Dir.	Average Winds					Cyclonic Conditions				
	Sum	Aut	Win	Spr	Ann.	Sum	Aut	Win	Spr	Ann.
N	1	4	8	3	4	0	0	1	0	2
NW	2	7	15	10	8	0	1	5	2	8
W	7	13	22	19	15	1	3	13	7	24
SW	22	16	19	24	20	5	3	9	6	22
S	34	20	9	21	21	15	5	1	5	25

Note: Total annual values do not equal 100% due to the omission of landward directional components

The average sea as recorded by ships masters as in Table III is similarly concentrated from W, SW and S. The swell from the cyclones passing from W to E in the 40° to 60° latitudes across the southern Indian Ocean as in Table III are mainly from the SW quadrant for low, medium and high conditions. Both average seas and swell from the N and NW are minimal.

Table III Percentages of average Sea and Swell

Height Group	Dir.	Average Sea					Swell				
		Sum	Aut	Win	Spr	Ann.	Sum	Aut	Win	Spr	Ann.
Low	N	-	-	-	-	-	-	-	-	-	-
	NW	-	2	4	-	2	-	-	1	-	-
	W	13	6	5	4	7	-	7	8	3	5
	SW	1	2	8	8	5	9	17	7	11	11
	S	11	7	3	16	9	7	5	-	7	5
Med.	N	-	-	4	-	1	-	-	-	-	-
	NW	-	-	11	4	4	-	-	1	-	-
	W	-	6	14	10	8	3	7	25	7	11
	SW	16	14	11	14	14	21	19	10	13	16
	S	22	12	-	13	12	16	8	3	3	9
High	N	-	-	-	-	-	-	-	-	-	-
	NW	-	3	2	-	1	-	-	3	-	1
	W	-	1	5	4	3	3	5	24	11	11
	SW	1	-	2	6	2	12	12	19	24	17
	S	6	2	-	3	3	29	24	-	10	11

Thus the preponderance of waves on this section of coast is from the SW quadrant which results in northerly drift of sediment on the open coast. This direction of nett movement must change in sheltered regions such as Cockburn Sound where waves from the NW quadrant and waves diffracted SE by Garden Island make for a nett southerly drift.

The deepwater waves seaward of the reef fronting Warnbro Sound will be reflected and broken over the structure, be they swell or Sea, which will be breaking already when it arrives at this steep walled structure. The only wave energy entering the Sound is transmitted through openings in the reef as illustrated in Figure 1, where the reef is picked out in thick lines and the relevant openings displayed by parallel lines. It is seen that waves from the NW can enter gaps both at the centre of the Sound (with width of 625 m) and at the northern tip (with width of 440 m). Westerly waves have three entrances of 375, 187 and 150 m width whilst those from SW have two openings of

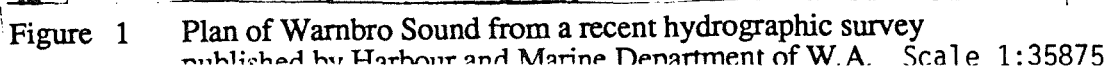


Figure 1 Plan of Warnbro Sound from a recent hydrographic survey published by Harbour and Marine Department of W.A. Scale 1:35875

total width 450 m.

These waves concentrate some 850 m inside the main gaps near the centreline of Warnbro Sound and proceed to diffract or spread their energy, by way of crests in concentric circles. Orthogonals have been drawn normal to the coastline at A, B, C, whose equal lengths from the beach to the point of diffraction are denoted by the circles. Thus all these deepwater waves arrive normal to the Warnbro Sound periphery, which implies they do not have any longshore components of energy when breaking. Thus they cannot produce any longshore drift, so that this coast is in static equilibrium.

The local winds blowing across the Sound are oriented in various directions and can therefore generate a longshore littoral current. They will not be fully arisen seas due to the very limited fetches within the Sound and probably also due to the limited duration or time over which they blow. However the fetch will be the main controlling factor.

1.2 Shoreline Processes

As swell waves approach a shoreline they decrease in length and rise in height until they become unstable and break, after which they proceed to the beach as a bore. Prior to this the orbital motions at the bed, which are rectilinear horizontal oscillations, disturb the bed and place sand particles in pseudo suspension. These are carried forward or towards the shore by the net movement each wave cycle known as "mass transport" due to the waves. This increases as shallower depths are reached and are maximum at and after breaking. Thus in the surf zone much material is being carried towards the beach. This only occurs whilst a surplus of sand is available to be so transported. The bed steepens towards the beach face so that gravity plays its part in constructing an equilibrium profile for the swell waves existing.

As the sediment-laden swash travels up the beach face the water percolates through it and soaks down to some distance below the surface, at or slightly above the mean sea level (MSL) (see Figure 2a). This occurs whilst there is a reasonable time between each wave, as exemplified by swell of periods from 7 to 14 seconds. The downrush from these waves is small due to the prior percolation, so that little sand is moved down the beach face. Thus the bulk of the material carried in the uprush is left stranded on the beach, up to the height of the uprush of the waves. For an open coast this results in a beach berm 1.5 to 2.0 m above the MSL, but on a more protected beach may be only 1.0 to 1.5 m above it, due to the smaller incident wave height.

Thus it can be accepted that swell waves accrete the beach until the offshore profile is such to balance the shoreward mass transport and gravity acting seawards. There may

be a slight mound formed in this otherwise parabolic curve due to the modest hydraulic jump formed as the downrush meets the next wave trough, but this is not significant.

When storm waves arrive, with many components of varying length and increasing height, a crest is arriving at the beach face almost every second. This soon saturates the slope which increases the volume of backrush which drags some materials down (see Figure 2b). The surfeit of groundwater must return to the sea which does so in a rising condition where the large hydraulic jump is forming. This upward flow causes a quick-sand effects which helps in the suspension of material which removes sand from the toe of the beach face. This results in slumping and a steeper slope of the beach face. This provides greater reflection for the storm waves, so forming partial standing waves. The berm is quickly removed by this steep slope receding across it, which is effected in a matter of hours.

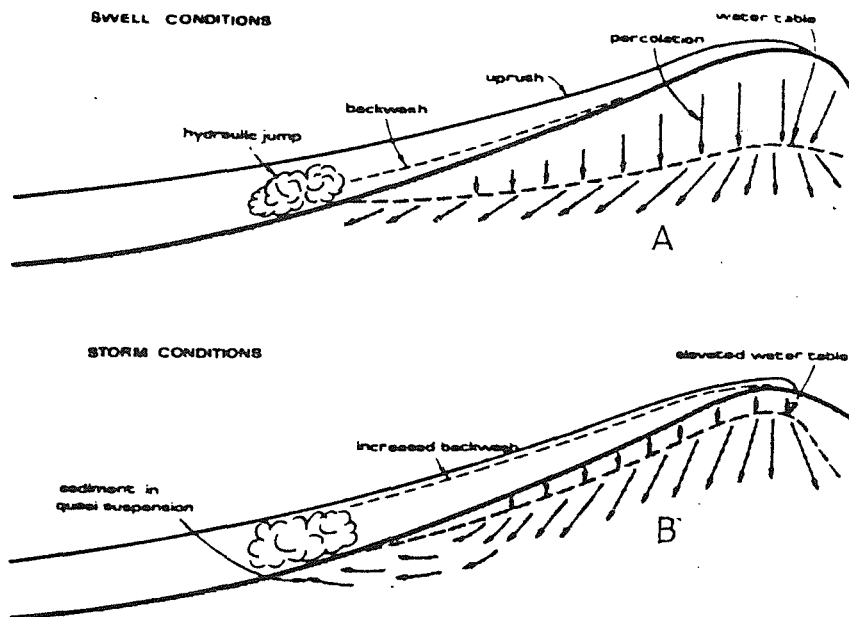


Figure 2 Hydraulic flow pattern for A : swell conditions and B : storm conditions.

The excess water, thrown onto the beach and returning to the sea via the ground water, plus turbulence from the jump, moves seawards. Because of its greater density, due to its sediment load, it travels at seabed level, aided by the strong shoreward current at the surface caused by shear of the strong wind accompanying the storm. As deeper water is reached this density current is reduced in velocity so causing it to drop its load. A mound or bar is formed offshore whose position can be dictated by the partial standing wave, previously alluded to, when zero water oscillation occurs at the antinode, where the incident and reflected waves make the greatest height. The distance from the

reflecting wall, which is the slumping beach face that changes position as the berm is removed, is dictated by the period of the largest waves in the spectrum. It occurs at a quarter wavelength of these shallow water waves.

Sand is removed from the beach and transferred to the bar until its height is sufficient, or the depth above is reduced sufficiently, for incoming storm waves to break over it. At this stage erosion ceases (see Figure 3). It is seen that this is Nature's way of defending the coast and is beautiful to behold. It involves the transportation of hundreds of tons of soil in very quick time to construct this protective offshore bar which runs parallel to the beach. The breaking of waves is aided by the contra current as the excess water forced over the bar returns to the sea over it. The first storm of winter exerts the greatest change in the beach condition, changing the full beach profile built by swell to a negligible width with an equal volume of material placed offshore. This can be envisaged as the sand being "put into circulation" where the waves can work on it. Whilst it is in the berm the waves can only disturb that segment within the surf zone, which is very narrow under swell conditions; whereas, in the storm profile the surf zone is much wider. A second storm might demand more beach if it is accompanied by a storm surge (build up water level due to shear force of the wind) or higher tide. Also if it is of longer duration the continuing swell waves still reaching the retreated steep beach face can nibble more material and fill the swale between the bar and the beach, so demanding more beach and so causing greater erosion.

As soon as the swell arrives after the storm it breaks over the bar and due to its mass transport effect sweeps the material back to shore. Refurbishing of the beach is swift at first, taking only a day or two to have its width back to half its previous width. However, it may take 2 to 3 weeks for the bar to be completely transferred back, since removal is slowed as the bar is lowered and the original swell built profile is reached. If a second storm arrives during this process the full bar is quickly reformed and its protection afforded to the beach.

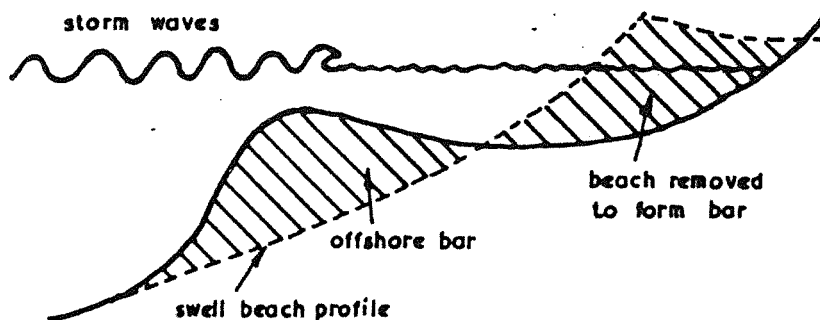


Figure 3 Storm beach profile showing offshore bar.

As the sand is dried out on the berm face winds can blow it landwards. Where vegetation grows at the back of the berm it reduces the wind velocity at the surface and hence a dune begins to form. As it grows so does the vegetation until the height of the dune itself impedes horizontal movement of sand. Any seeds that may have fallen on the beach will be removed offshore with the sand during a storm and will not return as they are light in weight and are continually moved seawards like the fine grains of sand which are sorted offshore. Thus the vegetation line can be accepted as the limit where seeds have remained long enough, two years say, to take root and provide plant growth. This shows the limit of demand for bar protection over a period of a year or so. At less frequent intervals a stronger than normal storm may occur, accompanied by higher water levels, when this segment of berm or foredune is also demanded.

1.3 Longshore Transport

Should the swell waves, that return the bar to the beach, arrive normal to the coast, they will return this material directly back to where it came. No net erosion will thus occur and the waterline remains steady. If the swell waves arrive obliquely they will not only move sand towards the beach but also along it. If the volume removed from any segment of coast is replaced by an equal volume from upcoast, the beach may return to its former waterline and can be considered in "dynamic equilibrium". If, however, the supply of sediment is less than that removed the beach suffers longer-term erosion. This only takes place when the swell waves arrive obliquely to the coast and hence this condition can only provide the long-term erosion that is the continual problem to coastal managers.

There are many causes for fluctuations in sediment supply on any coast, some of longer term than others. There have been periods over geologic time when a surfeit of sand has been available from rivers, which supply the bulk of longshore drift. In the past rivers have been able to flood and so supply large volumes of material to the coast, but in historic time they have been harnessed for drinking water and flood mitigation, so reducing their capacity to deliver sand. The coast previously built out is now under attack by the continual longshore energy of obliquely arriving swell. Also man has exerted other influences directly on the coast by constructing structures which intercept this littoral drift such as groynes and breakwaters. Another development of much greater influence is the dredging of deep channels from ports to the open sea. Sediment caught in them is dredged and the spoil dumped offshore for convenience. These long channels

therefore act like an equivalent structure built over the same length. The offshore area receives no new material and hence is deepened, the offshore bed is steepened and so more material is demanded for the protective offshore bar. Much of this is not returned to the beach as Nature needs to maintain the previous profile, shoreline recession is the result.

As noted already, the movement of sediment from the bar is swift at first, reducing as this mound is reduced in size. The longshore transport accompanying this shoreward action also fluctuates greatly, being optimum just after a storm and reducing to negligible proportions as the swell-built profile is reformed. This aspect of littoral drift is not taken into account in formulae and calculations made of this phenomenon, which generally assume a uniform slope offshore, a fixed size of sediment and some average characteristics of swell waves (including direction) which is not indicative of the actual conditions. It could be shown that the sorting of sand, both in forming the bar and its replacement on the beach, will cause a change in sediment size during these pulses of littoral drift. Finer material is moved first and for longer distances downcoast with coarse grains remaining almost in the same position. It is the swell directly after a storm, say for a 2 or 3 weeks period, that dictates the direction and total rate of transport. It can also be accepted that the number of storms in any year will determine the average littoral drift, not the average swell height and direction.

When there is a surfeit of sand and a sharp change in direction of the shoreline, it will form a spit parallel to the incoming swell waves. As seen in Figure 4, these oblique swell waves are refracted greatly at the end of a spit and hence cause a negative littoral current. At this transition of longshore and offshore current sand is deposited, so lengthening the spit. The fast growth of the spit occurs during the 2 to 3 weeks when the bar is being returned to the beach. As depicted in Figure 5, the continual swell during the period of little drift will result in the spit having its tip eroded and turned inwards. When the next pulse occurs the spit is lengthened and so the process continues.

Along coasts where sand has been available in large volumes in past geologic ages these "barrier beaches", as they are called, have formed on long lengths of shoreline so enclosing large bodies of water. Sometimes, with excessive periods of calmer weather these spits have been sculptured to attach themselves to the mainland to form elongated lagoons. Good examples of this are displayed south of Mandurah. Other examples could be supplied world wide, the best known being the barrier beaches down much of the east coast of the United States and the Gulf of Mexico.

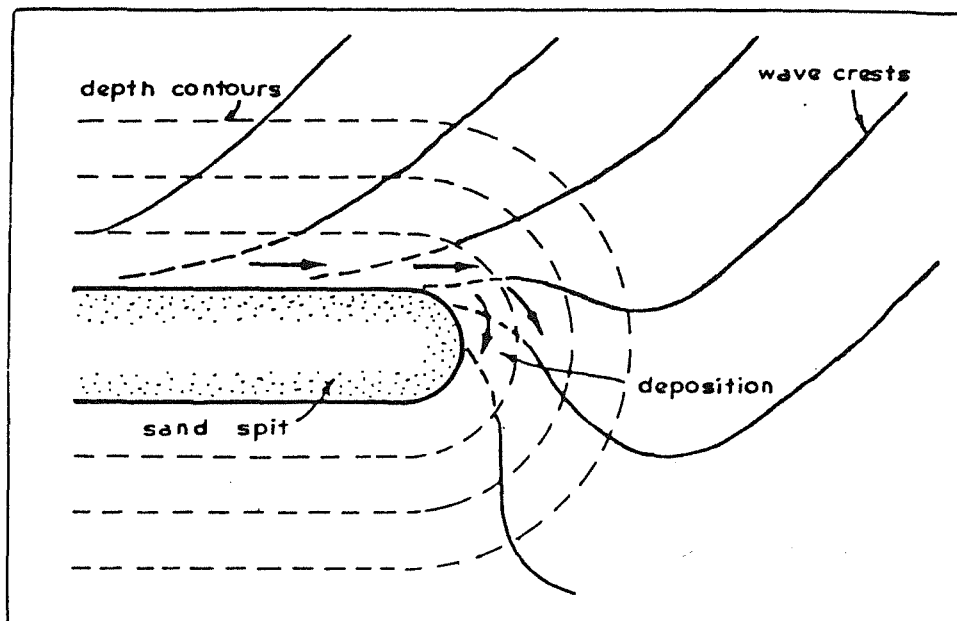


Figure 4 Shoreline processes in forming a spit.

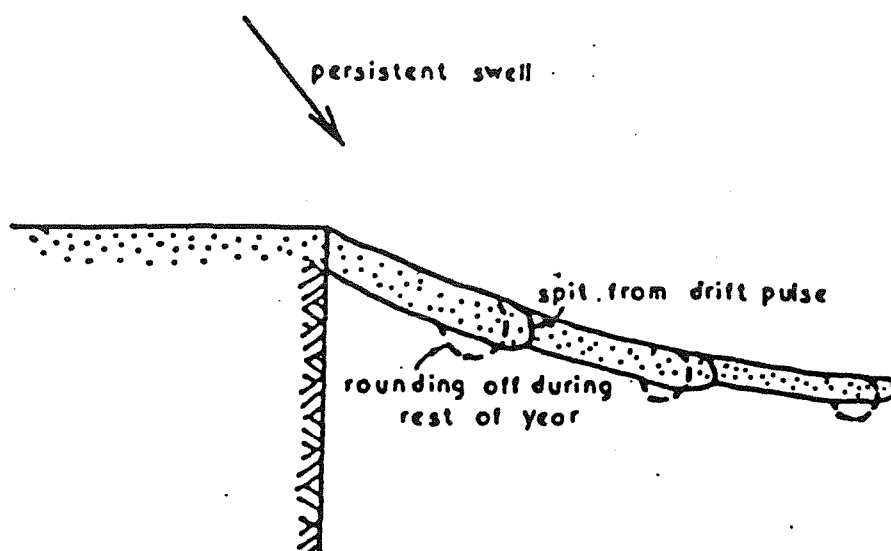


Figure 5 Progressive elongation and rounding of a natural spit.

1.4 Limestone Reefs

On any coast, where sand has accumulated in the form of high dunes and hot weather has existed to periodically dry out the whole mass of sediment, processes occur that result in the formation of limestone. When sand has been slowly moved along the coast, out to sea and back again at least once a year, it can accumulate calcium carbonate on its grains. Particularly is this so in warm waters, such as those existing on the Western Australian coast. The percentage of this to the total content of the sediment can reach 90% or higher. When this is available in a high dune the fresh water percolating through it from rain dissolves this calcium carbonate and carries it down to lower levels. When drying takes place in the hotter summer it is reprecipitated and cements the granules of quartz and other materials together to form limestone. With the repetition of this over hundreds or thousands of years the limestone can become well cemented. As this limewater travels along its subterranean water courses the limestone is formed as large horizontal massives. Depending upon the location of prior cementation the concentration of lime water and subsequent cementation can vary tremendously, making for a great variety in strength and ability to withstand water motion.

If the barrier beaches, alluded to in the previous section, comprised such large dunes they could in later geologic time be eroded away leaving the limestone to withstand the impact of the waves. This erosion is aided by the reflective nature of these almost vertical walls of stone, resulting in deep scour on the seaward side of these protuberances from the bed, which may penetrate the water surface to form inlands or act as submerged reefs. Even those that were formed above the sea surface will be attacked more vigorously at this level and hence collapse down to just below it. In this condition they can last much longer. However, the continual action of storm waves and swell can remove erodable material at their base and so cause slumping and disappearance of the reef as a protective structure. In zones of weaker limestone wearing and collapsing can take place more readily so causing complete breaks in the reef. Even so the limestone at lower depths will receive less impact from the waves and so remain as a more modest protrusion from the bed.

The presence of such offshore reefs can effect substantial longshore drift without sediment reaching the shore. The oblique reflection of either swell, which is more persistent, and storm waves, which are less frequent but more fierce, can readily transport material at large depth due to the very complex orbital motions of the water particles. The fact that it cannot be seen in motion does not mean that this massive transport is not occurring.

1.5 Cusped Forelands

When sediment is moving along a mainland by oblique swell the presence of an island or reef offshore intercepts these waves causing them to diffract or twist into the leeward zone (see Figure 6). This reduced zone of water motion, caused by the reduction in wave height, causes sediment to be deposited. A shoal forms and perhaps this penetrates the water line to form a shoreline which becomes a protuberance known as a cusped foreland. If this extends out to the island or reef it is termed a tombolo. An obvious cusped foreland is Quinns Rock, north of Perth, but there are several others along the Wanneroo coast. The point to be made is that they form in the lee of the reefs, where waves are broken due to the shoaling effect of the small depth over them, by the diffraction of waves either side or at one end of them. They are not formed at the break in a reef because at such a break waves can penetrate and will spread energy to form forelands either side of the break.

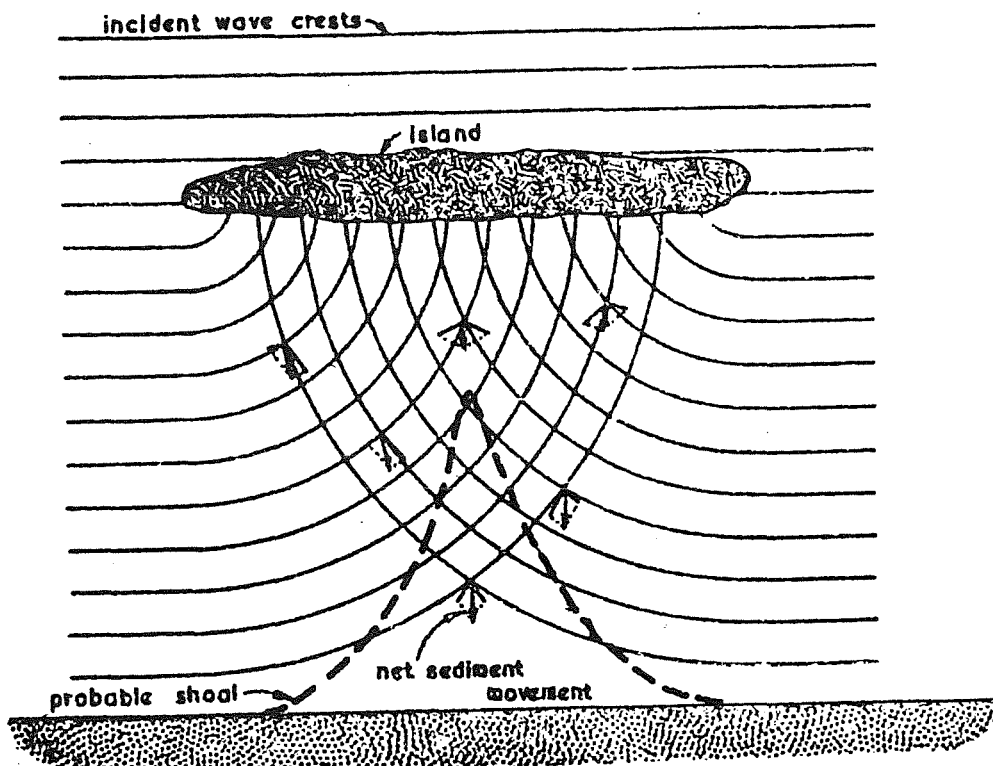


Figure 6 Wave propagation in shallow zone of an island or reef structure.

Wave patterns entering a gap between headlands, or a gap within a reef that dissipates waves passing over it, are exhibited in Figure 7. The waves retain their straight alignment between the orthogonals passing through the extremities of the gap. Either side in the shadow zone the waves assume quadrants of a circle (discounting refraction due to changes in depth) where energy is being transferred from the central portion of the wave, in a process known as "diffraction". The heights reduce around this crest periphery, being least adjacent to the island or reef itself. They also decrease the further the wave proceeds from the entrance, as does the height of the central straight segment of crest due to energy demand from the sides.

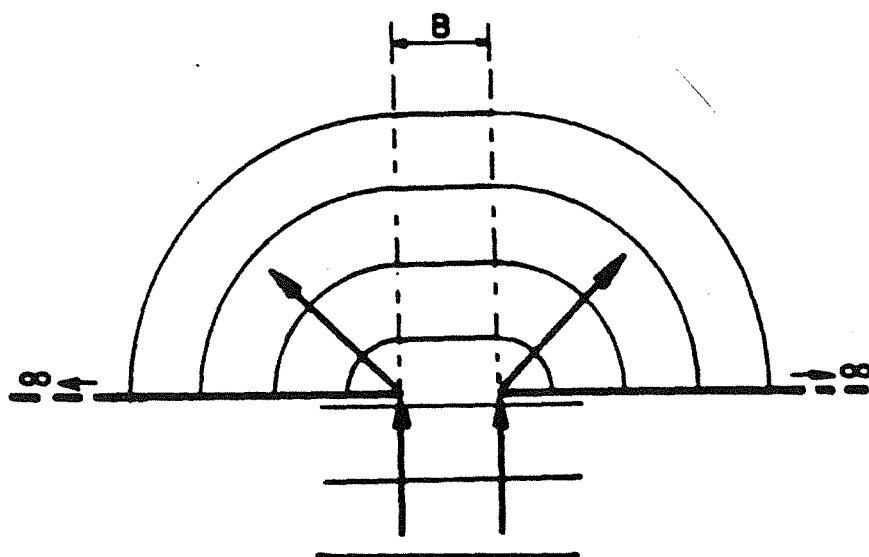


Figure 7 Wave patterns within a gap of breakwater or reef.

Any sediment fed through the gap will be carried by the mass transport to form a beach parallel to the shoaling and breaking wave. This implies that the beach will protrude from the original shoreline to the centreline of the obstructing structure. Material could be eroded from the shoreline at the centreline of the gap because of the oblique approach of diffracting waves. In Japan beach stabilization is carried out by inserting offshore breakwaters parallel to the coast in echelon fashion, as displayed in Figure 8. The spacing is generally half the length of each breakwater unit. Sand passes through these openings, which has been removed from the seaward side of them, and is then transported to form either modest cusped forelands or tombolos centred on the breakwaters.

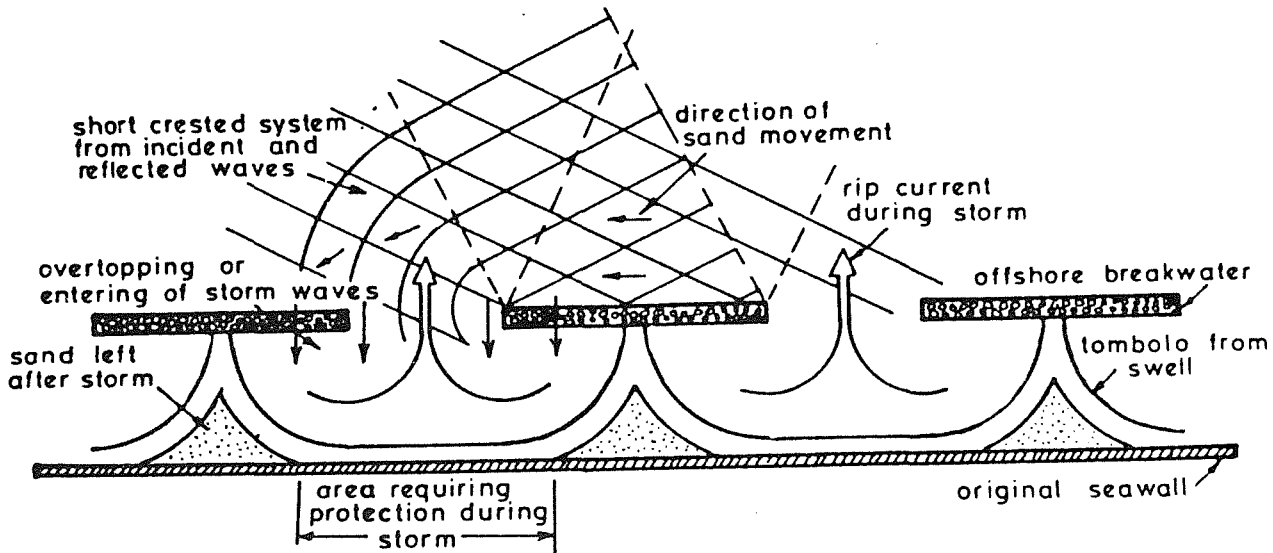


Figure 8 Beach formation in the lee of offshore breakwaters.

1.6 Wave Diffraction

The height of waves entering a gap, as in Section 1.5 above, is predictable from theory and experiments verifying it. The Reviewer has examined this phenomenon (2) and produced a graph related to the width of the ribbon of crests entering it as defined in Figure 9. Its width B will be a fraction of the actual gap depending upon the approach angle θ , it being unity for $\theta = 90^\circ$. The width can be non-dimensionalised by dividing it by the wavelength in the depth of water accepted as uniform. The fraction of the wave height K to the incident wave height, known as the diffraction coefficient (i.e. $K = H/H_i$) can then be considered at some radius R (or R/L) at some angle α to the centreline of the incident waves through the centre of the gap. This coefficient K is determined from the parameter $K(R/L)^{1/2}/(B/L)$ in Figure 10 for various angles α and specific B/L values.

It is obvious from Figure 10 that the waves will be optimum along the centreline of the wave through the centre of the gap and will reduce along angles α from this line at rates dependent upon the width ratio B/L . The larger this ratio the more concentrated the higher waves near the centreline. As B/L reduces so the more even the waves throughout

the shadow region, as expected by the curve for $B/L = 0.5$, although these will be smaller in height. The zone of highest waves will change with the approach angle θ of the wave to the breakwater alignment.

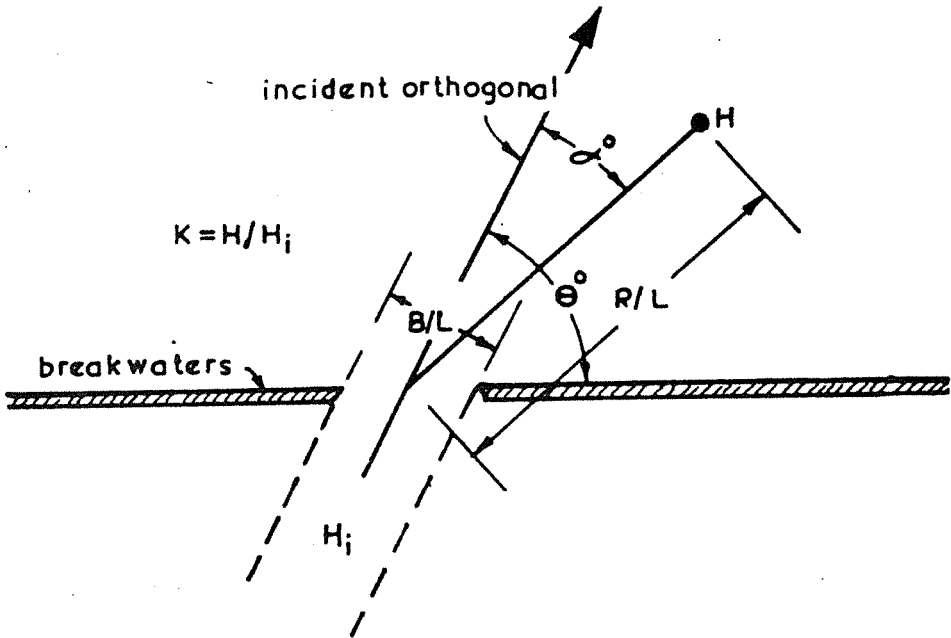


Figure 9 Definition sketch of waves entering a breakwater gap.

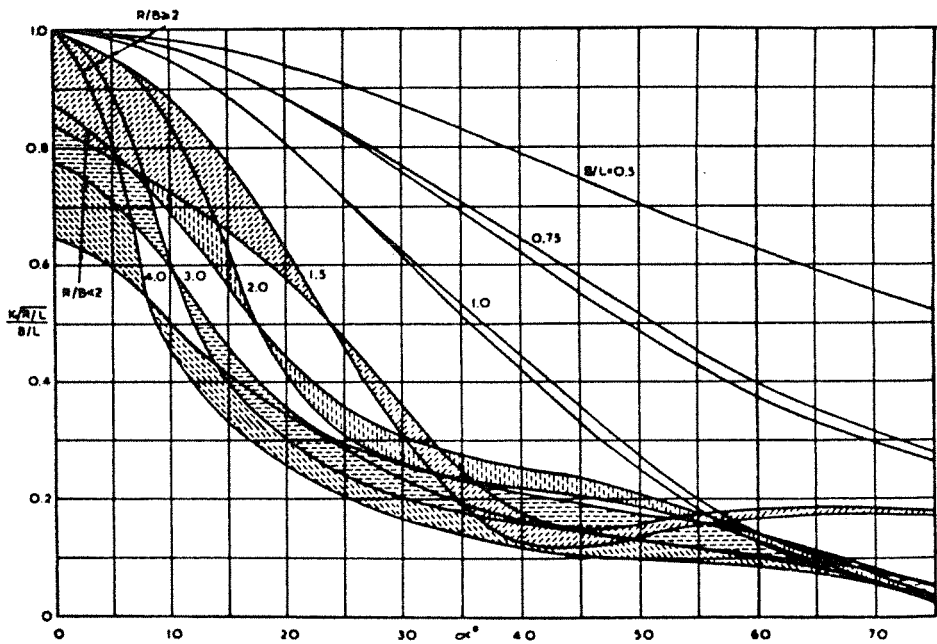


Figure 10 Parameters of wave diffraction through a breakwater gap.

APPLICATIONS TO WARNBRO SOUND

All the above data and processes have some influence in the initial sculpturing of Warnbro Sound and the existing shoreline processes that are taking place. The wave climate inside it, the longshore processes involved, the action of the reef in dissipating waves, the sediment transport at Becher and Mersey Points, and wave diffraction within the Sound, all can be assessed from the general review in Section 1 above.

2.1 Wave Climate

The deepwater waves entering the several openings in the reefs fronting Warnbro Sound will, in the main, diffract from a zone just inside the entrance, towards the periphery of the bay. Their heights will be discussed in Section 2.6, but their influence on longshore drift problems is negligible due to their normal approach to the whole periphery of the Sound.

As stated in Section 1.1 waves will be generated within the Sound by winds from various directions. Due to their short wavelengths, and the depth of water over the greater proportion of the area (being 17 m), these waves can be considered to be in deep water and therefore will not refract until passing over the narrow platform adjacent to the beaches. They therefore retain the same direction as the wind. In this context it should be remembered that in developing seas waves are generated over a fairly wide fan of directions either side of the wind vector, but a resultant direction can be considered on that orientation.

The waves produced in the NW and SW quadrants are important in shoreline processes as they interact with the normally approaching waves that have been diffracted through the gap, to effect longshore drift. The waves generated by westerly winds within the Sound can be ignored as they also arrive essentially at right angle to the beach periphery.

For the purposes of wave energy in effecting a littoral current the wave height should be squared (i.e. H^2). The total energy in a wave is actually H^2L , where L is the wavelength in deep water in this case which is proportional to T^2 . Thus H^2T^2 should be assessed in the two quadrants for comparing northward and southward movement of sediment.

The duration of the wind from any direction is also important as a variable since the length of the time over which energy H^2T^2 is applied to a beach the greater the longshore drift. In Appendix G of the ERMP Report a wind rose is presented as Figure 3.1 but a

table is also available in the original (RB) submission to Delta Holdings Pty Ltd which was omitted in their report to the EPA. These more accurate figures will be used. However, they do not provide a complete picture since the wind duration for any sequence is not known. If a total of hours is made up of bursts of fractions of an hour the waves so presented could be duration limited and so not be as high as the fetch might indicate. However, the fetches are of such limited size that saturation, time-wise, would be reached very quickly and hence the average durations will be accepted in the assessment of overall wave energy.

It can be shown (3) that the following proportionalities exist for wave height (H) and wave period (T) just being generated, in what are termed "developing seas", with wind velocity (U), duration (t) and fetch length (F)

$$H \propto U^{1.3}; \quad H \propto t^{0.5}; \quad H \propto F^{0.25}$$

$$T \propto U^{0.2}; \quad T \propto t^{0.33}; \quad T \propto F^{0.33}$$

The fetches (F) for Westport are in the following proportions:

$$N = 6; \quad NW = 13; \quad SW = 7; \quad S = 2.$$

The table available lists durations of winds, in increments of 2 m/sec for the above directions. A minimum velocity of 5 m/sec is accepted, since those less than this are unlikely to generate waves of any consequence. The respective fetches (F) and durations (t) are then employed as above to determine both wave height (H) and period (T). Values of H^2 and T^2 are then computed and the product (H^2T^2) obtained. The summations of these for all wind velocities can then be compared to find the relative energies from the SW and NW quadrants. The results are presented in full as Table IV for checking and discussion. The average wind durations have been derived from data taken over the years 1979-1984. The maximum wind was designated 14.1 m/sec & over so a value of 17 m/sec was accepted, equating to 34 knots approximately, which is the maximum to be expected for any length of time in the Perth Metropolitan area.

It is seen from Table IV, based upon these 5 years of wind records, that over 3 times the wave energy from locally generated waves emanates from the SW quadrant than from the NW. This is for Westport which is just south of the centreline of Warnbro Sound. For points further north the only change will be in the proportions of fetches from the various directions, which will give greater percentages of northerly directed energy. The fact that the Sound is a quadrant of a circle in apparent equilibrium with major long period waves entering the gap in the reef the actual conversion of this oblique wave energy into sediment transport appears to be minimal.

Table IV Energies (H^2T^2) of waves generated within Warnbro Sound

Dir.	Variable							Total	Quadrant	
N	U m/sec F proportion t %	5 6 1.80	7 6 1.40	9 6 1.10	11 6 0.55	13 6 0.30	17 6 0.20	19,434	51,734	
	$H\alpha U^{1.3}F^{0.25}t^{0.5}$ $T\alpha U^{0.2}F^{0.33}t^{0.33}$	17.0 3.0	23.2 1.3	28.6 2.9	26.2 2.4	24.0 2.0	27.8 1.9			
	H^2 T^2 H^2T^2	289 9.00 2,601	538 1.69 909	818 8.41 6,879	686 5.76 3,951	576 4.00 2,304	773 3.61 2,790			
NW	U m/sec F proportion t %	5 13 1.10	7 13 1.00	9 13 0.90	11 13 0.65	13 13 0.40	17 13 0.45	32,300		
	$H\alpha U^{1.3}F^{0.25}t^{0.5}$ $T\alpha U^{0.2}F^{0.33}t^{0.33}$	12.0 3.3	23.8 3.4	26.8 3.5	18.1 3.27	33.7 2.9	15.3 8.9			
	H^2 T^2 H^2T^2	144 10.89 1,568	566 11.56 6,543	718 12.25 8,795	328 10.67 3,500	1,136 8.41 9,554	234 79.2 2,340			
SW	U m/sec F proportion t %	5 7 2.85	7 7 3.25	9 7 2.90	11 7 1.90	13 7 1.00	17 7 0.75	135,185		
	$H\alpha U^{1.3}F^{0.25}t^{0.5}$ $T\alpha U^{0.2}F^{0.33}t^{0.33}$	22.2 3.7	34.8 4.1	48.2 4.2	34.9 3.8	45.6 3.2	56.0 3.0			
	H^2 T^2 H^2T^2	493 13.69 6,749	1,211 16.1 20,357	2,323 17.64 40,978	1,218 14.14 17,588	2,079 10.24 21,289	3,136 9.00 28,224			
S	U m/sec F proportion t %	5 2 4.40	7 2 4.25	9 2 3.10	11 2 2.05	13 2 0.85	17 2 0.45	30,287	165,472	
	$H\alpha U^{1.3}F^{0.25}t^{0.5}$ $T\alpha U^{0.2}F^{0.33}t^{0.33}$	20.2 2.8	30.8 3.0	36.4 1.7	38.5 2.6	21.2 2.0	31.7 1.7			
	H^2 T^2 H^2T^2	408 7.84 3,199	949 9.00 8,541	1,325 2.89 3,829	1,482 6.76 10,018	449 4.00 1,796	1,005 2.89 2,904			

2.2 Shoreline Processes

The storm waves entering Warnbro Sound through the gap will vary in intensity around the periphery, being maximum on the centreline of their particular deepwater approach directions. The proportional wave height will vary with the gap width (or widths) applicable to that direction, as will be discussed in Section 2.6. But overall, the wide spectrum waves of any storm sequence will have lower wave heights than on an open section of coast and hence their demand for beach berm to form the protective offshore bar will be less. This implies that the subsequent berm formed on return of this material will be narrower. This small width is a predominant feature of the Sound, as well as the modest offshore platform supporting it. The width of this platform also reflects the intensity of the storm waves received. It is significant that it is greater in the northern half of this circular beach than the southern half. This implies either that deepwater storm waves from the NW are smaller than from SW or that the gap widths relating to these two directions differ. Since as seen in Figure 1, the gap width for NW waves is 625 m and the total width of the two gaps for SW wave entry is only 450 m, the conclusion must be that NW storm waves are of lesser energy content. This is borne out both by the Wind data of Table II and the average Sea wave data of Table III.

In spite of the beach being narrower than normal the sand can still be blown from it against the first dune which is much higher than those behind it due to the lesser demand even during the fiercest of storms. This high profile prevents the loss of much material from the beach even though at its soffit sand is being blown inland, burying some of the vegetation. This is a natural process since at this height ground cover has difficulty in growing. There are advantages in bringing this level down close to the water table in order that grass, plants and trees can spread more readily. Besides a landwards aeolian transport there is a northwards movement due to the persistent southerly winds during the summer period. The wider expanse of sand at Bridport Point permits larger volumes of sand to be blown NE and northwards onto the dune and on to the platform which widens at this transition.

2.3 Longshore Transport

The normal approach of most waves, but particularly long period swell, will effect little longshore transport as it moves the offshore bar back to the beach. There is a theory that sediment will move towards zones of lower breaking wave height. Since these swell waves, essentially from SW in deepwater will be reducing towards the south

when breaking at the beach, then a drift in a southerly direction might be indicated. This could offset the movement northwards of littoral drift envisaged in Section 2.1 above. This influence is more pronounced from the centre of the Sound to where it curves westward at the northern end. In balance the overall drift is very small. The interaction of these oblique short waves with the normally approaching swell can optimise this mode of transport.

2.4 Limestone Reefs

The presence of limestone reefs along the Western Australian coast from Mandurah to Wanneroo points to the fact that barrier beaches could have existed along this alignment in previous geologic time. These have since been blown away or removed by the constant northward drift of material from the predominant SW swell. All that is left are the fixed stone outcrops which are now a significant feature in the protection of the mainland.

Just northwards of the headland at Mandurah, itself a limestone reef, the reefs have been undermined and collapsed, leaving more open sea to the coast. Such subsidence could occur in the future. The Reviewer recalls a statement by an officer of the then Harbours and Rivers Branch of the PWD that in the 1960's a substantial collapse occurred in the reef just south of Becher Point which could have affected the southern margin of this cusped foreland. Should further removal occur seawards of Warnbro Sound the wave climate in this embayment could alter significantly. This however cannot be planned for in the present development. It is more likely to influence events than any hypothetical change in wave conditions due to a surmised long-term change in climate.

2.5 Cusped Foreland

As noted previously these occur leeward of major reef segments and not at gaps in them. Typical of them are Becher Point to the south and Mersey Point to the north. Whereas the latter is maintained by Penguin Island, Becher Point itself is maintained by the balance in wave energy from the south and the diffracted wave energy through the gap at the centre of Warnbro Sound. This point is purely sedimentary and is thus subject to the balance of this energy. In the event of a long duration and fierce storm from the NW, which is very infrequent, the point could be diverted southward. When there is a

concentration of strong waves from the south the point can be diverted northwards, with material being fed on to the coast just west of Bridport Point.

2.6 Wave Transmission through Reef

The distribution of storm wave heights around the periphery of Warnbro Sound will vary with their angle of entrance to the gap. Although strong waves might be envisaged from the NW the known paths of cyclones across the coast would indicate that their duration is very short, which is confirmed in Tables II and III. As the storm centre passes across the coast, normally south of Perth, strong winds from the west and then SW, will generate waves from that direction, perhaps with the concurrent arrival of high swell waves from the SW. Thus it is believed by the Reviewer that the higher storm waves will arrive from the SW rather than the NW direction and will be of longer duration.

Taking the period of the highest waves in the storm spectrum as 12 seconds their wavelength within Warnbro Sound, of average depth 17 m, will be around 140 m. The total width of gap for SW waves is 450 m (see Figure 1) and hence $B/L = 3.2$. For westerly waves $B/L = 5$, whilst for NW waves $B/L = 4.5$. A mean value of $B/L = 4$ will be assumed. As seen in Figure 10, this B/L value will have fairly concentrated energy along the straight orthogonal for each deepwater wave approach, and will decrease rapidly either side of this. The radial distance, from the point at which diffraction commences, to the beach is 4.4 km or $R/L = 32$. From Figure 10, the ordinate at the centreline ($\alpha = 0^\circ$) is unity for $R/B > 2$, so that K can be derived from parameter $K(R/L)^{0.5}/(B/L) = 1$. Values for various angles α from the centreline are given in Table V.

Table V Diffraction coefficient K at various angle α from centreline of entering wave orthogonal

	α (degrees)							
	0	5	10	15	30	45	60	75
$K(R/L)^{0.5} / (B/L)$	1	0.8	0.45	0.32	0.17	0.1	0.09	0.02
K	0.71	0.56	0.32	0.22	0.12	0.07	0.06	0.01

It is seen from Table V that the waves prior to shoaling at the beach are about 3/4 their deepwater value on the centreline, reducing to 1% at the orthogonal 75° deviation from it. Thus the evaluation of a general diffraction coefficient for the Sound has very little meaning.

The breaking, reflection and transmission of waves over submerged mounds has been adequately analysed in coastal engineering literature (4). The variables associated with this are depicted in Figure 11. A graph is available which gives the maximum value of h/L_0 for any given deepwater steepness (H_0/L_0) and width to submersion depth ratio (B/L). Assuming a reef width of 10 m (even though these appear in Figure 1 to be much wider than this) and depths over it of 1.0 and 0.5 m then $B/L = 10$ and 20. Taking deepwater wave heights (H_0) of 7, 4, 1 and 0.5 m, ranging from storm waves to low swell, then waves of 10 second period would give values of H_0/L_0 as listed in Table VI. From the graph mentioned above the maximum value of h/L_0 to produce breaking is listed, together with the actual values of h/L_0 .

Table VI Maximum values of h/L_0 to produce wave breaking over a reef

		H_0 (m)	7	4	1	0.5	Actual
h (m)	B/h	H_0/L_0	0.045	0.025	0.0065	0.0032	h/L_0
1.0	10		0.12	0.058	0.016	0.008	0.0064
0.5	20		0.17	0.063	0.018	0.010	0.0032

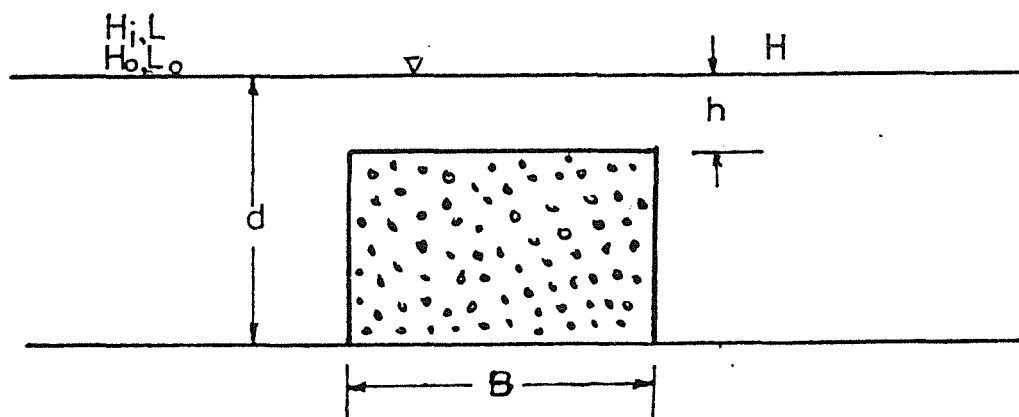


Figure 11 Variables in wave transmission over a submerged reef.

It is seen in Table VI that the actual values of h/L_o are less than the required maxima and hence breaking will occur under all circumstances. The closest it comes to non-breaking is for the smallest wave height ($H_o = 0.5$ m) and largest depth ($h = 1.0$ m). This is understandable as the wave finds it difficult to steepen to the limit for breaking.

Another graph (4) provides reflecting coefficient ($K_r = H_r/H_i$) and transmission coefficient ($K_t = H_t/H_i$) for various h/H_i values and specified d/L which in this case for 10 m seaward depth and 10 second wave is 0.1. For the range of wave heights as before h/H_i ranges from 0.1 to 2.0 for which specific values are listed in Table VII together with K_r and K_t . Since $K_r^2 + K_t^2 + K_l^2 = 1$ then coefficient of loss (K_l) due to breaking can also be determined as listed.

Table VII Reflection, transmission and energy loss coefficients over a submerged reef

h/L_i	0.1	0.5	1.0	2.0
K_r	0.73	0.60	0.43	0.15
K_t	0.40	0.54	0.70	0.95
K_l	0.55	0.59	0.57	0.27

It is seen that K_r decreases and K_t increases as depth over the reef increases which is understandable. The loss of wave height due to breaking is sensibly constant until the ratio h/H_i reaches 2 when it drops to 0.27. It was seen in Table VI that in this situation the wave was almost not breaking, which means less energy loss in this condition. However the wave being transmitted over the reef is very small or 95% of 0.5 m.

The Reviewer therefore concludes that with reflection and dissipation at the reef essentially no energy is transmitted shorewards from it. Whereas at the gaps, even with some massifs of stone on the floor the bulk of energy can enter.

This variance in storm wave height will demand greatly varying volumes of sand for the offshore bar and hence will result in differing beach berm widths. No mention is made in the ERMP Report on these widths. It also makes a difference in the widths of the offshore platform which has resulted from the repetitive formation of this bar. The widths of this, as seen in Figure 1, are greater at the northern extremity. It is thus concluded by the Reviewer that waves from the SW apply the greater storm wave energy

to this coast and can substantially affect the Safety Bay coast oriented almost E-W.

This section of coast is also influenced by the infrequent NW storm waves entering Warnbro Sound through the Penguin Island-Mersey Point gap. The shoaler depths in this region decrease the wavelength (L) and hence increase the B/L value to near 8, which diffracts and refracts waves along this shoreline and moves material eastwards. This is quite separate from any littoral drift generated along the main Warnbro coastline. There is a protruding point at the eastern end of Safety Bay (see Figure 1) similar to Bridport Point on the northern flank of Becher Point. The shoreline just western of both these points follows the general trend of the circular waterline of the main periphery. This indicates the important influence of the persistent waves diffracting from the main gap in the reef, which arrive normal to these waterlines.

The orthogonals of diffracting waves from just inside the main gap in the reef are of equal length, implying that the shoreline of Warnbro Sound is a quadrant of a circle. Waves therefore will break simultaneously around this periphery with zero littoral drift from these long period waves arriving normal to the beach. This whole segment of coast can therefore be considered as in static equilibrium. These orthogonals are almost straight due to passing across the Sound of uniform depth.

The slightly shorter radius of C in Figure 1 is probably due to the lower speed of the waves in the 15 m depth of its traverse of the Sound. A straight orthogonal has been drawn from just west of Bridport Point at E, which travels across the 3 to 5 m depth. Its length to the centre is therefore shorter. A slightly curved arc, shown dotted, from E' accounts for some refraction over the transversally sloping bed but the starting point matches those of the other orthogonals A, B and C. The orthogonal from F similarly traverses a shoaling depth from 10 to almost 1 m and hence its length to the shoreline is shorter. Another from F' would suffer refraction due to its oblique crossing of contour lines.

The submission received from Delta Holdings Pty Ltd will now be discussed with concentration on the contents supplied by Le Provos, Semenink and Chalmer (LPSC) and Riedel and Byrne Pty Ltd (RB), who dealt mainly with coastal processes. Besides Vols II which contains the detailed Appendices from these two consultants, the Reviewer obtained the complete reports to the proponent, portions of which were omitted in an abridging process. These permitted more background knowledge and thought processes of the consultants.

This section of the Review is divided into the following topics :

- 3.1 Wave Climate
- 3.2 Longshore Transport
- 3.3 Coastal Periphery Changes
- 3.4 Influence of Breakwaters.

Quotations are made verbatim in order that any reader of the Review does not need to trace through the original ERMP Report for them. In some respects the Review finds the submissions rather lacking in knowledge in wave and shoreline processes from a coastal engineer's viewpoint. Reference will be made where applicable to Sections 1 and 2 of this report.

3.1 Wave Climate

In the submission by (LPSC) great emphasis is placed on wave refraction over the reef as exemplified by the statement in Vol. I, p.33 : "Ocean swells are largely refracted and attenuated by the chains of reefs and islands to form complex patterns in the water body behind." and "Although the Sound is partly open to the west, large storm waves are strongly refracted and the amplitude of these waves is thus restricted."

On p.43 of Vol. I, it is also stated : "Predicting the direction and volume of longshore transport in Warnbro Sound is difficult due to the variability in the intensity, and approach direction of refracted swell and locally generated wind and storm waves." and "The oceanic swells approach the coast from a more westerly than southwesterly direction in winter, but this seasonal change has little effect on the angle of swell wave impingement on the Warnbro shore due to extensive refraction over the shallow bank tops."

In Appendix E p.9, it is stated : "Refraction effects over the shallow barrier bank tops causes convergence of this remnant swell wave energy toward the central axis of the

banks." The reader is referred to Figure 20 (which refers to a Figure 9) which shows refracting waves over shoals with orthogonals crossing haphazardly. These have nothing to do with passage through gaps in reef at all. This figure was taken from a Ph.D. thesis by Searle (1984) which has many erroneous concepts quoted from it.

It is not understood by the Reviewer whether the writers have mis-interpreted refraction from diffraction. Refraction is twisting of waves when they pass obliquely across bed contours, whereas diffraction is the transfer of energy along a wave crest as it spreads into a shadow zone behind a breakwater or island structure. However a quotation on p.9 of Appendix E shows that the writers have little knowledge of diffraction : "Diffraction of swell waves energy also occurs around emergent elements of the Garden Island Ridge Crest. However, the mechanics of diffraction ensure that this has only a minimal effect on wave energy distribution within the Warnbro - Cockburn Depression." The Reviewer believes this to be absolutely incorrect as discussed in Sections 1.1, 1.6, 2.1 and 2.6. Diffraction is the sole mechanism in effecting this distribution of energy and also the direction of approach of waves to the Warnbro Sound periphery.

With the writers' acceptance of refraction over the reef, rather than diffraction through the major gap, the crest patterns shown in Figure 14c of Vol. I, Figure 11 (22 in the text) of Appendix E, and Figure 6 (21 in the text) of Appendix F, all appear erroneous to the Reviewer. For example in Figure 14a waves are illustrated for summer, winter and NW storm conditions. The summer waves are swell from the SW and locally generated waves from same direction. The former inside Warnbro Sound show fairly uniform crests just beyond the reef with refraction taking place over the southern bank. The crest nearest the shore has a southerly component of wave energy. The northern part of the Warnbro shoreline is not included for some reason. The shorter locally generated waves are shown to pass over the reef with no change in direction. These waves would already be breaking when they arrive at the reef because they are steep during the generating process. When they reach the small depths over the reef this breaking would be enhanced and hence the waves could be completely dissipated when traversing the reef. Thus their interaction with the swell waves to create a northerly littoral current, as indicated by the arrows purportedly showing sediment drift would not operate. Perhaps waves generated within Warnbro Sound by the wind, which will be very small in the 5 km fetch, could effect a slight northerly drift from the centre of the Sound shoreline to the northern limit, but this would be very modest, as pointed out in Section 2.3.

The wave crests south of the Becher Point, in Madora Bay, again are shown to traverse the reef without too much directional change. The swell crest nearest the beach

would be breaking towards the SE whilst the locally generated waves appear to arrive normal to the beach. Even so the arrows are showing a current or sediment movement towards the NW. The Reviewer believes these waves will diffract or twist around the southern limit of the reef which is half way down Madora Bay. They will therefore arrive almost normal to this beach which is a zone of accretion. At the tip of Becher Point there is a balance of energy in waves diffracted through the Warnbro reef gap, arriving from NNW and waves diffracted around the southern tip of the reef, arriving from SSW. These waves with an angle of 30° between the crests maintain and build out this spit.

In the central square of Figure 14a storm waves from the SW are shown. Those in Warnbro Sound are not concentric circles which they would be if proper diffraction were considered. The interaction with locally generated waves, with no diffraction effect accepted, result in eastward to northeastward arrows of drift which the Reviews cannot condone. Waves south of Becher Point also show incorrect direction at the coast which purport to provide a SE drift. This is in error because these will arrive normal to the coast, the same as those in the upper figure.

The bottom square of Figure 14a shows waves from NW crossing the reef with no change in direction. Presumably this is because they are of short period being locally generated. As noted above they will be already steep and breaking when they arrive at the reef where the shallow depths will completely dissipate them, except at the gap where they will enter Warnbro Sound and will diffract in concentric circles. Their interaction with waves generated within the Sound might provide a slight southerly drift.

Figure 11 (22 in the text) of Appendix E shows crests for SW swell (top square), westerly and southwesterly wind waves (central square), and northerly storm waves (bottom square). Those in the top square are reasonably correct. The crests shown in the central square exhibit no change in direction across the reef even though these locally generated waves would be dissipated over it and diffracted through the major gap of Warnbro Sound and from the southern tip of the reef. Those generated within the Sound, which would be small in height, would be angled to the shore but their effect in littoral drift minimal. The same argument applies to the northerly storm waves in the bottom square.

In Figure 6 (21 in the text) of Appendix F is essentially the same as that in Appendix E, even though waves are slightly altered in initial directions. Similar criticisms apply to these crest alignments due to diffraction not being properly taken into account.

Also associated with wave climate is the question of what have any of the contributors to the ERMP report thought about the significant wave reflection taking

place at the reef. In Appendix E p.4, it is stated under the heading Geomorphology that the ridge stands some 20 m above the sea bed, with equal depths either side. This high almost vertical wall would reflect a large proportion of the waves either of swell, storm, or locally generated character, but certainly more effectively the longer period components of the wave spectrum. This, together with the breaking in the shallow depths over the reef, would leave negligible energy for transmission into Warnbro Sound. On p.5 it is stated : "Adjacent to the centre of the Madora Basin (Comet Bay; Figure 12) the ridge occurs only as a discontinuous series of entirely submarine rocky hummocks that commonly rise only 2 to 6 m above the surrounding seafloor." As previously stated waves from any direction, from NW to SW, will diffract around the southern tip of this vertical breakwater and hence wave directions should be taken as arcs from this point.

It is admitted on p.9 of Appendix 5 that : "As these waves (of 10 to 14 second period) impinge on the perforated Garden Island Ridge Crest some energy is dissipated by reflection or shoaling . The remainder passes shoreward over the submarine parts of the ridge crest." The magnitude of this loss of energy is not discussed. It would be more correct to say the dissipation occurred due to reflection and shoaling. In fact reflection takes place from both the seaward and leeward faces of these rectangular mounds. Where there are minor spaces between them the diffracted waves will be moving in opposite direction just landward of the reef so causing standing waves which doubles the wave height and promotes breaking. It is only where a substantial section of reef does not exist that waves will penetrate to any large degree. The only location of such a possibility is at the centreline of Warnbro Sound as discussed in Sections 1.6 and 2.6.

In the same page (p.9) it is stated : "Seagrass meadows on the bank top increase the bottom roughness factor, which causes significant further dissipation of swell wave energy as they pass shoreward." Reference to Figure 7 of Appendix C shows that over the complete area of Warnbro Sound deeper than 10 m, which is the bulk of the Sound, there are no seagrasses. This is the zone that diffracting waves will pass on their way to the curved shoreline. Only a small band exists on the slope of the narrow platform which margins this coast. Of this it is stated on p.8 of Appendix C : " This suggests that the seagrasses around parts of the eastern margin of Warnbro Sound may also be undergoing a decline of some form which is associated with a loss of sediment leading to the exposure of the rhizomes." If anything, sand will be added to this slope and not removed. But the point to be made is that no attenuation of swell waves will take place during their passage to the coast in question.

Appendix B of the original RB submission to the proponent was entitled

"Refraction, Diffraction and Shoaling", showing techniques and results in determining wave heights within Warnbro Sound from the deepwater values previously assessed. From discussion with the actual consultant it was found that diffraction was not utilised in this analysis because of its considered unimportance. Waves were transmitted over the reef as though it was a larger than normal roughness on the floor. Some breaking was taken into account but reflection was not considered to occur. The Reviewer believes that reflection and shoaling, with its concomitant wave breaking, are extremely important in calculating a transmission coefficient for the waves (see Section 2.6). The twisting of a wave or its refraction over a reef is not of importance as on the leeside it would twist back to its original alignment. However, when waves are considered to be propagating over the complete reef with little change in height they reform and traverse the shoals within the Sound and hence suffer some refraction. It must be this refraction that is encompassed in the calculations.

It is the Reviewer's opinion that these deepwater waves dissipate grossly over the reef so that the major energy enters through gaps in it and diffract across the Sound and have fractions of the original height near the beach as shown in Table V.

In Table 4.3 (p.9) of Appendix G the wave coefficients in 3.6 m depth at Westport are listed for swell from various deepwater directions. Those for 12 second waves (assumed in Table V) from NW, W and SW are listed in Table VIII, together with their arrival direction in degrees.

Table VIII Computed coefficients and directions by RB
for waves arriving at the Westport site.

Deepwater Direction	NW	W	SW
Coefficient	0.55	0.84	0.70
Arrival Direction	285	285	281

It is seen that the proportions of deepwater wave height approximate those as given in Table V at the centreline for waves entering from any given direction. However in Table VIII a minimum is shown at Westport for NW waves whereas it would be inferred from the Reviewer's computations that this would be maximum and from the SW minimum. For the SW approach the angle α in Table V to Westport would be approximately 60° or a coefficient of 0.09 and not 0.70 as given in Table VIII.

The direction of wave arrival in Table VIII varies very little between waves from the three deepwater directions and equates to that derived by the Reviewer by diffraction through the main gaps in the reef. This constancy in wave direction is explained by the consultant in the comment p.9 of Appendix G : "Common swell wave orthogonals approach the shore from about the same direction almost irrespective of the deepwater direction." This is correct for an open coast where the depth is 3.6 m and also for a specific point on the coast where diffraction occurs through a fixed gap of an offshore structure. It appears fortuitous that these values by either approach result in sensibly the same direction. However the coefficients so obtained are in error due to refraction above being considered rather than diffraction which will distribute wave energy in a completely different manner.

3.2 Longshore Transport

If Figure 11 of Vol. I of the ERMP Report is accepted as a true isometric view of the reef structure and Warnbro Sound it can be accepted that the seaward slope along the reef is very steep. The recent hydrographic chart submitted as Figure 1 shows depths seawards of the northern half of the reef fronting the Sound in the order of 10 m whilst those on the leeward side as around 3 m. The southern half fronting Becher Point are about 5 m seawards and 2.5 m landwards of the reef. With these large almost vertical faces incoming waves, predominantly from the SW, will reflect obliquely and hence transport large volumes of sand northwards. Very little will penetrate the gaps. The bulge in the 10 and 15 m contours just eastwards of the major openings indicate some movement through them but these contours compared with a survey chart with information up to 1950 show little or no movement.

A comparison of the more recent chart, probably of 1985 vintage, and the one 35 years previously shows some sections of reef have disappeared or subsided to the floor. Thus the openings at Leading Light and Coasters Channel have widened during this period. Further collapses of reef could be expected due to undermining and breaking due to storm wave forces on them. Such breakages will tend to occur at some height above the bed so that northward transport could continue without sand penetrating the reef. However more wave energy could enter Warnbro Sound.

The transport rate in Madora Bay quoted on p.39 of Vol. I of 100,000 m³/annum is a figure the Reviewer would question but this has very little to do with transport within Warnbro Sound. Another figure of 60,000 m³/annum is quoted for movement towards Becher Point. On p.45 it is stated : "It could reasonably be concluded that the volume of

north moving littoral drift that could pass the Westport site will be significantly less than 60,000 m³/year and most likely only around 10% of the amount, i.e. 6000 m³/year." On p.48 another consultant states: "Given that Warnbro Sound is protected, the maximum net volume of littoral drift is unlikely to exceed say, 10% of the maximum drift on the open coast, i.e. 10% of 100,000 m³ = 10,000 m³/year ..."

Thus these two sources of information on the most crucial aspect of this environmental study differ by 67% in their long-term assessment of littoral drift. Why values of 10% should be chosen anyway makes these evaluations worthless. This northerly trend is discounted by estimates from wave energy directions in the top table on p.46 of Vol. I where a net southerly drift is predicted of 2100 m³/year. A conclusion is drawn on p.47 (b) that: "deepwater waves are transformed by the offshore reef and sand bank system so that they tend to have a nett southerly drift at the Westport site". In conclusion (d) it is stated: "Severe storms could move up to 3000 m³ of sand during each event. In most cases this sand would be moved in a southerly direction." The Reviewer would dispute these conclusions for many reasons, but the direction of optimum waves during a storm event could arrive equally from the SW and not the NW which could negate the above conclusions.

The summary of transport trends contained on p.48 of Vol. I contains confusing remarks such as in (b) where it is stated: "As the Warnbro Coast is still prograding in the long term, the volume of these pulses must more than cancel the net seasonal movement identified above (a)." In (c) a possibility of a change in wind and wave climate over time is envisaged, as it is by other contributors throughout the Report. The Reviewer believes that in the long-term one of the constants to be accepted is the deepwater wave climate and even generation of waves within Warnbro Sound.

The reflection and breaking of waves over the reef can be considered almost complete leaving little energy to be transmitted landwards from it. Even when storm waves are accompanied by a storm surge they will be continually breaking before arrival at the reef due to their excessive steepness (ratio of height to wavelength). The wide shoal over the reef will precipitate more breaking even though the water depth over the reef may have increased by a metre. Thus the only wave energy reaching the Warnbro periphery will be that from waves penetrating the gaps as shown in Figure 1.

It is stated on p.1 of the Appendix H that: "An experimental groyne is being installed at the site to verify the mathematical predictions." This cannot be done because the waves calculated for November 84 to October 85 do not apply to the measurements made in 1986-7. A new set of wave data would be required to cover the monitoring period, but this does not appear to be warranted as the treatment of the waves in

traversing the reef is questionable according to the Reviewer.

On p.44 of the ERMP Report it is stated that : "Along the west facing shores of Warnbro Sound prevailing conditions imply a northward transport." No evidence seems to be supplied for this contention. On p.14 of Appendix G it is stated : "Locally generated seas, because of the longer fetch to the north also tend to cause a nett southerly drift." As seen in Table IV, not only fetch but also wind velocity and duration are important in assessing wave energy for this transport. At the Westport site, inspite its location south of the centre of the Sound, the nett movement appears to be northward. This is due to the paucity of winds from the N and NW directions.

The directions of sediment transport, as contained in Figure 14a of Vol. I and similar figures throughout the Appendices, the Reviewer would question, due to lack of adequate treatment of waves across the reef and the lack of diffraction studies through its gap. The authors appear to lack confidence in this presentation as it is stated on p.45 : "As noted above, superimposed on the nett drift is a seasonal flux of sediment - the volume of which cannot be estimated by the model shown in Figure 14 a and b."

The Reviewer agrees with the statement on p.45, namely : "Given that the swell and wave regime in Warnbro Sound may not alter dramatically despite a change in direction in the open ocean, it is possible that little major long-term increase in wave-induced littoral drift will be experienced." He also believes that there is not likely to be any change in the deepwater wave climate.

On p.64 it is stated : " Potential loss of sand offshore is, however, of concern ..." as sand will be lost. In the next paragraph is the comment : "At present there is clearly little loss from the active beach/bar system down the slope." It then mentions some possible deflection of material by the proposed groyne system if the shoreline advances. It is more likely to occur with strong NW winds when a strong littoral current carries sand into deeper water. This point is discussed in Section 3.4.

On p.33 of Appendix E it is stated that the offshore platform is less than 60 m wide. Whereas on p.13 it is said to extend about 100 m from shore. These variations are not extremely important but does not induce confidence in the authors who are discussing the area in detail.

Statements of sediment exchange across Becher Point are inconclusive as the authors are not aware of the forces that maintain this sedimentary headland. On p.12 of Appendix E it is stated : "In Figure 22 (Figure 11 as supplied) the resulting vectors of sediment transport under the varying wave conditions are presented in a semi-quantitative fashion. The size of the arrows represent the relative importance of the transport vectors." Inspection of this figure, with some sequential arrows varying in

length by 400%, does not provide much confidence for which "semi-qualitative" would be a more fitting description.

It is noted on p.9 of Appendix F that the quartz content of the sands around Becher Point from the south into and along the shoreline of Warnbro Sound decrease progressively even though rather haphazardly from 30% to about 10%. This implies that the contents of calcium carbonate increases, either as biological debris or as attachment to each sand grain. The authors explain this by either

- " (i) progressive dilution of the same volume of quartz by increasing amount of carbonate (i.e. increase nett transport), or
- (ii) progressive loss of the entrained quartz into sinks (i.e. constant or diminishing nett transport)."

The Reviewer believes that sand grains washed up on the beach and dried out will have calcium carbonate contained in the seawater precipitated on them. On an open coast where storm energy is more pronounced the procedure of taking the beach berm to offshore and back again may help remove part of this skin of carbonate and hence maintain a larger proportion by weight of the quartz content. In Warnbro Sound storm wave action in removing sand to form an offshore bar is much more modest, this is the reason for the narrow beach along its shoreline, and hence removal of the carbonate skin does not occur so readily. However, sequential douching in seawater is necessary for the continued build up of carbonate. The higher content measured on the Warnbro shoreline indicates the longtime retention from south of Becher Point. No distinction could be drawn from samples at the waterline or those in 1 or 2 m depth because all this sand intermingles during the transfer of beach berm to bar and back again.

The Reviewer cannot agree with the conclusion on p.10 of Appendix F that : "The major and important implication of the results of the shoreline provenance study is that quartzose sediment from south of Becher Point is transported around the apex of the Point and is then distributed north along the shores of Warnbro Sound."

The changing values of carbonate content in the sediment, which is quite variable along the coast, only indicates the length of time it has been in a relatively sheltered area. it does not provide evidence, in the Reviewer's opinion, for longshore movement.

Thus the Reviewer does not agree with the contention expressed on p.12 of Appendix F that : "From these compositional gradients and a knowledge of potential sediment sources, it would be possible to assess the scale of nett transport, and/or gross transport, in and around Warnbro Sound." The only sure way of proving sediment transport is looking at the energy input on a macro-scale because chemical analysis is subject to so many other variables, one of which is time over which changes taken place.

In respect to by-passing sediment across the Westport mouth it is stated on p.24 of Vol. I of ERMP Report that : " It is anticipated that bypassing operations will be restricted to winter months when beaches are least used." Since the greatest changes will take place just after the winter sequence, a matter of 2 or 3 weeks after the final storm of the season, it seems preferable to the Reviewer to carry out this monitoring in the August/September period. This is when dredging is required at the Peel Entrance Inlet. Prediction of requirements from a previous year cannot be accurate due to the large fluctuations that can occur.

Besides a modest nett littoral drift northwards around Warnbro Sound there could be significant blown sand by the incessant S-SW winds, particularly during summer. This has occurred along the northern halves of cusped forelands in the Wanneroo coastal zone where it has produced a surfeit of sand which has buried vegetation and wrongly termed as blowouts. Such aeolian transport could transport sand from Bridport Point into the entrance channel at Westport. The magnitude of this is difficult to assess.

On p.91 of Vol. I it is stated : "It is not anticipated that sand accumulating against the breakwaters will blow inland from the beach as this is not occurring with the experimental groyne." It would be too short a period to make such a judgement but the widening of the beach would be so minimal to effect much change. If accretion occurs against the southern breakwater there will be a tendency for this additional sand to blow N or NE into the entrance channel but this only needs monitoring, with minor dredging requirements very infrequently.

One of the contributors to the ERMP Report (LPSC) believes that developers should cater for very long terms in sediment transport fluctuations even if these cannot be predicted. On p.39 of Vol. I it is stated : "The cause of these changes and whether they are cyclic or random is not clear, nor are the periods between them. It is possible that they are related to long term changes in climate and weather pattern which affects the degree of storminess and the approach direction of the prevailing swell within a period of 200 - 400 years. As these changes occur within a time scale of 100's of years they must be taken into account."

The Reviewer questions any substantial changes in deepwater wave climate in this time scale even though he acknowledges substantial differences from one year to another. These statistical variations or optima are predictable. Even so they are unlikely to affect the waves reaching the shoreline of Westport as waves enter a fixed entrance in the reef and will be drastically reduced by diffraction as they pass across Warnbro Sound. This is the first time that the Reviewer has come across the contention that planners must cater for variables extending over 100's of years. Most engineering

projects are said to have a lifetime of 50 years after which many new proposals will have emerged. In the construction of offshore rigs and platform a 100 year storm wave is introduced on a statistical bases for design, but other criteria are not introduced for such periods. The only likely major change in wave climate and therefore sediment transport within Warnbro Sound is that of further collapse of the reef fronting it. This is an unknown that is unpredictable without underwater inspection of the limestone rock of which it is composed, which is a very dangerous undertaking.

On p.43 of Vol. I it is further stated : "Predicting the volume and nature (direction and timing) of this longshore drift over the next 100 years or so is necessary therefore to gain appreciation of :

(c) the likely management costs associated with accomodating these impacts in the :

- (i) short term (seasonal)
- (ii) medium term (5 - 10 years pulses)
- (iii) long term (200 - 400 years cycles)
- (iv) geologic time (evolution)

This proposition appears to the Reviewer as ludicrous, where even the fluctuations at the present moment, with a large input of scientific expertise, cannot firmly be stated by the contributors. Certainly, any significant trends in the next few years should be elucidated, but to require management proposals for 100's of years or geologic time is fanciful to say the least.

3.3 Coastal Periphery Changes

On p.39 of Vol. I of the ERMP Report it is stated : " As the processes are still operating and sand is still being generated and transported into the ocean, general growth of the coast can be expected to continue." This could be accepted for the southern shore of Becher Point but does not apply to Warnbro Sound itself as all other indications are for long term stability, as accepted by the same authors.

On p.11 of Appendix F, it is stated : "The banks of northern Warnbro Sound are largely protected from storm action." The Reviewer disputes this because the offshore platform in this region from just north of the Sound centre is widest in this region. This implies that larger volumes of beach have been deposited in the form of a bar during storms which has remained offshore when it has reached the slope of this feature. Waves arriving from the SW, which can be part of a storm sequence, have a total gap width of 450 m whilst from the W they have 712 m. Thus storm waves between W and SW have a large area through which they can penetrate to the shore, being maximum on the

orthogonal of this orientation. The minimal width of platform, and probably of beach berm width, is in proximity to the Westport entrance, or just north of Bridport Point. This indicates a lesser influence of storm waves.

These volumes comprising the berms and offshore platform have been formed over some 1000's of years and are not likely to change in the foreseeable future. Hence the Reviewer would question Conclusion (ii) on p.12 of Appendix F which states : "both the submarine banks and overlying sandy shores of Warnbro Sound are still rapidly evolving; there are only local and temporary states of dynamic equilibrium or dis-equilibrium between the energy regime and transfer processes." This statement itself appears rather contradictory.

Conclusion (iii) on the same page similarly is difficult to interpret, namely : "evidence in northern Warnbro Sound suggests that changes in rates of net sediment transport associated with the local re-establishment of a dynamic equilibrium situation have probably varied by up to a factor of 10 over a time scale less than 100 years." The Reviewer believes this area has been static for periods of ten times that stated in this conclusion.

Besides the impact of storm waves from the SW and diffracted through the central gap which arrive on this northern segment of Warnbro Sound there is also the possibility of strong NW storm waves entering the Sound between Penguin Island and Mersey Point where there is a gap 440 m wide (see Figure 1). These waves will diffract and refract onto shoreline of Safety Bay and effect swift changes in the shoreline with large transport of material around Mersy Point. This supply and movement of sediment is quite separate from that around the circular periphery of Warnbro Sound.

One consultant (LPSC) has examined Admiralty Charts for this area going back to 1837. It was found that substantial accretion and erosion occurred in segments of this shoreline from which transport rates were computed. These drastic changes occasioned the remark quoted above of the factor of 10 in less than 100 years. In the original submission p.25 this factor was only 5 in the same period. On this same page it is stated : "The terrain as mapped in 1859 shows a series of low sand ridges alternating with elongate wetlands. This array of land form is typical of beachridge/beachridge swale topography. In this case the orientation of beach ridges (aligned approximately east west) indicate a prograding shoreline with input of sediment from southeast and east, a situation only possible under summer conditions." This inference of sediment supply from south and southeast to the Reviewer is quite erroneous. The source has been from the west even though the diffracted swell has put this material on the beach with this alignment.

The inference then made was that a rate of 171,700 m³/annum was transported up the shoreline of Warnbro Sound from the south. This prodigious rate exceeds by 70% the assumed drift past Mandurah which is purported to be accreting on the southern part of Becher Point. If such an annual rate were to be feeding to the northern beaches there should be some recent evidence of this mammoth input. Of course, there is no such evidence, as the figures, even if they are correct, devolve from storm action entering at the northern tip.

On p.36 of Vol. I of the ERMP Report it is stated : "The steepest slopes occur adjacent to the narrow marginal platform to the north Bridport Point. The deeper parts of the bank slope progressively more up to the angle of repose of about 30 deg. (1 in 2) without seagrass cover, to merge with the Basin floor." This indicates to the Reviewer that this segment of coast is least influenced by storm waves since these have a tendency to disturb sediment on such a slope and cause subsidence. Any material that reaches deeper water is less affected by the orbital motions in waves and hence rests at its angle of repose.

Greater demand is made of the beach when the water level is higher due to the presence of a storm surge. This will be at its highest when winds are the centre of a cyclone passes across the coast south of Warnbro Sound when strong westerly winds exist, together with storm waves from that direction. In Figure 1 it is seen that the platform has a protuberance in it just north of the centre of the Warnbro shoreline. This indicates the largest movement seawards of the beach berm as the waves will also be optimum at the time of this high water.

Whilst material is offshore after such a storm sequence it is moved back to shore by subsequent swell. Any locally generated waves arriving at the beach during this period will help in moving such sediment alongshore. This time period could be 2 or 3 weeks. The winds after a cyclone on this coast could be from any direction and therefore the direction of drift cannot be predicted on any long term basis. It is stated on p.11 of Appendix F : "Although the shoreline and infrequent storms can significantly contribute to the gross sediment transport of the Warnbro Sound system." Should winds oblique to this coast not occur whilst the beach is being refurbished by the swell waves no longshore drift will take place. This could happen most of the time.

On p.12 of Appendix F is the conclusion : "the aerial photographic record of coastal dynamics spanning only 43 years is not an adequate basis on its own for reliable prediction of local coastal dynamics over the design of a coastal project (50 to 100 years)." The Reviewer believes that there would be few places where such a comprehensive series of photographs is available for such a study. The fact that these

show little change is being interpreted as lack of information, whereas they are extremely good confirmation that Warnbro Sound is in complete static equilibrium.

The views of LPSC on long term movements around Becher Point appear conflicting as they appear to not know about the balancing forces that constructed it in the first place. For example on p.14 of Appendix E it is stated : "In the context of the staged model of bank/cusp evolution developed by Searle (1984) (Figure 15) the submarine bank broadens during stage 3 in response to the geometry of beaches in the adjacent ridge crest together with cross-bank wave action and the current flows diverting sediment down the bank sides." Searle (1984) (5 in this report) contends in this figure

that Becher Point has been constructed by sand entering a gap in the reef which grows as this gap widens. It can be seen from Figure 9 in Vol. I and the Reviewer's Figure 1 that this cusped foreland is centred on a comprehensive section of reef, or in its shadow, and not on a gap in the reef. If such an opening existed, and certainly if it widened over time, the incidence of waves would spread any material that did enter into curved beaches either side, just as Warnbro Sound has been sculptured by waves entering the gap near its centreline (see Sections 1.6 and 2.6). Thus this model should be ignored as it is completely erroneous.

The axis of the Becher Point foreland has altered over some 6000 years as stated on p.7 of Appendix F : "However, over the last few thousand years the southward migration of the axis has slowed and then ceased." The reasons for this change are illustrated in the Reviewer's Figure 12, which is a tracing of Figure 2 (17 in the text) of Appendix F, together with wave orthogonals which dictate beach alignment that are normal to it. It is seen that orthogonals from the NW originate from a constant point of diffraction which is the current point of entry. Orthogonals from the southwest changed position since 1000 years ago when the axis of Becher Point moved northwards. This would have been due to some of the Madora Bay reef at the southern end being undermined by waves and collapsing into the sea. This process can continue over long time periods when further sediment will be forced into the area west of Bridport Point. This will stay essentially in the one position, forming a beachline in keeping with the NW orthogonal in the area since practically no longshore drift exists in Warnbro Sound. This view is in agreement with that expressed on p.15 of Appendix E : "The slow migration (over years) and dissipation only over the short segment of shore between Bridport Point and the cusp apex indicates limited net transport." This is contradicted by a statement on p.8 of Appendix F : "Significant amounts have been transported around the apex of Becher Point and north along the shores of Warnbro Sound."

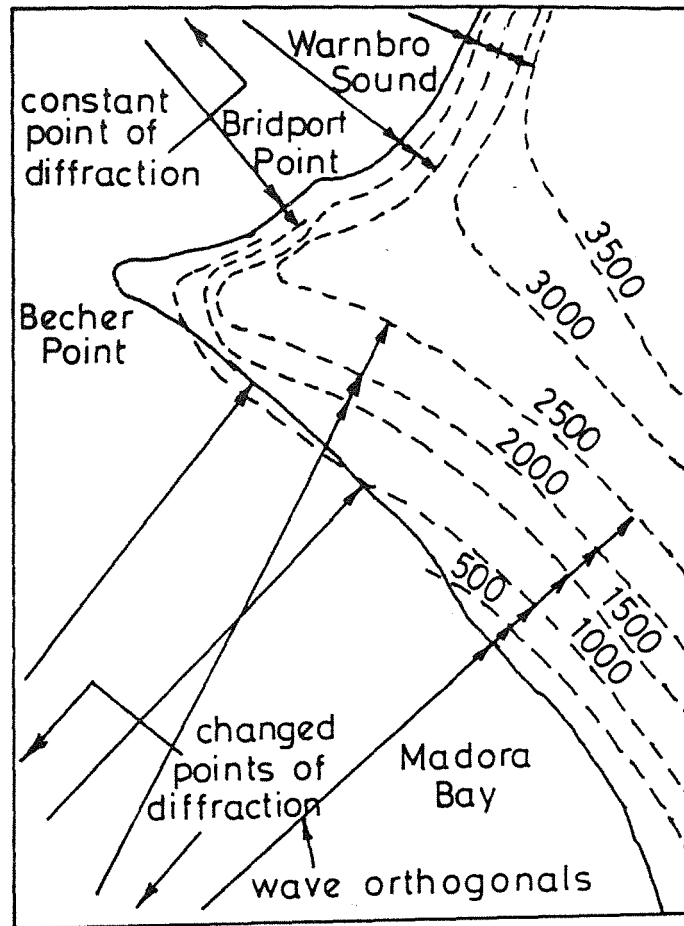


Figure 12 Progressive development of Becher Point.

The erroneous view (5) expressed on the formation of a spit and submerged foreland centred on a gap is due to the authors' wrong assumptions regarding wave diffraction patterns at such openings. There were made available to the Reviewer by LPSC as Figure 4 (p.40) of their section : "Sediment Transport in Southern Warnbro Sound" submitted to the proponent, which was abridged in the ERMP Report, causing this figure to be omitted. It is reproduced as the Reviewer's Figure 13. The correct wave patterns are presented in Figure 7 and 8 which indicate that the wave energy entering a gap will spread sediment into the lee of the obstructing structure.

The semi-circular shorelines so resulting are similar to Warnbro Sound itself, when the bulk of the energy reaching the shore has been diffracted after passing through the gap. Becher Point as well as Mersey Point, the extremities of the Sound are maintained by the continuous reef in the south and Penguin Island in the north. Being only sandy prominences they are very subject to change in wave climate either side of them which

otherwise retain the apex in position. Especially can they be eroded swiftly by storm waves from some oblique direction.

The large erosion on the southern flank of Becher Point from 1955 to 1979, which the authors state occurred mainly in the 1970's, could be due to recent collapse of reef at its southern end, so causing a deviation westward of the orthogonals reaching this coast. On p.7 of Appendix F it is stated that : "the coast retreated a maximum of 20 m between 1942 and 1955 (1.5 m/year)." However, inspection of Figure 3 (18 in the text) shows that there was accretion during this time and then a modest erosion to 1965 and substantial denudation between 1965 and 1979, supporting the view previously expressed of massive erosion in the late 1970's.

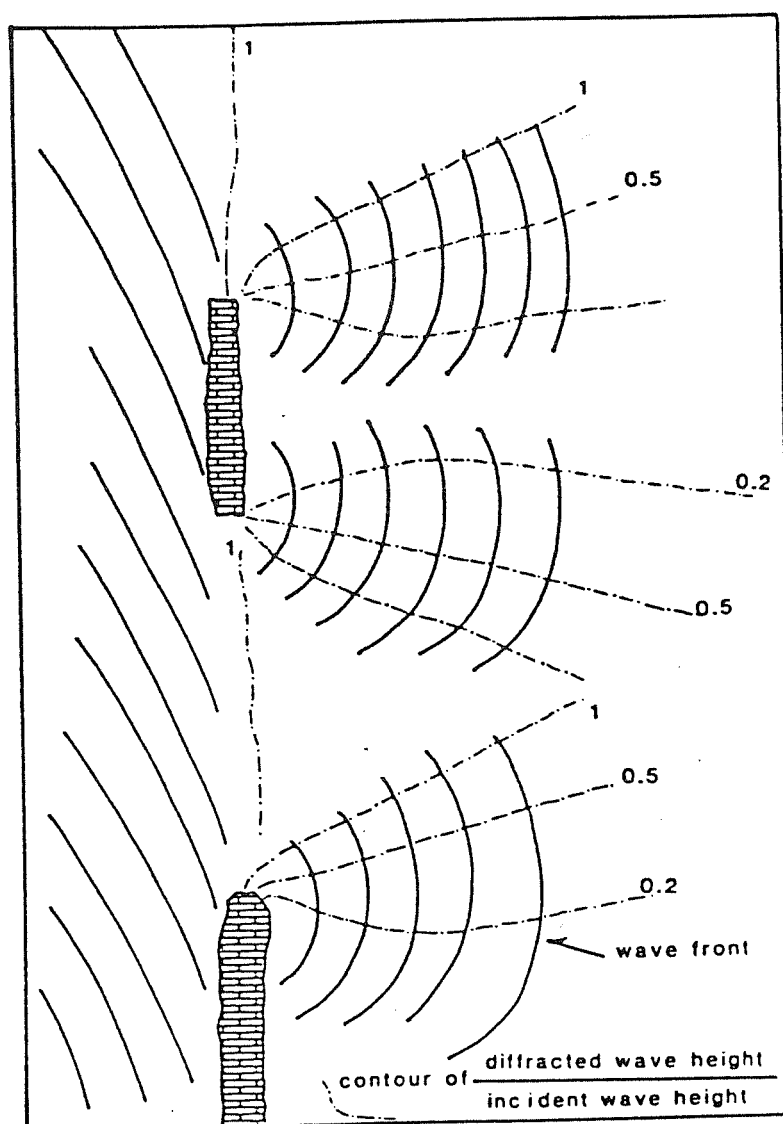


Figure 13 Wave pattern assumed by Searle (5) inside a reef gap.

Comparison of accretion and erosion south of Becher Point and in proximity of Bridport Point shows that from 1942 to 1955 accretion occurred simultaneously in these two locations. From 1955 to 1965 slight erosion occurred south of Becher Point whilst slight accretion occurred near Bridport Point. Hence correlation of shoreline processes in the two locations with completely different wave climates cannot be undertaken. The erosion from 1965 to 1979 on the south flank of Becher Point was substantial but only mild at Becher Point. Building out of shorelines can be associated with the more severe storms which demand frontal dunes besides beach berm. The extra large volume in the offshore bar is then returned to make a wider beach berm.

In respect of shoreline movements at the Westport site the authors acknowledge that accretion and recession is very slight. On p.41 of Vol. I of the ERMP Report it is stated : "This indicates that the rate of progradation has declined within the last 1000 years to level well below the average of 0.17 m/year ... Evidence from aerial photographic records suggests that progradation since 1942 at least has been negligible."

In the prediction of future trends of the shoreline due to the Westport breakwaters the protection of a similar entrance channel at Jurien Bay is cited by RB in Appendix H. This bay is a crenulate shaped bay in its southern half, up to Middle Head which is a natural headland. By tests available, the Reviewer was able to check that this portion of the embayment is in static equilibrium. This implies that little or no sediment is passing Island Point, to the south, into this section of coast. It infers also that littoral drift in the long term is zero or the bay is stable. In this sense it equates Warnbro Sound exceedingly well, since it too is in static equilibrium.

The major difference in swell wave propagation between the two settings is that in Warnbro Sound the orthogonals are essentially straight whilst at Jurien Bay they refract across the shoaling depths. However, in each case they arrive normal to the coast around the whole periphery and hence the stability of both. As already discussed a small amount of drift can occur daily or seasonally due to oblique locally generated waves arriving at any location which will vary with their duration and possible fetch. In Warnbro Sound this fetch is limited to the confines of the reef whilst at Jurien Bay the W to NW waves have almost infinite fetch.

It is stated in Appedix H "300 m north of the breakwater around 25 m of erosion has been recorded." This could be due to oblique reflection of swell waves from this structure, angled approximately 60° to the shoreline. The reflected waves, in conjunction with the incident waves could scour the bed about this location and cause beach recession. A similar local degradation could occur some 100 m north of the northern oblique breakwater at Westport but this is only a local effect.

Two short groynes have been installed south of the entrance in Jurien Bay of which RB comment : "South of the southern groyne (Hastings Street) there has been little change in shoreline position and so far no evidence of any sand accumulation in the groyne field to the north. Seasonal realignment of the shore between the structure is , however, evident as is minor movement of sand past the ends." This would indicate to the Reviewer that this shoreline is in static equilibrium from the predominant swell. The persistent southerly winds are unlikely to move sediment where the groynes are located, although they could effect more further north along the coast where the entrance is. But the breakwaters have only been in position for under two years and the beach renourishment carried out recently would hide any long-term changes.

The comparison with Westport is not convincing as acknowledged by RB in the statement : " Obviously the harbour gives no clue as to its impact on the longer term coastal processes."

3.4 Influence of Breakwaters

At Westport the northern breakwater is angled at 45° to the shoreline and hence suffers two disadvantages. Firstly, it will receive swell waves at about this obliquity and hence generate short crested waves due to the interaction of reflected and incident crests. These are conducive to scour, with material moved along it to the NE. This transport will be aided by the waves generated within the Sound by S and SW winds. The scour trough could be sufficiently deep for subsidence of the breakwater to occur. Although this structure is only 150 m long the shallow depths could cause this scour to be of some concern. In Japan many long breakwaters are angled at 30° to 45° with resulting scour, for which much research has been undertaken. Similar tests have been carried out at the University of Western Australia. As there is no addition to the sand being removed during the summer period the removal adjacent to the breakwater face needs some thought.

The second disadvantage is that during periods of N and NW waves the longshore littoral current could carry sand along this angled face, aided by the short-crested pattern formed by swell diffracted through the reef entrance, and deposit it at the entrance of the channel and perhaps down the slope of the offshore platform. If this occurs during a storm sequence the transporting activity will be occurring further offshore than normal, nearer the tip of the breakwater. Hence shoaling of the entrance can be more pronounced.

It is not appropriate for the Reviewer to suggest changes to the breakwater geometry to offset these deficiencies but he would strongly suggest an alteration to prevent offshore deflection of this littoral drift which could result in loss offshore or siltation of the channel.

Two aspects of the waterways created require comment, namely, the exchange of water within the system with that in the open ocean, and the likely movement of sediment on the slopes adjacent to the vertical walls supporting the allotments.

4.1 Set-Up due to Winds

It is stated on P.23 of Vol. I of the ERMP Report that : " the long axis of the waterway is orientated north-south to enhance circulation by maximising set up of wave and surface currents by prevailing south-southwesterly winds."

By taking this N-S length as 1600 m (see Figure 14) and the mean depth of water as 3.0 m and a wind speed of 10 m/sec the Reviewer's calculation (6) of set-up without waves is 2 cms which is unlikely to cause any significant exchange of water along the waterway. If a depth of 3.5 m is assumed this value decreases to 1.5 cms. An increase of wind speed to 15 knots increases the set-up for the smaller depth to about 5.0 cms, which is still extremely small.

The wave set-up will be minimal due to waves refracting towards the shoaling bed adjacent to allotments and diffracting along the cross-canals. Hence the wave heights will be small without any substantial increase in height due to shoaling as on a normal beach. This component of set-up can therefore be ignored. The Reviewer believes, therefore, that some attention needs to be given to retaining the quality of the water in these shallow depths during the hot summer periods when algae tends to form.

The statement on p.23 of Vol. I that the sloping sides of the canals will enhance flushing "due to the greater impact of wind on the increased surface area" appears rather irrelevant due to the overall small area of the total waterway. On the same page it is stated : "the cross-canals are orientated east-west to take advantage of easterly winds."

These are of small velocity, for which a value of 7 m/sec might be assumed. There are four such cross canals, two of which are narrowed to 28 m from 60 m, with lengths of 500 m. The set-up resulting from this wind is, according to the Reviewer, only 1 mm. Hence the above statement appears presumptuous.

The tidal range in Warnbro Sound is around 0.4 m with very infrequent surges of up to 1.0 m. These high and low water levels last for a matter of 4 hours during which time water must flow through the entrance. This entrance is only 40 m bottom width and just over 50 m at the surface. It therefore acts like a nozzle restricting flow. It could be improved by widening to the 100 m width just inside the entrance. The waves entering

would be minimal but could be reduced by providing spending beaches in place of the curved wall on the northern side of the approach channel.

4.2 Sand Movement

Waves generated within the long N-S canals by southerly winds although small could be refracted towards walls supporting the allotments by the sloping bed adjacent to them. At these end allotments the waves will reflected obliquely and so cause scouring of bed with the small depths at the wall from zero to - 0.8 m (7). This material will be transported into the canals on the northern side and create shoaling as illustrated in Figure 14. This will create a navigation problem unless these land extremities have a bed protection preferably of a mattress type to withstand these short-crested waves. In the figure the zones most affected are designated. Where scouring occurs the supporting walls could collapse.

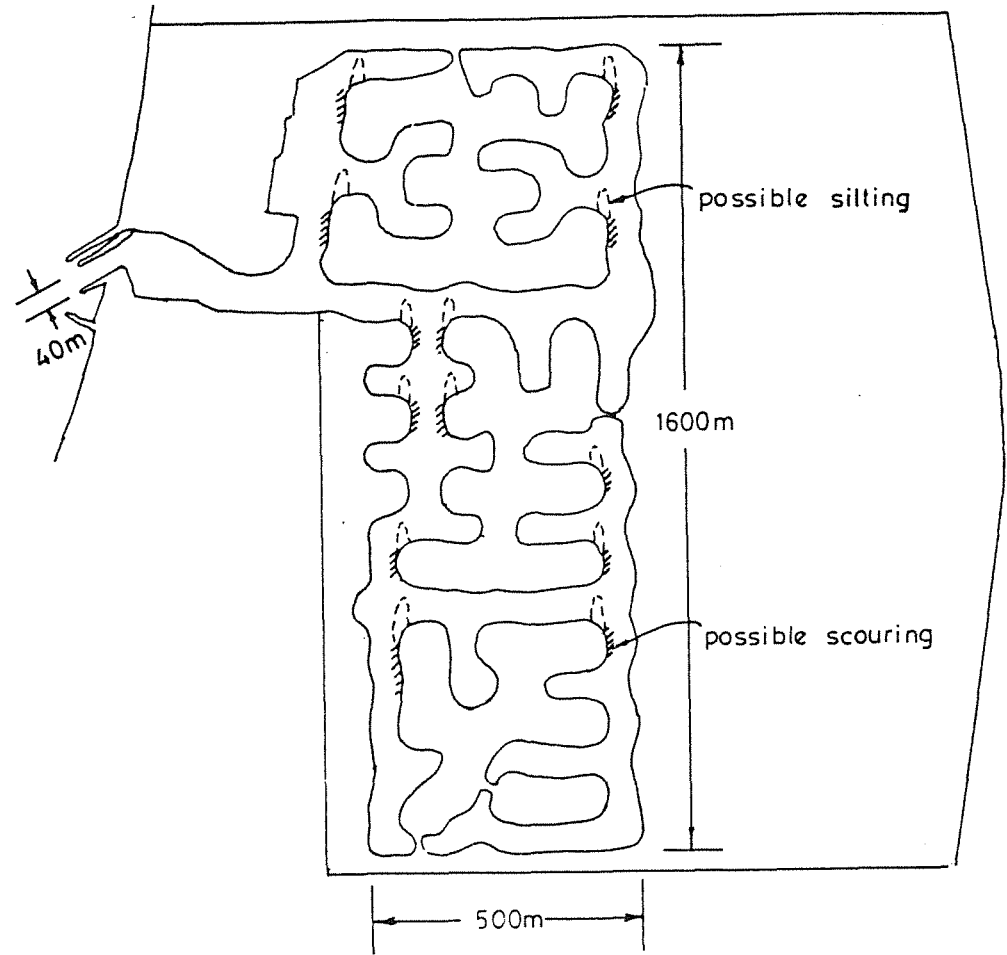


Figure 14 Plan of canals showing possible zones of erosion and accretion.

REFERENCES

1. Silvester, R. and H.L. Mitchell (1977) Ocean waves around the coastlines of Australia. Proc. 6th Austral. Conf. Hydraulics and Fluid Mech., Part I, pp. 160-164.
2. Silvester, R. (1981) Diffraction through a breakwater gap. Trans. Instn. Engineers Australia., Vol. CE23, No. 2, pp.114-117.
3. Wiegel, R.L. (1964) Oceanographical Engineering. Prentice-Hall, New York, pp.216.
4. Silvester, R. (1974) Coastal Engineering Vol. I, Elsevier, Amsterdam, pp. 338-340.
5. Searle, D.J. (1984) A sedimentation model of the Cape Bouvard to Trigg Island sector of the Rottnest Shelf, Western Australia. Ph.D. Thesis, University of Western Australia.
6. Silvester, R. (1974) Coastal Engineering Vol. II, Elsevier, Amsterdam, pp.180.
7. Silvester, R. (1972) Wave reflection at seawalls and breakwaters. Proc. Instn. Civil Engrs., Vol. 51, pp. 123-131.

AN EVALUATION OF THE WESTPORT E.R.M.P.

BY

J. R. HUNTER

THE RESULTS OF WORK FUNDED BY :

THE ENVIRONMENTAL PROTECTION AUTHORITY,
WESTERN AUSTRALIA, 6000

PROJECT : CMST057

MAY. 1987

REPORT : C87-4

CENTRE FOR MARINE SCIENCE AND TECHNOLOGY,
CURTIN UNIVERSITY OF TECHNOLOGY,
(FORMERLY WESTERN AUSTRALIAN INSTITUTE OF TECHNOLOGY),
WESTERN AUSTRALIA, 6102

CONTENTS	PAGE
1 INTRODUCTION	1
2 DETAILED EVALUATION	3
2.1 EVALUATION OF VOLUME 1 OF E.R.M.P.	3
2.2 EVALUATION OF APPENDIX B, VOLUME 2 OF E.R.M.P.	4
3 CONCLUSIONS	9
REFERENCES	10
APPENDIX	
THE FLUSHING OF BASINS IN WESTERN AUSTRALIA	
1 FLUSHING MECHANISMS AND REQUIREMENTS	1
1.1 FLUSHING MECHANISMS	1
1.1.1 Introduction	1
1.1.2 Flushing by Astronomical Tides	1
1.1.3 Flushing by Barometric Tides	2
1.1.4 Wind-induced Flushing	3
1.1.5 Slope-induced Flushing	4
1.1.6 Wave-induced Flushing	4
1.1.7 Density-induced Flushing	5
1.2 FLUSHING REQUIREMENTS	6
2 THE DOMINANT PROCESSES IN WESTERN AUSTRALIAN BASINS	7
REFERENCE	7

1. INTRODUCTION

This report was commissioned in April, 1987, as an evaluation of aspects of water quality and exchange in the Environmental Review and Management Programme, submitted by Delta Holdings Pty. Ltd, for the proposed Westport development near Wanbro Sound, Western Australia (Delta Holdings Pty. Ltd, 1986).

The E.R.M.P. deals with the above aspects in a quite thorough way, except for various inaccuracies and apparent inconsistencies, and the omission of a proper treatment of horizontal water exchange within the proposed canal development (see Section 2). The overall treatment is one of

- (1) Estimating the various pollutant loads to the waterways.
- (2) Estimating the rate of flushing between the waterways and Wanbro Sound. There is a limited discussion of exchange within the waterways, and also of exchange between Wanbro Sound and the more open shelf waters.
- (3) Combination of the results of (1) and (2) to yield estimates of the concentrations of various pollutants in the waterways and (to a lesser extent) in Wanbro Sound.

While the above method probably has the capacity to yield the best available estimates of pollutant concentrations in the environment, it is characterised by two main problems :

- (a) Each step in the calculations involves considerable error. The accumulation of these errors in the final predictions may lead to values with an acceptable mean value but a standard deviation that encompasses a wide range of unacceptable environmental conditions. The present E.R.M.P. makes no attempt to quantify these errors.
- (b) The assumptions are made that the input pollutant load are known and will remain unchanged through the life of the development. Scenarios such as the unforeseen dumping of large quantities of nutrients in the waterways (eg. by the transport of seagrass wrack or other sources of nutrients from the open sea) are not considered.

The approach adopted by the present author is simpler, rather more pragmatic and also more conservative. In order to reduce the error in the final predictions, less steps are involved. Only the flushing and exchange characteristics are considered. It is assumed that :

- (i) The the dominant threat in a Western Australian

coastal basin (be it a harbour, marina or canal estate) is one of nutrient enrichment and consequent unacceptable algal growth.

- (ii) The basin should be capable of enduring a massive load of nutrients without major environmental problem.

The above criteria are satisfied if the flushing time of the basin is less than the time constant for algal growth (typically, a few days). It is clear that Western Australian coastal basins do not generally satisfy this criterion, as indicated by the fact that their waters often contain visible algal populations. There also have been few public health or chronic aesthetic problems with such basins. However, that does not necessarily mean that such problems will not occur in the future (perhaps as nutrient loads change), or that effort should not be expended in actually improving on existing environmental conditions. It is the author's view that basin design should at present be based on a "flushing time" criterion. These arguments, and methods of evaluating the flushing time, are described in the Appendix to this report. For a basin connected to the sea, it is provisionally suggested that the exponential flushing time (as defined in the Appendix) should be less than 3 days. It may well be that subsequent experience with existing developments causes a minor modification of this figure - however the flushing time at present appears to be the best classification parameter for these basins.

It is with these latter arguments in mind that the following evaluation has been prepared.

2. DETAILED EVALUATION

The following evaluation concentrates only on issues that the present author regards as contentious or wrong. The absence of any comment on a particular water quality issue indicates that in that instance the present author is in broad agreement with the E.R.M.P..

2.1 EVALUATION OF VOLUME 1 OF E.R.M.P.

Page 19, last para., line 5.

Although it is probable that wind-driven exchange within the waterways is enhanced by their lying in a north-south direction, this effect is not quantified either here or in Appendix B. Section 2.2 of this report does provide such an estimate, but a better evaluation of this exchange mechanism should be carried out based on a rather more realistic model that includes the statistics of the time variations of wind speed and direction. Section 2.2 of this report also suggests that the depths of the eastern and western north-south waterways differ by about 0.5 metre, to greatly enhance wind-driven exchange within the basin.

Page 23, "5.5.2 Waterways Design"

These "beneficial" aspects of the canal design are not quantified either here or in Appendix B. Unfortunately, Morris (1981), from whom these criteria were derived, does not provide quantitative estimators of these effects, but does suggest computer models that may be used for predicting them. Apparently conflicting aspects (c) and (d) indicate the importance of including the statistics of the time variation of wind speed and direction in any model of wind-induced exchange. Aspect (e) is obscure - presumably it relates to the generation of circulating flows by the interaction of wind stress and a variable bottom topography. However, as shown in Section 2.2, a far better way to employ this effect is to dredge the two major north-south channels to different depths. Aspects (f) and (g) are not quantified.

Page 25, "5.6.1 Staging"

The staging of the construction does enable aspects of the exchange processes predicted both in the E.R.M.P. and in this report to be verified and adjusted accordingly.

Page 73, Section 7.3.3, 3rd para.

As noted above, these "features that contribute to efficient internal circulation and mixing" are not quantified.

Page 73, last 2 lines

As detailed in Section 2.2 of this report, the present author believes that situations could arise where the water quality within the waterways would be considerably worse than that in Wanbro Sound.

Page 74, 2nd para.

Since the quantitative aspects of the physical background to the Marine del Rey in California is not given here, and since they could differ markedly from conditions in Western Australia, little weight can be placed on this comparison.

Page 74, last para. to page 75, 5th para.

As noted in Sections 1 and 2.2 of this report, these estimates of pollutant concentration in the waterways could be considerably in error, especially as regards the issue of internal horizontal exchange within the basin.

Page 75, last para.

Due to unquantified errors in the predictions of pollutant concentrations, and due to the absence of suitable treatment of the internal exchange mechanisms in the waterways, comparisons between these predictions and the DCE Water Quality Criteria are open to doubt.

Page 88, 5th para.

As noted in Section 2.2 of this report, forced mixing of the whole area of the waterways would be very difficult.

Page 89, 2nd para.

For reasons given above, and in Section 2.2, the statement that "water quality in the waterways will be little different from that in Wanbro Sound" is open to question.

2.2 EVALUATION OF APPENDIX B, VOLUME 2 OF E.R.M.P.

Page 3, last para.

This description of wind-driven flows in Wanbro Sound is consistent with current thinking. The mechanism of topographically-induced gyres is the same as that suggested later in this section as a means of enhancing the internal wind-driven exchange in the waterways (ie. by dredging the main north-south channels to different depths).

Page 13, "3.2.1 Water Balance"

There appears to be considerable discrepancy between the

values given in Figure 6, and those give in Appendix A, pp. 16 and 17. However, these values do not appear to be used in the evaluation of the pollutant loads.

Page 19, penultimate para.

Rather than use tidal forcing to produce a net circulation around the islands, it is much easier to use wind forcing and a variable bottom topography (see comment on page 23, 1st para.).

Page 20, 1st para.

The discussion of density currents is not quite correct. While the freshwater flow is less than 1% of the tidal flow, this can still give rise to significant density-induced circulation. Using the method of classification of Hansen and Rattray (1966), it may be shown that a freshwater flow of 1300 cu. metres / day (on a rainday, see Section 3.2.1 of E.R.M.P.) would give rise to a "fjord-like" circulation with a thin fresh water layer flowing seaward on the surface at a speed of around .01 metres / sec. (of the same order as the tidal current). Such circulations are common in the weakly-mixed estuaries of Western Australia.

Page 20, 2nd para.

The assumption of 90% exchange of "waterways" water with "Sound" water, while a guess, is probably reasonable. However, it should be noted that this does not mean that the water passing out of the waterway on the ebb tide contains 90% "waterways" water. It is highly unlikely that the present configuration of basin would allow near-complete horizontal internal mixing within the waterways during one half tidal cycle.

Page 20, last para.

See comment on "Page 20, 1st para."

Page 21, 3rd para.

The statement that the thermocline would be "close to the floor because of the clarity of the water" presupposes that significant light (and heat) would penetrate to the bottom. Experience of the conditions in other Western Australian basins does not support this.

Page 21, last para.

While 3 watts / megalitre may be required to mix a water column that is already vertically thermally stratified, it is likely that less power (typically 1 watt / megalitre) would be required to keep the water vertically mixed, once

any initial stratification were removed. Hence it is probable that the median wind (of speed 5 m/s) would be adequate to ensure vertical mixing. However, it should be born in mind that figures that relate to the apparently low power requirements of environmental mixing and exchange are often misleading. For instance, a figure of 5 kilowatts is given on page 23 (para. 4) as the total power requirement for mixing the whole basin (a figure derived from the above power density and the basin volume), should artificial mixing be required. However, this power would need to be reasonably evenly distributed over the whole basin, presenting formidable problems and a power requirement far in excess of 5 kilowatts. A further example of the misleading nature of these power estimates is the power needed to circulated the water horizontally. It can be shown that the power required to overcome friction and pass one basin volume through the basin in 7 days is less than 1 watt. However, this would require a mean flow of 2.8 cu. metres / sec. (of the same order as the discharge from a reasonably sized marine sewage outfall). If this flow rate were to be supplied by a pump, through a reasonably dimensioned culvert, the power requirements would of order 100 kilowatts - an increase by a factor of 100,000 over the "environmental" estimate ! Hence one should beware of the apparent ease of artificially influencing mixing and exchange in the environment.

Page 22, 2nd para.

While boundary mixing may have been shown theoretically to be a viable mechanism of mixing in canal estates, it is doubtful whether this has been confirmed in practice.

Page 23, 1st para.

It should be noted that the tidal exchange mechanism yields an absolute minimum flushing time of 7 days. Wind-driven overturning in the vicinity of the entrance may be sufficient to bring this down to about 5 days (this may require some widening of the entrance channel, to bring it into line with the total cross-sectional area of the main north-south channels). It is also necessary for the basin to be horizontally internally mixed with a similar time scale, and it may be shown that wind-driven overturning is probably sufficient to give an internal exponential exchange time of about 5 days. Dredging of the two main north-south canals to different depths (differing by only about 0.5 metres) would promote lateral circulation and give an internal exchange time of around 1 day (this depends on the interaction of wind stress and variable topography (Hearn et al, 1987)). Whichever mode of internal mixing applies, it would appear that the overall exponential flushing time would be limited by exchange at the entrance to about 5 days. If it is accepted that a flushing time of 3 days be adhered to, then the main north-south canals would need to be dredged to different depths, and some method

of improving the exchange at the entrance would have to be invoked. Suitable candidates for the latter task are :

- (1) Dredging a second entrance to the sea from the southern end of the basin.
- (2) Redesign and enlargement of the existing entrance channel.
- (3) Artificial pumping of seawater through the basin at a rate of about 6.6 cu. metres per second, and a power consumption of hundreds of kilowatts.

Page 23, 4th para.

The comments concerning page 21, last para. should be noted. It should also be emphasised that the type of mixing referred to would only remove vertical stratification, and would not contribute to horizontal exchange within the basin.

Page 23, "3.4 Water Quality"

The techniques presented here are conventional "one-box" modelling, and are quite sound if the initial assumption that the waterway "is well mixed" is correct. However, as is shown above, this may or may not be true, depending on the relative magnitudes of exchange at the entrance and within the basin.

Page 28, 2nd para.

The calculation to predict the effect of the waterways on water quality in Wanbro Sound is obscure. Without some information on the flows that flush the Sound, it does not seem possible to make this calculation. However, since the flows flushing the Sound will be much larger than the flows flushing the waterways, it is felt that, if the water quality in the waterways is satisfactory, then so too will be the water quality in the Sound. This may be quantified as follows

Assume the typical current flowing through Wanbro Sound

= .03 metres / sec. (using measurements from nearby coastal regions, Steedman and Craig, 1983)

and the typical cross-sectional area of Wanbro Sound

= 45,000 sq. metres.

Hence the oceanic flow flushing Wanbro Sound

= .03 x 45,000 = 1350 cu. metres / sec.

Volume of the waterways

$$= 1,700,000 \text{ cu. metres}$$

If the waterways flush in 3 days (as is probably required), the flow flushing the waterways to the ocean

$$= 1,700,000 / (3 \times 24 \times 3600) = 6.6 \text{ cu. metres / sec.}$$

Water leaving the waterways will hence be diluted up to :

$$1350 / 6.6 = 200 \text{ times in Wanbro Sound.}$$

This level of dilution would clearly not apply in the immediate vicinity of the entrance channel to the waterways. However, the concentration of contaminants in the Sound would decrease quite rapidly from the "waterways" value near the entrance channel to around (1 / 200) times this value in the middle of the Sound.

Page 30, 1st para.

See comments to page 21, last para.

Page 32, 4th para.

See comment to page 20, 1st para.

Page 32, 5th para.

See comment to page 21, 3rd and last para.

Page 32, 6th para.

As has been noted in the comments to page 23, 1st and 4th para., the problem of *horizontal* exchange within the waterways was not addressed, although it is probable that the existing configuration would have an internal wind-driven flushing time of about 5 days. As noted in Section 1 of this report, it is not felt that this rate of flushing is adequate, and that a figure of 3 days is more appropriate.

CONCLUSIONS

The treatment, in the E.R.M.P., of aspects of water quality and exchange, although thorough in many respects, is deficient in the following main areas :

- (1) The flushing time derived from tidal flushing (7 days) is inadequate to prevent algal blooms, in the event of unforeseen nutrient loads to the waterways. A figure of 3 days would be more appropriate.
- (2) The problem of horizontal exchange within the waterways was not properly addressed, although it would appear that wind-driven overturning would yield an internal exchange time of about 5 days.

It would appear that the canal system could be designed to satisfy the "3 day flushing time" criterion if the following modifications are made :

- (a) The two main north-south canals are dredged to depths differing by about 0.5 metres.
- (b) The exchange at the entrance is improved by such facilities as the provision of a second entrance; enlargement and re-design of the existing entrance; or artificial pumping of seawater through the basin.

Such re-design should be accompanied by a modest modelling effort to elucidate the wind-driven flushing of the basin. This modelling should take account of the statistics of the time variation of the wind speed and direction.

REFERENCES

- Delta Holdings Pty. Ltd., 1986. Environmental Review and Management Programme for Westport, Volumes 1 (Report) and 2 (Appendices), Nov. 1986.
- Hansen, D.V. and Rattray, M., 1966. New dimensions in estuary classification, *Limnology and Oceanography*, Vol. 11, No. 3, pp. 319-326.
- Hearn, C.J., Hunter, J.R. and Heron, M.L., 1987. The effects of a deep channel on the wind induced flushing of a shallow bay or harbour, *Journal of Geophysical Research* (in press).
- Morris, F.W., 1981. Residential canals and canal networks : design and evaluation, Florida Sea grant College, Report Number 43.
- Steedman, R.K. and Craig, P.D., 1983. Wind-driven circulation of Cockburn Sound, *Aust. J. Mar. Freshw. Res.*, Vol. 34, pp. 187-212.

APPENDIX
THE FLUSHING OF BASINS IN WESTERN AUSTRALIA

1 FLUSHING MECHANISMS AND REQUIREMENTS

1.1 FLUSHING MECHANISMS

1.1.1 Introduction

Decay, growth and flushing processes may be characterised by specific time scales, generally termed "time constants". Some confusion exists due to the existence of different ways of defining a time constant. Two common forms are in general use :

(a) The exponential time constant

This is the time required for growth or decay by a factor of "e" (2.718). It is the reciprocal of the "rate constant".

(b) The 90 percentile time constant

This is the time required for growth or decay by a factor of 10. It is frequently referred to as the "T90" time.

(a) and (b) are related by :

$$(90 \text{ percentile time constant}) = (\text{exponential time constant}) \times 2.303$$

In this document, all such time scales relate to the exponential time constant. In cases where the derivation is based on a process being effectively carried out to completion (eg. the wind-driven flushing of a basin, 1.1.4 (b) below), then that divergence from the normal notation is indicated.

Harbours, marinas and canal developments ("basins") may be flushed by a number of mechanisms, as described below.

1.1.2 Flushing by astronomical tides

Many areas of the World, including Fremantle, are subject to significant vertical oscillation of the sea surface due to the astronomical tides. During a complete tidal cycle, a volume of water is removed from the basin and replaced with a volume of water from the ocean. Depending on the nature of the mixing processes operating in the ocean, some or all of this returned water may consist of water that had previously been removed from the basin. For optimum flushing, none of this returned water should consist of water previously removed from the basin. The water that is returned from the ocean may then mix with water already existing in the basin. For optimum flushing, this mixing process should be completed before the subsequent ebb tide (ie. the next removal of water from the basin). The process of tidal exchange hence depends on three

main factors :

(a) The ratio :

$$\frac{(\text{volume of basin})}{(\text{tidal prism})}$$

(where the "tidal prism" is the volume of water removed each tidal cycle)

(b) The amount of mixing of water in the ocean

(c) The amount of mixing of water in the basin

If (b) and (c) are completed at the appropriate time in the tidal cycle (ie. (b) between ebb and flood, and (c) between flood and ebb) then the flushing time applicable to this mechanism is given by multiplying the ratio in (a) by the tidal period :

$$\text{Flushing time} = \frac{(\text{volume of basin}) \times (\text{tidal period})}{(\text{tidal prism})} \quad (1)$$

For the case of a flat-bottomed basin and a level sea surface the flushing time becomes :

$$\text{Flushing time} = \frac{(\text{depth of basin}) \times (\text{tidal period})}{(\text{tidal range})} \quad (2)$$

Unfortunately, however, mixing processes (b) and (c) are generally far from complete and the above relationship yields an absolute lower limit to the flushing time appropriate to tidal mechanisms.

For a small basin, such as a harbour or a marina, the tidal currents required to cause the observed oscillation in surface elevation within the basin are rather small. For diurnal tides, the maximum tidal current is given approximately by :

$$\frac{(\text{tidal range}) \times (\text{horizontal dimension of basin})}{28,000 \times (\text{depth of basin})}$$

Hence, for a basin of horizontal dimension 250 metres and depth 4 metres, and a tidal range of 0.4 metres, the maximum tidal current is approximately .001 metres per sec..

1.1.3 Flushing by barometric tides

The sea level in this region also undergoes fluctuations of

range typically 0.2 metres and time scale roughly 5 days, caused by meteorological forcing ("barometric tides"). Since the flushing time given above is proportional to the tidal period, and inversely proportional to the tidal range, flushing caused by barometric tides would, at first sight, appear to be an order of magnitude smaller than that caused by astronomical tides. However, since the time scale is longer, there is more time for the mixing processes in the ocean and in the basin ((b) and (c), above) to act. Hence the true flushing time is probably determined only by the ratio of basin volume to the volume of water removed in a "barometric tidal cycle", and is given adequately by equation (1) or equation (2) (where the "tidal period" is roughly 5 days and the range typically 0.2 metres).

1.1.4 Wind-induced Flushing

The effect of wind stress on the sea surface gives rise to current flows both inside and outside the basin. Inside the basin, the currents may be divided into two types :

(a) Lateral Circulations

This type of circulation generally only exists in basins of non-uniform bottom topography (ie. a bottom which is not flat). The circulation pattern normally consists of a water flow in the wind direction in the shallower water, and a compensating flow against the wind in the deeper water (eg. Hearn, Hunter and Heron, 1986).

(b) Vertical Circulations (Overturning)

Any basin (including one with a flat bottom) exhibits this type of circulation, consisting of a water flow with the wind near the sea surface, and a compensating flow against the wind near the bottom.

As a rule-of-thumb, the magnitude of this circulation (ie. the current strength, averaged over the depth) is about .15 % of the wind speed. For the complete flushing of a basin of length L, the maximum distance a water particle needs to travel is approximately $2 \times L$. An estimate of the time for complete flushing of a basin, by wind-induced overturning, is hence :

$$\frac{2 \times L}{.0015 \times (\text{wind speed})} \quad \text{seconds}$$

where the "wind speed" should generally be taken as the component of wind blowing from the entrance, either into or out of the basin.

This formulation should be modified slightly by the consideration of vertical mixing processes, which effectively "short-circuit" the simple overturning mechanism, thereby increasing the flushing time. An adjustment should also be made to convert the above time for complete flushing to an exponential flushing time (thereby decreasing the value). For a basin of the dimensions of a harbour or marina, these two effects approximately cancel, so for the present work it is assumed that the exponential flushing time by vertical overturning is give by :

$$\frac{2 \times L}{.0015 \times (\text{wind speed})} \quad \text{seconds.}$$

Lateral circulations may be stimulated by designing basins with non-uniform bottom topography. Such circulations are generally preferable to vertical circulations for the following reasons :

- (a) Vertical circulations may be suppressed (or confined to a surface mixed layer) if there is sufficient vertical density stratification of the water column, as frequently occurs in harbours, marinas and canal developments.
- (b) Vertical circulation is not an adequate flushing agen for buoyant contaminants (eg. oil or floating seaweed). It may even serve to concentrate floating matter in the basin (under conditions of wind blowing into to basin from the ocean).

1.1.5 Slope-induced Flushing

A basin with two distinct entrances (or with one entrance together with a culvert or section of porous breakwater) may be flushed if a significant difference in sea level exists between the seaward ends of these entrances. This level difference may be induced by the tidal or wind-induced motions in the adjacent ocean, or by the presence of variations in the ambient wave climate (as described in 1.1.6, below). Simple hydraulic calculations for a small basin with two entrances show that a sea level difference of less than 1 mm. is generally sufficient to ensure adequate flushing. Unfortunately, a slope of this magnitude is in many cases not maintained for a sufficiently long time in the ocean region adjacent to the basin.

1.1.6 Wave-induced Flushing

Waves may induce circulations in a basin by two main

mechanisms :

- (a) Waves impinging on, and being partially reflected by a breakwater cause a mean set-up of the sea surface near the wall, due to the momentum transferred in the wave direction. A difference in sea level may hence occur across the wall. If the wall is porous, or if a culvert is placed through the wall, this level difference drives a flow into the basin. The set-up may be estimated for the case of the complete reflection of a shallow-water wave from a vertical wall :

$$\text{Set-up} = (\text{Square of wave height}) / (8 \times \text{water depth}).$$

Hence, for a wave height of 1 metre and a water depth of 4 metres, the set-up is about .03 metres.

Simple hydraulic calculations indicate that the presence of a culvert in a breakwater has a negligible effect on the flushing of all but the smallest basins. There also appears to be no data on the performance of porous breakwaters, as regards flushing, although hydraulic estimations would indicate that these, too, would have little beneficial effect.

- (b) Waves transport surface water in the direction of wave propagation (at a rate of a few percent of the wind speed, in the open ocean). However, since the generation of waves by wind is still not well understood, it is normal to either include this contribution as part of the overall wind-induced circulation described in 1.1.4, above, or to ignore it altogether (in most harbours, marinas and canal developments, the waves are, by design, small).

1.1.7 Density-induced Flushing

Flushing of a basin may be driven by horizontal pressure gradients arising from horizontal variations in water density. These density variations may be caused by changes in water temperature (eg. by differential heating or cooling within the basin) or by changes in salinity (eg. by the addition of fresher water through land or sewerage drainage, or by the process of surface evaporation). These effects are clearly site-specific. A well-designed basin would generally have little inflow of fresher water, due to the fact that such inflows are generally accompanied by a nutrient load that could lead to eutrophication problems. However, it is quite likely that differential heating or cooling of the basin (an effect that would be enhanced if the basin topography were variable) could lead to substantial density variations, both through thermal expansion and through evaporation.

1.2 FLUSHING REQUIREMENTS

The principal marine environmental problem likely to be encountered in a well-managed harbour or marina with insufficient flushing is one of organic and inorganic nutrients entering the basin (both through the entrance and via stormwater) leading to the formation of algal blooms, the generation of organic detritus and consequent oxygen depletion. The relevant time scales are as follows :

Algal growth (marine conditions)	: 3 days
Algal growth (river conditions)	: 1.5 days
Oxidation of organic matter	: 4 days
Oxygenation of water of depth 4 metres	: 3.3 days

Algal problems should hence not occur if the flushing time of the basin is no larger than the appropriate algal growth time. As a rule-of-thumb, the flushing time for a "marine" basin should be less than 3 days, while that for a "river" basin, less than 1.5 days.

In practice it would appear that few existing harbours, marinas or canal developments in Western Australia satisfy above criterion. However, it is also clear that there are at present no dramatic eutrophication problems in these basins. These two apparently conflicting statements may be reconciled by the fact that algal levels are at present most probably limited by the available nutrient supply, and not by the flushing characteristics. If the nutrient supply were raised (eg. by increased levels of runoff to the basin, or increased nutrient concentrations in that runoff) then algal blooms may well result. It seems clear that the flushing levels are not in general, adequate to ensure environmentally satisfactory conditions under all possible levels of nutrient loading.

THE DOMINANT PROCESSES IN WESTERN AUSTRALIAN BASINS

An analysis of the mechanisms described in Section 1, applied to harbours, marinas and canal developments in Western Australia, indicates that the dominant flushing mechanisms are most probably (in rough descending order of importance) :

- (a) Wind-induced flushing
- (b) Slope- and wave-induced flushing
- (c) Flushing by astronomical tides

Flushing by barometric tides is undoubtedly negligible for basins as small as harbours, marinas and canal developments. The importance of density-induced flushing in Western Australia is really unknown at present.

Flushing by astronomical tides in the southwest part of Western Australia is, unfortunately, rather weak. Equation (2), a typical tidal range of 0.4 metres and a basin depth of 4 metres yields an absolute minimum flushing time of $4 / 0.4$ tidal periods or 10 days.

Slope- and wave-induced flushing is only significant if the basin has more than one connection with the sea (eg. a second entrance, a culvert or a section of porous breakwater). As noted in Section 1.1.6, the presence of a culvert is probably only beneficial for very small basins (eg. of the size of Challenger Harbour, Fremantle), and the performance of porous breakwaters is at present unverified, although hydraulic estimates suggest that they have little beneficial effect.

It seems clear that the dominant current-generating mechanism is the effect of the surface wind stress. This undoubtedly drives significant overturning currents within a basin (typically of strength .15% of the wind speed, or roughly .01 metres / sec.), and, in the case of basins of variable bottom topography, significant lateral circulations. While these currents undoubtedly serve as mixing agents within the basin, their contribution to the exchange of water with the external sea is strongly dependant on the geometry of the basin mouth (eg. the ratio of the mouth cross-sectional area to the basin volume). It may well be that, in many basins with relatively small entrances (eg. the Fishing Boat Harbour, Fremantle), the wind-driven exchange with the sea is rather small.

REFERENCE

- Hearn, C.J., Hunter, J.R. and Heron, M.L., 1986. The effects of a deep channel on the wind induced flushing of a shallow bay or harbour, Journal of Geophysical Research (in press).

GUIDELINES FOR WATER QUALITY MONITORINGWaterway and Adjacent Waters

Sampling - daily to monthly as appropriate

Light	0.5m from surface
Salinity	"
Temperature	"
Dissolved Oxygen	"
pH	"
Total N	"
Total P	"
Suspended solids	"
and organic matter	"
Chlorophyll 'a'	"
Bacteria	"

Biota

Sampling - 12 monthly as appropriate

Mytilus edulis (mussels) - once colonised

Analyse for Cd, Pb, Cu, Sn, Zn, E. coli

WESTPORT PROJECTENVIRONMENTAL REVIEW AND MANAGEMENT PROGRAMMECOMMITMENTS BY THE DEVELOPER

In the ERMP commitments have been made in the following Sections:-

Section 1 - pages 6 - 10, Summary
Section 5 - pages 29 - 30, Project Description
Section 8 - pages 84 - 97, Management
Section 9 - pages 99 - 100, Management

Reference is also made in Volume 2 Appendix "J", Operational Responsibilities and in the draft Agreement between the State, The Minister for Transport, Department of Marine & Harbours, Shire of Rockingham and the Developer.

Additionally, in the responses to comments on the ERMP some issues needed elaboration and two new issues required a commitment.

For ease of reference all the commitments are collected in this Statement and arranged in the following order:-

1. Construction, Operation and Funding Commitments extracted from Draft Agreement with the Minister for Transport and Shire of Rockingham.
2. Environmental Management Commitments:
 - (a) Before and during construction
 - (b) After construction
3. Monitoring Commitments:
 - (a) Before and during construction
 - (b) After construction

The aims, purpose and detail are not repeated in this Statement.

.....

1.1. MANAGEMENT AND MONITORING COMMITMENTS

Responsibility

The significant impacts associated with this project will be managed as follows:

- (a) Delta Holdings Pty Ltd, the Developer, will be responsible for the costs and works associated with construction and development of the residential waterways project and the environmental monitoring and management programme. The Developer will in the future appoint a Manager who will then become responsible for this programme.
- (b) The Developer will enter an Agreement with the Shire of Rockingham and the Department of Marine and Harbours which will specify the responsibilities and obligations of the parties. Commitments made in this document will be incorporated in this Agreement.
- (c) The Developer will obtain relevant licenses and leases from the Department of Marine and Harbours in relation to construction, operation and maintenance of the breakwaters, waterways, marina and jetties etc.
- (d) The Developer will lodge a bond of \$250,000 with the Shire of Rockingham to guarantee construction, operation and maintenance of the complete waterways and breakwaters including foreshores, entry channel and water quality.
- (e) In order to minimise the impact of the project both during and after construction and to guide development of future stages of the project, a management and monitoring programme has been initiated. Results of monitoring and any management action will be made available to the Shire of Rockingham and relevant State Agencies annually or as required.
- (f) The Developer/Manager and his consultants will carry out the monitoring and management programme which has been designed to address foreseeable contingencies. In the event that water quality within the waterways declines, or the breakwaters lead to unacceptable changes in shoreline position, the Developer, or his successor, will undertake whatever action is necessary by agreement with State Agencies as detailed in Section 8.4.4.
- (g) The operation and management of the project will be funded initially by the Developer and later by users of the facilities and residents through a Body Corporate (Trust) and differential rating of waterfront lots.

1.2 Management Commitments

1.2.1 During Construction

(a) Land Stability and Dust Control

An earthworks and stabilisation programme will be implemented (Section 8.3.1.1).

The programme is based on that recommended by the Soil Conservation Service of the Department of Agriculture and involves:-

- (i) stripping and stockpiling of topsoil and vegetation from areas to be disturbed prior to earthworks commencing;
- (ii) minimising the area of bare land at any one time;
- (iii) resspreading top soil on completed areas with appropriate seeds and fertilizer;
- (iv) carrying out the bulk of the earthworks in winter.

Due to the presence of water from dewatering operations, bare and newly seeded areas will be irrigated if required.

If necessary, a stabilising medium (eg. hydromulch or rolled limestone gravel) will be applied to areas where a vegetated cover has not established. At all times pedestrian and vehicular access on newly planted areas will be controlled.

(b) Turbidity

Excavation will be mainly carried out "dry" - the only true dredging will take place when the waterways are connected to the sea or one stage to another.

Any dredged spoil will be discharged into sand cofferdams to allow fines to settle. Where possible discharging waters will be directed inland and not directly on to the beaches.

Any dredging will avoid the period of high seagrass productivity (see Section 8.3.1.2).

(c) Frontal Dunes Stability (See also 1.2.2 (b))

During the construction phase the frontal dunes will be recontoured and revegetated (see Section 8.3.1.3) and will involve:

- (i) import of sand to fill in blowouts and depressions;
- (ii) recontouring of the dune belt to minimise isolated high spots and reduce steep slopes;
- (iii) bare areas on the front face of the dune belt being covered with topsoil and vegetation recycled from adjacent areas and seeded;

- (iv) should the need arise, areas in danger of mobilisation will be treated by brushing or stabilising membrane, eg. adjacent to the entrance channel.

The foreshore land will be transferred to the Shire of Rockingham as a foreshore reserve following rehabilitation and development.

(d) Groundwater - Dewatering

Some of the groundwater pumped from the excavation, will be irrigated over bare and revegetating areas to control dust and to promote growth of vegetation. The remainder will be discharged to the north and east of the excavation to minimise lowering of the groundwater table, especially beneath the houses to the north.

In this manner the majority of the groundwater will be recycled into the ground to minimise fluctuations in the watertable.

If any houses in Warnbro have their borewater supply disrupted during dewatering, they will be compensated for the cost of mains supply over that period. In the unlikely event of longer term effects their bores will be deepened.

(e) Social Disruption

During construction noise will be controlled to within statutory limits. If required an attempt will be made to reduce noise levels further. Dust will also be controlled as outlined in (a) above.

1.2.2 Post Construction Phase

(a) Water Quality

Maintenance of good quality water to meet Schedules 2, 4, 5, 7(2) & 16 (and if possible Schedule 1) will be achieved by minimising entry of pollutants and pathogenic organisms to the waterways through:

- (i) control of drainage;
- (ii) collection and removal of organic matter, litter and other flotsam;
- (iii) control of hydrocarbon and sewerage discharge from recreational craft;

Drainage from within the waterways catchment area which can contain nutrients, hydrocarbons and heavy metals will discharge into the waterways via silt and oil traps. Drainage from outside the waterways catchment will enter the groundwater system through inter-connecting compensating lakes.

Any organic matter (seagrass wrack, litter or other flotsam) will be removed as necessary. Due to the presence of seagrass in Warnbro Sound it is possible that seagrass wrack will wash into the waterways. If sufficient wrack accumulates it will be manually removed and disposed of on land.

Discharge of litter, oil and sewerage into the waterways will be prohibited by regulation. In order to be able to enforce regulations, garbage bins, a vacuum pumpout facility and sewer toilets will be provided around the waterways. Equipment will be provided to contain major spills which can then be allowed to evaporate or be removed or treated as necessary.

In the event that water quality within the waterways declines the Developer (and his successors) will undertake whatever action is necessary to prevent poor quality water developing and then leaving the waterways (see Section 8.3.2.1).

If coliform bacterial counts ever exceed permissible limits, appropriate signs will be erected within the waterways and on the foreshore.

Heavy Metals

Runoff from hardstand areas will be trapped in sumps and periodically removed. Entry of particulate heavy metals in runoff will be minimised as storm water will be discharged through silt and oil traps before entering the waterways. If accumulation of heavy metals is found to be occurring in sediments and biota the Developer will undertake whatever action is necessary following negotiations with State and Local Government Agencies (Section 8.3.2.1(b)) eg. remove enriched top sediments.

(b) Foreshore Reserve

The Dune Management Zone will be fenced with the only access through it on fenced paths - vegetation will be monitored closely. The Dune Development Zone will be recontoured, grassed, planted with trees and irrigated. Public facilities will be provided by agreement with the Shire of Rockingham (Section 8.3.2.2).

(c) Sediment Movement and Shoreline Change

The amount of sand accumulated, and the position of the shoreline, will be monitored twice a year. A sand bypass operation will be carried out if required using a front end loader and trucks. Bypassing will be restricted to daylight hours in winter.

In regard to the possible need to bypass sand the Developer, or his successor, undertakes at his cost to do the following:

- (i) in the event that an accumulation of sediment adjacent to the southern breakwater is deemed by the responsible Authorities to have resulted in erosion of the beaches to the north, sufficient sand to make up the erosion will be transported to, and distributed upon, the northern beach in amounts exceeding 5,000m³ at a time.

- (ii) in the event that an accumulation of sediment adjacent to the northern breakwater is deemed by the responsible Authorities to have resulted in erosion of beaches to the south, sufficient sand to make up erosion will be transferred to, and distributed upon, the southern beach in amounts exceeding 5,000m³ at a time.
- (iii) in the event that an accumulation of sediment adjacent to the northern breakwater is not deemed by the responsible Authorities to have resulted in erosion of the beaches to the south and has become trapped, the excess accumulation will be redistributed along the northern beach in amounts exceeding 5,000 m³ at a time.

This should avoid the possibility of sand being lost to the system by spilling down the bank slope

After completion of all stages of the development if sand is lost downslope and erosion of beaches is attributable to the Westport Project, the Developer, or his successor, undertakes to do the following;

- (i) import at his cost from a site nominated by an agreement with State Agencies and distribute sufficient sand to make up any erosion in amounts exceeding 10,000m³ at a time.
- (ii) construct engineering structures by agreement with State Agencies.

Management of the breakwaters, and bypass and entry channel will be the Developer's responsibility in perpetuity unless there is a change in policy by a future Government or the Department of Marine and Harbours (see Section 8.5).

(d) Groundwater

See Sec. 1.3.1 (c)

1.3 Monitoring Commitments

A monitoring programme with the following aims will be implemented:

- (a) Pre-construction - to establish:
 - (i) background levels of nutrients, heavy metal, pathogenic organisms in water and sediments adjacent to the waterways entry;
 - (ii) the position of the shoreline;
 - (iii) the nature of the groundwater regime.
- (b) Post-construction - to guide the management programme so as to minimise or avoid problems with:
 - (i) water quality and accumulation of heavy metals;
 - (ii) dune stabilisation;
 - (iii) sediment movement and shoreline change;
 - (iv) groundwater.

1.3.1 Pre-Construction

Background Nutrient and Heavy Metal Levels

- (a) Samples of seagrass, shellfish (eg. Donax) and sediments will be taken at 6 representative sites within 200 metres of the entrance channel and analysed for heavy metals (Cu, Sn, Pb, Zn, Cd) and pathogenic organisms. Similarly water samples will be taken off the entrance channel, 2000m north of the entrance, and 2000m south, and analysed for nutrients, suspended solids and chlorophyll 'a'.

- (b) Shoreline, Seabed and Seagrass

Regular monitoring of shoreline position, seabed profile and seagrass distribution has been undertaken since April 1986 at sections 10, 25, 50, 100, 200 & 300m north and south of the experimental groyne. Monitoring of these three parameters will continue on the same profiles but extended to 1200m north and south.

- (c) Groundwater

A groundwater extraction programme aimed at minimising changes in the groundwater regime will be determined after monitoring of trial bores has been assessed (Section 8.3.2.4). Twelve observation bores will be drilled into the Safety Bay Sand and the upper part of Rockingham Sand as soon as E.P.A. approval is granted and monitored. Two large diameter bores will be drilled and test pumped to determine hydrological characteristics of the Safety Bay Sand. As soon as results are to hand computer model of groundwater regime will be prepared and the groundwater extraction programme finalised after agreement with the West Australian Water Authority (Sec 8.4.1.3).

1.3.2 Post-Construction

Once construction of the first stage of waterways is complete regular monitoring of water quality (including nutrients, pathogenic micro-organisms), heavy metals (in sediments and biota), dune stability, sediment movement, shoreline change, seagrass distribution and groundwater will be carried out.

The programme will be flexible in that the parameters and their frequencies of measurement will be tailored to the character of the waterways as on-site experience is gained.

(a) Water Quality

Regular monitoring of water quality will be undertaken at representative sites and depths in the waterways and in the adjacent Sound waters. Monitoring will be monthly, or more frequently if required, during the first year and thereafter at intervals to be dictated by experience. The Table shows the range of monitoring parameters and sampling frequencies considered appropriate.

(b) Sediments and Biota

Regular monitoring of heavy metals and nutrients in sediments, and heavy metals and pathogenic micro-organisms in biota, will be undertaken at representative sites in and adjacent to the waterways. The procedure to be adopted for analysis of organisms will follow the standard mussel-watch programme. Analysis of sediment will be standardised to ensure constant depth and area of seabed sampled. The Table shows the parameters and sampling frequencies considered appropriate.

(c) Dune Stability

Regular inspection of the frontal dunes will be made especially during summer holidays, weekends and following storms.

(d) Shoreline, Seabed and Seagrass

Regular two monthly monitoring of the shoreline position, seabed profile and state of seagrass adjacent to the breakwaters will be continued on established sections until a clear picture of the annual longshore transport regime has been established. At this time the monitoring interval may be varied as the aims of the programme will then be to establish whether there is any variation in transport regime between years and the impact of major storms (i.e. end March, end September).

The monitoring programme will also clarify whether sand is lost down the bank slope or not, and the response of the seagrass to the waterways and breakwaters.

(e) Groundwater

Regular three monthly monitoring of the volume of water extracted, groundwater levels, groundwater quality (nutrients and salt content) and the position of the saltwater interface will be continued as outlined in Section 8.3.2.4.

1.3.2.1 Sample Analysis and Interpretation

Monitoring and analysis will initially be carried out by the Developer, and subsequently by the Manager on behalf of the Developer and later the Westport Body Corporate, in accord with the above programme.

Interpretation of results will to a large extent determine the success of avoiding problems with water quality, dune and shoreline stability and groundwater. Consultants engaged by the Developer or Manager will supervise monitoring and interpretation of results and recommend appropriate management action.

1.3.2.2 Reporting and Review

Results of the management and monitoring programme will be supplied on an annual (or as otherwise determined) basis to the following agencies:-

(a)	earthworks and stabilisation	SOR	DCE	SCS
(b)	water quality management	SOR	DCE	DMH
(c)	foreshore reserve management	SOR	DCE	SCS
(d)	sand bypass operation	SOR	DCE	DMH
(e)	groundwater management	SOR	DCE	WAWA

SOR = Shire of Rockingham

DCE = Department of Conservation and Environment

SCS = Soil Conservation Service

WAWA = Western Australian Water Authority

DMH = Department of Marine and Harbours

The reports will contain:

- (a) the results of monitoring and management action over the period;
- (b) an analysis of the results in relation to previous periods;
- (c) a discussion on the relevance of the results in terms of impact on the environment;

- (d) recommendations with respect to (for example):
 - (i) modifications to the monitoring and management programme;
 - (ii) management action by the Developer;
 - (iii) action by a State agency;
 - (iv) modification to further stages of the project.

The annual reports will also provide a means whereby the monitoring and management programme as well as plans for future stages can be reviewed, and if necessary modified, in light of experience gained on site. The Developer undertakes to respond to comments made by the responsible Authorities on the annual reports.

1.3.2.3 Contingencies

The monitoring and management programmes have been designed to address foreseeable contingencies. The Developer/Manager and his staff will be equipped to deal with fuel spills, fires, stratification of the water mass and the impact of storms. The Developer/Manager will carry public liability insurance and individuals will be responsible for their own property and craft.

In the event that water quality within the waterways declines the Developer (and his successors) will undertake whatever action is necessary to prevent poor quality water developing and then leaving the waterways (see Section 8.3.2.1).

In the event that the breakwaters lead to unacceptable changes in the shoreline position the Developer (and his successors) will undertake to import sand and if appropriate to construct groynes to redress the problem (see Section 8.3.2.3). Any contingencies and action taken will be included in the next monitoring report.

ENVIRONMENTAL MONITORING PROGRAMME

HARBOUR AND ADJACENT WATERS

Sampling - Daily to Monthly as appropriate

Light	0.5m intervals to bottom
Salinity	"
Temperature	"
Dissolved Oxygen	"
pH	"
NH ₄	0.5m depth (or 0.5m depth and
NO ₃ /NO ₂	0.5m from bottom if stratified)
Total N	
PO ₄	"
Total P	"
Suspended solids and organic matter	"
Chlorophyll 'a'	"
Bacteria	
Hydrocarbons	

WEATHER

Sampling - Daily to Monthly as appropriate

Wind speed/direction
Atmospheric pressure
Temperature
Humidity
Tide
Rainfall

BIOTA

Sampling - 6 - 12 monthly as appropriate

Mytilus edulis (mussels)
Posidonia sinuosa (seagrass)

Analyse Cd, Pb, Cu, Sn, Zn, E. coli

SEDIMENTS

Sampling - 6 - 12 monthly as appropriate

Analyse for organic carbon Cd, Pb, Cu, Sn, Zn, E. coli

ADDITIONS TO COMMITMENTS FROM RESPONSES

TO COMMENTS ON ERMP 12.5.87

Groundwater

1.2.1 (d)

Dewatering will be done by using a number of lines of "spears" which have separate pumps and can be shifted from time to time as the adjacent water table drops. Water quality will be monitored and once any line exceeds say 2,000 p.p.m. it will be diverted seawards.

Saline/brackish groundwater will be disposed of by soakage into depressions in the foredunes near the beach.

Social Disruption

1.2.1 (e)

A pedestrian bridge over the entry channel has been considered. At this stage the financial burden could be more than the Project can bear, but at a later date when the development is more advanced and particularly if the northern part of the Port Kennedy development is proceeding, the Developer would be prepared to reconsider the matter.

The Developer has no objection to people using another route through his land to Port Kennedy so long as they behave responsibly.

Unexploded Ordnance

1.2.1 (f)

The Developer accepts the position in regard to the possible existence of unexploded ordnance at the project site.

The Developer and his contractors will proceed as they did for the 163 lots already created without problems. Buyers must sign a note of awareness. If anything happened in construction, the Defence Department would be sued and the Developer reserves the right to negotiate for further clearances and indemnity from that Department. The Shire is not seen as being liable.

Foreshore Reserve

1.2.2 (b)

The Developer would agree to be responsible for maintenance and management of the foreshore dunes for a five year period following transfer of the reserve to the Rockingham Council provided this has become standard practice. However, if the Developer is still financially responsible after having done all the rehabilitation and given up the land, some adjustment in the rates ought to be made.

Groundwater

1.3.1 (c)

The Consultants will confer with the Geological Survey Department and Water Authority of W.A. to reach agreement on the detailed technique to be used in the monitoring bores.

WESTPORT PROJECT ERMP
COMMITMENTS BY DEVELOPER
EXTRACTS FROM DRAFT AGREEMENT

(DEC 1986)

.....

3. THE COMPANY'S OBLIGATIONS - CONSTRUCTION

Subject to the due completion, provision or satisfaction of the Statutory Requirements by the relevant authorities, the Company agrees with the Minister and the Shire that it will -

- (a) progressively carry out the Project in accordance with the Structure Plan and as detailed in the ERMP, and in particular -
 - (i) construct the Breakwaters;
 - (ii) construct the waterways in such stages as may be agreed with the Minister and the Shire;
 - (iii) establish the small open space areas adjoining the waterways including the public areas (foot-paths, edging, beaches, verges) within the Development Area;
 - (iv) rehabilitate the Foreshore Reserve in accordance with plans and specifications approved under the Metropolitan Region Scheme and the Town Planning Scheme including landscaping and irrigation but not public buildings, lighting or carparking;
 - (v) undertake all necessary earthworks;
 - (vi) provide all necessary roads and local drainage;
 - (vii) provide all water, sewerage and arterial drainage services within the Development Area in accordance with the requirements of the Water AUTHority.
- (b) carry out all construction works for the Project in a competent manner and employ or engage competent staff and consultants in relation to the carrying out of the Project.

- (c) install within the Waterways, and, to the extent that it lawfully can, in Warnbro Sound and on land in the vicinity of the waterways, such navigational aids approved of by the Minister for Transport as to design, specification and location, as may be reasonably required by the Minister for Transport for safe navigation to in and from the waterways;
- (d) accept all the obligations undertaken in the ERMP as part of this Agreement especially in relation to monitoring and management of a Sand Bypass system and water quality within the waterways as detailed in Section 8 of the ERMP.
- (e) provide in favour of the Minister prior to the commencement of construction a guarantee from a Bank for an amount of \$250,000 as security for the Company's obligations to construct and maintain the Breakwaters, shoreline and the waterways and manage water quality in accordance with this Agreement and the ERMP. The amount of such guarantee shall be reviewed (up or down as the case may require) by the Minister in respect of each 5 years of the term of this Lease after the first five years, the first review to take effect on the first day of the 6th year of the term. Without limiting the matters which the Minister may take into account on such a review, the Minister shall take into account that -
 - (i) inflation has affected the real value of the guarantee;
 - (ii) the Breakwaters and shoreline may have become stabilised and maintenance requirements may then be known;
 - (iii) the quality of water in the Waterways may be better known and future management costs may then be defined accurately.

.....

6. THE WATERWAYS - OPERATION

- 6.1 Upon the completion of the construction of the Breakwaters and the first and subsequent stages of the Waterways to the satisfaction of the Minister and the Shire and the transfer to the Crown of the Foreshore Reserve marked "B" on the Structure Plan the Minister for Transport shall grant to the Company or such subsidiary of the Company as the Company may nominate in writing to and as may be approved of by the Minister for Transport, a lease of the Harbour Bed under and subject to the Marine and Harbours Act 1981 for a term of 50 years with an option to renew the term for a further term of 50 years at the rental and in the form set out in Schedule 5 to this Agreement whereby the lessee shall, amongst other things, be liable to:-

- (a) maintain the Breakwaters and replace armour if needed after severe storms;
- (b) maintain the Waterways entrance channel to a depth of -4m AHD;
- (c) maintain the shoreline and beach alignment by bypassing sand as defined in the ERMP;
- (d) maintain navigation markers and lights;
- (e) maintain the water depths of the Waterways at not less than the approved design depths;
- (f) maintain the beaches and foreshores of the Waterways;
- (g) maintain the quality of the water in the Waterways including:-
 - (i) collecting floating rubbish;
 - (ii) enforcing regulations with boat owners such as sewage pumpout, fuelling, paint stripping and rubbish disposal;
- (h) maintain canal walls, jetties and boat ramps to private lots (to be recouped from owners);
- (i) maintain marina areas including jetties, walls, hard-stand, electricity, lighting, water, rubbish removal, toilets, pumpout, security, fuelling, slipways, hoists, etc. (all of which may be sub-leased by the Company);
- (j) maintain bridges and culverts to islands;
- (k) maintain road verges and small areas of public open space on the islands and waterfront including watering and mowing grassed areas, planting and pruning trees and shrubs;
- (l) maintain in Westport Village steps, pathways, retaining walls, promenades, landscaping;
- (m) maintain the public launching ramps and mooring facilities at the western end of Chelmsford Ave;
- (n) carry out the monitoring programme defined in the ERMP especially concerning sediment movement, shoreline changes and water quality;
- (o) in the event of any unforeseen problems revealed by the monitoring programme, carry out remedial measures as defined in the ERMP;
- (p) be responsible for the activities of any sublessees such as the marina operator(s), strata title bodies;

- (q) administer the waterways regulations and bylaws under various State Acts;
- (r) provide a guarantee from a Bank for an amount of \$250,000 as security for its obligations under the above paragraphs and under the ERMP as referred to in Clause 3(e).

.....

8. MANAGEMENT OF OPERATIONS

- 8.1 Overall management of the Waterways development and subsequent operation will be the responsibility of the Company under the various forms of lease and license described in this Agreement.
- 8.2 The Company may appoint a Manager and will create an operating Trust. The Trust will have the lease over the Waterways with the exception of the area assigned to the Marina Operator(s). The Trust will eventually be taken over by the waterfront residents and lease holders as they become more numerous and the Company's ownership declines. It will have members from the ratepayers and Shire Council from the start and be funded by the Company initially.
- 8.3 The Company/Manager will appoint inspectors to carry out day to day duties. They will use the Council bylaws and provisions of two State Acts related to the Waterways which will automatically apply to Westport (i.e. Navigable Waters Regulations and Western Australian Marine Act).

9. MANAGEMENT FUNDING

- 9.1 The Shire has accepted in principle the application of a differential rate for all lots with water frontage, i.e. the single residential lots, the marina lots and the village lots. This differential rating will occur from day one and will amount to 50% of the normal rate.
- 9.2 The differential rate from the waterfront owners will go into the Trust funds which will be used for the operation and maintenance activities described in this Agreement.
- 9.3 Due to the high value of the waterfront lots, estimated to be five times the equivalent "dry block", the Shire will receive a greater than normal rate return on a per lot basis with only the normal dry lot maintenance costs.
- 9.4 As the control of the Trust gradually passes from the Company/Manager to the local owners, it will retain any surplus in the fund, as well as continuing its maintenance responsibilities.

- 9.5 In the setting up of the Trust by the Company there will be provision for it to be taken over by the Shire at any time after the expiry of the first five years if the Shire is prepared to take on the responsibilities. If the Shire exercised this option then the differential rating system would be abolished.
- 9.6 As the construction of the waterways is staged, the above arrangement will apply to the first stage. The Company will maintain any new stages until the first fee on adjoining canal lots is paid to the Trust.
- 9.7 The Company itself will pay for rectifying any design defects and non recurring maintenance arising therefrom. Unforeseen defects in the Sand Bypass system, water quality control or other matters shall be covered by the Trust funds with such assistance as may be required from the Company. The works shall be properly insured at all times by the Company/Trust.
- 9.8 The Company's guarantee of \$250,000 will be held under the terms of clause 3 (e) to cover default by the Company, it's Manager or the Trust.

.....

SUMMARY OF ISSUES RAISED IN SUBMISSIONS

SUMMARY OF ISSUES RAISED IN PUBLIC SUBMISSIONS

Need for the project

- . There is a lack of demonstrated need for a canals development in this location.
- . Population level projections and demand for residential land and boat ownership in the ERMP appear to be optimistic.

Adequacy of the ERMP

- . Questionable accuracy of predictions in the ERMP based on inadequate research.
- . Inconclusive statements do not provide convincing evidence of what will happen.
- . Very little comparison of similar projects put forward.
- . Tenuous assumptions and estimates in the ERMP and therefore flawed management proposals.
- . The ERMP contains many qualifications on assumptions and conclusions it presents, especially in relation to sediment transport/coastal stability.

Impacts on the Physical and Biological Environment

- . Loss of seagrass habitat and fish breeding area.
- . Potential to increase erosion of beaches around Warnbro Sound, to increase inland wind-driven sand movement and potential siltation of the harbour entrance.
- . Potential reduction in groundwater level and quality in areas outside the project site.
- . Few conclusions drawn on the effect of the project on marine biota and habitats; over-exploitation of adjacent marine area from recreational fishermen due to increased population and accessibility including impact on the proposed marine reserve (System 6 Recommendation M101).
- . Potential problems with water quality within and outside the harbour.
- . Concern at possible lack of flushing of waterways because of low tides.
- . Endangering wildlife and vegetation, flora and fauna outside the project area may be affected by lowering of the water table and/or salt intrusion.

- . Interruption of natural sand cycle; limited assessment of littoral drift
- . Concern over the possible impact on System Six areas M103 and M106.
- . Increased pressure on offshore reefs and islands and should be given some management priority.
- . Stability and stabilisation of the frontal dunes is of major concern.

Recreational Activities/Public Amenity

- . Loss of continuous access along the beachfront.
- . Loss of tranquil and undeveloped feeling of the area.
- . Possible restricted public access to beaches adjacent to the project site.
- . Danger of unexploded ordnance.

Management and Monitoring

- . No indication of how the proponent intends to achieve management and monitoring goals both financially and legally.

SUBMISSIONS RECEIVED FROM GOVERNMENT AGENCIES

SUMMARY OF KEY POINTS RAISED IN GOVERNMENT SUBMISSIONS

Foreshore Stability

- . More studies are required on the impact of the breakwaters, especially in relation to littoral drift and loss of sand offshore to the submarine platform; the ERMP states that further studies will be required to allow an adequate quantitative investigation to be made.
- . Investigations should be carried out to address the maximum amount of sand that could accumulate before loss down the bank slope occurs and methods of prevention of sand loss.
- . The management of seagrass accumulations against the entrance channel breakwaters and their consequential effect on the proposed methods of mechanical bypassing should be addressed further.
- . Shoreline stability requires on-going assessment.
- . The project may have a severe offsite erosion impact.

Hydrology and Groundwater Quality

- . Assumptions related to groundwater predictions in the ERMP should be re-evaluated with completion of the proposed or modified drilling and testing programme prior to approval of the development or as a condition of approval. This would provide a clearer evaluation of the existing and future groundwater regime.

- . The prediction that the saltwater interface will not extend a great distance into adjoining land north and south of the project site is not substantiated; close monitoring is required.
- . It should be ensured that the dewatering operations and permanent waterways will not have any adverse affect on the aquifers by salt water intrusion in relation to the Warnbro townsite, Port Kennedy land and Parks and Recreation Reserves to the east.
- . The proposed dewatering during construction will lower the water table level within the suburb of Warnbro and may effect operation of some domestic bores.
- . The proposed slotting of 7 of the 12 observation bores against the entire saturated section of the Safety Bay Sand should be modified so that each of the 7 observation sites are equipped with two bores, one monitoring the water table and the other the base of the aquifer.
- . The ERMP does not recognise that water availability within the site may be affected by groundwater draw on land up gradient of the site.
- . Compensation for affected groundwater users would be expected.
- . The use of artesian aquifers is under statutory control and approval for its use is required.
- . Any variation to the proposed construction method should be subject to assessment of its affects on the groundwater system and its users in the area.

Surface Water Quality

- . It should be ensured that the design and construction of the entrance channel, harbour and waterways is adequate to achieve total mixing to maintain water quality.
- . It should be ensured that disposal of saline/brackish water into the ocean or existing waterways does not affect water quality or public use of the beaches.
- . The proposal to discharge stormwater directly into waterways using only silt/oil traps as a means of filtering is questioned.

Marine Biota

- . The project would cause increased pressure on recreational fishing in the area, especially in conjunction with the proposed Port Kennedy marina.
- . Anti-fouling paints contain compounds which are harmful to marine biota at very low concentration; considerable attention should be paid to monitoring levels of the compounds in the biota and sediments of the waterways and adjacent coastal waters.

Responsibilities

- . The draft Agreement prepared by the proponent requires substantial modification before it can be considered to be acceptable.

Project Planning

- . The Department of Marine and Harbours should thoroughly investigate the proposed construction of the waterways and infrastructure to ensure that the facilities can be managed and maintained satisfactorily.
- . All development should be in accordance with the Recommendations for the Development of Canal Estates prepared for the Steering Committee on Canal Developments, 1984.
- . The densities of development for the proposed Westport Village cannot be assumed to be acceptable prior to finalisation of the Shire of Rockingham Town Planning Scheme No 1; any development should conform with the State Planning Commission's current Interim Statement on Coastal Development.
- . The Proposed Structure Plan incorporates a subdivision design which may not be approved in its present form, in the event that the project is found to be environmentally acceptable.

Unexploded Ordnance

- . The possible existence of unexploded ordnance and the dangers it might present are not addressed in the ERMP.
- . The proponent should consult the State Emergency Service in regard to the possibility of ordnance being found at greater depth.

Aboriginal Sites

- . Although there are no Aboriginal sites registered by the Department of Aboriginal Sites to date in the area concerned it is possible that sites may be discovered during development.
- . The proponent should be asked to report any site discoveries to the Department of Aboriginal Sites and allow for their investigation.

Recreation

- . The Rockingham Shire Council supports the provision of a pedestrian bridge across the entrance channel to ensure continued public access along the Warnbro Sound beachfront.

Environmental Management

- . The adequacy of the bond figure of \$250 000 to cover costs of the order which the project may incur is questioned.
- . More information is required on the management programme for the dunes including revegetation species, irrigation, extent of works and whether dunes on the southern side of the channel would be covered by the management programme.
- . The proposed 500 bay public carpark should be sealed.
- . The developer should be responsible for the maintenance and management of the foredunes for a five (5) year period following transfer of the

reserve to Council. A similar approach was adopted for the Hooker Rex Warnbro Dunes subdivision and the Secret Harbour Project.

- . The ERMP does not contain details of the proposed final contours. These should be provided in order that assessment of landscape considerations and dune management can be completed.
- . Is the use of a compressor and small work boat sufficient to maintain water quality within the canal estate, should calm conditions precipitate a decline in quality.
- . The monitoring of the shoreline is to be undertaken twice a year. It is considered that monitoring should be undertaken more frequently.
- . An upper limit should be placed on the amount of sand to be shifted during sand bypass.
- . The possibility of dredging the waterways for sand to replace sand on the beach should be considered in light of the statements in the ERMP that sediment in the waterways would contain accumulated heavy metals and other impurities.
- . Proposed irrigation of the Dune Development Zone may not be possible because of salinisation of the groundwater under this area.

REPLY TO ISSUES FROM SUBMISSIONS27TH MARCH, 19871. Shoreline StabilityComment

The ERMP does not stand up to scrutiny in the critical areas of sand transport and shoreline stability. The assumptions and estimates made are tenuous and the proposals for management of the coastline are, as a result, flawed. The attached excerpts from the ERMP (underlining by the author of the submission) are cited in support of these contentions.

Response

The estimates of sand transport are not tenuous. They are supported by actual measurements which have continued to verify calculations by Riedel and Byrne made prior to actual measurements being available.

Management proposals have been demonstrated by the measurements and experience on the experimental groyne to be more than adequate. These proposals are more comprehensive than for any other similar project including Jurien Bay and Sorrento/Hillarys which are not having unexpected problems.

The excerpts quoted below are taken out of context and were used to show that all adverse possibilities had been recognised initially and duly considered. Responses are given point by point.

P.38 "...establishing the nature and scale of the coastal processes currently operating in Warnbro Sound....has not proven to be an easy task with differing opinions of longshore drift being obtained from various consultants."

Response

True - The methods being used by LeProvost Semeniuk and Chalmer in particular, were unsuitable for this exercise in this location. The provenance method could never have achieved a firm result or estimate seasonal variations and was abandoned in favour of direct calculation from wave hind-casting and the experimental groyne.

P.45 "...superimposed on the nett drift is a seasonal flux of sediment - the volume of which cannot be estimated by the model....No attempt has been made to estimate the volume of drift associated with longer scale (200-400 years) fluctuations....it is possible that little major long term increase in wave-induced littoral drift will be experienced."

Response

Who can say what will happen anywhere in the next 200-400 years? Last remark out of context.

P.48 "...the maximum nett volume of littoral drift is unlikely to exceed say, 10%, of the maximum drift on the open coast..."

Response

This was based on the respective wave spectrums which were reasonably known. The wave height distribution in Warnbro Sound is about one third of that on open shorelines nearby and since wave energy varies as the square of wave height, the energy was about 10%. On top of this the physical configuration of Warnbro Sound led to even lower littoral drift.

P.63 "As yet no indication of this volume (i.e. the volume of sand which has to be artificially bypassed) can be made ..."

Response

This was an unduly conservative statement and should have been made stronger. The full years measurements and comparisons with the previous hindcast year, indicate that bypassing will not be necessary in most years (net transport) nor on a seasonal basis (gross transport). The threshold adopted for bypassing of 5,000m³ net in any year, or cumulatively in a number of years, seems to have been a good choice. (See April 1987 report on first years measurements).

P.64 "...unless there is a loss of sand offshore, it would appear that a stable shoreline and navigable entrance channel can be maintained....Thus there is the real possibility that sand will be lost down the slope if the shoreline advances too much and sand is cycled offshore during storms."

Response

This was a recognition of a mechanism that could take sand out of the system. That was one of the reasons for all the profiling north and south of the experimental groyne which has shown that additional sand will not be lost down the slopes under contemporary weather conditions at least. The shoreline will not be allowed to advance except temporarily very close to the breakwaters.

P.65 "...bypassing of material as a result of this factor should be relatively easily accounted for provided longshore transport volumes are in order of 10,000 m³/yr. There is, however, no data on the volumes associated with long term changes....Ideally more hard data is desirable...."

Response

The volumes in gross terms are of the order 10,000m³ and are demonstrated not to need bypassing. In net terms the volume is much less. Provision is made in the design to store 20,000m³ each side of the breakwaters. There is no way that useful long term data can be obtained.

p.66-7 "Whether any (sand) loss will be cancelled by nett transport into Warnbro Sound is not yet clear."

Response

Still not clear and not relevant to Westport.

Comment

Further serious doubts are raised by various observations in the work done by LeProvost, Semeniuk and Chalmer (excerpts from the ERMP are again cited below).

LE PROVOST STUDIES

Appendix E

P.15 "...changes to platform or loss of seagrass, or interruption of littoral transport could cause a significant disequilibrium. This could result in substantial erosion or accretion of the shore in response....calculations of nett transport are of much less use than gross transport rates in predicting the effects of artificial coastal perturbation..."

Response

This was a fair comment made in May 1985 at the beginning of studies. It was used to assist in the direction of the further studies.

Appendix F

P.2 "...an unknown volume of sediment does leak around Becher Point....whilst there may presently be a period of relative calm dynamics, this may only be a temporary respite which could rapidly change as the very recent and substantial changes at Becher Point show the shoreface of Warnbro Sound...is potentially unstable.... sediment....is being lost from the nearshore down the steep submarine slope..."

Response

As above. It could perhaps have been added that the coastal dynamics are currently very active just south of Becher Point. The lower shoreface of Warnbro Sound is in fact an angle of repose of 1:2 which has been taken into account in the design.

P.6 "With the continued loss of seagrass...there may be an increasing loss of sediment from the nearshore and beach irretrievably down the slope...these factors would tend to result in a narrower beach and more frequent wave attack on the foot of the foredune...(which) would tend to remove vegetation cover and so promote the development of blowouts..."

Response

There will not be continued loss of seagrass. During subsequent studies, particularly a full years monitoring of seagrass north and south of the experimental groyne, (see separate report) it was found that the seagrass only grows below -4.5m and sand at this level is already irretrievable. The seagrass would slow the movement of sand to the steeper slopes lower down. The shoreface is advancing into Warnbro Sound very slowly and the beach will not get narrower.

A detailed analysis of shoreline movements just north of Westport, was recorded in a recent Town Planning Appeal by Hooker Rex Estates. All the experts in this field gave evidence and there was little evidence supporting any erosion of the Warnbro primary dunes over the last 700 years and no indication that the beach was getting narrower.

P.10 "Further provenance analysis and modelling are required before volumes of sediment can be extrapolated from these initial results."

Response

The Developers and their Consultants felt that this method could never lead to a quantitative result on this particular site. It was decided to concentrate on direct calculation from wave hindcasting and measurements on profiles at the experimental groyne.

P.12 "... changes in rates of nett sediment transport associated with the local re-establishment of a dynamic equilibrium situation have probably varied by up to a factor of 10 over a time scale of less than 100 years... it will be necessary to commence additional investigations to quantitatively resolve aspects of the sediment transport model and the scale of associated shoreface dynamics."

Response

This remark was made in relation to the silting up of Peel Harbour in Safety Bay in the middle of last century. The additional investigations were carried out and showed among other things that the coastal dynamics in Safety Bay are not related to those at Westport. The sediment transport model in Fig 14b demonstrates the results.

(End of LeProvost quotes)

Comment

The wave study undertaken is based on only one year's records of swell activity and, as acknowledged by the consultant responsible for this study (refer to Appendix G, page 13) "...it (i.e. the wave study) still must be considered an approximate method..."

Response

Agreed

Comment

For the groyne trial, only eight months' data have been appraised, and the structure is approximately half the length of the proposed breakwaters which is relevant in terms of both the amount of sediment the structure would intercept, and its proximity to the deeper offshore zone (thereby heightening the risk of sediment loss offshore, and associated seagrass disturbance).

Response

Full 12 months results now available. The experimental groyne did not allow bypassing of sand. Last point agreed but see report on full years results and comments relevant to breakwater design.

Comment

The validity of extrapolating experience gained at Jurien to the Warnbro site is questioned on the basis of the statement in ERMP Appendix H (Woods - P.1) about the dangers of comparing one section of coast with another, and as the Jurien facility has been in place for only fourteen months.

Response

Dr Woods was involved in both Jurien and Westport. It was he who felt the comparison was valid. The Department of Marine and Harbours are of the same opinion. The period is now nearly two years for the breakwaters.

Comment

In view of the concerns raised regarding the assumptions upon which the examination of sediment movement is based, concern is similarly expressed at the management responses suggested, particularly the fall-back strategy at P.91 of the ERMP which includes the statement that "...the possible requirement for extra sand.....has not been investigated in any detail...."

Response

The sediment movement is not based on assumptions. It is based on perhaps the most detailed years testing ever carried out for a similar project in W.A. (Jurien had no

tests at all). The calculations from wave hindcasting are also probably the best ever carried out in W.A. Regarding the possible requirement for extra sand, the volume is so small that it could be got from anywhere on the Westport Estate or even purchased from sand suppliers for very little cost.

Comment

In addition to the many direct and implied questions posed by the above observations (and they need to be convincingly answered), the following specific questions are posed.

- (i) Will the proposed bypass system take account of gross sand movement and thus of individual events rather than merely nett annual transport? Sand movement related to one major storm event or a closely spaced series of storms is more commonly associated with major coastal erosion than is nett sediment movement over the space of a year. Such event related movement is, however, more difficult to plan for and accommodate than a cumulative annual movement.

Response

The bypass system can take account of gross (seasonal) sand movement and individual storm events. However, the groyne experiment and calculations from wave hindcasting are conclusive that this will not be necessary so long as current weather patterns persist. Provided the coastline is not affected, it would be an exercise in futility to keep physically bypassing sand from one side to the other every six months (backwards and forwards).

Comment

- (ii) If the predictions in the ERMP prove incorrect, will the Developer or some future manager be able to alter management and funding to adequately accommodate such circumstances? (i.e. contingency planning).

Response

The worst that could happen is that the volume to be bypassed would need to be increased and the volume to be stored north and south of the breakwaters would need to be increased. A four fold increase in net bypass up to say 10,000 m³ per year is a minor problem and even eight fold to 20,000 m³ is not a serious economic problem in a project of this size.

The design of breakwaters could be adjusted fairly easily to store 40,000 m³ on either side.

Comment

- (iii) Who assumes responsibility for long term management of sand bypassing and the maintenance of coastal stability

if the Developer fails before completion of the project? The lack of success of the dryland Westport development cited as a source of concern in this regard.

Response

An operating Trust has been proposed in the ERMP. The Trust will have income from half the rates of all waterfront properties which is substantial. The Government will retain a guarantee which could be secured against the land titles which are of considerable value. The problem of sand bypass (and water quality) is regarded as so minor by the Department of Marine and Harbours that they have offered to take over the proposed Trust's operation.

The dry land subdivision was delayed a year trying to resolve the question of sewerage treatment and temporary pumping which is at last sorted out.

2. Hydrogeology and Groundwater

Comment

The main constraining factor on the analysis and predictions presented in the ERMP (Appendix A) is the reliance on existing bores and data. A number of deficiencies in the assumptions on which the theoretical analysis and predictions are based are highlighted (as follows).

- (i) Section 5.1 Water Level Contours - in the ERMP it is acknowledged that the water levels monitored do not reflect average head throughout the Safety Bay Sand. However, head variations at depth (to enable assessment of possible recharge and discharge zones, which is essential for the prediction of future groundwater changes) are not indicated.

A particular value for groundwater velocity is given in the ERMP (i.e. between 0.1 and 0.2 m/d). However, based on other hydraulic conductivities quoted in the ERMP, groundwater velocities could equally range from 0.09 to 0.72 m/d.

Response

The Safety Bay sand in this area is reasonably homogeneous. Head variations within it are likely to be minimal. More substantial changes could occur in the Rockingham sand below. Monitoring bores will be established before bulk earthworks or dewatering begins.

The groundwater velocity chosen seemed to be the most appropriate for the area and no reason is seen to change it.

Comment

- (ii) Section 5.2 Hydraulic Parameters - because of reliance on values quoted in other reports, provisional values for hydraulic conductivity have had to be adopted. Verification of the assumed values by drilling and testing is necessary.

Response

Agree

Comment

- (iii) Section 5.3 Recharge - again, as an average value has been adopted from a wide range of quoted values, verification of the adopted value is necessary.

Response

Agree

Comment

- (iv) Section 5.5 Seawater Interface - although the calculation of the extent of the interface is probably reasonable considering the broad assumptions made regarding the hydraulic parameters, the thickness of freshwater at the coastline, the width of the freshwater seepage face, and the shape of the interface should also have been determined.

Response

This is felt to be unreasonable.

Comment

- (v) Section 5.9 Present Water Balance - the calculation of groundwater inflow (GI) and groundwater outflow (GO) is unclear. GI and GO values appear to have been determined at the eastern and western boundaries of the project site, however these boundaries cut across the water table contours. If GI is calculated over the 3.00m contour, and GO over the 1.75m contour, different values to those presented in the ERMP would be obtained.

Recharge from rainfall has apparently been calculated over the whole project site. However, if recharge (R) is calculated over the area of the above-mentioned bounding water table contours, different values from those presented in the ERMP are obtained. The combination of the reassessed GI, GO, R and evapotranspiration suggest zero leakage.

This reassessment does not necessarily indicate that there is no actual leakage, as leakage to the Rockingham Sand in one area may be balanced by leakage from the Rockingham Sand in another. Whether or not this occurs will affect the future predicted water balance and therefore needs to be established. Leakage in either direction can only be determined from a drilling programme.

Response

If the leakage is zero it would be helpful. The Consultants have no further comment at this time.

Comment

- (vi) Section 6 Expected Changes to the Groundwater Regime - in projecting changes to the groundwater regime, all water inputs and outputs and estimated recharge for each area and type of development have been evaluated, and the future water balance predicted. While the estimates of the components of the water balance may be reasonable, the adopted average value for leakage to the Rockingham Sand is by no means certain (as indicated in response to Section 5.9).

Leakage at a rate less than predicted in the ERMP will influence the projected movement of the saltwater interface, and the toe of the interface could be some 50m further west (if there is no leakage) than predicted.

The projection of groundwater contours (at Section 6.7) is purely conjectural because of the assumptions used in the estimation of recharge and groundwater flow. Groundwater contours can only be confirmed by appropriate monitoring.

Because of assumptions regarding GI from the east and leakage, GI to the artificial waterway could be higher than predicted.

Response

It was hoped that the estimate for leakage to the Rockingham Sand will prove conservative (too high). If the toe of the salt water interface is 50m further west it would be an advantage, but very minor compared to the planning concept of the waterways as a whole.

The groundwater gradients and direction of flow are not conjectural. The shape of the contours should therefore be reasonable. The actual contour level is most in need of confirmation by monitoring.

It is agreed that inflow to the waterway could be higher than predicted.

Comment

- (vii) Section 9 Conclusions - the need for verification of the assumed values indicated in the ERMP is supported. Investigation and monitoring bores should be installed as a matter of urgency. These are needed to confirm hydraulic parameters and assist in the prediction of the saltwater interface. Insufficient data are presently available to satisfactorily determine its position following construction of the artificial waterways.

Response

As indicated above the position of the saltwater interface to an accuracy of +/- 50m is not important in the overall plan.

Comment

(viii) Section 10 Recommendations - the suggestion in the ERMP that 7 of the recommended 12 observation bores into the Safety Bay Sand and upper part of the Rockingham Sand should be slotted against the entire saturated section of the Safety Bay Sand is unsatisfactory. If there is a saltwater wedge under the area now, or if one will exist in the future, upward heads could occur at depth in the aquifer. If bores are slotted over the entire saturated section, upward movement of saline water within the bores could occur, thus rendering them unsuitable for monitoring. Each of the seven sites should be equipped with two bores, one monitoring the water table, the other the base of the aquifer.

The proposed conductivity profiling would not be necessary if fully slotted piezometers are not used. Other recommendations made in the ERMP are endorsed.

Response

The Consultants will confer with the Geological Survey Department and Water Authority of W.A. to reach agreement on the detailed technique to be used in the monitoring bores.

Comment

Overall, the method of approach adopted in the analysis of the hydrogeological and groundwater implications of the proposed development is not satisfactory. This is because of the reliance on existing data derived from elsewhere than the project site, and because the only available on-site bores are of limited value.

A clearer evaluation of the prevailing hydrogeological conditions and the implications of the proposal is required and could be achieved by implementation of the recommendations made by the proponent's consultant in the ERMP (modified as per the above comments) prior to development approval.

Response

No amount of new data from the monitoring bores is going to change the fundamental picture that sea water from the waterways will extend a wedge of saline water about 150m beyond the waterways. The islands and peninsulas between the waterways and the coast will be underlain by saline water with a "pool" of freshwater on top.

While the Developer believes the cost/benefit ratio of the monitoring exercise is some 10 times what it should be, he has agreed in the ERMP, and will proceed to install the bores before any earthworks or dewatering is commenced.

3. Overview of the ERMP

Comment

Although most potential adverse impacts that could arise from the proposed development have been addressed in the ERMP, much of the information presented in response to anticipated impact is inconclusive. There is over-reliance upon desk analysis in the assessment of and response to impacts. Insufficient physical (i.e. on-site) investigation has occurred and in the case of the monitoring groyne, the duration of the observation period is insufficient for sound conclusions to be drawn.

Response

This must be a better ERMP than the predecessors for Sorrento, Mindarie and Waterside Mandurah (and Jurien and Esperance which had none). For anyone reading the two volumes of the ERMP properly, they could not fairly say there was over reliance on desk analysis and insufficient on site investigation. More site work has been done over a longer period than for any of the examples cited above. The water table bores for example were monitored for more than three years and the condition of the seagrass monthly for a whole year.

In regard to the monitoring groyne, this must be the best experiment of this type ever performed for a similar project in W.A. It is true that the report on the first full year is only now available. Our consultants on this matter (Riedel & Byrne and Dr Woods) are as good as anyone in Australia and they certainly believe sound conclusions can be drawn as does the Department of Marine & Harbours. In fact those experienced in coastal engineering could easily anticipate the result beforehand. In hindsight the ultra scientific approach of the "provenance" group only served to mask the fundamental issues in a cloud of impenetrable mystery.

4. Project Justification

Comment

Projections for future population levels, demand for residential land and boat ownership used in the ERMP appear to be optimistic.

Population trends for Rockingham and Kwinana for the period 1976 to 1985 suggest a 2040 population within 15 kilometres of the project site of about 130,000, some 50,000 less than 180,000 estimated in the ERMP.

Response

The Developers do not believe the future population, demand for residential land or boat ownership are optimistic. It is true that official estimates have been downgraded, but

the use of original figures seems to be supported by six new major industrial plants, now going in to the lower end of the Kwinana strip and the home porting of half of Australia's navy at Garden Island. Some changes in Government priorities are understood to be under consideration as a result.

Comment

Council data show low building rates at Warnbro and on this basis, there appear to be adequate supplies of residential lots available both at Warnbro and elsewhere in the Rockingham Shire. In addition, a number of other residential subdivisions (either approved or at the concept stage) are cited as further evidence that an adequate supply of residential lots exists.

Response

Low building rates at Warnbro are a reflection of the existing area not having been cleared of Army projectiles and the low quality of the subdivision. Nevertheless there are not many vacant lots in Warnbro and no new lots have been created because of lack of sewerage for one thing.

It is agreed that there is plenty of zoned urban land in Rockingham and Delta Holdings owns directly 17% and controls another 8% of it which will be developed in due course in any event. Delta has pioneered the provision of sewerage in the Warnbro area at considerable cost.

Comment

The availability of existing canal/waterway lots in the Mandurah/Murray area is also cited as lessening demand for the proposed development, and the already approved but dormant Secret Harbour project is suggested as indicating that demand for lots of the type proposed is limited. Because it is already approved, the Secret Harbour project is also suggested to be in a better position than the Westport proposal to satisfy any increased demand for waterway lots.

Response

Demand for waterfront lot is increasing worldwide including Australia. Demand and price are related to location and quality. Some of the existing developments in Mandurah fail this test. The best development is Waterside Mandurah which has been selling well at good prices and has proved the demand for single residential waterfront lots.

Westport is closer to Perth, will have unrestricted but sheltered access to the Indian Ocean and will have blue water canals and white sandy beaches. No other development of this size can ever be built closer to Perth.

The Developer cannot comment on any problems Secret Harbour may have, but its turn will come as the urban front and tourism expand.

Comment

Evidence of the demand for additional boating facilities that is cited in the ERMP is questioned, based on the already questioned population projection and the number of approved or proposed boating related projects elsewhere throughout the metropolitan and near-metropolitan region.

Response

The Department of Marine and Harbours have offered criticism that the boating and commercial facilities at Westport Village are not adequate in number of boats or size of boats provided for. Their experience at Hillarys has demonstrated the great change which is occurring in commercial attitude to these developments. Nearly everyone (4,000 comments plus media) said at the time of Hillarys ERMP that it would be a "white ele phant". Now it turns out to be a success story, commercially, environmentally and socially.

5. Dune Systems and Foreshores

Comment

Coastal development is currently a high profile issue in the local community, both in terms of the ownership of the foreshore areas (i.e. public reserve or private development), and the level of management applied to the foreshore area. The high levels of management required have not always occurred and by interfering with the natural coastal processes, the proposed development will precipitate even greater management requirements, not only at the project site but probably elsewhere (eg to the north where the coastal reserve/buffer is of a limited width only and, therefore, potentially vulnerable to oceanic damage which could be exacerbated as a result of the proposal).

Response

The Shire of Rockingham have a good record in rehabilitation and management of dunes. The Developers believe they have shown that management requirements will not be increased by the Westport Project and that adequate safeguards have been provided for the State and Local Authority. A great deal of the effort in the ERMP has been directed to the above issues. The Department of Marine and Harbours believe this is one of the three best locations in W.A. for a troublefree boat harbour entry. They have offered to assume control of it on a commercial basis.

The dunes are not managed at all at present and are deteriorating rapidly.

Comment

Whether or not the public will have access to the beach through the project site is queried. Informal access through the project site is well established and although this causes

environmental damage, exclusion of public access as a result of the development would be socially undesirable. Breaching of the presently available continuous access along the beach by the waterway entrance channel regarded as unacceptable.

Response

It should be abundantly clear if people making submissions read the ERMP, that total beach access is provided together with landscaping, pathways and carparking on private land being given up by the Developer to the public. Trail bikes and four wheel drive vehicles will be banned from the dunes and beaches. The Developer has no objection to people using another route through his land to Port Kennedy so long as they behave responsibly.

Obstruction to continuous access along the beach by the entry channel is an unavoidable impact. Alternate access by tunnel or high bridge is not desirable in this type of development. Obstruction to access is currently provided by nude bathers who make conditions unpleasant for traversing by the general public in summer. Very few people walk or run the full length of the beach at present.

Comment

Virtually all aspects of present human use of the beach and adjacent marine and terrestrial areas are considered likely to be adversely affected by the project (more so than a dry land subdivision which is acknowledged as possible under the current zoning), if only because the character of the general area would be changed.

Response

Fewer than 20 people have commented on these issues despite widespread advertising of the ERMP, distribution of pamphlets in 4,000 letterboxes around Rockingham, public meeting in Warnbro, local press coverage and a TV news plug. Presumably most of the people in Rockingham either don't care or agree with the Developers that human uses will benefit greatly from the Project. The quality of life provided by Westport will be a great improvement on the flat, soul-less urban sprawl currently proceeding in Rockingham.

6. Marine Environment

Comment

Appendices C and D of the ERMP detail existing conditions in the marine environment but few conclusions are drawn as to the likely effects of the project on this environment (eg as a result of seagrass loss, increased boating and fishing activity etc) and the capacity of the environment to assimilate increased human pressures. The possibility of poor water quality in the artificial waterways and this pollution being transmitted into Warnbro Sound (the flushing of which is not addressed in the ERMP) is a particular concern.

Response

The seagrass loss of 1.5 ha out of 930 ha is regarded as negligible. Increased boating and fishing activity is inevitable and this impact was dealt with in Volume I. It was not the purpose of Appendices C and D to deal with impacts. It was the purpose of Appendix B to determine pollutant loading in the waterways and its dispersion. It was the function of Dr Woods to collate all the information from Volume 2 and draw out conclusions in Volume I.

In numerous waterway developments around the world under similar climate and tidal conditions there have not been problems in the waterways and the effects have only extended 200-300m from the ocean outlet. This clearly is not going to affect Warnbro Sound.

Most of the pollution entering the waterways is not generated by boats but from surface drainage and groundwater inflow. This would be discharged eventually into Warnbro Sound in any event as is all the rest of the drainage from Safety Bay. This was clearly dealt with in the ERMP.

7. Management

Comment

The ERMP broadly canvasses management requirements but does not provide detailed cost estimates or demonstrate the Developer's capacity to satisfy these requirements. A proposal that is premised on a high level of continuing management input should proceed only if the ongoing management requirements have been conclusively demonstrated to be achievable (both during and following the development process) in financial and legal terms.

Response

The Developer was told that detailed cost estimates and financial status were not part of the ERMP. Other similar projects have not included this information.

The ongoing management requirements do not require a high level of cost input. The proposed funding from differential rating of waterfront properties is adequate and details already provided to both the Department of Marine and Harbours and the Shire of Rockingham, will be provided to the EPA if so required in a separate submission.

A draft agreement between the State, the Shire, Marine and Harbours and the Developer has been circulated for discussion. Marine and Harbours have suggested they take on responsibility for the breakwaters, entry channel and waterways on a commercial basis.

Comment

In view of the estimated cost of the project, bonds in excess of the proposed \$250,000 should be lodged against unforeseen management contingencies.

Response

The Developer believes cost of the project has nothing to do with the bond for unforeseen contingencies or default in management responsibilities. The \$250,000 would bypass sand for the next 25 years although this cost is met from the Trust's funds. The breakwaters are not susceptible to big storm damage and water quality is known from a wealth of similar experience. The Developer believes the bond is adequate and will apply whether Marine and Harbours are the operators or not.

Comment

The proponent's responsibilities in regard to the existence and clearance of unexploded ordnance at the project site should be clearly indicated.

Response

The Shire is not seen as being liable. The Developer and his contractors will proceed as they did for the 163 lots already created without problems. Buyers must sign a note of awareness. If anything happened in construction, the Army would be sued for what that is worth.

REPLY TO ISSUES FROM SUBMISSIONS

APRIL 9TH, 1987

5.5 Construction Method

5.6.1 Staging

This section refers to the requirement to recontour and restore the dunes to the north and south of the proposed entry channel following construction.

- Has the State Planning Commission, which controls the relevant land to the south, indicated approval for any such work to be carried out?

Response

In so far as the entry channel and southern breakwater construction and maintenance affects SPC land, written approval has been given (copy attached).

5.6.2 Method

During dewatering of the proposed canal areas, fresh and saline/brackish water will be disposed of, the former to the landward-side of the development area and the latter either into the ocean or into a pre-existing waterway.

- How will it be ensured that disposal of saline/brackish water into the ocean does not affect water quality or public use of the beach areas?
- Additional details need to be provided on the proposed method of distinguishing between fresh and saline/brackish water during the dewatering programme.

Response

Saline/brackish groundwater is best disposed of by soakage into depressions in the foredunes near the beach.

Dewatering will be done by using a number of lines of "spears" which have separate pumps and can be shifted from time to time as the adjacent water table drops. Water quality will be monitored and once any line exceeds say 2,000 p.p.m. it will be diverted seawards.

7 Environmental Impacts

7.2.2 Coastal Processes

This section of the document describes the anticipated effects on sediment transport, changes to the coastline (shoreline movement and stability) and seagrass meadows which will result from construction of the breakwaters and entrance channel.

- This section refers to a follow-up report being produced to clarify the predictions on nett transport of sediment. Results of that report have not been supplied. When will they be supplied?
- What is the maximum volume of sediment which could accumulate adjacent to either of the proposed breakwaters before sediment loss occurs down-slope, into the Sound?
- Is any seagrass meadow rehabilitation proposed?

Response

The follow up report on a complete years experience with the experimental groyne has just been completed and a copy is attached.

On the north side, 20,000 m³ of sediment can be accumulated easily without losing sand downslope out of the system. Detailed design will probably show this figure to be 40,000m³ without any special provisions.

On the south side an offshore plateau does not form in the summer build-up period in the absence of storm waves, and the storage is relatively less than on the northside. A very minor beach realignment adjacent to the southern breakwater will allow the effective storage to be increased above the 20,000 m³ already provided in the design (see annual report).

No artificial rehabilitation of seagrass is proposed because the area lost is so small. A report in the first years observation on the seagrass profiles is also now available.

7.2.4 Hydrology and Groundwater Quality

This section describes the impact on groundwater during construction and following completion of the project.

- An explanation is needed of conflicting statements made in the document in relation to the affect of establishing waterways on groundwater, namely Section 1.4(c) which states that the development will not affect the groundwater regime beneath houses at Warnbro, however, Section 6.5.7 states that approximately 28 with private bores may be affected by the project.
- Have investigations been undertaken into the possible effects on existing waterways of dewatering operations to be carried out in subsequent stages and if so what are the likely effects?
- What is the distance to which the water table will be lowered to the north of the development area? Dwellings are located within 230 metres of the northern waterway, not 300 metres as stated in the document.

Response

The permanent effect on the 28 houses about 300m of the northern edge of the waterways is estimated at only 10 cms. There is so small that the general statement of no effect was made. No specific investigations have been undertaken on the effects of subsequent stages on previous stages. A drop in the freshwater mound on the islands is possible but this could be recharged if it appeared critical. Section 7.2.4.2 refer to water table drop of 25 cms at 150m north of the development where there is no east/west groundwater flow to the waterways. Only 7 lots are within 300m of the waterways. The 28 dwellings referred to average more than 300m away.

7.3.3 Impact on Warnbro Sound

- What are the results of purported investigations into methods of stripping nutrients from discharging stormwater?

Response

Will need advice from Dr Woods who is away. It is understood that flow through limestone or limesand does partially strip out one of the main nutrients but not the other.

7.3.4 Impact of Heavy Metals Accumulation

This section of the document states that the concentration of heavy metals in the water body will not be significant because of its flushing characteristics. However, elsewhere in the document (Section 1.5.2(f)) it is suggested that heavy metals will not be flushed, but will accumulate in sediment in the waterways.

- Clarification should be provided as to whether heavy metals would accumulate in waterways sediment or be flushed into the Sound as a part of the waterbody.

Response

Will have to await advice from Dr Woods.

7.4 Impact on Human Environment

7.4.8 Sand Bypass Operation

- Are any techniques to bypass sand being considered other than using a front end loader and truck?

Response

No - Sand pump and pipeline on this small scale is not warranted. It is aesthetically undesirable for infrequent use.

8 Environmental Management

8.3 Management Programme

This section deals with aspects of the proposed management programme covering land and waters, from during construction to after completion.

- o What regulations will control discharge of litter, oil and sewage into waterways if these areas are to be subject to private leasing arrangements? What Authority would enforce these regulations?

Response

1. Navigable Waters Regulations - Dec 1981
2. Western Australian Marine Act - 1982
3. Marine and Harbours Act - 1981
4. Jetties Act - 1926

These acts automatically apply as soon as a connection is made to Warnbro Sound. The waterways on completion become vested in the Minister for Transport who administers the Department of Marine & Harbours and the above acts. The Management Trust as Lessee, will enforce the regulations through its own inspectors with assistance from Marine & Harbours and the Shire in the event of prosecutions being necessary. See also Appendix "J".

- o Is the use of a compresor and small work boat sufficient to maintain water quality within the canal estate, should calm conditions or any other conditions bring about a decline in water quality?

Response

Will have to await advice from Dr Woods.

- o More details in regard to sand bypassing should be given such as the names of the 'responsible authorities' and the upper limit on the amount of sand to be shifted.

Response

Responsible authorities are :-

Department of Marine & Harbours
Shire of Rockingham
Environmental Protection Authority

These Authorities would seek other advice if so required. The upper limit of sand bypass does not really exist. The Developer has undertaken to bypass such amount of sand from time to time as is needed to preserve the beaches and shoreline.

- o The question of importing sand to replace that which is lost to the system has not been adequately addressed. Would sand from waterways construction be suitable for beach use? What are your intentions in relation to disposal of dredge spoil from waterways which may contain accumulated heavy metals?

Response

Importing sand if ever needed, would come primarily from within the Westport Estate. At a later time it could be bought in from commercial suppliers. Sand from waterways construction is clean beach sand and would be suitable for beach use. The Developer does not envisage any significant accumulation of heavy metals in the waterways generally. It is more likely in the proposed marina area despite precautions being taken. The question of disposal has not yet been addressed.

- o Why is monitoring of shoreline movement twice per year considered to be adequate?

Response

The experimental groyne has confirmed that sand movements are generally north in spring/summer and south in winter. The peaks in the respective directions are reached in March and September depending on the exact weather pattern each year. Intermediate measurements were of use in the mathematical calibration but serve little purpose in ongoing monitoring.

- o The use of compensating basins to filter stormwater has been required from the Secret Harbour project. The use of a silt/oil trap to filter nutrients, heavy metals and hydrocarbons is questioned. Explanation of why compensating basins are not to be used should be given.

Response

It seems unreasonable to require compensating basins when most of the pollution is from urban drainage and groundwater which would find its way into Warnbro Sound in any event. Indeed the Water Authority had proposed an ocean outfall for drainage of this area as existing for the rest of Safety Bay. Very few similar projects around the world use compensating basins to filter stormwater. Detailed examination of water quality in the waterways is made in Appendix B.

It is agreed that the silt/oil traps are mostly to remove unpleasant and unsightly materials from drainage.

- o Should the project proceed, would the company be willing to be responsible for maintenance and management of the foreshore dunes for a five year period following transfer of the reserve to the Rockingham Council? A similar approach has been adopted for the Secret Harbour and Hooker Rex Warnbro subdivision.

Response

If this has become standard practice the Developer will agree. However, the Shire of Rockingham is organised and is doing this kind of work. If the Developer is still financially responsible after having done all the rehabilitation, one wonders what contribution the Shire is making for its rates. This is privately owned land which is to become a public beach and recreation area.

8.5 Management Responsibility

- o Further details should be provided on the proposed structure, responsibilities and method of operation of the Westport Body Corporate (Trust).

Response

This is dealt with in Appendix "J" - Operational Responsibilities.

It is also detailed in the Draft Agreement between the State, the Shire, Marine & Harbours, and the Developer. Another copy can be supplied if needed. As this matter needs further discussion and Marine & Harbours have expressed an interest in operating the waterways, channel and breakwaters, it is suggested that it be dealt with separately from the ERMP.

- o How was the figure of \$250,000 determined and why was it considered to be sufficient to cover the stated works over an ongoing maintenance period?

Response

This has been answered on Page 13 of the first group of comments and responses. It is believed to be the figure adopted for Mindarie Keys and sufficient for any contingency.

- o Why is the Rockingham Shire considered to be the most appropriate authority to hold the bond to cover works associated with the waterways?

Response

It was thought the Shire would be more directly involved than other Departments and acting on their behalf. If Marine and Harbours do take on the operation, no doubt they will want to hold the bond.

Further Issues raised

Structure Plan, Subdivision Design

- (a) Densities shown for Westport Village depend on Amendment 145 to Rockingham Town Planning Scheme - Agreed.
- (b) Subdivision design may not be approved in its present form - no comment.