COCKBURN CEMENT

CONSULTATIVE ENVIRONMENTAL REVIEW

MEDIUM-TERM SHELLSAND DREDGING
OWEN ANCHORAGE

AUGUST 1996

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AN INVITATION TO COMMENT ON THIS CER

Cockburn Cement Limited (Cockburn) and the Environmental Protection Authority (EPA) invite people to make a submission on this Consultative Environmental Review (CER).

Cockburn proposes to dredge shellsand from Success Bank in the area between the existing Fremantle Port Authority (FPA) shipping channel, and the second shipping channel to the east until approximately the end of 2001. In accordance with the Environmental Protection Act 1986, a CER has been prepared which describes this proposal and its likely effects on the environment. The CER is available for public review for 4 weeks from 20 August 1996.

Comments from Government Agencies and the public will assist the EPA to prepare an assessment report in which it will make its recommendations to Government.

Why write a submission?

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

All submissions received by the EPA will be acknowledged. Submissions will be treated as public documents unless specifically marked confidential, and may be quoted in full or in part in each report.

Why not join a group?

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

Developing a submission

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

When making comments on specific proposals in the CER:

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

Points to keep in mind

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

- attempt to list points so that the issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the CER; and,
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name;
- address;
- date; and,
- whether you want your submission to be confidential.

The closing date for submissions is:

23 September 1996.

Internet Access:

This document will be accessible on Internet from 5 September 1996. The address for access by WWW (html readers) is:

http://sage.wt.com.au/~cockburn/

Submissions should be addressed to:

The Chairman
Environmental Protection Authority
Westralia Square
141 St Georges Terrace
PERTH WA 6000

Attention: Mr Tim Gentle

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EXECUTIVE SUMMARY

1. THIS DOCUMENT

This Consultative Environmental Review provides details to support a proposal by Cockburn Cement Limited (Cockburn) for the dredging of shellsand from Success Bank, Owen Anchorage until approximately the end of the year 2001. This shellsand is used mainly in the manufacture of quicklime which is an essential product for the State's mineral processing industry. Cockburn currently provides about 90% of the State's requirements for lime.

The area proposed for dredging is located between the existing Fremantle Port Authority (FPA) shipping channel, and the second shipping channel, and is referred to as the proposed medium-term dredge area. Dredging is presently underway in the adjacent short-term dredge area.

2. BACKGROUND TO PROPOSAL

Cockburn has been dredging shellsand in the Owen Anchorage area since 1972 in accordance with conditions defined in an Agreement Act with the State of Western Australia. Initially, dredging took place on Parmelia Bank, and in 1987, dredging was transferred to Success Bank due primarily to requirements for a higher quality resource.

In 1986, specific environmental requirements were included under the revised State Agreement Act, requiring Cockburn to submit its ten year dredging management plan (DMP) to the Minister each two years for approval. DMP 1 and DMP 2 were approved. DMP 3, which was submitted in 1990, was approved for only 2 years primarily because of concern for the long term stability of the Banks and the loss of seagrass. The ten year dredging plan included in DMP 4, which was submitted in 1992, was not approved based on similar concerns. Concurrently Cockburn had investigated possible alternative resources including the Mewstone area and concluded no suitable alternative resources to Success Bank existed at that time. In addition Cockburn had been supporting detailed research into monitoring slope stability, natural recolonisation of dredged slopes, and seagrass transplantation, and commenced investigation of beneficiation process.

With uncertainty over long-term access to resource, in 1993 Cockburn sought formal assessment for its dredging proposal, and was requested to prepare a Consultative Environmental Review (CER) for access to resource for the short-term (approximately 2 years). This was submitted in February 1994, and approved by the Minister in a statement issued in August 1994. The statement also addressed the issue of medium-term (approximately another 5 years) and long-term (to the year 2021, which is to the end of the Agreement Act including a 10 year extension from the year 2011) access to shellsand resource. The statement required Cockburn to prepare an acceptable Environmental Management Programme (EMP) to gain access to the medium-term resource.

This EMP was to address issues of:

- ecological significance of seagrasses;
- seagrass transplantation;
- wave climate implications;
- alternative resources; and,
- beneficiation.

Cockburn prepared the EMP which was submitted in February 1995. After modifications to the EMP, it was approved by the Minister in December 1995.

In March 1996, the Supreme Court of Western Australia passed down its judgement on an action brought against the EPA by the Coastal Waters Alliance. The Supreme Court upheld the action and ruled that the EPA had gone beyond its statutory powers in its evaluation of the 1994 CER and that the advice it gave to the Minister was flawed. This decision rendered null and void all approvals provided to the Company since August 1994 and meant that the assessment of the 1994 CER for short-term dredging was not yet complete. The December 1995 decision of the Minister concerning the acceptability of the EMP was therefore also invalidated by the Court's decision.

Cockburn advised the Minister on its commitment to continue its dredging operation in accordance with the Agreement Act, and to continue to implement the EMP research programmes as though the Minister's decisions of August 1994 and December 1995 were still binding on the company.

The Minister has not yet received the recommendations of the EPA on its evaluation of the 1994 CER for short-term dredging.

Cockburn is presently dredging in the short-term area in accordance with its Agreement Act, and seeking environmental approval to do so. Cockburn is also committed to providing lime to Western Australian industry. In May 1996, Cockburn resubmitted a proposal to DRD for dredging for the medium-term (approximately 5 years). The assessment level set for the proposal was as a CER.

This document is the CER, and seeks to gain approval to dredge that part of Success Bank between the FPA shipping channel and the second shipping channel, which is referred to as the proposed 'medium-term' resource.

At forecast rates of demand, it is anticipated that this resource will last until approximately the end of the year 2001. During this period, Cockburn commits to continuing its substantial programme of research as documented in its EMP, and further commits to referring to the EPA its proposal for the long-term dredging strategy at least 15 months prior to the anticipated depletion of the medium-term resource.

3. COCKBURN'S RESOURCE REQUIREMENTS

Cockburn currently produces approximately 1.1 million tonnes of quicklime (calcium oxide) and cement annually. The basic raw material for both of these products is calcium carbonate. In 1995 Cockburn used approximately 1.9 million tonnes of calcium carbonate materials, of which 1.7 million tonnes was obtained by dredging shellsand on Success Bank.

Shellsand seldom occurs completely pure, with the main impurity being silica. For lime production, Cockburn requires a resource that has a minimum of 92% calcium carbonate. Success Bank is the main source of shellsand of this grade, with shellsand of lower grade being more widely dispersed in the area. Over the next five years (1997–2001 inclusive) Cockburn has a requirement for approximately 11.5 million tonnes of shellsand of grade 92% or better.

4. EVALUATION OF ALTERNATIVES

This proposal to dredge the area of Success Bank designated as the medium-term area was prepared after a detailed evaluation of ten alternatives for the acquisition of raw material. These include:

- beneficiation of lower quality shellsand, limesand and limestone;
- completion of the second channel through Success Bank;
- completion of the second channel through Parmelia Bank;
- use of spoil from maintenance dredging of the FPA channel through Success and Parmelia Banks;
- widening the existing FPA channel through Success and Parmelia Banks;
- dredging areas of shellsand with low seagrass cover around Mewstone, west of the existing FPA channel;
- terrestrial sources of limestone within the metropolitan region;
- terrestrial limestone or limesand from Geraldton to Augusta;
- relocation of Cockburn's South Coogee cement and lime plant; and,
- dredge area on Success Bank between FPA shipping channel and second shipping channel.

These options were evaluated based on Cockburn's resource requirements for the next 5 years, and on environmental, social, and economic considerations.

The evaluation indicated that:

- Tamala limestone is unsuitable as a resource;
- Cockburn requires a resource for lime manufacture that has a minimum grade of 92% calcium carbonate. No resources of this quality other than those on

Success Bank are within a distance of Perth for economic transport of the raw material;

- Cockburn's dredge and barges are not able to operate effectively on Success Bank west of the FPA shipping channel;
- the beneficiation process, which is promising at a test level, has still to be proven for commercial production;
- relocation of lime manufacturing facilities would incur enormous capital expenditure. In addition, there would be additional costs and impacts associated with the transport of lime to existing customers that are mainly located in the south west of the State;
- Cockburn has a contractual obligation to continue to provide lime for Western Australia's mineral industry;
- two options exist for acquiring small amounts of suitable grade material with minimal environmental effects. These are: remove the material on the floor of the second channel through Success Bank (approximately 0.5 to 1 million tonnes); and, widen the existing FPA channel (3 million tonnes); and,
- the only practical option available that enables the resource requirements of Cockburn to be met over the next five years is dredging the area on Success Bank between the FPA shipping channel and the second shipping channel. This preferred option is referred to as the **proposed medium-term** area.

It is recognised that this option involves the dredging of 147 ha of Success Bank to an average depth of about 13 to 14 metres, and will result in the removal of 57 ha of shallow unvegetated sediment with seagrass cover less than 25%, 46 ha of low density seagrass (25–50% cover), and 44 ha of high density seagrass (50–100% cover).

The evaluation also indicated that development of beneficiation will markedly increase the potential resource that would be available. The implementation of commercial beneficiation is expected to take up to another 5 years. With commercial beneficiation techniques, at least 2 further options for the acquisition of significant amounts of shellsand can be considered, these being:

- completion of the second shipping channel through Parmelia Bank; and,
- dredging the area around Mewstone.

Implementation of these options would require prior environmental approval.

5. THE DREDGING PROGRAMME

The dredging programme has been developed to provide a source of raw material to meet Cockburn's medium-term requirements. The dredging programme is designed to dredge areas of lower seagrass cover first, to allow for the concurrent development of seagrass transplantation techniques.

Sea state conditions during winter impose restrictions on where the dredge and barges can operate. The dredging programme therefore involves dredging the northern (or more exposed) end of the area in summer, and the southern end in winter.

6. EXISTING ENVIRONMENT

Success and Parmelia Banks are deposits of unconsolidated sediments that have formed during the last 7000 years by accretion and consist largely of carbonaceous sands that have been transported towards the shore. Water depth over the Banks is less than 5 metres at their shallowest.

Sediment transport, caused by a combination of wind, waves and currents, occurs mainly across the tops of the Banks, and it is estimated that approximately 60,000 cubic metres of sand reaches the shore of Owen Anchorage annually. This sand is redistributed along the shores of Owen Anchorage, and beaches have been growing consistently, with detailed measurements of this growth since 1972. The shoreline of Owen Anchorage has been heavily modified during the last century by the construction of groynes and sea walls. In addition, nearshore waters of Owen Anchorage have received wastes discharged from industries along its shore; this practice has virtually ceased over the last five years.

The area is used for a small commercial and recreational fishery for squid, octopus and whiting, and for other recreational boating activities. Otherwise Success Bank is used primarily by Cockburn for the recovery of shellsand.

The Banks support a wide range of seagrass assemblages which differ in structure, density, species composition and distribution.

The distribution and density of seagrass assemblages on the Banks have varied significantly at least since 1965, when aerial photographs of Owen Anchorage were first obtained. The areas that could be identified with a degree of certainty in aerial photographs as containing seagrasses on Success and Parmelia Banks in 1971 (just before Cockburn commenced dredging) and 1995, are shown below:

LOCATION	1971	1995
Success Bank	978 ha	1503 ha
Parmelia Bank	1004 ha	866 ha

In particular, the density and cover of seagrasses has increased on the eastern side of Success Bank, and on the western side of Success Bank to the north and south next to the FPA shipping channel. Seagrass losses have occurred on Parmelia Bank, close to the Owen Anchorage shoreline on the eastern side of Success Bank and in the centre of the west side of Success Bank. Losses are due to pollution (eutrophication), dredging, and to natural causes (erosion). Gains are attributed to natural causes, these being a combination of seedling establishment and rhizome (or root) extension. The main species associated with the increase in area of seagrass cover on Success Bank are *Posidonia coriacea* and *Amphibolis griffithii*.

7. IMPACTS OF DREDGING

The proposed medium-term dredge area covers 147 ha, comprising 57 ha of shallow unvegetated sediment (seagrass cover less than 25%), 46 ha of low density (25–50% cover) *Posidonia coriacea*, and 44 ha of high density (50–100% cover) meadows of mixed *Posidonia coriacea* and *Amphibolis griffithii* seagrass. The main impacts of dredging are:

- the alteration of the wave climate of the immediate area due to the change in bathymetry; and,
- the removal of seagrasses prior to dredging.

7.1 Effects on Wave Climate and Shoreline Stability

The effects of the changes in bathymetry due to dredging on wave climate have been assessed using a sophisticated numerical model calibrated with one year of measurements of wave characteristics.

The medium-term dredging will cause small changes in wave height and wave direction in the vicinity of the dredge area. The changes are not considered significant for the management of shipping in the FPA channel. It is anticipated that no change in wave climate at the Owen Anchorage shoreline will occur, nor will there be effects on sediment transport patterns along the shoreline. It is therefore anticipated that the beaches of Owen Anchorage, which have not been affected by the dredging that has occurred since 1971, will similarly not be affected by the proposal for medium-term dredging. The minor modifications to the wave climate are not expected to have any effects on the remaining seagrasses on the eastern side of Success Bank.

7.2 Effects of Loss of Seagrass

The geographic area of relevance to this proposal includes Parmelia and Success Banks, and Owen Anchorage and covers approximately 13,000 ha. Of this, about 3,000 ha is seagrass meadow, where meadows are defined as having greater than 25% seagrass cover. The proposal for medium-term dredging involves the removal of 90 ha of banktop seagrass meadows. This comprises about 3% of the seagrass meadows of the immediate area. This loss will involve roughly equal areas of patchy meadow (25–50% cover) and dense meadow (greater than 50% cover).

In terms of ecological functioning in this area seagrasses play a minor role in the accumulation and stabilisation of sediments, in wave baffling and in influencing physical processes. However, they are important for their contribution to primary production (and therefore the food web), for the provision of a complex three dimensional habitat for other plants and animals, and for nutrient recycling.

In the areas that would be dredged during the proposed medium-term programme, some limited natural seagrass regrowth on slopes and at depth will occur after dredging. This regrowth will be with a far lower density of seagrass, and with a different species composition compared to present conditions.

Overall, given the small scale of seagrass loss that will occur with medium-term dredging, it is unlikely that the influences of dredging on the ecological functioning will be significant or measurable.

Fish use seagrass meadows as one of many feeding grounds and/or areas for shelter, and the majority of commercially and recreationally important species of fish range over hundreds or even thousands of kilometres. Severe loss of seagrass may affect the fisheries when a large proportion of the adults live and spawn in the area. This does not apply to the majority of fisheries species in the area, but may apply to blue manna crabs and some species of squid, both of which live in seagrass meadows. Conversely, creation of deeper, less vegetated areas may favour other species of fish such as snapper. Given these factors, and the proportionately small area of seagrass lost by dredging the medium-term resource, it is estimated that the influence on recreational and commercial fisheries will not be significant or measurable.

7.3 Effects on Stability of Dredge Slopes

Regular monitoring has shown that after dredging, there is some regression at the top of the edge of dredge slopes. This regression occurs up to about a maximum of 50 metres and reaches stability in about 3 years.

8. ENVIRONMENTAL MANAGEMENT

8.1 Objective

The proposed medium-term dredging will be undertaken according to a dredging plan that prioritises dredging in areas of least seagrass cover to allow the greatest time for the development of seagrass transplantation techniques. Concurrently a series of detailed scientific studies will be undertaken; these studies form an Environmental Management Programme (EMP). The EMP studies, appropriately modified after discussions with the EPA and DEP, have previously been evaluated by the Minister and found to be "environmentally acceptable".

The management plan that will be used for the proposed medium-term dredging, therefore has the following main objectives:

- to minimise the potential for adverse environmental effects arising out of the medium-term dredging;
- to implement findings from the EMP studies as soon as practical to further reduce any adverse environmental effects arising out of the medium-term dredging; and,
- to provide sufficient technical information to allow Cockburn to develop a comprehensive long-term programme for resource acquisition for the period 2002 up to 2021, which is the end of the State Agreement Act.

8.2 Key Principles

The key principles used to guide the management plan for the proposed medium-term dredging programme are:

- an adaptive environmental management approach will be used whereby the management plan will be regularly reviewed and modified as appropriate as the results of EMP technical studies become available;
- non-renewable natural resources are to be used as efficiently as current technology allows;
- the proposed medium-term dredging operation and associated rehabilitation programme will be undertaken with the aim to maintain ecological function and to result in no net loss of ecological function due to dredging in the Owen Anchorage/Cockburn Sound area; and,
- implementation of the medium-term dredging programme will be conducted in an open manner, involving regular reporting to the authorities, independent peer review of the EMP studies, dissemination of study results, and consultation with the local community.

9. EMP STUDIES

9.1 Timing and Implementation

The EMP studies proposed by Cockburn, and their project leaders are shown below.

PROJECT TITLE	PRINCIPAL PARTICIPANTS
A1: Programme Management	Dr D A Lord (DAL)
C1: Wave Climate Study	M Rogers (MRA), Prof I Young (ADFA)
C2: Shoreline Monitoring	M Rogers (MRA)
C3: Banks Sedimentology	Dr B Hegge (DAL)
S1: Seagrass Ecological Significance	Prof D Walker (UWA); Dr F Wells (WAM); Dr P Lavery (ECU); Dr P Morrison (Kinhill); D Annandale (MU); Dr K Hillman (Kinhill)
S2: Seagrass Rehabilitation	Dr E Paling (MU); Dr D Gordon (LDM); J Phillips (Ocean Industries); R Dyhrberg (Diver I/Diver II)
S3: Habitat Mapping	I LeProvost, P Collins (LDM); A Wyllie (NGIS)
S4: Artificial Reefs	M Rogers (MRA); F Wells (WAM)
S5: Slopes Monitoring	Dr D Gordon, P Collins (LDM)
R1: Beneficiation	CSIRO (Minerals); Cockburn Cement
R2: Alternative Resources	DME (WA); DRD (WA).
R3: Dredging Plan	BHP; Cockburn Cement
R4: Innovative Dredging	MTI (Holland); Aquamarine; Ocean Industries

ADFA = Australian Defence Force Academy
DAL = D A Lord & Associates
DME = Dept of Minerals and Energy, WA
DRD = Dept of Resources and Development, WA
ECU = Edith Cowan University
LDM = LeProvost Dames & Moore
MRA = M Rogers & Associates
MU = Murdoch University
NGIS = National Geographic Information Systems
UWA = University of Western Australia
WAM = WA Museum

9.2 Seagrasses

9.2.1 Ecological Significance of Seagrasses

Seagrass meadows have both an intrinsic biological value and a value to people — together this provides a basis for evaluating their ecological significance.

Seagrasses are considered important for several reasons, including:

- assisting in the regional productivity of commercial and recreational fisheries;
- binding and trapping sediments;
- providing a source of food and shelter for animals; and,
- supporting human activities such as recreation, research and tourism.

The presence of seagrass beds in the proposed dredging area of Success Bank is one of the primary concerns for evaluating the effects of the proposed dredging. Detailed studies are being undertaken to examine the extent of seagrass meadows, to determine their ecological significance, and to determine the influence of dredging on the ecological significance of the areas being dredged, as well as those of Owen Anchorage and its surrounds. These aspects will be interpreted in terms of their 'ecological function' which is considered to be the combined characteristics and processes occurring within an area.

9.2.2 Seagrass Rehabilitation

One of the main goals of the EMP is to undertake dredging and appropriate mitigation to ensure that dredging does not result in a net loss of ecological function in Owen Anchorage and its surrounds. It is recognised that dredging will increase water depth, and that the replacement of any seagrasses that are lost through dredging is unlikely to be totally equivalent at the dredging site. Achieving no net loss in ecological function for the area involves the investigation and implementation of programmes of rehabilitation, including all techniques that are available for restoring previous ecological function, or providing additional or alternative ecological function.

The range of potential techniques currently being considered includes:

- transplanting seagrass from areas to be dredged into appropriate areas, for example on Success Bank, Parmelia Bank and in Cockburn Sound (ie. return seagrass to historically degraded parts of Cockburn Sound);
- protection of high value natural seagrass beds;
- use of colonising species to return function to dredged slopes; and,
- installation of features such as artificial reefs in deep dredged areas.

It is likely that a mix of all the above techniques will be required to replace any ecological function lost through dredging. Because of the scale involved, there will be an emphasis on the development of techniques for the bulk transplantation of seagrass.

9.3 Resources

Cockburn will continue to examine all options for making efficient and effective use of non-renewable resources. In particular, this includes the beneficiation of lower grade resources, as well as the identification of alternative resources within the region.

Beneficiation is the process of removing impurities from limestone or shellsand to increase its calcium carbonate concentration. However, whilst beneficiation is technically feasible at pilot scale, significant problems exist with the process at the scale required for commercial production. For example, the use of electrostatic separation techniques require substantial quantities of fresh water for washing shellsand, as well as the disposal of the reject material from the beneficiation process.

Cockburn has already expended over $1.3 million investigating beneficiation techniques and is continuing to support research in this area because the company is committed to making efficient use of natural resources by maximising the period of resource availability.

Cockburn therefore proposes a phased investigation aimed at demonstrating the economic and technical feasibility of commercial beneficiation by April 2000. It is possible that Cockburn will have constructed and commenced operation of a 200,000 tonnes per annum beneficiation demonstration plant by the end of 1998.

Cockburn continues to investigate the location and availability of other limestone and limesand deposits in the area from Geraldton to Augusta.

9.4 Coastal Processes

The influence of dredging on the wave climate of the area, and particularly the affects of dredging on shipping, sediment transport processes and ultimately shoreline stability, has been examined by Cockburn, using a combination of computer models and field observations. These models will continue to be applied to potential dredging options. In addition, monitoring of the eastern shoreline of Owen Anchorage will continue.

9.5 Management and Implementation of the EMP

To manage the EMP, Cockburn have established a complex management structure, which includes an independent Environmental Management Advisory Board (EMAB), as well as comprehensive national and international peer review of the technical programme. Cockburn will undertake their own compliance auditing system as well as complying with the auditing system proposed by the DEP. Annual reports on the progress of the EMP will be prepared.

10. ENVIRONMENTAL MANAGEMENT AND COMMITMENTS BY COCKBURN

An analysis of the environmental factors that pertain to the area in the vicinity of the proposed dredging, the likely effect of the proposal on these, the predicted outcome of the proposal, and the management of these, is summarised in Table S1, according to physical factors, biological factors, and social factors.

11. COMMUNITY INFORMATION AND PARTICIPATION PROGRAMME

Cockburn will continue a programme of community information and consultation during the medium-term dredging. The purpose of this programme is to provide information on the management of the shellsand dredging operation, and the results of the EMP studies, as well as to enable community views to be incorporated into management protocols.

Table S1 Summary of Effects of Proposed Dredging, and Management Commitments

A: PHYSICAL FACTORS: WAVE CLIMATE AND SEDIMENT TRANSPORT

ENVIRONMENTAL FACTORS	EFFECTS OF PROPOSAL	ANTICIPATED OUTCOME	MANAGEMENT ACTIONS AND COMMITMENT
Area presently experiences reduced wave energy and modified wave direction as result of offshore reefs and general bathymetry. The wave climate controls patterns of sediment transport, and therefore the formation and maintenance of Banks and beaches.	Dredging will modify bathymetry in immediate vicinity, creating a basin of area of 147 ha and of depth 11 to 14 metres. This will modify wave climate shorewards of dredging, changing wave height and wave direction. In return, this could effect: • banktop stability • seagrasses on banktop • coastal stability • turbidity of water • navigation	Effects of dredging were examined using numerical modelling and observations, and show that dredging will cause little change to wave height, but some minor change in wave direction locally. Consequently, • banktop stability will not be affected by small change in wave climate. Sediment transport patterns along Banks will remain largely unaltered • seagrasses on eastern Success Bank will not be eroded as a consequence of wave climate modifications • models show no effects on shoreline sediment transport patterns. Shoreline of Owen Anchorage will continue to show accretion, with erosion occurring with winter storms. • no anticipated changes in turbidity over Success Bank due to wave climate changes. Turbidity effects due to dredging will be limited to the vicinity of dredging • no adverse effects on navigation in FPA channel through Parmelia Bank	• maintain wave climate and sediment transport model, and apply to any new or modified dredging options • continue shoreline monitoring (winter and summer)

B: BIOLOGICAL FACTORS: SEAGRASSES AND ASSOCIATED FEATURES

ENVIRONMENTAL FACTORS	EFFECTS OF PROPOSAL	ANTICIPATED OUTCOME	MANAGEMENT ACTIONS AND COMMITMENT
Seagrasses are found along the WA coast from Shark Bay to Cape Leeuwin. The same species occur within the study area. The total area covered by seagrasses in the study area is 3088 ha (1995 figures) Seagrasses have ecological attributes that include: • provision of three dimensional habitat structure	The proposed dredging will cover 147 ha, and will remove: • 57 ha of sparsely vegetated bank tops (seagrass cover <25%) • 46 ha of low density (25-50%) cover of *Posidonia* coriacea • 44 ha of high density (75-100%) mixed *Posidonia* and *Amphibolis* meadows These areas will be replaced by deeper (11-14 metres) of largely unvegetated sediment	Measurements, and comparative studies indicate: • some loss of three dimensional habitat will occur. The dredged areas will be recolonised by benthos and will provide some replacement ecological function. • a small proportion of seagrasses in the study area will be lost. However the amount of seagrass cover on Success Bank is presently increasing. • seagrass habitat is widespread in the region. Most species associated with seagrass recruit by spores, larvae and propagules. It is considered most unlikely that local or regional biodiversity will be adversely affected by this project.	• implement detailed scientific research and technical investigations to define and to measure ecological significance of seagrasses • undertake intensive development of techniques for seagrass transplantation • develop artificial reefs to enhance production • dredge areas of low seagrass cover(<25%) first, to maximise time for development of transplantation techniques

B: BIOLOGICAL FACTORS: SEAGRASSES AND ASSOCIATED FEATURES (CONT)

ENVIRONMENTAL FACTORS	EFFECTS OF PROPOSAL	ANTICIPATED OUTCOME	MANAGEMENT ACTIONS AND COMMITMENT
• nutrient cycling • maintenance of biodiversity • support for commercial and recreational fisheries • sediment supply (carbonate production) and sediment stabilisation		• It is not possible to presently predict with reliability the effect of this proposal on commercial and recreational fisheries. However fishing activity over these seagrass meadows is low and only a relatively small area of seagrass in the area is being removed. Most fisheries species have large territorial distribution ranges and are unlikely to be influenced by this change. In addition, there is no published evidence that fisheries have suffered as the result of the significant seagrass loss in Cockburn Sound. Therefore, it is considered most unlikely that significant adverse impacts on commercial and recreational fisheries of the area will occur with this proposal. • It is estimated that there will be no significant adverse effect on sediment supply as seagrasses are not a major source of sediment to Success Bank.	• undertake detailed evaluation of alternative resources (marine, terrestrial) with no/lower seagrass cover • develop shellsand beneficiation technology to enable lower grade shellsand with low seagrass cover to be used.

C: SOCIO-ECONOMIC FACTORS

ENVIRONMENTAL FACTORS	EFFECTS OF PROPOSAL	ANTICIPATED OUTCOME	MANAGEMENT ACTIONS AND COMMITMENT
The study area supports the following main activities: • shipping, with use of the FPA shipping channel to Cockburn Sound, as well as for small craft • recreation, including beach use, and boating • education and research • shellsand extraction by Cockburn	The proposed medium-term dredging will occur only in the area between the existing FPA shipping channel and the second shipping channel	• wave modelling shows that navigation in the FPA channel will not be affected • no effect on recreational use of area • scientific studies that form part of this CER will provide substantial increase in knowledge of local coastal processes, especially the ecological role of seagrasses • development of world-leading technology for seagrass transplantation • maintenance of Cockburn operations	• continued liaison with FPA on navigational matters • community information and participation programme

1. INTRODUCTION

1.1 THIS DOCUMENT

This document is a Consultative Environmental Review (CER) produced by Cockburn Cement Limited (Cockburn) in accordance with Part IV of the Environmental Protection Act 1986. The purpose of this CER is to:

- gain approval to continue dredging shellsand from parts of Success Bank occurring between the FPA Shipping Channel and the Second Channel offshore of Fremantle (Figure 1.1 and Figure 1.2). This is identified as the 'medium-term' dredging area, and would provide resource for Cockburn until approximately the end of the year 2001; and,
- enable the public to comment on the proposal.

Accordingly, this report is intended to:

- describe the proposal;
- enable the Environmental Protection Authority (EPA) to assess the environmental aspects of the proposal in detail;
- provide a basis for government agencies, members of the public and other parties to evaluate the proposal and make commitments to the EPA; and,
- state the Company's commitments for managing the environmental effects of the proposal.

The CER has been produced to read as a stand-alone document but refers to the many studies conducted since 1985 by Cockburn's consultants. These documents are available for perusal at the Company's offices in South Coogee.

1.2 THE PROPONENT

The proponent, Cockburn Cement Limited, is an unlisted public company registered in Western Australia. It is a wholly owned subsidiary of The Rugby Group, a United Kingdom based public company that manufactures building materials in several countries.

Cockburn has been engaged in the manufacture of cement and lime at its works at Russell Road, South Coogee since 1955 and currently produces approximately 1.1 million tonnes per annum of these products. Cockburn has dredged shellsand from the Owen Anchorage area since 1972 in accordance with conditions defined in an Agreement Act with the State of Western Australia (WA). Most of the dredged material is used in lime manufacture, for which a raw material of high (not less than 92%) calcium carbonate content is needed; the remainder is used, together with limestone and other materials, in cement manufacture.

Detail on Cockburn's dredging operations, contribution to the State's economy and management approach is provided below.

1.2.1 Dredging Operations

Since 1971, Cockburn has invested in both floating and shore based plants designed specifically to extract the shellsand resource from within the Agreement Area (see Section 1.3.1 below and Figure 1.2) and to operate in the sea conditions prevailing there.

1.2.1.1 Dredge and barges

Cockburn's dredge 'Success', a water-jet suction dredge (Plates 1 and 2), recovers shellsand at the rate of 800 tonnes per hour in water depths varying from 5 to 16 metres. It operates 12 hours a day, 365 days a year, subject only to weather conditions and major maintenance requirements.

The dredged shellsand is transferred from the dredging site via three split hopper bottom opening barges which travel to Cockburn's jetty at Woodman Point and discharge their load on the seabed alongside.

1.2.1.2 Reclaiming, washing and pumping

The shellsand is reclaimed from the stockpile around the jetty by a suction nozzle mounted on the jetty. It is then pumped ashore to the nearby wash plant where it is washed, using artesian water from the Company's bores. The washed shellsand is pumped 7 km through a 200 mm steel pipeline to the main works at South Coogee.

The only material returned to the sea from the washing plant is wash water with fine sediments in suspension, which is discharged into the sea near the end of the jetty.

In addition, reclaimed water from below the shellsand stockpile at the main works is returned to the wash plant for reuse to ensure no increase in salt content of groundwater at the main works.

1.2.2 Contribution to Western Australia

Cockburn operates entirely within Western Australia and had an annual turnover of $130 million in 1995. The Company employs about 340 people, mostly at its South Coogee plant and in addition spends $60 million per annum on local goods and services.

Cockburn's products are essential to the State's resource processing and building industries. Its lime is the most extensively used alkali in mineral processing. Cockburn is the sole supplier of lime to the alumina industry, and is the single largest producer of lime in Australia.

The importance of Cockburn's lime to the Western Australian economy was recognised by Resource Development Minister, Colin Barnett, in a statement released on 20 April 1996 which indicated that Western Australia's alumina, gold and mineral sands processing industries contributed some $6 billion worth of production a year, much of which was reliant on Cockburn's lime as an essential reagent.

Cockburn is also at present constructing a sixth kiln at its South Coogee plant, at a capital investment of about $80 million.

Cockburn has recently announced a $30 million investment into the construction of a lime kiln at Dongara, for the production of approximately 100,000 tonnes of lime annually. This kiln will use approximately 200,000 tonnes per annum of terrestrial deposits of limesand contained in dunes, as source material. The lime produced will support the mineral sands industry in the Geraldton area and gold mines in the Murchison region. These users are presently being supplied with lime transported from Perth. Construction of access roads to the site has already commenced, and production will start in early 1998.

1.3 BACKGROUND TO PROPOSAL

1.3.1 Agreement Act

Cockburn commenced dredging shellsand from Parmelia Bank in 1972, operating under the Cement Works (Cockburn Cement Limited) Agreement Act 1971. The areas dredged by Cockburn since 1972 are shown in Figure 1.2, and include an area on Parmelia Bank that was dredged between 1972 and 1987, and the proposed second shipping channel through Success Bank, that was dredged between 1987 and 1994.

The Act was amended in 1986 [Cement Works (Cockburn Cement Limited) Agreement Act 1986]. Both Acts give Cockburn rights to extract shellsand within a radius of 5 miles (8 km) from a point on Coogee Beach approximately 950 metres north of the Explosives Jetty ("the Agreement Area") (Figure 1.2) until the year 2011, with rights of extension to 2021. The 1986 Act confers a number of rights and obligations on the Company and places the following obligation on the State:

"If and when it should become impracticable for the Company to obtain shellsand pursuant to this clause, the State will use every endeavour to find other shellsand within a reasonably economic distance from the jetty, and if other shellsand is not available, then other equivalent material."

1.3.2 Dredging and Management Programmes, 1986 to 1992

The 1986 Act included specific environmental management requirements relating to dredging, thus formalising the environmental monitoring that had been taking place previously. The Act requires Cockburn to submit a Dredging and Management Programme (DMP) every two years covering the Company's dredging plans for the ensuing 10 years, with details for the monitoring, protection and management of the environment. Each DMP requires the approval of the Minister for Resources Development. The Minister, in practice, takes advice from a 'DMP Committee' comprising representatives of the DEP, Fremantle Port Authority, Department of Minerals and Energy and Cockburn Cement under the chairmanship of an officer of the Department of Resources Development.

DMP 1 (submitted in 1986) included an environmental appraisal of Cockburn's operations to date and an assessment of the 10 year plan for 1987 to 1996. The appraisal concluded that insufficient information was available to undertake reliable assessment and recommended a wide range of studies. The first two years of DMP 1 (1986) were approved by the Minister to ensure sufficient available resources for Cockburn's operations. The remaining eight years (ending 1996) were approved subject to regular review based on the findings of additional studies. These studies were completed over the next two years and findings reported in DMP 2 which concluded that the proposed 10 year plan, forecasted to dredge some 150 ha of Success Bank to produce a second shipping channel parallel to and east of the existing FPA shipping channel, was unlikely to cause significant adverse environmental impacts and would also have the benefit of creating a second navigation channel through the Bank into Owen Anchorage. DMP 2 (1989 to 1998) was subsequently approved by the Minister who acknowledged that ... "the impact of dredging is localised and within acceptable environmental limits and that the presently planned extent of dredging can take place".

When submitting DMP 3 in December 1990, Cockburn was contemplating expansion of its South Coogee plant and, in order to facilitate planning of this expansion, was requested to include a 30 year concept dredging plan in the DMP. This DMP was opposed by the EPA, primarily because of concern for the long-term stability of the sandbanks and the effects of the loss of large areas of seagrass on the local ecosystem, and the Minister subsequently approved only the first two years of DMP 3.

During 1991 and 1992, the State made efforts to secure alternative resources for the Company, which in turn expended $616,000 in investigating possible alternative resources including the Mewstone area (refer Figure 1.1 and Figure 1.2) at the request of the Department of State Development. At the time DMP 4 was submitted in December 1992, these investigations were not yet finalised.

In DMP 4, Cockburn stated as its primary 10 year plan the intention to continue dredging on Success Bank until 2002, but to relocate to the Mewstone area during this time subject to legal, economic, technical and environmental feasibility. Because of the reservations of the EPA over significant loss of seagrass on Success Bank, the 10 year plan was not approved. Approval for approximately three years further dredging on Success Bank in the Second Channel and in a 78 metre strip along the east side of the FPA channel between Beacons C and F was granted.

1.3.3 Developments in 1993

Cockburn initiated the studies proposed in DMP 4, and completed its investigations into the feasibility of dredging the Mewstone area. It subsequently submitted reports supplementary to DMP 4 which concluded that dredging of the Mewstone area was not economically or operationally feasible and that there were no alternatives to the use of Success Bank resources (refer Chapter 2).

The supplementary documents also reported the following encouraging environmental findings:

- natural seagrass recolonisation on slopes and floors of previously dredged areas;
- some success with seagrass transplanting trials conducted by Murdoch University for the Company; and,
- evidence supporting the contention that the slopes and banks adjacent to dredged areas stabilise within 3 years with finite regression of the adjacent bank and seagrass meadow of up to a maximum of 50 metres.

1.3.4 The 1994 CER for Short-term Access to Success Bank

In late 1993, Cockburn ascertained that the volume of resource available in the FPA Channel was substantially less than anticipated and that, as a result, it only had access to resources until August 1994 at current dredging rates.

This, together with the findings of the DMP 4 studies and the Company's need for long-term resource security, prompted Cockburn to request a review of the EPA's position on the environmental issues associated with its dredging operations. The Government responded by requesting Cockburn to prepare a Consultative Environmental Review (CER) addressing its proposed resource access requirements for the next two years (to approximately September 1996), to be followed by an Environmental Review and Management Programme (ERMP) for a long-term (15 year) dredging strategy.

Cockburn produced the CER and, in January 1994, submitted it to the EPA for evaluation. In the CER, Cockburn requested access to 67 ha of Success Bank which was for the most part, barren of seagrass (refer Figure 3.1). Cockburn also committed itself to undertaking an Environmental Management Programme and to preparing an ERMP for its long-term dredging strategy during the ensuing two years.

1.3.5 The Ministerial Statement of Approval

Cockburn subsequently obtained approval to undertake its short-term dredging proposal in a statement released by the Minister for Environment on 4 August 1994. That statement also addressed the issues of medium-term and long-term access to shellsand by stipulating a set of conditions to be met by the Proponent prior to gaining access to resources other than those available in the short term. The medium-term resource was identified as that area of Success Bank occurring between the FPA Shipping Channel and the Second Channel dredged by Cockburn.

To gain approval for medium-term access, Cockburn was required to prepare an acceptable EMP to incorporate details on the following:

- proposed studies to determine the feasibility of rehabilitating seagrass (Condition 5-3);

- proposed studies to determine the ecological significance of seagrass in Owen Anchorage and its surrounds (Condition 5-3);
- investigations into the technical and economic feasibility of beneficiation (Condition 5-4);
- investigations to identify alternative lime resources to those of Success Bank (Condition 5-4);
- studies to determine the implications of short-term and medium-term dredging on the wave climate of the area, and on shoreline stability (Condition 5-3);
- a dredging plan detailing Cockburn's proposed resource requirements and dredging strategy for the medium term (Condition 5-5); and,
- fulfilment of the commitments made in the CER and in response to issues raised in submissions (Condition 1-1).

Condition 6 of the Ministerial Conditions stipulated that long-term access by Cockburn to shellsand resource which would impact on seagrass would be contingent upon the results of the EMP studies demonstrating either that seagrass can be successfully rehabilitated, or that its removal through dredging would have acceptable ecological and wave climate consequences (Condition 6-2). To this end, the Minister requested Cockburn to submit its proposal for long-term access to shellsand resource not less than 15 months before depletion of the approved medium-term resource (Condition 6-1). The medium-term resource is expected to last until the end of the year 2001, and fifteen months prior to its depletion is approximately September 2000.

Condition 6 effectively removed the need to produce an ERMP in 1996 as had originally been proposed by Cockburn in the 1994 CER, and replaced it with the requirement to implement a detailed EMP.

Further Ministerial Conditions required that:

- the EMP be subject to a four week public review period (Condition 5-2);
- the proponent rehabilitate any areas dredged from the date of issue of the Conditions (4 August), consistent with the results of the studies required by Conditions 5-3 (ie. seagrass rehabilitation and ecological significance, and wave climate implications of dredging); and,
- a compliance auditing system be initiated and reported on annually to the Department of Environmental Protection (DEP) (Condition 9 and Condition 11).

1.3.6 Cockburn's Response

Cockburn accepted the Ministerial Conditions of approval and appointed a project manager for the preparation of the EMP, and the implementation of the proposed technical investigations and scientific studies. A Technical Advisory Group (TAG) comprising mainly marine scientists from the CSIRO, Western Australian universities, the WA Museum and consultancies, was established to define these tasks. A series of workshops were held and study teams established to develop the terms of reference and work plans for each of the various investigations proposed for the EMP.

Informal discussions were held with the DEP and its advisers regarding their interpretation of the Ministerial Conditions, and draft EMP documents were forwarded to the DEP for comment.

In February 1995, Cockburn submitted its detailed EMP (Cockburn Cement Limited, 1995) to the EPA for evaluation and subsequent approval to gain access to the medium-term resource.

1.3.7 The EMP

The EMP was subjected to four weeks public review and was also reviewed by DEP advisers, and selected Government departments. Whilst this review was taking place, Cockburn initiated all of the studies outlined in the EMP. On 5 July 1995 Cockburn received interim advice from the DEP which requested them to undertake further work on the EMP document aimed at clarifying the objectives of some of the studies and the performance criteria by which those objectives would be judged to have been achieved.

After further rounds of discussions, meetings and drafts, a Supplement to the EMP was produced and forwarded to the EPA in September 1995. In November 1995, the EPA advised the Minister for the Environment that the EMP, as modified by the Supplement, could be approved.

The EMP was subsequently approved by the Minister for Environment in a statement released in December 1995 (EPA Bulletin 803).

1.3.8 Implications of the Supreme Court of WA Decision

In March 1996, the Supreme Court of WA passed down its judgement on an action brought against the EPA by the Coastal Waters Alliance. The Full court upheld the action and ruled that the EPA had gone beyond its statutory powers in its evaluation of the 1994 CER and that the advice it gave to the Minister was flawed.

This decision rendered null and void all approvals provided to the Company since August 1994 and meant that the assessment of the 1994 CER for short-term dredging was not yet completed. The December 1995 decision of the Minister concerning the acceptability of the EMP was therefore also invalidated by the Court's decision.

Cockburn advised the Minister on its commitment to continue its dredging operation and EMP research programmes as though the Minister's decisions of August 1994 and December 1995 were still binding on the company.

The assessment of the short-term dredging proposal is still underway and the recommendations of the EPA, and the Minister's decisions are still to be released. This CER has therefore been prepared in the absence of any directives that would be obtained from the Minister's decision, but with informal consultation with the DEP.

1.3.9 Present Situation

Cockburn now finds itself:

- dredging in accordance with its Agreement Act, and seeking environmental approval to do so;
- conducting costly and extensive research into studies requested by the Minister on the advice of the EPA which has subsequently been invalidated;
- running out of short-term resource;
- committed to both long-term supply contracts to Western Australia's alumina and gold processing industries, and the presently ongoing \$80 million development of a sixth kiln at its Coogee plant; and,
- incurring additional costs for the preparation of documentation to seek another formal approval for dredging.

Consequently, in May 1996 Cockburn resubmitted to the DRD a proposal for medium-term dredging. This proposal was referred to the EPA, who set the level of assessment for the proposal as a CER.

1.4 THE PROPOSAL

The purpose of this CER is to seek approval to dredge that part of Success Bank occurring between the FPA Shipping Channel and the Second Channel which is identified as the 'medium-term' dredging area (refer Figure 1.2).

At forecast rates of demand, it is anticipated that this resource will last approximately until the end of the year 2001. During this period, Cockburn commits to continuing its substantial programme of research as documented in its EMP, and further commits itself to producing an environmental assessment of its proposal for the long-term dredging strategy some 15 months prior to depletion of the medium-term resource (estimated to be about September 2000).

2. COCKBURN'S RESOURCE REQUIREMENTS

2.1 RAW MATERIAL

Cockburn currently produces approximately 1.1 million tonnes of quicklime and cement annually. The basic raw material for both of these products is calcium carbonate which is found either loose as part of marine sand called shellsand, or in unconsolidated sand on land called limesand, or consolidated in limestone rock. Cockburn currently obtains the bulk of its resource from shellsand dredged from Success Bank, Owen Anchorage and, in 1995, used approximately 1.9 million tonnes of these raw materials to meet product demands; 1.7 million tonnes was obtained by dredging shellsand and the remainder by quarrying of limestone.

2.2 REQUIREMENTS FOR QUALITY OF RESOURCE

The process of converting shellsand (or any other calcium carbonate source) to quicklime is called calcining. It involves heating calcium carbonate to a temperature of around 1,000°C to remove carbon dioxide and produce calcium oxide, as shown in the equation below:

$$CaCO_3 + \text{heat} \rightarrow CaO + CO_2$$

The loss of carbon dioxide that occurs during the calcining process means that, for each 1,000 kg (or tonne) of calcium carbonate used as raw material, 560 kg of calcium oxide is formed.

The effective production of lime is based on three main quality characteristics being met. These are:

- grade of resource;
- particle size distribution of resource; and,
- physical integrity of resource.

Shellsand (or any other source of calcium carbonate) seldom occurs completely pure. The quality or purity of shellsand is referred to as **grade**. On Success Bank, much of the shellsand is of grade 92% or better as total carbonates (expressed as calcium carbonate), with grade in some areas falling as low as 80%. The major impurity in shellsand is silica sand, which at best is unaffected during the calcining process and, depending upon conditions, may react to form an unwanted byproduct called calcium silicate during the calcining process.

Lime (or calcium oxide) is mostly sold according to its active calcium oxide content, measured according to the Available Lime Index. The final Available Lime content that is obtained from shellsand is therefore a function of shellsand grade, nature of impurities, kiln type and kiln operation including heating characteristics and fuel type used.

Experience from Cockburn's production process indicates that a shellsand of grade 92% will result in almost 77% Available Lime, whereas a shellsand of grade 89% will yield only 70% Available Lime. Even 77% Available Lime is considered low grade by world standards. Universally, customers desire the highest cost effective Available Lime content because it is the chemical activity of quicklime that is purchased. All other components in quicklime can therefore be regarded as contaminants, incurring additional transport costs and, in some cases, a requirement for the removal of impurities from individual processes.

To satisfy requirements in a market that is becoming increasingly demanding, the manufacture of quicklime requires a source of shellsand or limestone that is more than 92% total carbonate. Within the region prescribed by the Agreement Act, shellsand of this quality occurs principally on Success Bank. Even then, quality is variable. Shellsand with lower carbonate content and therefore higher silica content, is more widely spread throughout the coastal area. Limestone with a wide range of grade is found on land but grades above 85% are rare close to Perth.

Material averaging 78% carbonate is suitable for cement manufacture and Cockburn has limestone deposits in or near the metropolitan area sufficient for its needs for the next 20 to 40 years. For cement manufacture, Cockburn also uses a proportion of shellsand which, being of higher grade than the limestone, permits the use of lower grades of limestone and hence extends the effective tonnage and life of the limestone reserves.

The **particle size distribution** required of the resource is influenced by the kiln process. Cockburn's major lime kilns use a gas suspension preheat process which requires a particle size within the range of 0.15 to 3 millimetres. Particles finer than 0.15 millimetres may be lost from the furnace during calcining, while particles larger than 3 millimetres may not remain suspended in the gases.

Physical integrity of the resource is the third main requirement for resource quality. This means that the lime produced should retain its granular properties, and not disintegrate into dust during handling before or after passage through the kiln. This process of disintegration of lime is termed 'decrepitation'.

Shellsand and limesands generally are of suitable particle size and physical integrity for calcining in gas suspension kilns. Limestone neither occurs naturally at this size range nor is it easy to grind and size to this range. The grinding of limestone may produce a substantial amount of fines (less than 0.15 millimetres) during the grinding. In addition, grinding may introduce stress fractures in the particles which promotes decrepitation after calcining.

Cockburn's kilns have been specifically designed to use shellsand.

2.3 FORECASTS OF RESOURCE REQUIREMENTS

Cockburn operates five kilns for the manufacture of cement and/or lime and is currently constructing a sixth kiln. This sixth kiln will be commissioned in 1996. It will be used for lime production only and will replace lime production of three smaller kilns which were originally designed for the production of clinker used in cement production. These kilns will be returned to clinker production, obviating the need for Cockburn to regularly import part of its clinker requirements from interstate or overseas as has been necessary since 1990.

Cockburn has also announced the construction of a kiln to produce lime in Dongara, commencing in 1998. This kiln will use limesands available from unconsolidated sand dunes, at a rate of approximately 200,000 tonnes per annum. Lime produced in Dongara will be used to supply the mineral sands industry in Geraldton, and the gold industry in the Murchison. This lime is presently being provided from Cockburn's South Coogee plant.

Cockburn has produced a forecast for shellsand requirements for its South Coogee plant for the period 1996–2001 which is shown in Table 2.1 below.

Table 2.1 Shellsand requirements: 1996–2001.

YEAR	SHELLSAND REQUIRED (million tonnes)
1996	1.80
1997	1.95
1998	2.30
1999	2.40
2000	2.42
2001	2.43
TOTAL	**13.30**

This forecast has been developed using the following assumptions:

- anticipated market demands, plus a 15% contingency;
- additional shellsand requirements for the production of clinker that was previously imported; and,
- reduction of shellsand requirement by construction of the Dongara lime kiln.

2.4 DISTRIBUTION OF SHELLSAND RESOURCE ON SUCCESS BANK

A detailed analysis of the distribution of shellsand resource on Success Bank has been completed (BHP, 1995). This analysis was based on existing information obtained from numerous drilling programmes and on information obtained during dredging.

A three-dimensional (3-D) diagram indicating the simulated distribution of these resources is shown in Figure 2.1 and presents the distribution of shellsand that has a total carbonate (expressed as calcium carbonate) content greater than 92%, shellsand having total carbonate content between 88% and 92% and shellsand having total carbonate content less than 88%.

The simulation of carbonate resource indicates a number of features:

- the resource lies on top of a base that includes sediments of the previous Swan estuary. This base in turn overlies Tamala Limestone;
- the resource is variable in grade. Resource grades are higher in the centre of Success Bank. Significant amounts of higher grade resources also exist to the west of the existing FPA shipping channel, as well as to the east of the incomplete second shipping channel;
- the depth limit of the resource in the medium-term dredge area varies from 10 to 17 metres; and,
- the total resource available in the short-term and proposed medium-term areas is 14.9 million tonnes. At the dredging rates that have occurred, and are forecast for the future, these resources will last until approximately the end of the year 2001.

2.5 EVALUATION OF OPTIONS FOR OBTAINING RESOURCE REQUIREMENTS

Over the last five years, and more intensively over the last two years, Cockburn has investigated the following alternatives for its resource requirements. These are:

- beneficiation of lower grade shellsand, limesand and limestone;
- completion of the second shipping channel through Success Bank;
- completion of the second shipping channel through Parmelia Bank;
- maintenance dredging of the FPA channel through Success and Parmelia Banks;
- widening existing FPA channel through Success Bank;
- dredging the Mewstone area (west of Success Bank);
- use of terrestrial resources in the metropolitan region;
- use of terrestrial resources from Geraldton to Augusta;
- relocation of Cockburn's South Coogee plant; and,
- dredging of the area on Success Bank between the existing FPA shipping channel and the second shipping channel.

Each of these options is described below, indicating their respective advantages and disadvantages.

2.5.1 Beneficiation

Beneficiation is the process of removing some or all of the unwanted materials from a mineral resource in order to improve its purity or 'grade'. In theory, low grade shellsand or limestone could be 'beneficiated' to a grade suitable for lime manufacture, thus allowing a wider choice of raw materials reserves.

Beneficiation of Western Australian shellsand or limestone has never been done on a commercial scale and no equipment supplier has proven equipment of the capacity required. Cockburn has carried out substantial laboratory trials using two different beneficiation techniques and has the only pilot scale plant in Australia operating on these materials.

To date laboratory trials carried out on the beneficiation of shellsand and limesand are encouraging; however similar trials with limestone are not optimistic. Although shellsand beneficiation is not proven it has significant potential, Cockburn will continue to develop these processes. It is estimated that assuming continued successful trials, a small scale development beneficiation plant for processing 200,000 tonnes per annum of shellsand or limesand will be operational by the end of 1998. It is further estimated that it will take upwards of five years for the commercial development to the scale required. Cockburn would therefore require the full period of the medium-term resource to develop, construct, and commission a beneficiation plant for the production of 1.1 million tonnes per annum of lime. Further details of the proposed development of beneficiation and associated facilities are provided in section 7.4.2 of this document.

The implementation of beneficiation will require additional raw material, as during the beneficiation process, approximately 20% of the feed material is rejected. This requires disposal. For the production of 1 million tonnes per annum of lime from shellsand of 88% grade, approximately 2.2 million tonnes of raw material is needed, of which about 400,000 tonnes will be reject material requiring disposal. The process of electrostatic beneficiation may also require the use of large volumes of fresh water for washing, and energy for heating the raw material prior to separation.

2.5.2 Completion of the Second Channel through Success Bank

Cockburn's dredging operation from the second channel on Success Bank has been completed. The quality of the remaining material in the northernmost section is too low to be suitable for Cockburn's present manufacturing process and will be left *in situ*. This material could be considered for use with beneficiation.

Some material, estimated at between 0.5 and 1 million tonnes, is available on the floor of the existing channel. This material will require a modified 'dust-pan' type dredger for its extraction. This would require design and construction, would cost $1.25 million and would take a minimum of 1 year to implement.

Should a suitable vessel (dredge) visit the area during the period of medium-term resource, Cockburn will consider the opportunity of dredging this remaining shellsand.

Risk of contamination from underlying sediment is significant, and considered with the low volume of the available material means that this option does not provide a significant resource, and could at best be a minor supplement to Cockburn's requirements.

2.5.3 Completion of the Second Shipping Channel through Parmelia Bank

Cockburn's dredging on Parmelia Bank took place from 1972 to 1987, within the alignment of the proposed second shipping channel through Owen Anchorage. In 1987 Cockburn's dredging operations were moved from Parmelia Bank to Success Bank due to the hardness of the deposit and the low and variable quality of the resource encountered.

The option exists to return to Parmelia Bank and to complete the second shipping channel to a width of 450 metres, which is the same size as the second channel through Success Bank. Approximately 10 million tonnes of shellsand with grade of 88–92% exists in this area.

Operation on Parmelia Bank would require modification of the dredge to overcome the hardness problem. More importantly, the shellsand would require beneficiation to achieve the required grade. In addition seagrass of medium/dense cover exists in parts of the proposed second channel.

This option has strategic importance to the state, especially in terms of the proposed shipping developments for the Kwinana area. The implementation of this option would require the support of other agencies, such as the FPA, and the Royal Australian Navy (RAN).

The implementation of this option can only be considered with commercial scale beneficiation.

2.5.4 Maintenance Dredging of the FPA Channel through Success and Parmelia Banks

In 1994, the FPA undertook a dredging programme of the Success and Parmelia Bank shipping channels to deepen these to a minimum of minus 14.7 metres. In total, approximately one million cubic metres of material were dredged from the Success Channel and 0.7 million cubic metres from the Parmelia Channel. These materials were separately stored in Spoilground No. 3 in Owen Anchorage (refer to Figure 1.2).

Cockburn has undertaken some preliminary assessment of the quality of the material from the Success Channel, which was found to be of a grade varying from 88 to 91%. This material could be considered by Cockburn with beneficiation. It is unlikely that all of it can be recovered without some contamination from underlying material.

2.5.5 Widen Existing FPA Channel through Success Bank

Results of the wave study recently completed as part of Cockburn's EMP studies (see Section 5.2 for further details) have indicated that dredging of the proposed medium-term area is likely to have only limited consequences to navigation in the existing FPA channel and that the maintenance of a 100 metre buffer between the FPA channel and the proposed medium-term dredging area may not be necessary. The option may now exist to extract high grade resource from the eastern side of the FPA channel, thereby widening the FPA channel. This buffer area contains about 3 million tonnes of shellsand of suitable quality. This buffer zone covers 42 ha, of which 26 ha is covered by seagrass of greater than 25% cover.

This option will continue to be evaluated in association with the FPA. In particular, the FPA will evaluate the removal of this buffer zone particularly on ship motion and under-keel clearance.

2.5.6 Dredging The Mewstone Area

An alternative resource of substantial quantities of shellsand has been investigated by Cockburn in the vicinity of Mewstone (see Figures 1.1 and 1.2). The Mewstone area extends from the western edge of the existing FPA shipping channel to beyond Mewstone itself. It includes an area within the boundary of the existing Agreement Act area as well as to the west of this boundary. A feasibility study of the area confirmed that Cockburn's present dredge is unsuitable for operating continuously in that area because of the significantly greater swell of the area (Evers, 1993). This study indicated that the existing dredging equipment used by Cockburn is limited by sea swell, and cannot operate where substantial swell exists. Appropriate conditions for operation were defined as those having a significant wave height (H_S) of less than 0.6 metres.

There are calm periods during the year when swell conditions at Mewstone would be suitable for the use of Cockburn's current dredging facilities. Evers (1993) showed that for a site in the Mewstone area of approximately 8 metres depth these low swell criteria were met on average for 21% of the year. Further analysis showed that the duration of these calm periods was highly variable, and frequently of very short duration, such as only a couple of hours. For practical reasons, at least 3 consecutive days of calm would be required to warrant moving the dredge to this area. The analysis of a typical year (1992) of wave data indicates that at Mewstone, appropriate 3 day calm periods occurred only 4 times during the year.

Consequently, it has been concluded that this option is impractical using Cockburn's existing dredging facilities.

The total resource within the Mewstone area is substantial. Although average grade of the material is less than 92%, there are pockets of 92% or better material. Unfortunately, these high grade shellsands are overlain and interleaved by low grade sands and would require extremely close control of the dredging operation for their selective extraction. This selectivity is not achievable with the existing dredging equipment. In addition part of the area contains limestone pinnacles and/or is overlain by limestone caprock. These areas would also not be able to be dredged using existing equipment.

For the existing dredge to operate in the Mewstone area, a cutter head would be needed on the dredge nozzle, and in addition, due to the increased distance from shore, at least one extra barge would be required for transportation of the dredged material.

It is likely that environmental issues associated with dredging in the Mewstone area would be at least as substantial as those at Success Bank. These include:

- dredging of the Mewstone area will have a greater influence on the wave climate on Success Bank and Owen Anchorage area than dredging on the eastern side of Success Bank;
- an awareness that the Mewstone area may be important for recreational and commercial fisheries; and,
- seagrasses occur at various sites throughout the area.

Based on the above, the dredging of the Mewstone area is not considered a practical option in the medium-term.

This option has not been rejected for the longer-term dredging and its implementation will among other things depend on:

- the development of a suitable shellsand beneficiation process;
- replacing Cockburn's current section dredge and three barges with a larger single vessel trailer section dredge; and,
- environmental approval.

2.5.7 Terrestrial Resources of Limestone from the Metropolitan Region

The question of other "Terrestrial deposits of limestone or limesand suitable for replacing Owen Anchorage shellsand for the manufacture of quicklime" was investigated by the Department of State Development in January 1991 and a file note and report were prepared on this topic on 14 February 1991 (Department of State Development, 1991). The report concluded that there are no available terrestrial deposits of limestone or limesand in the metropolitan region that could be considered as an equivalent material to shellsand dredged from Success Bank.

A subsequent review by Cockburn (Halligan, 1996) has confirmed the low potential for alternative resources near metropolitan Perth.

2.5.8 Terrestrial Limestone or Limesand From Geraldton to Augusta

There are deposits of limesand of suitable quality in the Dongara region of Western Australia, and more distant locations in the State and overseas. The only proven resource of suitable grade that could be considered as an alternative to Success Bank material, would be limesand from the Dongara region. This would involve transporting approximately 2 million tonnes of material annually (see Table 2.1 in Section 2.3) by road from Dongara and through the Perth metropolitan area, at an estimated additional cost in excess of $40 million per annum. Such an option would require either some 240 truck movements, each of 40 tonne capacity, between Dongara and the plant site every day of the year (ie. one passing every 10 minutes throughout the day and night), or some nine train movements, each of 1,000 tonne capacity, per day. This option has been rejected by Cockburn because of the cost, the environmental impact of the transport task and the relatively short lifetime of Cockburn's Dongara reserves if these quantities of greater than 92% grade are selectively mined.

Recent work undertaken for Cockburn by DOME and scheduled to be completed by the end of 1996, has identified areas with potential reserves of limesand to be in the Wedge Island, Lancelin, and Guilderton areas. These will continue to be investigated.

2.5.9 Relocation of Cockburn's South Coogee Plant

The option to relocate Cockburn's South Coogee plant to Dongara, has been briefly considered. Capital costs for this have been estimated to be in excess of $300 million. In addition, the bulk of the lime produced would have to be transported back to Perth and areas south of Perth, to major customers. This option has been rejected on commercial, transport and practical grounds. In addition, the proven resource is not sufficiently large.

2.5.10 Dredge Area on Success Bank between FPA Shipping Channel and Second Shipping Channel ie. Proposed Medium-Term Resource

The resource in this area is known to be of suitable grade (greater than 92%), and together with the shellsand remaining in the short-term area, this resource will last approximately to the end of 2001 based on current resource requirements. Existing dredging equipment can operate effectively in the area ensuring continuity of supply of raw material for lime production. Studies that have been completed have shown that the consequences of dredging this area on wave climate are acceptable both to navigation, as well as to the shoreline stability of Owen Anchorage. In addition, there are no major commercial or recreational fisheries in the area proposed for dredging.

The single major disadvantage of dredging in this area is the removal of seagrasses.

The area was identified by the Ministerial directive of the 4 August 1994 (and which has since been declared null and void) as the most likely area for medium-term dredging, and is within the study area for the current programme of research and investigation being supported by Cockburn. This programme includes:

- assessment of the ecological significance of seagrasses;
- development of mechanical methods for the transplantation of seagrasses;
- detailed mapping and monitoring of seagrass cover on Success Bank, and its changes with time;
- development of alternative habitats (artificial reefs); and,
- influences of dredging on wave climate and shoreline stability.

2.6 EVALUATION OF OPTIONS FOR ACQUIRING RESOURCES

The ten options that have been considered for the acquisition of medium-term resource are summarised in Table 2.2. The evaluation and selection of the preferred option was based on the following requirements:

- approximately 10 million tonnes of suitable resource of greater than 92% or better grade;
- minimal environmental effects; and,
- ability to use existing dredging equipment until alternative options can be assessed.

The evaluation indicated that:

- Tamala limestone is unsuitable as a resource;
- relatively small deposits of limesands at Dongara are the only proven terrestrial resource of sufficient magnitude that could be considered as a medium-term resource;
- all options where the resource is of grade less than 92% are not feasible until beneficiation is proven;
- two options exist for acquiring small amounts of suitable grade material with minimal environmental effects. These are: remove the material on the floor of the second channel through Success Bank (approximately 0.5 to 1 million tonnes); and, widen the existing FPA channel (3 million tonnes); and,
- the only practical option available that enables the resource requirements of Cockburn to be met over the next five years is dredging the area on Success Bank between the FPA shipping channel and the second shipping channel. This preferred option is referred to as the **proposed medium-term** area (see Figure 1.2).

It is recognised that this option involves the dredging of 147 ha of Success Bank to an average depth of about 13 to 14 metres, and will result in the removal of 57 ha of shallow unvegetated sediment with seagrass cover less than 25%, 46 ha of low density seagrass (25–50% cover), and 44 ha of high density seagrass (50–100% cover).

The evaluation of alternative resources also indicated that development of beneficiation will markedly increase the potential resource that would be available. The development of commercial beneficiation is expected to take another 5 years. With commercial beneficiation techniques, at least 3 further options for shellsand acquisition can be considered, these being:

- completion of the second shipping channel through Parmelia Bank;
- dredging the area around Mewstone; and,

Table 2.2 Evaluation of alternative resources: summary.

OPTION	ADVANTAGES	DISADVANTAGES	CONCLUSION
1. **BENEFICIATION**	• large potential resource available • can target areas of lower environmental sensitivity	• not commercially proven • environmental issues - disposal of reject material - use of water & fuel for process - larger volumes of resource extracted • substantial extra costs for lime	• not applicable immediately • requires further development • potential for commercial implementation at 2 million tpa in about 5 years
2. **COMPLETE SECOND SHIPPING CHANNEL THROUGH SUCCESS BANK**	• dredging equipment suitable	• variable and generally low quality of resource • small resource • seagrass cover	• insufficient material at low quality • leave in situ. Could be considered in the future with beneficiation • small amount of suitable material on floor of 2nd channel. Requires modified dredger for extraction
3. **COMPLETE SECOND SHIPPING CHANNEL THROUGH PARMELIA BANK**	• close to wash plant • all weather dredging • strategic to development in Kwinana area	• lower quality resource • some modification of dredging head required • seagrass cover • potential wave effects as dredging closer to shore • no impact assessment undertaken	• requires support of other agencies • resource requires beneficiation • not feasible in immediate future
4. **MAINTENANCE DREDGING OF FPA CHANNEL**	• advantage to FPA	• small resource • variable and low quality	• requires beneficiation • not practical for substantial contribution to resource requirements
5. **WIDEN EXISTING FPA CHANNEL**	• widen FPA shipping channel • resource grade acceptable	• limited volume of resource	• continue to investigate
6. **DREDGE MEWSTONE AREA**	• significant resource	• existing dredging equipment unsuitable • resource variable in quality • pinnacles and cap-rock • wave climate, seagrasses & fisheries implications	• continue investigation. Future implementation will depend on: - new dredging equipment - development of beneficiation - environmental approval • not practical within 5 years
7. **TERRESTRIAL RESOURCES: METROPOLITAN REGION**	• close to South Coogee works • no removal of seagrass	• no known available resource	• not feasible
8. **TERRESTRIAL RESOURCES: GERALDTON TO AUGUSTA**	• no removal of seagrass	• no known substantial resource available immediately • potential resources owned by others • environmental concerns with mining & transport • substantial extra costs for lime	• continue investigation • very unlikely to contribute significant resource within 5 years
9. **RELOCATE COCKBURN SOUTH COOGEE PLANT**	• move close to resource (Dongara)	• prohibitive capital expenditure • large environmental impact of increased transportation distances • insufficient resource	• not feasible
10. **DREDGE AREA ON SUCCESS BANK BETWEEN FPA SHIPPING CHANNEL AND SECOND SHIPPING CHANNEL**	• significant resource of suitable quality • existing dredging equipment appropriate • acceptable effects on wave climate and navigation • EMP underway	• removal of seagrasses	• preferred option,

- acquisition of approximately 1 million tonnes of material in Spoilground No 3 from FPA maintenance dredging.

Implementation of these options would require prior environmental approval.

2.7 NEED FOR THE PROPOSAL

Cockburn produces cement and quicklime, vital commodities used extensively by Western Australian industries. The ready availability of the Company's products is essential to the future economic viability of many industries dependent upon these products.

Cockburn's facility at South Coogee has been developed particularly to service the needs of the Western Australian mineral processing industry with over 90 percent of its lime needs supplied by Cockburn. There is no other Australian or overseas source with the current capacity of supplying this mineral processing industry should Cockburn be unable to supply. As such, the shellsand deposit is a resource of strategic importance to Western Australia.

The quantity of resource covered by the CER is needed so that the Company can:

- continue to operate and supply product while developing a proposal to secure access to longer term resources;
- further develop a beneficiation process;
- continue to evaluate alternative resources, particularly to be upgraded through beneficiation;
- further investigate techniques for mitigating seagrass loss;
- further investigate environmental effects of longer term dredging; and,
- prepare a proposal for longer term dredging.

3. THE DREDGING PROGRAMME

The programme that has been prepared for the dredging for the proposed medium-term area is based on a consideration of resource requirements, resource quality, and environmental considerations.

3.1 DREDGING SCHEDULE

The total tonnage of shellsand available within the proposed medium-term areas calculated by BHP (1995) indicates an inferred resource of approximately 9 million tonnes. Allowing for a 15% contingency (overestimate) to cover possible variations in annual demand, Cockburn's requirements for shellsand up to approximately the end of the year 2001 can be met by the shellsand resource remaining in the short-term area and present in the proposed medium-term area.

This demand forecast presented in Section 2.3 has been used in the preparation of a dredging schedule up until the end of the year 2001. The plan is presented here as a proposed schedule for the dredging of a series of 75 x 100 metre blocks. The individual blocks or paddocks are show in Figure 3.1, which also includes an overlay showing seagrass cover in the area. The Dredging Plan used by Cockburn for operational purposes is far more detailed, and provides the dredging schedule on a weekly basis.

This dredging plan was prepared based on a series of considerations. These are:

- dredging will initially occur in areas where seagrass cover is less than 25%. Dredging will then progressively access areas of seagrass cover of between 25% and less than 50%, and then areas of higher seagrass cover. This schedule is designed to provide the maximum amount of time possible for the development of seagrass transplantation techniques;
- dredging of the northern part of the resource will generally occur in the summer period, while dredging in the southern part of the resource will generally occur in the winter period, to accommodate seasonal differences in sea swell conditions. The requirements for calm conditions for winter dredging means that in some cases, some seagrasses of higher density cover (greater than 50%) may be dredged before seagrasses of lower density cover;
- dredging will occur to the full depth of the available resource. This will ensure that the maximum amount of resource is extracted for each unit of surface that is disturbed. Lowest grade for resource extraction will be 88%. Shellsand dredged which is between 88 and 92% grade would be blended into material used for cement manufacture. The areas covered by these resources are represented by the yellow and green tones shown in Figure 2.1;
- edge slopes will be allowed to adjust to a stable configuration naturally. It is known that lateral regression of the edge of the dredge slope of up to a maximum of 50 metres can occur, with stability achieved in approximately 3 years;
- stability of final dredge slopes will be monitored; and,

- stable dredge slopes will be used for experimental studies on seagrass transplantation.

3.2 REVIEW OF DREDGING PLANS

A review of dredging plans will be undertaken each quarter by Cockburn as part of its normal operation. Each year, detailed dredging plans will be revised and these will be included in annual reports to the EPA. The review and revision of dredging plans will take particular cognisance of:

- market demands, as well as;
- results of studies of ecological significance of seagrasses and other habitats, to reduce impacts on the most significant habitats;
- results of investigations and developments into rehabilitation techniques, including mechanical transplantation;
- results of investigations into beneficiation techniques;
- results of investigations into alternative sources of raw material; and,
- results of additional drilling that may be required to confirm aspects of shellsand resource distribution. Information on shellsand grade is routinely obtained during dredging.

4. EXISTING ENVIRONMENT

4.1 AVAILABLE INFORMATION

The coastal region that is pertinent to this proposal lies offshore between Fremantle and Woodman Point, and is adjacent to Gage Roads to the north and Cockburn Sound to the south. It includes the Owen Anchorage basin, Success Bank in the north and Parmelia Bank in the south, and extends from the Owen Anchorage shoreline to just west of the Stragglers (Figure 1.1). This principal region of interest is called the study area.

There is a substantial amount of information available for the study area, largely as a result of work programmes undertaken by Cockburn as part of its DMP commitments and more recently as part of the EMP research programme. The description of the environment presented in this report is based largely on these studies which include:

- a review of existing ecological information on the study area prepared as background to the design of studies to determine the ecological significance of the Success Bank seagrass ecosystem;
- geomorphological investigations into the sedimentology of Success and Parmelia Banks;
- analysis of seagrass distributions from aerial photography;
- mapping of seagrass assemblage distribution;
- wave climate investigations;
- monitoring and assessment of coastal stability;
- monitoring of dredge slope stability; and,
- seagrass transplantation experiments and research into rehabilitation techniques.

4.2 PHYSICAL ENVIRONMENT

4.2.1 Regional Setting

The coastal environment of southwestern Australia has been separated into five sectors (Searle & Semeniuk, 1985), each with its own processes of sedimentation, erosion and sediment transport.

The study area lies within the northern part of the sector that stretches from Cape Bouvard (approximately 20 km south of Mandurah) to Trigg Island (approximately 20 km north of Fremantle). In this sector the shoreline is comprised mostly of deposits of geologically recent sediment (eg, Woodman Point) with intervening sandy beached basins, limestone rocky shores and headlands.

Five major sand banks occur in the area between Fremantle and Becher Point (Figure 1.1). These are Fairway Bank off Fremantle, Success and Parmelia Banks located between Fremantle and Woodman Point forming the northern and southern sills respectively of Owen Anchorage, and Rockingham Bank and Becher Bank, located to the north and south respectively of Warnbro Sound.

4.2.2 Local Setting (Success and Parmelia Banks)

On its northern side, Success Bank rises from the southern side of the Gage Roads basin at a depth of approximately 15 metres and approaches mean sea level where it abuts the mainland shore. The top of Success Bank is relatively flat, at a depth of within 4 to 5 metres of the surface. To the west the bank merges with the shallow north south trending banks located in the lee of the reefs and islands of the Garden Island Ridge. To the south the bank falls away steeply into the Owen Anchorage basin (Figure 1.2).

Parmelia Bank slopes steeply from the floor of the Owen Anchorage basin, shoaling to depths of 2 to 3 metres in its centre, before again sloping steeply into Cockburn Sound.

4.2.3 Sedimentology of the Banks

Success and Parmelia Banks are broad flat submarine banks of unconsolidated carbonate sands. Previous research on the sedimentology of the Banks has been conducted by France (1977) and Searle (1984). More recently, Cockburn has supported a study of the sedimentology of the Banks as part of its Environmental Management Programme (DAL, 1995). This recent study of the sedimentology of the Banks benefited by having access to a large number of samples obtained by Cockburn during its exploratory drilling in the area, particularly those obtained between 1990 and 1993.

4.2.3.1 Bank composition

The banks are composed of a limited range of particle types and exhibit a relatively uniform internal structure. The banks have a basal depth in the order of 16 m below present sea-level and are situated on top of a deposit of coarse quartz sands within a matrix of fine brown clays. The lowest 1 to 2 m of the Banks are characterised by sediments with a large proportion of quartz grains within a matrix of fine carbonate sediment. The remainder of the Banks are composed of well worn carbonate sands with a calcium carbonate content in the order of 90%.

4.2.3.2 Bank formation

Radiocarbon dating of the Banks presented by Searle (1984) indicated that Success Bank is about 2,500 years old and Parmelia Bank is about 4,000 years old. As part of Cockburn's EMP six samples from Success Bank were submitted for radiocarbon dating which indicate that Success Bank may be about 5,500–7,500 years old.

Based on present knowledge, it is deduced that the formation of the Banks commenced after the rapid rise in sea-level between about 15,000 and 7,000 years ago during which the sea-level rose by approximately 100 m. By 4,000 years ago the sea-level was at approximately the present level and has remained within ±1 m of this level until the present.

The rapid sea-level rise resulted in the submergence and erosion of the Garden Island Ridge. The submerged carbonate sands were transported shorewards and accumulated as shore-perpendicular ridges in the lee of elevated areas of the Garden Island Ridge; Straggler Rocks for Success Bank and Carnac Island for Parmelia Bank. As the Banks continued to grow and shallow, sufficient light to support seagrasses would have begun to reach the Bank tops. At a water depth shallower than 9 m sufficient light would have reached the bottom to support extensive meadows of *Posidonia* and *Amphibolis* seagrasses. The Banks have continued to shallow and have supported a highly variable coverage of seagrasses.

4.2.4 Forces Acting on Banks

The main physical forces acting on the Banks and the adjacent shoreline of Owen Anchorage are winds, waves and currents. These forces affect the Banks and adjacent shoreline to varying degrees. Any assessment of the dynamics of the Banks and shoreline should be made with a proper understanding of these physical forces and their importance in the formation and stability of the Banks and beaches. A brief outline of the important physical forces is provided below.

4.2.4.1 Winds

The seasonal weather patterns at Fremantle are largely controlled by the position of the Subtropical High Pressure Belt. This is a series of discrete anticyclones that encircle the Earth at mid latitudes (20 to 40 degrees). Throughout the year, these high pressure cells are continuously moving from west to east across the southern portion of the Australian continent. A notional line joining the centres of these cells is known as the High Pressure Ridge.

In winter this ridge is to the north of Fremantle, and low pressure systems and westerly winds dominate local weather patterns. Cold fronts associated with the low pressure systems frequently pass over the Fremantle region, and can bring storm force winds from the northwest through west and southwest directions.

In summer the ridge is to the south of Fremantle, and high pressure cells dominate local weather patterns. As the high pressure cells approach, winds are from the southeast to east, changing to northeast to north as the pressure cells move eastwards. Superimposed on this pattern is the sea breeze effect. This is a daily variation caused by differential heating of the land and sea, which results in the easterly winds being regularly supplanted by a strong south westerly sea breeze, which is generally present by midafternoon and continues until evening.

Occasionally in late summer, dissipating tropical cyclones may pass through the region. These have a pronounced, short-term effect on the regional weather patterns.

The wind regime influences the coastal region through the generation of waves and currents as well as feeding dune systems with wind blown beach sand.

4.2.4.2 Wave climate

Wave measurements and observations taken in the deep water (greater than 50 m) offshore from Fremantle indicate that the area experiences reasonably high wave energy. The main elements of the offshore wave climate are as follows:

- seas generated locally by the passage of cold fronts during winter. The wave heights and periods (the time between the passing of successive waves) vary markedly from storm to storm. Often the wave heights exceed 4 m and the wave periods reach 6 to 10 seconds. The direction from which these storm waves approach can range from northwest to southwest during the passage of the storm.
- swell waves from distant storms in the Southern Indian Ocean continually reach the offshore area throughout the year. The swell waves often exceed 2 metres in height, and typical periods are between 8 and 16 seconds. The swell waves commonly approach from the west southwest, and tend to be slightly lower and more southerly in summer compared to winter.
- seas produced by the seabreeze. Waves are typically 0.5 to 1.5 metres high with periods of 3 to 6 seconds. The direction of these waves is generally from the southwest to south.
- severe waves caused by dissipating tropical cyclones. These storms are infrequent at Fremantle, however, when they do occur they cause severe conditions for short periods of time.

Offshore mean significant wave heights are about 50% higher in winter than in summer. Cockburn has completed one full year of directional wave measurements at a site about 15 km southwest of Rottnest Island (Rogers & Associates, 1995a), and a summary of these data is given in Table 4.1.

Table 4.1 Southwest Rottnest mean significant wave heights (H_S).

WAVE COMPONENT	SUMMER	WINTER
Measured Wave	1.8 m	2.5 m
Sea Component	1.3 m	1.5 m
Swell Component	1.2 m	1.9 m

Note: Waves consists of components contributed by sea and swell. The energy of the sea and swell components combine to provide the total energy of the measured wave. Arithmetic summation of component wave heights does not equal the measured wave height.

As the offshore waves travel toward the shore, they are greatly affected by the nearshore bathymetry and the chain of reefs and islands extending from Garden Island to Rottnest Island (Figure 1.1 and Figure 1.2). Wave energy is reduced and wave direction is changed due to the following physical processes:

- reflection off the reef faces;
- depth limited breaking on the reef tops and in shallow areas;
- diffraction through the gaps in the reefs;

- attenuation due to hydraulic turbulence as the waves travel over the reefs and other areas of shallow water; and,
- refraction and shoaling.

Wave measurements taken southwest of Rottnest Island and near the Mewstone reefs suggest that offshore waves of 4 to 5 metres in height are reduced to about 1.5 to 2 metres by the time they reach the western portion of Owen Anchorage. Thus much of the wave energy is dissipated before the waves reach Owen Anchorage. The significant natural protection provided by the reefs and nearshore bathymetry has also been illustrated in wave modelling completed for Cockburn. The set-up, calibration and verification of the computer based wave model is outlined in Rogers & Associates (1995a).

Detailed wave modelling of Owen Anchorage shows that the low frequency wave energy, such as the background swell, is focussed by refraction effects onto Success and Parmelia Banks. Model output of the directional wave spectra for locations on Success Bank show that the swell energy arrives from two distinct directions: one lobe of wave energy arrives from the north northwest and the second from the west southwest. The resultant waves that are focussed onto the Banks and break on the beach are believed to have a strong influence on the movement of sand along the Banks towards the shore at Catherine and Woodman Points and in the shallow littoral zone of the beaches in Owen Anchorage. Waves are very effective at initiating sediment movement in shallow waters by means of two mechanisms. Firstly, changes in pressure associated with the peaks and troughs of waves result in fluctuating pore pressure in the sediments (which makes the sediments easier to resuspend). Secondly, movement occurs due to the rapidly oscillating currents generated by water on the seabed. As the current decreases the sediment is deposited. This process is complex and is explained in van Rijn (1989). The waves are therefore important in the formation and maintenance of the banks and beaches.

4.2.4.3 Nearshore currents

The currents in Owen Anchorage are dominated by wind-driven circulation, astronomical tides, density gradient effects, and continental shelf influence. Table 4.2 presents the estimated speed ranges of the currents in Owen Anchorage and in the vicinity of the shipping channels.

Table 4.2 Estimated speed ranges of the currents in Owen Anchorage.

TYPE OF CURRENT	CURRENT SPEEDS (cm s^{-1})	
	TYPICAL	STRONG
Wind driven	0–20	35
Astronomical tide	0–2	3
Density effects	0–5	10
Continental shelf	0–5	5

Source: Cockburn Cement Limited, 1994.

The wind driven currents are usually of speed less than 35 cm per second. The dominant southerly winds in the region generally create northerly currents, but periods of reversal occur during winter storms. Regionally, the nearshore currents are generally parallel to shore and in a north to south direction with local bathymetry modifying these patterns. The magnitude of these nearshore currents is such that they have a minor effect on the movement of sand on the Banks and adjacent beaches except when acting in concert with waves.

4.2.5 Coastal Stability

Cockburn has completed a detailed study of the stability of the Owen Anchorage shoreline since 1942 (Rogers & Associates, 1995b). The study used the extensive monitoring data collected by Cockburn since it commenced dredging in 1972. These data include aerial photographs, beach surveys and shoreline movement plans.

From a detailed coastal engineering analysis of the data, it was concluded that the shoreline is generally quite stable or accreting. There are no areas experiencing significant long-term erosion. This is clearly illustrated in Figure 4.1, which shows the position of the coastal vegetation line in 1942 and 1994. At places such as Quarantine Beach and near the South Fremantle Power Station, the vegetation line is now more than 100 metres seaward of the position in 1942.

The general accretion of the Owen Anchorage shoreline is primarily due to onshore feed of sand from both Success and Parmelia Banks. Over the period 1976 to 1994 estimated sediment fluxes from these sources are approximately 40,000 m^3/yr and 20,000 m^3/yr respectively. The sediment feed from these Banks is believed to be concentrated in the vicinity of Catherine Point and Woodman Point. Once onshore, the sand is moved to the adjacent areas by wave induced longshore transport. This is shown diagrammatically in Figure 4.2.

Man-made structures, such as groynes and breakwaters, along the Owen Anchorage shoreline have significantly altered the natural longshore transport regime. These have also isolated Owen Anchorage from beaches north of Fremantle Harbour and from Cockburn Sound to the south. In the northern half of the Owen Anchorage shoreline, the more significant structures are thought to be Catherine Point Groyne and the Power Station Breakwater, both of which restrict sand feed from Success Bank to Coogee Beach. To the south, the WAPET Groyne has significantly changed the sediment transport dynamics at Woodman Point and restricted sand movement to Quarantine Beach.

The northern beaches are bounded by various rock structures and the beach alignment in these compartments rotates by about 10° on a seasonal basis. In summer the sea breeze seas are dominant, whereas in winter the background swell and northwesterly storm seas dominate.

The southern beaches (Coogee and Quarantine) are long and sandy, without groynes or other impediments to longshore drift. These beaches are in tune with the background swell and are less influenced by sea breeze waves.

The Owen Anchorage shoreline appears well protected from severe storm activity. A severe storm occurred in May 1994 which is believed to have a return period of about 25 to 50 years; yet this storm caused only minor erosion of the Owen Anchorage beaches. Subsequent monitoring showed that the beaches recovered their sand in the months following the storm.

These historical surveys show that the dredging on Success Bank by Cockburn since 1987 has not affected the stability of the beaches adjacent to Owen Anchorage.

4.3 BIOLOGICAL ENVIRONMENT

4.3.1. Regional Setting

The study area occurs in a region of biogeographical overlap, between the warm temperate southern Australian marine biota found from Cape Leeuwin to South Australia and the tropical marine biota of the region northeast of North West Cape (and continuous with the Indo-West Pacific region). In the region between Cape Leeuwin and North West Cape both temperate species and tropical species are found, but the species diversity of the fauna and algae is far less than that of the two main biogeographic regions. The study area is at the southern end of the overlap region, and therefore temperate species predominate. Species endemic to Western Australia (species only found in Western Australia, such as the Western Rock Lobster) make up 10–25% of the flora and fauna, depending on the taxonomic group being considered.

Seagrass species diversity is, however, the highest in Australia. The study area contains six main types of benthic habitats: patchy meadows of the seagrass *Posidonia coriacea*; dense meadows dominated by the seagrass *Amphibolis griffithii*; dense meadows dominated by *Posidonia sinuosa*; sandy unvegetated areas in shallow waters (5–8 metres deep); limestone reef; and, sand/silt unvegetated areas in deeper waters (10–17 metres deep), such as in the Owen Anchorage basin. These habitats and their associated biota in them are widely distributed, and therefore neither biogeographically unique or rare and endangered.

The Owen Anchorage basin has nearby counterparts in the larger and slightly deeper basins of Cockburn and Warnbro Sounds (Figure 1.1), whilst shallow unvegetated areas and seagrass meadows are common in the lee of the chain of reefs and islands that extends up to 4 km offshore between Yanchep and Mandurah, and in the shallow waters around Rottnest Island. *Posidonia coriacea* is found from Shark Bay to South Australia and *Amphibolis griffithii* occurs from Geraldton to South Australia. The eight other species of seagrass found in the study area (see Section 4.3.2) are also common along the southwestern coast of Australia, although *Halophila decipiens* and *Syringodium isoetifolium* reach the southernmost limits of their distribution at Garden Island.

In local coastal waters the most extensive stands of seagrass occur in sheltered embayments and consist of meadows of *Posidonia sinuosa* and *Posidonia australis*: the meadows of *Posidonia coriacea* and *Amphibolis griffithii* found in the study area are, however, typical of less sheltered areas, since these two species tolerate conditions of greater wave and current action. The animals associated with the seagrass meadows are also widespread, and no species identified to date are known to occur only in the study area.

4.3.2 Geomorphic Units and Biotic Assemblages of the Study Area

The principal geomorphic units and associated biotic assemblages of the study area have been identified by LeProvost, Semenuik and Chalmer (1988). Figure 4.3 shows the distribution of the units which are as follows:

- sand/silt floored basins;
- limestone pavement and sand veneered limestone pavement;
- submarine sand banks; and,
- sandy beaches.

In addition there are two units created by human activity. These are:

- dredged channels, pits and slopes; and,
- limestone armoured moles, groynes and seawalls.

4.3.2.1 Sand/silt floored basins

The sand/silt floored basin unit occurs in the deeper, western portion of Owen Anchorage, between depths of approximately 10 and 17 metres, and tends to accumulate finer carbonate sediments and detritus from surrounding areas.

The deep floor of the basin, although not investigated in detail, has been observed to be colonised by a sparse surface fauna comprised largely of starfish and sea urchins, and a burrowing fauna of worms and bivalves. There is generally no attached seagrass or algal growth.

4.3.2.2 Limestone pavement and sand-veneered limestone pavement

The limestone pavement unit occurs in the eastern portion of Owen Anchorage, mostly at depths of less than 10 metres. The pavement is generally continuous but is largely covered by a veneer of sand. Conspicuous biota on the exposed parts of the pavement include algae and attached invertebrate fauna such as sea squirts and bivalves, and occasionally corals. Sand-covered parts of the pavement may be colonised by patches of seagrass, commonly species of *Posidonia*.

4.3.2.3 Submarine sand banks

The two submarine banks in the study area are Success and Parmelia Banks. The bank surfaces are composed of unconsolidated sands and are exposed to moderate to low wave energy. At the large scale the surface is generally level, but smaller scale features may include sand waves, scours and mounds. Water clarity over the banks is generally high and large parts of the bank surface are colonised by seagrasses. To date, 10 species of seagrass have been found on Success and Parmelia Banks (LeProvost Dames and Moore, 1996a).

These are:

- *Posidonia australis;*
- *Posidonia sinuosa;*
- *Posidonia coriacea;*
- *Posidonia denhartogii;*
- *Amphibolis antarctica;*
- *Amphibolis griffithii;*
- *Heterozostera tasmanica;*
- *Halophila ovalis;*
- *Halophila decipiens;* and,
- *Syringodium isoetifolium.*

The seagrass on the two banks are a mosaic of meadows of different degrees of cover and species composition. The degree of cover ranges from small patches amongst the sand to large meadows that cover almost 100% of the seabed, and species composition ranges from monospecific meadows (ie. meadows dominated by one species) to mixed assemblages containing up to five species of seagrass (see Section 4.3.3). The fauna associated with the seagrass meadows include fish, sea urchins, sea pens, starfish, brittlestars, sea squirts, anemones, gastropods, bivalves, worms and crustaceans.

4.3.2.4 Sandy beaches

The shoreline which forms the eastern boundary of the study area consists primarily of sandy beaches. These are colonised by a sparse burrowing fauna of crabs, worms and bivalves. Seasonally, particularly following winter storms, seagrass and to a lesser extent algal detritus accumulates along the shoreline where it decomposes. The decomposing seagrass and algal wrack is considered an important habitat and food resource, particularly for juvenile fish (Lenanton et al. 1982; Robertson 1983).

4.3.2.5 Dredged channels, pits and slopes

The existing dredged channels, pits and slopes have been constructed for either navigation or previous shellsand extraction. The channels and pits are sand floored at depths ranging from 13 to 15 metres. Wrack from the adjacent banks frequently accumulates on the floor of the channels. The channel floors mostly comprise bare sands but there is sparse and variable colonisation by seagrasses. Patches of *Halophila* and *Heterozostera* occur, and there are isolated stands of *Amphibolis* and *Posidonia* (LeProvost Environmental Consultants, 1993a). The extent of colonisation may however be limited by the frequent re-mobilisation of sands resulting from shipping movements (under-keel clearance for the larger ships is minimal), as well as by natural factors. Periodic maintenance dredging also prevents long-term regrowth in the navigation channels.

The slopes link the natural bank surfaces and the channel floors. Following dredging they undergo a period of instability but the slope stabilises within 3 years, and may then be colonised by seagrasses. This has occurred to varying extent along the channel walls (LeProvost Environmental Consultants 1993a; LeProvost Dames and Moore, 1996b). Species which have been found to occur on the slopes include *Posidonia sinuosa, Posidonia coriacea, Amphibolis griffithii, Heterozostera tasmanica* and *Halophila ovalis*, which occur as monospecific meadows and clumps and occasionally small mixed meadows. The fauna of these colonised areas has not been studied in detail but is known to include typical seagrass associated species including starfish, sea urchins, brittlestars, anemones, gastropods and worms.

4.3.2.6 Limestone armoured moles, groynes and seawalls

Modification of the sandy beach unit has been created by the construction of various erosion protection measures. The rock surfaces of these structures are colonised by a range of organisms typical of natural limestone rocky shores, including algae, mussels, gastropod molluscs, barnacles and other crustaceans, and sea squirts. Reef dwelling fish, particularly wrasse and rock cod are commonly associated with this habitat.

4.3.3 Seagrass Assemblages of Study Area

Mapping of the seagrass assemblages of the study area was undertaken using aerial photographs taken in January and February 1995 and an extensive field survey programme involving 373 diving sites. Nine main assemblage types were identified based on the dominant species present:

- predominantly *Posidonia sinuosa*;
- predominantly *Posidonia australis*;
- predominantly *Posidonia coriacea*;
- predominantly *Amphibolis antarctica*;
- predominantly *Amphibolis griffithii*;
- predominantly *Amphibolis griffithii* and *Posidonia coriacea*;
- predominantly *Posidonia sinuosa* and *Posidonia australis*;
- predominantly *Amphibolis* species and *Posidonia sinuosa*; and,
- predominantly small species of seagrass (*Heterozostera tasmanica, Halophila ovalis, Halophila decipiens*).

The distribution of the assemblages is shown in Figure 4.4 and some general patterns can be discerned. For example in the southern areas of Success Bank seagrasses are patchily distributed in beds of area less than 100 square metres that overall, cover less than 25% of the seabed. These patches are predominantly *Posidonia coriacea*. The smaller seagrasses like *Heterozostera* and *Halophila* also form beds in this southern region. In the central part of Success Bank, there are extensive meadows of *Amphibolis griffithii* that cover more than 70% of the seabed. These meadows of

Amphibolis griffithii also contain small amounts of *Posidonia coriacea,* whilst in the north western part of Success Bank the meadows are almost exclusively *Amphibolis* species.

The seagrass assemblages shown in Figure 4.4 have been characterised by their predominant species irrespective of the total degree of seagrass cover present. The degree of cover is an important feature of seagrass meadows, and this was mapped separately. Percentage seagrass cover was broadly classified as dense (76–100% cover), medium (51–75% cover), patchy (26–50% cover), and sparse (less than 25% cover). The resultant map is shown in Figure 4.5. Comparison of Figures 4.4 and 4.5 emphasises that on Success Bank, *Posidonia coriacea* is the predominant seagrass in sparse and patchy meadows, and *Amphibolis* species are predominant in medium to dense meadows.

4.3.4 Dynamics of Seagrass Cover

Seagrass meadows are generally viewed as stable features that change little in extent, and that do not re-establish (with the same species) when they are removed. This is definitely the case under certain environmental conditions (usually in fairly sheltered embayments), but a growing body of information indicates that in higher energy environments where sediment movement occurs such as Success Bank, Rottnest Island and Warnbro Sound, seagrass meadows are far more dynamic with continuous active colonisation, recession and changes in seagrass cover.

The dynamic nature of seagrass meadows on Success Bank became apparent when seagrass distribution in 1972 and 1993 was compared (LeProvost Dames & Moore, 1996). Areas of both losses and gains were apparent, but on the eastern side of Success Bank there has been 50% increase in seagrass area since 1972, mostly associated with growth of meadows of *Posidonia coriacea* and *Amphibolis* species. The changes in seagrass cover/density on Success Bank between 1971 and 1995 are shown in Figure 4.6.

This analysis of changes in seagrass cover between 1971 (when Cockburn first commenced dredging on Parmelia Bank) and 1995 (most recent aerial photography) included Cockburn Sound. A summary of the areas identified as containing seagrass in 1971 and 1995 in Owen Anchorage and Cockburn Sound is shown in Table 4.3.

Table 4.3 Areas identified as containing seagrass in 1971 and 1995 in Owen Anchorage and Cockburn Sound and changes in area between 1971 and 1995 (all areas as hectares).

LOCATION	1971	1995	CHANGE IN AREA
Success Bank	978	1503	+525
Parmelia Bank	1004	866	-138
Garden Island (western shoreline)	510	397	-113
Southern Flats (east of causeway)	428	293	-135
Cockburn Sound (mainland shoreline)	153	29	-124
TOTAL	**3073**	**3088**	**+15**

Some of the changes with time were further examined using fine scale analysis of aerial photographs taken in 1973 and 1993, and the results are shown in Figure 4.7. It can be seen that over this time (21 years) seagrass loss has occurred to the west of the FPA channel due to the natural eastward migration of a tongue of sand, but some areas near the southern end of the FPA shipping channel that were previously patchy *Posidonia coriacea* meadows have either had an increase in density of *Posidonia coriacea* or are now *Amphibolis* meadows. Recent sediment cores taken in these *Amphibolis* meadows have confirmed the presence of *Posidonia* root and rhizome fibre. Furthermore, during the course of research currently underway, large numbers of *Posidonia coriacea* seedlings have been found as well as active horizontal tillering by the same species, both of which indicate meadow expansion due to colonisation and vegetative spreading. Conversely, on Parmelia Bank there has been a 14% loss in seagrass area since 1971 attributed to eutrophic waters from Cockburn Sound, dredging and erosion. Overall there has been little net change in seagrass cover in the study area since 1971.

What is not yet known is when the changes in the distribution of seagrass meadows took place, and at what rate these changes have been occurring.

4.4 SOCIAL ENVIRONMENT

4.4.1 Beneficial Uses (BU) of the Study Area

The water, seabed and shorelines of the study area are used for a variety of activities that may be considered in terms of recognised beneficial uses. The DEP originally defined sixteen beneficial uses for marine and estuarine waters of Western Australia (Department of Conservation and Environment, 1981), but these have been subsumed under five 'environmental values' (synonymous with beneficial uses) in the latest DEP draft guidelines (Environmental Protection Authority, 1993), in accordance with national guidelines (ANZECC, 1992). The relationship between the DEP's original sixteen beneficial uses for marine and estuarine waters in Western Australia (Department of Conservation and Environment, 1981) and the five environmental values in their recent draft guidelines for fresh and marine waters (Environmental Protection Authority, 1993) is shown in Table 4.4.

Only one systematic attempt has been made to map human uses of the study area. The report by Beckwith and Associates (1995) for the DEP's Southern Metropolitan Coastal Waters Study investigated what it called cultural uses of the entire Cockburn Sound area. Beckwith and Associates divided the region into four sub-areas and applied a set of 'cultural use criteria' to each sub-area: the sub-area of Owen Anchorage encompasses the study area for this document. The criteria of Beckwith and Associates (1995) were based on the DEP's beneficial use concept (Department of Conservation and Environment, 1981; Environmental Protection Authority, 1993), and defined seven distinct cultural uses:

- direct contact recreation (primary and secondary contact);
- commercial fishing;
- harbours and marinas;
- mineral recovery;
- navigation and shipping;
- effluent disposal; and,
- marine park.

The report indicated that the following should be considered to be the four main uses of the study area:

- ports and shipping;
- shellsand dredging;
- primary and secondary direct contact recreation based around the Woodman Point reserve; and,
- industry at Coogee.

Primary contact recreation includes swimming and SCUBA diving, and secondary contact recreation includes sailing, pleasure boating and fishing. Recreational activities also take place around the shoreline, including sunbathing, picnicking, and beach, groyne and jetty fishing. It was also suggested that the study area had significant potential for marina development and aquaculture.

The uses of the study area are shown in Figure 4.8. Beckwith and Associates (1995) concluded that divergent interests had, to date, managed to coexist within the study area without noticeable conflict. A warning was offered, however, about the potential for increased user conflict as population increases and the demand for recreational access rises in tandem. The proposed redevelopment of the area between Catherine Point and Coogee Beach is also likely to result in an increase in recreational activity in this area, as may the relocation of the FPA port from Fremantle to Cockburn Sound.

Table 4.4 Comparison between environmental values (Bulletin 711, Environmental Protection Authority, 1993) and beneficial uses (Bulletin 103, Department of Conservation and Environment, 1981) used for Western Australian waters.

BULLETIN 711 (Environmental Protection Authority, 1993)	**BULLETIN 103 (Department of Conservation and Environment, 1981)**
Recreational water quality and aesthetics	BU* no. 1: direct contact recreation
Protection of aquatic ecosystems	BU* no. 2: harvesting of aquatic life (excluding molluscs) for food BU* no. 3: harvesting of molluscs for food BU* no. 4: harvesting of aquatic life for non-edible uses BU* no. 5: passage of fish and other aquatic life BU* no. 6: aquaculture of all forms BU* no. 7: maintenance and preservation of aquatic ecosystems BU* no. 8: maintenance and preservation of foreshores and banks BU* no. 9: scientific and educational uses BU* no. 10: flushing water and water replenishment
Raw water for drinking supply	BU* no. 11: potable water production
Agricultural water use	BU* no. 12: agricultural water supply
Industrial water quality	BU* no. 13: recovery of minerals BU* no. 14: industrial water supply BU* no. 15: power generation BU* no. 16: navigation and shipping

4.4.2 Recognised Conservation Values

Criteria to assess the environmental significance of marine habitats have not been developed in Australia. The justification for protection of marine areas within Western Australia (for example, by the creation of marine parks) has been made largely on the basis of ecological features and character (eg, Ningaloo Marine Park, Shark Bay Marine Park and Hamelin Pool Marine Nature Reserve) or, as in the case of Marmion Marine Park and Shoalwater Islands Marine Park, the perceived need to maintain a range of representative habitats and biota for the purposes of conservation, recreation and research (Environmental Protection Authority, 1991; CALM, 1994). Assessment on a strictly biological basis is often based on the criteria of diversity, representativeness (the assumption is usually made that a reserve system that is representative of a region's ecosystems will maximise species diversity, even if floral and faunal composition is not fully known), naturalness (preference is given to areas little affected by human activity), and the effectiveness or manageability of the area (CALM, 1994).

Of the criteria for protection listed above, none apply to the study area. Nor does the study area support rare or endangered species: there are no species of invertebrates or marine fish listed as endangered in Australia (SOMER, 1995), and although the occasional loggerhead turtle is found in local coastal waters, turtles inhabit subtropical and tropical waters. Australia has the largest area and highest diversity of temperate seagrass meadows in the world, for which reason they are considered unique (SOMER, 1995), however the seagrass meadows within the study area are well represented elsewhere along the temperate Western Australian coastline, particularly between Geographe Bay and Kalbarri.

4.4.2.1 Existing or proposed reserves

The study area is not covered by any existing or proposed conservation reservation. The nearest areas covered by System Six Recommendations (Environmental Protection Authority, 1983) are Woodman Point and Carnac Island, and the nearest marine reserves and parks occur at Rottnest Island, Shoalwater Islands Marine Park and Marmion Marine Park. The Marine Parks and Reserves Selection Working Group has recommended that the representativeness of the existing Shoalwater Islands Marine Park would be enhanced by extending its boundaries to include the area west of Garden and Carnac Islands out to Five Fathom Bank (CALM, 1994), but this is only the south-western extreme of the study area, and does not include seagrass meadows on Success Bank.

4.4.2.2 Archaeological significance

Owen Anchorage was the site of a number of the early ship landings during the settlement of Perth in the early part of the nineteenth century. During that period a number of vessels were wrecked or foundered and, in addition a large number and variety of objects were jettisoned from foundering vessels, dispersed from wrecks by storm and wave action, or lost overboard during unloading.

Although the locations of the major wrecks are known, it is not possible to pinpoint the locations of individual objects. All wrecks or objects dating prior to 1900 are deemed to be `historic shipwrecks or relics' within the meaning, and subject to the provisions, of the Maritime Archaeology Act of 1973. The requirements of the Act are that the finding of any object subject to the provisions of the Act be notified and that in the case of any discovery being made of a number of objects, or a wreck site, all activity be halted until an investigation to assess the importance of the site has been carried out.

The area proposed to be dredged contains no known wrecks, and dredging in adjacent areas has revealed no historic relics. Cockburn is aware of this provision of the Act, and will advise the Museum in the event of any historic item being located in the course of its operations.

4.4.3 Condition of the Ecosystem

As a consequence of its location adjacent to a port, river mouth and industrial area, Owen Anchorage and the adjacent banks have been progressively modified by human activity since the early days of European settlement.

The larger and more significant of these changes have been:

- the discharge of nutrient-rich and dark coloured waters from the Swan River during late winter;
- the construction of the FPA Channel through Success and Parmelia Banks, initially in 1919 to a depth of 8 metres, with subsequent periodic deepening and widening, to provide its present width of 152 metres (at the bottom of the channel) and a minimum depth of 14.7 metres below low water mark;
- the discharge of effluent, including nutrients, from industries located along the Owen Anchorage shoreline. Much of this discharge has ceased or been brought under more effective management in recent years;
- the effect of enriched waters from Cockburn Sound being exchanged with those of Owen Anchorage. This effect has been implicated in the loss of seagrass from Parmelia Bank;
- shellsand dredging by Cockburn. The dredging process has reduced the height of dredged areas of the banks (in the second channel) to a level similar to that of the adjacent basins and FPA navigation channel; and,
- the alteration of shoreline sediment dynamics by the construction of numerous rock groynes and sea walls which have basically turned a long sandy coastline into a series of small pocket beaches.

The region is heavily utilised and modified, and as such is not in pristine condition. Water quality on the eastern side of Owen Anchorage was poor during the 1970's, but has since improved dramatically due to better environmental practices by industries in the area. On the basis of phytoplankton levels, concentrations of total inorganic nitrogen and water clarity, the current water quality of Owen Anchorage meets criteria that are being proposed by the DEP to maintain acceptable environmental conditions.

5. ENVIRONMENTAL EFFECTS

5.1 INTRODUCTION

This chapter outlines the potential physical, biological and social effects that dredging of the medium-term resource may have on the study area. Assessment is based largely on information from the technical investigations and scientific studies of the EMP research programme initiated by Cockburn in response to the requirements of the Minister for the Environment. These specifically required Cockburn to carry out studies to determine whether 'seagrass on Success Bank and its surrounds can be successfully rehabilitated, or that its removal through dredging would have acceptable ecological and wave climate consequences'. Using the results to date of the EMP studies the direct effects of dredging the medium-term resource are identified, and the potential indirect effects which may subsequently occur are discussed. Each effect is then evaluated to determine its likely significance.

5.2 PHYSICAL EFFECTS

The major direct physical effect of dredging the medium-term resource will be the change in bank bathymetry, with the secondary potential effects of a modified wave climate and dredge slope instability. The issues associated with changes in the wave climate of the area are:

- sediment transport patterns on the Banks and coastline;
- the turbidity of the waters (due to increased sediment suspension); and,
- the shipping and navigation uses of the area.

The issue associated with dredged slope instability is bank top stability.

A minor direct physical effect will be intermittent localised water turbidity in the vicinity of the dredge when the barges are loading, and in the vicinity of the wash plant reclaimer jetty when the barges dump their load. Localised water turbidity will also occur in the vicinity of the reclaimer jetty as a result of wash plant discharges containing silt particles.

These physical effects and potential concerns are discussed in greater detail below.

5.2.1 Bathymetry and Slope Stability

Dredging of the medium-term resource will effectively remove most of the shallow sands between the FPA channel and second shipping channel. Presently it is proposed that a buffer zone parallel to the FPA channel about 100 metres wide at the crest would be left to isolate the dredged area from the FPA shipping channel.

The two shipping channels and dredged area will consist of an undulating basin floor at a depth of 11–15 metres that is linked to the adjacent shallow sand banks by relatively steep dredged slopes. The dredged slopes undergo slumping until a more stable profile (according to prevailing hydrodynamic conditions) is achieved, and this results in some loss of bank top habitat along the edges of the dredged areas.

The size and rate of this 'edge effect' has been monitored at fourteen sites with dredged slopes of differing ages and orientation to prevailing winds and water movement over the last 5 years (LeProvost Dames & Moore, 1996b). Two natural slopes were also monitored for comparison. The findings indicated that most slumping at the crest of dredge slopes occurs within the first year after dredging, a lesser amount occurs in the second year, and at the end of about two years the slopes reach a stable angle of repose, and little further change occurs. The older dredged slopes and the two natural slopes that were monitored showed little change over the last 5 years. Regression of seagrass meadow edge occurred on dredged slopes on the eastern side of the second shipping channel; regression was between 4 and 11 metres in the first year after dredging, but this slowed to 0 to 5 metres in the second year. It has been conservatively estimated that a maximum regression of 50 metres will occur, and that the dredge slope will be stable after 3 years. These features are illustrated in Figure 5.1, which shows annual changes in the seabed profile of a dredged slope created on the eastern side of the second shipping channel in 1992.

5.2.2 Modification of Wave Climate

A sophisticated computer-based numerical model of the present wave climate on Success Bank has been prepared and calibrated using the existing bathymetry of the study area and appropriate wind and wave data. The model also incorporates different friction factors to take into account whether the seabed is reef, seagrass meadow or unvegetated sediment. The model provides excellent simulation of present wave conditions in the study area, and has been run with a modified bathymetry that simulates the effect of dredging the medium-term resource to examine the associated changes on wave climate in the study area.

The model was run with four typical meteorological/oceanographic conditions to cover the range likely to occur in the study area. These were:

- a moderate swell;
- a typical sea breeze pattern;
- a moderate storm; and,
- a severe storm.

The changes in bathymetry due to dredging the medium-term resource produced little change in wave height for all four events. Most of the study area had no change or less than a 0.05 metre change in wave height. In severe storms some localised areas had a predicted increase in wave height of 0.1–0.2 metres, but this was small compared to the 1–2 metre waves experienced during this event. Significant changes in mean wave direction were predicted in the deeper areas of Owen Anchorage and some localised areas on the Banks, but little change in wave direction was predicted on the shoreline. Evaluations of the effect of the modified wave climate on shoreline sediment transport, bank stability and seagrass integrity, water turbidity, and shipping and navigation in the area are described in detail in Rogers and Associates (1995a, 1996), and summarised below.

5.2.2.1 Shoreline and sediment transport

Calculations of sediment transport along the beaches of the study area show no alterations due to the changes in wave climate.

5.2.2.2 Bank stability and seagrass integrity

Calculations of sediment transport along Success Bank under swell conditions (when most sediment movement occurs) also show little change due to dredging. Further evaluation of the model will continue to confirm that model predictions are realistic (see Section 7.2.2).

Similarly, with the very limited change in sediment transport along the Bank tops that will occur due to dredging, seagrasses will not be eroded. Evidence based on wave energy modelling shows that seagrasses on the western side of Success Bank are presently continuously exposed to far higher wave energies than would occur on the eastern side of Success Bank after dredging. It is expected that sediment transport along the banks which is frequently observed as the passage of 'sand waves' will continue as before, with the bulk of the sediment transport occurring during major storms.

5.2.2.3 Water turbidity

The clarity, or light penetration in these waters is influenced primarily by:

- water colour;
- phytoplankton concentrations; and,
- turbidity due to suspended particles.

Increasing wave energy can cause significant increases in the resuspension of seabed particulates and therefore turbidity.

During the Perth Coastal Waters Study it was found that significant wave height had to exceed a certain 'threshold' value before pronounced sediment suspension (and therefore increased turbidity) occurred (van Senden et al, 1994). This threshold value is exceeded regularly during the heavy swells associated with storms in winter and early spring, but seldom during the remainder of the year. Similar findings have been made in the DEP's Southern Metropolitan Coastal Waters Study (unpublished data).

Wave climate modelling has indicated that dredging the medium-term resource will result in a very small proportion of the study area experiencing a small increase (less than a few centimetres) in significant wave height. Pronounced sediment suspension is largely associated with winter storms, and the predicted slight increases in wave height are unlikely to significantly increase the number or length of periods when the threshold value is exceeded in these areas, particularly as the areas involved are relatively deep (more wave energy is required to suspend sediments in deeper areas than in shallow areas). Since the majority of the study area will experience no change in wave climate and some areas will actually experience a decrease in significant wave height, it is unlikely that the overall turbidity of the study area will increase significantly. Any increases that do occur should be extremely localised and of short duration.

5.2.2.4 Navigation

The FPA controls shipping in the vicinity of Owen Anchorage. Vessels that service the various industries in Cockburn Sound all use the FPA channel that has been dredged through Success and Parmelia Banks. This channel was dredged to more than 10 metres depth in the 1950's to provide access for the British Petroleum (BP) facilities in Kwinana. Since then the channel has been further deepened to accommodate deeper draft ships. Recently, because of the high cost of additional dredging, the FPA in conjunction with BP has established a sophisticated monitoring system to enable accurate prediction of the under-keel clearance of the ships using the channel. This system permits better utilisation of the available depth of water in the dredged channel. The limiting oceanographic conditions are generally long period swell waves (John Barraclough, FPA pers comm). Apparently, under these conditions, the response to the swell is oscillating translations and rotations of the ship in a number of directions. These various motions can reduce the available clearance between the ship and the bottom of the dredged channel.

Given this background, the likely impacts of the dredging proposed by Cockburn on the swell wave conditions along the FPA shipping channel and in adjacent navigation areas were fully explored in Rogers & Associates (1996). Six sites were chosen for a detailed comparison of the modelled swell conditions before and after the proposed dredging. The sites included the area offshore from Fremantle Harbour, the FPA shipping channel through Success and Parmelia Banks, and the northern end of Cockburn Sound. The predicted changes are summarised in Table 5.1.

Table 5.1 Predicted changes to swell wave conditions due to proposed medium-term dredging.

LOCATION	1994 BATHYMETRY		AFTER PROPOSED DREDGING	
	H_S (metres)	DIRECTION (°)	H_S (metres)	DIRECTION (°)
Site 1 - breakwaters off Fremantle Harbour	0.60	291	0.60	290
Site 2 - FPA channel, Success Bank	0.39	267	0.38	269
Site 3 - FPA channel, Parmelia Bank	0.37	245	0.40	258
Site 4 - FPA channel, Parmelia Bank	0.28	226	0.29	231
Site 5 - northwest Cockburn Sound	0.26	297	0.27	298
Site 6 - northeast Cockburn Sound	0.19	287	0.19	298

Note: H_S = significant wave height, which is the average height of the largest one-third of the waves

Table 5.1 clearly shows that the proposed dredging would have minimal effect on the swell wave heights near Fremantle Harbour, along the FPA channel and in Cockburn Sound. The predictions of the effects of the dredging indicate that wave direction would change by about 13° at Site 3, but in perspective, the directional wave spectra at site 3 show that the swell wave energy arrives from a wide range of directions, spanning about 180°. The conclusion is that the proposed dredging would have little effect on the FPA shipping operations within the study area.

5.2.2.5 Small boat harbours in the study area

There are a number of harbour and coastal structures along the coast of Owen Anchorage and the adjacent areas. These range from North and South Moles at Fremantle Harbour to the WAPET Groyne at Woodman Point. The various harbours located near Fremantle are likely to have been designed for severe storms with return periods of about 20 to 50 years. Department of Marine & Harbours (1988), Steedman Science & Engineering (1988) and Riedel & Byrne (1988) suggest that the recent Rous Head development at Fremantle Harbour was designed for a significant wave height of about 3 to 3.5 metres. The lower end of this range is also believed to be about the wave height used for the design of the small boat harbours at Fremantle.

The design conditions for the coastal structures to the south are likely to be somewhat less because of the sheltering effects of Success and Parmelia Banks and wave breaking in shallow water. The significant wave height used in the design of these structures is believed to be about 2 to 3 metres.

Rogers & Associates (1996) used the verified wave model to predict the changes in wave conditions during a severe storm which has an estimated return period in excess of 10 years. This work indicated that, during severe storms, there is likely to be less than 0.1 metre increase in the wave heights near the various harbours and coastal structures. This minor increase is believed to be insignificant, and would not affect the performance of these facilities and structures.

5.2.3 Effects of Dredging on Turbidity

The intermittent increases in water turbidity which occur at the dredge when the barges are loaded and at the jetty head when the barges dump their load of shellsand are localised and short-lived, and disperse in various directions depending on the prevailing wind and current conditions.

An investigation of light attenuation caused by the plume generated during barge loading by the dredge was conducted in summer 1990 (LeProvost, Semeniuk and Chalmer, 1990). The findings showed that, under the summer conditions surveyed, the plume was narrow (100–200 metres wide) and up to 1 km in length and consisted of a number of discrete 'patches' of turbid water, each representing a separate loading event. Light attenuation characteristics were generally back to background levels approximately 1 km downstream of the dredge and sometimes closer.

A similar dispersal pattern has been observed to occur at the jetty head as a result of intermittent dumping of barge loads.

The characteristics of the washing plant wastewater discharge plume at the jetty were investigated in 1987 (Steedman Limited, 1987). Measurement showed the discharge plume to be a buoyant, fresh water surface layer up to 1 metre thick, in which fine silts and clay size particles originating from the seabed are suspended. This buoyant surface layer is readily moved about by the prevailing wind and may cover an area of up to 2 square kilometres. On occasions the surface plume moves against the shoreline to the east and west of the washing plant depending on the prevailing wind conditions. The characteristics of this discharge plume are not expected to change as a result of the proposed medium-term dredging strategy.

5.3 BIOLOGICAL EFFECTS

The main direct biological effect associated with dredging the medium-term resource is the loss of bank top habitat (seagrass meadow and bare sand) and associated biota at a depth of 5–8 metres and replacement with steep sandy slopes and an undulating sandy seabed at a depth of 11–15 metres that will eventually be recolonised by different biota. A lesser direct effect may be lower productivity of benthic plants (principally seagrass) due to short-term, localised increases in water turbidity due to the operation of the dredge, and longer-term changes in turbidity due to modifications to wave climate. The main concerns associated with these losses/changes are their significance to the ecological functioning of the study area, and to commercial and recreational fisheries. These effects and potential concerns are discussed below.

5.3.1 Habitat Loss/Change

Dredging the proposed medium-term resource (which covers an area of 147 ha) will result in the loss of 44 ha of dense *Amphibolis griffithii/Posidonia coriacea* meadow, 46 ha of patchy *Posidonia coriacea* meadow and 57 ha of shallow unvegetated habitat, and an increase of 147 ha of deeper unvegetated habitat.

The distribution of bare sand, limestone reef and seagrass assemblages in the study area has been mapped, and in Table 5.2 the area that these habitats occupy before and after dredging is shown for both the short-term area that has been dredged, and the proposed medium-term dredge area. Bare sand (unvegetated sediment) habitat was subdivided on the basis of the depth at which it exists, as sediment and benthic fauna characteristics change with depth. An edge effect of 50 metres was allowed for losses due to slumping of dredged slopes.

The changes due to dredging may also be viewed in terms of relative change in broader categories of habitats; for this purpose seagrass meadows are defined as areas where seagrass cover is greater than 25%. The study area is accordingly comprised of about 22% in area of known seagrass meadow, 38% shallow unvegetated habitat, and 30% deeper unvegetated habitat. Of the remaining 10% in area of unconfirmed seagrass/reef (see Table 5.2), about half may also be seagrass meadow. On this basis, in the study area about half of the area of seagrass meadow is of medium to dense cover and half is patchy cover. Dredging of the short-term and medium-term resources will result in the loss of about 2% of the area of meadows of medium to dense cover, 5% of the patchy seagrass meadows and 2% of the shallow unvegetated areas in the study area, and an increase of 5% in area of deeper unvegetated habitats.

Table 5.2 Area occupied by various habitats within the study area before and after short-term, and the proposed medium-term dredging (based on data from LeProvost Dames & Moore, 1996).

HABITAT	AREA OCCUPIED AFTER DREDGING (HA)		
	PRE-DREDGING	SHORT-TERM	MEDIUM-TERM
Predominantly *Posidonia sinuosa*	633	633	633
Predominantly *Posidonia australis*	129	129	129
Predominantly *Posidonia coriacea*	638	635	589
Predominantly *Amphibolis antarctica*	28	28	28
Predominantly *Amphibolis griffithii*	497	497	497
Predominantly *Amphibolis griffithii* and *Posidonia coriacea*	622	621	577
Predominantly *Posidonia sinuosa* and *Posidonia australis*	65	65	65
Predominantly *Amphibolis* species and *Posidonia sinuosa*	240	240	240
Predominantly small species of seagrass*	138	138	138
Total area of known seagrass	2990	2986	2896
Unconfirmed seagrass/reef**	1,149	1,146	1,140
Shallow unvegetated sediment	5,012	4,947	4,896
Deep unvegetated sediment	4,050	4,122	4,269
Reef	130	130	130
Total	**13,331**	**13,331**	**13,331**

* *Heterozostera tasmanica, Halophila ovalis and Halophila decipiens..*

** *Identification of habitat type unconfirmed as yet. Possibly about half of this area is reef and half seagrass meadow.*

5.3.2 Changes in Seagrass Area

In section 4.3.4, the dynamics of seagrasses on Success Bank were described, with the comparison of aerial photographs taken in 1971 and 1995 showing significant changes in the patterns of distribution of seagrasses particularly on Success Bank, where it is estimated that an increase of as much as 500 ha of cover with seagrass of density greater than 25% occurred during this time.

The changes involved with dredging the proposed medium-term resource are therefore of far lesser magnitude than the gains and losses in seagrass cover and area that appear to have occurred in the study area between 1972 and 1993.

5.3.3 Ecological Function

To assess impacts on ecological function an understanding of the ecologically significant features of the area in question is required. Before ecological significance can be assessed it must first be defined, and obviously the definition will, in turn, shape how any subsequent assessment of ecological significance is carried out. The definition of ecological significance is therefore pivotal to the assessment process.

A definition of ecological significance has been developed for the study area, and is based on the environmental management principles of the World Conservation Strategy and on the identification of the environmental values that need to be protected within the study area. These environmental values are based on those recognised in national guidelines (ANZECC, 1992), and include ecosystem protection, recreation, aesthetics, education and commercial activities (see also Section 5.4).

Since it is seagrass habitat that will be most altered by dredging, the definition of ecological significance that was developed and used to protect these environmental values placed particular emphasis on seagrasses, although it is also applicable to other habitats in the study area.

Seagrasses are recognised as being ecologically significant because of their potential roles in:

- sediment trapping, binding and production;
- assimilation and cycling of nutrients and other chemicals (biogeochemical cycling);
- primary (plant) and secondary (faunal) production;
- provision of habitat;
- maintenance of biodiversity; and,
- provision of amenity for recreation, education and research.

It was therefore proposed that the ecological significance of the study area be defined in terms of:

- physical attributes:
  - sediment accumulation and stabilisation;
  - wave baffling and other hydrodynamic processes;

- effects on light climate; and
- degree of complexity in terms of three dimensional structure;

- chemical attributes:
  - biogeochemical cycling;

- biological attributes:
  - floral and faunal abundance and diversity;
  - plant production; and
  - faunal production (including fisheries);

- cultural attributes:
  - recreational and commercial uses;
  - educational uses; and,
  - aesthetics.

This definition has also been discussed, widely reviewed and formally approved by the DEP. The ecological functions of seagrass meadows and unvegetated habitats in the study area are discussed below in terms of the attributes identified in the definition of ecological significance, and an assessment is made of the significance of habitat changes due to dredging the medium-term resource.

5.3.3.1 Physical attributes

a) Sediment accumulation and stabilisation, wave baffling, and effects on light climate.

It appears that the majority of the sediment forming Parmelia and Success Banks has been derived from the erosion of the Garden Island Ridge. The seagrass meadows on the Banks maintain a variety of carbonate producing organisms which have provided an additional contribution of sediment to the Banks, but the *in situ* seagrasses have only contributed carbonate sediments towards the volume of the Banks in recent geological times, following the shoaling of the Banks to a depth of about 9 metres.

Initial calculations of the current carbonate productivity of the seagrass meadows on the Banks indicate that the carbonate producing organisms within the seagrass meadows contribute a relatively minor volume of sediment to the Banks (Table 5.3). These findings are in contrast to the previous estimates of carbonate productivity in the Owen Anchorage area by Searle (1984) who employed an indirect method for their measurement. It should also be noted that the productivity estimate by Searle (1984) is an order of magnitude greater than others presented in the literature from a wide variety of habitats (Table 5.3).

Over the last 5,500–7,500 years the Banks have grown by about 645 million cubic metres of sediment. Conservative calculations (that take the highest value for calcium carbonate production by seagrass biota in the study area, and assume that both Parmelia and Success Banks are entirely covered by dense seagrass) indicate that seagrass meadows would have contributed less than 5% of bank sediments during the formation of the banks.

Table 5.3 Estimates of organic calcium carbonate production for a variety of habitats and species.

HABITAT	LOCATION	CALCIUM CARBONATE PRODUCTIVITY (gm m^{-2} year^{-1})	SPECIES	METHOD	REFERENCE
Seagrass meadows	Owen Anchorage, Western Australia	2,200	Mixed assemblage dominated by *Amphibolis* & *Posidonia* species	Estimated total alkalinity	Searle (1984)
Seagrass meadows (*Amphibolis* & *Posidonia*)	Owen Anchorage, Western Australia	130–210	Epiphytes and interstitial molluscs	Direct measurement	DAL (1995)
100 % Posidonia meadow	Owen Anchorage, Western Australia	86	Epiphytes and macrofauna	Direct measurement	EMP Study unpublished
100 % *Amphibolis* meadow	Owen Anchorage, Western Australia	263	Epiphytes and macrofauna	Direct measurement	EMP Study unpublished
Mixed *Posidonia* / *Amphibolis* meadow	Owen Anchorage, Western Australia	402	Epiphytes and macrofauna	Direct measurement	EMP Study unpublished
Bare sand (<10 m)	Owen Anchorage, Western Australia	6	Epiphytes and macrofauna	Direct measurement	EMP Study unpublished
Bare sand (>10 m)	Owen Anchorage, Western Australia	18	Epiphytes and macrofauna	Direct measurement	EMP Study unpublished
Seagrass meadow (*Thalassia*)	Graham's Harbor, San Salvador	136–304	Epibionts and calcareous algae	Direct measurement	Armstrong (1989)
Seagrass meadows	Largo Sound, Florida	60	*Archaias angulatus* (foraminifera)	Direct measurement	Hallock et al. (1986)
Seagrass meadow	Princess Royal Harbour, Western Australia	30–117	Coralline epiphytes of *Posidonia australis*, *P. sinuosa* and *A. antarctica*	Direct measurement	Walker et al. (1991)
Seagrass meadow	Shark Bay, Western Australia	35–500	Coralline epiphytes on *Amphibolis antarctica*	Direct measurement	Walker & Woelkerling (1988)
Seagrass meadow	Tropical waters	40–180	Coralline epiphytes on *Thalassia testudinum*	Direct measurement	Land (1970)
Seagrass meadow	Rottnest Island and Warnbro Sound, Western Australia	150–220	Coralline epiphytes of *Amphibolis antarctica*	Direct measurement	Sim (1991)
Coral reef (total)	Not stated	1,200	Not stated	Estimated	Wollast (1994)
Banks & embayments	Not stated	250	Not stated	Estimated	Wollast (1994)
Shelf (non-carbonate)	Not stated	5	Not stated	Estimated	Wollast (1994)
Shelf (carbonate)	Not stated	45	Not stated	Estimated	Wollast (1994)
Coral reef	Not stated	4,000	Not stated	Estimated	Wollast (1994)
Coral lagoon	Not stated	800	Not stated	Estimated	Wollast (1994)
Continental slope	Global	18	Not stated	Estimated (sediment traps)	Wollast (1994)
Deep sea	Global	4	Not stated	Estimated (primary production)	Wollast (1994)
Enclosed basins	Global	9	Not stated	Estimated (sediment traps)	Wollast (1994)

Under certain conditions the presence of seagrass meadows can also change the rate and type of sediment accumulation in an ecosystem. The presence of seagrass (or any other similar feature) on the sea floor will increase friction, and result in the deposition of materials in the water column. Seagrasses though are not able to dampen the rapid pressure fluctuations from waves. Under calm conditions, the seagrasses on Success Bank would enhance deposition particularly of finer particles. However, under strong wave conditions, with associated current, sediments both within and outside of seagrass can be mobilised and transported. This would be particularly so on Success Bank because *Posidonia coriacea* meadows have a very open structure, and although *Amphibolis griffithii* meadows have dense canopies, at the seabed surface the individual plants are widely spaced. Consequently on Success Bank, it is considered that the distribution of sediments is a function of wave energy, and not seagrass distribution.

This conclusion is supported by the results of a study of sediment characteristics in the study area. Sediments were taken from a range of habitats from bare sand to areas of up to 100% seagrass cover, but no significant (or consistent) differences in sediment characteristics were found with increasing seagrass cover. These data suggest that any material produced and/or trapped within the seagrass meadows is rapidly transported across the Banks under the action of the vigorous wave and current regime of the area. The Banks are therefore largely maintained by oceanographic and sedimentological process, although sediment transport along the bank axes is to some extent now restricted by the trapping effect of the FPA Channel (maintenance dredging has to be carried out by the FPA to remove accumulated sediment).

Seagrasses in the study area are therefore believed to have little impact on sediment accumulation and stabilisation, wave climate, and therefore on light climate (see Section 5.2.3) on the Banks. The loss of 90 ha of seagrass during the proposed medium-term dredging (which is about 3% of the area of seagrass meadows in the study area) is therefore unlikely to have a measurable influence on these processes.

Dredging will however, both remove seagrass and increase water depth, and since the deeper water will have slower bottom currents, these areas will have greater tendency towards deposition than erosion. Thus there will be a slight increase in the area of habitat available for the accumulation of sediments and organic material.

b) Three dimensional structure

Seagrasses provide a complex, three dimensional habitat for biota. They are a substratum for the attachment of algae, small animals and microbes, and the leaves (and stems, depending on the species of seagrass involved) of the seagrass offer an attachment surface that is both considerably more stable and many times greater in area than that of the sediment on which they grow. The three dimensional complexity of the leaves, stems, epiphytes, roots and rhizomes of seagrass meadows also provide a variety of diverse microhabitats for a wide range of fauna, as well as offering protection from predators. Seagrass species and meadow patchiness are important factors in determining three dimensional habitat complexity.

The deeper unvegetated habitats and shores of the study area also offer a complex three dimensional habitat to biota, since they accumulate algae detached from the offshore reefs and seagrass from the adjacent meadows: they also offer a calmer environment because of their greater depth. This accumulated 'wrack' can often be quite deep, and although less 'fixed' than seagrass meadows, nonetheless offers habitat and protection from predators for many species of fauna. The nearshore accumulations of wrack in local coastal waters are believed to be an important habitat for juvenile fish (Lenanton et al, 1982).

The scale of changes in area of available three dimensional habitat due to dredging the medium term resource (loss of 2% of medium/dense seagrass meadow and 5% of patchy seagrass meadow, and a gain of 5% in deeper habitats where wrack can accumulate) is unlikely to measurably affect this aspect of ecological functioning in the study area, particularly against the background of the 16% increase in area of seagrass meadow in the study area that is believed to have occurred since 1972 (see Section 5.3.2). The proportions of area of broad habitat type in the study area (one third seagrass meadow, one third shallow unvegetated sediment and one third deeper unvegetated habitat) are little changed due to dredging the medium-term resource, and although there will be slight loss of three dimensional habitat associated with seagrasses, there will be a gain in three dimensional habitat available in wrack that accumulates the deeper habitat.

5.3.3.2 Chemical attributes

Compared to shallow unvegetated areas, seagrass meadows represent considerable accumulations of carbon, nitrogen and phosphorus, particularly in the nutrient-poor environments where they typically occur. The role that a seagrass meadow plays in nutrient cycling within an ecosystem also depends on its net losses (such as export of eroded material, particularly during storms) or gains (from nitrogen fixation, sedimentation of phytoplankton and detritus, and leaf uptake from the water column). The effective retention of organic matter and recycling of nutrients that usually occurs in seagrass meadows has led to them being viewed more as closed systems rather than open systems that contribute nutrients to other areas. In effect, the high concentrations of nutrients that exist within seagrass meadows are largely recycled to support the continued existence of seagrass meadows, and these nutrients are largely unavailable to other biota in the ecosystem for most of the year. However, at the end of summer and during winter storms in local coastal waters, large amounts of seagrass can be dislodged and accumulate on the beach or in deeper waters, as can macroalgae from the offshore reefs.

The loss of seagrass meadows associated with dredging the medium-term resource will result in a loss of about 2% of the nutrient pool associated with seagrass meadows in the study area, but there will be a 5% increase in the area of deeper habitat, which will increase the potential ability of the study area to retain nutrients in the form of detached seagrass material and algae from offshore reefs. The degree of nutrient turnover due to phytoplankton may also increase, as a greater depth of water column will be available to these organisms in some areas. However the scale of all these changes is minor, and nutrient cycling within the study area is unlikely to be measurably affected.

5.3.3.3 Biological attributes

The biological attributes of floral and faunal abundance and diversity and primary production are considered here. Fisheries are discussed in Section 5.3.4.

Floral and faunal communities in seagrass meadows are generally more diverse and abundant than in nearby unvegetated areas, but they vary considerably in both space and time, with the result that no 'characteristic assemblage' can be described for a particular seagrass meadow. Much of this variation can be attributed to differences in physical parameters affecting the habitats (such as depth, wave energy, sediment characteristics, latitude and salinity). However, the overriding influence of recruitment is likely to be more significant, particularly on the smaller spatial scales, since most of the biota in seagrass meadows arrive there as propagules or larvae carried by water currents. The deeper unvegetated habitats within the study area also have more abundant and diverse communities than the shallow unvegetated areas, although not as abundant and diverse as seagrass meadows. It should also be noted that the species that occur within seagrass meadows are also found on and in unvegetated areas and reef habitats.

The overall productivity of any area depends on its primary (plant) production: plants convert carbon dioxide into chemical energy (food) that is then available to the food web. Within the study area the primary producers include phytoplankton, seagrasses, seagrass epiphytes, reef algae, and sand microflora. Calculations have indicated that the primary production in areas with dense seagrass meadows (which includes seagrass, epiphyte, sand microflora and phytoplankton production) is about double that in patchy meadows or unvegetated areas of the same depth, however the production of phytoplankton may actually slightly increase overall productivity in dredged areas due to the greater depth of water column available for them to inhabit.

This primary production can enter the food web in one of two main ways:

- via grazing food chains, in which the living plant matter is directly grazed by a herbivore, which in turn is eaten by a higher order consumer, and so on; and,
- via detrital food chains, in which plant material and other types of organic material undergo decomposition by microbes, which in turn are consumed by macro-invertebrates (polychaetes, bivalves, amphipods, gastropods, echinoderms), and they in turn by higher order consumers (fish and large invertebrates such as crabs and squid). Decomposing material is also consumed directly by some species of fish and macro-invertebrates, particularly crustaceans.

In local seagrass meadows the dominant grazers are gastropods and small crustaceans that demonstrate a clear preference for epiphytic and sand microalgae. Many of these grazers are favoured food items for fish, thus much of this algal primary production is transferred through higher trophic levels of the food web. Similarly, a high proportion of phytoplankton production (80%) is usually grazed at its source and enters the food web directly. In contrast, very little seagrass is directly grazed—most ends up as detritus, and most of this production is lost (through respiration as it passes through the microbial food chain) before it reaches higher order consumers (fish and crustaceans). It has been estimated that epiphytic algae may supply up to ten times more carbon to the food web than seagrass (Klumpp et al, 1989), nonetheless this algal carbon is only available to the food web because of the existence of the seagrasses. Detached seagrass material and algae from reefs can also contribute to detrital food webs in deeper waters and onshore wracks, and can include material imported from other regions. The importance of onshore wracks of detached macrophyte material as habitat and feeding areas for juvenile and adult fish has been acknowledged, and the deeper areas may be important for prawns and crabs.

The habitat changes in the study area due to dredging the medium-term resource will result in decreased species abundance and diversity in the 90 ha of seagrass meadow that is lost, but species diversity and abundance will eventually be higher in the 51 ha of shallow unvegetated habitat when it becomes deeper habitat (and is recolonised). Similarly the 2% loss in seagrass production within the study area due to dredging the medium-term resource may be offset by increased phytoplankton production and increased detritus accumulation in the deeper areas. However as with nutrient cycling, the scale of these changes is minor and unlikely to be measurable within the context of the ecological functioning of the study area: natural between-year variations in seagrass and phytoplankton primary production can be an order of magnitude higher than the changes discussed above, and the changes in seagrass cover in the study area since 1972 (Section 5.3.2) are also of greater magnitude.

5.3.4 Influence on Commercial and Recreational Fisheries

There are commercial fisheries data for the region that extends from Gage Roads in the north, east to a north-south line aligned on the Stragglers, and south to include all of Cockburn Sound. Bait fish (for the rock lobster industry and for line fishermen) are the main target species, and to a far lesser extent fresh table fish (especially crabs and squid) for the Perth market (fresh table fish usually come from regions further offshore). Information available on commercial fisheries in the area applies to the entire Gage Roads to Cockburn Sound region; consequently it is not possible to separately assess commercial fisheries catches from Owen Anchorage. Similarly available recreational fisheries data identify the catches of boats at the site where they were launched, but do not identify where the fishing actually took place (and boats launched from Cockburn Sound or Owen Anchorage may fish many miles offshore or at Rottnest Island). Anecdotal information is that snapper are fished from the deeper unvegetated areas, whiting from the sand-veneered limestone pavement near Woodman's Point, and octopus and squid from the seagrass meadows.

Information on the fisheries species associated with seagrass meadows along the Western Australian coastline is limited to the extent that reliable fisheries estimates for the study area cannot be made. Recent investigations using seine netting in shallow sand areas and seagrass meadows in Cockburn Sound have shown that significantly greater species richness of fish can occur in areas of patchy seagrass when compared with dense stands (unpublished data, Edith Cowan University). In contrast, a recent study of the larval fish assemblages in seagrass meadows in Cockburn Sound did not discern any effect of seagrass cover (Jonkers, 1993).

Fish may utilise seagrass meadows as feeding grounds and/or shelter (particularly the juveniles). Fish in seagrass meadows can be classified as permanent residents, temporary residents (species whose juveniles use the meadows as nurseries) or transients, with the majority of species in the first two categories. On the basis of the limited local information, it appears that a large proportion of the fish inhabiting seagrass meadows are juveniles. Surprisingly few are, however, commercially important species. The only data available for local waters (Cockburn Sound) indicate that of the sixteen most abundant species (comprising 95% of the fish caught) in seagrass meadows only three species of leatherjacket could be regarded as commercially important fish (Dybdahl, 1979). Squid, however, are usually fished from areas with seagrass.

The adults of many species of commercially important fish have ranges of hundreds or even thousands of kilometres, and seagrasses are just one of several feeding habitats they use. Loss of seagrass may not affect the fisheries unless a large proportion of the species live and spawn within seagrass meadows in the study area. This is not the case for any commercially important species of fish found in the study area, but may apply to some species of squid which both spawn and live within seagrass meadows. Conversely, the creation of additional areas of deeper, unvegetated habitat by dredging may favour other species of fish (snapper, crabs).

Given the above factors, it is difficult to predict whether dredging of the medium-term resource will be deleterious or even beneficial to the fisheries. There will be some loss of food items favoured by fish such as the molluscs and small crustaceans that are abundant in seagrass meadows, but there may be increased plankton production (for plankton feeders such as pilchards), and communities of invertebrate fauna (ie. potential prey for fish) will eventually establish on the seabed of the dredged areas. Due to the proportionately small changes in area of habitat due to dredging the medium-term resource, measurable impacts are unlikely, particularly when viewed within the range of territory that most commercially important species have.

5.3.5 Effects of Turbidity

The amount of light reaching the seabed is considerably influenced by water depth and turbidity, and light is considered to be the main factor affecting seagrass growth and distribution. Seagrasses at the depth limit of their range are particularly sensitive to decreases in light supply, but due to the logarithmic nature of the decline in light supply with increasing depth, a change in turbidity that will result in loss of or severe declines in the productivity of the deeper fringes of a seagrass meadows (12-15 metres depth for the study area) will only cause small changes in the growth rates of seagrasses in the middle depth range, and will have little effect if any on seagrasses in the shallower depths (5 metres or less for the study area).

In Section 5.2 the effects of dredging operations and any subsequent modification of the wave climate on water turbidity in the study area were discussed. Previous studies (LeProvost, Semeniuk and Chalmer, 1990; Steedman Ltd, 1987) have indicated that increases in turbidity associated with dredging in the study area are patchy, temporary and intermittent; and that although light levels reaching seagrasses adjacent to the dredged area are at times below their minimum requirements, this reduction is of insufficient duration to cause their decline. Insofar as changes to wave climate are concerned, wave climate modelling has indicated dredging the medium-term resource will only result in a very small proportion of the study area experiencing slight increases in wave height, and these changes are unlikely to affect the overall turbidity of waters in the study area. Furthermore, any effects would be largely in winter, when seagrasses at the deeper fringe of meadows (which are most at risk to decreased light supply) are receiving insufficient light to actively grow anyway: current research suggests that their survival depends on food reserves laid down during summer and autumn. It is concluded that the survival and growth of seagrasses in the study area will not be significantly affected by changes in turbidity associated with dredging the medium-term resource.

5.4 SOCIAL EFFECTS

As described in Section 5.3.3, the environmental values for the study area have been derived based on national (ANZECC, 1992) guidelines, and include:

- ecosystem protection, which includes:
  - maintenance of ecological function; and,
  - maintenance of biodiversity;
- recreation (including commercial activities related to recreation);
- aesthetics;
- education; and,
- commercial activities, which include:
  - mineral recovery;
  - fisheries; and,
  - shipping.

The effect of dredging the medium-term resource on each of these is assessed below.

5.4.1 Effects on Ecosystem Protection

National guidelines (ANZECC, 1992) recommend six biological factors to assess ecosystem protection, four of which are applicable to this CER:

- species richness of the predominant macrophyte, periphytic, phytoplanktonic, benthic and planktonic invertebrate or vertebrate assemblages;
- species composition;
- net primary production; and,
- ecosystem function (measured as the relative importance of the detrital and grazing food chains, and production to respiration ratios).

The remaining recommended factors of nutrient and toxicant concentrations in the water column were not used, since Cockburn's operations do not affect these features nor are they an issue in the area being dredged.

Species richness and species composition of the dredged areas will alter from those of seagrass meadows and shallow unvegetated habitats to those of a deeper, unvegetated habitat, but the areas involved are proportionately small. Net primary production will change little, and the loss of seagrass meadow production will be offset to some extent by increased phytoplankton production due to the deeper water column (see Section 5.3.3).

The relative importance of detrital and grazing food chains is not appropriate for use in this assessment. Open water primary production (phytoplankton) is largely utilised via grazing food chains; however, as discussed in Section 5.3.3.3, within seagrass meadows it is the grazing of benthic and epiphytic algae that is the main pathway of carbon to higher trophic levels, rather than detrital pathways. Therefore the relative importance of carbon produced within seagrass meadows compared with carbon produced within unvegetated areas was used a basis for comparison. Calculations indicate that carbon produced within seagrass meadows contributes 47% of total primary production in the study area, and unvegetated areas contribute 53% (the contribution of reefs is minor), but because of the proportionately small areas of seagrass involved, the changes associated with dredging of the medium-term dredging resource (less than 1%) are considerably less than natural year to year variability (see Section 5.3.3.3).

In conclusion, dredging of the medium-term dredging resource is likely to have little impact on ecosystem protection.

5.4.2 Effect on Other Beneficial Uses

Recreation

As discussed in Section 4.4, recreational use of the study area is centred largely around the Woodman Point reserve, and to a lesser extent Coogee Beach. Recreational use of these areas is shore-oriented and includes swimming, picnicking, sunbathing, beach and jetty fishing, and windsurfing, although yachting and boat fishing are also popular. No quantitative data are available, but within the study area diving from boats tends to focus more on reefs than seagrass meadows or bare sand habitats. Fishing tends to be concentrated in areas where sand or deeper areas are adjacent to seagrass meadows, although squid are fished from seagrass meadows, and the sand-veneered limestone pavement in the southeast of the study area (see Figure 4.3) is favoured for whiting. Commercial boat tours operating from Fremantle rely more on the scenic value of the reefs and islands (particularly the sea lions on Carnac Island) than on seagrass meadows or bare sand. The recreational use of the study area is therefore likely to be little affected by the loss of seagrass meadows due to dredging of the medium-term resource.

Aesthetics

The aesthetic value of the study area landscape resides in the scenic value of the coastline and islands, and the clarity of the water. Reefs are the favoured underwater habitat for scuba and snorkel divers; very few people dive on seagrass meadows for aesthetic reasons. The aesthetic value of the study area is therefore unlikely to be changed by dredging of the medium-term resource.

Education

Woodman Point reserve and Coogee Beach are used by schools for recreational outings; otherwise the study area is little used for educational purposes (sites further south such as Cape Peron and Penguin Island tend to be favoured for ecological instruction). Cockburn Sound and Parmelia Bank have been the subject of much research due to environmental degradation (Department of Conservation and Environment, 1979; Silberstein 1980), but within most of the study area little research has been carried out. The resource studies, ecological studies, and studies of coastal physical processes that have been initiated by Cockburn represent a major increase in research activity in the study area, and include two 'world-firsts' that have major export potential:

- mechanical transplantation of seagrasses; and,
- large scale beneficiation.

Commercial Activities

Mineral recovery

Shellsand dredged by Cockburn is used to produce the lime needed by Western Australia's mineral processing industries, particularly alumina, gold refining and mineral sands (which combined are worth $6 billion of mineral production a year). Since Cockburn produces about 90% of the State's supply of lime, the shellsand resource has considerable economic importance for Western Australia. Cockburn also employs over 300 people mostly at its South Coogee plant, and spends about $60 million a year on local goods and services. Obvious major benefits of dredging the medium-term resource are the continued employment of the Cockburn workforce, the support to local goods and services, and the contribution to the State economy by the continued supply of a strategically important mineral.

Fishing

As discussed in Section 5.3.4, the importance of commercial fishing in the study area is difficult to gauge, since the only available data include the region from Cockburn Sound to Gage Roads. The effect of seagrass loss (through dredging) on the fisheries is also difficult to predict because the only data available for local waters (Cockburn Sound) indicate that few of the fish found in seagrass meadows can be regarded as commercially important. In addition, the mobility of most commercially important species of fish means that adults harvested in the area may neither have grown there nor be using it as other than one of many feeding grounds. Resident populations of species such as some types of squid may be affected by seagrass loss, but the creation of additional areas of deeper, unvegetated habitat may favour other fish.

Dredging of the medium-term resource will cause little change to the relative proportions of habitat type in the study area, and any changes to the commercial and recreational fisheries are unlikely to be measurable. On the basis of available information, it is not possible to state whether the changes in habitat will be deleterious or beneficial.

Shipping

Cockburn Sound is the outer harbour of the Port of Fremantle, and the navigation channel dredged through Parmelia and Success Banks is the only means of access to Cockburn Sound for larger cargo and naval vessels. The channel is under the jurisdiction of the Fremantle Port Authority (FPA), and requires regular maintenance dredging. There are also a number of small boat harbours south of Fremantle. Increases in recreational boat traffic can be expected with population increases, and commercial traffic will increase as the FPA implements its long-term plan to gradually (over the next twenty years) move the Port of Fremantle into Kwinana.

Waves reach the FPA channel before they reach the proposed dredged area, and computer modelling indicates that the change in bathymetry due to shellsand dredging of Success Bank will not affect navigation in the channel. Navigation and breakwater stability at the small boat harbours south of Fremantle is also expected to be little affected. This subject is discussed more fully in Section 5.2.

5.5 SUMMARY OF THE EFFECTS OF THE DREDGING OF THE PROPOSED MEDIUM-TERM RESOURCE

The effects of dredging of the proposed medium-term resource have been summarised and presented in Table 5.4, according to physical effects, biological effects and social effects.

Table 5.4 Summary of the effects of dredging the proposed medium-term resource.

A. PHYSICAL EFFECTS

ENVIRONMENTAL FACTOR	PRESENT STATUS	EFFECT OF PROPOSAL	POTENTIAL EFFECT OF PROPOSAL	PREDICTED OUTCOME
Change in wave climate	Area experiences reduced wave energy and modified wave direction as result of offshore bathymetry. Present wave climate is important to formation and maintenance of banks and beaches.	Will modify immediate bathymetry by creating a 11–14 metre deep basin over an area of 147 ha	May modify wave climate shoreward of dredging area and affect banktop and coastal stability and water turbidity of nearshore waters	Wave modelling shows that proposal will cause little change to wave height but some minor change in wave direction locally.
Change in wave climate on banktop stability	Bank approximately 7000 yrs old and still growing. It is gradually shallowing near shore and in places offshore as result of sediment accumulation. Most sediment coming in from offshore - seagrasses only produce small proportion of bank sediment (less than 10%)	As above. Since dredging area is located between 2 existing channels it will not affect remainder of Success Bank. Some minor loss of sediment supply from seagrasses.	As above	Wave modelling shows no significant change likely to occur to present banktop wave climate. Hence banktop stability unlikely to be adversely affected.
Change in wave climate on coastal stability	Shoreline presently stable and accreting due to onshore feed of sand from eastern parts of both Success and Parmelia banks. Coastline stabilised by man-made structures	As above	As above	Wave modelling shows no significant change likely to occur to present wave climate at the shoreline. Hence coastal stability unlikely to be adversely affected.
Change in wave climate on water turbidity	Turbidity of area varies seasonally from very turbid in winter (as result of sediment suspension and Swan River discharge) to clear in late summer.	Intermittent increases in turbidity will occur locally in vicinity of barge loading and jetty head as has occurred since 1979.	May cause increased light attenuation leading to reduced seagrass growth and survival	Previous studies by Cockburn have shown that intermittent turbidity caused by operations unlikely to cause long term adverse ecological effects. Wave modelling shows that it is unlikely that the overall turbidity of the study area will increase significantly.

Table 5.4 Summary of the effects of dredging the proposed medium-term resource.

B. BIOLOGICAL EFFECTS

ENVIRONMENTAL FACTOR	PRESENT STATUS	EFFECT OF PROPOSAL	POTENTIAL EFFECT OF PROPOSAL	PREDICTED OUTCOME
Loss of seagrass habitats and associated ecological attributes	Some loss of seagrass has occurred on Parmelia Bank primarily as a result of water pollution, erosion and dredging. However substantial growth of seagrass has also occurred on Success Bank since 1972. There are also signs of natural recolonisation by seagrass of dredged slopes.	Loss of: • 44 ha of dense *Posidonia* and *Amphibolis* meadows • 46 ha of low density *Posidonia coriacea* meadow • 57 ha of sparsely vegetated bank tops Replacement by: • 147 ha of deeping largely unvegetated sediment	Loss of: • The physical attributes of seagrass meadows, generally believed to include sediment production, accumulation and stabilisation, and wave energy reduction by baffling. • Three dimensional habitat structure in seagrass meadows • Chemical attributes of seagrass beds related to *in situ* storage of carbon, nitrogen and phosphorus, and in wrack exported seasonally from area • Biological attributes of flora and fauna diversity and abundance and primary production	No significant adverse effect because investigations shows that seagrasses are not a major source of sediment to Success Bank, seagrasses in study area do not play a significant role in wave energy reduction, and the dredging area is isolated from the remainder of Success Bank by two dredged channels. Loss will occur and will be replaced by the three dimensional habitat of wrack in deeper waters. Loss will occur, and will be replaced to an as yet unknown extent by accumulation of wrack in newly created deeper areas. Loss will occur, but will be replaced by an as yet unknown extent by benthos recolonising the dredged area and by more phytoplankton inhabiting the increased depth of water

Table 5.4 Summary of the effects of dredging the proposed medium-term resource.

B. BIOLOGICAL EFFECTS (cont)

ENVIRONMENTAL FACTOR	PRESENT STATUS	EFFECT OF PROPOSAL	POTENTIAL EFFECT OF PROPOSAL	PREDICTED OUTCOME
Maintenance of ecological functions	Ecological function of seagrasses in the study area is not fully known at present	Not Known	Loss of ecological function	A small proportion of seagrasses in the study area will be lost and amount of seagrass cover on Success Bank is presently increasing. The dredged areas will also be recolonised by benthos and will provide replacement ecological function. It is considered unlikely that the overall ecosystem of the study area will be adversely or measurably affected .
Maintenance of biodiversity	Seagrass species involved are widely distributed between Shark Bay and Cape Leeuwin on WA Coast	Will remove seagrass meadows and associated biota from medium term dredging area.	Loss of regional biodiversity.	Given the widespread availability of seagrass habitat in region and the fact that most species recruit by spores, larvae and propagules, it is considered most unlikely that biodiversity will be adversely affected.
Maintenance of commercial and recreational fisheries	Medium-term dredging area is not a popular fishing area	Not Known	May be both beneficial to some table fish species (eg. snapper) and disadvantageous to others (eg. squid)	Not possible to reliably predict at present. However fishing activity over seagrass meadows is low and only a relatively small area of seagrass is being removed. Furthermore, most fisheries species have large territorial distribution ranges. It is noted that there is no evidence that fisheries have suffered as the result of massive seagrass loss in Cockburn Sound. Therefore, it is considered most unlikely that significant adverse impacts will occur.

Table 5.4 Summary of the effects of dredging the proposed medium-term resource.

C. SOCIAL EFFECTS

ENVIRONMENTAL FACTOR	PRESENT STATUS	EFFECT OF PROPOSAL	POTENTIAL EFFECT OF PROPOSAL	PREDICTED OUTCOME
Maintenance of shipping and navigation	Study area occurs within Port limits. FPA Shipping Channel is an important navigation route. Small boat harbours occur south of Fremantle	Minor modifications to wave climate in deeper waters of Owen Anchorage.	Interference in navigability of area	Wave modelling shows that navigability of area will not be adversely affected.
Maintenance of recreation activities	Most recreation activities in area are shore based or involve yachting.	No effect on recreational activities	None	No adverse effects
Maintenance of aesthetics	Aesthetics relate to coastal island landscape	No affect on aesthetics	None	No adverse effects
Maintenance of education values	Area is little used for education purposes	No affect on education values	Substantial increase in knowledge on seagrass ecology	No adverse affect,and substantial benefit to education and national estate
Maintenance of employment and Cockburn operation	Cockburn employs some 340 persons directly and some 600 others indirectly	Will enable Cockburn to maintain operations	Will enable Cockburn to investigate importance of mitigation techniques for seagrass loss over next five years	Major economic benefit to State whilst investigating the solution to the issue of long-term access with high possibility of acceptable outcome
Maintenance of WA Economy	Cockburn lime is essential product for WA mineral processing industries valued at $6 billion	Will enable Cockburn to provide essential chemical for mineral processing	Will enable Cockburn to investigate importance of mitigation techniques for seagrass loss over next five years	Major economic benefit to State whilst investigating the solution to the issue of long-term access with high possibility of acceptable outcome. May also result in two world firsts: • Commercial beneficiation • Mechanised seagrass transplantation

6. ENVIRONMENTAL MANAGEMENT

6.1 OBJECTIVE

Environmental management includes the implementation of measures that minimise environmental effects, provide mitigation where needed, and where possible, enhance the natural environment. These procedures are consistent with the principles of Ecologically Sustainable Development (ESD). For this proposed medium-term dredging programme, the overall goal of the environmental management plan is to manage the dredging programme with the objective to ensure no net loss of ecological function of Owen Anchorage and its surrounds.

The proposed medium-term dredging programme will be undertaken according to a dredging plan that prioritises dredging in areas of lowest seagrass cover to allow the greatest time for the development of seagrass transplantation techniques. Concurrently, a series of detailed scientific studies will be undertaken; these form an Environmental Management Programme (EMP). The EMP studies have already been evaluated by the Minister and found to be "environmentally acceptable".

The results obtained from these EMP studies will be used to develop Cockburn's strategy for acquisition of long-term resource.

6.2 COCKBURN'S ENVIRONMENTAL POLICY

In recognition of its responsibilities and in compliance with the Agreement Amendment Act and current DMP approvals, Cockburn has developed its own Environmental Policy.

Cockburn's Environmental Policy, while recognising that the Company's operations by their nature will have an impact on the environment, is to establish and achieve practicable environmental performance standards that are acceptable to the community as a whole. The Company intends that this Policy will be implemented in a number of ways including:

- *Keeping abreast of current developments in environmental management.*
- *Regularly reviewing and auditing the Company's environmental standards and performance, with the aim of continual improvement.*
- *Ensuring the adverse impacts are controlled and minimised and that, where possible, beneficial impacts are planned and maximised.*
- *Cooperating closely with the relevant State and Local authorities concerned with environmental matters.*
- *Complying with all Government regulations relating to the environment.*
- *Maintaining a programme of two-way communication with neighbours who may be affected by the Company's operations.*
- *Considering environmental management factors when planning any changes or developments in the Company's physical operations.*
- *Making efficient, effective use of non-renewable resources.*

- *Maintaining a continuing programme of tree planting, landscaping and quarry reinstatement.*
- *Where practicable, using or recycling waste materials, or making them available to others for use or recycling.*
- *Assisting or sponsoring selected environmental research projects relevant to the Company's operations and products.*

6.3 IMPLEMENTATION OF AN ENVIRONMENTAL MANAGEMENT PLAN

The environmental management plan to be implemented by Cockburn will recognise the principle of adaptive environmental management, which is aimed at minimising environmental risks and impacts.

Cockburn's dredging plan for the proposed medium-term places priority on dredging of areas of least seagrass cover first. The dredging plan is reviewed each quarter and revised each year. Along with market demand, the development of techniques for seagrass transplantation in particular will be central to the amendment of the dredging plan during the proposed medium-term dredging. Inherent in Cockburn's approach is the resolution of critical issues as soon as practical and findings of studies will be considered as soon as they become available.

During the proposed medium-term dredging, Cockburn will develop a strategy and a proposal for long-term access to suitable resources. The development of this proposal will be completed at least 15 months prior to the depletion of the medium-term resource. The contents of the proposal will depend heavily on information to be obtained from the existing EMP suite of scientific studies and technical investigations. These are described in further detail in Chapter 7. The procedure and timetable for developing the long-term dredging proposal is provided at the end of Chapter 7, in Section 7.6.

7. ENVIRONMENTAL MANAGEMENT PROGRAMME

7.1 INTRODUCTION

The scientific studies in Cockburn's EMP have been developed to provide the required understanding of the physical, chemical and biological processes in the study area, that is needed for a scientifically rigorous assessment of the effects of shellsand dredging as well as to enable practical management procedures to be implemented. The scientific studies have been developed using a conceptual understanding of what are believed to be the critical features and processes occurring in seagrass meadows, and which should be present in a meadow established by transplantation.

This chapter is a general description of the scientific studies of the EMP, including the technical investigations undertaken on resources. These studies are presented in the broad categories: Physical Processes (C series), Biological Studies (S series) and Resources (R series). Table 7.1 shows the projects and their study leaders.

Table 7.1 Studies currently being undertaken for Cockburn and associated project leaders.

PROJECT TITLE	PRINCIPAL PARTICIPANTS
A1: Programme Management	Dr D A Lord (DAL)
C1: Wave Climate Study	M Rogers (MRA), Prof I Young (ADFA)
C2: Shoreline Monitoring	M Rogers (MRA)
C3: Banks Sedimentology	Dr B Hegge (DAL)
S1: Seagrass Ecological Significance	Prof D Walker (UWA); Dr F Wells (WAM); Dr P Lavery (ECU); Dr P Morrison (Kinhill); D Annandale (MU); Dr K Hillman (Kinhill)
S2: Seagrass Rehabilitation	Dr E Paling (MU); Dr D Gordon (LDM); J Phillips (Ocean Industries); R Dyhrberg (Diver I/Diver II)
S3: Habitat Mapping	I LeProvost, P Collins (LDM); A Wyllie (NGIS)
S4: Artificial Reefs	M Rogers (MRA); F Wells (WAM)
S5: Slopes Monitoring	Dr D Gordon, P Collins (LDM)
R1: Beneficiation	CSIRO (Minerals); Cockburn Cement
R2: Alternative Resources	DME (WA); DRD (WA).
R3: Dredging Plan	BHP; Cockburn Cement
R4: Innovative Dredging	MTI (Holland); Aquamarine; Ocean Industries

ADFA = Australian Defence Force Academy
DAL = D A Lord & Associates
DME = Department of Minerals and Energy, WA
DRD = Department of Resources and Development, WA
ECU = Edith Cowan University
LDM = LeProvost Dames & Moore
MRA = M Rogers & Associates
MU = Murdoch University
NGIS = National Geographic Information Systems
UWA = University of Western Australia
WAM = Western Australian Museum

7.2 PHYSICAL PROCESSES

7.2.1 Background

Success and Parmelia Banks were formed in fairly recent geological times (within last 7000 years), as a result of a rise in sea levels followed by the transport of sand towards the shore. On its northern side, Success Bank rises from the southern edge of the Gage Roads Basin at a depth of approximately 15 metres and approaches mean sea level where it abuts the mainland shore. In the vicinity of the FPA Channel, the bank rises to within 4 to 5 metres of the surface. To the west, the bank merges with the shallow north-south trending banks located in the lee of the reefs and islands of the Garden Island Ridge. To the south, the bank falls away into Owen Anchorage (Figure 1.2). Parmelia Bank slopes more steeply from the floor of Owen Anchorage, shoaling to depths of 2 to 3 metres in the vicinity of the FPA Channel before sloping down into Cockburn Sound. These two banks are comprised mainly of calcium carbonate material (80–95%) with the remainder being predominantly silica.

Five Fathom Bank and the string of islands and reefs between Garden Island and Rottnest Island cause significant changes to incident ocean waves as they travel from the offshore regions, through to the Success and Parmelia Banks, and then to the coastline, by reducing their energy, as well as modifying the direction in which the waves travel. Measurements taken in 1991 indicate that a 2 metres offshore wave would be reduced to about 0.8 metres by the time it reaches the Mewstones to the west of the FPA Channel, and about 0.6 metres in height by the time it reaches the dredged area on Success Bank. This highlights the importance of the reefs in reducing wave energy and causing the calmer conditions in Owen Anchorage. It also indicates that the seagrass meadows are not the main cause of the calmer conditions in Owen Anchorage.

Altering the shape of the banks by dredging will influence the wave climate of the area, with possible effects on the following being of greatest concern:

- navigation in the FPA Channel;
- navigation and breakwater stability at the small boat harbours at Fremantle;
- stability of the beaches between Fremantle and Woodman Point; and,
- stability of the bank to the east of the dredged area.

Previous assessments of the influences of dredging (Cockburn Cement Limited, 1994) have indicated that no significant effects on navigation in the FPA Channel would be experienced because the incoming waves pass over the FPA Channel before reaching the dredged areas. In addition, preliminary numerical modelling undertaken by Lawson & Treloar (1987) indicated that dredging of an area comparable to that for the medium-term resource (the area between the two shipping channels) would have a negligible impact on navigation or breakwater stability in the small boat harbours south of Fremantle. Similarly, the 1987 study of Lawson & Treloar indicated that large-scale dredging on Success Bank (an area far larger than the medium-term resource) could cause slight changes in the alignments of the various beaches, with rotations of up to 2 degrees indicated. The report concluded that the indicated changes to the shoreline were likely to cause little, if any, problems.

In the EMP detailed studies on the effect of dredging the medium-term resource on wave climate and its implications (Project C1) have been undertaken as part of a direct Ministerial requirement. Two additional studies have also been undertaken to improve understanding of physical processes in the study area:

- Project C2 (Shoreline Monitoring) - an investigation of the stability of the shoreline from Woodman Point to Fremantle, to identify the dominant coastal processes that have shaped the beaches of the coastline in the last half century; and,
- Project C3 (Bank Sedimentology) - an investigation of the structure and developmental history of Success and Parmelia Banks, including the degree to which calcium carbonate producing organisms in seagrass meadows contribute to the Bank sediments.

These three projects are described in more detail below.

7.2.2 Project C1: Wave Climate Studies

The objective of the wave climate study is to determine the implications of dredging both the short and medium-term resource areas on the wave climate of the surrounding waters and adjacent coastline. To achieve this objective, an intensive wave measurement and modelling study was undertaken.

The measurement of offshore waves and winds commenced in late winter 1994 and continued for one full year. Nearshore wave measurements were completed in August and September 1994 and during the summer of 1995. The study required collection of appropriate wave and wind data, and then establishing and calibrating a sophisticated computer-based numerical model of the present wave climate on Success Bank using existing bathymetry. The model has been calibrated and modification of the model bathymetry was made to simulate the effects of dredging. The model was then re-run to examine the associated changes on wave climate of the study area. A preliminary interpretation of the results of the model was presented in Section 5.2.2, and further testing and interpretation are continuing. Modelling of the influences of the longer-term dredging programme that will be developed will be undertaken as required, and will be completed by the end of 1999.

7.2.3 Project C2: Shoreline Monitoring

Sandy shores, such as the eastern side of Owen Anchorage, are typically dynamic, undergoing cycles of erosion under storm conditions and accretion during periods of calm. In addition, sediment transport occurs along the shore. The extent to which these processes occur depends on the prevailing wave conditions, in particular the height and steepness of waves when they break, as well as the direction of approach of the wave to the shore. Clearly, any alteration of the nearshore wave conditions may influence sediment transport patterns close to shore.

The eastern shoreline of Owen Anchorage is already substantially modified by the construction of piers, groynes and boat harbours, all of which influence the transport of sediment along the shore.

As part of its Environmental Management Programme, Cockburn commissioned a detailed study (M P Rogers & Associates, 1995b) of the stability of the Owen Anchorage shoreline, extending south from Fremantle and including all of Woodman Point. The study identified the dominant coastal processes that have shaped the beaches along this coastline over the last half century. Data used for the study included:

- Shoreline Movement Plans: 1942, 1976, 1987, and 1994 vegetation lines along the shoreline were used.
- Beach Profile Surveys: Cockburn has regularly conducted beach profile surveys along 15 transects on the Owen Anchorage shoreline since 1976.
- Aerial Photographs: Cockburn has regularly taken aerial photographs of Woodman's Point since 1973, and extended the coverage to include Catherine Point in 1989.

The report showed that the Owen Anchorage shoreline is generally quite stable and is fed by significant quantities of sand from Success and Parmelia Banks. It is estimated that about 40,000 cubic metres per year is fed onshore from Success Bank to Catherine Point and 20,000 cubic metres per year from Parmelia Bank to Woodman Point. Once the sand reaches the shore it is moved alongshore by wave induced longshore drift. The amount and direction of drift varies from year to year and there is a 10° rotation of the beach from summer to winter every year.

The groyne at Catherine Point and the breakwater at Power Station have together restricted the movement of sand to Coogee Beach. To the south, the WAPET Groyne has markedly altered the sediment transport dynamics at Woodman Point, and limited the natural feed of sand from Parmelia Bank to Quarantine Beach.

Cockburn's dredging of shellsand on Success Bank does not appear to have had any significant effect on the stability of the Owen Anchorage shoreline.

Profiles of the shoreline of Owen Anchorage will continue to be measured using aerial photography and ground surveys twice each year (late summer, late winter). In addition, each two years, a detailed bathymetric survey will be undertaken out into Owen Anchorage beyond the region of littoral transport.

7.2.4 Project C3: Sedimentology of Success & Parmelia Banks

Cockburn has conducted numerous exploratory drilling programmes in the Owen Anchorage area over the last 30 years to assay the carbonate grade of the sediments. More recently, information on the geotechnical and sediment properties of the deposit has been obtained; however, detailed information on the grain size and chemical composition of the Banks has not previously been presented. Two previous studies have examined the Holocene sedimentology of the Banks. The major findings of these studies were conflicting and this study undertook a detailed examination of the sedimentology of Success and Parmelia Banks in order to describe the:

- composition and structure of the Banks;
- origin and formation of the Banks;
- sediment production within the seagrass communities; and,
- role of the seagrass meadows in sediment trapping.

The study is largely complete, and will use information on carbonate production rates by organisms in the seagrass being gathered by the WA Museum until 1999 to modify and confirm carbonate production rates.

7.3 BIOLOGICAL STUDIES

7.3.1 Background

Seagrass assemblages are a marine habitat found in many tropical and temperate areas of the world's oceans. Approximately 50 species are known worldwide, over a third of which occur in Western Australia. Seagrasses are ecologically distinct from other subtidal plant habitats such as algae or seaweeds in that they are angiosperms or flowering plants. As such, seagrasses have roots and rhizomes which penetrate the substrate, in contrast to algae which live only on the surface. Seagrass meadows have both an intrinsic biological value and a value to people.

Seagrass beds in the proposed dredging area of Success Bank are one of the major concerns in evaluating the effects of the proposed dredging, and virtually all of the biological work proposed in the EMP deals with establishing the extent of seagrass meadows, their ecological significance and possible means to mitigate their loss.

Project S1, the Ecological Significance of Seagrasses, is designed to fulfil a direct Ministerial requirement to 'determine the ecological significance of seagrasses'. Ecological significance has been broadly defined to include both ecological and cultural concerns, and the requirements of the study also entail assessing the ecological significance of other habitats within the designated study area, including unvegetated sand and reefs. Project S2, 'Seagrass Rehabilitation', is also designed to fulfil a ministerial requirement to undertake studies into seagrass rehabilitation that arose, in turn, out of Cockburn's offer to do so in the 1994 CER. Mapping of seagrass (Project S3) has provided crucial information on the distribution, relative abundance and dynamics of seagrasses in the study area. Project S4 (Artificial Reefs) involves another internationally accepted approach to mitigation being investigated by Cockburn: artificial reefs are already present elsewhere in Western Australia, and although they are popular with local recreational fishermen, little is known about their biological productivity. Project S5 (Slopes Monitoring) has examined the stability of dredged slopes, and associated changes in seagrass cover.

The biological studies Cockburn has commissioned as part of its EMP will constitute one of the largest investigations of the functioning of seagrass ecosystems ever to have been undertaken in Australia, and the information produced will be of worldwide scientific interest. In recognition of this, Cockburn has formally committed itself in the EMP document to encourage scientists involved in the project to publish their results in the scientific literature as they consider appropriate. A paper on the dredged slopes monitoring programme has already been presented to an international seagrass workshop and published in the workshop proceedings (Gordon et al., 1996).

The five biological studies are described in more detail below.

7.3.2 Project S1: Ecological Significance of Seagrasses

7.3.2.1 Introduction and work to date

The specific objectives of Project S1 have been defined as follows:

- define ecological significance and describe the approaches to be used in its determination;
- assess the ecological significance of seagrasses and other habitats in the Success Bank and Owen Anchorage region;
- formulate an estimate of the potential loss of ecological significance through dredging; and,
- formulate an estimate of the amount of ecological function that can be replaced by mitigation techniques (such as seagrass re-vegetation, or the deployment of artificial reefs).

As discussed in Chapter 5 a definition of ecological significance has already been developed, and has been formally approved by the DEP. Assessment of the influence of dredging the medium-term resource will be carried out within the framework of the definition of ecological significance.

Preliminary assessment has indicated that there will be little loss of ecological significance in the study area caused by dredging the medium-term resource. This assessment is considered realistic, but it had to be made using estimates rather than detailed, site-specific data. The study area is characterised by a mosaic of bare sand and patchy seagrass assemblages containing a mixture of seagrass species, and is quite unlike the extensive monospecific meadows on which research in Western Australia has focused almost exclusively.

7.3.2.2 Proposed research programme

In terms of attributes listed in the definition of ecological significance, the synthesis of information to date has indicated that seagrasses in the study area have little effect on sediment accumulation, wave baffling and other hydrodynamic processes, and light climate. They are, however, important in terms of provision of complex habitat, nutrient cycling, and plant and animal abundance, diversity and production. The importance of seagrasses to the fisheries is less clear. Effort will therefore concentrate on measuring the attributes of known importance, and obtaining information on fisheries. This information will be used to assess the role of the various habitats in the ecological functioning of the study area, and to assess the effect of dredging.

Two further tasks will also be carried out in Project S1; a survey of recreational use in the study area, and an investigation of a variety of assessment techniques that can be used for measuring changes in ecological function, particularly those known as multi-criteria analyses, which have the ability to incorporate both scientific data and public opinions and values.

A brief description of the main tasks involved in Project S1 is given below.

7.3.2.3 Degree of habitat complexity

It will be important to determine whether habitat complexity influences the type and abundance of species that utilise the various habitats in the study area. This information is not only required to assess the effects of dredging, but may also influence both the dredging programme and planting strategies for Project S2 (Seagrass Rehabilitation). The three dimensional structural complexity of seagrass meadow and reef algal communities will be assessed in terms of various plant parameters such as biomass and leaf area, and (for seagrass meadows) patch characteristics.

7.3.2.4 Nutrient cycling

The relative importance of the various habitats to nutrient cycling and calcium carbonate production in the study area will be assessed. Nutrient cycling will be simply measured as the nutrient turnover of the various components of the flora (phytoplankton, benthic microalgae, reef algae, seagrasses and epiphytic algae). In addition, primary production and nutrient content of the various components of the flora and the calcium carbonate produced by epiphytic algae and invertebrate fauna will be determined.

7.3.2.5 Plant and animal abundance, diversity and production

Measurements will be made of differences between habitats in the study area in terms of the abundance, diversity and production of the plants and animals, with these related to habitat complexity.

The sampling programme recognises three distinct regions on Success Bank; the western, central and eastern. Within these regions fragmented seagrass landscapes (where seagrass meadows occur as patches that overall cover less than 30% of the sand) and continuous seagrass landscape (where seagrass meadows cover more than 70% of the sand) have been defined, and within each landscape type the major seagrass habitats (ie. dominated by one or two species of seagrass) will be sampled. Shallow and deep unvegetated (sand) habitats will also be sampled for the fish and invertebrate biota.

The role of epiphytes will be examined for three reasons: firstly as part of the abundance and diversity of biota in the various seagrass habitats; secondly because some epiphytes contribute calcium carbonate to the sediments; and thirdly because epiphytes are believed to be the major food source for the small invertebrate grazers that in turn constitute a large part of the diets of many species of fish and crustaceans, including commercially important ones. The small invertebrate grazers are generally found in far greater numbers in seagrass meadows than in unvegetated areas, and it is logical to assume that this is due in large part to the abundant food supply (epiphytes) that is available. Epiphyte production may therefore be an important component of the food web in the study area. The species of epiphytes present, their nutrient and carbonate content, and their biomass and growth rates will be measured.

The importance of seagrasses as primary producers and as a habitat in the study area will be determined using both the above-ground leaves and the below-ground roots and rhizomes of the main meadow forming species in the study area; *Posidonia coriacea*, *Amphibolis griffithii* and *Heterozostera tasmanica*. Below-ground characteristics are seldom measured in most seagrass studies, but are important since seagrasses extend into new areas via rhizomes, and below-ground biomass may also influence the diversity of sediment fauna and the ability of a meadow to withstand disturbances such as storms. Seagrass growth rates will also be measured.

In addition, the 'patch dynamics', (ie. the dynamics of growth and loss of seagrasses within patches in areas with different scales of patchiness in seagrass cover) will be analysed. Meadows consisting of small patches of seagrass may have quite different characteristics to large, dense meadows. An understanding of patch dynamics has important implications for seagrass rehabilitation.

Benthic invertebrates will be examined as they are a major component of the abundance and diversity of biota in seagrass meadows and play a key role in transforming the plant production within seagrass meadows into animal tissue (and therefore food) available to fish and large invertebrates such as crabs, squid and octopus. Benthic invertebrate communities also establish in unvegetated areas, where food webs are based on accumulated detritus. Certain benthic invertebrates also produce calcium carbonate, and therefore contribute to the sediments.

7.3.2.6 Fisheries

As noted in Section 5.3.4, there is some information on commercial fisheries in the 'block' that stretches south from Gage Roads to include all of Cockburn Sound, and how these have changed over time. These data do not allow fisheries activity in Owen Anchorage to be separately addressed, since the returns of individual fishermen are considered confidential information. Similarly WA Fisheries does not maintain separate records on recreational fishing for Owen Anchorage: some records are maintained, but they only identify launch sites, not where the fishing took place. There is anecdotal information for the Owen Anchorage/Cockburn Sound area that indicates that seagrasses are little utilised for commercial or recreational fishing except for some squid fishing, and the lack of commercially or recreationally important species within seagrass meadows is generally confirmed by the scientific data available. Nonetheless seagrass meadows do contain large numbers of certain benthic invertebrates that are the favoured food items for many commercially or recreationally important species of fish.

The significance of seagrasses to the fisheries will depend on fish using the meadows as:

- a permanent habitat — where the fish spend their entire life cycle within the meadows;
- nurseries — providing shelter and food for juveniles; or
- a food source — where adult fish forage for the plants and/or animals that live within the meadows, but also utilise other habitats as well.

Sampling of fish communities will be undertaken in both seagrass meadows and unvegetated areas (in deep and shallow waters) using a commercial size beam trawl modified to limit damage to seagrass beds, with mouth dimensions of 4.5 by 1.5 metres. The net mesh size of about 2.5 cm will enable juveniles and adults to be captured, but not larval fish. The fish captured will be identified to species level, weighed and measured. Initial sampling design has been approved by WA Fisheries. Gut contents will be available for further analysis if required, and samples will also be kept for possible stable isotope analysis (both of these measurements are used to investigate food webs). Available fisheries data will also be analysed to discern historical changes and to determine the main commercial and recreational target species.

Information from this sampling programme will allow determination of:

- the species diversity, density and biomass of fish in seagrass meadows and unvegetated areas in the study area;
- the significance of the various areas and the total study area to commercial and recreational fisheries; and,
- the role played by seagrasses as a nursery to juvenile fish.

7.3.2.7 Survey of recreational use

The report of Beckwith and Associates (1995) on cultural use of the study area (see Section 4.4.1) was based on data collected from interviews with relevant Government agencies and selected private businesses: there were no data from direct surveys of public users of the study area. The lack of primary research on public use of the study area is considered a key gap in Project S1 data requirements, and a survey of recreational use in the study area is planned.

7.3.2.8 Assessment of Multi-Criteria Analysis (MCA) techniques and public consultation exercises

A variety of MCA techniques including the Goals Achievement Matrix (GAM) will be investigated for use in assessing the effect of shellsand dredging on the study area. In addition, MCA techniques are a means of assessing the effects of various development options, and development scenarios that can incorporate subjective as well as quantitative information.

All MCA techniques have the following components:

- a finite number of alternative plans or options for comparison;
- a set of criteria by which the alternatives are to be judged; and,
- a method for ranking the alternatives based on how well they satisfy the criteria that have been established.

Criteria may be quantitative, qualitative or a mixture of both. They can be selected by a panel of experts or by panels made up of community members. Criteria are usually also weighted since it is recognised that all comparison criteria are not necessarily equally valued by individuals. The weighting can also be done by either experts or community panels.

Since a key feature of MCA techniques is that they can include public input, a public consultation exercise is also envisaged, with community interest groups, members of the scientific community and other interested parties involved in the selection and weighting of criteria to be used in the analysis selected for final assessment.

7.3.2.9 Assessment of Ecological Significance

Assessment of the influence of dredging on the ecological significance of the study area will be carried out within the framework of the definition of ecological significance. Three approaches will be used: one based entirely on biological data, one based on beneficial uses impacts, and one involving an appropriate MCA.

Most of the attributes listed in the definition of ecological significance depend on biological characteristics that can be represented by measurable parameters. Suitable parameters to represent the ecological significance of the habitats will be chosen, and the data on these parameters will be processed using various mathematical techniques which are able to incorporate the natural variability of biological data. The definition of ecological significance proposed for Project S1 also covers cultural concerns, and assessment incorporating both cultural attributes and quantitative biological data will be accomplished by means of beneficial uses assessment (using the beneficial uses identified for the study area in Section 5.4), and the MCA technique chosen for Project S1.

7.3.3 Project S2: Seagrass Rehabilitation

7.3.3.1 Introduction and work to date

The basic goal of the seagrass rehabilitation project is to develop new seagrass meadows to replace those lost due to dredging. Two possible methods are available to achieve this; these are the use of seeds or shoots to plant new areas, or removal of existing seagrasses by transplanting them from areas to be dredged to localities outside the dredging plan. The large scale of the Cockburn project requires rehabilitation by mechanical means, not manual methods, to meet the performance criteria for the seagrass rehabilitation which were agreed to by the EPA and DEP.

These are:

- greater than 0.1 ha of successful transplantation with greater than 36 months survival; and,
- greater than 1 ha of successful transplantation with greater than 12 months survival,

15 months prior to the depletion of the medium-term dredging resource. Since the medium-term dredge area is scheduled to last at least until about the end of 2001 the aim of the seagrass rehabilitation programme is to meet the performance criteria by September 2000.

The approach is to establish a small area (greater than 0.1 ha) of new seagrass meadow as soon as practical and demonstrate that it can survive through seasonal and annual variations, particularly winter storms which might uproot the seagrass. As techniques are developed, the process will be scaled up to incorporating a full 1 ha or more which survives for a year.

In preparation for more detailed studies and the field programme, a number of reviews of the literature on seagrass rehabilitation were commissioned by Cockburn (Gordon, 1995; Paling, 1995a; Paling, 1995b; and, Paling and Gordon, 1995). In addition a report was commissioned on pilot experiments conducted in Western Australia by CSIRO on the potential for restoration of seagrass meadows (Kirkman, 1995). The reviews established that local seagrass meadows are dynamic, able to recover from disturbance, have considerable natural variation in their density and area over a large spatial scale, have the ability to colonise new sand areas, and may undergo dramatic changes in a relatively short time scale.

About 12,000 units of seagrass of different sizes have been transplanted in Western Australia to date. Species of the dominant meadow forming genera *Posidonia* and *Amphibolis* have been transplanted using a variety of techniques. The majority of transplants have failed for the following reasons (in order of importance): insufficient anchorage; sediment movement or smothering; and enhanced epiphyte growth (often water quality related). Grazer damage and disease have also contributed to the lack of success in transplants although they are less important. Success of the transplant unit is related to size; larger units show very good survival and growth. These results suggest the development of a large capacity mechanical unit to transplant seagrass is the technique with the best prospects of success and efficiency.

Sites have been selected on the eastern side of Success Bank for transplantation. Site selection criteria include: wave energy, sediment dynamics, sediment depth, water depth, and water clarity.

The preferred target species for mechanical transplanting are *Posidonia coriacea* and *Amphibolis griffithii*, the dominant species on Success Bank, and approximately 10 sites, each of about 0.5 ha, have been identified for possible use in transplantation.

Experimental transplant studies will be undertaken to test seagrass survival and growth under different combinations of substrate, depth, light, spacing of propagules and hydrological conditions as well as different sizes and types of propagules. Preferred target species are *Amphibolis griffithii* and possibly *Amphibolis antarctica*. Locations have been chosen that are shallow and flat, offer the best water quality and light clarity and are next to, or are known to support, seagrass beds. Initial trials will target, in order of priority: hydrologic conditions (determined from advice/models of sea floor energetics); species; and depth (5 to 12 metres). Monitoring of sediment horizons and movement will also be given close attention to determine the cause for non-survival of transplants as this will be very important in enhancing success.

7.3.3.2 Proposed rehabilitation program

As part of its work on seagrass rehabilitation, Cockburn commissioned the Perth firm Ocean Industries to design and develop a prototype harvester for transplanting seagrass. ECOSUB 1 (Plate 3) is a 4.8 metres long pilot harvester which has a dry weight of 2 tonnes. The submarine is operated by a diver but uses hydraulic power and high pressure water provided by a support vessel moored near the vehicle. A sod of seagrass with a surface area of 75 x 50 cm and a depth of up to 50 cm is cut from the bottom and placed in a storage hopper. Up to 6 sods, with a total weight of one tonne, can be stored at one time on the harvester. The sods are then transported to the planting site and transplanted sediment. The harvester has four wide tyres to minimise damage to plants. The sods can be moved up to 2 km underwater using the harvester.

The two aspects of the rehabilitation project, manual and mechanical transplantation, will run simultaneously, but greater emphasis will be given to the latter, as it will return area at a greater rate than manual techniques. The major function of the manual trials is to provide the flexibility to test different areas and conditions (eg. hydrologic regimes, depth and species) firstly to gain information on particular species' capabilities and secondly to assist in the selection of the best sites for mechanical transplants: choosing the appropriate sites for transplantation is a critical ingredient of success. The optimal sites have been selected and are now being used for the mechanical trials.

7.3.4 Project S3: Seagrass Mapping

A rectified map detailing the distribution of habitats within the study area, including parts of Cockburn Sound, and the distribution and relative abundance of seagrass species within each habitat has been produced (LeProvost, Dames and Moore, 1996a).

The habitat map base was prepared from both high resolution colour aerial photography and digital video imagery of the study area, and was presented on a rectified digital base map for storage on GIS. Subsequently a brief pilot study was undertaken to confirm the interval at which the images were ground-truthed. A total of 373 dives were undertaken in the study area to determine the species composition of seagrasses at individual sites. The results of the mapping work were presented earlier in this CER (Chapters 4 & 5). Briefly, the beds are a rich mosaic of different seagrass assemblages and their associated epiphytes and animal communities. It is anticipated that the mapping exercise will be repeated in 1999.

Historical aerial photography of both the study area and Cockburn Sound has also been reviewed to quantify gains and losses in seagrass cover over the period of the aerial photographic record. Long-term seagrass meadow dynamics have also been measured, and potential sites for rehabilitation trials and small-scale meadow dynamics studies identified.

7.3.5 Project S4: Artificial Reefs

The removal of seagrass beds from Success Bank will remove habitat that may support species of fish, crabs and squid which are targeted by both recreational and professional fishermen. To mitigate the loss of this habitat to fishermen, Cockburn proposes to investigate the feasibility of establishing a number of artificial reefs within or close to the dredged area. Artificial reefs have been successfully established in Geographe Bay, Warnbro Sound, and off Port Hedland and Dampier. They basically provide fish aggregation devices which have become popular fishing spots. The reefs will increase the complexity and diversity of habitat available in the region, and will produce a localised increase in biological productivity of the dredged area.

An engineering investigation of the design, location, and construction of the habitats has been completed, and a preliminary design of an artificial reef has been prepared, with limestone boulders proposed for use for reef construction. Discussions with the Fremantle Port Authority have identified potential sites within Owen Anchorage for a test reef.

Once installed, the artificial reef will be monitored for diversity and abundance of biota which colonise the reef. This monitoring will be undertaken by Project S1 (Ecological Significance of Seagrasses), and will enable the ecological function of the reef, and the environment benefit of an artificial reef, to be assessed. The construction of artificial reefs is seen as an important means of enhancing the environment value of an area.

7.3.6 Project S5: Dredged Slopes Monitoring

Monitoring of permanent transects established across a number of dredged slopes of varying age and orientation to prevailing wave climate within the study area commenced in 1990 as part of the research commitments of DMP 3 (LeProvost Environmental Consultants, 1993a) to quantify the scale and rate of the slope stabilisation process.

After 5 years of annual monitoring, results (LeProvost Environmental Consultants, 1993b; Gordon et al., 1996) show that slopes eventually stabilise after modifying to angles of repose which are compatible with local sediment characteristics and wave climate. Only the recently dredged slopes have shown major readjustment in slope angle. All older (+ 10 years) slopes have recorded stable profiles over the monitoring period.

7.4 RESOURCES

7.4.1 Background

Cockburn has invested a considerable amount of time and money in examining available options for the efficient and effective use of non-renewable resources. Studies on the technical and economic feasibility of beneficiation (Project R1) and alternative resources (Project R2) have been undertaken in response to ministerial conditions, but added impetus to these studies comes from potential commercial benefits and Cockburn's own policy of resource extraction according to technical, economic, environmental and social considerations.

The Dredging Schedule (Project R3) aims to maximise efficient retrieval of shellsand whilst minimising adverse environmental effects. Innovative dredging techniques have also been investigated (Project R4) to see if the effects of Cockburn's current dredging methods on seagrass meadows could be lessened.

Details on these resource studies are presented below with the exception of Project R3 (the Dredging Schedule), which was reported in some detail in Chapter 3.

7.4.2 Project R1: Beneficiation

Beneficiation is the process of removing silica from limestone or shellsand in order to improve the calcium carbonate ($CaCO_3$) content which can be converted into calcium oxide (CaO), or quicklime, at high temperature. In theory, low grade shellsand or limestone could be beneficiated to a grade suitable for lime manufacture, thereby allowing a wider choice of raw materials which might possibly occur in less environmentally sensitive areas.

Although well known in the mineral sand industry, the technology for beneficiation has not been used for the removal of silica from shellsand. Consequently, neither the technology nor its capacity has been developed and proven. For some years Cockburn has been investigating the technical and economic feasibility of beneficiating limestone, limesand and shellsand for a 1.1 million tonne per annum lime manufacturing process, and a suite of processes have been evaluated.

Electrostatic separation techniques are known to provide the separation required. Cockburn installed and optimised a pilot plant electrostatic separation equipment from a proprietary equipment supplier on its site at South Coogee. The initial trials identified a number of limitations of the equipment and a second generation plant has now been installed. The results of the tests to date are encouraging for both shellsand and limesand. Further testing work based on physical characteristics of the various materials is proceeding. Evaluation of alternative electrostatic equipment and technology for separation is continuing, however to date no acceptable alternative to the conventional pilot equipment currently being tested has been found. Preliminary tests on limestone have not been encouraging and show little promise for optimisation.

The next stage will be to carry out an engineering feasibility study for installing a production plant to use a defined shellsand or limesand resource. It is anticipated that a small scale demonstration plant that beneficiates 200,000 tonnes per annum could be operating by the end of 1998.

In addition, research is being carried out in cooperation with CSIRO into alternative technologies for beneficiation, again using shellsand, limesand and limestone. To date laboratory trials carried out on shellsand and limesand have been encouraging but results obtained with limestone have not proved optimistic. The next phase will include the testing of shellsand and limesand on site in a pilot plant which is currently under construction. The test work will also address any environmental issues that may need to be overcome in implementing a full scale production plant. It is anticipated that the test work will not provide definitive answers until the last quarter of 1996. However, in order to determine the process and costs of a full scale production plant, an engineering feasibility and costing study will be carried out simultaneously.

The work with CSIRO is being carried out under the terms of an Agreement binding both parties to confidentiality about the process.

It should be noted that whichever process may finally be adopted there are a number of environmental issues that will arise as a direct result of the process. These include the disposal of a large quantity of reject silica material, substantial use of fresh water in the washing process, and substantial amounts of fuel for heating and drying the material. These issues will be addressed as part of the environmental assessment procedure once the beneficiation process has been selected.

To date no commercially operating plant of the proposed capacity has been developed or is operating anywhere in the world.

7.4.3 Project R2: Shore Based Resources

In April 1995 Cockburn, in cooperation with Department of Resources Development (DRD) and Department of Minerals and Energy (DME), contracted the DME to carry out a comprehensive study of geological information, based on all known information of resources of limestone and limesand within the metropolitan region, and north to Geraldton and south to Bunbury. The DME utilised their computer based GIS system to determine:

- all resources greater than 92% total carbonate; and,
- all resources greater than 80% total carbonate suitable for beneficiating up to a minimum of 92% of total carbonate.

Matters for consideration included the following:

- differentiating suitable resources which are on private land from those on Crown/Reserve land;
- identifying the private land under which suitable resources lie;

- identifying geological significant sites;
- identifying cultural sites;
- identifying the Mining Act tenements and extractive industry licenses under which suitable resources lie;
- identifying local government boundaries;
- determining the distance from suitable resources to Cockburn's existing or potential plants;
- identifying which suitable resources are situated upon groundwater mounds; and,
- identifying suitable resources outside urban zoned areas.

This work will enable Cockburn to determine the presence of any resource in this area and its availability for use in the manufacture of quicklime and/or cement. A report on this work is scheduled for completion by the end of 1996.

Once potential resources have been identified, their potential will be assessed, and further investigations undertaken if warranted.

7.4.4 Project R4: Innovative Dredging Techniques

During 1995 IHC/MTI of Holland carried out an investigation on the feasibility of developing and testing innovative dredging techniques which will help to ameliorate the effects of Cockburn's current dredging operation on the seagrass habitat. Their report summarises a literature search of all available equipment and information for investigation based on relevant details provided by Cockburn concerning its existing dredging programme, ie. nature of materials, environmental conditions, wave, weather, habitat and ecology etc. Details are presented of a site visit and meetings with the scientific community involved with Cockburn's research and development programmes into seagrass ecology, rehabilitation wave climate and sedimentology. Their conclusions and recommendations are as follows:

- existing literature research clearly shows that to date no technology is available that is used in similar circumstances;
- removing shellsand from under seagrass root mass is not feasible;
- conventional dredging methods could be used for transplanting seagrass, including:
  - backhoe or clamshell;
  - core technology; and,
  - developing transplanting equipment based on preliminary results; and,
- improving existing recovery of resources from dredging area, by:
  - use of a dust pan drag head fitted to the existing dredge; and,
  - improved control and automation of the existing dredge.

Consequently, no further development of innovative techniques for reducing effects on seagrass is planned, other than the development of mechanical transplantation techniques. Cockburn will continue to modify and improve existing dredging techniques to maximise resource recovery.

7.5 TIMETABLE

A timetable for the implementation of the components of the EMP is shown in Table 7.2.

Annual reports of the results from the EMP studies will be prepared and submitted to the Minister in the middle of each year.

7.6 DEVELOPMENT OF A STRATEGY AND PROGRAMME FOR ACCESS TO RESOURCE FOR THE LONG-TERM

During the proposed medium-term dredging programme, Cockburn will develop a strategy and proposal for long-term access to suitable resources along with a capability to manage their acquisition and efficient utilisation.

Cockburn's proposal for long-term dredging will be formulated largely in the light of findings from studies included in the EMP. In particular these include:

- market demands;
- the assessment of the ecological significance of seagrasses;
- the development of techniques for seagrass transplantation and the measurement of natural regrowth;
- the prediction of wave and shoreline effects through modelling and monitoring;
- the development of techniques for the beneficiation of shellsand and limesand; and,
- evaluation of alternative resources.

The key milestones for completing the EMP studies, the interpretation of results from these studies and the development of a programme for the acquisition of resource for the long-term are shown in Table 7.3.

Table 7.2 Summary timetable for implementation of technical studies.

CODE	STUDY		1995	1996	1997	1998	1999	2000	2001
R1	Beneficiation	Phase 1/2 - Pilot tests	■■	■■					
		Phase 3/4 - Trials (100,000 tpa)			■■	■■	■■		
		Phase 5 - Select technology					■■		
		Phase 6 - Build						■■	■■
R2	Alternative Resources	Phase 1 - Review	■■	■■					
		Phase 2 - Feasibility		■■	■■	■■	■■		
R3	Dredging Plan	Review	■□	■□	■□	■□	■□	■□	■□
R4	Innovative Dredging	Review	■■	■■					
C1	Wave Climate Study	Phase 1 - Short & Medium-Term Dredging	■■	■■					
		Phase 2 - Long-Term Dredging				■■	■■		
C2	Shoreline Monitoring		□■	□■	□■	□■	□■	□■	□■
C3	Banks Sedimentology	Phase 1 - Review	□■	■□					
		Phase 2 - Assessment		□■					
S1	Ecological Significance of Seagrass	Phase 1 - Review	■□						
		Phase 2 - Baseline	□■	■■					
		Phase 3 - Monitoring		□■	■■	■■			
		Phase 4 - Evaluation	□■	■□		□■	■□		
S2	Seagrass Rehabilitation	Phase 1 - Review	□■						
		Phase 2 - Implementation		■■	■■	■■	■■	■□	
		Phase 3 - Assessment			□■	■■	■■	■□	
S3	Habitat Mapping	Phase 1 - Seagrass Mapping 94/95	■■	■□					
		Phase 2 - Seagrass Dynamics		■■					
		Phase 3 - Seagrass Mapping 98/99				□■	■□		
S4	Artificial Reefs	Design & Installation			■■				
		Monitoring			□■	■■	■□		
		Assessment				□■	■□		
S5	Slope Monitoring		■□				■□		

Table 7.3 Major milestones for acquiring information to be used in preparing Cockburn's strategy for long-term resource acquisition.

ITEM		DATE
1.	**EVALUATE ECOLOGICAL SIGNIFICANCE OF SEAGRASSES**	
1.1	Initial appraisal for proposed medium-term area	complete
1.2	Develop detailed assessment procedures based on measurements	mid 1998 to mid 1999
1.3	Evaluate ecological effects of dredging potential sites for long-term resource - Success Bank - Parmelia Bank - Mewstone - other areas	mid 1999
2.	**SEAGRASS TRANSPLANTATION**	
2.1	Develop and construct prototype mechanical transplanter	complete
2.2	Trials, modification	mid 1997
2.3	Implement experimental transplantation	mid 1997 to mid 1999
2.4	Design/develop/test high rate transplantation procedures	1998 onwards
2.5	Monitor results	continuous
3.	**WAVE MODELLING**	
3.1	Develop and calibrate wave model for Owen Anchorage	complete
3.2	Assess influence on wave climate on proposed medium-term dredging	complete
3.3	Evaluate effects on wave climate of dredging potential sites for long-term resource - Success Bank - Parmelia Bank - Mewstone - other areas	1997 to mid 1999
4.	**BENEFICIATION**	
4.1	Laboratory trials	complete
4.2	Pilot Plant (0.1–5 tph)	mid 1997
4.3	Design/construct small scale demonstration plant (200,000 tpa)	mid 1998
4.4	Select technology for full scale beneficiation of 2 million tpa	mid to end 1999
4.5	Design, construct and commission full scale production facility	2000 and 2001
5.	**ALTERNATIVE RESOURCES**	
5.1	Terrestrial Resources	
	5.1.1 Review potential terrestrial resources Geraldton to Augusta	end 1996
	5.1.2 Assess potential for terrestrial resources	mid 1998
	5.1.3 Select sites, acquire resource	1999–2001
5.2	Marine Resources	
	5.2.1 Review existing information	complete
	5.2.2 Assess potential resources; grade, ease of extraction, environmental issues	mid 1998
	5.2.3 Recommend potential marine resources for long-term dredging	mid 1999
	5.2.4 Design/modify dredging equipment for use in other marine resources	1999
6.	**DEVELOPMENT OF PROPOSAL FOR LONG-TERM RESOURCE ACQUISITION**	
6.1	Preliminary review and feasibility study of all potential resources with regard to economic, environmental and practical issues	mid 1998
6.2	Identification of candidate sites for long-term resource acquisition	mid 1998
6.3	Undertake detailed environmental assessments of candidate sites	mid 1997 to mid 2000
6.4	Recommendations for long-term resource acquisition	mid 2000
6.5	Gain approval for site(s) for long-term resource acquisition	end 2001

8. MANAGEMENT AND IMPLEMENTATION OF THE EMP

8.1 INTRODUCTION

This section describes the mechanisms and procedures that have been established for the management and implementation of the EMP. These include:

- Cockburn's environmental management procedures;
- coordination and management of technical studies of the EMP;
- mechanisms for the incorporation of results of technical studies into the EMP;
- evaluation of technical studies by peer evaluation; and,
- Cockburn's commitment to undertake community consultation, and to provide a community information programme.

8.2 MANAGEMENT, ADMINISTRATION AND REVIEW OF THE EMP

8.2.1 Cockburn Cement Limited Management Team

Cockburn has established a management team that is responsible for the management of its shellsand dredging operation in accordance with the principles of Cockburn's environmental policy, all relevant statutory requirements, and for the implementation of the EMP. The Cockburn management team includes:

Mr Don McDonald	Chief Executive — responsible for the overall policy and direction of environmental management programmes;
Mr Andrew Robertson	Manager, Business Development and Resources — responsible for implementation of programmes of environmental management, and research and development; and,
Mr Roger Wilson	Manager, Dredging — responsible for management of all dredging and dredging-related activities.

8.2.2 Studies Project Manager

Cockburn has appointed Dr Desmond Lord, D A Lord & Associates, to be Project Manager for the management, coordination and implementation of the technical investigations that are part of the EMP. The Project Manager has the responsibility of:

- overall coordination of the management of the technical investigations and scientific studies;
- coordination of the peer review of EMP studies;
- representation on the Advisory Board; and,

- coordination of reporting to the Minister.

8.2.3 Studies Technical Advisory Group

A Technical Advisory Group (TAG) has been established to provide the direction, implementation and review of the detailed programmes of technical investigations and scientific research that are part of the EMP. The TAG includes all of the project leaders and major participants of the various studies. The TAG includes the following:

Dr Des Lord (convenor)	D A Lord & Associates
Mr Don McDonald	Cockburn (ex officio)
Mr Andrew Robertson	Cockburn (ex officio)
Mr Roger Wilson	Cockburn (ex officio)
Prof Di Walker	Department of Botany, UWA
Mr Ian LeProvost	LeProvost Dame & Moore
Dr David Gordon	LeProvost Dame & Moore
Mr Mick Rogers	M P Rogers & Associates
Dr Eric Paling	School of Environmental Science Murdoch University
Dr Fred Wells	Western Australian Museum
Dr Paul Lavery	Department of Environmental Management Edith Cowan University
Dr Gary Kendrick	Department of Botany, UWA
Dr Peter Morrison	Kinhill
Mr Jim Phillips	Ocean Industries
Mr Roger Dyhrberg	Diver 1/Diver 2
Dr Hugh Kirkman	Division of Fisheries, CSIRO (by invitation)
Dr Don Martin	Department of Resources Development
Dr Paul Vogel	Department of Environmental Protection
Mr Colin Chalmers	WA Fisheries
Mr John Barraclough	Fremantle Port Authority (FPA)

8.2.4 Environmental Management Advisory Board (EMAB)

An Environmental Management Advisory Board (EMAB) has been established to provide advice to Cockburn on matters relating to policy, finances, and strategic decisions that will be required for the implementation of the EMP.

The Advisory Board has the responsibility for:

- the continuous review and assessment of the progress of technical investigations and scientific studies being undertaken as part of the EMP;
- the continuous review and assessment of Cockburn's shellsand dredging operation;

- the integration of the results of the technical investigations and scientific studies, and for providing Cockburn with advice and recommendations on the incorporation of the results of this work into their environmental management procedures;
- participating with Cockburn in the strategic planning of the future environmental management of the resource;
- the review and endorsement of the annual report that is required to be submitted to the Minister of the Environment on the implementation of the EMP; and,
- ensuring implementation of an appropriate community consultation and community information programme, and also for ensuring the issues raised during this programme are addressed by the management programme.

The EMAB consists of:

- Mr Don McDonald, Chief Executive, Cockburn;
- Mr Andrew Robertson, Manager Business Development and Resources, Cockburn; and,
- Dr Des Lord, Project Manager for the EMP Technical Investigations and Scientific Studies

Plus three independent advisers, namely:

- **Mr Noel Fitzpatrick — former Director of the WA Department of Agriculture, and Chairman of the Murray Darling Basin Commission**
  Mr Fitzpatrick was nominated to EMAB by the Australian Academy of Technology Sciences and Engineering.
- **Professor Arthur McComb — Department of Environmental Sciences, Murdoch University**
  Professor McComb is experienced in environmental management in Western Australia and has conducted extensive research on the biology of seagrasses. He has served as Chair of the National Parks and Nature Conservation Agency of Western Australia.
- **Professor Emeritus Des O'Connor**
  Professor O'Connor has consulted widely in environmental matters. He served on the Environmental Protection Authority from 1981 to 1984 and is a former Deputy Chairman of the EPA.

8.2.5 International Peer Review

An independent International Peer Review Group (IPRG) has been appointed to provide regular advice and comment to the Advisory Board, with particular regard to:

- technical content of specialist studies; and,
- overall scope and direction of the studies.

The IPRG comprises:

- **Dr Bill Dennison (Convenor) — University of Queensland**
  Dr Dennison has undertaken significant research into seagrasses throughout the world and had a major involvement in the successful Chesapeake Bay study in the USA that had as one of its objectives the restoration of seagrasses in the Bay.

- **Dr Marion Cambridge — University of Utrecht, Holland**
  Dr Cambridge is an expert in seagrass ecology and has worked extensively in Australia and the Mediterranean. Dr Cambridge undertook much of the early work documenting changes in seagrasses in Cockburn Sound.

- **Professor Doug Foster — D Foster & Associates, Tasmania**
  Professor Foster is an experienced coastal engineer previously with the University of New South Wales. He has over 30 years experience in coastal engineering aspects of major projects, including wave effects on shipping, dredging of submarine sands, influences of the Botany Bay runway extension and the Dawesville Channel.

- **Professor Alistair Gilmour — Macquarie University**
  Professor Gilmour has considerable experience in the management requirements for coastal systems. He directed the original Port Phillip Bay study in the 1970's, was involved in the development of the management programmes for the Great Barrier Reef Marine Park Authority, and is now Professor of Environmental Studies at Macquarie University.

- **Professor Robert Orth — Virginia Institute of Marine Science, USA**
  Professor Orth is an international expert in the field of seagrass ecology and seagrass rehabilitation, and was a major contributor to the Chesapeake Bay study in the USA.

- **Professor Alex Meinesz — Université de Nice-Sophia Antipolis, France (note: Prof Meinesz did not attend the IPRG meeting held in Jan/Feb 1996)**
  Professor Meinesz is Head of the Marine Littoral Laboratory at the University of Nice, France. This research group has an international reputation in the rehabilitation of seagrasses in the Mediterranean, and the use of artificial habitats for fish enhancement. He has broad national and international experience in coastal management.

Additional specialists advice and review will be obtained as needed.

The IPRG reviewed the initial EMP in 1995, and has since been closely associated with the EMP.

The IPRG met in Perth in late January 1996 to evaluate initial progress of the technical investigations and scientific studies of the EMP. This period coincided with the organisation of an international workshop on seagrasses which was held at Rottnest Island. The IPRG report and the response to their recommendations have been completed and provided to the EPA and the DEP.

The IPRG will continue to remain closely associated with all aspects of the EMP. The next detailed review of the entire EMP is scheduled for early 1998. Peer review of specific projects will be implemented more frequently.

8.2.6 Management Structures

A summary of the management structure for the implementation of the EMP is shown in Figure 8.1.

8.2.7 Reporting

Reporting of the progress of the EMP studies will occur in a number of different ways, including:

- Annual Reports to the Minister for the Environment;
- technical reports on projects as they meet various milestones;
- scientific papers, presented at national and international conferences, and published in the international literature;
- seminars and talks; and,
- general articles to allow for a wide dissemination of the results of the EMP.

9. COMMUNITY INFORMATION & COMMUNITY CONSULTATION PROGRAMME

9.1 INTRODUCTION

In accordance with Cockburn's Environmental Policy of communicating with sectors of the public who may be affected directly or indirectly by Cockburn's operations, a community information and consultation programme will be undertaken during the medium-term dredging programme. This is not an EPA requirement, but is considered essential by Cockburn. The objectives of this programme are:

- to transfer information to the community on the implementation and management of the shellsand dredging operations;
- to transfer information to the community on the results, conclusions and recommendations being obtained from the various technical studies, particularly:
  - ecological significance of seagrass;
  - seagrass transplantation;
  - alternative resources; and,
  - beneficiation.
- to enable community views and recommendations on the EMP to be incorporated into management plans.

These objectives will be achieved by:

- the distribution of newsletters and information brochures;
- organising open day activities and presentations which will enable members of the public to view Cockburn's operations and discuss environmental management issues; and,
- establishing regular communication with community groups.

9.2 PUBLIC INFORMATION

The company has established a pattern of public communication through the local media, using both editorial and advertising to provide information on its operations. This will provide a method for regularly providing information about the dredging operations throughout the period of the CER.

Plans are also under consideration for the formation of a Community Environmental Consultation Group which will provide a forum for discussion of a range of environmental topics, including the dredging operations.

9.3 MARINE SPECIAL INTEREST GROUPS

The Company recognises that marine special interest groups, which have particular interest in the progress of the programme, need to be provided with regular information.

Examples of these groups include:

- Coastal Waters Alliance
- Cockburn Power Boat Club
- Cockburn Sound Conservation Committee
- Conservation Council of WA
- Friends of Woodman Point
- (WA) Australian National Sportsfishing Association
- (WA) Marine Conservation Society

9.4 INFORMATION PROGRAMME

Environmental Management Programme presentations, workshops and briefings have been given to a series of groups, representatives of groups, individuals, and/or groups of individuals including:

Community Groups
Alcoa Community Consultative Group
All employees of Cockburn Cement
Anthony Briffa - Coogee Progress Association
CSBP Community Consultative Group
Plastics & Chemical Industries Association Community Advisory Panel
Recreational Fishing Advisory Committee
Rockingham SHS
Hamilton SHS

Professional Groups & Associations
Institute of Mechanical Engineers
Quarry Institute

Elected Officials
Barbara Scott - MLC
Barry Blaikie - MLA, Vasse
Bill Thomas - MLA, Cockburn
Cheryl Davenport - MLC
Colin Quinn - Councillor, City of Kwinana
Eric Ripper - MLA, Belmont
Fred Tubby - MLA, Roleystone
Jim McGinty - Leader of the Opposition

Elected Officials (cont)
John Day - MLA, Darling Ranges
John Grlijusich - Councillor, City of Cockburn
Judith Edwards - MLA, Maylands
Mike Board - MLA, Jandakot
Ray Lees - Mayor, City of Cockburn
Rhonda Parker - MLA, Helena

National, State and Local Government
Officers of City of Cockburn
Officers of City of Fremantle
Officers of Royal Australian Navy
Officers of WA Department of Fisheries

Industry/Business
Clive Latcham - CSBP
Denis Neil - BP Kwinana
Malcolm Wilkinson - Transfield
Customers of Cockburn

Special Interest Groups
Angus Horwood - Recreational and Sportsfishing Association
Bob Slight - Coastal Waters Alliance
Cliff Mullins - Coastal Waters Alliance
Giz Watson - The Marine and Coastal Community Network
John Smedley - Coastal Waters Alliance
T Baird - Community Consultative Group
Fran Chambers - Conservation Council of WA

In addition, close communication has been maintained with the EPA, the DEP, the DRD and the FPA.

10. COMMITMENTS

Based on their immediate requirements for resource volumes of suitable quality, the need to use existing dredging equipment until possible alternatives can be properly evaluated, and the need to minimise environmental effects, Cockburn reaffirms that its only practical option in the medium-term is to dredge shellsand between the FPA channel and second shipping channel. Cockburn recognises the environmental effects that this option involves, and therefore makes the following commitments:

1. Cockburn will commit itself to implementing all of the programmes of scientific and technical investigation as outlined in the EMP (Cockburn Cement Limited, 1995a) and its Supplement (Cockburn Cement Limited, 1995b). The major studies, which are summarised in Table 7.3, include:
   - determining the influence of dredging on wave climate and shoreline stability;
   - determining the ecological significance of seagrass;
   - developing techniques for seagrass rehabilitation;
   - developing techniques for beneficiation; and,
   - examination of alternative resources.

2. Cockburn will commit itself to the detailed audit programme that will be developed for this project. A proposed audit programme is shown in Appendix 1.

3. Cockburn will refer its plan for long-term resources for assessment by the EPA under Part IV of the Environmental Protection Act at least 15 months prior to the expected depletion of the medium-term resource.

4. Cockburn will implement a dredging programme that prioritises dredging areas, gaining access to areas of lower seagrass cover first.

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The report was compiled and edited by **Dr D A Lord** with assistance from **Dr K Hillman**, and in consultation with **D McDonald, P Tencate, A Robertson, A Dobbs** and **R Wilson** (Cockburn). Major contributions to the contents of this report were provided by **Dr K Hillman** (Kinhill), **Professor D Walker** and **Dr G Kendrick** (UWA), **Dr E Paling** (Murdoch), **Dr P Lavery** (Edith Cowan), **M Rogers** (M Rogers and Associates), **Dr B Hegge** (D A Lord & Associates) and **I LeProvost** (LeProvost Dames and Moore). The report was reviewed by **Dr F Wells** (WA Museum) on behalf of the study team.

Draft versions of this report have been reviewed by the Department of Environmental Affairs, the Department of Minerals and Energy, the Fremantle Port Authority, and the WA Fisheries Department as members of the Technical Advisory Group (TAG) for this programme. The review of this report by government agencies does not necessarily constitute support or approval of its contents.

The report has also been evaluated by **Professor A McComb**, **N Fitzpatrick**, and **Professor D O'Connor**, as independent advisors on the Environmental Management Advisory Board (EMAB) for this project.

The report was typed by **Mandy Hodgson** and **Heather Ross** (DAL), and diagrams were produced by Environmental Drafting Services.

GLOSSARY

The following list provides a brief and general interpretation of terms which appear in the CER.

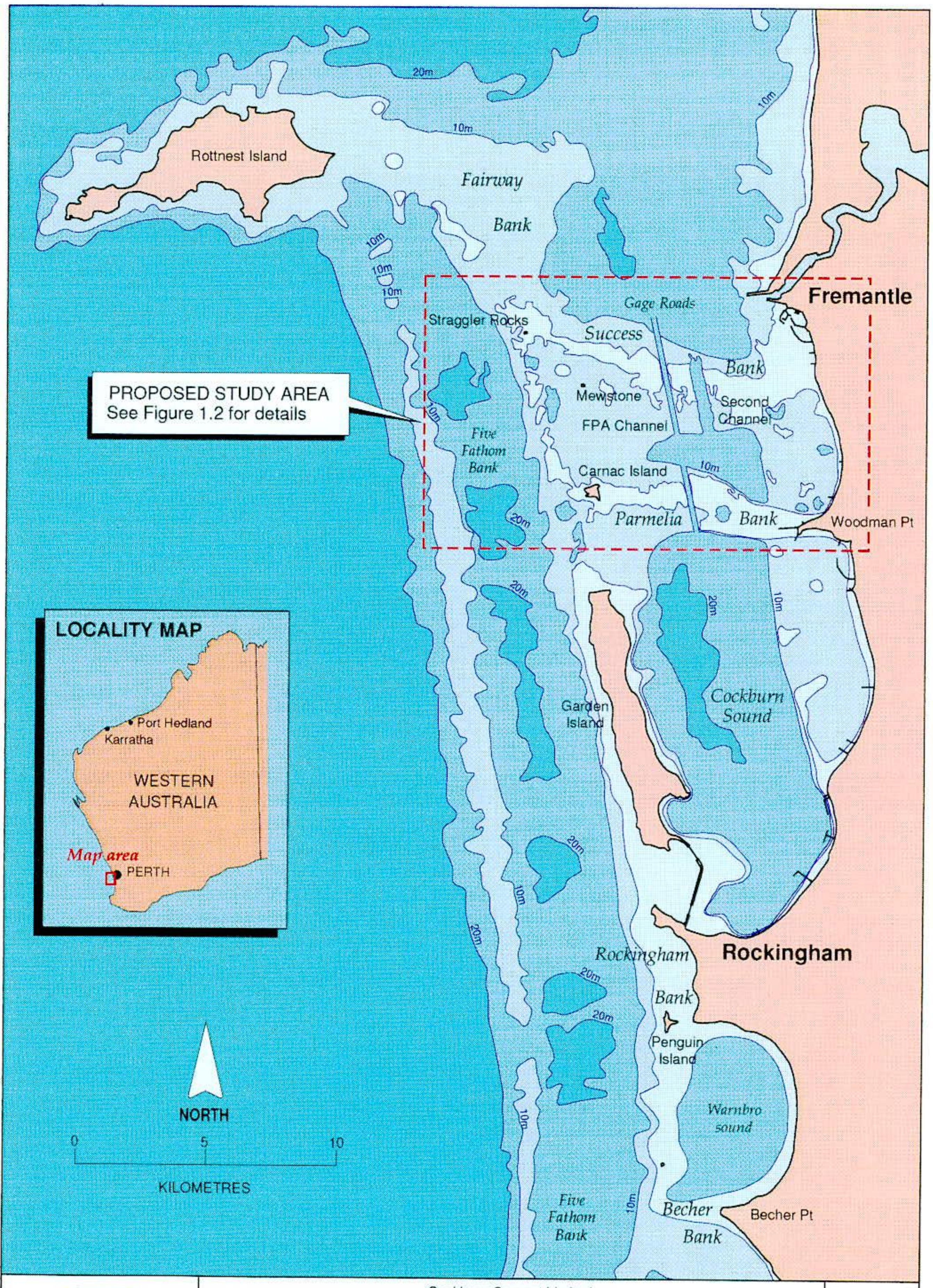
Accretion:	building up; accumulation; growth by enlargement
Algae:	non flowering aquatic plants. The larger plants of this group that occur in marine environments, are called seaweeds and the microscopic plants that float in the water are called phytoplankton
Anticyclone:	atmospheric high-pressure system
Assemblage:	recognisable grouping or collection of individuals or organisms
Baffling:	reduce energy
Bathymetry:	measurement of the changing depth of the seafloor
Beneficial uses:	the ways a society uses or values an area (synonymous with environmental values)
Beneficiation:	improving the quality or grade of a raw material by the removal of impurities
Benthic:	bottom dwelling
Biota/biotic:	animals/plants; related to living organisms
Calcining:	process of converting shellsand to quicklime
CER:	Consultative Environmental Review
Clinker:	material produced in a kiln that is grounded up to make cement
Colonisation:	movement of an organism into an area in which it was not previously present
Compliance:	the degree to which stated project goals or requirements are attained
Decrepitation:	disintegration of sediment into fine dust sized particles
DEP:	Department of Environmental Protection
Detritus:	small particles in the water or on the seabed or shoreline arising from breakdown of organic matter which provide a food source to aquatic organisms
Directional spectra:	data plot showing wave energy, frequency and direction for a particular location
Dissipate:	reduce; disperse
DMP:	Dredging Management Plan
Donor bed:	a seagrass bed from which seagrass planting material is obtained for the purpose of seagrass restoration, enhancement, mitigation or experiment
DRD:	Department of Resources Development

Dredge plume:	the trail of suspended particles visible in the water away from a source of dredging
Ecological Function:	combined characteristics and processes occurring within an area
Ecosystem:	a community of organisms, interacting with each other plus the environment in which they live and with which they also interact
EMAB:	Environmental Management Advisory Board
Emergent:	that which appears; comes into view
EMP:	Environmental Management Programme
Environmental values:	the ways a society uses or values an area (synonymous with beneficial uses)
EPA:	Environmental Protection Authority
Epiphyte:	plant which grows attached to another plant
ERMP:	Environmental Review and Management Programme (a detailed and comprehensive document prepared for the purposes of environmental assessment of projects and which, in W.A., usually includes a public consultation period of ten weeks)
Eutrophic:	nutrient enriched (usually associated with deterioration of natural water bodies where nutrient enrichment occurs through man's activities)
Fauna:	animals
Flora:	plants
FPA:	Fremantle Port Authority
Geomorphology:	study of the physical features of the earth's surface and their relation to geological structures
Grade:	quality or purity of shellsand
Goals Achievement Matrix:	a form of multi-criteria analysis
Habitat:	the place or environment occupied by individuals of a particular species, population or community; has physical, chemical and biological attributes conducive to the maintenance and propagation of those biota
H_S:	significant wave height. This is normally calculated as the average of the largest one-third of the waves at a site over a given time
Invertebrate:	collective term for all animals which do not have a backbone or spinal column
IPRG:	International Peer Review Group
Larvae:	pre adult form of some animals that hatch from an egg
Light attenuation:	light reduction (usually refers to a decrease in available light which occurs with increasing depth of water)
Local:	refers to the general project area (ie. Success Bank, Parmelia Bank, Owen Anchorage, Cockburn Sound) rather than to other parts of

	the metropolitan coastal waters
Macroalgae:	large algae; seaweed
Mitigate:	reduce the effect of
Mitigation:	alleviation, abatement or diminution of anything afflictive; for seagrasses this refers to the restoration, enhancement or creation of seagrass areas to compensate for permitted seagrass losses; to the installation of artificial reefs, or to the change in project design to reduce loss of seagrass in the first place
Monospecific:	consisting of a single species
Multi-criteria analysis:	technique of assessing various scenarios that mathematically include value judgements as well as qualitative data
Perennial:	lasting for more than one year or one growing season
Phytoplankton:	microscopic algae that float in the water column
Planting off-site:	planting seagrasses at a location away from that where seagrass has been damaged or lost
Planting unit:	a general term to denote different types of seagrass planting material or propagules eg. plug, sprig, seedling, seed
Plug:	excavated seagrass unit consisting of rhizome, leaves and roots with sediment intact
Productivity:	in this sense, the turnover, of photosynthate (food material) obtained by a plant through the process of conversion of energy from sunlight into useable food sources (photosynthesis)
Propagules:	part of plant/algae capable of growing into new organism
Quicklime:	calcium oxide
Re-colonisation:	movement of a seagrass species back into an area in which it used to grow; usually refers to the lateral movement or spread of seagrass into an area rather than to the re-activation of previously existing or damaged seagrass beds
Reflection:	rebounding (eg. of waves)
Refraction:	bending or deflecting around (eg. of waves)
Regression:	moving backwards
Rehabilitation:	a general term with the sense of improving, augmenting or enhancing a degraded or affected area. This term may or may not refer specifically to seagrass (eg. it may be used to describe the use of artificial reefs where these are used to replace lost seagrass beds). With respect to seagrasses this implies improvement by return of seagrass and seagrass ecosystem function, partly or in whole. Depending on what is possible, this may be return of all that was there before (eg. restoration of previously existing seagrass area), creation of new seagrass beds with different species to the original or the return of seagrass or seagrass function through mitigative action

Restoration:	returned to pre-existing condition; implies return of all aspects of the previous seagrass system, lost or damaged
Rhizome:	underground stem bearing buds
Salvage operation:	transplanting seagrass from an area where activities are planned that will destroy that seagrass
Seagrass:	a marine flowering plant, or angiosperm, (contrast with alga, a non flowering aquatic plant); the word "seagrass" is a general term applied to all seagrasses; reference should be made, however, to a particular species of seagrass where this detail is appropriate
Seedlings:	here refers to seagrasses; the seedling is the young plant that develops following germination of the seed; the seedling usually consists of young leaves and roots; the residual food storage tissue of the seed (endosperm and pericarp) may still be present
Species composition:	number and abundance of different types of species in a habitat
Species richness:	number of different types of species in a habitat
Spreading:	the lateral growth of planted out seagrass propagules, which eventually coalesce (join up) to provide recognisable seagrass vegetation cover
Sprig:	vegetative portion of a seagrass which is free of sediment; sprigs include a section of rhizome with shoots, leaves and with roots attached
Staple:	a device, usually a metal bar or wire (staple), which is then inserted point down into the sediment, pinning the seagrass to the seafloor
Standing stock:	amount of organic matter contained in a related group of organisms
Stratigraphy:	order and relative position of strata (eg. the order of sequence of layers in a physical structure)
Substratum:	underlying layer or substance; foundation
System:	seagrass ecosystem, the entity comprising of the seagrass community and its ecological interactions
TAG:	Technical Advisory Group
Tillering:	spreading of a plant by means of side shoots that arise at ground level from horizontal rhizomes or 'runners'
Transplantation:	taking seagrass from one area and moving it to another
Trophic:	energy level in a food chain
Turbidity:	measure of the clarity of a water body
Unconsolidated:	not solidified or formed into a solid mass
Wild stock (stands):	material obtained from natural seagrass beds
Wrack:	detached seagrass and algae (usually detached leaves and other debris removed during storm activity)

Figures



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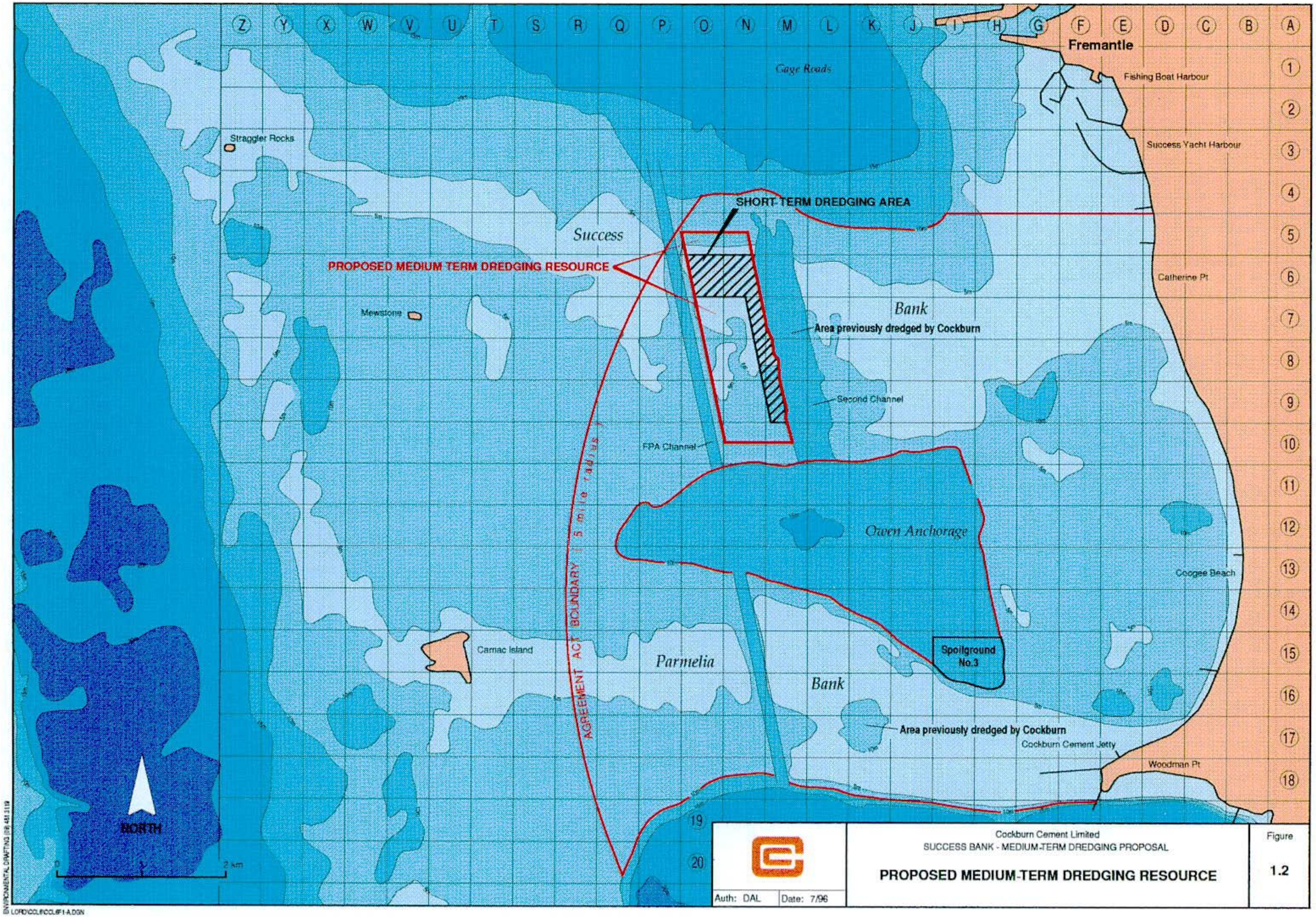
Cockburn Cement Limited
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

LOCALITY MAP

Figure
1.1

Auth: DAL | Date: 7/96

LORD/CCL6/FIG1-1.DGN



Cockburn Cement Limited
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

PROPOSED MEDIUM-TERM DREDGING RESOURCE

Figure 1.2

SECTIONS

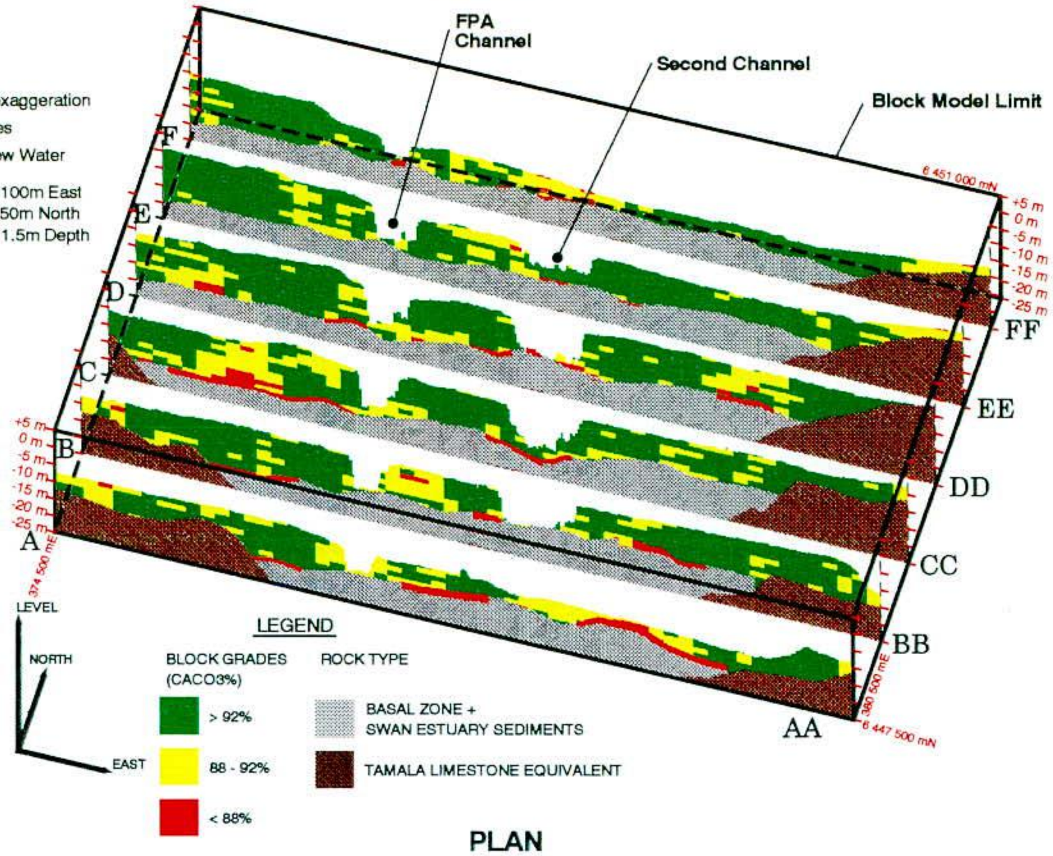
NOTES:-

40 Times vertical exaggeration

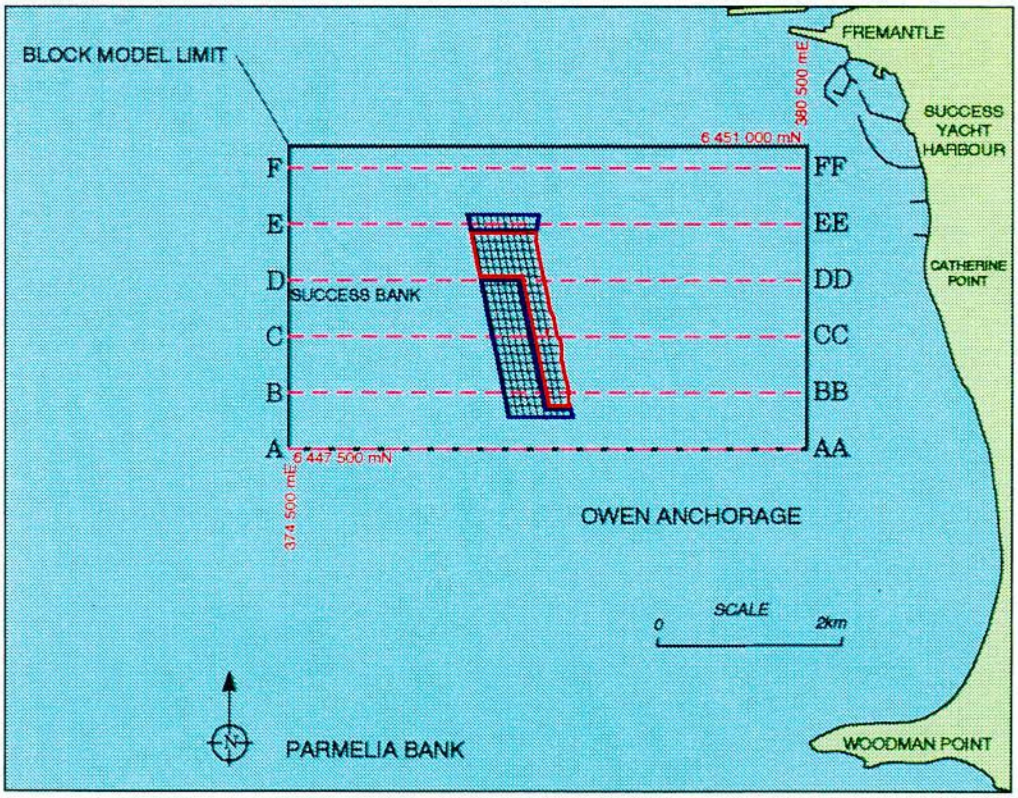
MGA94 Coordinates

Level relative to Low Water Mark Fremantle

Parent Block Size 100m East, 50m North, 1.5m Depth



PLAN



LIMIT OF SHORT-TERM DREDGING AREA

LIMIT OF PROPOSED MEDIUM-TERM DREDGING AREA

BHP

BHP Engineering
BHP Service Companies

BHP Engineering Pty Ltd ACN 008 690 500
221 St George's Terrace Perth
Western Australia 6000 Australia
Telephone 61 9 426 5700 Facsimile 61 9 426 5670

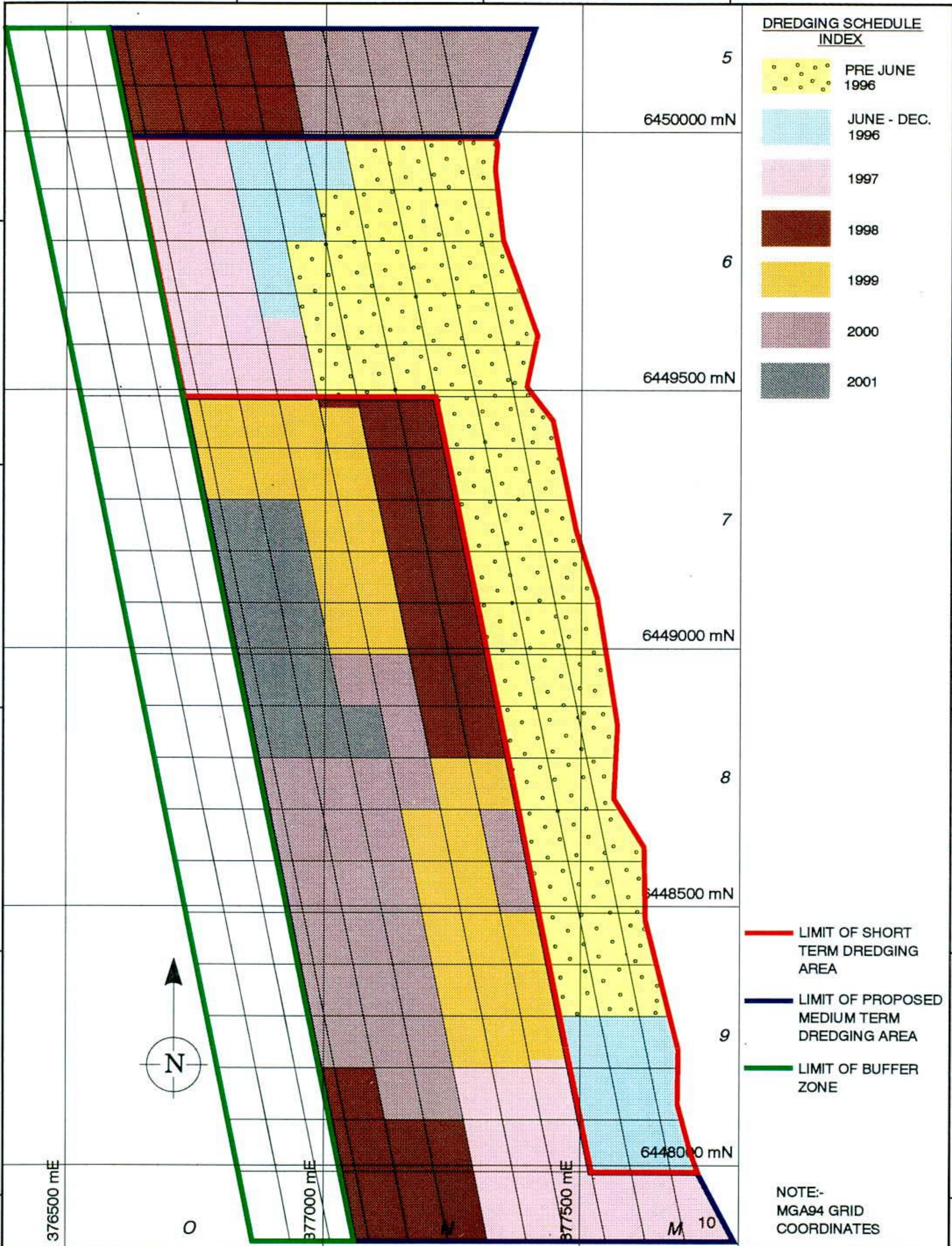
		Sign	Date
Drawn			
Drafting	CHK.	N.R.T.	14-8-96
Eng.			
Eng.	APPROVAL		
Project			
Client			

COCKBURN CEMENT LIMITED

Map of Shell Sand Resources in Success Bank

Figure 2.1

Scale N.T.S. | A4 | Drg. No. DAL017 R.1.



BHP

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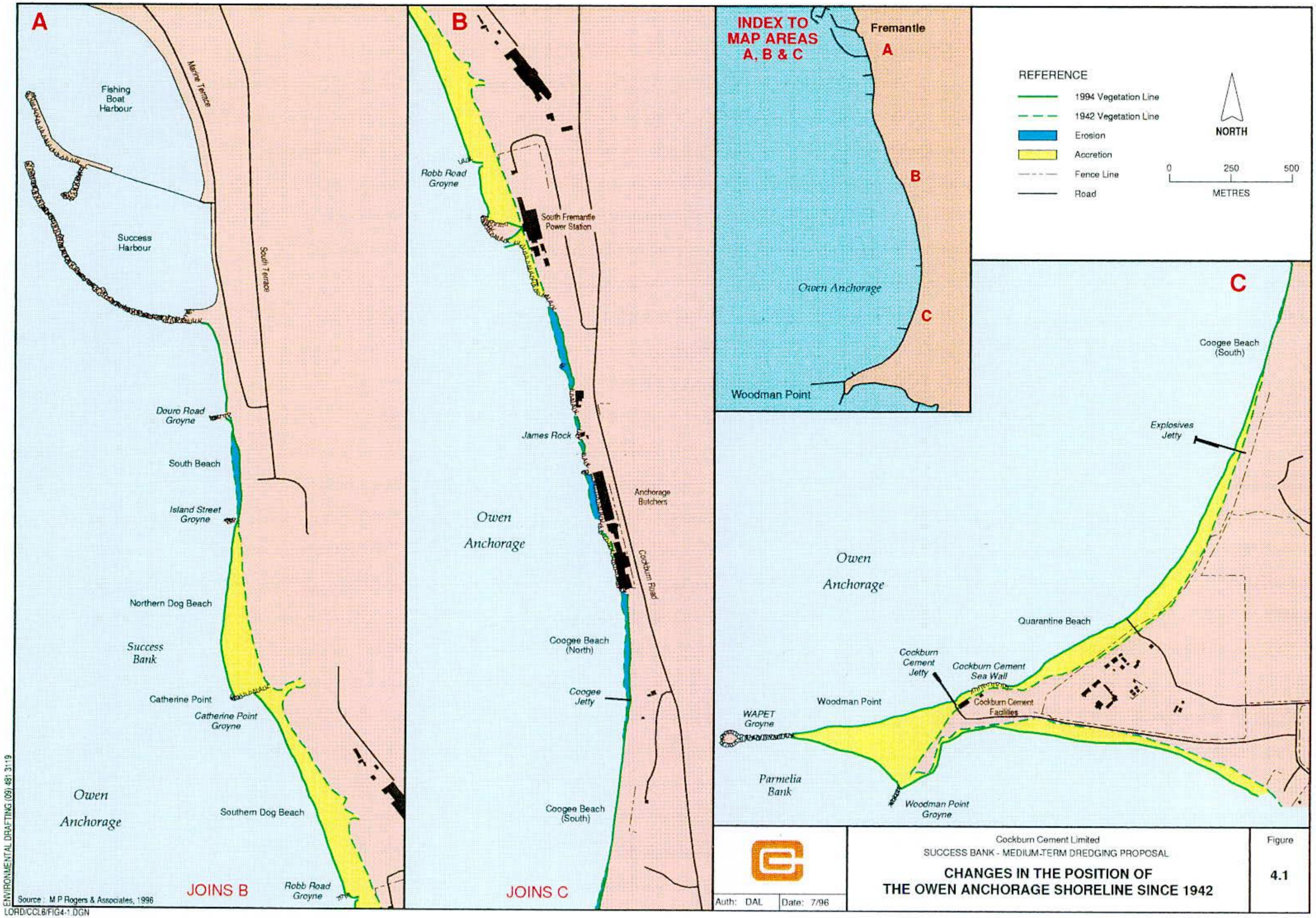
		Sign	Date
Drawn			
Drafting	CHK.	N.R.T.	14 -8-96
Eng.			
Eng.	APPROVAL		
Project			
Client			

COCKBURN CEMENT LIMITED

Proposed Dredging Schedule Overlay Showing Seagrass Cover

Figure 3.1

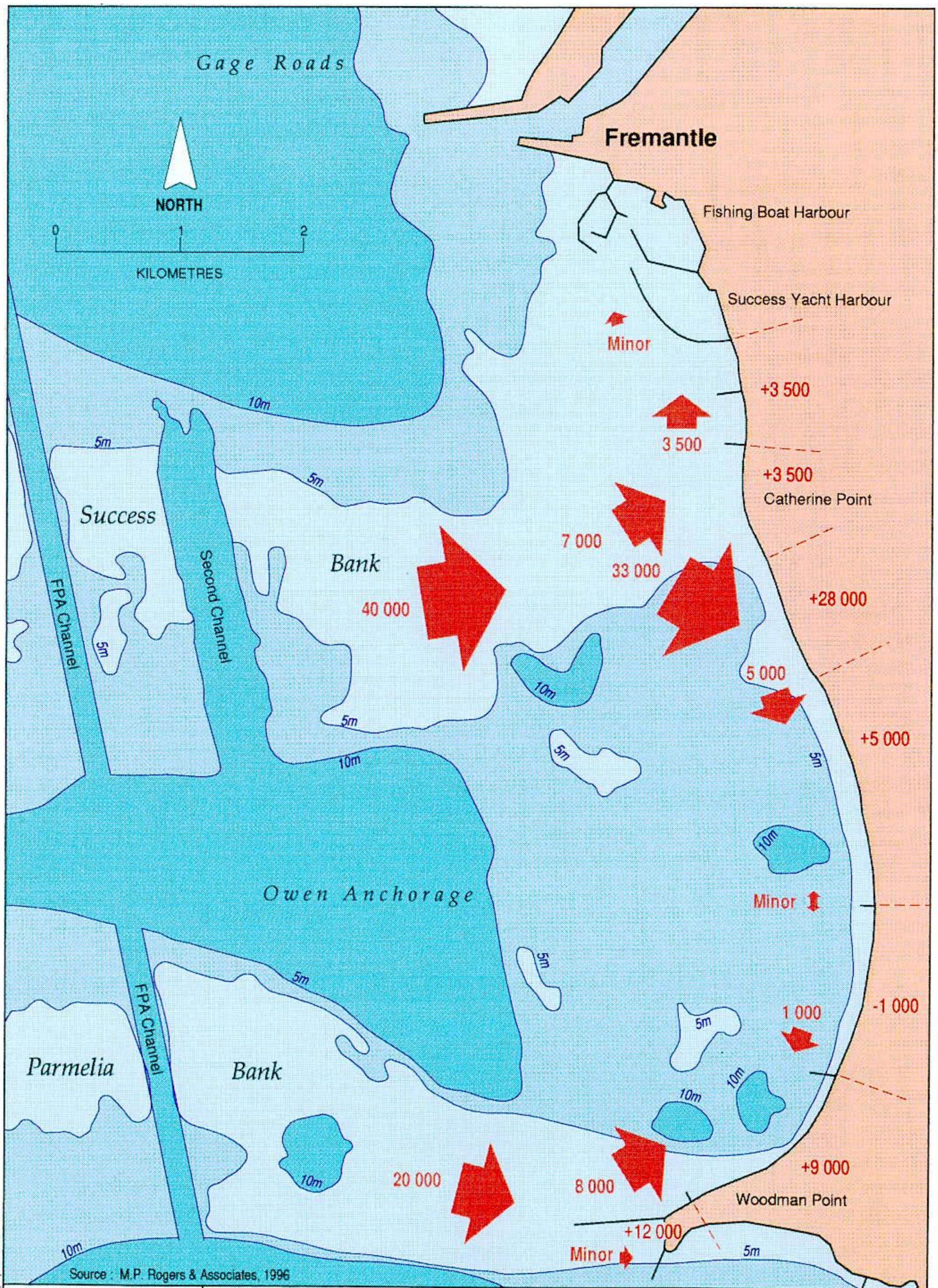
Scale		Drg. No.	Rev. No.
1:10000	A4	DAL016	2



Cockburn Cement Limited
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

CHANGES IN THE POSITION OF THE OWEN ANCHORAGE SHORELINE SINCE 1942

Figure 4.1



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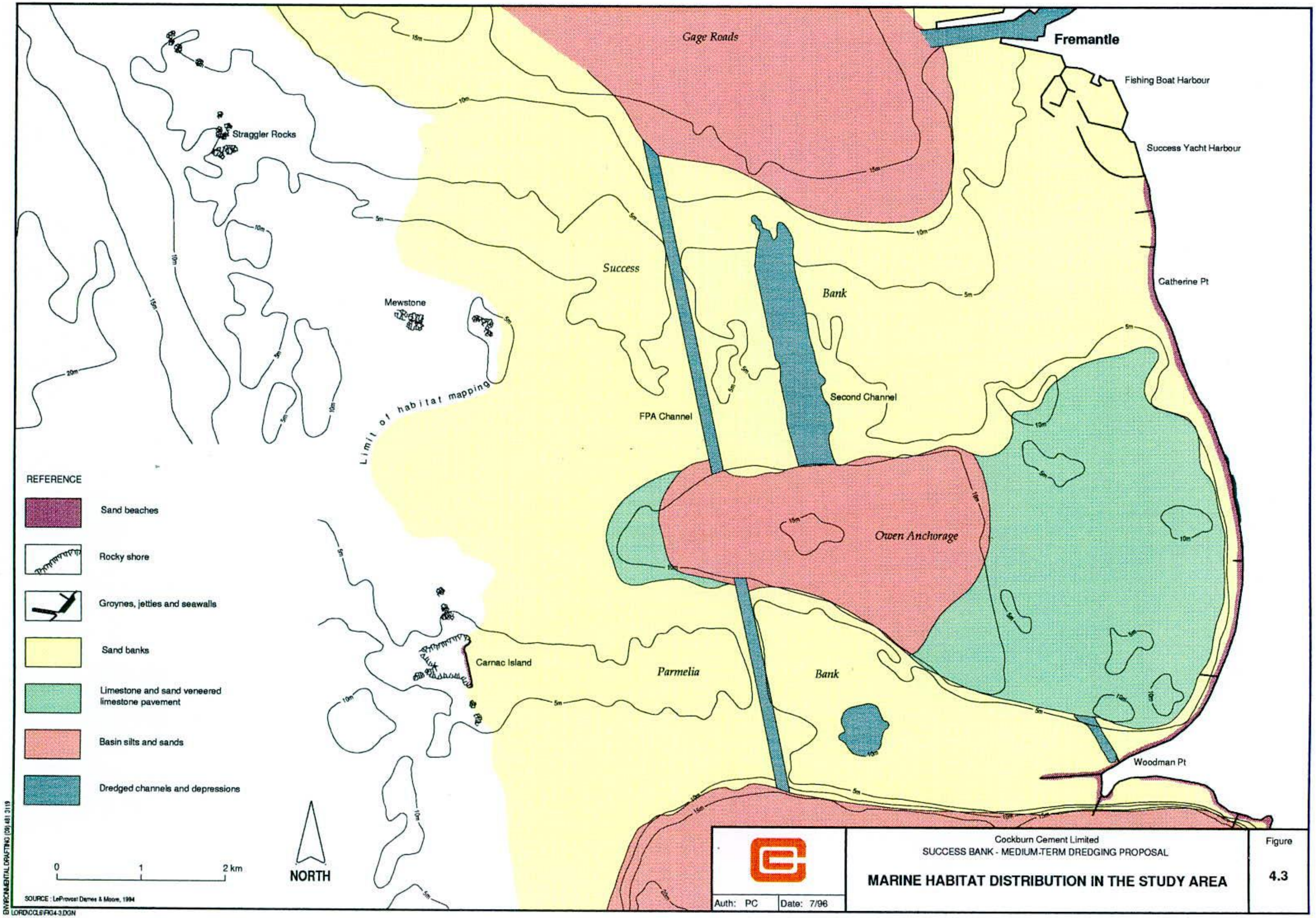
Cockburn Cement Limited
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

ESTIMATED NET ANNUAL SEDIMENT FLUXES (m^3/yr) IN OWEN ANCHORAGE, 1970 - 1990

Figure 4.2

Auth: MPR&A | Date: 7/96

LORD/CCL6/FIG4-2.DGN



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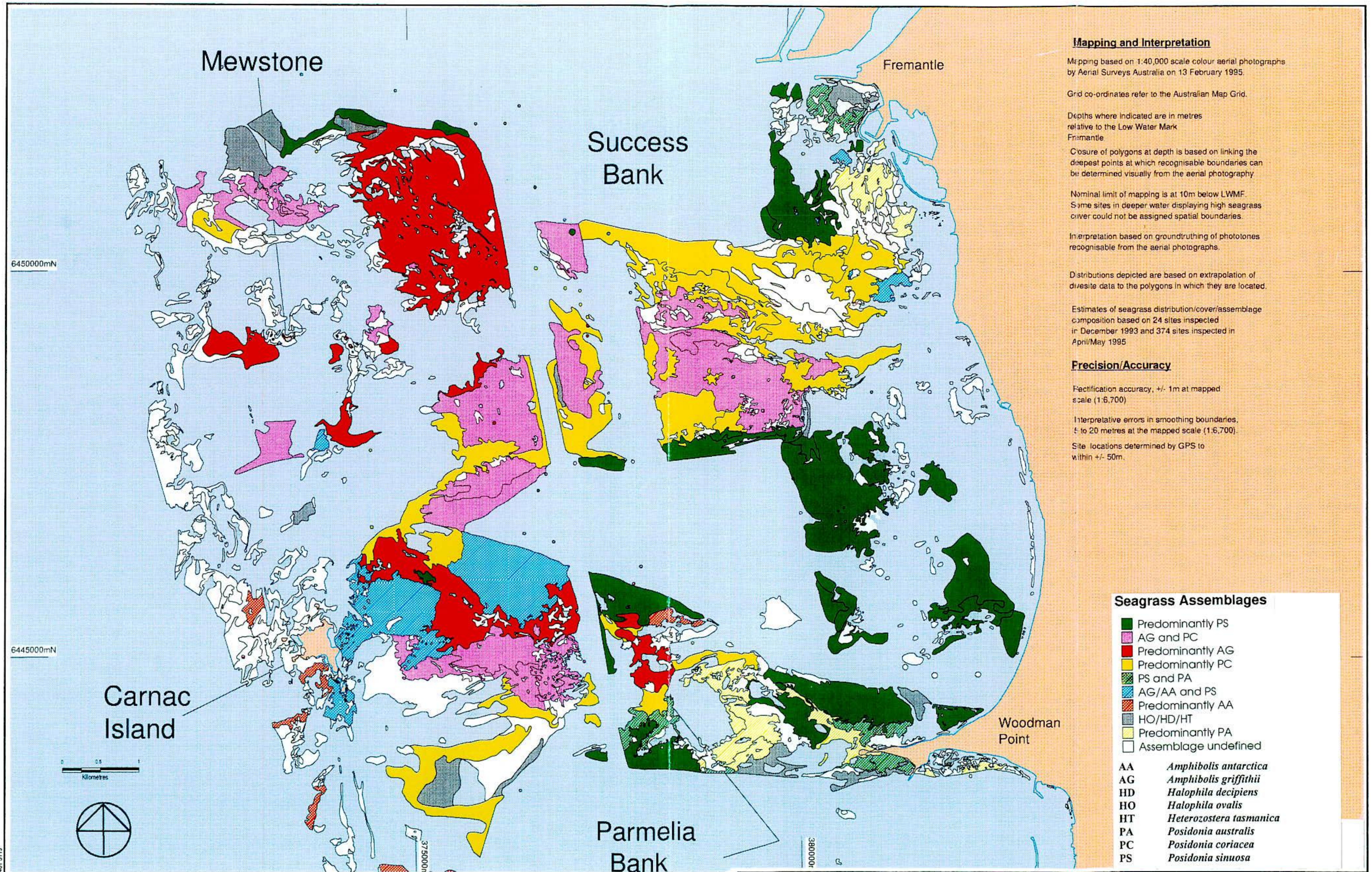
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

MARINE HABITAT DISTRIBUTION IN THE STUDY AREA

Figure 4.3

Auth: PC | Date: 7/96



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SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

SEAGRASS ASSEMBLAGES IN THE STUDY AREA

Figure 4.4

Auth: DAL | Date: 7/96

SOURCE : LeProvost Dames & Moore, 1996

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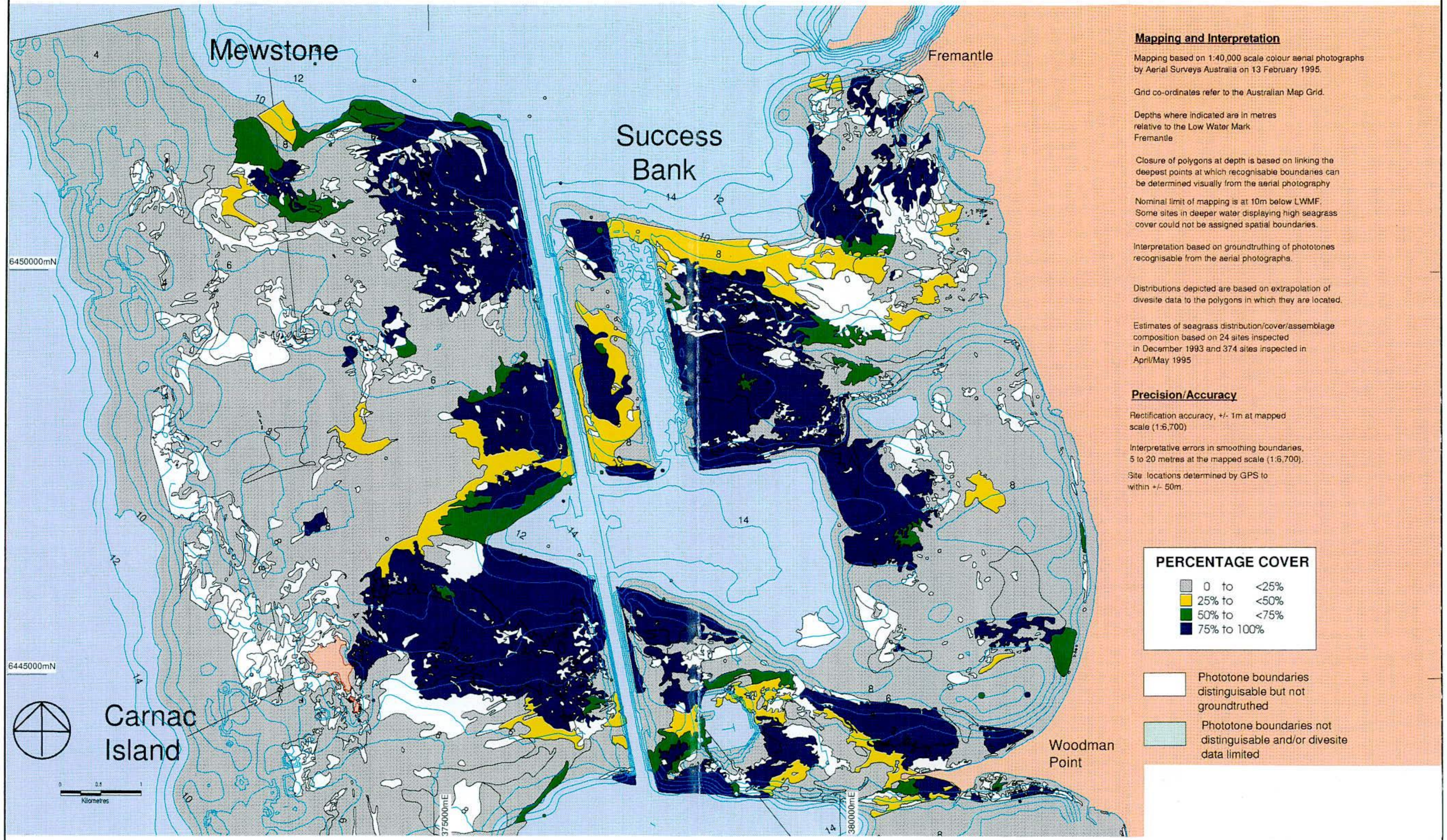
LORD\CCL6\FIG4-4.DGN



SOURCE : LeProvost Dames & Moore, 1996

	Cockburn Cement Limited SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL **DENSITY OF SEAGRASS COVER IN THE STUDY AREA**	Figure 4.5
Auth: DAL	Date: 7/96		

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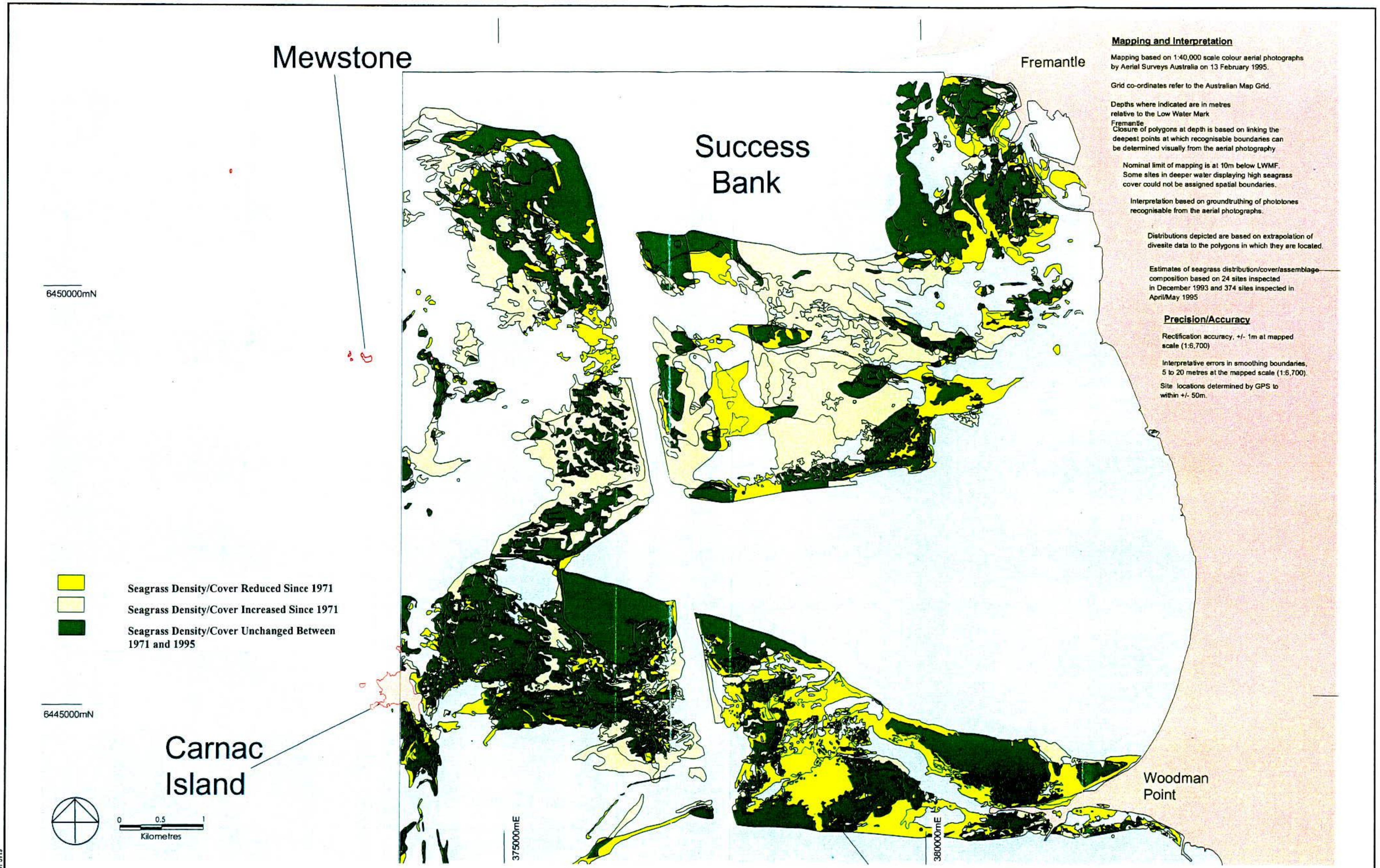
LORD\CCL6\FIG4-5.DGN



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SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

COMPARISON OF SEAGRASS COVER / DENSITY SUCCESS AND PARMELIA BANKS 1971 AND 1995

Figure 4.6

Auth: PC Date: 7/96

SOURCE : LeProvost Dames & Moore, 1996

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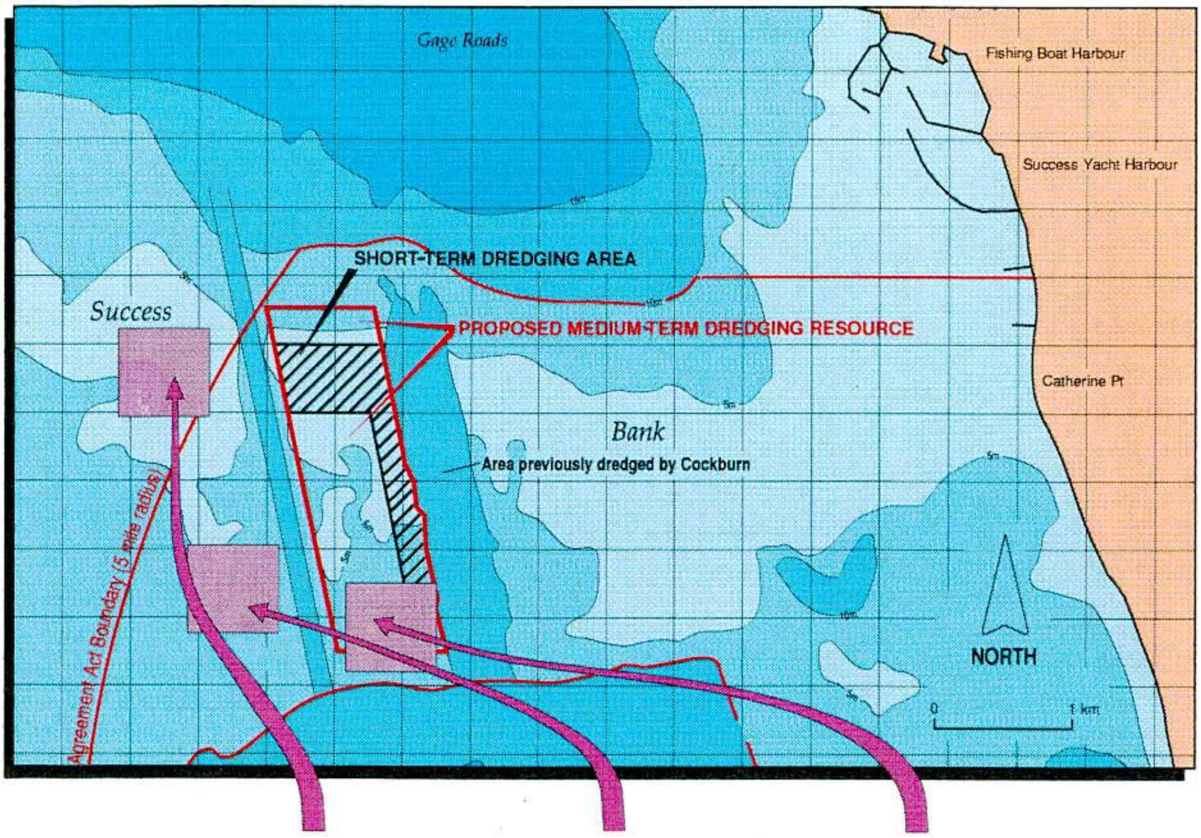
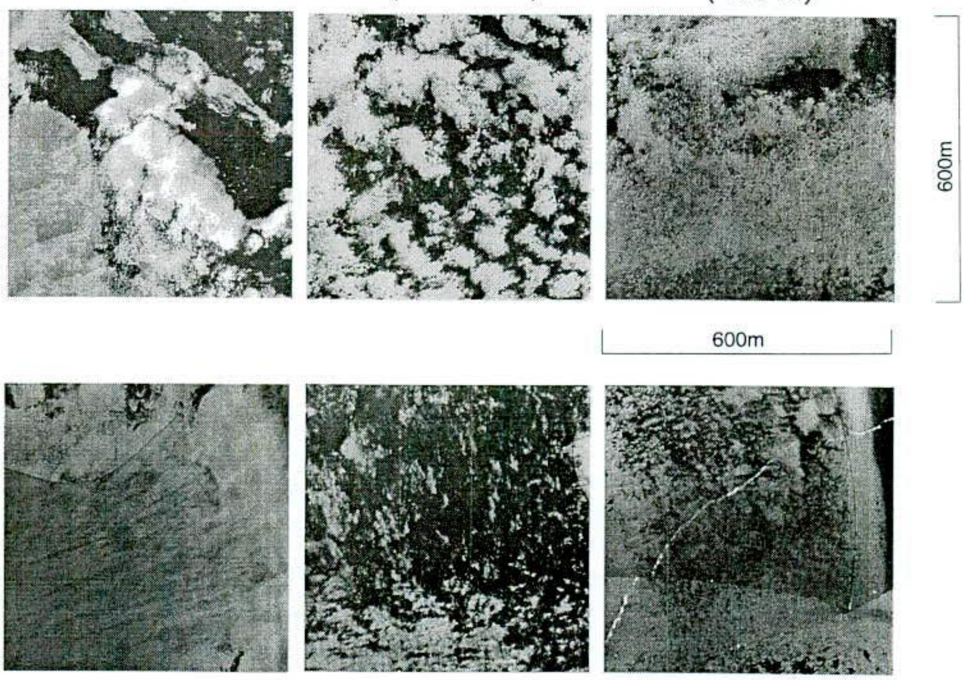
LORD\CCL6\FIG4-A.DGN



Large Scale Changes (>100 m)	Medium Scale Changes (20 - 50 m)	Small Scale Changes (<10 m)

1972

1993



Loss of seagrass due to sand migration west of FPA channel	Seagrass infilling of sand patches west of the southern end of the FPA channel	Increase in size and numbers of seagrass patches at southern end of medium term dredging area

	Cockburn Cement Limited SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL **CHANGES IN SEAGRASS COVER ON SUCCESS BANK BETWEEN 1972 AND 1993**	Figure **4.7**
Auth: DAL Date: 7/96		

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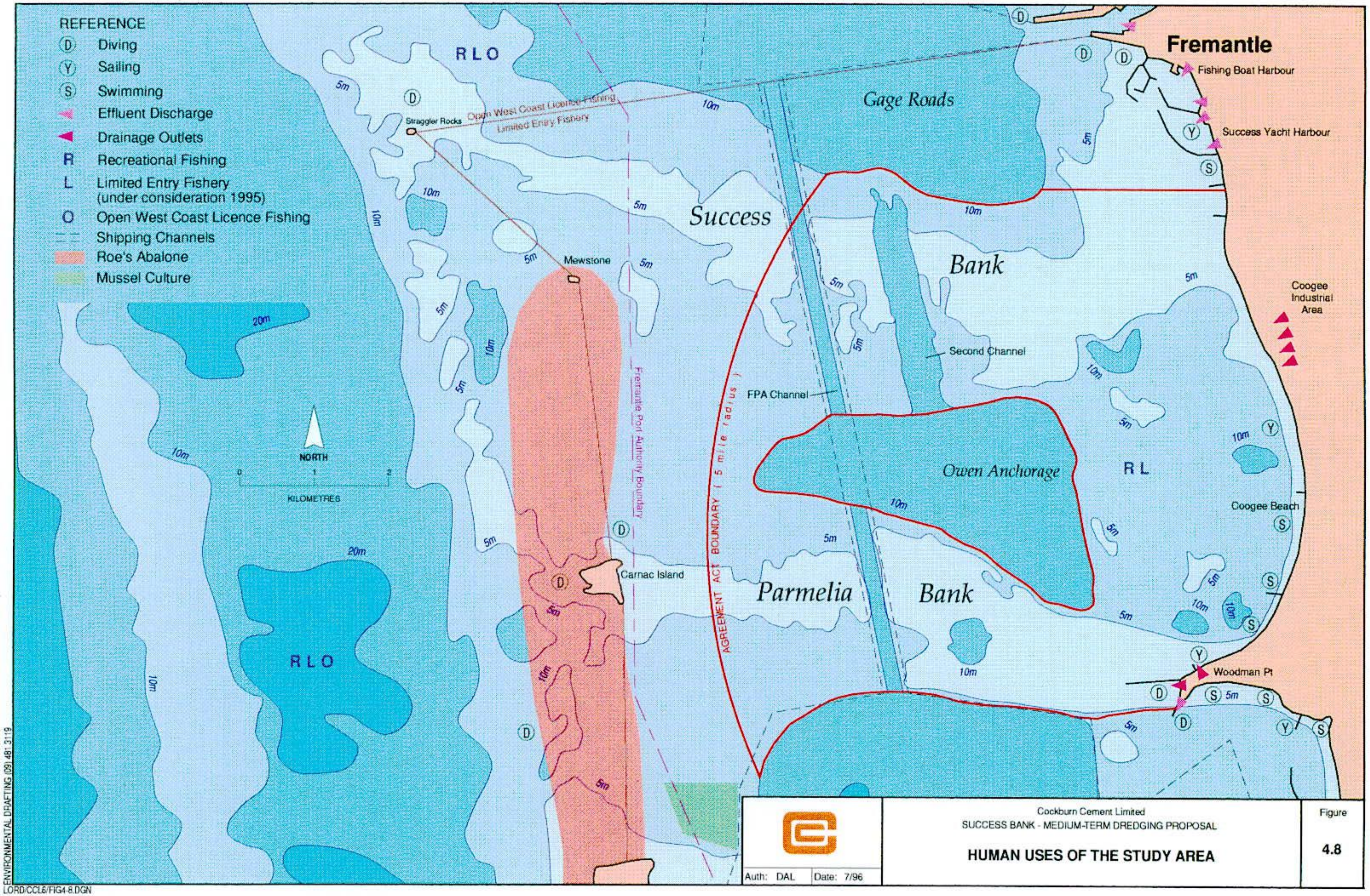
LORD\CCL6\FIG4-7.DGN



Cockburn Cement Limited
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

HUMAN USES OF THE STUDY AREA

Figure 4.8

Auth: DAL Date: 7/96

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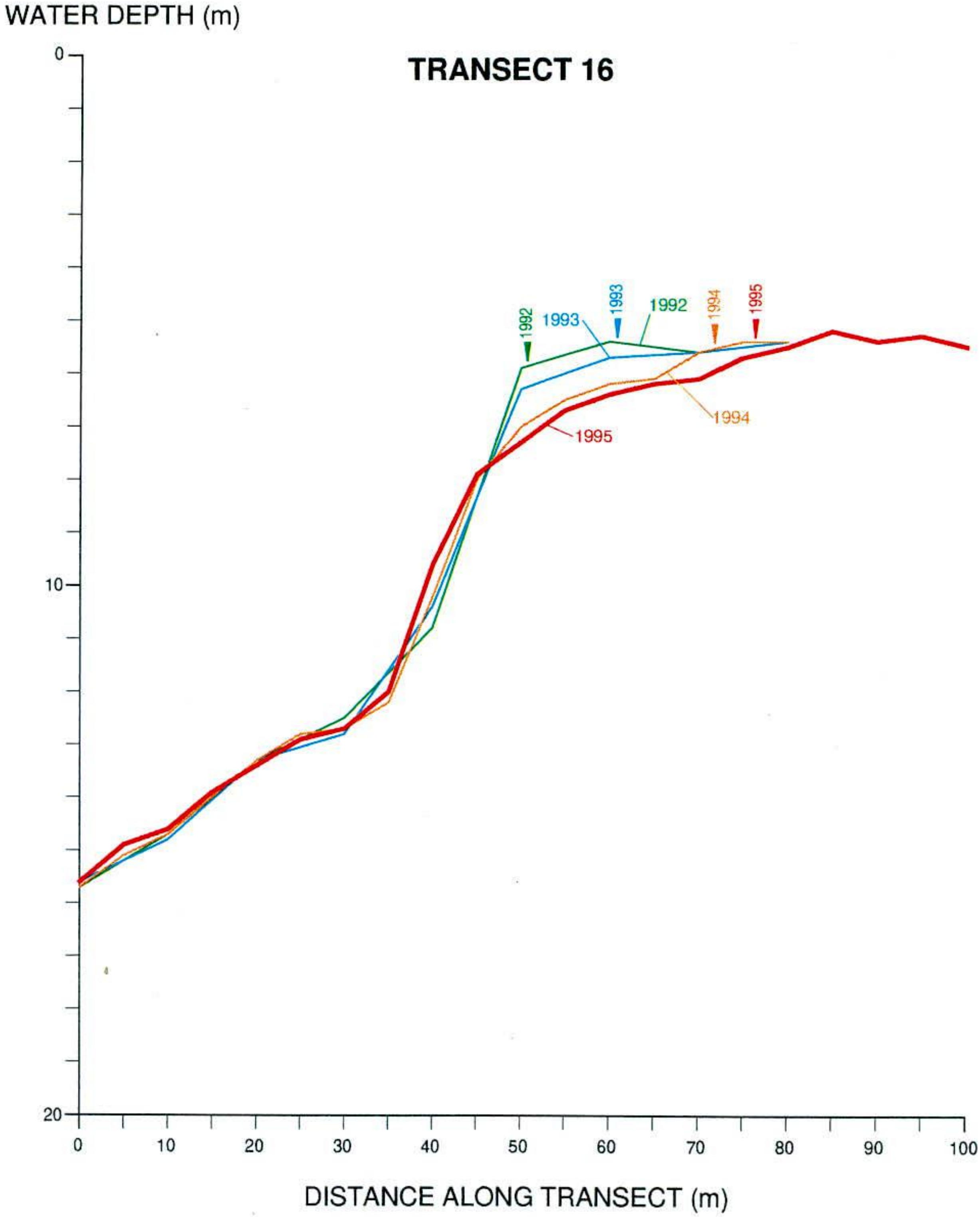
LORD/CCL6/FIG4-8.DGN



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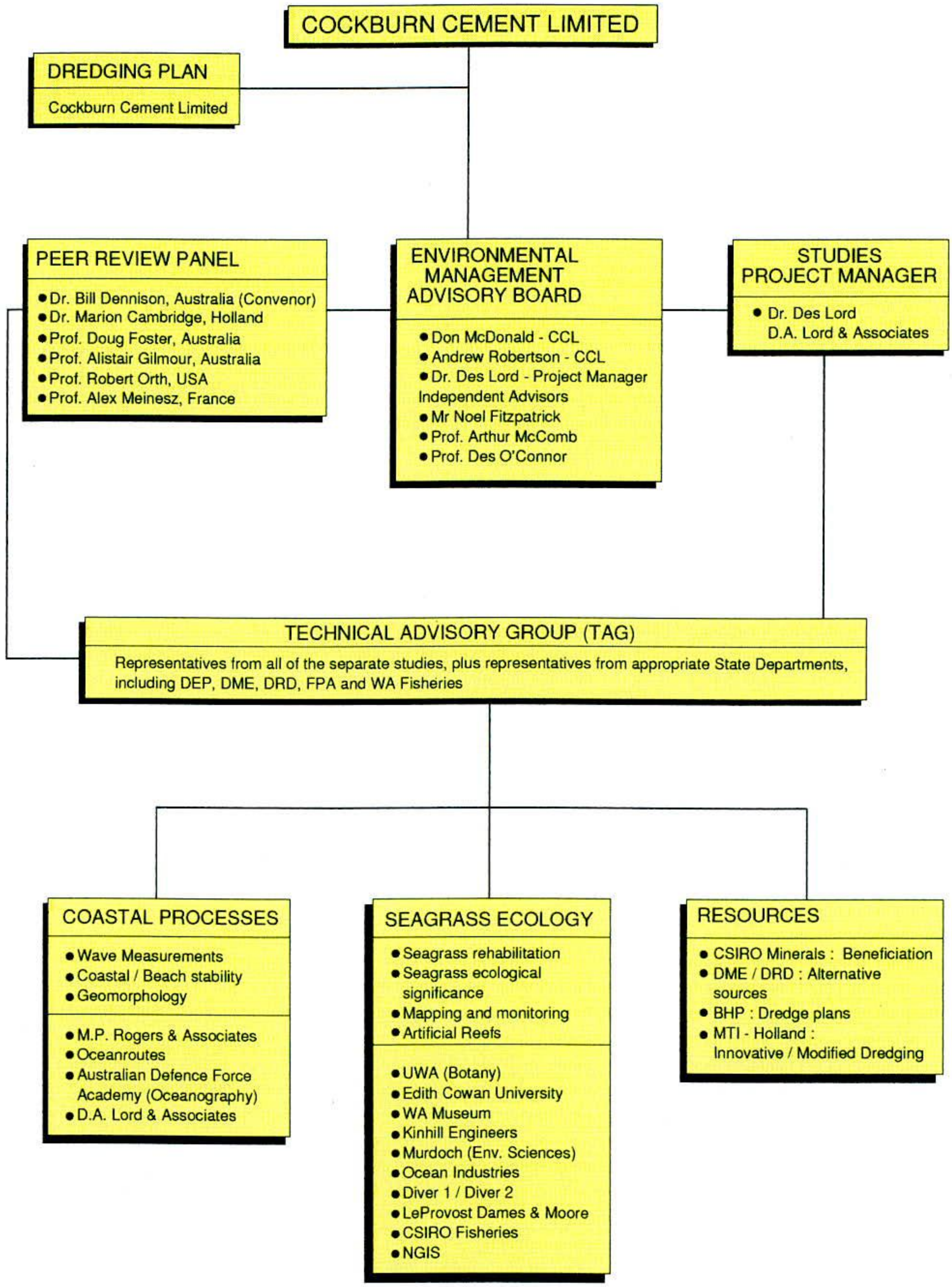
LORD/CCL6/FIG5-1.DGN

Cockburn Cement Limited

SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

ANNUAL CHANGES IN A DREDGED SLOPE PROFILE ON THE EASTERN SIDE OF THE SECOND SHIPPING CHANNEL

Figure 5.1



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Cockburn Cement Limited
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

MANAGEMENT STRUCTURE FOR IMPLEMENTATION OF THE EMP

Figure **8.1**

Auth: DAL | Date: 7/96

LORD\CCL6\F8-1.DGN

Plate 1: The water jet suction dredge 'Success'.

Plate 2: Dredge in operation. Downstream turbidity is intermittent and limited in area.

Plate 3: ECOSUB1 underwater seagrass transplanter.

Cockburn Cement Limited
SUCCESS BANK - MEDIUM-TERM DREDGING PROPOSAL

PLATE 3

Auth: DAL	Date: 7/96	Plate 3

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LORD\CCL6\CCL6PLA2.DGN

Appendix 1

Auditing System for the Management of the Medium-Term Dredging Programme

APPENDIX ONE

AUDITING SYSTEM FOR THE MANAGEMENT OF THE MEDIUM-TERM DREDGING PROGRAMME

1. PURPOSE AND COMPONENTS OF AUDIT SYSTEM

This Appendix outlines the Compliance Audit System proposed by Cockburn with regard to its proposal for medium-term dredging. Audit Systems are normally established after Ministerial approval for a project has been given. Consequently, Audit Systems are constructed based on a combination of Ministerial requirements and the proponent's commitments. This Audit System has been prepared by the proponent prior to any approval and therefore only refers to commitments by the proponent. It is anticipated that this Audit System will be discussed with the DEP and modified where necessary subsequent to the review of this proposal.

The **objective** of a Compliance Audit System is to ensure that all of the proponent's commitments and the Ministerial Conditions applicable to a proposal are met by the proponent at the appropriate time and stage in the proposed project's life. The **purpose** of an Audit Compliance System is to provide a formal mechanism by which the DEP and the Company can track the progress of a project, and determine when and how the environmental conditions have been satisfied. This is achieved by establishing an Audit Table which identifies the auditable elements of the project and the associated timetable for compliance, and by provision of periodic Progress and Compliance reports by the proponent to the DEP.

2. AUDIT TABLE

The purpose of an Audit Table is to identify the features that must be audited, to provide a timetable for actions to be taken and to indicate how environmental clearance is achieved. An Audit Table has been prepared for the components of the proposed medium-term dredging programme and is presented in Audit Table 1. This is accompanied by Addendum 1 which provides specific milestone dates for certain of the auditable features.

AUDIT TABLE NO 1: Conditions which Apply to the Medium-Term Shellsand Dredging: Owen Anchorage Project

CONDITIONS/COMMITMENT NO ENVIRONMENTAL FACTOR	WHAT ACTION MUST BE TAKEN	TO REQUIREMENTS OF	STATUS (if blank, activity not scheduled)
P1: COMMITMENTS	Action: Fulfil the commitments How: As per CER	DEP	
P2: IMPLEMENTATION OF PROPOSAL	Action: Adhere to the proposal How: In accordance with any designs, specifications, plans and or other technical material submitted by the proponent to the Environmental Protection Authority	DEP	
P3: REHABILITATION	Action: Rehabilitate any areas dredged from the date of commencement of medium-term area consistent with the results of the EMP studies	DEP	
P4: DREDGING	Action Any medium-term dredging to be confined between the FPA shipping channel and the second channel on Success Bank Report: Annual reports	FPA DEP	
P5: EMP COMMITMENT - ECOLOGICAL SIGNIFICANCE OF SEAGRASS	Action: Evaluate the Ecological Significance of seagrasses, according to Addendum 1 of this audit table Report: Annual reports	DEP With advice from: FPA WA Fisheries DME	Underway
P6: EMP COMMITMENT - SEAGRASS TRANSPLANTATION	Action: Develop Technology for Seagrass Transplantation according to Addendum 1 of this audit table Report: Annual reports	DEP With advice from: FPA WA Fisheries DME	Underway

AUDIT TABLE NO 1: Conditions which Apply to the Medium-Term Shellsand Dredging: Owen Anchorage Project

CONDITIONS/COMMITMENT NO ENVIRONMENTAL FACTOR	WHAT ACTION MUST BE TAKEN	TO REQUIREMENTS OF	STATUS (if blank, activity not scheduled)
P7: EMP COMMITMENT - SEAGRASS MAPPING	Action: Undertake mapping of seagrass cover in study area, according to the following timetable: • map seagrasses 1995 — complete • time series analysis 1965-1995 — June 1997 • map seagrasses 1999 — 1999 Report: Annual reports	DEP With advice from: FPA WA Fisheries DME	Underway
P8: EMP COMMITMENT - ARTIFICIAL REEFS	Action: Develop Artificial Reefs, according to the following timetable: • design — 1997 • installation, if feasible — 1997 • assessment — 1999 Report: Annual reports	DEP With advice from: FPA WA Fisheries DME	Underway
P9: EMP COMMITMENT - COMMERCIAL BENEFICIATION	Action: Develop commercial beneficiation process, according to Addendum 1 of this audit table Report: Annual reports	DME	Underway
P10: EMP COMMITMENT - ALTERNATIVE RESOURCES	Action: Evaluate alternate resources, according to Addendum 1 of this audit table Report: Annual Reports	DEP DME FPA	Underway
P11: EMP COMMITMENT - MEDIUM-TERM DREDGING PLANS	Action: Prepare dredging plans for medium-term dredging, and review regularly; at least quarterly Report: Annual reports	FPA DEP	Underway

AUDIT TABLE NO 1: Conditions which Apply to the Medium-Term Shellsand Dredging: Owen Anchorage Project

CONDITIONS/COMMITMENT NO ENVIRONMENTAL FACTOR	WHAT ACTION MUST BE TAKEN	TO REQUIREMENTS OF	STATUS (if blank, activity not scheduled)
P12: EMP COMMITMENT - WAVE MODELLING	Action: Undertake wave modelling of medium-term and potential long-term dredging options according to Addendum 1 of this audit table Report: Annual reports	DEP	Underway
P13: EMP COMMITMENT - SHORELINE MONITORING	Action: Implement routine summer and winter shoreline monitoring of Owen Anchorage Report: Annual reports	FPA DEP	Underway
P14: EMP COMMITMENT - PEER REVIEW	Action: Undertake international peer review of EMP studies Report: Periodically, at programme milestones and as projects end	DEP	Underway Initial review complete
P15: EMP COMMITMENT - LONG-TERM RESOURCES	Action: Develop a proposal for the long-term acquisition of resource, according to Addendum 1 of this audit table Report: Interim reports annually; proposal at least 15 months prior to the depletion of medium-term resource	DEP With advice from: FPA WA Fisheries DME	

ADDENDUM ONE TO AUDIT TABLE ONE: Major milestones for implementing EMP studies and for preparing Cockburn's strategy for long-term resource acquisition as described in this CER.

	ITEM	DATE
1.	**EVALUATE ECOLOGICAL SIGNIFICANCE OF SEAGRASSES**	
1.1	Initial appraisal for proposed medium-term area	complete
1.2	Develop detailed assessment procedures based on measurements	mid 1998 to mid 1999
1.3	Evaluate ecological effects of dredging potential sites for long-term resource - Success Bank - Parmelia Bank - Mewstone - other areas	mid 1999
2.	**SEAGRASS TRANSPLANTATION**	
2.1	Develop and construct prototype mechanical transplanter	complete
2.2	Trials, modification	mid 1997
2.3	Implement experimental transplantation	mid 1997 to mid 1999
2.4	Design/develop/test high rate transplantation procedures	1998 onwards
2.5	Monitor results	continuous
3.	**WAVE MODELLING**	
3.1	Develop and calibrate wave model for Owen Anchorage	complete
3.2	Assess influence on wave climate on proposed medium-term dredging	complete
3.3	Evaluate effects on wave climate of dredging potential sites for long-term resource - Success Bank - Parmelia Bank - Mewstone - other areas	1997 to mid 1999
4.	**BENEFICIATION**	
4.1	Laboratory trials	complete
4.2	Pilot Plant (0.1–5 tph)	mid 1997
4.3	Design/construct small scale demonstration plant (200,000 tpa)	mid 1998
4.4	Select technology for full scale beneficiation of 2 million tpa	mid to end 1999
4.5	Design, construct and commission full scale production facility	2000 and 2001
5.	**ALTERNATIVE RESOURCES**	
5.1	Terrestrial Resources	
	5.1.1 Review potential terrestrial resources Geraldton to Augusta	end 1996
	5.1.2 Assess potential for terrestrial resources	mid 1998
	5.1.3 Select sites, acquire resource	1999–2001
5.2	Marine Resources	
	5.2.1 Review existing information	complete
	5.2.2 Assess potential resources; grade, ease of extraction, environmental issues	mid 1998
	5.2.3 Recommend potential marine resources for long-term dredging	mid 1999
	5.2.4 Design/modify dredging equipment for use in other marine resources	1999
6.	**DEVELOPMENT OF PROPOSAL FOR LONG-TERM RESOURCE ACQUISITION**	
6.1	Preliminary review and feasibility study of all potential resources with regard to economic, environmental and practical issues	mid 1998
6.2	Identification of candidate sites for long-term resource acquisition	mid 1998
6.3	Undertake detailed environmental assessments of candidate sites	mid 1997 to mid 2000
6.4	Recommendations for long-term resource acquisition	mid 2000
6.5	Gain approval for site(s) for long-term resource acquisition	end 2001