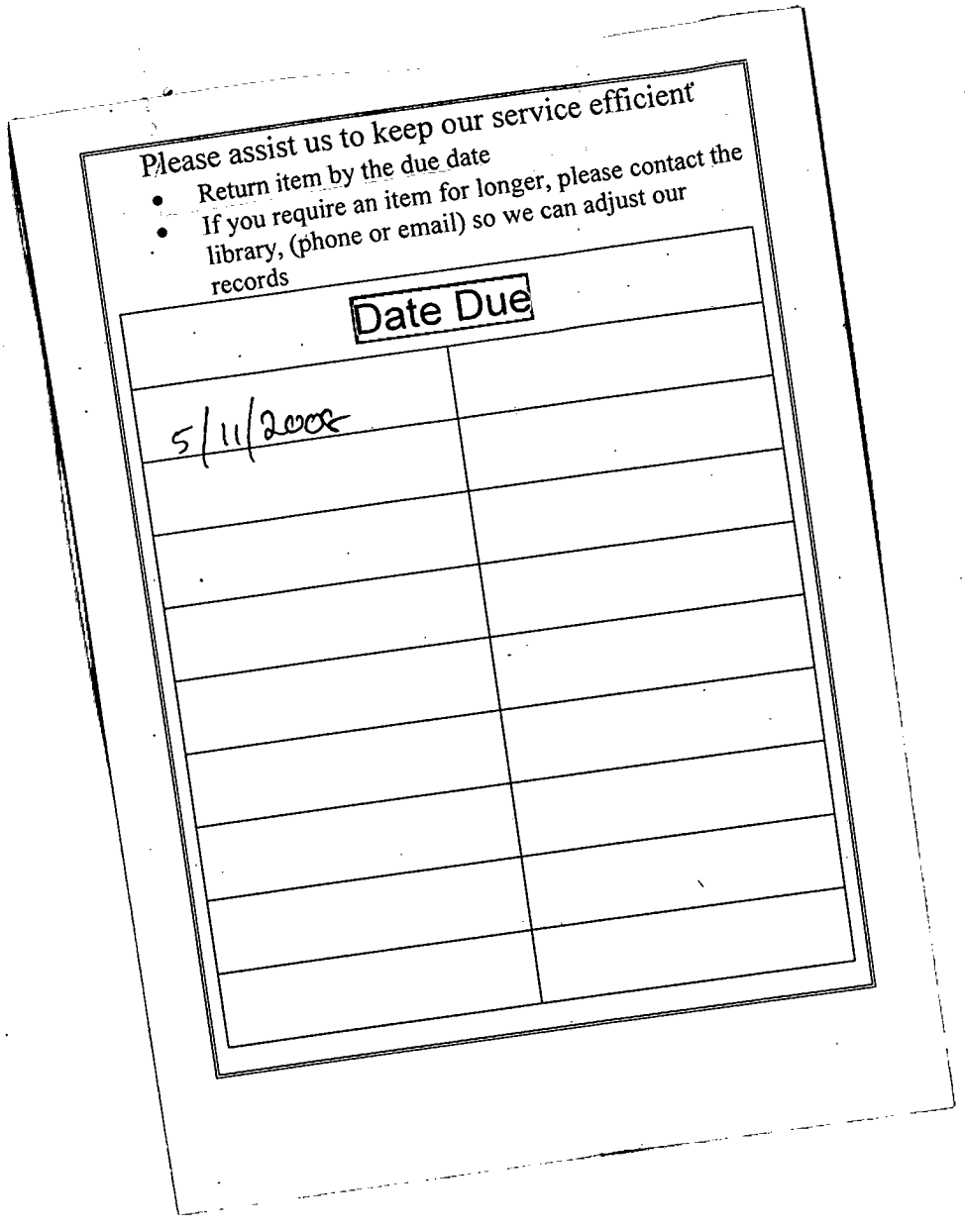
CONSTRUCTION OF ADDITIONAL CRYSTALLISERS
Useless Loop, Shark Bay

Shark Bay Salt Joint Venture

CONSULTATIVE ENVIRONMENTAL REVIEW

September 1998



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Invitation to make a submission

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

Shark Bay Resources Pty Ltd, on behalf of the Shark Bay Salt Joint Venture proposes to construct a new levee for crystalliser development within Mineral Lease 260SA at its salt field at Useless Loop, in Shark Bay. In accordance with the Environmental Protection Act, a Consultative Environmental Review (CER) has been prepared which describes this proposal and its likely effects on the environment. The (CER) is available for a public review period of 4 weeks from Monday 31 August, 1998 closing on Monday 28 September, 1998.

Comments from government agencies and from the public will help the EPA to prepare an assessment report in which it will make 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 provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part in the EPA's report.

Why not join a group?

If you prefer not to write your own comments, it may be worthwhile joining with a group 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 specific 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 more environmentally acceptable.

When making comments on specific elements of the (CER):

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

Points to keep in mind

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

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the (CER);
- if you discuss different sections of the (CER), keep them distinct and separate, so there is no confusion as to which section you are considering;
- 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: 28 September, 1998.

Submissions should be addressed to:

The Environmental Protection Authority
Westralia Square
141 St George's Terrace
PERTH WA 6000

Attention: Ms Rochelle Smith

SUMMARY

The Shark Bay Salt Joint Venture (SBSJV) proposes to extend its existing salt crystalliser pond facilities at the mouth of Useless Loop, Shark Bay. The additional ponds will be located within the SBSJV's existing Mining Lease ML260SA. The mining lease boundary is 1.5 sea kilometres from the closest point of the Shark Bay World Heritage Area/Marine Reserve.

An estimated 300,000 m^3 of calcareous, marine-origin borrow (from an existing borrow pit near the construction site) will be used to construct the 2,000-metre-long sea-wall of the facility. The pond so created will have an area of 150 hectares; approximately 60 ha of this area is a seagrass meadow composed almost entirely of *Posidonia australis* and *Amphibolas antarctica*, which are the most common species of seagrass in the Shark Bay region, and are not the preferred food resource of dugongs, which inhabit the region.

The embankment will be rock-armoured on the seaward side. Both rock and general fill will be extracted from the borrow pit with an excavator and front-end loader, and placed by dumping from trucks and pushing with a dozer.

To commission the crystallisers, bitterns from the existing salt-field operations will be evaporated in successive layers to seal the pond bottom. Pickle will then be introduced as part of the integrated salt-production process.

The only significant environmental impact of this proposal is the loss of some 60 hectares of seagrass – 0.014% of the total seagrass resource of the Shark Bay area. Most of the seagrass to be lost is *Posidonia australis* and *Amphibolas antarctica*, neither of which is a preferred food resource for the dugong.

Indirect impacts on undisturbed seagrass and the World Heritage Area/Marine Reserve are considered improbable. Coastal engineering studies indicate that sediment generated during construction and/or from erosion of the operating facility will not travel more than a few hundred metres offshore. No impact on the World Heritage Area/Marine Reserve is therefore expected, and the sediment plume which is generated from construction activities is unlikely to blanket nearby seagrass communities, because of its physical properties and its marine origin.

The probability of significant impacts on marine fauna, terrestrial fauna, rare and priority flora, seabirds, recreation, foreshore habitats and heritage sites is small, even inconsequential. Other than the seagrass environment, habitats and sites lost through development of this project are either already well represented in the area or will in part be re-created on the seaward wall of the proposed facility.

The following table (Table 1) summarises the impact assessment analysis conducted for this proposal. Table 2 summarises the proponent's commitments to environmental management.


CRYSTALLISER
DEVELOPMENT

SHARK BAY SALT FIELD

Figure (1)

LOCATION MAP

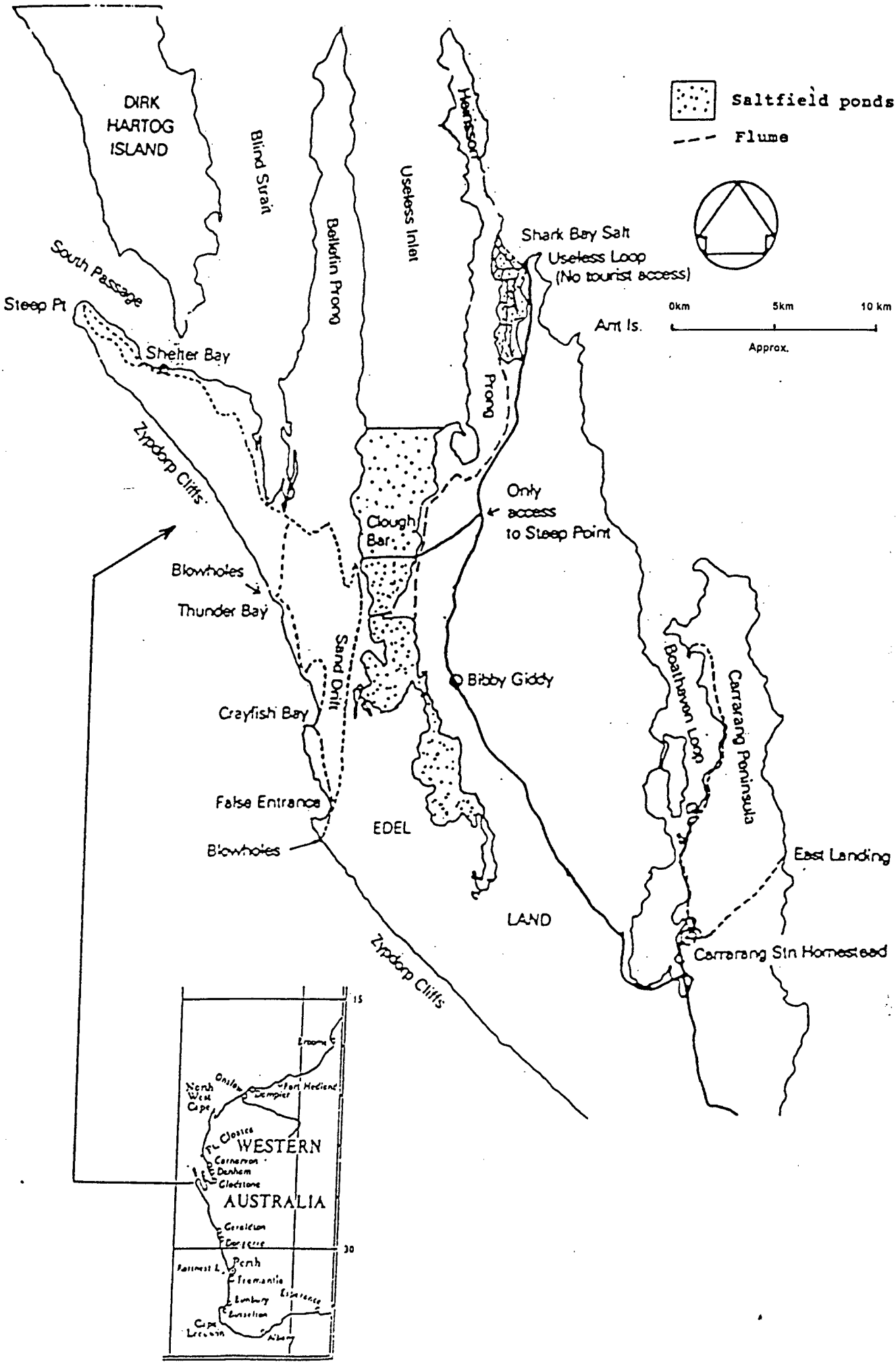
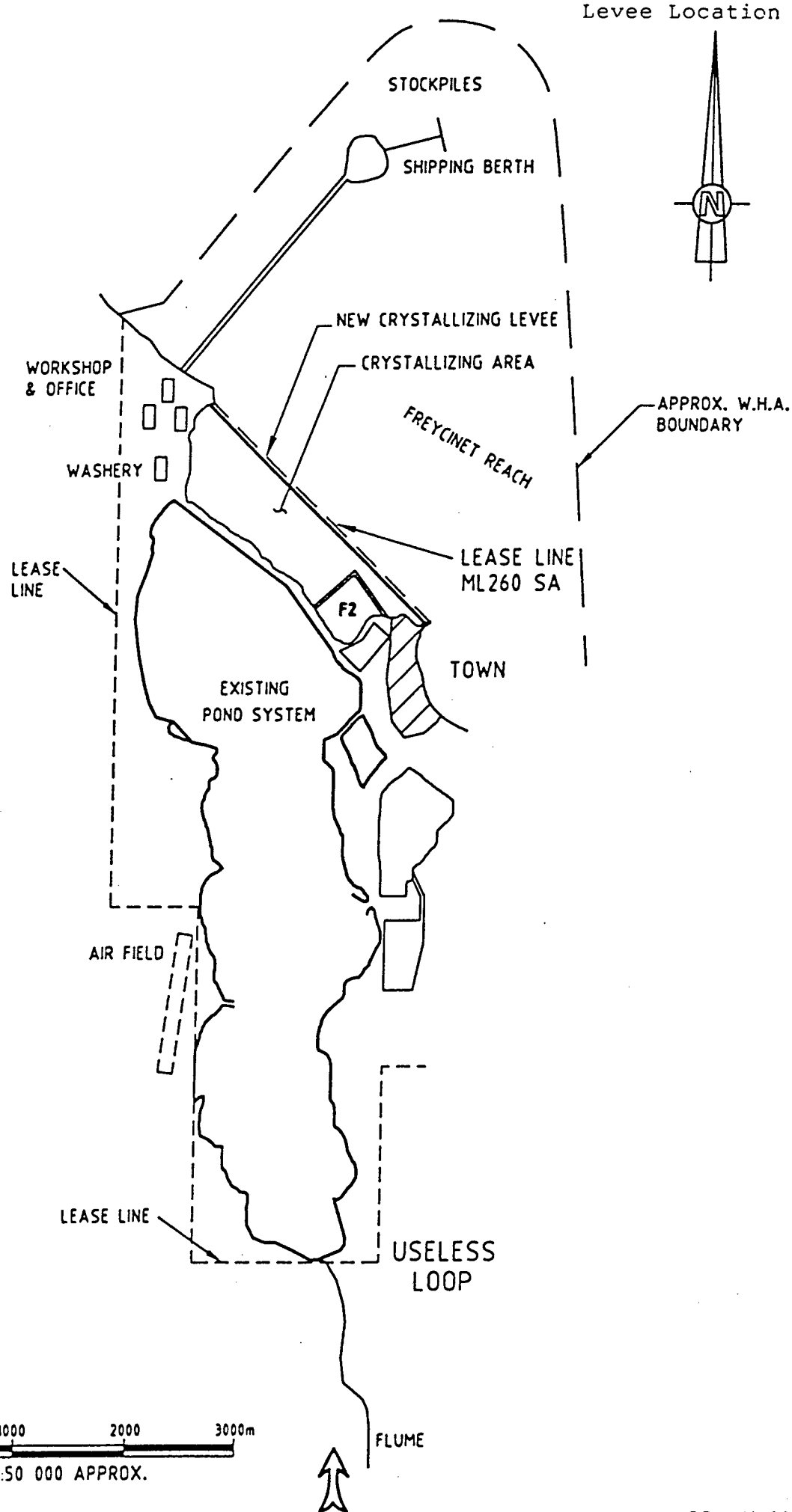


Figure (2)
Levee Location



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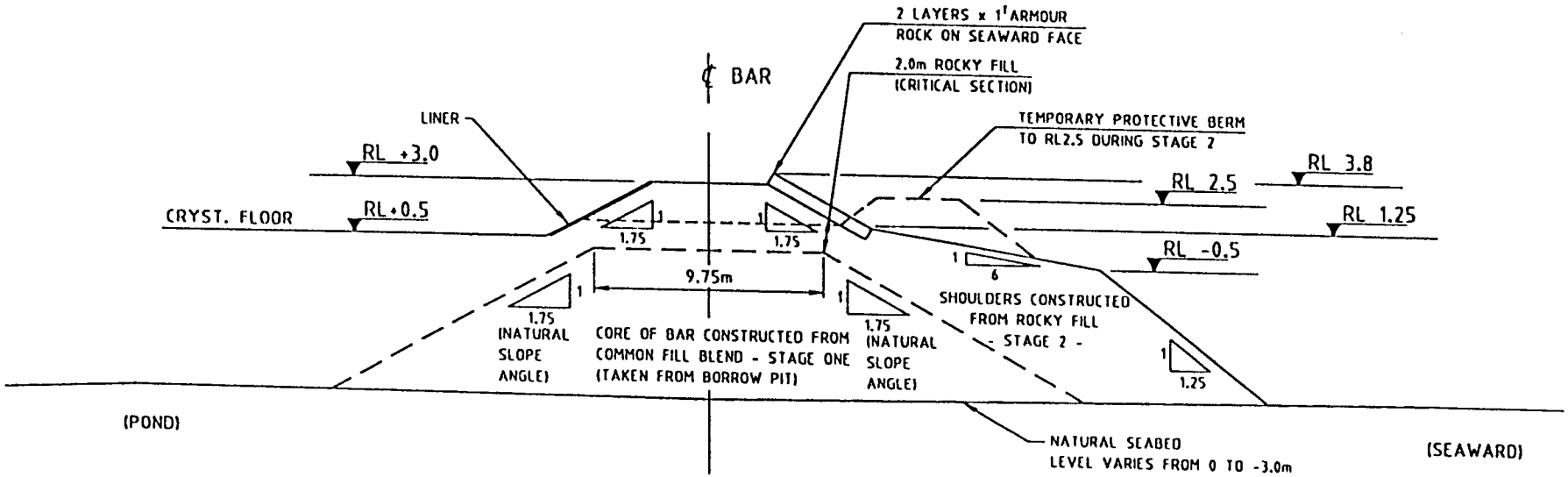

NEW CRYSTALLISERS LEVEE

TYPICAL CROSS SECTION

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FOR FRONT POND

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Figure (3)
Typical Cross Section

TABLE 1. Summary of issues and relevant environmental factors

Environmental Factor	Existing Environment	Value of site on regional scale	EPA objective	Potential environmental impacts	Relevant standards or regulations	Management response	Predicted outcome
BIOPHYSICAL							
Seagrass	Mainly *Posidonia australis* and *Amphibolas antarctica* meadow.	Area lost would represent less than 0.014% of the total Shark Bay seagrass resource. Seagrass species are not prime food for dugongs.	Maintain the ecological function, species diversity and geographic distribution of seagrass.	In addition to direct loss of 0.014% of total regional resource, turbidity from construction and operation could impact nearby seagrass areas. However, coastal engineering studies suggest insignificant impacts.		Turbidity and other monitoring programmes, similar to those used successfully in recent development at Useless Inlet, will be established. Construction activity will be halted if high-risk weather and tide situations require.	Impacts restricted to 0.014% of total Shark Bay seagrass resource. Indirect impacts manageable, using proven monitoring programmes.
Marine fauna	No local recreational fishing. Dugongs and turtles are rare visitors. Fish numbers are low, mainly mullet, whiting etc.	Fishing resources are well replicated in the region, and better food resources for dugongs exist elsewhere in the region. No special characteristics as turtle habitat. Not utilised by dugongs	Avoid impacts on marine fauna and their habitats. Meet the requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act. Adhere to national and international legal obligations.	Loss of habitat.	Wildlife Conservation Act. Endangered Species Act (C'wlth).	Fish habitat to some extent replicated on outer wall of proposed facility. Dugong and turtle presence will be monitored and any animals entering the work area protected.	Small loss of fish habitat (in part replicated). No impact on larger fauna.
Seabirds	Occasional use of artificial shore and near-shore area by low numbers of various birds.	Relatively low; better habitats have been created by the biota-rich ponds elsewhere in the salt-field.	Avoid impacts on seabirds and their habitats; meet requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act; adhere to national and international legal obligations.	Loss of small habitat, with part re-creation on outer side of proposed facility.	Wildlife Conservation Act. Endangered Species Act (C'wlth).	None required	No significant impact.
Terrestrial fauna	Extremely small area of dry land affected: expansion of existing borrow-pit in disturbed area.	Very low; area highly disturbed for transport and township-related activities.	Maintain the abundance, species diversity and geographical distribution of terrestrial fauna	Loss of vegetation	Wildlife Conservation Act	No significant action required	No significant impact.
Declared rare and priority flora	Extremely small area of vegetation affected: expansion of existing borrow-pit in disturbed area.	Very low; area already highly disturbed (see above).	Protect declared rare and priority flora.	Loss of vegetation in already-disturbed area.	Wildlife Conservation Act.	Conduct survey for declared rare and priority flora in area to be disturbed.	No impact; area already disturbed; survey shows no occurrence of DRF found in comparable communities elsewhere in the area. and DRF unlikely to be found.

Foreshore	Artificial environment created by pond construction across Useless Loop. Gently-sloping beach and shallows providing minor bird and fish habitats.	Site is well-replicated in many bays and inlets in the region.	Maintain the integrity, function and environmental values of the foreshore area.	Loss, through inundation when crystallisers constructed and commissioned.		Foreshore values will in part be re-created on the outer wall of the proposed crystalliser embankment.	Loss of existing artificial habitat will be in part compensated by creation of similar site on proposed facility.
POLLUTION MANAGEMENT							
Marine water quality	Existing salinity slightly elevated compared with open sea; a function of evaporation characteristic throughout Freycinet reach. Water quality good – monitored as part of long-established environmental programme by SBSJV.	Value is that of all non-World Heritage areas of water in Shark Bay; buffer to the World Heritage Area.	Maintain or improve the quality of marine water.	Turbidity from construction activities and erosion of constructed embankment.	Draft WA Guidelines for Fresh and Marine Waters (EPA, 1993).	Monitor turbidity during construction, using methods applied successfully to recent similar developments. Suspend construction activities in the event of weather and tides likely to affect water quality significantly. Relocate existing chemical water quality monitoring to waters immediately offshore new facilities.	Minor, transient increases in turbidity during embankment construction. Coastal engineering studies indicate low probability of significant or frequent impacts.
Shipping	Existing channel to open sea and turning basin near ship-loader are part of Carnarvon Harbour.	Limited environmental value, but very large economic value.	Ensure that any increase in shipping activities from the project does not adversely impact on surrounding environment.	Potential impacts are small; channel and turning basin are well-established navigation areas. And increased size of ships expected to offset need for additional voyages.	Marine Accidents and Pollution: Impacts on the Marine Environment from Shipping Operations (ANZECC, 1995).	Continueimplementation of ballast-management protocols and adherence to relevant regulations by shipping operators.	No increase in impacts anticipated; Use of larger ships is expected to counter-balance increased production.
SOCIAL SURROUNDINGS							
Shark Bay World Heritage/Marine Reserve	Internationally-recognised environment for protection of marine ecosystems.	Exceptionally high on local and global basis.	Protect the conservation values, biodiversity and ecosytem functions of the Shark Bay World Heritage/Marine Reserve.	Significant impacts are improbable, due to remoteness of project area from conservation area, but theoretical potential for impacts on water quality.	CALM and other Management Plans for conservation area.	Monitor water quality during construction and in operations. Suspend construction activity in adverse weather and tide conditions.	No impacts anticipated.
Recreation	Area not used for recreation.	No particular value; site-type is well replicated in the area and region.	Ensure that the recreational values of the area are not compromised.	Loss of access to reclaimed waters.		Comparable sites exist nearby, and access to these sites is encourage by SBSJV. Fishing habitat will be in part re-created on seaward side of the proposed facility.	No significant impacts'; many under-utilised alternatives in the area.
Heritage	No known significance; shore is artificial and near-shore area has no particular characteristics.		Comply with statutory requirements in relation to areas of cultural or historical interest.	None perceived.	Aboriginal Heritage Act.	Observe requirements of the Aboriginal Heritage Act, especially during borrow pit operations.	No impacts anticipated.

TABLE 2. Summary of proponent's commitments

For the construction and operation of the F-series crystallisers at Useless Loop, the Shark Bay Salt Joint Venture makes a number of commitments to environmental management. These commitments are discussed in detail in the body of this document, and are summarised below for convenience.

Commitment	Objective	Action	Timing	On advice from	Measurement/Compliance
1. Protection of seagrass outside levee from indirect impacts	To protect undisturbed seagrass from unacceptable impacts from turbidity generated from the crystalliser embankment.	The proponent will: (a) employ the turbidity-monitoring methods proven in recent times for pollution prevention during bar construction in Useless Inlet; (b) monitor weather and tide conditions and cease construction operations in adverse situations; (c) relocate the established marine water-quality programme to the seaward side of the new facility.	(a) During construction. (b) During construction. (c) Immediately after project approval is received.	(a) The Department of Environmental Protection (DEP). (b) Proponent's Resident Manager. (c) DEP.	(a) Secchi disk measurements and visual observation (land-based and aerial). Summary of results to be included in Annual Environmental Report (AER). (b) Based on experience with recent bar construction in Useless Inlet. Actions to be logged and included in AER
2 Protection of rare and priority flora	To ensure that no rare and priority flora are affected by borrow-pit activities.	Supplement previous DRF work by examination of areas prior to disturbance	Pre-construction.	Department of Conservation and Land Management (CALM).	Consult with CALM in the event of doubtful plant identification, and if rare or priority species are discovered.
3. Marine fauna.	Compliance with Wildlife Conservation Act and C'wlth Endangered Species Act	In the event of dugong or turtle activity in the construction area, ensure that fauna are not trapped in ponds, or threatened by construction work.	During construction.	CALM.	Log incidents and report – to CALM immediately if serious incident; otherwise in AER.
4. Marine water quality.	Compliance with draft WA Guidelines for Fresh and marine Waters (EPA, 1993).	See 1(a) and (c) above.	Construction and operations.	DEP.	Report immediately to DEP is incident serious; otherwise in AER.
5. Shipping-sourced pollution.	Compliance with protocols contained in "Marine Accidents and Pollution: Impacts on the Marine Environment from Shipping Operations" (ANZECC 1995).	Continueawareness of and compliance with ballast-management protocols.	Operations.	Australian Quarantine and Inspection Service.	Report incidents to DEP immediately if serious; otherwise in AER.
6. Fugitive dust.	Minimise dust generation from borrow pit and roads.	Ensure regular watering of borrow pit work areas and roads.	Construction.	Proponent's Site Manager.	Report in AER.
7. Heritage.	Ensure compliance with the Aboriginal Heritage Act.	Monitor borrow pit activities for evidence of Aboriginal artefacts or materials. Cease work and seek advice in the event of discovering artefacts or materials.	Construction.	Proponent's Site Manager.	Report to Department of Aboriginal Affairs in event of encountering artefacts or materials.

CONTENTS

1. Introduction

1.1 The proponent

Shark Bay Salt Joint Venture (SBSJV), the proponent of this proposal, is a joint venture between Shark Bay Salt Pty Ltd (35%), Salt Investments Pty Ltd (35%) and Mitsui Salt Pty Ltd (30%). Shark Bay Salt Pty Ltd and Salt Investments Pty Ltd are wholly-owned subsidiaries of Shark Bay Resources Pty Ltd, which is owned by AMP Investments Pty Ltd (50%) and Clough Limited (50%).

SBSJV is managed by Shark Bay Resources Pty Ltd, of 22 Mount Street, Perth, WA 6000.

The project operates under the aegis of the *Solar Salt (Shark Bay) Agreement Act 1983*. This act superseded a similar act which mediated the initial establishment of the project in the 1960s.

1.2 History of the project

The SBSJV solar salt project was the first modern salt project in Australia, constructed in 1965 to supply the growing markets of Asia.

The first shipments of salt were made in 1967, when 25,426 tonnes were exported. By 1997, annual production was almost 1,000,000 tonnes.

In 1989, a proposal to increase production capacity by constructing an additional primary pond in Useless Inlet was assessed under the *Environmental Protection Act 1986* at the level of Public Environmental Review (PER). Construction of the new pond (called PM1) took place in 1997/1998.

1.3 Location and access

The project is located 700 km north of Perth, at the southern end of Shark Bay, outside of but close to the Shark Bay World Heritage Area (Fig.1) – a situation which guarantees a high purity of sea water entering the salt field. The project area is within Mining Lease ML260SA, administered by the Department of Minerals and Energy.

Brine is first concentrated in primary ponds in Useless Inlet before being pumped 22 km to crystallisers in Useless Loop (Fig. 1).

Operations personnel reside in the Useless Loop Township. Access is possible by both road, air and sea; regular air services utilise the airstrip located between the Inlet and the Loop, approximately 3 km from the Township.

2. Outline of the proposal

2.1 Project description

Following the successful construction of the F2 crystalliser at the mouth of Useless Loop in 1996/1997, it is proposed that a series of additional crystallisers be built (Fig. 2) – effectively completing the line of facilities that was predicated by the F2 construction. The area of near-shore sea to be affected is 125 hectares, of which some 60 ha is seagrass; approximately 15 ha of this is a very low-density meadow.

The crystalliser embankments will be constructed with earth won from the borrow pit used for the construction of the F2 crystalliser (Fig. 2). Details of the embankment design are given in Figure 3.

2.2 Benefits of the proposal

Implementation of the proposal will allow SBSJV to complete its pond-construction programme within the marine portions of its mining lease, utilise the brines generated by the newly-completed primary pond (PM1) and take advantage of the economies of scale that are an increasingly important aspect of solar salt production and marketing. Fixed costs will be diluted by increased capacity afforded by the additional crystalliser area.

2.3 Legislative requirements and approval processes

Since the proposal involves no impact on the Shark Bay World Heritage Area, only the legislative requirements of the State of Western Australia should be applicable.

The Environmental Protection Authority (EPA) has set the level of assessment under the provisions of Part IV of the *Environmental Protection Act 1986* at Consultative Environmental Review (CER). Since the project is operated on a mining lease, the approval of the Department of Minerals and Energy (DME), which administers the *Mining Act 1978*, will also be required. The project is subject to the *Solar Salt (Shark Bay) Agreement Act* and, accordingly, the Minister for and Department of Resources Development are also involved.

It is intended that this document serve as the basis of seeking approval from all the above authorities. Additional information will be provided to individual parties as required.

2.4 Alternatives to the proposal

The only alternative to the proposed site for the F-series crystallisers is the World Heritage area to the west of the island causeway.

It is clearly inappropriate to impact the World Heritage area. Moreover, capital and operating costs would be significantly higher in this area.

The area south of existing Useless Loop ponds is earmarked for future development of additional concentration ponds; approval to construct these ponds, part of the strategic plan to optimise salt-field development within the Mining Lease, will be sought at some time in the future. Moreover, the location of crystallisers in this area would not suit flow patterns within the pond complex – expensive pumping over long distances would be required. This is not a practicable alternative.

2.5 Consequences of not implementing the proposal

Without this project, SBSJV's competitive position would be jeopardised. The salt industry is highly competitive, so that expansion of production capacity is necessary to achieve economies of scale. The initial development of the Shark Bay saltfield envisaged such expansion over time, utilising all the mining lease granted for the project.

3. Existing environment

The near-shore environment at the mouth of Useless Loop to be affected by the proposal is in part an artificial one, created by the construction of the existing causeway which forms the northern embankment of the pond system within the Loop.

Water depth is maximally 4 metres, with some seagrass (*Posidonia australis*). Approximately 60 ha of seagrass would be lost through implementation of the proposal.

No mangroves exist in the project area. There is some limited use of the (artificial) shore itself by seabirds, but this habitat is extensive throughout the Shark Bay area in general, and will be replicated with the proposed new facilities.

The area from which construction material will be won is already partly cleared and highly disturbed. It lies within a few hundred metres of the Useless Loop Township, and was the source of construction material for the recently-completed F2 crystalliser. The vegetation is described by Mattiske (1996) as low closed to open shrubland with occasional emergent *Acacia ligulata* over *Triodia plurinervata* and the Declared Rare Species *Plectrachne bromoides*. During the 1996 vegetation survey, the borrow-pit area was examined for the latter species; no population existed then, or has been observed in follow-up surveys by SBSJV's environmental officer.

No area impacted by the proposal is a conservation reserve, or has been identified as having characteristics which would warrant inclusion in the conservation estate.

4. The proposal

The following table summarises the key characteristics of the proposal.

Characteristic	Value
Period of construction	Four (4) months.
Life of total project	At least twenty (20) years.
Area of disturbance	150 hectares, of which 60 ha is seagrass.
Construction materials	Estimated 300,000 m^3 of marine-origin sedimentary materials, including rock (armouring of seaward face of embankment).
Bitterns discharge	None envisaged; bitterns used to seal pond floors.
Shipping impacts	Existing oil-spill and ballast- and waste-management protocols will continue.
Decommissioning	Long project life; decommissioning options, which include breaching or even removal of embankments, are regularly reviewed.

The F-series crystallisers will involve a sea-wall some 2,000 metres long (Fig. 2). The cross-section of the embankment is shown in Fig. 3, which also indicates areas which would be rock-armoured to control erosion. A total volume of approximately 300,000 m^3 of earth will be used in construction of the embankment.

Material won from the borrow pit by front-end loader and/or excavator would be hauled in trucks to the work-site using the haul road established for construction of the F2 crystalliser and the existing causeway across the mouth of the Loop. A short haul road might be required at the western end of the proposed embankment.

Dumped material would pushed out by dozer and grader, and the embankment shaped with excavators. Rock armour will be installed by a combination of dumping and placement.

The borrow to be used in embankment construction is an inert calcareous material of marine origin. It therefore contains no significant amounts of heavy metals or other potential contaminants.

After completion, the floors of the crystallisers would be repetitively flooded with bitterns to provide a seal over which pickle would be introduced for commercial salt production.

Earthmoving equipment would be fuelled from service trucks drawing from the existing central hydrocarbon storage. That storage conforms with standards set by the Department of Environmental Protection for the prevention of soil and water contamination from spills.

Dust would be controlled through the application of water from dedicated tanker trucks.

5. Potential impacts and their management

5.1 Seagrass

The EPA objective of maintaining the ecological function, species diversity and geographic distribution of seagrass is recognised. It was on that basis that the SBSJV commissioned a seagrass study of the project area in June 1998 by the Marine and Freshwater Research Laboratory (MAFRL) of Murdoch University. A copy of MAFRL's report is included in Appendix A.

MAFRL observed that the seagrass in the project area is predominantly *Posidonia australis*, with trace amounts of *Heterozostera tasmanica* and *Halophila ovalis*, mainly on the leading edges of the seagrass beds. Outside the mining lease, and in a small section within the lease, mixed beds of *P. australis* and *Amphibolus antarctica* occur. There is a 200- to 300-metre section of bare seabed extending from the shore to the start of the seagrass meadows.

P. australis and *A. antarctica*, the main components of the seagrass beds, are noted by MAFRL to be the two most common seagrass species in Shark Bay, and are not preferred food resources for dugongs.

Additionally, MAFRL have noted that the seagrass lost to this project would represent less than 0.014% of the total seagrass resource within Shark Bay.

To assess the potential impacts of crystalliser construction and operation on seagrass beds in the vicinity of the proposed facilities, SBSJV commissioned port and coastal consultant Dr W S Andrew to investigate tidal conditions and sediment transport. Dr Andrew's report is included here as Appendix B.

Dr Andrew's investigations concluded that, during construction, turbidity generated from earthwork activities is unlikely to travel more than a few hundred metres. Moreover, for much of the time the direction of movement of the turbidity plume will be alongshore, rather than offshore. Importantly, it is noted that the fill material, being calcareous and of marine origin, is unlikely to disturb the local environment for more than a few tidal cycles; it will not settle on seagrass, but on the seabed.

Under normal post-construction weather and tide conditions, Dr Andrew has concluded that only minor impacts on seagrass near the facility are anticipated; only a very small amount of turbidity will be generated. Under cyclonic conditions, there may be greater loss of material from the sea-wall, but it must be noted that, under such conditions, the general turbidity of local waters would already be greatly elevated.

Based on experience with the recent construction of the PM1 bar in Useless Inlet, and of the impacts of the F2 crystalliser construction, SBSJV is confident that no significant impacts will be caused to seagrass at distances of more than a few tens of metres from the facility. In both of those cases, visible and sediment plumes rarely extended more than a few tens of metres from the work-site and dissipated rapidly, and there has been no visible deterioration in the extent or vigour of nearby seagrass meadows.

Based on the success of the monitoring programme applied to the PM1 project in 1997/1998, SBSJV will establish a similar programme for the F-

series crystalliser project. *In situ* measurement of turbidity around the work-site and in open water will be conducted, and sediment plumes monitored by both ground and aerial observation. Should it prove necessary, work will be halted during periods when sediment plumes might threaten seagrass meadows.

In the operational phase, the existing programme of monitoring near-shore salinity at the mouth of the Loop will be relocated to the ocean north of the F-series crystallisers.

5.2 Marine fauna

Other than the few fish of various species (mullet, whiting) that use the project area, few marine fauna are observed. In particular, dugongs and turtles are rarely seen, presumably because there are better alternative habitats. Moreover, fauna such as dugongs and turtles would not be threatened by the established crystallisers, since they will not be open to the ocean.

No significant commercial or recreational fishing occurs in the area; there are more productive areas in the region. There are no corals or sponges in the project area.

5.3 Seabirds

The existing foreshore habitat that is lost through construction of the F-series crystallisers will in large part be replicated by the new sea wall of the crystalliser complex. The artificial foreshore that will in part be lost experiences low seabird visitation (see next paragraph), with vagrant waders in ones and twos occasionally observed. Flocks of migratory bird species are not seen.

Moreover, other areas of the salt-field offer a haven for seabirds, especially the biota-rich ponds in Useless Inlet – seabird activity in these areas is much greater than in surrounding, non-project areas. In this context, the SBSJV project provides habitats which would not otherwise exist: for example, bird numbers and activity in the primary pond system in Useless Inlet are many times larger than on the open sea because enriched biota and larger area of pond water. On this basis, and since there is no unique habitat to be lost through implementation of the proposal, it is apparent that seabird populations will not be impacted by the proposal.

5.4 Terrestrial fauna

Other than the seabirds discussed in Section 5.3 above, no terrestrial fauna are known to rely on, or use, the non-marine parts of the area affected by the proposal. The shore part of the proposed crystalliser area is immediately adjacent to the causeway transport link across the mouth of Useless Loop – the Town lies to the east and the washery and offices to the west – and the proposed borrow pit is already partly cleared and highly disturbed (mainly because of its close proximity to the Township).

5.5 Declared rare and priority flora

A search for declared rare flora (DRF) was conducted by Mattiske Consulting over the project area in 1996. The DRF species *Plectrachne bromoides* was discovered in similar low closed to open shrubland vegetation to the south, but does not occur in the area of the borrow-pit, the only land area to be disturbed for this proposal. However, SBSJV's environmental staff, guided by the Mattiske (1996) work, will examine the small vegetated areas that will be disturbed to ensure that *P. bromoides* or other DRF species are not present. If populations are discovered, their management will be determined in consultation with CALM.

5.6 Foreshore

As noted above, the existing foreshore across the mouth of Useless Loop is artificial, and will in part be replaced by the sea-wall of the new crystalliser complex.

A small area of natural foreshore on the western side of the Loop will be slightly affected by the proposal, in that it will border the western-most crystalliser cell. When compared with the many kilometres of natural foreshore that exist in the area and region (which is characterised by peninsulas, prongs and bays, the loss of this few hundred metres of foreshore will be of little significance.

5.7 Marine water quality

As noted in Section 5.1 above, SBSJV will monitor marine water physical and chemical quality during construction and operations. SBSJV has not discharged bitterns into the sea since 1987 (and has no plans to do so), and the established water-quality monitoring programme at the mouth of Useless Loop has shown no impacts of SBSJV's operations to date – there is no reason to believe that this proposal would alter that situation.

5.8 Shipping

It is expected that the increased production and changes to customers' shipping programmes could lead to increased use of larger vessels to export salt product from Useless Loop. This will reduce the number of voyages compared with that which would be required using smaller vessels. Shipping will continue to be monitored and controlled under the Joint Venture's present procedures. These have operated successfully for many years.

SBSJV follows the precepts of shipping-impact minimisation set out in the March 1995 ANZECC paper on "Maritime Accidents and Pollution: Impacts on the Marine Environment from Shipping Operations", and is committed to maintaining awareness of legislative developments and the enhancement of codes of practice concerning ballast management and hydrocarbon management.

It is a SBSJV requirement that all ships arriving at Useless Loop have re-ballasted in the open ocean before entering Australian waters; this is a standard quarantine protocol to prevent the introduction of exotic biota and disease micro-organisms. Ships' Masters are required to maintain Logs of such re-ballasting, including the latitudes and longitudes at which they occurred, these details are recorded by SBSJV. Nothing but open-ocean ballast water may be discharged while ships are arriving, loading or departing Useless Loop: waste and sewage are required to be retained for the several-day periods that ships are in the area.

The shallow waters of Shark Bay (small wave action), sandy sea-floors and low ship speeds make relatively small the risk of oil spills. In 30 years of operations at Useless Loop, no such spill has occurred. Nonetheless, SBSJV has an oil-spill contingency plan (OSCP) in place, with Department of Transport spill-management equipment and facilities stored on site ready for immediate deployment in the case of a spill.

It must also be borne in mind that the Shark Bay region and its World Heritage Area experience shipping activity other than that associated with SBSJV.

In the event of approaching cyclones, ships either put to sea or remain safely anchored or moored at Useless Loop.

5.9 Shark Bay World Heritage Area

The proposal lies approximately 1.5 km the World Heritage Area, and direct impacts are highly improbable.

If indirect impacts were to occur, they are most likely during construction of the F-series crystallisers, mainly in terms of turbidity. As noted in Section 5.1 above, any impacts are expected to be small, and transitory. The monitoring and response programmes described in Section 5.1 above are designed to manage these low-probability risks.

5.10 Recreation

The SBSJV, and this proposal, are located on a Mining Lease. No commercial or significant recreational fishing or other recreational activity occurs in the proposal area.

5.11 Heritage

No recognised area or structure of cultural or historical significance will be disturbed by the proposal.

5.12 Workforce environmental awareness

All SBSJV employees and contractors receive an environmental induction, and are regularly "topped up". Issues dealt with in these awareness programmes include hydrocarbon management, off-road driving, fauna protection and control of land disturbance. It is pertinent in this context that the residents of Useless Loop are active and proud participants in the Biosphere project aimed at protecting and building populations of endangered marsupial species on Heirrison Prong, immediately north of Useless Loop.

There are standard environmental management procedures and protocols observed, and annual environmental reporting to Government.

Appendix A

EPA guidelines for preparation of this CER

Environmental Protection Authority

Consultative Environmental Review
Final Guidelines

CONSTRUCTION OF ADDITIONAL CRYSTALLIZERS USELESS LOOP, SHARK BAY

SHARK BAY SALT JOINT VENTURE

(Assessment Number 1193)

Part A	Specific Guidelines for the preparation of the Consultative Environmental Review
Part B	Generic Guidelines for the preparation of an environmental review document

Attachment 1	Example of the invitation to make a submission
Attachment 2	Advertising the environmental review
Attachment 3	Project location

These guidelines are provided for the preparation of the proponent's environmental review document. The specific environmental factors to be addressed are identified in Part A. The generic guidelines for the format of an environmental review document are provided in Part B.

A key proposal characteristics table and environmental commitments in tabular form as per the examples in Part 'B' of these guidelines must be provided as part of the environmental review document for approval prior to public review.

Part A: Specific Guidelines for the preparation of the Consultative Environmental Review

1. The proposal

Shark Bay Salt Joint Venture (the proponent) operates the Shark Bay salt field under the Shark Bay Solar Salt Industry Agreement Act 1983. The salt field consists of a number of condenser ponds in Useless Inlet which are connected to pickle and crystallizer ponds in Useless Loop. Loading facilities for the export of salt and the Shark Bay Salt township exist at Useless Loop.

Shark Bay Salt Joint Venture intends to construct a new series (F series) of crystallizer ponds at the northern edge of the existing Useless Loop salt field. Construction of the new series of ponds will enclose approximately 140 hectares of shallow marine environment up to the boundary of Mineral Lease 260SA. The proposed location of these additional crystallizer ponds is illustrated in Attachment 3.

Shark Bay Salt Joint Venture has advised that it is proceeding with an expansion programme at the Shark Bay salt field. Approval was recently given to construct an additional condenser pond in Useless Inlet. The construction of this pond is currently nearing completion. Shark Bay Salt Joint Venture has indicated that construction of the additional crystallizer ponds in Useless Loop is necessary so that the salt in the increased pickle production generated by the new condenser pond in Useless Inlet can be crystallized out.

2. Environmental factors relevant to this proposal

At this preliminary stage, the Environmental Protection Authority (EPA) believes the relevant environmental factors, objectives and work required is as detailed in the table below:

CONTENT	SCOPE OF WORK	
Factor	**EPA objective**	**Work required for CER**
BIOPHYSICAL		
Seagrass	Maintain the ecological function, species diversity and geographic distribution of seagrass.	Provide baseline information on seagrass in the vicinity of the proposal. Assess potential impacts (both direct and indirect) on seagrass in the vicinity of the proposal which may occur as a result of the proposal. Provide details of proposed management measures to meet the objective
Marine fauna	To avoid impacts on marine fauna and their habitats, to meet the requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act, and to adhere to national and international legal obligations.	Provide information on the populations of marine fauna which currently utilise the area. Assess potential impacts (direct and indirect) on marine fauna and their habitats which may occur as a result of the project. Provide details of proposed management measures to meet the objective and relevant legislation.

Seabirds	To avoid impacts on seabirds and their habitats, to meet the requirements of the Wildlife Conservation Act and the Commonwealth Endangered Species Act, and to adhere to national and international legal obligations.	Provide information on the populations of seabirds which currently utilise the area. Assess potential impacts (direct and indirect) on seabirds and their habitats which may occur as a result of the project. Provide details of proposed management measures to meet the objective and relevant legislation.
Terrestrial fauna	Maintain the abundance, species diversity and geographical distribution of terrestrial fauna.	Provide information on the populations of terrestrial fauna which currently utilise the area. Assess potential impacts (direct and indirect) on terrestrial fauna and their habitats which may occur as a result of the project (borrow pits/haul roads). Provide details of proposed management measures to meet the objective and relevant legislation.
Declared Rare and Priority Flora	Protect Declared Rare and Priority Flora, consistent with the provisions of the Wildlife Conservation Act.	Provide information on the terrestrial vegetation in the vicinity of the project area. Assess potential impacts on any declared rare and priority flora which may occur as a result of the project (borrow pits/haul roads). Provide details of proposed management measures to meet the objective and relevant legislation.
Foreshore	Maintain the integrity, function and environmental values of the foreshore area.	Provide information on the integrity, function and environmental values of the foreshore area. Assess potential impacts (direct and indirect) on the foreshore in the vicinity of the proposal which may occur as a result of the project, including changes to coastal processes, such as increased sedimentation and erosion. Provide details of proposed management measures to meet the objective.

POLLUTION MANAGEMENT		
Marine water quality	Maintain or improve the quality of marine water consistent with the draft WA Guidelines for Fresh and Marine Waters (EPA, 1993).	Provide information on the nature and quantity of any discharges associated with the project which may impact upon marine water quality, including increased turbidity and bitterns discharge. Assess potential impacts on marine water quality associated with the discharges identified above. Provide details of proposed management measures to meet the objectives including site specific best practice requirements.
Increased shipping	Ensure that any increase in shipping activities resulting from the project does not adversely impact on the surrounding environment.	Provide information on the increase in shipping associated with the proposed expansion to existing crystallizers, and the potential impacts such an increase may have on the marine environment (including impacts of increased ballast water and increased potential for oil and fuel spillages). Provide details of proposed management measures to meet the objectives including site specific best practice management.
SOCIAL SURROUNDINGS		
Shark Bay World Heritage Area/Marine Reserve	Protect the conservation values, biodiversity and ecosystem functions of the Shark Bay World Heritage Area/Marine Reserve.	Assess potential impacts on the Shark Bay World Heritage Area/Marine Reserve which may occur as a result of the project, including the risk of pollution. Provide details of proposed management measures to meet the objectives.
Recreation	Ensure that the recreational values of the area are not compromised.	Identify existing recreational values of the area in the vicinity of the proposal. Assess potential impacts on these recreational values. Provide details of proposed management measures to meet the objective.
Heritage	Comply with statutory requirements in relation to areas of cultural or historical significance.	Identify any areas of cultural or historical significance in the vicinity of the project. Assess potential impacts on these sites. Provide details of proposed management measures to meet the objective.

These factors should be addressed within the environmental review document for the public to consider and make comment to the EPA. The EPA expects to address these factors, and others that may arise during the course of the environmental impact assessment process, in its report to the Minister for the Environment.

The EPA expects the proponent to take due care in ensuring any other relevant environmental factors which may be of interest to the public are addressed.

3. Availability of the environmental review

3.1 Copies for distribution free of charge

Supplied to DEP:

- Library/Information Centre 9
- EPA members 5
- Officers of the DEP (Perth) 8

Distributed by the proponent to:

Government departments

- Department of Minerals and Energy 1
- Department of Resources Development 1
- Department of Conservation and Land Management 2
- Fisheries Department 1
- Department of Transport (Maritime) 1
- Department of Environmental Protection Mid-west Office 2
- Scientific Advisory Committee on Shark Bay World Heritage Property 1
- Community Consultative Committee on Shark Bay World Heritage Property 1
- Marine Parks and Reserves Authority 1

Local government authorities

- Shire of Shark Bay 1

Libraries

- J S Battye Library 3
- The Environment Centre 2
- Geraldton Library 1
- Carnarvon Library 1

Other

- Conservation Council of WA 1
- Marine and Coastal Community Network 1

3.2 Available for public viewing

- J S Battye Library;
- Geraldton Library;
- Carnarvon Library;
- Department of Environmental Protection Midwest Office; and
- Department of Environmental Protection Library.

Part B: Generic Guidelines for the preparation of an environmental review document

1. Overview

All environmental reviews have the objective of protecting the environment. Environmental impact assessment is deliberately a public process in order to obtain broad ranging advice. The review requires the proponent to describe:

- the proposal;
- receiving environment;
- potential impacts of the proposal on factors of the environment; and
- proposed management strategies to ensure those environmental factors are appropriately protected.

Throughout the assessment process it is the objective of the Environmental Protection Authority (EPA) to help the proponent to improve the proposal so the environment is protected. The DEP will co-ordinate, on behalf of the EPA, relevant government agencies and the public in providing advice about environmental matters during the assessment of the environmental review for this proposal.

The primary purpose of the environmental review is to provide information on the proposal within the local and regional framework to the EPA, with the aim of emphasising how the proposal may impact the relevant environmental factors and how those impacts may be mitigated and managed.

The language used in the body of the environmental review should be kept simple and concise, considering the audience includes non-technical people, and any extensive, technical detail should either be referenced or appended to the environmental review. It should be noted that the environmental review will form the legal basis of the Minister for the Environment's approval of the proposal and therefore the environmental review should include a description of all the main and ancillary components of the proposal, including options where relevant.

Information used to reach conclusions should be properly referenced, including personal communications. Assessments of the significance of an impact should be soundly based rather than unsubstantiated opinion, and each assessment should lead to a discussion of the management of the environmental factor.

2. Objectives of the environmental review

The objectives of the environmental review are to:

- place this proposal in the context of the local and regional environment;
- adequately describe all components of the proposal, so that the Minister for the Environment can consider approval of a well-defined project;
- provide the basis of the proponent's environmental management programme, which shows that the environmental impacts resulting from the proposal, including cumulative impact, can be acceptably managed; and
- communicate clearly with the public (including government agencies), so that the EPA can obtain informed public comment to assist in providing advice to government.

3. Environmental management

The EPA expects the proponent to develop and implement an Environmental Management System appropriate to the proposal consistent with the principles outlined in the AS/NZS ISO 14000 series, including provisions for accountability review and a commitment to continuous improvement.

The key components which should be included in environmental review documentation, depending on the scale of the proposal, are environmental management:

- policy;
- resources budget;
- programme;
- plan(s);
- training programme;
- monitoring programme;
- contingency plan(s); and
- improvement plan(s).

Documentation on the relevant components should be proportional with the scale of the proposal and the potential environmental impacts. If appropriate, the documentation can be incorporated into a formal environmental management system and provision made for periodic performance review. Public accountability is a principle that should be incorporated into the approach on environmental management.

The environmental management programme is the key document that should be appropriately defined in an environmental review. The environmental management programme should provide plans to manage the relevant environmental factors, define the performance objectives, outline the operational procedures and outline the monitoring and reporting procedures which would demonstrate the achievement of the objectives.

4. Format of the environmental review document

The environmental review should be provided to the DEP officer for comment. At this stage the document should have all figures produced in the final format and colours.

Following approval to release the review for public comment, the final document should also be provided to the DEP in an electronic format.

The proponent is requested to supply the project officer with an electronic copy of the environmental review document for use on Macintosh, Microsoft Word Version 6, and any scanned figures. Where possible, figures should be reproducible in a black and white format.

5. Contents of the environmental review document

The contents of the environmental review should include an executive summary, introduction and at least the following:

5.1 The proposal

Justification and alternatives

- justification and objectives for the proposed development;
- the legal framework, including existing zoning and environmental approvals, and decision making authorities and involved agencies; and
- consideration of alternative options.

Key characteristics

The Minister's statement will bind the proponent to implementing the proposal in accordance with any technical specifications and key characteristics[1] in the environmental review document. It is important therefore, that the level of technical detail in the environmental review, while sufficient for environmental assessment, does not bind the proponent in areas where the project is likely to change in ways that have no environmental significance.

Include a description of the components of the proposal, including the nature and extent of works proposed. This information could be presented in the form of a table as follows:

Table 1: Key characteristics (example only)

Element	Description
Life of project (mine production)	55 months
Size of ore body	682 000 tonnes
Area of disturbance	100 hectares
Ore mining rate • maximum • average	 • 200 000 tonnes per year • 160 000 tonnes per year
Background gamma radiation levels • maximum • average	 • 0.52 µGrey per hour • 0.16 m 0.08 µGrey per hour
Water supply • source • maximum hourly requirement • maximum annual requirement	 • Yarloop borefield, shallow aquifer • 180 cubic metres • 1 000 000 cubic metres
Heavy mineral concentrate transport • truck movements (maximum)	 • 75 return truck loads per week

[1] Changes to the key characteristics of the proposal following final approval, would require assessment of the change and can be treated as non-substantial and approved by the Minister, if the environmental impacts are not significant. If the change is significant, it would require assessment under section 38 or section 46. Changes to other aspects of the proposal are generally inconsequential and can be implemented without further assessment. It is prudent to consult with the Department of Environmental Protection about changes to the proposal.

The key characteristics table should be supplemented with figures to ensure that the proposal is clearly explained. Figures that should always be included are:

- a map showing the proposal in the local context - an overlay of the proposal on a base map of the main environmental constraints;
- a map showing the proposal in the regional context;

and, if appropriate:

- a process chart / mass balance diagram showing inputs, outputs and waste streams.

All figures should include a north arrow, a scale bar, a legend, grid co-ordinates, the source of the data, a title and (where applicable) the date of aerial photo.

Other logistics

- timing and staging of project; and
- ownership and liability for waste during transport, disposal operations and long-term disposal (where appropriate to the proposal).

5.2 Environmental factors

The environmental review should focus on the relevant environmental factors for the proposal, and these should be agreed in consultation with the EPA and DEP and relevant public and government agencies. Preliminary environmental factors identified for the proposal are shown in Part A of these guidelines.

Further environmental factors may be identified during the preparation of the environmental review, therefore on-going consultation with the EPA, DEP and other relevant agencies is recommended. The DEP can advise the proponent on the recommended EPA objective for any new environmental factors raised. Minor matters which can be readily managed as part of normal operations for the existing operations or similar projects may be briefly described.

Items that should be discussed under each environmental factor are:

- a clear definition of the area of assessment for this factor;
- the EPA objective for this factor;
- a description of what is being affected - why this factor is relevant to the proposal;
- a description of how this factor is being affected by the proposal - the predicted extent of impact;
- a description of where this factor fits into the broader environmental / ecological context (only if relevant - this may not be applicable to all factors);
- a straightforward description or explanation of any relevant standards / regulations / policy;
- environmental evaluation - does the proposal meet the EPA's objective as defined above;
- if not, environmental management proposed to ensure the EPA's objective is met;
- predicted outcome.

The proponent should provide a summary table of the above information for all environmental factors, under the three categories of biophysical, pollution management and social surroundings:

Table 2: Environmental factors and management (example only)

Environmental Factor	EPA Objective	Existing environment	Potential impact	Environmental management	Predicted outcome
BIOPHYSICAL					
vegetation community types 3b and 20b	Maintain the abundance, species diversity, geographic distribution and productivity of vegetation community types 3b and 20b	Reserve 34587 contains 45 ha of community type 20b and 34 ha of community type 3b	Proposal avoids all areas of community types 20b and 3b	Surrounding area will be fully rehabilitated following construction	Community types 20b and 3b will remain untouched Area surrounding will be revegetated with seed stock of 20b and 3b community types
POLLUTION MANAGEMENT					
Dust	Ensure that the dust levels generated by the proposal do not adversely impact upon welfare and amenity or cause health problems by meeting statutory requirements and acceptable standards	Light industrial area - three other dust producing industries in close vicinity Nearest residential area is 800 metres	Proposal may generate dust on two days of each working week.	Dust Control Plan will be implemented	Dust can be managed to meet EPA's objective
SOCIAL SURROUNDINGS					
Visual amenity	Visual amenity of the area adjacent to the project should not be unduly affected by the proposal	Area already built-up	This proposal will contribute negligibly to the overall visual amenity of the area	Main building will be in 'forest colours' and screening trees will be planted on road	Proposal will blend well with existing visual amenity and the EPA's objective can be met

5.3 Environmental management commitments

The implementation of the proposal and all commitments made by the proponent become legally enforceable under the conditions of environmental approval issued in the statement by the Minister for the Environment. All the key environmental management commitments should be consolidated in the public review document in a list (usually in an Appendix). This list is attached to the Minister's statement and becomes part of the conditions of approval.

The proponent's compliance with the key environmental management commitments will be audited by the DEP, so they must be expressed in a way which enables them to be audited.

A commitment needs to contain most of the following elements to be auditable:

- who (eg. the proponent)
- will do what (eg. prepare a plan, take action)

- why (to meet an environmental objective)
- where/how (detail the action and where it applies)
- when (in which phase, eg. before construction starts)
- to what standard (recognised standard or agency to be satisfied)
- on advice from (agency to be consulted).

The proponent may make other commitments, which address less significant or non-environmental matters, to show a commitment to good general management of the project. Such commitments would not normally be included in the list appended to the statement. The EPA expects that the proponent will audit these commitments by internal processes. Though the DEP would not subject the less significant environmental commitments to routine audit, it may periodically request that compliance with these commitments be demonstrated, so as to verify satisfactory environmental performance in the proponent's implementation of the proposal.

With the implementation of continuous improvement, the procedures to implement the commitments may need to be changed. These changes can be made in updates to the environmental management plan, whilst ensuring the objective is still achieved.

Once the proposal is approved, changes to the commitments constitute a change to the proposal and should be referred to the DEP.

Examples of the preferred format for typical commitments are shown in the following table:

Table 3: Summary of proponent's commitments (example only)

Commitment (Who/What)	Objective (Why)	Action (How/Where)	Timing (When)	Whose advice	Measurement/ Compliance criteria
1. XYZ Mining will develop a rehabilitation plan	to protect the abundance, species diversity, geographic distribution and productivity of the vegetation community types 3b and 20b	by limiting construction to a small area (10 ha) of Reserve 34587 and rehabilitating the area	before construction	CALM, NPNCA	fences built; species distribution and density consistent with vegetation community types 3b and 20b
2. XYZ Mining will minimise dust generation	to maintain the amenity of nearby land owners	by preparing and implementing a Dust Control Plan which meets EPA Dust Control criteria	before the start of construction phase	preparation: DEP; implementation: Shire	Letter from Shire submitted with Performance and Compliance Report.

Commitments should be written in tabular form, preferably with some specification of ways in which the commitment can be measured, or how compliance can be demonstrated.

Draft commitments which are not in a format that can be audited will not be accepted by project officers for public review documentation. Proponents will be assisted to revise inadequate commitments.

5.4 Public consultation

A description should be provided of the public participation and consultation activities undertaken by the proponent in preparing the environmental review. It should describe the activities undertaken, the dates, the groups/individuals involved and the objectives of the activities. Cross reference should be made with the description of environmental management of the factors which should clearly indicate how community concerns have been addressed. Those concerns which are dealt with outside the EPA process can be noted and referenced.

Appendix B

Report on seagrass survey by Marine and Freshwater Research Laboratory (Murdoch University)

Seagrass survey at Useless Loop for Shark Bay Salt

C. Wilson, K. Wienczugow and E. I. Paling

Client: Shark Bay Salt

Marine and Freshwater
Research Laboratory
Environmental Science

Institute for Environmental Science
(Report No. MAFRA 98/5)
Murdoch University
July 1998

CONTENTS

Tables

1.0 Introduction

Shark Bay is a large (13 000 km^2) semi-enclosed basin, situated in Western Australia, 700 kilometers north of Perth (Figure 1). Due to its restricted oceanic exchange and high rates of evaporation cause by an arid climate, it has a well developed hypersalinity gradient that increases with distance from the ocean (Logan *et al.*, 1970).

A Proportion of Shark Bay was inscribed on the World Heritage List in 1991 in recognition of the area's outstanding natural values including the largest reported seagrass meadows in the world, as well as some of the most species-rich seagrass assemblages (CALM, 1996). Of the twelve species of seagrass identified in Shark Bay, *Amphibolis antarctica* is the most abundant species present occupying 3676 km^2 or 85% of the area covered by seagrass. *Posidonia australis* is the next most abundant species covering approximately 5% of the area (Walker *et al.*, 1988). The high biomass and productivity of seagrass, coupled with the large accumulation of nutrients present in seagrass meadows, make them of great significance to the food chains of Shark Bay. They also are important habitat and nursery areas for fish and invertebrates, providing protection and food.

Salt is produced from mining leases at Useless Loop and Useless Inlet, adjacent to the Shark Bay Marine Park. The mining lease lies between 1.5 and 3.5 kilometres from the World Heritage Area. The salt operation is conducted in accordance with the Shark Bay Solar Salt Industry Agreement Act 1983, an agreement between the State Government and Shark Bay Salt joint venture (CALM, 1996). This Agreement Act provides the company with the right to carry out solar salt production on the whole area of the mining lease held by Shark Bay Salt, including any expansion at Useless Loop or Useless Inlet.

Shark Bay Salt plans to expand the solar salt production area at Useless Loop within its mining lease and requested The Marine and Freshwater Research Laboratory (MAFRL, Environmental Science, Murdoch University) to undertake an environmental investigation within the area in which the expansion was to take place. This investigation included seagrass mapping, species identification and biomass cover estimates. Due to time and seasonality constraints the results described in this report are a broad overview undertaken at one time; and, although it is considered by MAFRL that this represents a true depiction of the status of the area, more detailed seasonal studies would be required to determine annual variation of the area.

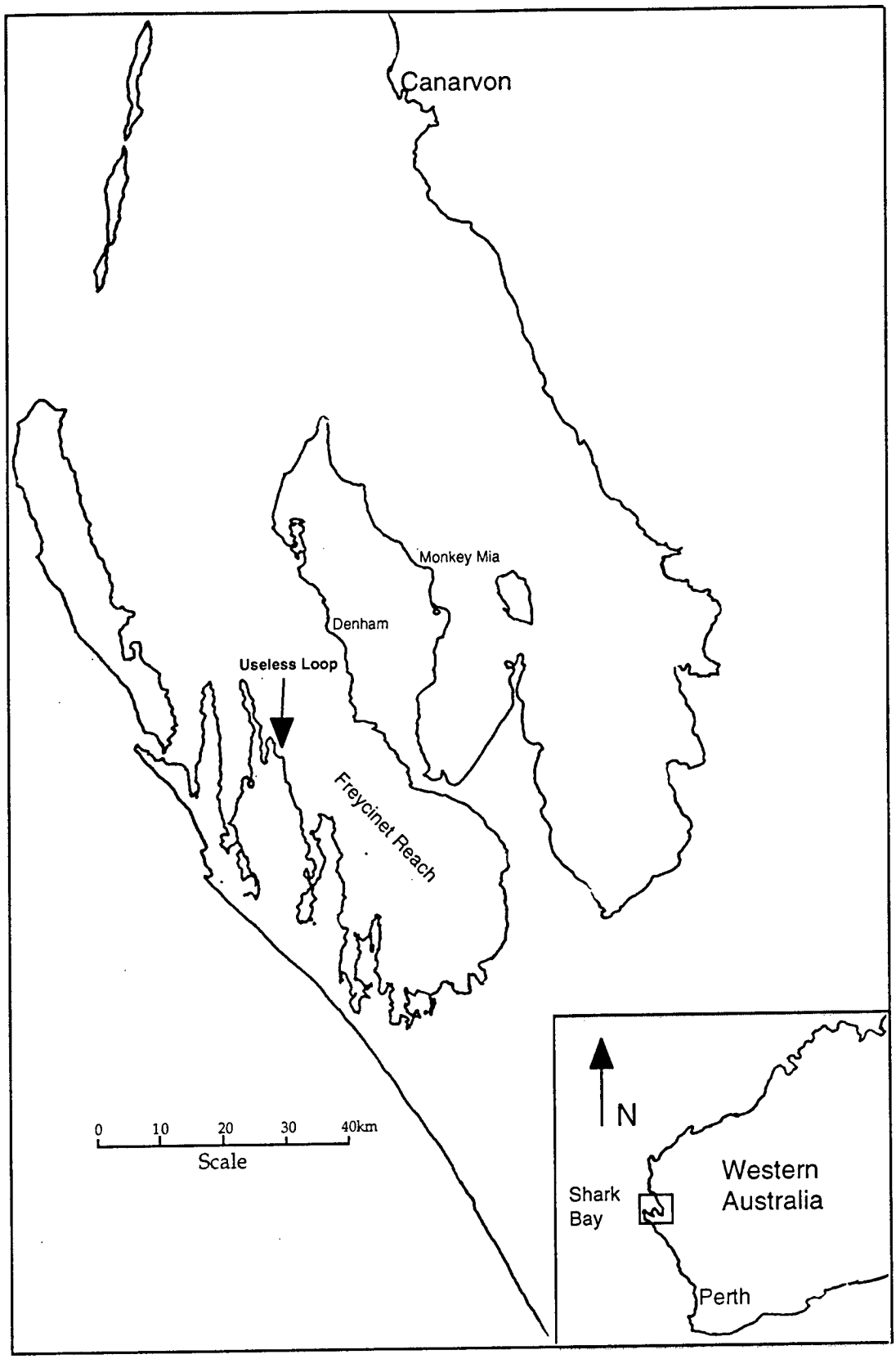

Figure 1: Map of Shark Bay, showing location of Useless Loop study site.

2.0 Methods

The Marine and Freshwater Research Laboratory (MAFRL) monitored seagrass distribution at Useless Loop over a two day period at the end of June 1998. Seagrass identification and biomass estimates were assessed by spot dives at approximately 300 meter intervals along transects within the Useless Loop mining lease and at approximately 500 meter intervals along transects outside the mining lease (Figure 2). Four transects were examined parallel to the shore within the mining lease and two transects outside of it. At each site a GPS (Global Positioning System) waypoint was recorded in addition to the type of seagrass, general health and an estimate of biomass (Appendix 1). Biomass was estimated visually by the Braun-Blanquet Scale (modified from Poore; 1955) and photographs were also taken. The GPS waypoints (Appendix 2) were corrected from GDA (geocentric datum of Australia) to AGD (Australian Geodetic Datum) to be plotted.

Water quality was monitored at eight sites within the mining lease and at twelve sites outside the mining lease (Figure 3). At each site, surface water was sampled for salinity and inorganic nutrients. Salinity samples were retained in 'Whirlpaks' (NASCO) and measured by a Hamon Salinity-Temperature Bridge (model 602, YeoKal) on return to the laboratory. Inorganic nutrient samples were filtered through 0.45 µm cellulose nitrate filter paper for ammonium, nitrate-nitrite and filterable reactive phosphate. Samples were retained in 10 ml polyethylene screw capped vials on ice until return to the laboratory and then frozen until analysis.

All analyses were carried out by the Marine and Freshwater Research Laboratory. Filterable reactive phosphate, nitrate plus nitrite and ammonium were analysed on a Lachat Automated Flow Injection Analyser by the methods Lachat Instruments (1996a, 1996b and 1994 respectively).

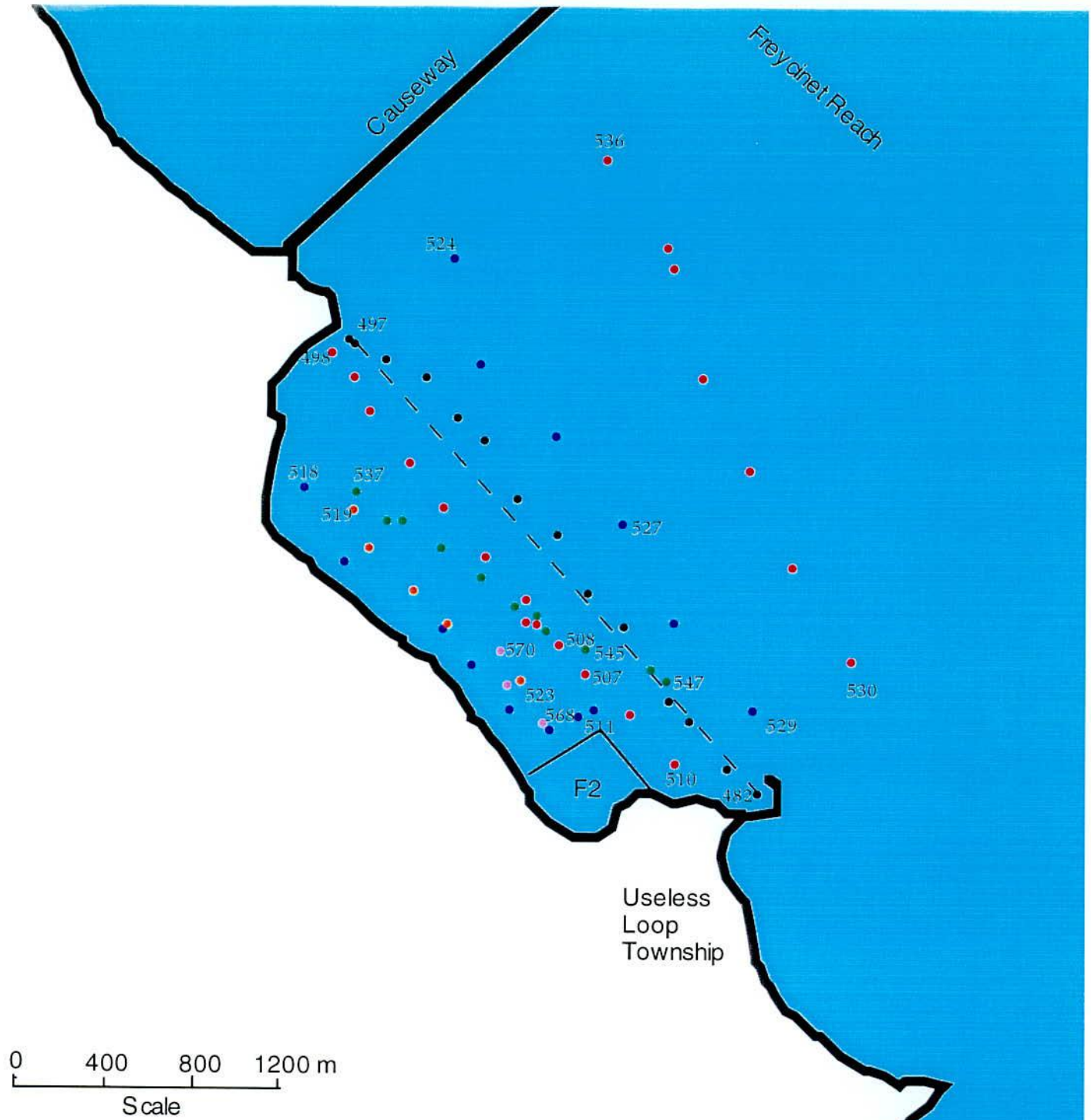

Figure 2: Seagrass sampling site locations (coloured dots) within the Shark Bay Salt mining lease (border shown by dotted line) and outside the lease area. Numbers and colours of dots refer to site descriptions found in Appendix 1 and 2. F2 is a reclaimed pond.

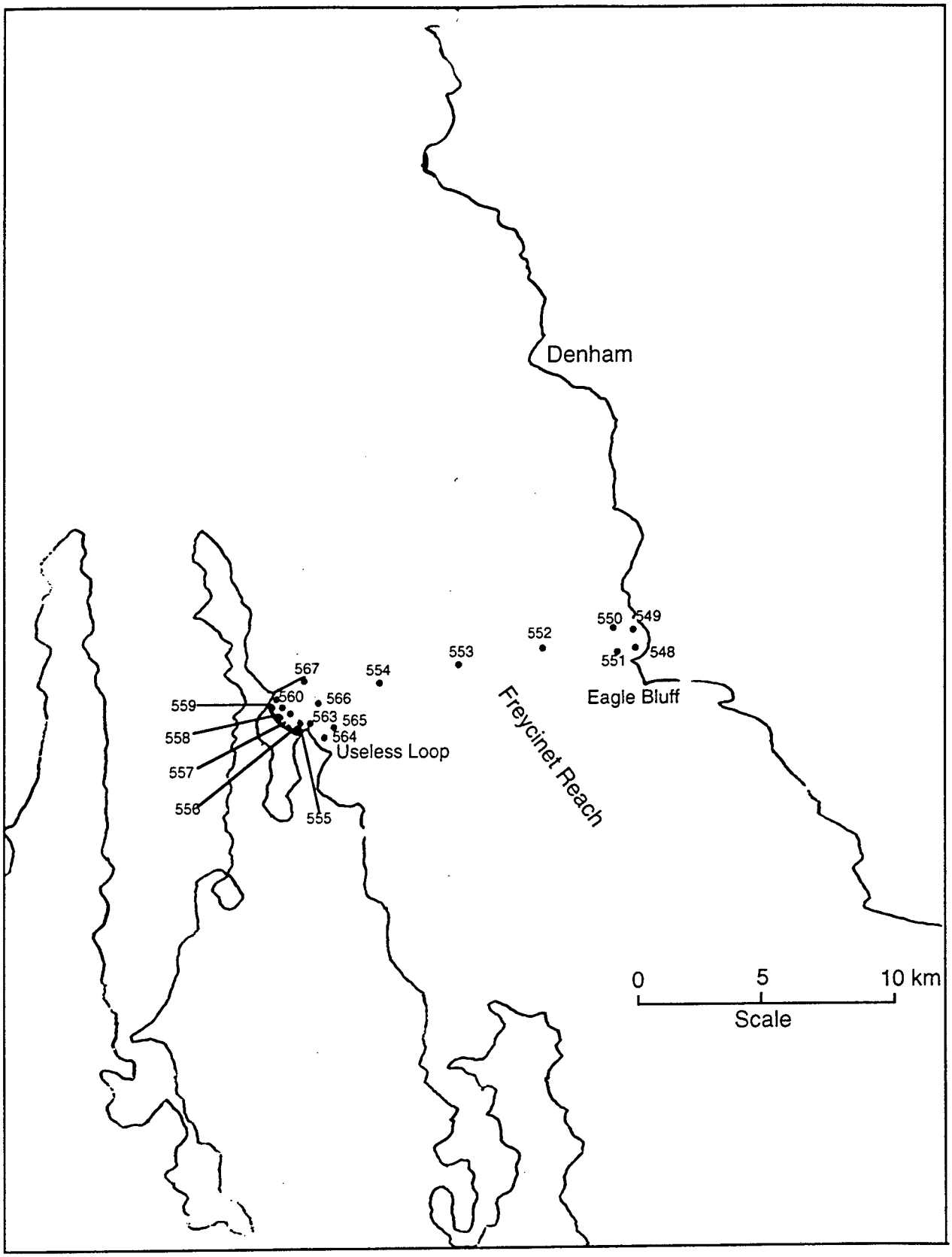

Figure 3: Locations of salinity and inorganic nutrient sampling sites. Numbers correspond to waypoints in Table 1.

3.0 Results

3.1 Salinity

Salinities ranged from 39.9 to 42.4 g L^{-1} in the surface water at sites depicted by waypoints 548 to 567 (Figure 3, Table 1). Salinities of surface water were highest at sites 548 to 551 located outside the Shark Bay Salt mining lease, across Freycinet Reach, north of Eagle Bluff on the Denham side (Figure 3, Table 1). High salinity was also recorded at site 564 in the bay south of the mining lease (Figure 3, Table 1). The lowest salinity was recorded at site 553, in the centre of Freycinet Reach between the mining lease and Eagle Bluff (Figure 3, Table 1).

Table 1: Salinity and inorganic nutrient concentrations of surface water from sites in Shark Bay (see Figure 3 for waypoint locations). 'FRP' denotes filterable reactive phosphorus.

Waypoint Number	Salinity g L^{-1}	Ammonium µg N L^{-1}	FRP µg P L^{-1}	Nitrate/Nitrite µg N L^{-1}
548	42.3	9	5	7
549	42.2	8	4	2
550	41.8	7	4	<2
551	42.4	8	4	<2
552	40.5	6	4	4
553	39.9	9	4	6
554	40.5	6	4	2
555	40.9	10	5	4
556	40.7	7	4	7
557	40.7	9	4	2
558	40.6	9	4	<2
559	40.5	10	4	5
560	40.4	11	4	4
561	40.7	6	3	4
562	40.7	7	4	2
563	40.8	6	4	3
564	41.2	10	4	7
565	40.8	7	6	5
566	40.8	8	4	5
567	40.5	7	4	2

3.2 Inorganic nutrients

All inorganic nutrient concentrations were low (less than 12 μg L^{-1}) in the surface water at all sites measured (Table 1). The range of filterable reactive phosphorus concentrations between sites was very small (3 to 6 μg P L^{-1}), with both the smallest and largest concentration measured within the mining lease (Table 1, Figure 3). In general the highest ammonium and nitrate-nitrite concentrations were found in each of the bays closest to shore (Table 1, Figure 3).

3.3 Seagrass distribution

In general the seagrass within the Shark Bay Salt mining lease was composed mainly of *Posidonia australis* (Figure 4, Appendix 3a). There were trace amounts of *Heterozostera tasmanica* and *Halophila ovalis* mainly on the leading edge of seagrass beds (Appendix 1, Appendix 3b). There was approximately 200 - 300 meters of bare sand from the shoreline to the start of the seagrass beds (Figure 4). Outside the mining lease the seagrass changed from monospecific beds of *P. australis* to mixed beds of *P australis* and *Amphibolis antarctica* to monospecific beds of *A. antarctica* (Figure 4, Appendix 3c). The centre of the area studied, consisted of a section with very little seagrass growth, comprising trace amounts of all the seagrass mentioned above (Appendix 3d, Figure 4).

3.4 Seagrass biomass

Seagrass biomass was generally high, and increased from the edges of the beds (approximately 20% cover) to their centres (approximately 40 - 60% for *P. australis* and 60 -100% for *A. antarctica*). There were two notable exceptions, the first being the centre of the study area with trace amounts of seagrass (< 5%; Figure 4, Appendix 3d). The second was an area within the mining lease, in the southern section of the *P. australis* bed, close to F2 (Figure 4), encompassed by the waypoints 507, 508, 545 and 568 (Figure 2, Appendix 1). The *Posidonia* in this section was sparse, stubby and contained a large quantity of dead wrack (Appendix 3e).

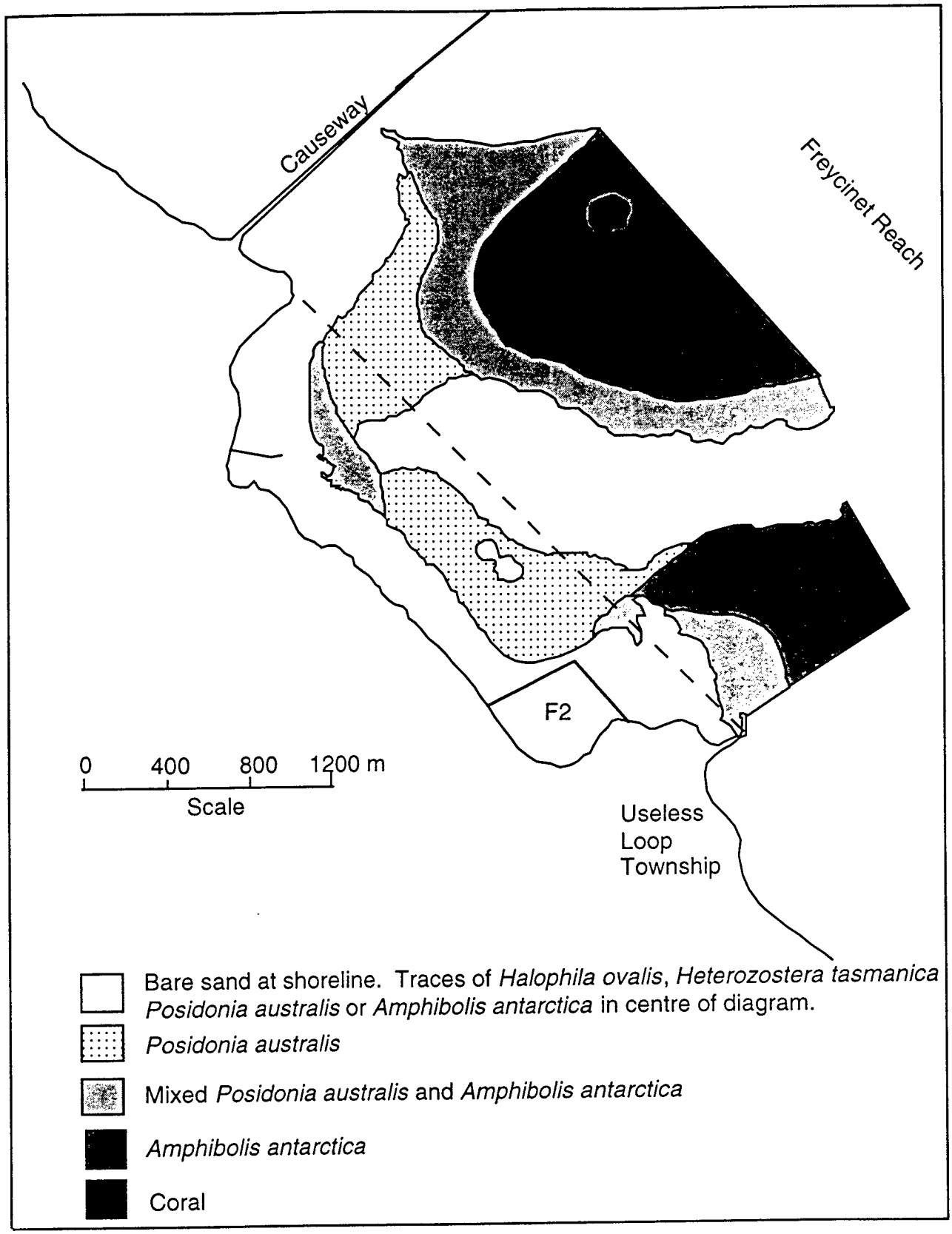

Figure 4: Distribution of seagrass species inside and outside the Shark Bay Salt mining lease (border shown by dotted line). F2 is a reclaimed pond.

4.0 Discussion

4.1 Salinity and inorganic nutrient concentrations

The range of salinities (39.9 to 42.4 g L^{-1}) recorded from the locations sampled (waypoints 548 to 567; Figure 3, Table 1) were within the metahaline range (40 to 56 g L^{-1}) characterised by Logan and Cebulski (1970) for this area. From the single series of surface water measurements made at the end of June 1998, it does not appear that Shark Bay Salt contributes to changes in salinity or inorganic nutrients within the water adjoining the lease area. In general, salinity and inorganic nutrient concentrations were slightly higher in each of the bays studied, which was probably due to higher evaporation rates in shallower waters and possible influences from the land.

4.2 Seagrass distribution and biomass

There was a 200 - 300 meter section of bare sand from the shoreline to the edge of any seagrass beds. This cut off point coincides with Extreme Low Water Spring tidal height, as the plants seem unable to tolerate exposure to very high light intensities and temperatures (Walker *et al.*, 1988).

The majority of seagrass within the mining lease comprised monospecific beds of *Posidonia australis*, changing to monospecific beds of *Amphibolis antarctica* outside the lease. Walker *et al.*, (1988) also recorded monospecific meadows of *P. australis* adjacent to *A. antarctica* on the 'leading edge', projecting into the prevailing current, where sediments were accreting.

The large section in the centre of the study area (Figure 4) with only trace amounts of seagrass, may be attributed to the release of bitterns (a byproduct of salt production) which occurred from the 1960's to 1987. Although the discharge of bitterns from the Shark Bay Salt operation has not occurred since 1987, the company may do so in accordance with the Environmental Management Program (EMP) approved for the operation. It has been over ten years since the bitterns discharge ceased but very little seagrass regrowth has occurred. It is suspected that the bittens discharge contributed to altering the sediment characteristics, which made it unsuitable for regrowth.

A smaller section of seagrass within the mining lease appeared to be damaged (tops of leaves ripped off , leaving shortened bases). It is not certain of the cause, however, it is

the closest section of seagrass to the newest mining lease extension (F2 a reclaimed pond, Figures 2 and 4). This section was built in 1996 and there is a possibility that it effected seagrass in this area either directly through the building process or indirectly by changing current or sedimentation processes.

5.0 Conclusions

The majority of seagrass found within the Shark Bay Salt mining lease were of the species *Posidonia australis* and *Amphibolis antarctica*. These are the two most common species of seagrass in Shark Bay and are not preferred food sources of the resident dugong population (CALM 1996). The area covered by seagrass within the mining lease, including sparse growth areas, is approximately 0.6 km^2. Compared with the total area of seagrass within Shark Bay (4,325 km^2), this would represent a loss of 0.014% of the total resource.

6.0 References

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Appendix 1: Waypoint numbers corresponding to seagrass sampling sites (colours refer to Figure 2) and associated field notes.

Lease border transect (Black dots)

- 482 - 484 Southern jetty - rack and bare sand
- 485 100 m along transect - isolated patches of *Posidonia*
- 486 bare sand around 100 m
- 487 approx 60% cover (BB 70%) of *Posidonia australis* and *Amphibolis antarctica*, trace of *Heterozostera tasmanica*.
- 488 approx 40% cover *Posidonia* (BB 30 - 40%), less dense, depth ~ 3 m.
- 489 as above
- 490 approx 5 - 10% *Halophila ovalis*
- 491 trace to 5% *Heterozostera*, stony bottom
- 492 trace Halo, *Amphibolis*, *Posidonia* and *Heterozostera*
- 493 approx 80% *Posidonia* (BB 100%)
- 494 80 - 100% *Posidonia*, NE 100 m 60 %
- 495 BB 40% *Posidonia* - high epiphyte coverage
- 496 bare sand, pearl shell, some rack, 1.2 - 1.5 m depth
- 497 100 m off beach, isolated clumps of *Posidonia* ~ 10% coverage

Transect 200 m West of lease border (inside lease, red dots)

- 498 5% *Posidonia*, 100 m from shore, rocky bottom, bare sand
- 499 ~ 250 m from shore, *Amphibolis* starts, mixed with *Posidonia* at 80 m (BB 70%), BB 100% *Amphibolis* (*Heterozostera* growing on edges of meadow only). Bare sand with penna and pearl shells to shore on West side. 1-2m depth.
- 500 ~3 m depth, BB 20% *Posidonia* (bottom covered with rack).
- 501 3 - 4 m depth, trace *Heterozostera*
- 502 3 m depth, BB 60% *Posidonia*, 30% coverage
- 503 3 m depth BB 20% *Posidonia*
- 504 sand patch 60 m diameter
- 505 coral patch
- 506 edge of patch into *Posidonia/Amphibolis* ~ 20% coverage
- 507 BB 10% *Posidonia* (~5 -10% rack)
- 508 BB 10% *Posidonia* (150 m from NE corner of F2)
- 509 bare sand
- 510 bare sand to beach

Appendix 1 continued

Inside lease (blue dots)

- 511 to 517 bare sand, 80 to 100 m from beach
- 518 intake pipe, bare sand

Transect running along edge of meadow (inside, orange)

- 519 1.2 m
- 520 bare sand 1.2 m
- 521 bare sand 1 m
- 522 same
- 523 *Posidonia* bed

First transect outside lease (Blue dots)

- 524 edge of seagrass 150 m from island, 1- 1.5 m depth, *Posidonia* (edge BB 20%, then BB 50 -70%), trace *Amphibolis*. *Amphibolis* (BB 100%) increasing along transect and *Sargassum* sp.
- 525 3.6 m depth, Posidonia BB 40-60%
- 526 4.8 m depth, trace *Amphibolis*, < 5% *Heterozostera*, *Penicillus nodulosus*, penna shells
- 527 4.8 m depth, < 5% *Heterozostera* and 10% *Amphibolis* coverage
- 528 4.9 m depth, to south *Posidonia* BB 60%, north 10% *Amphibolis*
- 529 4.4 m depth, 50/50 *Posidonia/Amphibolis* BB 50-60% epiphytes

Furthest transect outside lease (Red dots)

- 530 5.4 m depth, *Amphibolis* -tall BB 100%, trace *Posidonia*
- 531 5.5 m depth, trace *Heterozostera* and *Amphibolis*
- 532 4.9 m depth, 80/20 *Amphibolis/Posidonia*, trace browns
- 533 4.2 m depth, 100% *Amphibolis* BB 100%
- 534 4.2 m depth, *Amphibolis* BB 100%
- 535 Coral bombie
- 536 4.0 m depth, *Posidonia/Amphibolis* 100% cover

Appendix 1 continued

Diagonal transect within lease (green dots)

- 537 30/70 *Amphibolis/Posidonia* BB 10%
- 538 4.1 m depth, 15% cover of *Posidonia*, BB < 5%
- 539 40 m from 538, 2.2 m depth, *Amphibolis*
- 540 3.3 m depth, 100% *Posidonia*, BB 40%
- 541 As 540
- 542 3 m depth, edge of sandpatch (100 m), leading edge *Posidonia* then more *Amphibolis* to centre
- 543 centre of sand hole - lumps of rock
- 544 40 m from 543, start of seagrass, 95/5% *Posidonia/Amphibolis*, BB 60%
- 545 3.8 m depth, *Posidonia* BB 10% - *Posidonia* cut off short 140 m
- 546 2.2 m depth, went from short *Posidonia* (BB 10%) to *Amphibolis* and *Posidonia* (lots of epiphytes) as got shallower
- 547 1.7 m depth, edge of seagrass meadow, mixture of *Posidonia* and *Heterozostera* with pearl shells, sand and shell to Jetty

Salinity and nutrient sites (Figure 3)

- 548 - 567

Edge of seagrass meadow, northern site of F2 (Pink dots)

- 568 2.1 m depth, 70/30 *Posidonia/Amphibolis* for 30 m NE for 70 m all *Posidonia* (BB 15%) then short stubby *Posidonia* more sparse alot of wrack
- 569 Edge *Posidonia/Heterozostera* BB 5%, 30 m along short *Posidonia* denser BB 20, 40 m *Posidonia/Amphibolis* 60/40, longer *Posidonia* as got deeper (BB 15%).
- 570 Trace *Halophila/Heterozostera*, mainly *Posidonia* first 10 m (<5%) then BB 10-15%

Appendix 2: GPS waypoint northings and easting (GDA and AGD), location colours refer to Figure 2.

Location colour	Waypoint No	Easting (GDA)	Northing (GDA)	Easting (AGD)	Northing (AGD)
Black	482	741993.23	7108135.99	741851.81	7107994.57
	483	741989.32	7108104.66	741847.90	7107963.24
	484	741982.41	7108091.85	741840.99	7107950.43
	485	741840.22	7108247.84	741698.80	7108106.42
	486	741694.20	7108466.70	741552.78	7108325.28
	487	741616.03	7108567.91	741474.61	7108426.49
	488	741400.40	7108900.75	741258.98	7108759.33
	489	741231.45	7109053.53	741090.03	7108912.11
	490	741096.81	7109347.92	740955.39	7109206.50
	491	740895.63	7109471.72	740754.21	7109330.30
	492	740745.87	7109760.84	740604.45	7109619.42
	493	740619.64	7109879.57	740478.22	7109738.15
	494	740518.25	7110079.11	740376.83	7109937.69
	495	740283.36	7110185.06	740141.94	7110043.64
	496	740126.53	7110272.93	739985.11	7110131.51
	497	740095.98	7110334.46	739954.56	7110193.04
Inside Red	498	739986.85	7110205.31	739845.43	7110063.89
	499	740137.28	7110041.81	739995.86	7109900.39
	500	740231.16	7109886.74	740089.74	7109745.32
	501	740425.27	7109650.39	740283.85	7109508.97
	502	740553.67	7109468.82	740412.25	7109327.40
	503	740755.83	7109217.52	740614.41	7109076.10
	504	740937.33	7109022.03	740795.91	7108880.61
	505	740977.37	7108932.62	740835.95	7108791.20
	506	740947.02	7108914.70	740805.60	7108773.28
	507	741090.59	7108832.60	740949.17	7108691.18
	508	741227.90	7108682.27	741086.48	7108540.85
	509	741424.05	7108468.02	741282.63	7108326.60
	510	741610.88	7108290.89	741469.46	7108149.47
Inside Blue	511	741241.32	7108506.51	741099.90	7108365.09
	512	741192.45	7108479.71	741051.03	7108338.29
	513	741059.41	7108410.13	740917.99	7108268.71
	514	740857.84	7108511.77	740716.42	7108370.35
	515	740679.88	7108718.28	740538.46	7108576.86
	516	740540.90	7108868.65	740399.48	7108727.23
	517	740106.87	7109207.35	739965.45	7109065.93
	518	739931.14	7109535.73	739789.72	7109394.31
Inside Orange	519	740157.91	7109442.87	740016.49	7109301.45
	520	740245.93	7109241.73	740104.51	7109100.31
	521	740432.89	7109070.16	740291.47	7108928.74
	522	740584.45	7108878.93	740443.03	7108737.51
	523	740925.52	7108654.62	740784.10	7108513.20

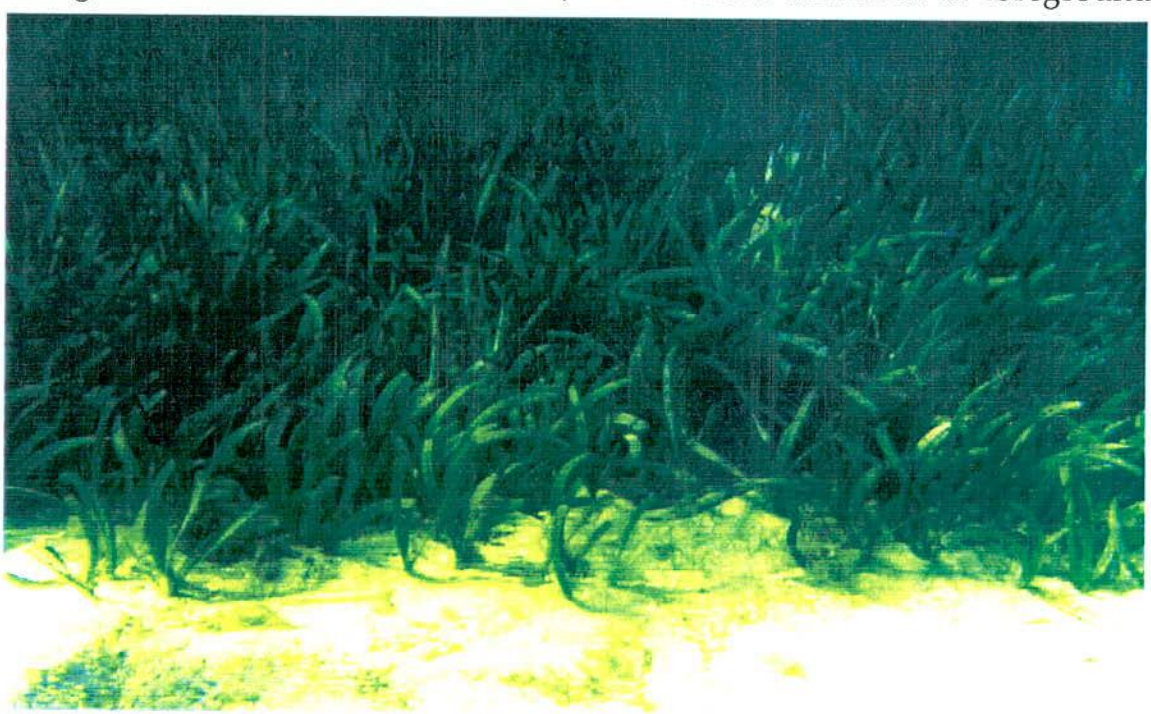
Appendix 2 continued

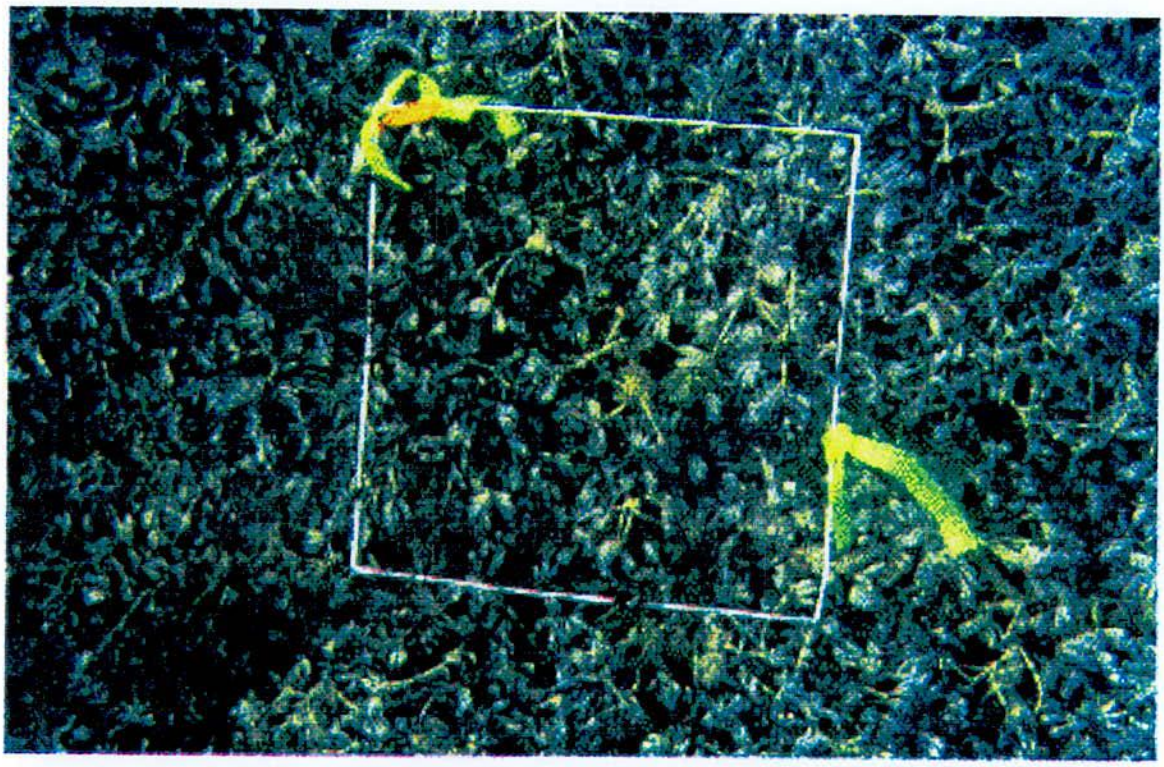
Location colour	Waypoint No	Easting (GDA)	Northing (GDA)	Easting (AGD)	Northing (AGD)
Outside Blue	524	740570.41	7110645.30	740428.99	7110503.88
	525	740723.17	7110156.61	740581.75	7110015.19
	526	741093.32	7109789.51	740951.90	7109648.09
	527	741372.90	7109396.37	741231.48	7109254.95
	528	741624.18	7108916.92	741482.76	7108775.50
	529	741983.26	7108496.42	741841.84	7108355.00
Outside Red	530	742443.39	7108755.73	742301.97	7108614.31
	531	742181.32	7109191.06	742039.90	7109049.64
	532	741966.15	7109638.45	741824.73	7109497.03
	533	741764.20	7110080.04	741622.78	7109938.62
	534	741613.94	7110611.19	741472.52	7110469.77
	535	741591.13	7110729.85	741449.71	7110588.43
	536	741295.12	7111138.07	741153.70	7110996.65
Inside Green	537	740157.71	7109522.32	740016.29	7109380.90
	538	740362.03	7109387.38	740220.61	7109245.96
	539	740308.75	7109392.06	740167.33	7109250.64
	540	740534.77	7109258.56	740393.35	7109117.14
	541	740719.04	7109122.14	740577.62	7108980.72
	542	740890.17	7108997.04	740748.75	7108855.62
	543	740982.75	7108952.84	740841.33	7108811.42
	544	741028.44	7108898.42	740887.02	7108757.00
	545	741240.23	7108807.66	741098.81	7108666.24
	546	741506.05	7108752.85	741364.63	7108611.43
	547	741587.59	7108653.42	741446.17	7108512.00
Salinity and	548	757655.56	7112686.95	757514.14	7112545.53
nutrients	549	757764.40	7114140.73	757622.98	7113999.31
	550	757352.71	7114080.50	757211.29	7113939.08
	551	757205.64	7112716.16	757064.22	7112574.74
	552	753394.76	7111682.30	753253.34	7111540.88
	553	749498.17	7110576.98	749356.75	7110435.56
	554	745726.34	7109412.78	745584.92	7109271.36
	555	741960.00	7108142.15	741818.58	7108000.73
	556	741471.05	7108304.58	741329.63	7108163.16
	557	741001.43	7108341.00	740860.01	7108199.58
	558	740536.24	7108796.68	740394.82	7108655.26
	559	740061.21	7109173.09	739919.79	7109031.67
	560	740125.72	7110228.61	739984.30	7110087.19
	561	740741.20	7109598.36	740599.78	7109456.94
	562	741401.17	7108852.71	741259.75	7108711.29
	563	742078.70	7108158.42	741937.28	7108017.00
	564	742406.80	7107598.08	742265.38	7107456.66
	565	742851.62	7107842.87	742710.20	7107701.45
	566	742132.95	7109639.04	741991.53	7109497.62
	567	741453.31	7111933.22	741311.89	7111791.80
Inside Pink	568	741015.19	7108453.44	740873.77	7108312.02
	569	740858.26	7108624.46	740716.84	7108483.04
	570	740819.45	7108780.36	740678.03	7108638.94

Appendix 3: Photographs of seagrass at the Useless Loop study site

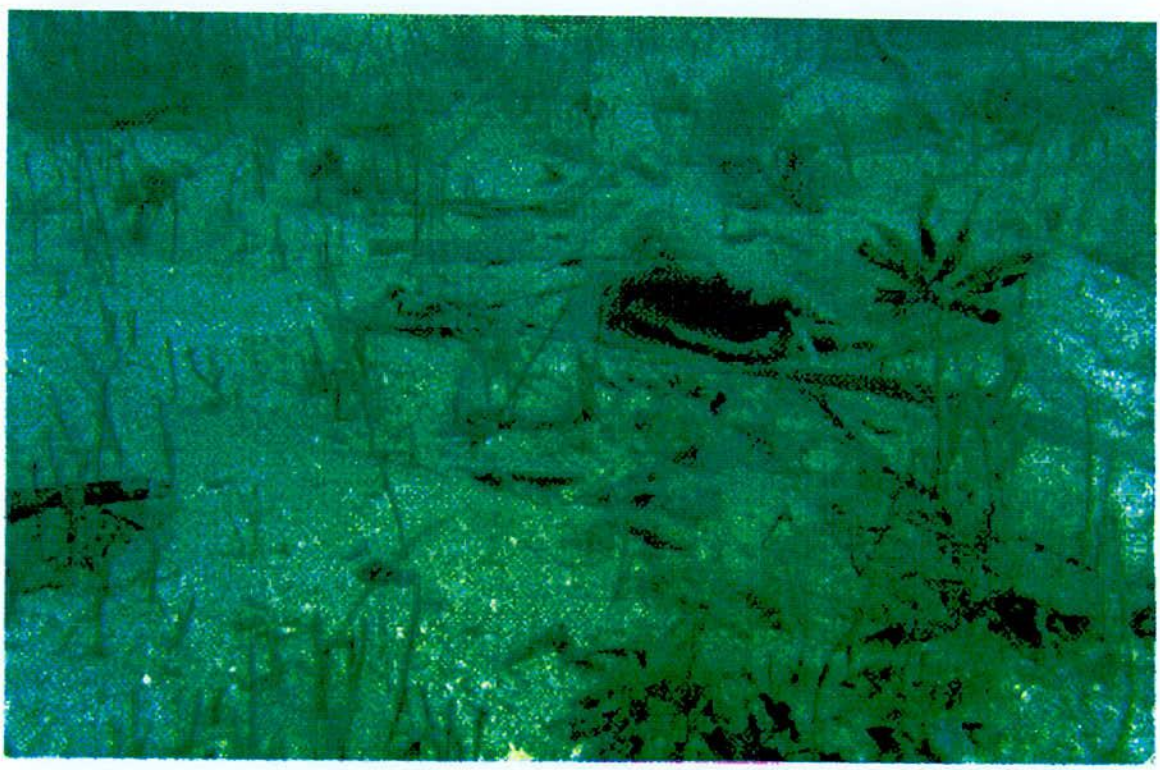
3a *Posidonia australis* within 50 x 50 cm quadrat (50% cover)

3b Edge of *Posidonia australis* meadow, *Heterozostera tasmanica* in foreground





3c *Amphibolis antarctica* within 50 x 50 cm quadrat (100% cover)



3d *Heterozostera tasmanica* and *Amphibolis antarctica* at waypoint 527 (Figure 4)

3e *Posidonia australis* (5-10% cover) with dead wrack. Photo taken 70 m North East of waypoint 568 (Figure 4).

Appendix C

Report on coastal engineering considerations by Dr W S Andrew

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Shark Bay Salt - Proposed F Series Crystallisers
Impact of proposed Bund Wall on adjoining Seagrass Beds.

The proposed bund wall for the F series crystallisers is located seawards of the original closing bund at Useless Loop. It is on an east-facing shore within the Freycinet Reach of Shark Bay which is sheltered fully from open ocean forces. Prior to the construction of the salt works this shore has been free of any human interference, having been formed and shaped by local wave and tide forces following the holocene inundation of some 9,000 years ago.

Examination of air photographs from before construction (1957) and of recent time (1992) suggests that the wave and tide forces have been of quite low impact by comparison with sites exposed to the open ocean. There has been some development of nearshore flats, caused by both cyclonic and local wind waves, but the main influence for sediment transport seems to be from tidal currents. Neither waves nor currents have transported shore sediments over any great distance, with the few evident transported deposits being where shore currents are concentrated, and being within tens of metres of the sediment source.

The wind regime at the site is dominated by strong southerlies for much of the year, which are parallel to the new bund. Associated waves thus have a negligible influence on the bund. For the winter months onshore easterlies and north-easterlies are common in the mornings but are of lower velocity. They commonly change in the afternoon, and are thus of insufficient duration to generate the larger waves of a fully developed sea.

Velocity tests suggest that the southerly winds do influence the velocity of tidal currents by enhancing the outflow from Freycinet Reach. Certainly it is the nearshore outflow current which has caused the original sediment movements mentioned above, where sediment deposits follow streamlines from points which protrude into the bay. All deposits are in the ebb direction and are aligned into the downstream embayment. A brief series of drogue tests to quantify velocities of the water body has been undertaken. In all normal circumstances bar the wind-assisted ebb, the peak velocity measured was 0.15 metres per second. That ebb was monitored up to 0.25 metres per second at mid-tide, so could perhaps rise above that velocity.

The tides themselves are of moderate size, with a predominantly diurnal astronomic range of about 1.5 metres. The daily range is about 0.8 metres at springs, 0.4 metres at neaps. A sustained strong wind can further change the level at the shore, by as much as 0.5 metres.

Cyclones are regularly experienced in Shark Bay, passing once every two or three years on average but passing directly over the Bay perhaps once per decade. They normally travel in a south to southwest direction and move rapidly. They do generate very strong winds and can cause a storm surge in Freycinet Reach. The additional height sea surface height has been assessed[1] to be from 1 metre to 2.3 metres each 10 to 100 years. The surge peak is only sustained for a few hours, and the whole surge is normally gone within 12 hours. The rapid movement of the storm centre causes the wind direction to change,

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[1]Department of Marine and Harbours, Western Australia. "Prediction of Extreme Water Levels Due To Storm Surge at Denham" Report DMH 12/88. (1988)

with the stronger winds moving through 90° in about two hours. The cyclone impact on a bund is noticeable, though it is extremely difficult to specify. Waves can be sufficiently large to break at the 5 metre water depth, after which the broken wave will most probably act at a higher-than-normal level and cause damage to the bund itself for a short time. Commonly, cyclone impacts from waves or currents are not sustained for a sufficient time for significant quantities of shore sand to be moved any distance in any particular direction.

The common onshore wave action at the crystalliser site is generated by winds of relatively short duration, typically from the winter easterlies. They are generated across a limited fetch of some 18 (E) to 25(NE) km. and will therefore be of short period (up to 4 seconds) and short wavelength (25 metres). Any big waves at normal sea levels will break at the toe of the bund. Smaller waves (1 metres or less) could progress across the sandy berm of the bund. However, the lack of changes to the natural shore over the 35 years of photographic review suggests that large wave action is rarely generated. The existing bunds within the salt complex also show little evidence of major damage, notwithstanding that they are similarly more vulnerable to direct wave attack than the more gently sloped natural shore boundaries.

Bund Construction Material

Samples of bund material have been put into suspension in sea water and then allowed to differentially settle in a water cylinder. This has allowed an indicative measure of the proportion of material which is fine enough to cause a turbid plume, as well as a measure of the time it takes to settle from the water column. In five separate tests of the finer fill material (sands and finer) between 5% and 13% was fine enough to remain in suspension for more than 30 seconds. The bulk (75%) of this fill was a coarse sand of 0.35 - 0.50 mm diameter, with 15% being 0.10 to 0.2 mm.

The suspended fraction cleared from below the water surface from about 45 seconds, virtually clearing the top 10 centimetres in ten minutes and being formed into a floc on the bottom by twenty minutes. Only a translucent haze remained until full transparency was restored in one to two hours. In all cases a surface froth remained on the top for 24 hours but had no substance.

Impact of Bund on adjoining Seagrass Bed.

This bund is to be located across some seagrass beds, in waters of up to 3.5 metres below datum. In addition to its direct contact impact under the structure, it will have some indirect impacts in the near zone to the east. The impacts will differ under the following circumstances.

1. **During Construction**

   A plume of suspended fines will be generated by the tipping of bund material into the water. It will settle as suggested by the above settling tests, being dispersed away from the tipping point if currents are present. The surface will commence clearing after 45 seconds, will be clear to 10 cm depth in 10 minutes, and will reach bottom, depending on depth, between 20 minutes and one hour. For rising tides or with easterly winds, the peak current of 0.15 m/sec. will move 180 metres in 20 minutes.

Since most of the velocities are lower, the greatest distance of sediment deposition will be of the order of 200 metres. At this distance, the thickness of deposit can be expected to be very small. Turbidity will be well below the surface within 100 metres. For most situations the flow, and deposition, will be along the line of the bund - the only circumstance causing offshore flow is with a rising tide and a strong southerly wind.

With a falling tide and southerly wind, the velocity will rise to at least 0.25 m/sec. The turbidity plume can move 300 metres in 20 minutes and 900 metres in one hour. It will thus be likely to be contained to an alongshore drift zone of about 1 kilometre towards the causeway. The amount of sediment thickness under this distribution will be very small indeed - perhaps only a few grains - since most of the fines have settled out of the water column in the first hour..

With both of the above current regimes, the thin sediment deposition from the turbidity plume will not settle on raised surfaces, such as the seagrass itself, but will be moved to the lowest level and will oscillate until it is sufficiently dense to stay on the seabed. It appears to be calcareous material, of marine origin, so is unlikely to disturb the local environment for more than a few tidal cycles.

2. Under Normal Post-Construction Conditions.

Wave - induced sediment movements may be initiated under easterly winds. Any fine material left in the upper layer of the bund berm could be put into suspension. Currents associated with tides will then move the suspended material to deposition sites down their flow paths. The berm is designed at 1:6 grade, which is close to the 1:8 "stable" slope of moderately protected ocean beaches. Only a small quantity of turbidity would be released as the berm flattens over the first one or two years, since the actual volume of sand being moved is small. This therefore will be a minor impact.

3. Under Cyclonic Conditions.

Under cyclonic conditions, waves have a potential to be 4 or 5 metres high with a wave length of perhaps 75 metres. The water level would also be higher than normal, for winds from the vulnerable direction. Waves greater than 3 metres will break out from the bund within the seagrass beds, damaging both the seagrass and the sea bed. These conditions will be rare - with a recurrence interval probably more than 100 years (though data is not available to justify this judgement) - so it would be reasonable to discount them for design, and just be prepared to repair local damage to the bund. The duration of such waves would also be brief - only an hour or so from the direction of the worst case situation - and would thus be unlikely to breach the bund.

The broken waves, together with smaller unbroken waves, will attack both the bund berm and its armoured revetment. They will tend to flatten the berm towards the "stable" 1:15 slope of sand of this median size, though their duration is unlikely to complete this task in any one storm. The 1 tonne armour stone should withstand waves of 2.5 metres with only minor damage, provided that they are not undermined at weak sections of the main bund by removal of the berm material.

Conclusions.

The bund to be constructed for the F series crystallisers is likely to produce local turbidity during construction, which will be effectively contained to within 200 metres of the dumping point under rising tides or east winds. The turbid cloud could reach up to 1 kilometre alongshore during a falling tide with a strong southerly wind. The turbidity will have largely settled within one hour, leaving a very thin layer of fine marine sediment on the bottom. Water will be substantially clear in 1-2 hours.

Under normal operating conditions only a small amount of turbidity will be generated under the waves caused by east winds. It will move alongshore under the common tide and wave conditions.

Under cyclone attack the bund berm may reshape, releasing some turbidity. There is a very low risk of major damage to the bund proper, provided that the seaward armour stone is well founded.

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