SHARK BAY SALT JOINT VENTURE

SHARK BAY SALT PROJECT

EXTENSION OF SALT PONDS, USELESS INLET

PUBLIC ENVIRONMENTAL REVIEW

VOLUME 1 of 2

LeProvost, Semeniuk & Chalmer

SHARK BAY SALT PROJECT

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NOTE :

On July 20th 1990, Agnew Clough Ltd changed its name to Mount Resources Limited.

SUMMARY

THE PROPONENT

The Shark Bay Salt project is owned by a joint venture of:

- Shark Bay Resources Trust (75% owned by Agnew Clough Ltd);
- Australian Mutual Provident Society;
- Mitsui Salt Pty Ltd.

The project is managed by Agnew Clough Limited in accordance with the terms and provisions of the Shark Bay Salt Agreement Act, 1983.

THE PROJECT

The salt project is located on either side of Heirisson Prong with primary concentration ponds located in the southern portion of Useless Inlet and salt crystallising ponds at Useless Loop (Fig. A). The project commenced in 1963. It currently earns some A$12.5 million of export revenue. The project is located in a remote area of Western Australia and is serviced by a company town of some 150 people located at Useless Loop.

THE PROPOSAL

In accordance with the provision of the Agreement Act 1983, the company now wishes to exercise its long-stated option of expanding the salt project within its existing mining lease. The completion is required to meet forecast demand and achieve efficiencies of scale to ensure the project remains cost-competitive.

The proposed expansion will involve the construction of a new causeway (levee) across Useless Inlet at a location some 6 km north of the existing Clough's Bar (Fig A) . Rock and fill material for the causeway will be obtained from two new quarries, one on each side of the Inlet. Construction will progress simultaneously from each shore. The new pond formed by the levee will enable the production of an additional 550,000 tonnes of salt per annum (an increase in production of some 85%). This increased production will be worth at today's prices approximately A$10 million annually in additional export revenue and will ensure the long term commercial viability of the salt project.

There is no viable alternative method of increasing salt production other than that proposed. Increased salt production will result in both increased bitterns disposal and shipping movements at Useless Loop.

THE EXISTING ENVIRONMENT

Shark Bay lies between latitudes 24° 30' and 26° 45' on the coast of Western Australia. It is a large bay covering some 28,690 km^2, with a coastline of over 1,500 km. The Bay is separated into a number of gulfs and inlets by a series of north-south trending peninsulas. The Shark Bay Salt project is located in the southwest portion of the Bay in the Edel Land Province.

Edel Land is characterised by a series of narrow islands, peninsulas and inlets, and is comprised primarily of calcareous dunes.

The Edel Land inlets have the following characteristic features:

- shallow banks and sills that form 'barrier banks' at their entrance;
- deep tidal channels which pass through these banks;
- one or more deep inlet basins surrounded by a wide and shallow sublittoral platform;
- intertidal/supratidal salt-mud and samphire flats in side embayments and southern ends.

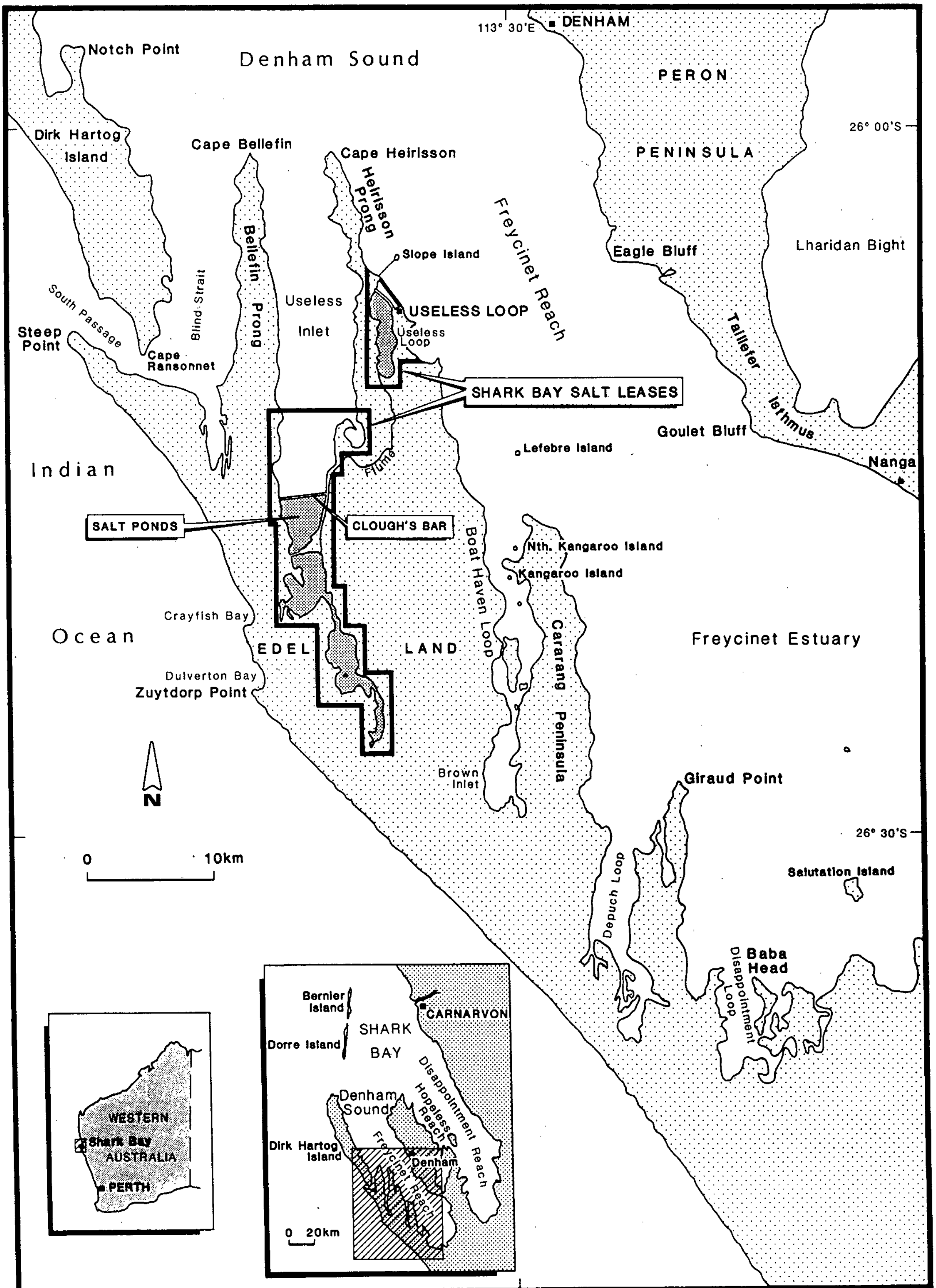
Western shorelines of the Edel Land Inlets tend to have long but narrow sandy beaches, whilst eastern shorelines are predominently rocky with sandy pocket beaches located between cuspate headlands. The waters of the inlets grade from metahaline to hypersaline and have low nutrient concentrations.

The climate of the region is semi-arid, with hot, dry summers and mild winters. Most rainfall occurs in winter, but periodic heavy falls occur in summer as a result of cyclones. The predominent wind direction is southerly. These winds are strong (20-25 knots) during summer but ease (10 knots) during winter. Annual evaporation is high (over 2000 mm). The climate is ideal for salt production.

MARINE RESOURCES OF SHARK BAY

The waters of Shark Bay support a number of marine resources which are of recreational, commercial, scientific and educational importance. The Bay supports major fisheries for prawn, snapper, whiting and scallops. It also supports unique biological resources such as stromatolites, the world's largest seagrass bank and possibly one of the world's largest 'local' populations of dugong.

The importance of the Bay's marine resources has stimulated scientific, commerical and social investigations in recent years. The most recent and comprehensive analysis of the region's resources is the Shark Bay Region Plan (hereafter termed the Region Plan), produced jointly by the State Planning Commission (SPC) and the Department of Conservation and Land Management (CALM) in 1988.



LeProvost Semeniuk & Chalmer Environmental Consultants

Comp : R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
Drawn : Environmental	**EXISTING FACILITIES AND MINING LEASE**	A
Date : June 1990		

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The Region Plan outlines a management strategy to safeguard the important natural resources whilst allowing traditional industries to remain and potential industries to develop. The Region Plan has undergone considerable public scrutiny through a formal submission process, and also because of the Federal Government's intention to nominate parts of Shark Bay for World Heritage Listing. The submissions received on the Region Plan have been evaluated by the Environmental Protection Authority (EPA), who reviewed the Plan in relation to their System 9 'Redbook' recommendations. Therefore community attitude to developments within the region has been widely canvassed and positions on various issues have been adopted.

Management recommendations of the Region Plan which are pertinent to this proposal are:

Mining development

(i) "The solar salt mining operation at Useless Loop should be continued in accordance with the Shark Bay Solar Salt Industry Agreement Act, 1983".

(ii) "Prior to any further expansion of the salt mining operations at Useless Loop which would result in further closure of Useless Inlet, it is essential that the operator undertake a study to determine the potential effects on existing seine and other fishing activities and recreational potential. This needs to comply with the assessment procedures of the EPA".

Fisheries development

(i) "The long term sustainability of the fishing industry at Shark Bay should be ensured by ongoing management by the Department of Fisheries and by members of the industry, and by protection of marine habitat, especially those areas which serve as breeding and nursery areas for juvenile fish".

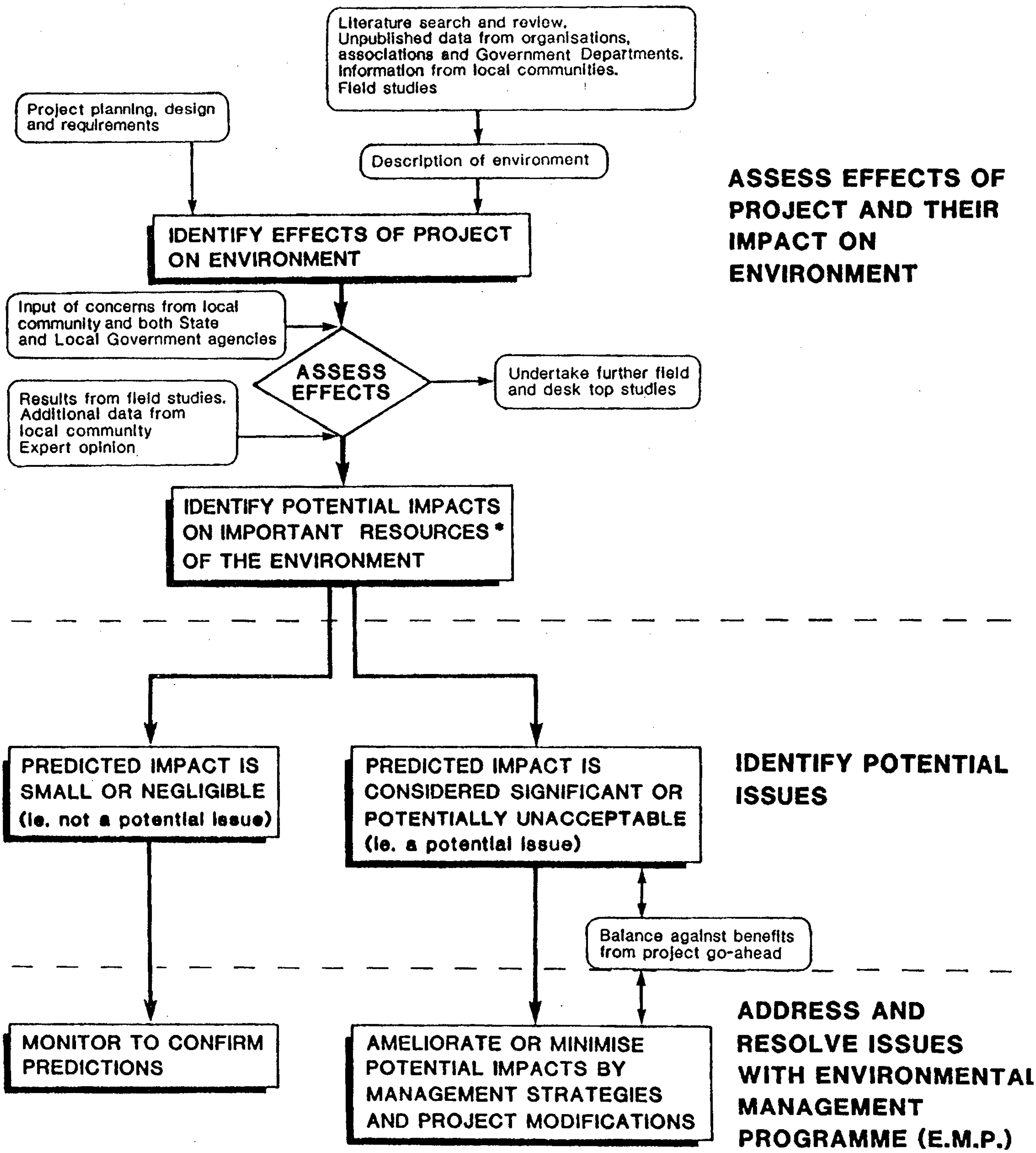
The Region plan also encompasses the development of various forms of commercial fish, prawn and algae aquaculture ventures.

Both the EPA's System 9 report (EPA, 1974) and Bulletin 305 (EPA, 1987) (which reviewed the Region Plan) acknowledge the continued existence of the solar salt project and its mining lease boundaries. The mining lease of the solar salt project is specifically excluded from the boundaries of the recently proposed Shark Bay Marine Park.

EFFECTS OF PROPOSAL ON REGIONAL AND LOCAL ENVIRONMENT

Project effects have been thoroughly investigated using a staged approach, wherein a preliminary report detailing the project was circulated to Local and State Government Departments and the Western Australian Fishing Industry Council for initial comment and feedback. The flow chart overleaf summarises the assessment process used by the review.

FLOW CHART SUMMARISING GENERALISED PROCEDURE OF PROJECT ASSESSMENT USED BY THIS STUDY



* Includes social, conservation and ecological resources

In compliance with the recommendations of the Region Plan and EPA terms of reference, the proponent has commissioned technical studies on the potential effects of the proposal on:

- the Shark Bay prawn fishery;
- the Denham commercial beach seine fishery;
- the nursery value of the proposed pond to commercial and recreational fisheries;
- the ecological and conservation values of the proposed pond area to the local and regional marine ecosystems; and
- the pattern of water circulation within the remaining 82% of open water area of Useless Inlet before and after levee construction.

In addition, the proponent has also investigated the aboriginal heritage value, waterbird usage and dugong usage of Usless Inlet, and has addressed both public access and the potential concerns of increased bitterns disposal and shipping movements.

POTENTIAL IMPACTS

The table overleaf summaries the potential adverse impacts of the proposal, their likelihood of occurrence, the perceived significance of each potential impact, and the management commitments proposed by SBS to mitigate impacts.

The proposal will not result in significant adverse impacts on either the regional marine ecosystem of Shark Bay or the regional community who derive benefit from the marine resources within the Bay.

There are no resources of identified conservation value which rely on the proposed pond area. The ecological value of the proposed pond is no higher than that of other similar habitats in Useless Inlet and elsewhere in the southwest or Shark Bay. Construction of the pond will not adversely affect the remainder of the Useless Inlet ecosystem, nor necessarily prevent existing public access to Steep Point and the open water of Useless Inlet.

The main potentially adverse impact identified by this review of the proposal is the 'trapping' of commercial scale fish stocks within the proposed new pond. This impact, however, is shown to be of minor commerical and biological significance to the Denham beach seine fishery, with this impact being mitigated by the management proposal presented in the Table. Conservative assessment of the effects of the new pond on the Shark Bay prawn trawling industry indicates the potential reduction in prawn numbers that will not be significant. This is because the reduction in number of prawns will be far less than the natural annual fluctuations in the size of the catch taken from Denham Sound, and this area is not the main trawling ground utilised by the Carnarvon prawn trawling fleet.

POTENTIAL ADVERSE IMPACTS PREDICTED, PROBABILITY OF OCCURRENCE, SIGNIFICANCE AND PROPOSED MANAGEMENT PROGRAMME TO MITIGATE IMPACTS FOR SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET

POTENTIAL ADVERSE IMPACTS	PROBABILITY OF IMPACT OCCURRENCE	SIGNIFICANCE OF IMPACT	ENVIRONMENTAL MANAGEMENT PROGRAMME AND COMMITMENTS
PHYSICAL ENVIRONMENT			
Construction of the proposed pond will modify the following topography of the project area:			
- the shoreline at each end of the proposed levee;	Inevitable	Low	
- 15ha of limestone and dunal ridge on the eastern side of Useless Inlet;	Inevitable	Low	The quarry sites will be rehabilitated once the levee has been completed except for a small portion of the eastern quarry to be reserved for maintenance purposes. Much of the eastern quarry will be masked from view by a dunal ridge. The access track will be either rehabilitated or left open for public 4WD vehicular access to new levee.
- 4ha of dunal ridges on the western of Useless Inlet; and	Inevitable	Low	
- slight modification to parts of the western shoreline between Clough's Bar and the western abutment to create an access track (0.5ha).	Inevitable	Low	
A temporary sediment plume of carbonate fines (that will vary in size, duration and direction on a daily basis) will be generated during construction of the levee.	Certain	Low	
The proposed new levee will alienate the southern end of Useless Inlet. This will shorten the length of the Inlet by 6km and reduce the volume capacity of the Inlet by 18%.	Inevitable	Low	The proposed levee has been located 400m to the south of the lease boundary to avoid containment of 15ha of mangroves within an embayment on the eastern shore of the Inlet.
Piloted shipping movements at Useless Loop will increase from 33 to about 60 vessels per year. This will double the risk of an accidental fuel oil spillage (only by ship wreck).	Remains very low	Medium	There are no fuelling facilities on (or planned for) the ship loading jetty. The proponent will assist with the development of an oil spill contingency plan in conjunction with appropriate authorities.

(cont'd) **POTENTIAL ADVERSE IMPACTS PREDICTED, PROBABILITY OF OCCURRENCE, SIGNIFICANCE AND PROPOSED MANAGEMENT PROGRAMME TO MITIGATE IMPACTS FOR SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET**

POTENTIAL ADVERSE IMPACTS	PROBABILITY OF IMPACT OCCURRENCE	SIGNIFICANCE OF IMPACT	MANAGEMENT PROGRAMME AND COMMITMENTS
BIOLOGICAL ENVIRONMENT			
Construction of the levee will alienate approximately 26km^2 (18%) of existing marine habitat in Useless Inlet.	Inevitable	Low	
Increased bitterns discharge has a potential to impact on adjacent biota if below-ground dilution is not adequate.	Very low	Medium	The proponent will continue to monitor.groundwater salinities and ionic composition in the Useless Loop area, together with extent of seagrass distribution.
Increased shipping movements at Useless Loop increase the potential for introducing undesirable foreign biota via the discharge of ballast water.	Low, provided ships continue to arrive from nearby SE Asian ports	High	The proponent will assist in the implementation and operation of any routine ballast water monitoring programme that may be established by the Carnarvon Port Authority and Australian Quarantine Service.
Closure of the levee has a potential to trap marine mammals and/or turtles within the proposed pond.	Low	Medium	At the time of levee closure, a final inspection will be made by boat and aircraft to ensure these animals do not remain inside the new pond area. Any trapped animals will be transferred to the inlet.
The new levee may alienate important feeding or breeding habitat for dugongs.	Very low	Medium	Aerial surveys of Useless Inlet will be undertaken before project commencement to confirm that area of proposed pond does not contain an important dugong habitat

(cont'd) **POTENTIAL ADVERSE IMPACTS PREDICTED, PROBABILITY OF OCCURRENCE, SIGNIFICANCE AND PROPOSED MANAGEMENT PROGRAMME TO MITIGATE IMPACTS FOR SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET**

POTENTIAL ADVERSE IMPACTS	PROBABILITY OF IMPACT OCCURRENCE	SIGNIFICANCE OF IMPACT	MANAGEMENT PROGRAMME AND COMMITMENTS
SOCIAL ENVIRONMENT			
Completion of the proposed levee will remove public access to the open waters of Useless Inlet via existing route.	Inevitable	Medium	It is proposed that the temporary haulage track located on the western shore could be left open to provide 4WD vehicle access to the new levee. Open water shoreline angling and beach launching of recreational fishing boats would thus be maintained.
The proposed pond will occupy part (~ 1.5%) of fishable waters presently utilised by some of the licensed beach seine fishing operators from Denham.	Inevitable	Low	The proponent will liaise with WAFIC and the WA Department of Fisheries in order to develop a pond management programme which can lead to regulated fish harvesting in the new pond.
The proposed pond will alienate 0.8% of the nursery grounds of western king prawns, which are taken from trawling grounds in Denham Sound by prawn trawlers based at Carnarvon.	Inevitable	Very Low	

The following benefits which will accrue to the community as a result of the proposal proceeding are listed below and summarised in the Table overleaf:

- Shark Bay Salt will remain economically viable and continue to provide employment opportunities in the region as well as maintain its management of convenient public access to Steep Point.

- The nation will receive an additional A$10 m of forgein earnings per annum that will help reduce the present foreign debt.

- The State and Commonwealth governments will benefit from increased receipts from taxes and royalties.

- Regional fisheries may benefit from the offer to participate in aquaculture research. Studies conducted for this assessment have shown that pond husbandry techniques can enhance fish production within the ponds, and that these fish are highly marketable. An opportunity exists to develop these findings further by researching the potential for commercial aquaculture within Shark Bay. Such an opportunity is consistent with recommendations of the Shark Bay Region Plan.

ENVIRONMENTAL MANAGEMENT PROGRAMME

The proposed Environmental Management Programme will minimise the potential for adverse impact arising from the proposed expansion. Examples of the proponent's commitment to minimise the potential effects of the proposal include:

- the location of the new levee some 400 m to the south of the existing mining lease boundary to avoid enclosure of a mangrove embayment on the eastern shore of the Inlet;

- the rehabilitation of the roads and quarries;

- the offer to provide additional public access and recreational facilities on the western shore of Useless Inlet subject to approval by relevant State authorites;

- the offer of assistance to relevant State and Commonwealth authorities in developing and implementing both an oil spill contingency plan and a ballast water monitoring programme;

- to enable regulated access to harvest the commercial stocks of fish within the new pond; and

- the offer to assist in an aquaculture research programme aimed at improving in-pond fish stocks.

BENEFICIAL IMPACTS PREDICTED TO RESULT FROM PROPOSED SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET

BENEFICIAL IMPACTS	COMMENTS
The proposed salt production extensions will provide additional export earnings estimated at A$10.4 million per annum.	Increased salt production is required to ensure the future viability of the Shark Bay salt works.
The proposed salt production extensions will provide employment for 25 construction workers during the 14 month construction period and an additional 15 full time staff during the operation of the expanded development.	All employees will be housed at the company town at Useless Loop.
The proposed pond will expand the area in the southernmost section of Useless Inlet presently used by migratory wading birds.	The existing primary salt ponds P2 and P3 currently provide an important waterfowl refuge of high conservation value.
The access track to the proposed levee can provide 4WD vehicle access to a boat launching and overnight camping area at the western end of the proposed levee, with public access along the new levee (as well as Clough's Bar) improving recreational angling, boating and bird watching opportunities in Useless Inlet.	The cleared area by the foreshore on the western end of Clough's Bar is currently used by tourists for these purposes. The proponent is prepared to allow public access to the western sector of the new levee and to provide camping areas and a boat launching ramp at the western end, subject to approval by CALM and Fisheries Dept.
The abundance of commercial teleost fish species within the proposed pond area is expected to increase, thereby leading to enhanced commercial fishing opportunity.	Regulated commercial harvesting of fish appears logistically viable within both the new and existing (PO) primary ponds, and may be an economically attractive operation.
The new pond has the potential for use as a site for aquaculture research in the Shark Bay region.	If required the proponent will assist in an aquaculture research programme for the Department of Fisheries and the Western Australian Fisheries Industry Council.

It is also worth recognising that:

- Useless Inlet is not a pristine, unmodified environment but one which appears to have undergone modification prior to the initiation of the salt project as a result of some 60 years of pearl oyster dredging activities between the 1870's and the 1930s;

- The present pond system supports enhanced numbers of some marine biota including commercial scale fish, and is an important refuge for both local avifauna and trans-equatorial migratory wading birds.

- The proponent does have an existing agreement with the State which foreshadowed the proposed expansion by granting of the mining lease. The proposed new levee is within the existing lease boundary. The proponent has fulfilled all obligations under that Agreement.

- The Shark Bay Region Plan and subsequent submissions, and the EPA evaluation of the Plan, all support the continuation of the solar salt project and, subject to its environmental acceptability, the proposed expansion.

- The Shark Bay Salt Project is an 'environmentally friendly' industry, in that it is based on a sustainable resource (seawater) produced by harnessing natural energies (sun, winds and tides). It does not require the consumption of large quantities of fossil fuels to produce the salt. It also does not produce hazardous or noxious wastes and is not a producer of Greenhouse gases.

Given all of the above and the proposed Environmental Management Programme, it is concluded that the benefits of the proposal substantially outweigh the potential impacts. It is therefore submitted that, subject to resolution and acceptance of the proposed Environmental Management Programme, the project can proceed without causing unacceptable deleterious impacts.

SHARK BAY SALT PROJECT

EXTENSION OF SALT PONDS, USELESS INLET

PUBLIC ENVIRONMENTAL REPORT

1 INTRODUCTION

1.1 THIS DOCUMENT

This document is a Public Environmental Review (PER) which has been submitted to the Environmental Protection Authority (EPA) of Western Australia by Shark Bay Salt Joint Venture (SBS) in accordance with the provisions of the Environmental Protection Act, 1986.

The PER, which comprises two volumes, presents a detailed environmental assessment of SBS's proposed expansion of their solar salt production facility at Useless Inlet in Shark Bay, Western Australia. The proposal is to construct a new salt concentration pond within SBS's existing solar salt production lease area in the southern portion of Useless Inlet.

The PER has been prepared in response to guidelines provided by the EPA following its review of a Notice of Intent produced by SBS. The guidelines provided to SBS by the EPA are reproduced in Appendix 1 (Volume 2).

Information is provided from desk study reviews of the pertinent environmental and social characteristics of the area, and from a series of extensive field surveys. These surveys were undertaken to determine the ecological and commercial value of the proposed pond area in a regional perspective.

The management commitments put forward in this document have been guided by or are consistent with the objectives and recommendations of the 1988 Shark Bay Region Plan and the EPA's Bulletin 305 (EPA 1987) on this plan. They also accord with the 1974 'Greenbook' recommendations endorsed by the EPA in its 1975 'Redbook' on System 9, in which areas excluded from proposed reserves included Useless Inlet and Heirisson Prong (EPA, 1987).

1.2 STRUCTURE AND CONTENTS OF REPORT

The structure of this report follows that recommended in the EPA guidelines (Appendix 1). Volume 1 comprises the main PER document, while Volume 2 contains the technical appendices which present the results of specific investigations conducted for this PER.

Section 1 of the PER (Volume 1) provides details of the proponent, a summary overview of the existing facilities and proposed expansion, and the reasons for the expansion. Legislative requirements are described, and the assistance of individuals and Government officers in the production of the PER is acknowledged.

Section 2 of this report describes the existing salt production process employed by SBS. Section 3 describes the proposal in detail. This detail is necessary background to understand why no cost-effective, practical alternatives to the proposal exist.

The environment is described in Sections 4 and 5. Section 4 describes the regional setting of the project to provide perspective on the location of the proposed pond. It describes the regional characteristics of Shark Bay and provides details on the characteristics of the Edel Land province. This province is the major geomorphic unit in which the project is located. The majority of information in Section 4 has been summarised from available literature and in particular the Shark Bay Region Plan (SPC, CALM, 1988).

Section 5 describes the environmental characteristics of the project locality focusing on Useless Inlet, Useless Loop and adjacent waters. Since little published information was available for this area, a wide range of field investigations were conducted during 1989 and in 1990 to provide the information presented in Section 5.

All perceived consequences of the proposal are discussed in Section 6. Means of minimising the effects of the proposal are discussed in Section 7.

1.3 THE PROPONENT

The proponent is the Shark Bay Salt Joint Venture (SBS). SBS is a Joint Venture between:

(a) Shark Bay Resources Trust (owned 75% by Agnew Clough Ltd);

(b) Australian Mutual Provident Society;

(c) Mitsui Salt Pty Ltd.

The Joint Venture operates a solar salt project at Useless Loop through Agnew Clough Limited, who manage the project (Fig. 1) in accordance with the terms and provisions of the Shark Bay Solar Salt Industry Agreement Act, 1983, with the Western Australian Government. The Act incorporates two leases for the production of salt. The location of the solar salt project and the lease boundaries are shown on Figure 1.

Shark Bay Salt (hereinafter referred to as SBS), currently produce 650,000 tonnes of high purity sodium chloride per annum, all of which is sold overseas and earns Australia some $12.5 million.

1.4 EXISTING FACILITIES

The Shark Bay Salt project is located in a remote part of Western Australia. Its operation is substantially self-contained and is serviced by a company town of some 150 people located at Useless Loop (Fig. 1).

The salt production process utilises a series of concentration ponds and crystallising ponds. The concentration ponds are located in the southern part of Useless Inlet. Brine from these ponds is pumped then gravitated to the crystallising ponds at Useless Loop via an open flume. Salt is harvested from the crystallising ponds, washed, stockpiled and subsequently loaded onto ships via a conveyor-belt ship-loader located on Slope Island, at Useless Loop. The location of the town, ponds and other facilities of the project is shown on Figures 1 and 2.

The concentration ponds in Useless Inlet and crystallising ponds in Useless Loop were formed by constructing levees across intertidal salt flat and shallow water areas. The previous shorelines of the inlet and loop provide the natural confines to the ponds. Each pond is connected via adjustable gates, weirs or channels so that the flow of the brine into or through a pond can be regulated.

Salt production relies on the steady flow of seawater through the pond system which is gradually concentrated as it approaches the crystallising ponds. Throughflow is initially driven by gravity feed from the primary pond (pond P0, Fig. 2), which captures seawater on high tides through two flap gates. It takes approximately three years for the seawater to proceed through the pond system to become salt in the stockpile.

The Shark Bay salt project was commenced in 1963 with development in Useless Loop, and has been extended twice by the construction of larger concentrating ponds in Useless Inlet. The first expansion occurred in 1968 with the construction of Carratti's Bar (between existing ponds P0 and P1, Fig. 3) and Reid's Bar (between existing ponds P1 and P2, Fig. 3). Clough's Bar, (Fig. 3) the present primary bar that created pond P0, was constructed between 1973 and 1974.

1.5 THE PROPOSAL

The proposal is to complete the project by a final increase in salt production to be achieved by constructing a new bar or levee across Useless Inlet at a location some 6 km north of Clough's Bar. Material for construction of the levee will be obtained from quarries established on both shores of Useless Inlet adjacent to the proposed levee. Construction will proceed from both shores towards the middle of the inlet. A permanent water intake structure will be constructed at the eastern end of the levee. The proposed location of the new bar and quarries is shown in Figures 3 and 5. The location of the new bar will lie 400 m south of the existing lease boundary as defined by the Agreement Act of 1983. This set back from the lease boundary will forego 8.5% of the possible expansion but has been made to avoid containment of a large mangrove embayment on the eastern shore of the Inlet (Fig. 5).

It is proposed to construct the new bar as soon as is practically possible because of market forces and the lead time of three years between construction and increased salt production.

1.6 NEED FOR THE PROPOSAL

Australia is the major producer of industrial salt to the Asian market area with most competition coming from Mexico. In order to preserve its market share and hold its strategic supply position, Australia needs to expand salt production capacity to meet forecast demand.

Salt is a relatively cheap commodity and many nations have the ability to produce the very high purity levels which industry demands and which Australia can supply as a standard product. Future investment in large scale quality salt production facilities in other nations is a real threat to Australia and necessarily means that Australia must continue to operate highly efficient, low operating cost, salt fields to preserve its market position.

All Western Australian solar salt fields are planning expansions to be able to maintain existing markets and to capture the benefits achieved by economy of scale. Mexico is also now substantially increasing production capacity for the same reasons.

Shark Bay Salt is by far the smallest solar salt field in Western Australia and the economic pressure to increase production is more critical than it is for the other producers. Without increased production, Shark Bay Salt will find its ability to maintain market share at a profitable level under severe threat. Without the proposed expansion the long term viability of Shark Bay Salt is uncertain.

The proposed extension will be highly cost effective and will enable an increase in salt production of some 550,000 tonnes three years after construction (i.e. an increase over present production of some 85%). Such an increase will ensure the commercial viability of the project and earn Australia a further $10.4 million per year in export earnings over the coming decade.

1.7 LEGAL REQUIREMENTS

Under the terms of Clause 16 of the 1983 Agreement with the State, SBS is entitled to enclose a further portion of Useless Inlet for salt production. The Agreement Act recognises that environmental approval for the extension will be required under the provisions of the Environmental Protection Act, 1986. SBS formally referred the extension proposal to the EPA on 25 January 1989 and was subsequently advised that a PER was required.

The 1983 Agreement is administered on behalf of the State of Western Australia by the Department of Resources Development (DRD). Other Government departments having responsibility to the project or project area are the Mines Department and Department of Land Administration. Government departments which have an interest in the project and in the project area include the EPA, Fisheries Department, Department of Conservation and Land Management (CALM), Department of Main Roads and the Department of Marine and Harbours (DMH).

The 1983 Agreement with the State enables SBS to renew its lease for a further two 21 year periods, commencing on 2004 and 2025. Salt production after 2046 would require a new Agreement. If salt production is discontinued on or before that date, SBS are required to breach the levees and remove artificial barriers and/or other constrictions such as pipes and culverts so as to ensure that a regular pattern of tidal flushing is restored to ponded areas in Useless Inlet and Useless Loop.

1.8 ACKNOWLEDGEMENTS

SBS provided the description of the existing project (Section 2), the description of the proposed extension (Section 3) and the management proposals (Section 7). The assistance of the following individuals in providing information for this report is gratefully acknowledged.

- Dr P. Anderson, Emeritus Professor, University of Calgary, Alberta, Canada.
- Mr J. Andrews, Western Australian Fisheries Department, Marine Research Laboratories, Waterman, WA.
- Mr L. Belotti, professional seine fisherman, Denham, WA.
- Mr A. Bennet, 1986-89 Steep Point Ranger, now at Eneabba, WA.
- Mr M. Cliff, Western Australian Fisheries Department, Marine Research Laboratories, Waterman, WA.
- Mr G. Finlay, Fisheries Inspector, Western Australian Fisheries Department, Denham, WA.
- Dr D.A. Hancock (reviewer of the Shark Bay pearl oyster industry), 29 Woodlands Way, Quindalup, WA.
- Mr D. Hoult, professional seine fisherman, Denham, WA.
- Dr J. Huisman, School of Biological & Environmental Sciences, Murdoch University, WA.
- Dr H. Jones, Western Australian Fisheries Department, Marine Research Laboratories, Waterman, WA.
- Dr H. Kirkman, CSIRO Marine Laboratories, Marmion, WA.

- Dr R. Lenanton, Western Australian Fisheries Department, Marine Research Laboratories, Waterman, WA.
- Dr D. Luketina, Centre for Water Research, University of Western Australia, WA.
- Dr H. Marsh, School of Biological Sciences, James Cook University, Townsville, QLD.
- Dr L. Marsh, Western Australian Museum, Perth, WA.
- Dr M. Moran, Western Australian Fisheries Department, Marine Research Laboratories, Waterman, WA.
- Officers of the Marine Impacts Branch, Environmental Protection Authority, Perth, WA.
- Dr J. Penn, Western Australian Fisheries Department, Marine Research Laboratories, Waterman, WA.
- Mr J. Poland, Professional Seine Fisherman, Denham, WA.
- Dr R. Prince, Department of Conservation and Land Management, Woodvale Research Centre, WA.
- Mr R. Shepard, Department of Conservation and Land Management, Denham Office, Shark Bay, WA.
- Dr D. Walker, Department of Botany, University of Western Australia, Nedlands, WA.

2 THE EXISTING PROJECT

2.1 SOLAR SALT PRODUCTION

The production of solar salt is based on the physical process of precipitation (crystallisation). Precipitation occurs when a solution becomes over saturated with the substance (i.e. there is an excess of salt in solution). Saturation occurs with increased concentration of the salts in solution following the evaporation of water. The production of solar salt is a process of gradually increasing seawater concentration (density) by evaporation to the concentration level where pure common salt (NaCl) precipitates out of solution.

As seawater concentrates its salts precipitate sequentially. Calcium carbonate ($CaCO_3$) is the first to fall out of solution when the seawater has been reduced to 85% of its original volume. This is followed by calcium sulphate (gypsum; $CaSO_4$), which starts to precipitate when volume has been reduced to 26%. Sodium chloride (common salt; NaCl) crystallises out at 11% of the original volume. Whilst there are overlap concentrations where mixed salts precipitate together, there is a specific density window in which extremely pure NaCl precipitates, and this is the basis of the solar salt industry. It is a complex process and requires careful physical and biological husbandry of the system, including continuous management of water density and biological activity within the evaporation ponds. The salt must be extremely pure 99.6% NaCl (dry basis) because its main use is in the electrolytic production of chlorine and caustic soda. These are two essential chemicals for industry.

2.2 THE EXISTING POND SYSTEM

2.2.1 Primary Concentration ponds

Figure 2 shows the location and numbering of the pond system as well as direction of water flow through the system.

The first concentration pond (P0) provides both the initial reduction in water volume and a hydrostatic head to drive the primary pond system by gravity feed. In the present operation, seawater enters into P0 through two weirs located on the levee commonly referred to as Clough's Bar (Fig. 2).

Each weir comprises a flap gate and a separate drop gate. The drop gate in its low position closes the weir. The weirs are occasionally closed for short periods if rainfall lowers the density sufficiently to be detrimental to the production process, or if levels in ponds should approach too high a level against internal pond levees.

The drop gate in its upper position, permits the flap gate to open in response to hydrostatic pressure from a rising tide. Seawater then enters pond P0. When the hydrostatic pressure reverses as the tide ebbs, the flap gate automatically shuts. Tidal entry of seawater continues for most of the year.

Progress of the water through the pond system beyond pond P1B is controlled manually by opening and shutting 2 m diameter culverts through the earth levees that divide one pond from the next. In this way, head differences and seawater density can be regulated so that a constant supply of water at prerequisite density can be provided to the crystallising ponds at Useless Loop.

Ponds P3A and P3B are the last in the primary concentration pond chain. At the northern end of the dividing levee between ponds P3A and P3B in Useless Inlet there is a pump station. Pumping can take place from either pond or simultaneously from both. By the time the brine has reached the pump station the seawater has been reduced by evaporation to a quarter of its original volume. All $CaCO_3$ has precipitated from the brine and $CaSO_4$ has commenced precipitation.

The water is pumped up to an open channel (flume) which conveys the brine along a steady slope (60 cm/km for 20 km) to the secondary concentrators at Useless Loop. These start with pond P4 at the southern end of Useless Loop.

2.2.2 Secondary concentrators and crystallising ponds

Pond P4 is used as a distribution pond, with gravity flows to ponds L1, C1 or R1. The secondary concentrators are basically three parallel chains of ponds known as L, C and R. The floor of these ponds is lined with plastic to prevent loss of brine.

	Secondary Concentrators	Crystallisers	Bitterns drainage
↗	L1 - L2 - L3 - L4 ⟶	W(1-5) ⟶	West Bittern Ditch (WD)
P4 ⟶	C1 - C2 - C3 - C4 - C5 - M6	M5 ; X ⟶	Pond Y
↘	R1 - R2 - R4 ⟶	R5;E(1-5) ⟶	East Bittern Ditch (ED)

In general terms, brine leaving ponds L4, M6 and R4 has concentrated to a stage of being saturated in NaCl and is at a density of 25.6^{o} Baume or higher (degrees Baume is the industry standard for density; 1^{o} Baume (Be) is equal to approximately 10,000 ppm total dissolved salts, i.e. 10 ppt salt). Some $CaSO_4$ is still present but the majority has already been precipitated, while NaCl may have commenced precipitation. $MgSO_4$ and $MgCl_2$ salts are still concentrating but have not reached saturation.

The saturated brine is moved to the crystallisers which are at the northern end of Useless Loop (W, M, and E series, plus ponds X and R5, Fig. 2). The crystallisers are lined with plastic over which a floor layer of dense impervious salt is maintained. In these crystallisers densities are generally maintained in the 25.6^{o}-30^{o} Baume range by further evaporation and then topping up with more concentrated brine at 25.6^{o} Baume. In this density range NaCl precipitates with minimal contamination from the other salts contained within the concentrated brine (such as $MgCl_2$).

After as many as three 'top ups' and final evaporation to approximately 30^{o} Baume, the magnesium ion concentration is such that it inhibits evaporation, so the spent brine (now called bitterns) is drained from the pond. A crystalliser drained of bitterns may be either programmed for harvest or refilled with concentrated brine and the evaporation/top-up programme repeated.

2.2.3 Bitterns disposal

The bitterns have a concentration of dissolved solids that is ten times that of seawater (i.e. approximately 360 grams per litre; Table 1). The dominant constituents of the spent brine are common salt (104 grams of NaC1 per litre) and magnesium chloride (135 g/L). Nearly one million cubic metres of spent brine containing 340,000 tonnes of bittern salts are currently produced each year (Table 1).

This liquid is discharged into one of three unlined drainage areas, two of which partially encircle the crystallisers, with the third (Y pond) lying in the centre of the crystallising area (Fig. 2). Y pond receives bitterns from ponds X and M5, whilst the outer western and eastern drainage areas receive bitterns from W1-W5 and from E1-E5 (and R5) respectively.

The eastern drainage area forms a canal which runs alongside the northeastern perimeters of crystallisers E1-E5 and R5 (i.e. adjacent to the inner wall of the Useless Loop levee). From these drainage areas the bitterns drain vertically into the sands of the original Useless Loop bar. Because the bottom of these unlined ponds is below mean sea level they never dry out. As the bitterns are more dense than seawater their solution moves downward through the porous sands of the area, where they become diluted by the underlying saltwater wedge of the adjacent Freycinet Reach. Bitterns do not contaminate the thin lenses of fresh to brakish goundwater that occur in the area, since these lie above the level of the drainage areas.

In earlier years, all bitterns drained to the West and East Bittern ditches which were joined near the wash pond at the northern end of the loop area. The two bittern ditches were disconnected in 1985 with the west side becoming a separate drainage area. Pond Y now has bitterns from M5 and X drained into it.

In early 1989, additional areas were constructed to take bitterns from both the East and West Bittern ditches. As a result discharge of bitterns into the sea has not occurred since early 1989.

As part of the existing management programme required by the Agreement Act the potential for dishcarged bitterns to effect nearby seagrass meadows within the lease area in Freycinet Reach is monitored by colour aerial photography. Photographs are taken every three years and forwarded to the Department of Resources Development. The photographs show that both the extent and pattern of seagrass cover adjacent to the Useless Loop levee has remained virtually unchanged since at least 1978. A recent underwater survey beside the Usless Loop levee also found no overt effect from bitterns disposal (Appendix 7).

2.2.4 Export of salt

The salt crop is grown from 'pregnant liquor' on top of a permanent salt floor. A drained crystalliser with a good depth of salt for harvesting is routinely available. It is mechanically harvested, loaded into trucks and carted to the washery. Here it is vigorously washed in concentrated brine to remove impurities such as dust and the majority of entrained gypsum precipitate. After drying, the high purity salt (99.6% NaCl) is trucked to a shipping stockpile on Slope Island (Fig. 1).

2.2.4.1 Shipping

Shipments of salt are made from the Slope Island stockpile using a conveyor-belt ship loader. No refueling is undertaken, since on arrival the ships carry sufficient fuel for their return journey (400-500 tonnes) and there are no fueling facilities at the shiploader.

Shipping movements average between two and three per month, with the annual number presently at 33. SBS does not make direct contractural arrangement with ship owners because vessels are chartered by the overseas salt purchasers in almost all cases. Therefore there are no ships which call regularly or whose master possesses a pilotage exemption certificate.

Vessels only up to 25,000 DWT are chartered due to depth and size restrictions at Shark Bay. Vessels with excessive freeboard (such as woodchip carriers) are also not acceptable, as there is a further restriction imposed by the height of the ship loader at Slope Island. Vessels loading at Slope Island arrive in ballast from Indonesia, Singapore, Malaysia and, far less frequently, from Japan. Inbound vessels are usually chartered at and depart from nearby ports in an effort to counter the freight handicap associated with their smaller size (compared with the 60,000-70,000 DWT 'Panamax' salt carriers that load at other salt terminals in the North West). Thus inbound vessels do not arrive from South America, Central America, the Mediterranean or Middle East.

Shipping movements in Shark Bay operate under the jurisdiction of the Department of Marine and Harbours (DMH) at Fremantle. DMH allocates the pilot who also acts as the Shark Bay/Carnarvon Harbour Master for the duration of each shipment. The pilot also inspects the holds for cleanliness. Inbound vessels never carry ballast water in their holds, as these have to be clean and dry, recently painted and/or coated in lime so as not to contaminate the salt, or be corroded by the salt.

2.2.4.2 Ballast water

Ballast water is carried in special tanks so that the empty vessel can fit underneath the ship loader. This water has to be discharged as loading progresses to enable the vessel to pass out through the 10 m depth Denham channel when fully-laden. This channel was dredged by the State Government in 1964. The cost of this facility has been paid back by way of a channel charge. Soundings in 1969 and a hydrographic survey in 1970 showed that the location and alignment of this channel was ideal, with tidal movement being oriented almost directly along its entire length.

2.2.4.3 Dredging

Maintenance dredging has been carried out only once (January 1982) to restore the sides of the channel and return its depth to 10 metres. Outbound ships usually depart Slope Island on the half flood tide, and so move down-channel during or close to full tide. This routine in part accounts for the fact that propellor scour has never shown in sounding surveys.

2.3 BIOLOGICAL HUSBANDRY OF POND SYSTEM

Biological husbandry of the primary pond system is required for three reasons:

(i) to increase water turbidity via algal growth, thereby improving absorption of solar energy and hence increasing the evaporation rate;

(ii) to produce an organic seal to the base of the ponds and thereby reduce head loss by percolation of water through the permeable sand substrate; and

(iii) to avoid excessive build up of organisms which can reduce the efficiency of the crystallisation process (blue-green algae).

The main husbandry technique involves occasional application of a granular fertilizer to the primary concentration ponds in sufficient amounts to produce a self-perpetuating closed biological system.

The fertilizer (e.g. triple superphosphate) promotes biological production in the form of algae. The algae are either suspended in the water as phytoplankton (thereby increasing water turbidity), or they colonise the pond floors as filamentous forms or benign unicellular blue-green forms, where they help to seal the bottom of the pond by secreting gelatin and polysaccharides which bind the loose sediments together.

Many herbivorous grazing organisms such as zooplankton and molluscs feed on the algae and increase in number. Their faeces as well as plant decay products produce organic detritus which is then inturbated into pond sediments by benthic infauna, including polychaete worms, bivalve molluscs and amphipods. It is this process which is primarily responsible for decreasing the porosity of the sediment. The resultant decrease in permeability of the pond floor reduces loss of head in the pond.

Application of fertilizer to the primary pond system ceased in 1985 because head loss in Pond 0 had been reduced and sufficient nutrient existed within the pond system. Further increasing the level of biological activity could cause problems in the quality of salt in the crystallisers. For example, blooms of toxic blue-green algae could overwhelm the brine shrimp which are crucial to the final water purification stage at the rear of the primary pond system in Useless Inlet.

Brine shrimp perform a cleansing function in the concentration ponds P2 and P3 at Useless Inlet by feeding on unicellular algae which otherwise contaminate the crystallisation process leading to poor crystallisation and a reduction in salt quality.

3 THE PROPOSAL

3.1 EXPANSION ALTERNATIVES

There are no practical and commercially viable alternatives to the proposal for increasing the output of salt at Shark Bay. The reasons for this are outlined below.

It is not possible to extract more salt from the existing pond system because all the brine currently being produced by the existing primary ponds in Useless Inlet and secondary ponds at Useless Loop is being crystallised out. Therefore construction of further crystallisers at Useless Loop is not an option because they would be starved of their feed stock, i.e. the concentrated brine. The only way in which substantial additional quantities of salt can be obtained is by increasing the feed stock to the existing crystallisers, i.e. by increasing the size of the primary concentration pond system.

The capacity of any solar salt field is a function of the area of ponds producing brine and the net evaporation available. A salt field operator cannot alter the weather and its attendant evaporation regime but can increase the brine-producing area. The size of the increase is governed by another fundamental, which is that density changes between ponds should be kept close to constant to ensure the regulated concentration and orderly precipitation of the various salts, and also to assist control of the biology of the ponds. This means that pond sizing must be such that as water flows through the system, its density is increased at a relatively constant rate.

Increasing density (from evaporation) is related to volume reduction in an exponential manner as shown in Figure 4. Thus initially large volumes of water are required to be evaporated to produce small density changes. For example, to double seawater concentration (3.8^{o} Baume at 100% volume) requires a volume reduction of 50%, whereas at the crystallising end of the system, relatively small absolute volume reductions produce relatively much larger increases in density.

Therefore, in order to increase density in manageable steps, pond sizing should ideally parallel the required volume reductions as shown in the density-volume reduction curve of Figure 4. This means that a new primary concentration pond must have an evaporative surface much larger than the next pond. The area of this pond would then satisfy the low density end of the graph shown in Figure 4, and allow a larger volume of saltwater to be progressively concentrated to the salt precipitation phase. Thus for two primary ponds to each produce an equal density rise (one pond following the other), the first pond needs to be double the area of the second.

3.1.1 Location of primary pond

There is only one practical and cost efficient location for the new primary concentration pond and that is adjacent to the existing primary pond P0 in Useless Inlet. This area is also the only expansion opportunity within the confines of the existing lease boundaries. The area was specifically included in the 1983 lease agreement as it was clear at that time that such an expansion would eventually be required.

Another location at the bottom end of Boat Haven Loop (Brown Inlet; Fig. 1) is engineeringly feasible, but would require substantial pumping and engineering works. Capital costs of installing large diesel pumping units and 12.5 km of a connecting flume (or pipe), together with the high operating costs for fuel ($0.5 million per year) and maintenance make this option only marginally profitable.

Moreover, this option has further significant drawbacks. It is not located within the existing leases and would require extensive negotiation for a new lease. This may prove difficult since Brown Inlet is proposed for national park/marine park status, and pond construction would involve flooding extensive areas of shallow salt flats which are used by migratory wading birds at certain times of the year.

Useless Inlet is therefore considered preferable on environmental as well as engineering, operational and financial grounds.

3.1.2 Location and features of proposed levee

The proposed primary pond can only be created by constructing a new levee. The 'ponding' of seawater behind this bar will enable the natural evaporative regime to increase density in this part of Useless Inlet by approximately 14% (i.e. from the present annual average density of 4.4^{o} Be to approximately 5.0^{o} Be; Table 2).

The position of the SBS lease boundary and the alignment of the proposed bar are shown in Figure 3. The sea wall is some 400 m south of the lease boundary, and its alignment intentionally foregoes enclosure of a large mangrove embayment on the eastern side of Useless Inlet. The embayment has been excluded because areas of mangroves and attendant samphire flat are known to be productive and ecologically important to Shark Bay, and this is by far the largest such area in Useless Inlet (Appendix 7). The exclusion reduces the size of the proposed pond by 8.5%. In projected revenue terms this exclusion equates to $0.9 million per annum foregone on capital outlay. Whilst SBS would prefer for economic reasons to construct the levee on their lease boundary, it is conceded that to do so would remove an ecologically important habitat from Useless Inlet.

As with the existing Clough's Bar, the proposed levee will contain two tidal gates that allow seawater to enter on flood tides but prevent its escape on the ebb. It is not possible to leave a permanently open channel in the new levee. Tidal gates are required for the following reasons:

(i) to ensure reliable and uniform increases in density by preventing the loss and mixing of concentrated seawater by tidal flushing.

(ii) to ensure that the head of water in the new pond is always sufficient to provide a gravity-induced flow through the primary concentration ponds, particularly over summer when wind-forcing and high barometric pressure reduces water levels in Useless Inlet (Appendix 8);

(iii) to prevent the loss of applied phosphate and winnowing of organic fines (which will be encouraged to accumulate in the floor of the new pond).

3.2 CONSTRUCTION DETAILS

3.2.1 Design criteria

Useless Inlet has a north-south alignment. The worst cyclonic conditions on the new bar will result from northerly winds when a cyclone is west of Useless Inlet and travelling south. In any other position, winds are across Useless Inlet with shoreline protection and a short distance of fetch for wave generation. Fetch for wave generation from the north is limited by the shallow waters at the entrance to Useless Inlet. The design criteria are based on the length of this fetch (15 km) and the depth of water (8-10 m) across it.

The design of the proposed bar incorporates the requirements of the relevant Australian Design Codes. Standard wind velocity has been taken at 49 m/s (100 mph), with a significant and maximum wave height of 1.6 m and 2.7 m respectively. The structure has been designed to withstand most cyclones and to accommodate partial damage (and need for subsequent repair) without breaching as a consequence of extreme cyclone events.

If Greenhouse predictions concerning a worldwide rise in sealevel and/or a gradual increase in cyclone strength begin to eventuate, the height of the levee and amount of 'rip rap' limestone armour can be readily increased.

Figures 6 and 7 show the proposed bar cross-section and details of the intake structure. The bathymetry of the area is shown in Figures 8 and 9. To minimise the volume of fill material required, the proposed bar has been aligned to capitalise on the shallowest bathymetry across Useless Inlet (Fig. 8). However, the new bar will still traverse some areas where depth exceeds 7 metres, and will therefore require considerably more fill material per unit length, and larger-sized armour stone to protect against wave action than was required for Clough's Bar, which lies in water depths of mainly 1-2 metres.

The design of the new water intake structure allows for the installation of counterbalances to the tidal flap gates. Counterweights will not only allow each flap to open wide, thereby reducing inward current velocity and turbulence, but also keep the gates open for virtually the entire period of a flood tide or during those periods when northerly winds or regional barometric pressure create higher water levels on the north side of the new levee. The design of the intake structure also permits the installation of panels within the flap gates that can be lifted to allow water to exit from the pond during ebb tides or whenever water levels within the pond are higher than outside the bar.

The design of the water intake structure for the bar will enable considerable flexibility for the future management of the ecosystem and water quality within the primary pond system. For example, the installation of counterbalances and lifting panels can make the tidal gates less restrictive to fish emigrating the pond than the present gate system on Clough's Bar.

3.2.2 Source of construction material

Material for the bar (1.177 million m^3) will be taken from a limestone ridge near the eastern shoreline and to the south of the eastern abutment of the proposed bar (Fig. 5). A small quarry site will also be developed at the abutment of the bar on the western shoreline of Useless Inlet for an additional 400,000 m^3 (Fig. 5).

The material to be quarried is similar to that used in the construction of Clough's Bar.

3.2.3 Construction methods

Armour-rock and fill material for the core of the levee will be quarried, sized and stockpiled at the borrow pits for loading onto trucks. The trucks will transport this material to the levee site and place it at the inlet end of the levee where bulldozers and a 'clam shell' bucket crane will place the various materials into the desired location.

The earthworks for the bar construction will be progressed simultaneously from both shorelines. Access to locate earthmoving equipment on the western abutment and quarry site will be by way of a temporary haulage track up the western shoreline from Clough's Bar. This track will be located above the high water mark on a route shown on Figure 5.

Existing roads to the location of the quarry and construction site on the eastern foreshore will be upgraded within the lease area. During construction of the levee, no more than 25 additional workers will be required. These will be accommodated by SBS at Useless Loop.

The tidal gates will be fabricated offsite and transported to site for insertion into the levee during levee construction. The proposed work programme from opening the quarry sites to initiating their rehabilitation is outlined in Table 3. The total construction period is estimated to require some 14 months.

3.3 OPERATION OF EXPANDED POND SYSTEM

The extension will provide an increase in evaporative pond area and result in higher density seawater passing through Clough's Bar and Carratti's Bar, thereby providing the means of increased salt production from the field. By the time of full production there will be a permanent increase of 15 full-time workers who will be accommodated in married or single quarters at Useless Loop.

The large volume of the new pond will enable a more constant density to be maintained at the Clough's Bar and Carratti's Bar control gates than existed previously. This will greatly assist pond management and production efficiency. The subsequent ponds in Useless Inlet will continue to be driven by gravity induced flow.

The predicted rises in the salinity concentration of the water as it passes through the pond chain in Useless Inlet are shown in Table 2. The increased concentration of the water pumped to Useless Loop via the flume (from 11 to 16 tonnes of salt per 100 m^3 brine) means that the area presently used for secondary concentration at Useless Loop can be accordingly reduced, thereby enabling excess ponds to be assigned to crystallisation. Existing unused pond areas R_3 and E_7, part of pond Y and areas on the perimeter of the Loop near L_4 and R_4 may need to be eventually developed. Expansion at Useless Loop will therefore be minimal.

It is likely that the new pond will require nutrient enrichment by controlled and periodic application of granular fertilizer. The purpose of this application is to stimulate sufficient biological production of organic material to promote a useful decrease in porosity of the shallow sand flat areas. A decrease in natural porosity by natural inturbation of detritus from biological activity will be required to reduce any significant head loss. The detritus will come from the breakdown of algae and other benthic and planktonic marine organisms. It is anticipated that as with existing ponds, the detritus will be naturally inturbated by marine burrowing animals over a period of two to five years, at which time the pond will then stabilise and behave biologically much as does the present pond P0. From this time on, there will be no requirement for consistent fertilization as sediment impermeability will be adequate and biological production will have become largely self-sustaining.

The fertilization regime will be managed by Professor Stephen Davis of the University of Florida. Professor Davis is an international specialist in the management of biological activity of solar salt ponds. He has been routinely consulting to SBS and managing the ponds for the past 18 years. He will provide specialist advice and monitor the fertilization regime for the new pond area.

3.4 SHIPPING MOVEMENTS

No expansion of Slope Island nor the loading jetty is required, since the export of the increased tonnage of salt can be still accommodated by loading one ship at a time.

Shipping movements are expected to eventually increase to approximately 60 vessels per annum at a rate of five vessels per month, when maximum salt production is attained. As with the existing operation, it is expected that the additional shipments will involve 20,000-25,000 DWT vessels chartered by salt purchasers from nearby ports. Each shipping movement into and out of Shark Bay will be piloted by the Carnarvon Harbour master as presently occurs.

4 DESCRIPTION OF ENVIRONMENT - PART A: REGIONAL SETTING

4.1 INTRODUCTION

This section provides a summary description of the salient environmental characteristics of the Shark Bay region. It includes a summary description of those items considered pertinent because the proposal lies within Shark Bay. Regional information required to provide a basis for impact assessment is presented in this section, whilst details on specific aspects of the local environment (i.e. the project setting) is presented in Section 5.

Information on the physical, biological and social aspects of the study area has been obtained largely from a desk review of available documents. Early work by Logan et al. (1970a, 1974) provided much of the baseline information on the geomorphic, hydrologic and biological characteristics of Shark Bay as a whole. Within this series of papers, Read (1974a,b) provided more specific information on the inlets of Edel Land (which form the region of the project). Information regarding present and future land use, demographic profile and socio-economic structure was taken from the Shark Bay Region Plan [State Planning Commission (SPC) & CALM, 1988], and supplemented by discussions with personnel from relevant authorities including the Fisheries Department and the Western Australian Fisheries Industry Council (WAFIC).

Conservation values are summarised from the Shark Bay Region Plan (SPC & CALM, 1988), from submissions and responses to this plan, from Nevill & Lawrence (1985), and from papers dealing with particular aspects of the Shark Bay environment (e.g. Anderson, (1986), for dugongs; Walker et al., (1988) for seagrasses).

Strategies for the future conservation, economic development and community development of Shark Bay are listed in the Shark Bay Region Plan (SPC & CALM, 1988). Implications of these strategies to the future conservation of Shark Bay have been taken from two documents; a review of the Shark Bay Region Plan by the EPA (Bulletin 305; 1987), and a briefing paper by CALM (1990) which outlines proposals for a marine park in Shark Bay.

4.2 PHYSICAL ENVIRONMENT

4.2.1 Shark Bay

4.2.1.1 Location and physical features

Shark Bay lies between latitudes $24^{o}30'$ and $26^{o}45'$ on the western coast of Australia. It is a large area covering some 28,690 km^2, with a coastline of over 1,500 km (SPC & CALM, 1988). The region is a series of north-south trending peninsulas and islands which separate the long inlets and gulfs of the Bay from each other and from the open ocean (Fig. 10). The Shark Bay Salt project is located on the western side of the Bay and utilises two inlets (Useless Loop and part of Useless Inlet) which are on the west and east sides of Heirisson Prong respectively (Figs 1, 3).

4.2.1.2 Bathymetry

Shark Bay is a large shallow marine embayment with an average depth of 9-10 m. Depths are greater in the northern part where the bottom gradually slopes from the 10 m contour to 18-35 m (Fig. 10). The major bathymetric features identified by Logan & Cebulski (1970) are:

(i) intertidal-supratidal platform extending from mean low water level (MLWL) to 2 m above this datum. The width of this platform ranges from 10-20 m for sandy beaches to 1-2 km in the case of tidal flats;

(ii) sublittoral platform: an inundated shallow terrace (sometimes as wide as 1.5 km) which slopes gradually from the intertidal zone to depths of 2 m. Below this point there is an increase in slope (5-30^{o}) in a descent to the basin floor or embayment plain. This feature borders much of the coastline of Shark Bay (Read, 1974a); and

(iii) embayment plain: a generally flat and featureless plain sloping from depths of 5 m in the south to over 15 m in the north (Fig. 10).

4.2.1.3 Geology

Shark Bay lies within the Carnarvon Basin, a deposition province in which marine sedimentation has occurred since the early Palaeozoic. The basement rock is a fossiliferous limestone of late Cretaceous age referred to as Toolonga Calcilutite. This formation is exposed as cliffs and mesas on the eastern margin of Shark Bay (Logan et al., 1970).

Quaternary deposits dominate the remainder of Shark Bay as a result of two phases of dune building in the Pleistocene era. The first of these phases led to the deposition of sediments comprising the Peron Sandstone, a red quartz sandstone found in the central portion (Peron Peninsula) of Shark Bay. The second dune-building phase formed the large ridges (up to 150 m) of calcareous aeolianite (= Tamala Limestone) which make up the western perimeter of Shark Bay (Logan et al., 1970). These are represented by Edel Land, Dirk Hartog Island and the Bernier-Dorre Island chain.

4.2.1.4 Geomorphology

Shark Bay is a series of inlets, basins and gulfs broken by north-trending dune ridges and seagrass banks. Shark Bay is divided into four general geomorphic subdivisions (Fig. 10; Logan et al., 1970):

(i) Gascoyne-Wooramel Province - an alluvial coastal plain with river floodplain deposits;

(ii) Peron Province - an area of red sand dunes;

(iii) Yaringa Province - a terrain of dissected Cretaceous and Tertiary limestone units;

(iv) Edel Province - a landscape of calcareous aeolianite dunes.

The SBS project occurs within the Edel Province.

4.2.1.5 Climate

Shark Bay has a semi-arid climate with hot, dry summers and mild winters. Annual rainfall ranges from 400 mm in the west to 200 mm in the east. Most precipitation is in winter (May-July) with periodic heavy contributions from summer cyclones (December-March). Annual evaporation is high, ranging from 2,000 mm in the west to 3,000 mm in the east. Summer temperatures average between 20°C and 35°C, and winter temperatures vary between 10°C and 20°C (SPC & CALM, 1988).

The wind regime is predominantly governed by southeast trade winds which generate southerly winds for most of the year. The coastal wind characteristics of the region are summarised in Figure 11.

Strong, persistent southerly winds averaging 10-15 knots are experienced during summer. The typical summer daily pattern is for strong southeast winds (20-25 knots) to blow in the morning, and even stronger south-to-southwest winds to occur in the afternoon (Logan & Cebulski, 1970). Winds of this magnitude (20-25 knots) may be sustained for three to five days as a result of trade winds being reinforced by locally-generated strong seabreezes.

Wind velocities in winter are lower (5-8 knots) with periods of calm being common. Intense low pressure systems influencing the southwest of Western Australia may also produce strong north to northwesterly winds in winter.
Tropical cyclones can generate strong destructive winds. Duration of cyclonic winds is usually up to 12 hours, with winds of 40-60 knots and gusting to 100 knots. Cyclones occur in the Shark Bay coastal area at the rate of one cyclone every three years (Southern, 1979).

4.2.1.6 Oceanography

(1) Tides

Shark Bay has a mixed tidal regime with semi-diurnal spring tides and diurnal neap tides. The astronomical tidal range varies from 1.2 m in Hopeless Reach to 0.6 m at the southern end of Hamelin Pool (SPC & CALM, 1988). Predicted tidal values for Denham indicate a spring tidal range in the order of 1.3 m (Australian National

Tide Tables, 1989). Useless Loop has a spring tidal range of 1 m and neap tidal range of 0.3 m (Read, 1974a). Tidal ranges in the other inlets of the Edel Province are similar to those at Useless Loop (Read, 1974a). Due to the north-south orientation of these inlets, the influences of prevailing winds and associated barometric pressure produces two seasonal mean water levels on which normal tidal oscillations are superimposed - a low level during summer and a high level during winter (Appendix 8).

Tidal current direction for flood tides are generally toward the south-southeast whilst ebb tide currents are typically north-northwest. Tidal current velocities are influenced by wind, especially in summer when strong southerly winds inhibit flood tides and reinforce ebb tides. Winter winds are much weaker except for occasional strong northerly winds which cause temporary banking of tidal waters toward the southern end of inlets and bays (Read, 1974a). Ebb tidal current velocities are often slightly higher than flood tide velocities, reaching 60 cm/sec over banks during spring tides (Read, 1974a).

(2) Wave climate

Edel Land, Dirk Hartog Island and the Bernier-Dorre Island chain form a barrier which protects Shark Bay from large oceanic swells. The development of waves within Shark Bay is dependent on wind velocity and duration, depth and fetch. Logan & Cebulski (1970b) recorded the development of steep wind waves up to 1.2 m in height as a result of 10-15 knot winds blowing for an 8-12 hour period. The prevailing southerly winds experienced in Shark Bay can produce substantial seas, and shallow coastal areas can be subjected to considerable wave action, particularly those with a southerly aspect (Logan & Cebulski, 1970). Occasional winter storms can generate substantial seas from the north, while maximum wave building occurs during periods of cyclonic northerly winds.

4.2.1.7 Hydrology

The hydrologic system of Shark Bay is considered to be generally stable owing to the slow exchange between the Bay and ocean. Average water residence time in the Bay, estimated from water and salt budgets, exceeds one year (Smith & Atkinson, 1984). Shark Bay receives virtually no input of freshwater via surface runoff from rivers or drainage areas. The stability of its marine hydrologic system is therefore balanced between the quantity of water lost by evaporation and the quantity of oceanic seawater brought in by tides (Logan & Cebulski, 1970).

In conjunction with climatic and other oceanographic processes, various factors such as salinity, temperature and nutrients help determine the overall pattern of hydrologic systems operating within Shark Bay. Variation of these parameters is also reflected by the distribution of organic and inorganic components of the marine environment within the bay. Publications discussing the inter-relationships of these factors include the following:

- Logan & Cebulski (1970):
  - distribution of modern carbonate sediments,
  - distribution of general biotic groups.

- Smith & Atkinson (1983, 1984)):
  - distribution of nutrients.

- Kimmerer et al. (1985):
  - distribution of plankton.

- Lenanton (1977) and Johnson, Creagh & Moran (1986):
  - distribution of fish.

- Walker, Kendrick & McComb (1988):
  - distribution of seagrass.

A summary of the major factors which govern the distribution of biota in Shark Bay is presented below.

(1) Salinity

Salinity in Shark Bay increases from oceanic values (36^{o}/oo; i.e. grams per litre) in the north to hypersaline values (60-65^{o}/oo) in the southern extremities of some bays and inlets. This increase is a result of evapo-climatic effects and a restricted circulation due to shoaling and hydrodynamic features. Comparable data collected by Logan & Cebulski (1970) and Smith & Atkinson (1983) suggest that the above values are stable. Vertical stratification of salinity is limited, indicating a thorough mixing of surface and bottom waters by currents and wave turbulence (Logan & Cebulski, 1970).

The horizontal salinity gradient divides the waters of Shark Bay into three major types (see Fig. 12):

(i) oceanic (36-40^{o}/oo) - northern embayment,

(ii) metahaline (40-56^{o}/oo) - Hopeless Reach, Denham Sound and Freycinet Basin;

(iii) hypersaline (56-70^{o}/oo) - Hamelin Pool, Lharidon Bight and the southern portions of Edel Land inlets (including Useless Inlet and Brown Inlet).

Read (1974a) demonstrated that salinity increases from 38-40% at the entrances of the Edel Province Inlets to values between 50-60^{o}/oo in the southern extremities (Fig. 13), with salinity tending to be higher over shallow sublittoral platforms compared to adjacent deeper areas. This is due to locally enhanced evaporation in shallow waters, with seasonal and daily factors influencing the overall pattern (Read, 1974a). For example, strong southerly winds and maximum evaporation in late summer produced higher values, whilst on a daily basis lower salinities occurred at high water following the influx of Bay waters (Read, 1974a).

(2) Temperature

Maximum temperatures of waters in southern Shark Bay range from 26° to 30°C in summer, and winter minimum temperatures range from 15° to 18°C (Logan & Cebulski, 1970). Diurnal and seasonal variation in water temperatures are strongly marked in shallow waters (e.g. sublittoral platform and shoals), and daily variations of 1-2°C have been recorded in autumn and spring. Larger variations occur in mid-summer (Appendix 3; Read, 1974a). The deeper waters of northern Shark Bay experience little diurnal variation, and seasonal changes in temperatures are related to oceanic waters entering from the Dirk Hartog Shelf (Logan & Cebulski, 1970).

(3) Nutrients

Net production in ecosystems within Shark Bay is regulated by nutrient input from external sources. Nutrient influx is limited owing to the long residence time of water in the Bay, the low ambient nutrient concentrations in offshore waters, and the very small amount of freshwater runoff (Smith & Atkinson, 1983). As such, studies detailing nutrient budgets have treated Shark Bay as an isolated system where net production is reflected by nutrient concentrations in sediments (Smith & Atkinson, 1984). Mean total nitrogen (N) levels in sediments are 0.4 mg/g in oceanic areas, 0.75 mg/g in metahaline areas and 1.3 mg/g in hypersaline areas (Table 3). Organic-rich sediments are common in those channel and basin subtidal areas stabilised by seagrass, as well as in intertidal mud flat environments that contain microbial rich algal growths (Logan & Cebulski, 1970).

Nitrogen fixation in the Shark Bay hydrologic environment supplements oceanographic N sources, which are low. While accumulation and recycling of internally-fixed N means that the supply of N is effectively limitless, the supply of phosphorus (P) is not. It is for this reason that overall net production is effectively limited by the oceanographic delivery of P (Smith & Atkinson, 1984).

4.2.2 Edel Land Province

4.2.2.1 Geomorphology

Edel Land is a geomorphic province characterised by a series of long and narrow peninsulas and inlets located in the southwestern part of Shark Bay (Figs 13, 14).

The western margin of the province is a series of high cliffs (Zuytdorp Cliffs) of Tamala Limestone that rise to 120-180 m above sea level and descend sharply to depths of about 40 m on to a gently sloping submarine shelf floor. To the east extends a series of low longitudinal dune complexes and interdune depressions. Dunes are flanked by sandy soils which have developed on the limestone and are stabilised by small shrubs. Long northward-prograding mobile dunes occur in belts 9-30 km in length and up to 0.5 km wide (Read, 1974b). The northward alignment of both limestone ridges and mobile dunes is a reflection of prevailing southerly winds.

On the eastern margins of Edel Land, interdunal depressions are occupied by a series of long narrow inlets (Fig. 13). Useless Inlet, Boat Haven Loop (Brown Inlet), Depuch Inlet and Disappointment Inlet open into Freycinet Reach and terminate to the south with one or more elongate tidal flats. North-trending dunal ridges up to 70 m high border the inlets and extend into Freycinet Reach below sea level as a series of shallow banks. A schematic diagram illustrating the relationship of the geomorphic features of an Edel Land inlet is presented in Figure 14.

The geomorphic features of the inlets can be divided into the following units (Read, 1974a):

(1) Barrier banks and sills

Flat-topped shallow banks with average depths less than 2 m (and with edges extending to 4 m) form partial barriers across the entrances of inlets and thus restrict tidal flow to southern parts (Fig. 14). Restriction of tidal flow promotes hypersaline conditions in the land-locked basins to the south (Read, 1974a). Aerial photographs show conspicuous megaripple and sand ribbon structures on sills. Megaripples are 3-20 m in wavelength and are orientated normal to the north-south direction of tidal flow across sills. Their crests are stabilised by seagrasses but troughs are often bare. Linear sand ribbons, i.e. low ridges of mobile sand several hundred metres long and less than 0.3 m high, are also present and lie parallel to the direction of tidal flow (Read, 1974a).

(2) Tidal channels

Tidal channels cut through sills and banks, and carry water from outside the inlets into inlet basins. Large tidal channels are often sinuous and extend for several kilometres through a barrier bank whilst sills within inlets tend to be cut by shallow and discontinuous channels (Fig. 14).

(3) Inlet basins

Flat or gently sloping plains form the seafloor of inlet basin areas (Fig. 14). The basin areas vary in depth from 9 m in the north of inlets to typically 3-5 m in the far south. They are bordered by sublittoral platforms and divided by sills. The barrier sills prevent them from merging with the embayment plain environments of Freycinet Reach and Denham Sound. The northern basin in Useless Inlet contains submerged dune ridges with a relief up to 3 m (Read, 1974a; Appendix 8).

(4) Sublittoral platform

Sublittoral platforms, much of which are exposed at low tide, extend from the intertidal beach zone to approximately 2 m depth. Platforms either merge with sills or descend to the basin floor or embayment plains. In many areas, the sublittoral platform comprises an abrupt wave-built terrace that was created by the seaward extension of tidal terraces through deposition of material eroded from the parent rock (Read 1974a). In many cases the wave built terrace is extended seawards by in situ sedimentation within fringing seagrass meadows. Linear sand ribbons are common on the shallower parts of platforms. These lie parallel with the directions of tidal flow and wave-current transport (i.e. north-south) in a similar fashion to those ribbons found on the sills. Sublittoral platforms border most of the inlet shores, and their outer margins either run parallel with the shore or form north-trending lobes that extend parallel to the shoreline.

(5) Rocky intertidal platforms

A rocky 'platform-notch-bench' morphology occurs along inlets where Tamala Limestone or younger Pleistocene sediments have been exposed to marine erosional processes. These platforms extend from MLWL to an undercut or notch at mean sea level (MSL). The notch is backed by a 'visor' or small cliff (1-2 m high) which forms the seaward edge of an emergent bench (2.5 m above MSL; Fig. 14). These platform complexes were formed by erosion and deposition when sea levels were higher during the Pleistocene, and have been subsequently modified during the Holocene and recent time (Logan et al., 1970c).

(6) Intertidal sandy beaches

In many bays along the edges of the Edel Land inlets, intertidal rocky platforms are overlain by beach sand deposits which form narrow belts 3-15 m wide and less than 2 m thick (Fig. 14). Beach sediments are composed of lithoclasts, mollusc coquinas and marine carbonates which have been carried shoreward from the sublittoral platform. Sediment contribution is also derived from erosion of the backing limestone.

(7) Intertidal-supratidal flats

Intertidal-supratidal flats are found in the southern extremities and the side embayments of inlets. They extend from MLWL to 2 m above this level. Water is supplied to these flats by a dendritic system of small tidal creeks (Fig. 14). Under certain climatic conditions (strong southerly winds), these flats may be exposed for long periods of time and are inundated only during peak flood tides or with the advent of strong northerly winds. Even in dry periods, however, the water table is only usually 10-20 cm below the surface, and thus the supratidal sediments remain moist. Such environments, which are typically low-energy and hypersaline, facilitate the growth of leathery algal and cyanobacterial mats. In other parts of Shark Bay (Hamelin Pool), the sediment trapping and binding ability of these mats has formed stromatolites (Logan, 1961).

4.2.2.2 Processes maintaining geomorphic units

The channels, banks, shoals, sills, islands and other marine geomorphic features in Edel Land and Shark Bay are a reflection of the coastal and marine processes (both physical and biological) operating on sediments within the environment. Carbonate deposition is predominant, with rates of sedimentation being indirectly controlled by factors such as waves, currents, benthic organisms and seagrass banks (Logan & Cebulski, 1970).

Erosion and transportation of sediments is dependent on wave and tidal-generated currents that create sufficient orbital velocities near the seafloor. Logan & Cebulski (1970) provide an analysis of wind data and orbital velocity/depth-fetch relationships in order to obtain a qualitative estimation of the potential frequency of reworking and winnowing of sediments by wave currents. Under average conditions, it was found that the sublittoral platform is subject to intensive winnowing, whilst sediments in embayment plain areas are rarely reworked. Ebb dominance of tidal currents, reinforced by strong southerly winds, result in a net northward movement of sediments over the banks (Read, 1974a). Supportive evidence for this process are the northward-trending lobes of sediment on the outer margins of the sublittoral platform, including those in Useless Inlet.

The numerous fringing seagrass banks found within Shark Bay and at the mouths of Edel Land inlets demonstrate the ability of seagrass communities to absorb wave energy and trap sediment. Sediments are trapped within seagrasses due to their 'baffling' effect on wave currents, and are also created within seagrass meadows by the rich epibiota. Seagrasses retain silt and clay-sized particles even under current velocities of 30 cm/sec and possibly higher (Logan & Cebulski, 1970).

The distribution of seagrasses influences the frequency of sediment reworking, since these banks contain dense stands that can completely cover the sediment-water interface. The seagrasses provide a habitat for epibiota and benthic organisms such as foraminiferans, sponges, molluscs and encrusting coralline algae, which in turn contribute large quantities of skeletal material to sediments. In the inlets of the Edel Province, seagrass banks help form and stabilise the mound-like masses of carbonate sediments, i.e. the barrier banks and sills which can partition an inlet into a series of distinct basins (Read, 1974a). At the intertidal and supratidal localities, leathery algal mats also function as sediment binding and trapping agents, although these processes have not led to stromatolitic formations in the Edel Land inlets.

Sublittoral platforms in the hypersaline southernmost areas of Edel Land inlets generally lack seagrasses and are often exposed to extensive winnowing, depending on fetch and weather aspect (Read, 1974a). Many tidal platforms and beaches are subjected to frequent wave attack generated by prevailing southerly and southwesterly winds. Intertidal-supratidal flats are protected from wave action during southerly winds but are occasionally exposed during winter storms, when strong northerly winds generate substantial seas and cause inundation of flats.

4.3 BIOLOGICAL ENVIRONMENT

4.3.1 Shark Bay

The biological resources of Shark Bay are the product of its location in an overlap zone of botanical and zoogeographic provinces and the diversity of habitats it contains. Much of the following description has been summarised from the Shark Bay Region Plan (SPC & CALM, 1988).

4.3.1.1 Marine biota

Marine biota from both the tropical Indo-Pacific region and the southern temperate zoogeographic region overlap in Shark Bay producing a wide range of biotic assemblages. Most of these assemblages are modified by the intense horizontal salinity gradient within Shark Bay which produces a range of habitats that contain distinct and unusual suites of species.

The shallow, clear and swell-protected waters of Shark Bay contain one of the largest and most diverse seagrass assemblages in the world (Fig. 15). This assemblage is the major reservoir of organic nutrient in the Bay, and provides a direct source of food for turtles and dugongs and some species of fish. The seagrass beds also support large detrital and epiphytic food chains that make these and adjacent areas important nursery habitats and foraging grounds for many species of fish and crustaceans.

Shark Bay waters also contain one of the largest dugong populations in the world, provide an overwintering ground for southern humpback whales, support dolphin populations (of which the Monkey Mia group has achieved international fame for its association with humans), and lie alongside turtle nesting areas (Fig. 15). The hypersaline waters within Hamelin Pool contain rare and biologically primitive cyanobacterial structures known as stromatolites which are of international significance (Fig. 15).

Both green and loggerhead turtles are thought to be widespread throughout the more oceanic parts of Shark Bay. The green turtle is carnivorous when young, before becoming mainly herbivorous on marine algae and seagrass. The loggerhead turtle is almost totally carnivorous, feeding on crustacea, fish and sponges throughout its life cycle (Jones, 1986).

4.3.1.2 Terrestrial biota

Two major biogeographic provinces overlap within Shark Bay (Fig. 15). The Eremean Botanical Province is an arid inland and open shrub-spinifex community dominated by Acacia and spinifex species. This province occurs on the eastern shore of the Bay and on most of Peron Peninsula. The Southwest Botanical Province is a semi-arid and coastal sand plain community which supports a taller open shrubland. It occurs mainly in southern parts of Shark Bay. Edel Land supports an intermediate botanical community containing species from both provinces (Fig. 15).

4.3.2 Edel Land Province

The project is situated within the Edel Land geomorphic province of Shark Bay. This section provides information on the biological character of this province.

4.3.2.1 Terrestrial flora and fauna

Edel Land supports an intermediate flora derived from two distinct botanical zones (Fig. 15). This mixture probably reflects the higher rainfall in western Shark Bay combined with the highly permeable calcareous sands and strong, drying summer winds (SPC and CALM, 1988).

The fauna of Edel Land varies according to the distribution of vegetation and soil types. Faunal assemblages typically consist of species utilising the spinifex/heath vegetation on white sandy soils, or the shrubs associated with limestone substrates. Storr & Harold (1978) list 46 species of reptiles and amphibians found primarily in the two predominant habitats of the province.

(i) coastal dunes typically vegetated with the coarse grass *Spinifex longifolius* and shrubs such as *Olearia axillaris* and *Myoporum insulare*;

(ii) limestone outcrops or shallow sandy veneers areas over limestone. The vegetation is more varied and includes *Triodia* (spinifex) and several species of tall and low shrubs.

Three species of lizard, a scinoid (*Menetia amaura*) and two legless lizards (*Pletholax gracilis edelensis* and *Aprasia haroldi*) are endemic to Edel Land (Storr & Harold, 1978; Nevill & Lawrence, 1985).

Avifaunal assemblages are mostly composed of spinifex/shrub dwelling species, i.e. the smaller passerines. Edel Land inlets support migratory waders, sea birds (including cormorants, pelicans and terns) and coastal raptors such as the osprey and white-breasted sea eagle (Storr, 1985).

4.3.2.2 Marine assemblages

Seven assemblages were recognised within Edel Land inlets by Read (1974a). His descriptions are outlined below and summarised in Table 6.

(a) Amphibolis community

This community is composed mainly of the seagrass Amphibolis antarctica with small amounts of Posidonia australis, and epiphytic organisms colonising these plants. These include:

- encrusting algae, articulated coralline algae and non-calcified algae on the leaves, leaf axes and/or rhizomes;
- epibiotic foraminiferans and encrusting bryozoans;
- polychaete tube worms colonising leaf axes and leaves;
- sponges, often forming thick rubbery sheaths around leaf axes.

(b) Pinna-Pinctada community

The community is characterised by the molluscs Pinctada albina (oyster) and Pinna bicolor (razor clam). Pinctada attaches to 'stunted' or relatively sparse stands of Posidonia seagrass or large shell debris by a strong byssus, while Pinna lives embedded in the sea floor. These molluscs are accompanied by an epibiota including cockles (Chama sp.), serpulid worms and bryozoans.

(c) Posidonia community

This community is characterised by the seagrass Posidonia australis and minor amounts of Amphibolis. Epibiotic coralline algae, foraminiferans and tube worms are common on seagrass leaves.

(d) Cerithium-Penicillus community

This assemblage is dominated by the gastropod Cerithium sp., and contains other other small gastropods and small amounts of seagrass in low-salinity areas; pelecypod molluscs, foraminiferans and seagrasses (Posidonia or Halodule) in metahaline areas; and principally by the codiacean algae Penicillus nodulosus and gastropods in hypersaline areas.

(e) Callista-Anomalocardia community

The thick-shelled sand-burrowing pelecypod molluscs Callista impar and Anomalocardia squamosa, together with small amounts of foraminiferans, form the bulk of this community.

(f) Algal mat community

Blue-green algae, unicellular green algae and purple-sulphur bacteria forming layered, rubbery and leathery mats.

(g) Halophyte community

A low, salt-tolerant heath community consisting of the following plant species: Pachycornia sp., Arthrocnemum arbuscula, Wilsonia humilis and Agianthus cunninghamii.

Read (1974a) related the above marine assemblages to the geomorphic zones described in Section 4.2.2 as follows:

(1) Sublittoral shallows, sills and barrier banks

Pinna-Pinctada mollusc communities are located on sandy sublittoral platforms at depths to 2m in the northern parts of Useless Inlet and in Blind Strait (near South Passage) where salinities are 36-40^o/oo. In these areas sediments are mobile and seagrasses occur in low density, forming scattered clumps or poorly developed rows (Read, 1974a).

Callista-Anomalocardia mollusc assemblages are found in hypersaline areas (46-56^o/oo) in the southern parts of Useless Inlet, Boat Haven Loop (Browns Inlet), Depuch Inlet and Disappointment Inlet; and in areas where depths range from 0 - 1 m. These areas are only occasionally exposed by very low spring tides.

Amphibolis seagrass communities are common on sublittoral platforms and sills within the metahaline parts of Brown's, Depuch and Disappointment Inlets and in the northern portion of Useless Inlet. In shallow areas (2-3 m deep) this assemblage comprises scattered stands, while narrow and denser rows occur on the crests of megaripples among wide areas of bare carbonate sands. The overall low coverage by this community within the inlets at depths below 5 m, contrasts markedly with the situation in eastern Shark Bay where continous, dense meadows extend to depths of 12 m (Read, 1974a).

(2) Tidal channels

Channels which divide the barrier banks at the entrance of inlets, and those which traverse sills within inlets, are swept by fast tidal currents and contain a Posidonia australis seagrass community that is interspersed among areas of bare and mobile sand.

(3) Inlet basins

These are often inhabited by the Cerithium-Penicillus assemblage, with the proportions of Pencillus and seagrasses such as Posidonia or Halodule being conversely related to salinity.

(4) Sandy beaches

Metahaline shallow sand flats from MLWL to 1 m are occupied by the Callista-Anomalocardia assemblage, and much less frequently by the Fragum-Hemicardium community described by Logan & Cebulski (1970). The latter consists of another sand-burrowing pelecypod community characterised by Fragum unedo and Hemicardium hemicardium.

(5) Intertidal platforms

Rocky platforms occurring in oceanic waters of Shark Bay frequently support a profilic growth of rock oysters. As salinity increases however, oysters decrease in abundance and in Edel Land inlets are replaced by a sparse community of mytilid and littorinid molluscs, barnacles and blue-green algae.

(6) Intertidal - supratidal flats

A cyanobacterial/alga community forms a thin mat on the surface of tidal flats. In the higher supratidal zone, a low heathlike community of halophyte grades into the intertidal zone. The community rapidly colonises newly-exposed sandy substrate, including parts of the southern most portion of Useless Inlet following the construction of saltworks levees (Read, 1974a).

4.4 HUMAN ENVIRONMENT

4.4.1 Historical perspective

Prior to European settlement, Shark Bay supported a small Aboriginal population (Appendix 4). The calm, shallow waters provided them with a plentiful supply of fish, shellfish and larger marine animals such as dugongs and turtles (SPC & CALM, 1988). Early European exploration in the region consisted of Dutch, French and English maritime expeditions from the early 1600s to the early 1860s. Shark Bay provided safe anchorage and water supplies for explorers and passing whalers. Captain H.M. Denham charted the waters of the Bay in 1858. The pastoral industry was initiated by the release of land to graziers in the 1860s. The industry has continued to the present day, after having experienced mixed success depending on season and wool price.

Shark Bay was settled first by Chinese sandalwood cutters who set up camps on Peron Peninsula in 1860, and then by European and Chinese pearlers in the 1870s (Slack-Smith,1978). Evidence of these pearling operations can still be seen approximately 20 km north of Clough's Bar on the eastern shoreline of Useless Inlet (Section 5.4). European, Malay and Thursday Islander guano miners and pearlers established the first large settlement in the region at Denham (known as 'Freshwater Camp' prior to 1898). Following World War I activities of the pearling industry intensified but then declined during the 1930's depression and ceased soon after the outbreak of

World War II (Slack-Smith, 1978; Hancock, 1989). During World War II an 83 mile unsealed defence road was constructed between Denham and the Northwest Coastal Highway.

With the steady decline of the pearling industry during the 1930s, scale fishing became the mainstay of Shark Bay settlements; the first cannery and processing works apparently having been established at Monkey Mia and Herald Bight as early as 1912 (Nevill & Lawrence, 1985). The catches were transported by State Shipping Service vessels. Despite the new defence road and the opening of several fish processing and freezer plants from 1942 onwards, the Denham scale fishing industry declined during World War II and did not recover until the 1950s. While a sharp decline in the annual scale fish catch between 1966 and 1968 coincided with the closure of the Planet freezer and processing plant at Denham in 1966, the decline was primarily related to previous overfishing and a subsequent reduction in fishing effort by over 50% (Slack-Smith, 1978; Fry, 1988; Appendix 6). The Denham economy and population finally became stabilised after the stabilisation and regulation of the prawn and scale fishing industries during the 1960s and 1970s.

Salt and gypsum extraction in Shark Bay commenced in 1963 with salt being derived from the solar evaporation of seawater at Useless Loop whilst gypsum was mined from land-based deposits on Heirisson Prong.

4.4.2 Economic profile

Mining, fishing, pastoral, tourism and service industries make up the main sources of employment to people in Shark Bay. Employment varies with the seasonal nature of many of these industries. Apart from being sources of employment, these industries have also helped to provide roads and other infrastructure which benefits the wider community. The following profiles describe the nature, regional value and future trends of these industries.

4.4.2.1 Mining

Shark Bay Salt Joint Venture has operated a solar salt project in the Useless Loop area since 1965. A gypsum mine was also operated for a while at Useless Loop. Until 1987, gypsum was also mined from enclosed evaporite ponds (birradas) at Bibby Giddy, 25 km south of Useless Loop.

Mining leases are held over other undeveloped high grade gypsum deposits in Shark Bay. These include substantial deposits at the northern end of Peron Peninsula. Commercial potash deposits are being sought on part of Coburn station by the holder of a mineral exploration lease. Application for sand mining on Dirk Hartog Island has recently been refused by the Minister for Mines on grounds of the environmental sensitivity of the island (Mines Department, 1989). Shark Bay Shire operates a coquina shell quarry as a cottage industry to provide shell grit to the poultry industry.

Recent proposals to extensively mine these deposits for cement manufacture have been rejected because of impending declaration of a marine park.

4.4.2.2 Commercial fishing

The Shark Bay region is the major fishing area in Western Australia for prawns, scallops, snapper and western sand whiting. In 1985 these fisheries were worth $18.5 million, $2.3 million, $3 million and $378,000 respectively. The total annual catch in Shark Bay was 2,172 tonnes, worth about $25 million. This represents about 15% of the State's fishing catch by weight (SPC & CALM, 1988). Recent estimates value the total catch at approximately $30 million (WAFIC, 1990). The main fishing grounds for each of these fisheries are shown in Figure 16.

Beside employment on the boats, the fishing industry provides considerable employment in the land-based processing and vessel maintenance industries, particularly at Carnarvon, where most of the catch is landed. Apart from Carnarvon's greater socio-economic infrastructure when compared to Denham, several historical factors have contributed to its superiority as a fishing port. The most significant of these were Denham's poor water supply and access road, its distance from the main fishing grounds and its inadequate labour pool (Slack-Smith, 1978).

Further detail on the history, operation and fishing grounds for each of the major fisheries of Shark Bay is presented below.

(1) Prawn fishery

The commercial prawn fishery became established during the early 1960s and since 1963 has been managed as a 'limited entry' fishery (Slack-Smith,1978). In 1987 there were 35 licensed prawn trawlers based at Carnarvon and Denham, each employing about five people (SPC & CALM, 1988). The fishing season typically extends from 1 March to 31 October, with peak catches being obtained in April and May.

Shark Bay provides about 60-70% of the total annual Western Australian prawn catch. The species caught are the western king, brown tiger and endeavour prawns, with western king prawns constituting the main catch. The total catch of prawns from Shark Bay in 1987 was 1,760 tonnes, a slight fall over 1986. The tiger prawn catch was 274 tonnes compared with 325 tonnes in the previous year (Fisheries Department, 1988; Appendix 3).

There are two prawn trawling grounds in Shark Bay; the large northern grounds (between Carnarvon and Bernier-Dorre Islands) and the smaller grounds in Denham Sound (Fig. 17). Unlike the northern area, Denham Sound yields only a 100-400 tonne annual catch of mainly western king prawns that has fluctuated markedly from year to year (Appendix 3). Small amounts of squid and scallops are also caught by prawn trawlers.

Whilst the total prawn catch has remained relatively consistent over recent years, the product price is under pressure from over supply of equivalent quality cultured prawn from South East Asia. The industry has recently removed eight licences under a buy-back scheme to maintain the fishery by enabling improved catch per unit effort.

(2) Scallop fishery

Shark Bay supports the major scallop fishery in Western Australia, with catches ranging from 500 to 3,500 tonnes live weight per year. The main scallop season is from March to October. Scallops are free moving animals and are caught with prawns and fish. They are shucked at sea by the crews who retain the meat only. Vessels employ up to 10 crew members. Due to concerns of over-harvesting, the fishery was the subject of a four year (1984-87) research programme. Management arrangements for the Shark Bay scallop fishery were decided upon in 1988 and, in accordance with the Minister for Fisheries guidelines, the fishery is managed on a limited entry basis with a maximum of 14 scallop boats. Prawning boats also pick up scallops as part of their catch.

(3) Snapper fishery

The pink snapper fishery commenced in the early 1960s following a decline in the rock lobster fishery south of Geraldton (Slack-Smith, 1978). The outer islands of Shark Bay and their adjacent oceanic areas now form important commercial snapper grounds, with the 1988 catch totalling 243.8 tonnes. Increased concern over the depletion of snapper stocks led to the introduction of a limited entry system in 1986, but total live weight catches increased from 494 tonnes (1986) to 568 tonnes (1987). Monitoring indicated that the management measures intended to limit fishing effort were not effective, and new limits on catch per boat in the main season have now been introduced (Fisheries Department, 1988).

(4) Beach seine fishery

A total of 14 licensed seining units presently operate in Shark Bay, principally from Denham. Each unit typically comprises a skipper and one or two crew operating a mother boat (about 10-12 m), a jet-boat (some 5 m) and a small dinghy (see Appendices 2 and 6). Historically this fishery was not economically stable owing to the high costs of processing, transporting and marketing its products, as well as inefficiencies with processing factory equipment, labour and management, and an expenditure of fishing effort sufficient only to earn a subsistence living (Slack-Smith, 1978). The industry has subsequently stabilised during the 1980's.

Whiting, tailor, mullet and yellowfin bream are seined from shallow waters (less then 2 m) within Shark Bay (Fig. 16). While some pink snapper are also taken, their contribution to the annual commercial seine catch is low (less than 5%) and does not form the mainstay of the fishery (M. Moran, pers. comm.). Hypersaline areas such as

Hamelin Pool, Herald Loop, Lharidon Bight and the southernmost portions of the Edel Land inlets (such as Brown Inlet) are not fished. The major catching seasons are April to August for whiting, January to May for mullet, February to May for tailor and August to September for bream (SPC & CALM, 1988).

Annual catches of the main seining species for the years 1986-88 are given in Table 4. Of these, the western sand whiting is the most commercially important, with the remainder forming by-catches or alternative-target 'subsistence' catches when whiting are not schooling. In 1985 whiting catches totalled 192 tonnes, worth $378,000 and representing 80% of the Western Australian catch for this species. This catch is close to the peak annual whiting catch of 209.5 tonnes caught in 1962 (R. Lenanton, pers. comm.; Appendix 6). The decrease to 90 tonnes in 1988 was due to a self-imposed management initiative that increased the minimum legal size by 3 cm (Fig. 20). The increase in minimum size is an attempt to make the western sand whiting competitive against the larger King George whiting in Eastern States markets.

The current returns of the Shark Bay beach seine fishery suggest an annual value of $600,000 shared between ten active fishing units.

(5) Distribution of marine resources

The distribution of the main commercial fishing and nursery areas is presented in Figures 16 and 17 and summarised below.

(a) Fishing grounds

- Seine fishing - shallow (less than 2 m) nearshore areas adjacent to much of the Shark Bay coastline, except for hypersaline areas.

- Prawns and scallops - the main trawling ground lies between Cape Peron in the south and the Quobba Point and Koks Island area in the north. A smaller ground, probably containing separate prawn stocks, is also trawled within Denham Sound (Fig. 17; Penn & Stalker, 1979; Heald & Caputi, 1981).

- Pink snapper - the main commercial snapper grounds are in oceanic waters north and west of Dirk Hartog Island, Bernier and Dorre Islands. Smaller quantities of snapper are taken inside Shark Bay by amateurs, and by commercial net fishermen in areas southeast of Cape Peron and in the southernmost areas of Freycinet Estuary (M. Moran, pers. comm.). The recreational snapper fishery is intensive and expanding. Its areas are located in Freycinet Reach, Denham Sound and inside Hopeless Reach. The 1983 amateur catch was estimated at about 45 tonnes of snapper, plus another 45 tonnes of assorted scale fish (M. Moran, pers. comm.). It has probably risen substantially since that time.

- Mackerel and tuna - a small amount of commercial trolling for mackerel and tuna occurs in open oceanic waters west of Edel Land, Dirk Hartog Island and further north.

(b) Nursery grounds

In order to maintain sustainable fishing yield from Shark Bay, the Fisheries Department has identified and given protection to large nursery areas within the Bay, i.e. areas containing sheltered waters that form spawning grounds and/or the feeding grounds of juvenile stages of commercial fish and prawns. Information pertaining to the nursery areas associated with each major commercial and recreational fishery of Shark Bay is given below.

- Beach seine species

  Nursery areas for scale fishes supporting the seine fishery (i.e. whiting, sea mullet, yellowfin bream) are tidal inlets containing mangroves such as Big Lagoon, tidal flats abutting Wooramel Seagrass Bank, and both the Peron Peninsula and the Edel Land inlets (Fisheries Department, 1986).

- Prawns

  Spawning occurs in deeper offshore waters north of Cape Peron between late autumn and early spring. This is followed by a series of planktonic larval immigrations (each approximately three weeks in duration) to shallow nursery areas where the post-larvae then settle on the seafloor (Fig. 17). At this time the post-larvae are some 10 mm in length (Penn & Stalker, 1979). Sub-adults move away from the nursery areas and onto the edges of the main trawling grounds in late summer and autumn of each year (Fig. 17). This migration coincides with their sexual maturation at lengths between 100 mm and 127 mm.

  Juvenile western king prawns prefer nursery grounds containing shallow sand and silt flats in areas between the low water mark and 2 m deep. This zone consists of fine silty sands with shell fragments and small clumps of fine algae (Penn & Stalker, 1979). By contrast, the preferred nursery grounds of the brown tiger juveniles are typically seagrass beds fringing the sand flats. This species prefers to inhabit the Posidonia seagrass areas, especially those where the grass is luxuriant (Penn & Stalker, 1979).

  Adults of both prawn species originate from the above habitats on the east coast of the Peron Peninsula (as far south as Dubaut Point), east of and around Faure Island, and on the mainland coast from Herald Loop to Carnarvon.

  Adult western king and the few brown tiger prawns which are trawled from the smaller Denham Sound grounds originate from nursery grounds on the shallow sandy areas of Freycinet Estuary and seagrass banks along the western shores of Denham Sound and Freycinet Reach (Penn & Stalker, 1979).

The Edel Land inlets also contribute to the nursery areas of the Denham Sound western king prawn population (Appendix 3).

As a result of the identification of these nursery grounds, no trawling is permitted south of lines extending east from Cape Bellefin and east from Cape Peron.

- Scallops

Scallop spawning occurs in December and January in the area currently used for prawn trawling. It is thought that water movements, particularly tidal currents, have a marked influence on the distribution and settlement of scallop spat. Tagging studies have indicated that migration of year 0+ age scallops to adult (year 2+) grounds does not occur (Heald & Caputi, 1979). The growth rate of scallops seems to depend more on hydrologic factors (e.g. low sea temperature and fast currents both reduce shell growth) than migration of spat to specific nursery grounds.

- Pink snapper

Recent tagging and genetic studies have demonstrated that the pink snapper of Shark Bay comprise three spatially distinct populations; an offshore population whose adults can migrate considerable distances along the coastline between the Abrolhos Isles and Koks Island, and two inshore 'gulf' populations whose adults migrate less than 46 km (Moran, 1987). The two inshore populations occur within the eastern and western gulfs of Shark Bay, i.e. to either side of Peron Peninsula. The offshore population provides the mainstay of the commercial snapper fishery, while the two 'gulf' populations support the recreational fishery and in part contribute to the beach seine fishery.

Genetic experiments have confirmed that these populations represent isolated breeding units rather than one large stock, and thus a mixed recruitment (in which the eggs, larvae or juvenile fishes of one population mix with those of another) does not occur (Moran, 1987). Thus separate breeding populations probably occur in Freycinet Estuary, the eastern embayment near Faure Island and in oceanic waters north of Koks Island (Johnson et al., 1986; Moran, 1987).

In their first year, pink snapper prefer flat sandy seafloor in water greater than 2 m deep. During the following two to three years they congregate around rocky areas such as islands, reefs and rocky shorelines (M. Moran, pers. comm.). It is thought that larger snapper seasonally move from deeper holes and channels to shallow and less saline areas (M. Moran, pers. comm.).

4.4.2.3 Tourism

Shark Bay is hot and very windy during summer but offers a dry mild climate during winter and many natural and recreational attractions to people visiting the area. The main tourist season is May to September, with peak visitor periods during school holidays, Easter and winter long weekends. Denham is the main tourist centre, with two caravan parks, hotel/motel units, self-contained cottages and some service facilities (see Section 4.5.4). Nanga and Monkey Mia have become important 'satellite' sites offering caravan park/camping and/or chalet accommodation (Fig. 1). A boat ramp and fish freezing facilities make Nanga a popular base for fishermen, while tourists visit Monkey Mia to see at close range a pod of dolphins that have achieved international fame (Fig. 15).

A steady increase in tourist numbers has lifted the economic importance of the tourist industry in the Shark Bay region. Future growth is expected to continue, with potential for local job creation. This expansion will be facilitated by the further development of tourist infrastructure, additional recreational facilities and the protection and/or enhancement of the resources which attract tourists. The Shark Bay Region Plan (SPC & CALM, 1988) provides strategies and a land use plan for these objectives. In this plan, potential tourism development sites identified on the Edel Land Peninsula are limited to Steep Point and its environs, which are currently used for camping, angling and some SCUBA diving and snorkelling.

The recreational attractions of Shark Bay are summarised below.

(1) Man-made attractions

- Nanga Station; holiday accommodation adjacent to recreational fishing grounds.
- Freshwater Camp: located at Nanga, it contains a pioneer Homestead Museum and the Pottery.
- Denham Townsite.
- Shell Block Buildings: including the Old Pearler Restaurant, St Andrew's Church and the Shark Bay Hotel at Denham.
- Solar salt operations at Useless Loop.
- Hamelin Telegraph Station.
- Monkey Mia vistor centre, settlement and pearl farm.

(2) Natural attractions

- Stromatolites at Hamelin Pool.
- Dolphins at Monkey Mia.
- Shell Beach.
- Red Bluff and Eagle Bluff.
- Big Lagoon and Little Lagoon.
- Dirk Hartog Island.
- Steep Point, South Passage and False Entrance.
- Zuytdorp Cliffs, and blowholes.
- Flora and fauna.

(3) Recreational fishing

Above-average fishing in relatively protected waters attracts many recreational fishermen. Mainly scale fish are caught by anglers from boat or shore, with catches representing an important part of the total Shark Bay catch (amateurs caught 8% of the 1983 professional catch). Pink snapper is the most important amateur species, followed by North West snapper, baldchin groper, mulloway, tailor, spanish mackerel, northwest cod, whiting, and bream.

Boat fishing accounts for the bulk of the recreational catch (85-95% of reef fish and 65-70% of game fish). Shore based recreational fishing is important at areas such as Steep Point and South Passage which are reknowned for mackerel and other gamefish species.

4.4.2.4 Pastoral industry

Pastoral leases presently occupy most of the land surface of Shark Bay. The study area defined by the Shark Bay Region Plan (SPC & CALM, 1988) extends from just south of Carnarvon to about 100 km south of the Overlander Roadhouse, and east to the North West Coastal Highway. In this region there are fifteen pastoral leases covering 1,111,000 ha. Eight of these leases lie only partly within the above boundaries.

Wool production is the main resource; in 1984 the region carried approximately 40,000 sheep. In times of low wool prices there has been local substitution of cattle for sheep. A small herd of fibre producing goats on Faure Island also contributes to the overall pastoral income.

The average gross income of the industry has been $1 million per year in recent times, $750,000 coming from wool sales and the remainder from sheep and cattle sales, feral goats, and goat fleece from Faure Island (SPC & CALM, 1988).

4.4.3 Demographic profile

4.4.3.1 Resident population

The Shire of Shark Bay estimated the resident population of Shark Bay in 1986 to be 690 people. Of these, 350 were based at Denham, 200 at Useless Loop and 140 in rural/pastoral areas such as Tamala and Carrarang (SPC & CALM, 1988). Thus employment created by the solar salt project is significant to the area.

Resident population growth for the decade up to 1986 was estimated as 2.7% per annum. A significant increase occurred following the expansion of salt mining at Useless Loop in 1968 (SPC & CALM, 1988). As is the case for most of the Gascoyne region, certain sections of the population are mobile due to the seasonal nature of industries such as tourism and fishing (DRDNW, 1988).

4.4.3.2 Visitors

The number of visitors calculated from occupancy rates of caravan parks and cottage/hotel/motel accommodation was 50,100 in 1985/86 (SPC & CALM, 1988). The real figure is undoubtebly higher owing to tourists who camp outside these areas. An Australian Bureau of Statistics census on 30 June 1986 counted 2,470 people in the area, of which 1,800 people were non-residents of Shark Bay.

4.4.4 Conservation and landscape values

Many of the biological and geological features of Shark Bay have significant scientific, educational and conservation value. These include:

(i) stromatolites and other unusual sedimentary deposits;

(ii) seagrass banks and their relationships to marine resources and sedimentary formations;

(iii) marine mammals;

(iv) endemic marine and terrestrial species and subspecies.

The economic profile of Shark Bay (Section 4.4.2) is largely dependant on the region's natural features and systems. Thus the Region Plan states that the aims of both conservation and economic development are best served by identifying and conserving the natural and recreational attributes of the region. It is therefore important to identify those parts of Shark Bay with high value for conservation so that the project area can be placed into this regional perspective.

4.4.4.1 Landscape and scenic values

The Zuytdorp Cliffs on the west coast of Edel Land provide spectacular scenery, with long sections of tall (50-170 m), vertical cliffs. Smaller cliffs (6-35 m in height) face east into the bay along Dirk Hartog Island. Dolphins, whales, sharks, rays, dugongs and various seabirds can be seen from these vantage points. Many locations on the Peron and Edel Land Peninsulas and around Hamelin Pool also provide uninterrupted and unspoilt coastal views of considerable aesthetic value.

4.4.4.2 Terrestrial fauna

While many aspects of the terrestrial fauna of Shark Bay are unusual and provide conservation value to the region as a whole, some species have been identified as being of high conservation status for the following reasons (Nevil & Lawrence, 1985 and CALM, 1986):

(i) formally widespread species have had their distribution drastically reduced. For example, the barred bandicoot (Perameles bougaiville) is now found only on Bernier and Dorre Islands, and the distribution of the thick-billed grasswren (Amytornis textilis) is now confined to saltbush at the northern end of Peron Peninsula;

(ii) many of the endemic species are allowing biogeographers to study the ways in which land bridges between islands and the mainland have been used. An example is the endemic form of the White-winged fairy wren (Malurus eucopterus) on Dirk Hartog Island;

(iii) Shark Bay contains overlap areas between major biogeographic zones. For example, Peron Peninsula forms the southern limit for the yellow silvereye (Zosterops lutea), while various regions in Shark Bay form the northern limit to many southern reptiles (Storr & Harold, 1978).

The numerous small islands of Freycinet Reach and Freycinet Estuary are important seabird breeding sites for species such as the white bellied form of wedge-tailed shearwater (Storr, 1985).

4.4.4.3 Stromatolites and other carbonate structures

The hypersaline waters and geomorphic features of Hamelin Pool have led to the development of unique geological and biological features including:

(i) stromatolites - the ultimate 'living fossils' similar to the oldest forms of life that dominated the biosphere between 3.5 and 0.5 billion years ago. Of great scientific interest, stromatolites form only when conditions enable cyanobacteria to trap and bind sediment, and/or promote increased precipitation of calcium carbonate without interference from grazing fauna or competition by faster-growing macrophytes and reef-building animals;

(ii) deposits of unconsolidated and lithified beach shell ridges of of Fragum erugatum;

(iii) coquina and ooid shoals.

The land use plan put forward by SPC & CALM (1988) has designated Hamelin Pool and Faure Sill as a reserve for the protection of stromatolites and sedimentary deposits. In early 1990, CALM released a notice of intent to proclaim a marine nature reserve over this part of Shark Bay, but its incorporation into the proposed Shark Bay Marine park as a 'special-category' zone is also being considered.

4.4.4.4 Marine mammals and reptiles

(1) Dugongs and dolphins

Shark Bay supports a population of between 1,000 and 10,000 dugongs (Dugong dugon) (Anderson, 1986; R. Prince, pers. comm.). This population is important for the following reasons:

- it is possibly only one of two populations of this size in the world;
- it is one of the few populations that is not hunted by man;
- it occurs at the southern limit of their range;
- clear and calm water in most areas allow the dugong to be observed by tourists as well as for scientific study.

Shark Bay dugongs rely on the extensive seagrass meadows and warm waters. Studies reported by Prince et al. (1981) and Anderson (1986) reported regular seasonal east-west migrations which were considered to be in response to the colder waters on the eastern shore of the Bay during winter.

In summer many dugongs return to forage on beds of tropical seagrass (Halodule sp.) in the Wooramel River delta near Gladstone, while others utilise seagrasses at the southern end of Freycinet Estuary. These habitats provide optimal thermal and dietary conditions in summer (Anderson, 1986). In winter, it was thought that most dugongs migrate to seagrass banks (mainly Amphibolis antarctica) on the eastern side of Dirk Hartog Island. During winter substantial numbers are also seen in South Passage but not in Edel Land inlets.

Recent evidence, however, suggests that the main migratory pattern is north-south rather than east-west, with dugongs in the western half of Shark Bay moving from summer areas in the lower Freycinet Estuary to over-winter off Dirk Hartog Island (R. Prince pers. comm.; Appendix 9).

Dolphins (Tursiops truncatus) are widespread within Shark Bay. The Monkey Mia phenomenon of 'wild' dolphins approaching humans has become one of the region's main tourist attractions, and has received extensive publicity. Dolphin lovers from all over the world have now made the trip to Shark Bay to experience this dolphin-human relationship (Nevill & Lawrence, 1985).

The Shark Bay Region Plan (SPC & CALM, 1988) recognises the importance of the region's dolphin and dugong populations and the habitats they utilise. The plan therefore proposed the creation of marine parks for the protection of marine mammal habitats. These habitats include Dirk Hartog Island (eastern side), Wooramel Delta, Bernier and Dorre Islands and the southwest portion of Freycinet Estuary. The recently released notice of intent for a Shark Bay marine park by CALM will give effect to these recommendations.

(2) Whales

Shark Bay is recognised as being a wintering area for the remnant population of the southern humpback whale (Megaptera novaeanglia). The numbers of southern humpback whales has been steadily increasing during the 1980s and is now believed to number approximately 2000.

(3) Turtles and sea snakes

Green (Chelonia mydas) and loggerhead (Caretta caretta) turtles are widespread in the Bay waters. They are especially abundant on Green Turtle Flat (north of Faure Island), and around the northern ends of the Peron Peninsula and Dirk Hartog Island. Loggerhead turtles nest on relatively remote northern beaches along Peron Peninsula and Dirk Hartog Island. Shark Bay also contains populations of at least six species of sea snake, including an endemic form of the species Aipysurus laevis (pooleorum).

4.4.4.5 Seagrass banks and fish nursery areas

The diverse seagrass assemblages in Shark Bay are of prime importance to the distribution of sediments and marine organisms, and the stability of the Shark Bay marine ecosystem. The Wooramel seagrass bank is the largest in the world, covering an area of 1,030 km^2 along the eastern shoreline of Shark Bay. Due to its conservation value, this area is to be managed as a prawn nursery and seagrass protection reserve (SPC & CALM, 1988). The land use plan advocated by SPC & CALM (1988) also outlines a recreation and commercial fishing zone in which the protection of nursery areas within the region's extensive seagrass beds, mangroves, coastal shallows and inlets is seen as a fundamental objective.

4.4.4.6 Conservation and land status

In 1974 the Conservation Through Reserves Committee published recommendations covering the Shark Bay area (System 9). These recommendations included:

- the marine waters south of the northernmost points of Dirk Hartog Island and Peron Peninsula to be protected as aquatic reserve;
- most of the adjacent pastoral leases be resumed and managed as a National Park.

Areas excluded from the above recommendations were Useless Inlet and Heirisson Prong, which are utilised by the solar salt project. These recommendations were endorsed by the EPA in 1975.

Under the Land Act, 1983, the State Government created the following reserves in Shark Bay:

- part of the shoreline of Hamelin Pool, between high and low water mark (for the conservation of stromatolites);
- Bernier and Dorre Islands (for the conservation of rare and endangered marsupials);
- Cooloomia Nature Reserve (south of Hamelin Station).

The Shark Bay Region Plan (SPC & CALM, 1988) has followed the general intent of the 1974 System 9 recommendations in regard to "long term conservation of the natural features and systems in Shark Bay, whilst accommodating appropriate levels of use consistent with the area's varied resources and capacity". The strategies and objectives of the 1988 Region Plan are to be achieved by a series of proposed land use zones and public purpose reserves based on multiple use concepts.

The EPA (1987) has evaluated the Shark Bay Region Plan (SPC & CALM, 1988) in terms of the region's general conservation values and the System 9 'Redbook' recommendations. While the EPA commended the region plan for its initiative and marine conservation proposals, it noted that more land areas should be reserved for conservation and that some pastoral lands should be protected from grazing (EPA, 1987).

Both the System 9 Redbook and the EPA's 1987 report on the Shark Bay Region Plan acknowledged the continued operation of the solar salt project and attendant mining lease in Useless Inlet, the latter remaining outside both the original and new aquatic park and reserve areas.

A notice of intent to declare the Shark Bay Marine park has recently been released by CALM following evaluation of public submissions on the proposed boundaries. The proposed marine park boundaries do not include the SBS lease areas. The proposal is now with the State Government.

4.4.4.7 World Heritage Listing

In 1974 Australia became a signatory to the World Heritage Convention. Listings within this inventory are made to ensure recognition of places of 'outstanding universal value'.

Parts of Shark Bay would meet some of the criteria set out by the World Heritage Commission for inclusion on the List. These criteria include:

(i) an outstanding example representing the major stages of the earth's evolutionary history;

(ii) outstanding examples representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment;

(iii) unique, rare or superlative natural phenonena, formations or features or areas of exceptional natural beauty;

(iv) habitats where populations of rare or endangered species of plants or animals still survive [International Union for Conservation of Nature and Natural Resources (IUCN), 1982].

The Australian Government has announced its intention to nominate part of Shark Bay for listing. Once nominated acceptance rests with the IUCN (International Union for Conservation of Nature), a committee of UNESCO.

4.4.5 Community attitudes and response to Shark Bay Region Plan

The responses and submissions to the Shark Bay Region Plan (SPC & CALM, 1988) highlight the diversity of community attitudes to future development, land use and conservation issues facing the Shark Bay region. Both the local and scientific community believe that the marine resources of Shark Bay are potentially at risk, an attitude summarised by the following statement; "public use of Shark Bay will increase and that measures to protect the basic marine resources and to manage their use are essential if deterioration due to over-use is to be prevented" (in SPC & CALM, 1988).

Public submissions regarding the solar salt project were received and summarised by the Plan. Six of these indicated that salt mining has important local, social and economic benefits. Another 28 submissions also indicated that the current salt mining operation should continue, but expressed concern that Useless Inlet could be an important fish nursery. Six submissions supported present strategies for solar salt mining and the further expansion of this activity, subject to environmental acceptability and adherence to local by-laws. One submission noted that the existing solar salt ponds provide an important autumn refuge for trans-equatorial migratory wading birds.

Those recommendations of the Region Plan pertinent to the proposed expansion of the primary pond system in Useless Inlet are quoted as follows:

Mining development

(i) "The solar salt mining operation at Useless Loop should be continued in accordance with the Shark Bay Solar Salt Agreement Act, 1983".

(ii) "Prior to any further expansion of the salt mining operations at Useless Loop which would result in further closure of Useless Inlet, it is essential that the operator undertake a study to determine the potential effects on existing seine and other fishing activities and recreational potential. This needs to comply with the assessment procedures of the EPA".

Fisheries development

(i) "The long term sustainability of the fishing industry at Shark Bay should be ensured by ongoing management by the Department of Fisheries and by members of the industry, and by protection of marine habitat, especially those areas which serve as breeding and nursery areas for juvenile fish".

(ii) "The viability of diversifying the fisheries within the region to include other species such as tuna, mackerel, squid and bait fish, should be investigated and where economically and environmentally feasible, should be pursued".

The last of these recommendations also encompasses the development of various forms of commercial fish, prawn and algae aquaculture ventures, a potential industry addressed in Section 2.3.6 of the Shark Bay Region Plan.

5 DESCRIPTION OF ENVIRONMENT - PART B: PROJECT SETTING

5.1 INTRODUCTION

In accordance with the recommendations of the Shark Bay Region Plan, the proponent has commissioned a range of studies to determine the potential effects of the proposed pond. Many of these studies provide useful descriptive information on the present characteristics of Useless Inlet and adjacent environs. The range of studies undertaken is as follows:

- fishdown exercise to assess stocks within existing ponds and the feasibility of commercial seining operations within the Useless Inlet pond system (Appendix 2).
- fish nursery survey to assess the value of the proposed pond area as a nursery for commercial and recreational species (Appendix 3);
- Aboriginal archaeological study to determine the potential significance of the quarry areas and shoreline of the proposed pond area (Appendix 4);
- avifauna survey to determine the significance of the southern parts of Useless Inlet as a resource for waterfowl (Appendix 5);
- biohabitat survey (including quantitative study on benthic organisms) to appraise both the ecological and productive value of the proposed pond area (Appendix 7);
- morphological and hydrologic study of Useless Inlet to elucidate its hydrodynamic regime (Appendix 8);
- review of available information on dugong use of Useless Inlet (Appendix 9);

In addition, historical information on the Denham beach seine fishery was provided by the Fisheries Department (Appendix 6).

5.2 PHYSICAL ENVIRONMENT

5.2.1 Morphology and hydrology of Useless Inlet

Useless Inlet is a narrow elongate embayment that is some 40 km in length and confined by the Bellefin and Heirisson peninsulas to its western and eastern sides respectively (Fig. 1). The entrance to Useless Inlet is 5 km wide, but the main tidal entrance channel is approximately 1.5 km wide owing to the presence of shallow sandy lobes that form a barrier sill (Fig. 18).

The southern and generally shallow portion of Useless Inlet has been ponded and forms part of the existing solar salt operation. The most recent salt pond was constructed in 1974 by installation of Clough's Bar. The length of the open portion of Useless Inlet (to the north of Clough's Bar) is just under 27 km (Figs 1, 18). No creeks drain into the inlet.

Examination of morphological and hydrodynamic characteristics of Useless Inlet shows that the flushing of its waters is tidally dominated, and that water circulation within this inlet is heavily influenced by buoyancy-driven flow (Appendix 8). The latter force arises from the distinct and essentially permanent salinity gradient, with typical salinities ranging from 40 ppt in the Inlet entrance area to 46-47 ppt near Clough's Bar. The southward increase in salinity is a function of increased evaporation rates along the shallow margins of the Inlet, as well as a reduced rate of tidal mixing and flushing of southern Inlet waters compared to that at the Inlet entrance (Appendix 8).

Other forces influencing water circulation within Useless Inlet include wind-induced stress. Winds acting on Useless Inlet are most common from the southerly quadrants, with a typical summer daily wind pattern commencing with SE/SSE winds that increase in speed and swing around to the SW as the strength of the coastal seabreeze component rises (SBS observations at Useless Loop). The dominance of SW-SSW winds is evidenced by the more eroded and cuspate eastern shoreline of the Inlet (Fig. 1).

The prevailing southerlies generate N-NE wave-trains that shoal onto the shallow banks off the eastern shoreline, thereby generating longshore currents that parallel this coastline in a NNW-NW direction, a pattern of littoral drift also observed by Logan & Cebulski (1970) for other parts of Shark Bay (Appendix 8).

Useless Inlet can therefore be classified as a tidal dominated inlet whose circulation pattern is heavily influenced by buoyancy driven flow and, to a lesser extent, by wind stress.

5.2.2 Geomorphology

The geomorphological units of the project setting have been identified from a comparison of the available literature (mainly Read, 1974a and Logan & Cebulski, 1970 ; refer Section 4), interpretation of colour aerial photographs and ground truthing during recent field surveys (Appendix 7). The distribution of the major geomorphic units in Useless Inlet and the nearby Boat Haven Loop is presented in Figure 18. Detail on the physical characteristics and distribution of each unit within the project area is presented below.

5.2.2.1 Intertidal/supratidal flats

No intertidal/supratidal flats occur within the area of the proposed pond (Figs 18, 19). Muddy saline flats occur in a side embayment on the eastern side of the inlet adjacent to the proposed pond area (Fig. 19). These flats are comprised of muddy carbonates with precipitated salts. The embayment also contains mangroves (Avicennia marina) along its narrow tidal channel, which enters the embayment through a constricted opening and then broadens out into mud/salt flats covered with samphire (Appendix 7). Inundation of supratidal areas occurs during periods of strong northerly winds or with the highest spring tides.

Boat Haven Loop (including Browns Inlet) possesses more side embayments than Useless Inlet (Appendix 7).

5.2.2.2 Intertidal beaches and limestone platform

Narrow intertidal sandy beaches are characteristic of most of the shoreline of Useless Inlet. Sediment is composed of carbonate sands and shell debris transported from shallow nearshore areas. These beaches are backed by low limestone cliffs, emergent benches or sand dunes (Figs 18, 19).

These beaches typically occur within small bays between rocky platforms and headlands on the eastern side of Useless Inlet. However, they form much longer and less cuspate stretches on the western side. A similar distribution pattern exists in Boat Haven Loop. The limited extent of sandy bays and the frequent exposure of underlying limestone on the tidal terraces of the eastern shoreline suggests that the east side of Useless Inlet and Boat Haven Loop are subject to greater erosion than the western shorelines, which contain longer stretches of sandy beaches backed by sand dunes (Figs 18, 19; Appendix 8).

Intertidal limestone platforms covered by a thin veneer of sandy sediment are common, particularly on the eastern side of Useless Inlet and Boat Haven Loop where they outcrop as intertidal extensions of rocky headlands or limestone cliff/terrace areas. The margins of the proposed pond comprise both intertidal limestone terraces and sandy beaches.

5.2.2.3 Sublittoral platforms and sandflats

Sandy veneers 0-0.5 m thick occur on many of the sublittoral platform and sill areas. Shallow depths (1-3 m) result in these environments being subjected to tidal current and wave action. Subtidal sand flats south of Clough's Bar in Useless Inlet are mobilised principally by wave action, leading to noticeable but usually temporary increases in turbidity (Appendix 2).

The platforms and their sand flats form gentle slopes from the intertidal zone to the platform margins where depths reach some 2 m. There is often a transition across this area from broad expanses of bare shallow sand to scattered patches of seagrass

(Section 5.3.1). The sill and barrier banks at the entrance to Useless Inlet and Boat Haven Loop are covered by a combination of sand flat and more luxuriant seagrass meadows composed of Posidonia and Amphibolis, with the seagrass community usually best developed on the crests of the megaripple structures and least in the troughs (see Section 4.2.2.2).

5.2.2.4 Subtidal basin

The basin comprising the central portion of Useless Inlet (Figs 18, 19) is composed of bare fine to medium grained skeletal sands laced with organic detritus. The latter originates principally from the decomposition of Posidonia leaf (Appendix 7). The basin has an whose average depth of some 7 to 8 m and contains a series of low, north trending dunal ridges with a relief up to 3 m (Appendix 8). In troughs between the submerged dunal ridges finer grained and silty sediments were predominant and turbidity was high. Compared to Useless Inlet, the basin area of Boat Haven Loop is less deep and contains less turbid waters overlying coarser sediments (Appendix 7).

The relatively large and deep (5-12 m) basin floor of Useless Inlet is a relatively low energy environment in which only the finer particulates are rountinely mobilised. The proportion of finer sediments is highest within the lee of Clough's Bar (Appendix 7).

5.2.2.5 Tidal channel

A single major tidal channel dissects the barrier bank area of the entrance to both Useless Inlet and Boat Haven Loop (Fig. 18). The tidal channel entering Useless Inlet is some 8 km in length with an average width of some 1.5 km. In cross-section, the channel forms a wide 'U' with relatively steep sides (20-30^{o}) and an overall depth of approximately 10 m. After passing a variety of shallow sand flats in the entrance area, the main tidal channel divides into a forked system on the inner (south) side of the entrance to Useless Inlet (Fig. 18). The arrangement of the shallow areas to the north (outer) and south (inner) of the entrance is related to the action of ebb and flood tidal currents respectively (Appendix 8). Together with the large sand flat in the middle of the entrance, the various shallow areas form the 'barrier sill' area to Useless Inlet.

5.2.2.6 Dunal ridges

The low limestone ridges associated with the proposed eastern and western quarry sites run parallel with Useless Inlet and are typical representatives of the north trending dunal ridge system that characterises the Edel Land Province (Section 4.2.2.1). The dunal ridges comprise calcareous (Tamala) aeolianite overlain by weakly-cemented calcareous and quartz sands, and are covered by a thin sandy topsoil stabilised by low shrub and heath vegetation. Mobile dunes are not present at the quarry sites.

The western quarry site (4 ha) comprises the northern portions of two low ridges which rise some 15-20 m above sea level. These ridges are separated by a sandy depression 150 m wide (Plate 1A). Apart from its northern end, the ridge closest to Useless Inlet is separated from the shoreline by a narrow sand plain and a wide emergent limestone bench. The sand plain partially overlays the bench, whose edge is about 2 m above MSL and forms the western shoreline (Plate 1B). Both dunal ridges finish abruptly at their northern end, dipping down to a small north-facing beach that forms a marked discontinuity on the western shoreline (Fig 5). The north end of the eastern dunal ridge terminates at the point where the western abutment of the proposed levee is to be constructed (cf. Figs 5,8).

The ridge extending into the main part of the 15 ha eastern quarry area is situated almost 1 km inland and rises to some 30-40 m above sea level (Plate 1C). Separated from the eastern shoreline of Useless Inlet by parallel but lower ridge (20-25 m), the main ridge of the quarry is underlain by Tamala limestone which outcrops at several places (Plate 1D). Both ridges continue southward from the quarry site for several kilometres, while to the north they fall away to terminate on a low sand plain some 5 m above sea level. This plain dips to the north-facing side of the large eastern embayment which, in turn, contains the entrance channel to the mangrove and samphire basin lying to the east of the quarry site (Fig. 5).

5.3 BIOLOGICAL ENVIRONMENT

5.3.1 Proposed quarry sites

5.3.1.1 Flora of western quarry

Plates 1A and 1B show the proposed quarry site on the western shore of Usless Inlet. Shoreline vegetation at the western quarry and adjacent abutment site comprises a small stand of *Avicennia marina* occupying 30 m of the north-facing beach. This is backed by a supratidal zone sparsely vegetated with saltwater couch (*Sporobolus virginicus*), the beach spinifex (*Spinifex longifolius*) and *Frankenia* and *Carpobrotus*.

Between this zone and the dunal ridges lies a narrow sand plain that is vegetated by a low shrub heath up to 1.5 m high, comprising *Olearia axillaris*, *Melaleuca*, *Atriplex*, *Scaevola*, *Acanthocarpus* and dominated by occasional emergent *Acacias*. The dunal flora is similar, although generally slightly taller and more diverse. Low herbs are more common, and the twining creeper *Cassytha* covers many of the shrubs. The depression area separating the two dunal ridges of the quarry area supports a similar assemblage, although in the lowest parts of the depression a dry samphire (*Halosarcia* spp.) herbland is present.

The landforms and vegetation of the western quarry area are replicated along much of the western shoreline of Useless Inlet.

5.3.1.2 Flora of eastern quarry

Plates 1E and 1D show the quarry site on the eastern side of Useless Inlet. The eastern margins of the quarry area lie near the large shallow intertidal and supratidal basin containing mangroves (A. marina), a broad fringe of samphires (Halosarcia spp. and Limonium sp.), and a low shrub heath on the raised margins. The eastern boundary of the quarry is marked by a low 3-4 m vertical cliff which marks the exposure of calcretised Tamala aeolianite that underlies the dunal ridge. The vegetation of the dunal ridge is very similar to that on the western quarry site (including Atriplex, Olearia, Melaleuca), although it is more mature and slightly taller, with occasional emergent Acacia 5 m in height.

5.3.1.3 Fauna of the quarry sites

Faunal surveys of the quarry sites were not undertaken because the two quarry sites occupy extremely small portions of the extensive dunal ridge system surrounding Useless Inlet. Moreover, the flora covering both the eastern and western quarry sites is typical of that elsewhere in the Edel Province (Section 4.3.2.1). Endemic fauna associated with this vegetation and landform are widely distributed in the region and cannot be endangered by the small scale of the proposed quarry operations.

5.3.2 Distribution of marine communities

Summary descriptions are provided of the marine communities in Useless Inlet and those close to the Useless Loop levee. Descriptions are based on data and observations from three field studies detailed in Appendices 2, 3 and 7. Where relevant, comparisons are made with Boat Haven Loop, a neighbouring and unmodified Inlet. The biohabitat study (Appendix 7) included a quantitative survey of the different types of surface-dwelling and burrowing animals (benthic fauna) inhabiting sediments of the deep basin floor, seagrass-covered sills and nearshore shallow sand flats.

5.3.2.1 Entrance channel and barrier bank

The main tidal channel and the various sandy lobes comprising the deltaic entrance area to Useless Inlet are edged by mainly monospecific stands of Amphibolis antarctica or Posidonia australis seagrass, as is the case for the narrower entrance channel to Boat Haven Loop.

Many parts of the shallow sandy areas forming the 'barrier bank' entrance to Useless Inlet and Boat Haven Loop are covered by Amphibolis meadow. Some of these occur in typical 'rill', 'circular' and 'doughnut' formations as described by Walker et al., 1988 for other areas of Shark Bay.

The western side of Freycinet Reach adjacent to the Useless Loop levee and ship loader is essentially a very large tidal channel. The upper slopes and edges of this part of the channel are also edged with Amphibolis and Posidonia australis meadows. Areas containing other species of seagrass (e.g. Halodule uninervis and Halophila spinulosa) and soft coral were common on the adjacent channel bottom in both Freycinet Reach and Boat Haven Loop (Appendix 7).

However in contrast to Boat Haven Loop and Freycinet channel, the bottom of the Useless Inlet entrance channel does not support extensive areas of seagrasses or coral (Appendix 7). A 1981 Western Australian Museum survey also did not find any corals in the Useless Inlet entrance channel (L. Marsh, pers. comm.). The bottom of the southern portion of Useless Inlet channel is comprised of bare megarippled sand.

5.3.2.2 Inlet basins

Underwater inspections and trawling showed that, in contrast to the basin area of Boat Haven Loop (where areas containing seagrasses such as H. uninervis, H. spinulosa and H. ovalis were common), the relatively much larger basin of Useless Inlet comprises predominantly bare areas of medium to fine grain carbonate sands (Appendix 7). No seagrasses were found at various sites inspected by underwater survey in the Useless Inlet basin (Appendix 7).

The calcified green alga, Penicillus nodulosus, was common in the southern and more saline part of the basin area in Useless Inlet (i.e. in the proposed pond area). This alga is also common in southern parts of Boat Haven Loop (Appendix 7).

The most numerous animals colonising the basin floor of Useless Inlet were five types of polychaete worm (capitellids, magelonids, nereids, opheliids and orbinids), three types of crustacean (gammarid amphipods, porcelanid crabs and isopods), and three types of bivalve mollusc (venerids, mytilids and cardiids: Appendix 7). A total of 37 different taxa were collected, and this diversity was equivalent to that found in similar bare basinal areas of Boat Haven Loop (38 taxa) and Freycinet Reach (31) (Appendix 7).

5.3.2.3 Sublittoral platform

A fringing seagrass meadow of P. australis colonises the margins of the sublittoral platform along Useless Inlet. The occurrence of Amphibolis along these margins rapidly diminishes south of the entrance area. The most southerly stand of Amphibolis was found beside the eastern sublittoral platform at a point 9.5 km south of the entrance and 16.5 km north of Clough's Bar (Appendix 7).

The lack of Amphibolis seagrass along the edges of the main basin of Useless Inlet is in direct contrast to the situation in Boat Haven Loop (where stands of Amphibolis also occur in the hypersaline southernmost areas) and in other areas of Shark bay such as Freycinet Harbour and Lharidon Bight (Walker et al., 1988; Appendix 7). Aerial photographic mosaics of Usless Inlet taken in 1957 (before the salt project commenced), 1973 (before completion of

Clough's Bar), 1978 and 1989 show that the distribution of both Amphibolis and Posidonia seagrass meadows north of Clough's Bar has remained remarkably constant during the period. Even small features (such as approximately 30 m wide 'blowouts') can be matched between the 1957 and 1989 mosaics. The lack of Amphibolis meadow might be linked to the activities of the pre-war pearling industry within Useless Inlet (Section 5.4.1.2: Appendix 7).

The Posidonia which fringes the shallow sublittoral platform is shorter and less dense than that in the entrance area and forms patchy meadows. Termed 'stunted' by Read (1973), these stands harbour razor clams, mytilids, oysters, tube-building worms, sponges and other encrusting forms that comprise the Pinna-Pinctada community described earlier (Section 4.3.2.2).

Various green and brown algae (e.g. Caulerpa, Udotea, Hormophysa, Cystoseira and 'drifting' Dictyota) occur on the predominantly bare sandy areas further inshore, as well as those surrounding the patches of fringing Posidonia. Areas where only a thin sandy veneer overlies the limestone platform are frequently covered by large numbers of mytilid shells as well as patches of algae. The shells are sometimes encased within thick sheets of encrusting sponge (Appendix 7).

The subtidal parts of the sublittoral platform grade imperceptibly into the wide intertidal zone, with the bare sandy areas in both zones containing a similar community of benthic animals that is described below.

5.3.2.4 Intertidal areas

The shallow subtidal and intertidal sandy areas of Useless Inlet support a benthic fauna very similar in species composition and density to that in the basin sediments, but more diverse than that colonising sediments within the nearby sparse Posidonia meadow (Appendix 7). The predominant taxa in the shallow sandy areas were polychaete worms (mainly capitellids, orbinids and oweniids), crustaceans (amphipods and tanaids) and venerid and mytilid bivalve molluscs.

The narrow sandy beaches and emergent limestone benches of Useless Inlet are sparsely colonised, the latter in marked contrast to many parts of Boat Haven Loop where limpets, littorinid molluscs and barnacles are present (Appendix 7). Small stands of mangroves (Avicennia marina) are present at several points along the western shoreline, most 30-50 m in length and occupying north-facing cusps at the southern end of sandy beaches.

There are only three stands of Avicenna along the eastern shoreline north of Clough's Bar. The largest stand colonises the edges of the small tidal channel that drains the large supratidal embayment to the east of the proposed bar and eastern quarry site (Fig. 19). The other stands are smaller (less than 80 m in length) and occupy two beaches to the north that are sheltered from southerly winds by prominent headlands (Appendix 7).

5.3.2.5 Primary pond system

Communities within existing primary pond P0 have been modified as a result of levee construction and subsequent nutrient enrichment (Section 2). Approximately 25% of the sublittoral shallows contain living roots and rhizomes of Halodule uninervis. Another marine angiosperm (Ruppia tuberosa) is common but seasonal in appearance. The shallow areas of Pond P0 are characterised by long and narrow green-brown patches which comprise filamentous green and red algae including Cladophora, Rhizoclonium, Chaetomorpha and Polysiphonia, interspersed with patches of the green alga Polyphysa peniculus. The calcareous green alga Penicillus is common in the deep channel area (Appendix 7).

The benthic animal community in all areas (i.e. deep, bare sandy shallows, and Halodule-covered shallows) is markedly less diverse than comparable areas north of Clough's Bar (Appendix 7). However the abundance and biomass of polychaetes, crustaceans and bivalve molluscs inhabiting the bare areas of the sublittoral platform were up to three times greater than those from the equivalent open portions of Useless Inlet. Similarly, the density and weight of venerid molluscs in the Halodule areas was almost triple that from seagrass areas sampled in Useless Inlet and Boat Haven Loop, although the number of polychaetes and crustaceans were lower (Appendix 7). The overall productivity of ponds P0 and P1 (as measured by these 'standing crop' indices) is high (Appendix 7) and accords with past managed input of phosphorus to promote an increase in primary production and organic silts.

5.4 HUMAN USE OF PROJECT AREA

5.4.1 Aboriginal history

Appendix 4 provides a detailed anthropological description of Useless Inlet and the project area prior to the establishment of solar salt operations in 1963, as well as the results of an archaeological survey of Aboriginal sites. Three shell midden and one (possibly two) rockshelter sites were identified in the project area by this survey. These sites indicate that, as with other midden and rockshelter sites in parts of Edel Land, this region was probably utilised by Aboriginals some 4,000-3,500 years ago (Appendix 4). None of these sites are apparently "ethnographic", (i.e. sites identified by Aboriginal people or documented as having historical significance).

More recent or more substantial Aboriginal campsites (including clusters of huts) have not been found in Edel Land. These appear to have been restricted to eastern parts of Shark Bay, including the northern half of Peron Peninsula where sources of freshwater are not as scarce (Appendix 4).

Aborigines returned to Useless Inlet as labourers following the establishment of the pearling camps on Heirisson Prong in the 1880s. All these camps lie well to the north of the project area (Fig. 18), with the Willi Mia campsite being listed as an ethnographic site (No. P5960) by the Western Australian Museum (Appendix 4). During the height of the Shark Bay pearling industry and the establishment of the Denham townsite (between the late 19th Century and the 1920s), the Aboriginal people became integrated with the Chinese, Malay and British settlers. By the outbreak of World War II, all the pearling camps in Useless Inlet had been abandoned, including two small camps ('Gus's' and 'Henfry's') which were established on opposite shores of the proposed pond area (Fig. 19; D. Hoult, pers. comm.).

5.4.2 History of pearling in Useless Inlet

The history of this industry has been reviewed by Hancock (1989) and in part described by Fry (1988). The following summary account is based on these publications and on additional unpublished information from Dr D.A. Hancock (pers. comm.).

Useless Inlet held some of the richest pearling grounds in Shark Bay and was the main focus of the pearling industry from the early 1870s until the mid 1930s. Old Fisheries Department charts made available by N. McLaughlan (Department of Fisheries) show that the lease areas established under the Shark Bay Pearl Fisheries Act 1892 covered more than 70% of the sublittoral platform north of Clough's Bar, and that other leases were subsequently granted for areas as far as 'Mantle Harbour' which lies to the south of Carratti's Bar (Fig. 21).

The first shipment of pearls from Shark Bay occurred in 1850, and by 1873 legislation was introducted to control the rapid entry of itinerant foreign vessels. Forty boats were issued with licenses and the industry entered a short-lived boom, with the Act providing a catalyst for further expansion. By 1874 'Useless Harbour' [i.e. Useless Inlet] "was fished out and other inlets were being explored" (in Hancock, 1989). It is not clear exactly when the use of the 'English' oyster dredge first became widespread, but its introduction "led to even more indiscriminate and wasteful harvesting, with the potential to damage not only the oysters, but also the environment on which they depended" (Hancock, 1989).

The second 'boom then bust' period occurred during the 1880's; a time when leases were issued to Europeans only, the fleet increased to 92 boats, and fishing was unsupervised and largely uncontrolled. "The main areas were gradually cleared of shell of all age groups and the constant dredging of shallow water banks or 'pick-up areas, denuded them almost entirely of the weed growth so necessary as holding material for oyster spat" (Brownfield; in Hancock, 1989).

Pearl dredging was not a seasonal activity and, subject to weather conditions, was undertaken throughout the year on an opportunistic basis (Hancock, pers. comm.). Recent tests with a single English oyster dredge showed that large sediment plumes can be generated, and its gradual increase in weight (as material is collected) is sufficient to cause it to remove seagrasses (Hancock, pers. comm.).

Between three and six dredges were commonly deployed from a sailing vessel (Fry, 1988), and more could be operated by motor vessels.

Banks depleted of oysters led to the industry being closed in 1891 by proclamation, with Useless Inlet specifically closed by the 1892 Pearl Fishery Act. However, exclusive leases were then issued in 1893 for rotation pick-up shelling in Useless Inlet, and dredging was allowed to resume in deeper waters, but not on the shallow 'pick-up banks'.

Although reserve areas were also created at this time, their intended value was largely defeated by poaching (Hancock, pers. comm.). However, some stability was brought to the industry through the reports and recommendations of W.S. Saville-Kent. Between 1896 and 1925 some 16-30 vessesls worked deep and shallow banks in an orderly fashion. By 1929 an inspector was to comment that "all areas inside Useless Inlet are in first-class condition" (Hancock, 1989). This statement probably refers to oyster numbers and Posidonia regrowth, since Amphibolis (wireweed) was largely considered "detrimental to pearl oyster stocks" (Brownfield; in Hancock, 1989).

Regular Departmental inspections ceased during the 1930's as a consequence of the Depression. Licensing and other administrative duties were subsequently carried out by the Denham police constable. Depressed markets and falling prices led to a further destructive phase.

Several quotations from Hancock's review portray the subsequent events in graphic manner:

- "From then on, no effort was made to conserve stocks or in any way to cultivate leases";
- "worked to the bone";
- "continuous dredging swept them clean of all holding material, and finally the banks were reduced to the condition noted by Saville-Kent some 50 years earlier";
- "It was in Useless Inlet that Brownfield in 1947 observed the serious problem of erosion following dredging ... The process of erosion is more clearly to be seen at the northern end of Useless Inlet, where certain areas present a picture of the stages which lead to the final and barren condition of the leases at the southern end. These stages are set in train by a sand drifting action from the denuded banks which action covers and smothers the oyster-supporting weed left on the more northerly banks".

Although some attempts were made to revive the industry following World War II, it did not recover owing to the larger pearls at Broome, the continuing lack of demand for yellowy mother-o'-pearl, and the continuing poor state of the banks (Brownfield 1947, in Hancock 1989). Following a private survey in 1980, a three year exclusive licence was granted at the northern end of Useless Inlet

Useless Inlet in 1982, and renewed in 1985, finally expiring in 1987. A subsequent application for a new lease in the northernmost part of Useless Inlet is still pending (Fig. 21).

5.4.3 Present population and facilities at Useless Inlet

All site workers of the Solar Salt Project reside in SBS's company town at Useless Loop. The residential population of approximately 150 at Useless Loop has not altered markedly throughout the 1980s, and in 1986 represented just under 30% of the population of the Shark Bay Shire (SPC & CALM, 1988). Some 70 people are directly employed in the salt production and export operations, while a further 25 are employed in full-time, part-time or casual positions that service the Useless Loop community and facilities.

Since Useless Loop is a private township of some 41 houses and other dwellings (including units and singleperson quarters), these and all service and recreational facilities have been provided by SBS (apart from standard Telecom communications). Facilities include the airstrip, mains power and water (from a 150,000 L/day desalinator); store, mess and licensed canteen; roads, playing field, park; a regular garbage service and ambulance; and a recreation centre including a gymnasium. A community hall, medical centre and a purpose-built school have also been provided.

Compared with other mining towns, the Useless Loop population has always consisted of a high proportion of 'permanent' families and a low proportion of itinerant single workers. The stability of the residential population can be related to the following;

- salt production, harvesting and export is a continuous process that can be continued indefinitely (as long as it remains commercially viable);
- pleasant working conditions that are well integrated into a relaxed social environment utilising a variety of nearby natural recreational resources;
- a regular air service which provides mail and fast travel to Denham, Kalbarri, Geraldton and Perth by direct flights three times a week.

Community participation in a variety of recreational and social activities is widespread, including involvement in environmental projects such as the reintroduction of rare mammals from Bernier and Dorre Islands to a quarantined area of Heirisson Prong. The local community is eager to have this area become a UNESCO "Man and the Biosphere" reserve.

The community also assists with company revegetation programmes and conducts greenbelt competitions. A wildlife park for injured animals is also supported by the local community.

5.4.4 Beneficial Uses of Useless Inlet

Bulletin 103 of the EPA ascribes water quality criteria for recognised Beneficial Uses of Marine and Estuarine Waters (EPA, 1981). Those Beneficial Uses (BU) which are considered to apply to Useless Inlet are as follows:

BU2 Harvesting of Aquatic Life (excluding Molluscs) for Food - a commercial beach seine fishery operates within the Inlet. Recreational fishermen also fish from Clough's Bar on either side of the water intake structures. Very little boat-based recreational fishing occurs in Useless Inlet.

BU4 Harvesting of Aquatic Life for non-edible uses - an application was recently made for a pearl-oyster culture lease off the northeastern tip of Heirisson Prong (Fig. 21). This application has been viewed as reflecting the need for access to deeper waters in Shark Bay for accommodating surface longlines for pearl-oyster culture, rather than the need for further sources of oyster stock (Hancock, 1989).

BU7 Maintenance and Preservation of Aquatic Ecosystems - the conservation value of the marine resources of Shark Bay has been widely recognised. The waters of Useless Inlet lie with a trawling exclusion zone and form part of a nursery area for prawns (Fig. 1b; Section 4.4.2.2).

BU13 Recovery of Minerals - the waters of Useless Inlet provide feedstock for the Shark Bay Solar Salt Project.

None of the other 13 Beneficial Uses are considered to apply to the waters of Useless Inlet. Detail on BU13 is provided in previous sections of this report. Further detail on BU2 and BU7 is provided below.

5.4.4.1 BU2: Beach seine fishery

The beaches and nearshore shallows within Useless Inlet (i.e. those south of and between Capes Bellefin and Heirisson) form one of six commercial beach seining areas within Shark Bay that were described during a research study on whiting carried out between September 1965 and February 1969 (Lenanton, 1970). Whiting, particularly the western sand whiting (Sillago schomburgkii forms the mainstay of the Denham beach seine fishery (Section 4.4.2.2 and Appendices 2 and 6).

The results of Lenanton's study indicated that the major cause of decreases in annual whiting catches (despite a marked increase in fishing effort in the years between 1961 and 1967 when additional fishing units from Mandurah visited Shark Bay each winter to target whiting) were caused mainly by overfishing rather than by the closures of Useless Loop and the southernmost part of Useless Inlet for salt production in the 1960s (Lenanton, 1970; Appendix 6).

While Lenanton's (1970) study could not ascertain the precise effect of these closures on the annual whiting catch, the subsequent installaton of Reid's Bar and Carratti's Bar (1968) and then Clough's Bar (1974) were not followed by marked declines in the annual whiting catches landed at Denham. Catches have risen fairly steadily between 1969 and 1985 with fluctuations apparently corresponding to fluctuations in effort (Fig. 20). The subsequent decline in annual whiting catch after the 1985 season reflects self-imposed restrictions (see Section 4.4.2.2). The intent of these restrictions is to harvest larger sized, and thus better priced whiting.

Other data collected from log books issued to the fishermen for the research programme indicated that Useless Inlet may contribute up to 15% of the annual whiting catches taken by all units operating from Denham (Table 7 in Appendix 2). SBS, through WAFIC, requested that the fishermen value a log of catches in designated sections of Useless Inlet in the 1989-90 season. Whilst it is understood this was done, the results are not yet available (R. Lenanton, pers. comm.).

Prior to the initial closure of Useless Inlet, pink snapper used to migrate into a deep channel area near Unknown Island in the southern-most portion of Useless Inlet, and were occasionally taken from this area by seine fishermen (M. Moran and L. Belotti, pers. comms; see also Appendix 3).

5.4.4.2 BU7: Marine resources

Stromatolites or other sedimentary deposits of scientific interest do not occur in Useless Inlet. Pods of dolphins are not common in the southern portion of the open waters of Useless Inlet, i.e. in the proposed pond area. Large numbers of dugongs have never been reported in Useless Inlet, although individuals are occasionally spotted by professional fishermen (Appendix 9). During the recent fish surveys between May and July 1989, no dugongs were observed in Useless Inlet, but were seen in Boat Haven Loop (Appendix 9). Dugongs have never entered the existing primary pond system through the tidal gates.

While the precise extent to which either species of turtle utilise Useless Inlet habitats is not known, turtle nests have never been reported along the beaches of the proposed pond area. Sea snakes are not uncommon in Useless Inlet and Boat Haven Loop. One sea snake was captured in the primary concentration pond during the fish nursery survey.

Compared to equivalent shallow water habitats of Shark Bay, the distribution of seagrasses in Useless Inlet appears to be far more patchy and less diverse (comprising mainly *Amphibolis antarctica*, *Posidonia australis* and possibly some *Halodule*; Walker *et al.*, 1988; Appendix 7).

It is possible that both the patchy distribution of *Posidonia* seagrass on the shallows, and the lack of *Amphibolis* and apparent lack or paucity of *Halodule* and *Halophila* seagrasses along the main basin area of Useless Inlet, might be due to the effects of the widespread pre-war oyster dredging activities (Section 5.4.2; Appendix 7). It is considered that, despite the passage of fifty years, it is likely that the effects of such widespread and long-term dredging operations are still reflected by the pattern of seagrass distribution in Useless Inlet (H. Kirkman, pers. comm.). For example, protracted dredging can have very long term effects on the distribution of Amphibolis and Posidonia (which can be viewed as the 'climax' communities of seagrass meadows). Such activities may have also altered the physical and/or chemical conditions of the sediments in Useless Inlet in such a way that 'pioneering' seagrasses (such as Halodule and Halophila that can re-colonise areas within 6 months) may not have been able to re-establish over the past 50 years (H. Kirkman, per. comm.).

It is therefore also relevant to record that the comparative paucity of Halodule and Halophila in the deepwater areas of Useless Inlet may be related to both the finer sediments and increased turbidity in the basin of Useless Inlet (cf. Boat Haven Loop and Freycinet Reach; Section 5.2.2.4), which in turn may be a long-term consequence of the dredging. Irrespective of the above conjecture it is important to recognise that Useless Inlet is by no means a pristine unmodified natural environment.

Useless Inlet contains a relatively rich fish fauna with the following groups well represented:

- sharks and stingarees;
- benthic fish (e.g. flathead, flounder, catfish, etc.);
- pelagic fish (e.g. garfish, sprat, long tom, etc.);
- seagrass fish (e.g. pipefish, blennies, sea horses, etc.);
- crustaceans (blue manna crab and western king prawn).

Many fish species typical of southwestern estuaries (including the Swan/Canning system) occur in Useless Inlet, such as the Perth herring, roach, hardyheads, sea mullet, long-finned goby and six-lined trumpeter. Detailed information on the distribution and abundance of the fish and crustacean fauna of the project setting is given in Appendices 2 and 3.

Various waterbird surveys carried out at Useless Inlet since 1981 have shown that the existing primary ponds (particularly ponds P1B, P2B and P3B) provide important feeding and roosting areas for large numbers of resident and transequatorial migratory wading birds (Appendix 5). The primary ponds also provide breeding areas for species such as the black-winged stilt, Australian shellduck, Caspian tern and red-capped plover (Appendix 5). These surveys have demonstrated that the primary pond system at Useless Inlet has created a number of habitats of considerable value to migratory waterbirds which are believed not to have utilised this area in such large numbers before the ponds were installed (Appendix 5).

Dugong numbers, migration and behaviour at Shark Bay are currently the focus of some scientific controversy. Although Useless Inlet does not form a focus of any dugong movements in Shark Bay, and although few areas of seagrass suitable for their foraging requirements were found south of the entrance channel, the value of the proposed pond area to dugongs has been appraised for this Review (Appendix 9).

Information on dugong sightings in Useless Inlet was sought from beach seine fishermen, the Denham Fisheries inspector, SBS workers, the 1986-89 Steep Point Ranger and the Department of Conservation and Land Management (Dr R. Prince, CALM). The summarised information was forwarded to Prof. Paul Anderson (a dugong specialist who has visited Shark Bay a number of times), whose opinion was also sought. All the information and views that have been gathered strongly indicate that the proposed pond area is little used by dugongs.

5.4.5 Tourism and Recreation

The causeway across Clough's bar presently provides 4WD vehicles access for tourists and recreational anglers to Steep Point and other attractions west of Useless Inlet, including the northernmost section of the Zuytdorp Cliffs (Fig. 1). The number of tourists crossing Clough's Bar in 1988 was 3,000 and in recent years a ranger based at Steep Point has been employed by Agnew Clough Ltd to oversee their activities (Appendix 9).

Some angling parties fish from Clough's Bar and/or camp beside the western end of this levee on their way to or from Steep Point. Recreational fishing boats up to 7 m long are occasionally launched into Useless Inlet (Appendix 9). These are driven through the proposed pond area and around the tip of Bellfin Prong for fishing in the South Passage and Steep Point areas (Fig. 1).

In contrast to recreational fishing boats, cruising yachts rarely penetrate south of the entrance area of Useless Inlet and instead often utilise the nearby and more picturesque Boat Haven Loop (G. Finlay, pers. comm.). This inlet provides more sheltered and scenic anchorages.

6 PROJECT EFFECTS AND THEIR ASSESSMENT

6.1 INTRODUCTION

The objective of this section of the PER is to assess the environmental significance of the effects associated with the proposal, and to identify areas where management is required to minimise the scale of potential impacts (see flow chart in Summary). As such this section has been structured in the following sequence:

- Effects arising from alterations to the physical, biological and social environment of the project area which will occur during construction and operation of the project are identified in Section 6.2;

- Concerns arising from these effects are outlined and subsequently assessed in Section 6.3 with reference to detail provided in technical appendices;

- Potential issues requiring management are identified in Section 6.4, with their resolution described in Section 7.0 of this report.

6.2 PROJECT EFFECTS

6.2.1 Introduction

The project area is defined as Useless Inlet and Useless Loop. Alterations to the environment of the project area will arise from:

- the construction of a levee across Useless Inlet;

- the operation of the new pond for solar salt production;

- increased bitterns disposal at Useless Loop;

- increased shipping movements at Useless Loop.

Of these alterations, the most visible impact will occur during the construction of the levee across Useless Inlet as a result of quarrying and earthmoving operations. After completion of the levee, operation of the new pond and/or the levee will affect waters:

- in the remaining part of Useless Inlet to the north of the levee;

- within the confines of the new pond area, and;

- within the existing solar salt pond system.

The effects of the alterations on the physical, biological and social environment of the project area are identified chronologically and in geographical sequence:

- construction effects at Useless Inlet;
- post construction effects
  - on Useless Inlet,
  - north of levee,
  - in new pond,
  - in existing pond;
  - on Useless Loop.

6.2.2 Construction effects at Useless Inlet

6.2.2.1 Terrestrial environment

Shoreline topography at each end of the proposed levee will be modified, as will the areas of the proposed eastern and western quarry sites. Much of the modification to the larger eastern quarry site will be masked from view by the dunal ridge that lies between this site and the eastern shoreline of Useless Inlet. Installation of the 6 km access track between Clough's Bar and the western abutment will require slight modification to parts of the topography near the western shoreline to ensure track stability.

The temporary loss of vegetation and habitat will be 15 ha of limestone and dunal country on the eastern side of Useless Inlet and 4 ha of predominantly sand-dune country on the western side (Fig. 5). These sites will be rehabilitated once the levee has been completed except for a small portion of the eastern quarry which will be reserved for maintenance purposes.

6.2.2.2 Marine environment

Construction of the levee will take approximately 14 months (Table 3). Placing and positioning of fill material will cause a plume of carbonate sediment fines to emanate from the end of each groyne as it is advanced across the inlet. The configuration of this plume will vary according to prevailing wind and tide conditions as well as grain size of material being placed in the water. During light winds and neap tides, the plume will be localised in the vicinity of the abutments. During strong winds and spring tides, it is expected to form a narrow plume of carbonate fines dispersing in the direction of the prevailing current.

Current will be strongest during summer (when strong southerlies predominate) and also towards the end of the construction period as the gap between the two groynes narrows, thereby increasing velocities of flow.

Water transparency in the immediate vicinity of these sediment plumes will be reduced as a result of increased turbidity. However the area affected will vary markedly on a daily basis as the result of changing weather and tidal conditions, and gradual extension of the end of the abutments into deeper water offshore. Based on past experience gained during construction of Clough's Bar, the plume is anticipated to be between 1-5 km in length and 10-100 m in width.

6.2.3 Post construction effects at Useless Inlet and Useless Loop

6.2.3.1 Useless Inlet north of levee

The proposed new levee will effectively shorten the length of Useless Inlet by some 6 km. This reduction will affect the remaining open portion of Useless Inlet in the following manner:

- the volume and surface area of the inlet will both be reduced by 18%;

- the length of fetch under southerly wind will be reduced by 6 km (24%).

Since the hydrodynamics of Useless Inlet are largely controlled by tide, wind stress and evaporation (refer Section 5 and Appendix 8) and since these factors are related to length of fetch and volume of tidal prism, it was considered possible that the hydrodynamics of the Inlet may be altered. The scale of this potential effect and its significance were investigated for this project (Appendix 8) and are shown to be minor, with the findings summarised in Section 6.3.3 of this volume.

6.2.3.2 Proposed new pond south of levee

Levee construction and subsequent management of the ponded area for concentration of seawater will modify this area in several ways, as detailed below. The predictions are based on observed effects of present operations in the existing ponds, together with reports to SBS by its consultant algologist (Professor J.S. Davies, University of Florida, Gainsville, USA), and a comparative survey of Boat Haven Loop, which is a neighbouring and unmodified Edel Land Inlet (Fig. 1; Appendix 7).

(a) Physical effects on proposed pond

The new levee and tidal gates will prevent tidal oscillation in the new pond. Low tides will no longer occur. Water level in the pond will remain close to high spring tide level for much of the year (Section 3.1.2). The existing pattern of wave-generation and water mixing by wind stress is unlikely to be modified however, since predominant winds are from southerly quadrants.

Evaporation of seawater and input of fertilizer will increase the concentration and availability of nutrients (primarily phosphate) to marine organisms within the pond area. Nutrient enrichment to increase biological productivity is required for a number of reasons (Sections 2.3 and 3.3). One is to reduce the porosity of the pond floor, with existing coarse and medium-sized carbonate sediments becoming covered and inturbated with finer organic silts (Section 3.3.1). Another reason is to increase growth of planktonic algae and hence turbidity and heat absorption by the water.

A temporary and localised increase in turbidity will result from the dispersal of fines and gradual loss of tidal flushing during the final period of levee construction. Fertilization will increase phytoplankton growth, in turn also reducing water clarity. After fertilisation, the turbidity regime is expected to mimic that in pond PO, a fluctuating event controlled primarily by nutrient recycling, wind mixing and sediment stirring.

Increased turbidity (promoting increased absorption of solar radiation), together with a vast reduction in tidal flushing and consequent dilution, is expected to cause an overall increase of between 1 and 2^{o}C in the average annual water temperature. This will promote increased evaporation which in turn will result in an increase in water salinity. Seawater salinity in the new pond area presently fluctuates between 42 ppt and 49 ppt. Once the pond is operational seawater salinities have been calculated to increase by (approx.) 3 ppt and will fluctuate between 44 ppt and 52 ppt. The consequent effect on salinty in subsequent ponds is given in Table 2.

(b) Biological effects on proposed pond

The present clear water, low nutrient regime in the proposed pond area will be replaced by a more turbid, phosphate-enriched and biologically productive regime similar to that presently occurring within pond PO. Whilst these conditions are favourable for fish and algae, they are not favourable for the small number of Turbinaria corals that occur near the centre of the proposed pond (Appendix 7). This genus of coral is well represented elsewhere in the Edel Land Region as well as in areas outside Shark Bay (Appendix 7).

Although the diversity of the present benthic fauna is expected to decrease as a consequence of the various changes outlined above, the increase in productivity will cause many organisms to proliferate, thereby creating an eventual increase in overall abundance and biomass of benthos (as well as phytoplankton and nekton), as is the case for the existing primary pond PO (Appendix 7).

Existing patchy areas of Posidonia seagrass which occur on parts of the sublittoral platform will probably be eventually replaced by other marine angiosperms (e.g. Halodule and Ruppia) and algae including Cladophora and Polyphsa, all of which are probably more tolerant of the new physical conditions since they are common in pond PO (Section 5.3.2.5; Appendix 7).

The new pond will contain warmer, more protected waters with a large supply of food, benthic and planktonic organisms and a reduced number of predators such as sharks. These conditions are expected to provide an ideal nursery ground for many commercial and non-commercial species of fish, as is already the case for ponds PO and P1 (see Appendices 2 and 3).

Individuals of those species which move or drift into the various bays and inlets of Shark Bay during the larval or juvenile stage of their life cycle, and which subsequenly migrate to oceanic waters in order to spawn and complete their life cycle (e.g. juvenile prawns), will be retained behind the new levee. This effect is appraised further in Section 6.3.11.

Experience with pond P0 shows that larger and more active marine animals including sharks, turtles, dolphins and dugongs, are discouraged from entering the pond by the design and operation of the tidal gate. However, it is recognised that a few marine mammals and turtles could be accidentally retained within the proposed pond area at the time of its closure. Remedial action to prevent this is addressed in Section 7.

(c) Social effects of new pond

The new levee will preclude boating access to fishing grounds used by traditional beach seine fishermen who currently utilise the Inlet. It will also prevent access to open waters of Useless Inlet by recreational fishermen, who sometimes camp and launch boats at Clough's Bar. It was further realised that the ability of the new pond to retain prawns (as described above) might adversely affect the commercial prawn fishery.

6.2.3.3 Post-construction effects on existing pond system

There will be no change to water levels or inundation of extra land downstream as a result of the new pond. Minor changes are expected to occur in the existing environment and biota in the present pond system which reflect adjustments to gradual elevation in salinities over a two to three year period following completion of the new levee (Table 2).

The most marked of these changes is expected to occur to the planktonic and fish communities in pond P1B, where the numbers of brine shrimp and associated planktonic algae and invertebrates are expected to rise whilst the diversity of fish species will fall (Appendix 3). Thus pond P1B may come to mimic the present situation in pond P2. The present brine shrimp community in the latter pond and in P3A is predicted (and required) to continue to dominate, since the overall increases in salinity (Table 2) do not represent the upper limit of the salinity tolerance of this community (Sections 2.3 and 5.3.1.6).

The predicted rise in the salinities within pond P1A and pond P0 (Table 2) will cause the former pond to eventually reflect the present situation in pond P1B, whilst parts of the southern half of P0 are expected to eventually resemble conditions in P1A, particularly in the summer months. Thus the present diversity and abundance of both juvenile and adult fish in P0 should not alter markedly, and pond P1A will also continue to support a variety and large number of juvenile and adult fish, particularly during the winter months (see Appendix 3).

Waterfowl usage

Of all the aquatic areas that are utilised by waterbirds in Useless Inlet, the southernmost areas (i.e. ponds P1B, P2 and P3A) are considered the most important in terms of waterbird usage (Section 5.4.3.2; Appendix 5). The above effects show that the features which make these areas an important waterfowl refuge (particularly those in pond P2) will not be reduced. In fact the predicted shift of the present regime in pond P1B towards that occuring within P2 is expected to benefit waterfowl usage by providing an increase in preferred habitat (Appendix 5).

6.2.3.4 Post-construction effects at Useless Loop

Two effects will arise at Useless Loop as salt harvesting and export start increasing. One is the increased production and disposal of waste salts (bitterns), the other involves the increase in shipping movements.

Bitterns disposal

Production and disposal of bitterns has been described in Secton 2.2.3. The gradual rise in salt production over a three year period following levee completion will be followed by a commensurate increase in the mass and volume of bitterns to be disposed (Table 1).

As described in Section 2.2.3, the bitterns drainage area at Useless Loop was modified and expanded in early 1989. The expansion comprises an additional western and central drainage area as well as the original eastern area that lies alongside the main Useless Loop levee (Fig. 2). This expansion is sufficient to deal with the increased production of bitterns arising from the proposed project.

Shipping movements

Shipping movements are expected to increase from 33 to some 60 vessels per year. This increase in numbers will double the risk of accidential oil spillage and the amount of ballast water discharged at Useless Loop. The potential for undesirable foreign biota to be introduced via this increased discharge is recognised.

6.3 IMPACT ASSESSMENT

6.3.1 <u>Introduction</u>

A substantial effort has been made to identify all concerns and potential issues associated with the proposed project. A scoping exercise was conducted at the beginning of the study in March 1989 and discussed with appropriate officers of the EPA and Fisheries Department. A detailed preliminary appraisal document was subsequently produced from a series of field studies and a comprehensive review of available literature including the Shark Bay Region Plan (1988) and submissions to that plan. This document was submitted to the EPA, Shark Bay Shire Council, WAFIC, Fisheries Department, and other State agencies for informal comment at the end of 1989. Additional studies and field investigations have since been undertaken to collect information necessary to resolve all the major concerns identified in follow up discussions.

As a result of the staged approach adopted for this study and the responses received from state and local authorities, the following concerns and potential impacts were identified, and are assessed in subsequent sections:

- The effect of localised increase in water turbidity on adjacent biotic assemblages to the north of the levee during the construction phase.
- The potential impact of earthworks on conservation values of Edel Land Province.
- The effect of the completed levee on the hydrodynamics of the remaining open part of Useless Inlet.
- The effect following unlikely structural damage to the levee (e.g. resultant leakage of nutrient enriched waters into the open waters of Useless Inlet).
- The potential impact of increased bitterns drainage on adjacent waters and biota (Section 6.3.7).
- The potential for introducing undesirable foreign biota via the discharge of ballast water to Shark Bay.
- The potential for a diesel fuel spill arising from a shipping accident.
- The potential for the new pond to hinder public access to Useless Inlet and adjacent areas.
- The potential impact of the loss of Useless Inlet waters on the ecological and conservation value of Shark Bay.
- The potential impact of the new pond on commercial fisheries of Shark Bay.

These concerns are appraised below to provide an assessment of their scale and significance. A number of specific investigations were conducted to resolve some of the above concerns and their results are presented in Appendices contained in Volume 2 of this PER. A summary of these appraisals is presented here. For further detail the reader is directed to the relevant appendix.

6.3.2 Turbidity effects during construction phase

The only biotic assemblage potentially at risk from the plumes of carbonate sediment which will emanate from the levee abutments during construction is the *Posidonia australis* seagrass community which colonises the shallow sublittoral sills of the Inlet. Few (if any) seagrass patches occur in the deep basin area between the proposed levee and the inner sandy lobes of the entrance (Section 5.3.2.2).

The risk of a significant adverse impact to the shallow sublittoral Posidonia seagrass community to the north of the proposed levee is considered to be minimal for a number of reasons:

- The area of seafloor affected by the sediment plume will vary markedly on a daily basis as a result of variations in prevailing wind and tide conditions and the regular seaward progression of the end of the levee groynes. Hence adjacent seagrass assemblages will only be affected temporarily, infrequently and over a short term.

- There are several examples along the West Australian coastline where construction of limestone rubble mound levees and groyne across similar seagrass (Posidonia) meadows has not resulted in measurable deleterious impact on these meadows (e.g. Hillary's Marina, Garden Island Causeway and the Geraldton foreshore development). There are also examples of seagrass growing within the turbid discharge plume from a lime sands washing plant in Cockburn Sound.

- Although seagrasses have been shown to be susceptible to the long-term effects of reduced light (e.g. Cambridge et al., 1986; Neverauskas, 1988; Gorden et al., 1990), a recent study on Posidonia sinuosa in Princess Royal Harbour found that this species displayed a high, though incomplete, recovery of the seagrass leaf canopy following light reduction of up to 99% incident light for over 5 months. This degree of shading also lowered leaf productivity but, as with the canopy, productivity also partially recovered (Gordon et al., 1990). Intermittent periods of turbidity arising from the construction of the levee is therefore expected to influence the density of the leaf canopy and possibly lower productivity. However, such temporary turbidity is much less severe than 99% light reduction, and it is considered highly unlikely to result in irreversible damage to the integrity of the seagrass meadows.

- There are no reports in the literature of seagrass dieback as a result of temporary water turbidity caused by rubble fill groyne construction.

- Inspection of the shallow sublittoral platform and central sand spits immediately to the north of Clough's Bar indicates that the patchy seagrass communities are in good condition (Appendix 7). Analysis of pre- and post-construction aerial photographs of this Bar confirm that there has been no change to the shape or extent of seagrass patches adjacent to its north side.

- The seagrasses now present in Useless Inlet have survived major and long-term disturbance and increased water turbidity caused by pearl oyster dredging prior to World War II.

6.3.3 Edel Land conservation values

The size of the proposed borrow pits and route of the temporary access road will not adversely affect present conservation values of the Edel Land Province. No species have been identified by this or previous studies as being dependent on the proposed quarry sites.

The low shrub vegetation which occurs within both quarry sites is widely distributed throughout the Edel Land region (Section 5.3.2), and the total 19 ha area of temporary loss represents less than 0.01% of that comprising the Intermediate Botanical Zone of Edel Land (cf Figs. 5 & 15).

It should also be noted that although the Edel Land zone supports three species of endemic lizard worthy of conservation status (Section 4.4.6.2), these are not considered endangered and have been collected at sites many kilometres to the south of the quarry sites (Storr & Harold, 1978). Thus terrestrial organisms within the quarry sites are highly unlikely to be rare and restricted to the dunal ridges alongside Useless Inlet.

The Aboriginal shell midden and rockshelter sites that have been identified near the eastern shore of the proposed pond (Section 5.4.1) will not be disturbed by the proposed eastern quarry or levee construction operations, since these lie to the west of the quarry and to the south of the proposed levee (Fig. 19). The 6 km access track on the western shoreline will be aligned to avoid crossing the two open midden sites that have been identified on Bellefin Prong (Fig. 19). The precise location of a small pearler's camp ('Henfry's) which was established on the western side of the proposed pond and would lie near the route of the access track has not been determined, since no signs or artefacts from this camp site have yet been found.

6.3.4 Effect of new levee on hydrodynamics of Useless Inlet

A desk study of potential effects of the bar was undertaken using standard principles of hydrodynamics and review of pertinent literature (Appendix 8). The hydrodynamics of Useless Inlet are summarised in Section 5.2.

The study shows that circulation within Useless Inlet is tidally-dominated, and influenced by buoyancy-driven flow and wind stress. Shortening the Inlet by 6 km at the southern end will cause a similar reduction in both the overall volume of the Inlet and that which is exchanged over a tidal cycle, and therefore the minimum residence time will remain essentially unchanged (Appendix 8).

This means that the existing salinity and temperature gradients (which produce buoyancy-driven flow within Useless Inlet) will also remain unchanged, with the shorter Inlet having a reduced upper limit of its salinity range compared with that presently occuring at Clough's Bar (i.e. approximately two ppt lower at the new levee; see Fig. 13). The new upper limit may subsequently move to a slightly higher value (some 1 ppt), an increase insufficient to produce significant alteration to the circulation pattern (Appendix 8).

Potentially significant changes to the existing pattern of circulation can be identified by comparing the 'before' and 'after' ratios of the various forces which control and influence circulation and residence time within Useless Inlet (Appendix 8). These forces comprise tidal flow, buoyancy-driven flow (from salinity/temperature gradients), wind-stress and the effects of the earth's rotation, and for comparison can be scaled to both tidal flow and Inlet length. Since the scaled ratios of these forces will remain essentially unaltered, it is highly unlikely that the new levee will promote a marked or noticeable change in the present circulation pattern of the remaining part of the Inlet (Appendix 8).

Overall wind-wave generation, mixing and other influences of wind stress on circulation will not be changed. Only a specific change involving wind 'set' can be expected (Appendix 8). This would occur in summer, when southerly winds are blowing along the full length of the Inlet. In this case, the reduction in fetch caused by the new levee could lead to a potential maximum 5 cm drop in the amount of water that is 'piled up' (wind set) at the northern end of the Inlet (assuming no water is flowing in or out of the entrance channel; see Appendix 8).

The main entrance channel to Useless Inlet is 8 km long, 1.5 km wide and some 10 m deep, with a maximum tidal flow of approximately 0.6 m/s (Section 5.2; Appendix 8). Shortening the Inlet by 6 km at its southern end will reduce its area and volume by 18%. Tidal amplitude and period will not be altered. However there will be a reduction in average maximum tidal velocity as a result of the decreased volume (Appendix 8).

The precise overall reduction in current speed at any one time will depend on the roles of the tidal flow, buoyancy-driven flow and wind stress. Reducing tide-induced velocity could, under certain circumstances, lead to sedimentation within the entrance channel. However, such sedimentation can occur only if sufficient material is transported by tidal flow or wave action from areas to the north or south, but where current velocities are much lower.

In Useless Inlet, current velocities inside the channel are greater than velocities in the open water bodies to the north and south of the barrier sill. Hence it is not likely that sedimentation will occur within the channel, and that any detectable shallowing (e.g. from 10 m to 9 m deep) would take several decades to occur Appendix 8).

Even if such a change were to eventually occur, the environmental consequence of such a change will be insignificant because the essentially bare habitat on the present floor of the channel entrance is likely to remain the same.

6.3.5 Release of nutrient enriched waters

Should the new levee be breached during an extreme cyclonic event a release of nutrient enriched waters into the Inlet could occur. The probability of such an occurence is particularly low given the engineering design specifications adopted for the levee (Section 3.2.1). It is also not in the proponent's interest to risk losing the enriched waters of the new pond.

However, in the unlikely event of a breach occurring, the effect will be movement of ponded water through the breach into Useless Inlet, coupled with a temporary sediment plume emanating from the edges of the breach. This will be followed by a gradual mixing and loss of the ponded water by tidal flushing until levee repair. Obviously it will be in SBS's interest to repair the levee as quickly as possible in order to regain full salt production. The release of ponded water would provide a temporary and short-lived pulse of nutrient availability (principally phosphate) to Useless Inlet.

The potential impact of such a nutrient pulse can be appraised by considering a hypothetical 'worst-case' event. This would involve a major breach in early spring, immediately after the proposed pond had received winter doses of fertiliser to promote the highest desirable orthophosphate concentration of 60 ug/L (i.e. 60 parts per billion).

This level is some three times that of oceanic seawater (e.g. 20 ug/L) and also higher than that recorded for the saltier and nutrient deficient waters of inner Shark Bay. In the portion of Useless Inlet north of the proposed bar, salinites range from 40-45 ppt, and it can be assumed that the concentration of orthophosphate ('available' P) ranges between 2 and 6 ug/L (derived from Smith & Atkinson, 1983).

At most the breach will only occur for a few metres below sea level. Two effects are likely to occur. Firstly, water levels will balance. Secondly the more dense and enriched water within the pond will be retained behind the sill of the breach. Thus it is highly unlikely that more than 50% of the pond water would mix with outside water, even in a worst case scenario. Nonetheless, assuming that the breach is large enough for all the ponded water to immediately escape (a most unrealistic scenario), buoyancy-driven flow in Useless Inlet would mix this water to produce a concentration of less than 20 ug/L within 24 hours. Further dilutions would then occur exponentially by tidal flushing, with falls to 10 ug/L and then 8 ug/L occuring after 6 and 9 ebb/flood cycles respectively (Appendix 8). Such a fall is too rapid to enable persistent algal blooms to occur within Useless Inlet. Furthermore, even if a bloom occurred it would be transient and most unlikely to cause discernible adverse impact on the biota of the inlet.

Hence such an event could not cause nuisance levels of eutrophication of the open part of Useless Inlet or result in adverse impact. It is also worth noting that a storm of the type required to breach the levee will probably cause more physical damage to the Inlet ecosystem than the release of imponded waters.

6.3.6 Bitterns discharge

As described in Section 6.2.3.4, production of bitterns will increase by 85% over a three year period following levee completion, and this waste fluid will be disposed via three drainage areas which lie behind the Useless Loop levee.

Aerial photography from SBS's present monitoring programme shows that there has been minimal discernible effect on the seagrass meadows that occur within and beyond the lease area on the outer side of the main Useless Loop levee (Section 2.2.3). Data from a recent field study also show that benthic animals sampled from subtidal sands in front of the levee are as diverse and abundant as those in other areas of Freycinet Reach and Useless Inlet (Appendix 7).

The lack of discernible harmful impacts on the marine ecosystem at Useless Loop is similar to the experience of other solar salt fields that have been operating in the North West (e.g. Dampier Salt, 1981); and where bitterns have been discharged directly into tidal creeks or coastal bays.

Thus the probability of adverse impacts arising from increased bitterns discharge volume is considered to be low. However, the concern is recognised and the proponent will continue to undertake monitoring.

6.3.7 Ballast water

It is impossible to determine the risk of introducing foreign biota into Shark bay waters as a result of this project. No monitoring of ballast water discharges into the Bay over the past 25 years has been undertaken and hence the potential for introductions is not clear.

However, in contrast to other Australian ports where inbound ships often arrive in ballast from the Americas, the Middle East or Japan, inbound shipping at Useless Loop arrives mainly from nearby ports in southeast Asia; typically from Indonesia, Malaysia and Singapore (Section 2.2.4). The risk of accidental importation of unwanted marine organisms from these nearby Indian Ocean parts is therefore much lower, particularly since the ballast water that is pumped out is carried in special tanks and not in the holds or bilges where sediments collect and the chance of foreign biota surviving is greater.

Ballast water monitoring programmes at various ports in Australia and overseas are now being considered to help ensure that contaminated ballast water is not discharged by inbound vessels, and to provide a more reliable and comprehensive database regarding the origin of undesirable biota. A voluntary code for the handling and discharge of ballast water has also been recently implemented, in which in-bound ships can elect to:

(a) carry 'cleansed' ballast water from their part of departure;

(b) re-ballast at sea when nearing Australia; or

(c) retain ballast water when in an Australian part.

The configuration of the shiploader at Slope Island is such that it is necesssary to deballast ship during loading. As the source of the ships is unlikely to change it is reasonable to assume that the risk of unwanted organisms arriving via ballast water at Useless Loop will remain low. Nevertheless, the possible need for routine ballast water monitoring at Useless Loop is recognised (Section 7).

6.3.8 Oil spills

The only way an oil spill can occur is through an accident to an inbound or outbound vessel, because there are no fueling facilities for oceangoing vessels at Useless Loop. Thus the risk of an accidental fuel leakage at the ship loader is remote, since this would have to involve very serious damage to the ship.

There are few rocky reefs subjected to high swell or wave energies in the southern half of Shark Bay. Most of the seafloor is flat and sandy. The chance of a salt carrier grounding and subsequently breaking up and spilling fuel inside the Bay is therefore very low, particularly since the fuel tanks would need to be ruptured to enable a spill to occur.

In the event of a salt carrier (or any cargo ship) undergoing a fuel spill in Shark Bay or at Useless Loop, the following actions are presently required to be taken:

- notification of the Carnarvon Harbour Master (if the ship is underway, the Harbour Master will already be on board ship as the pilot; if the ship is a salt carrier being loaded, he will be at Useless Loop; if the ship has already been piloted out of Shark Bay, he will either be in Carnarvon or at Perth);

- the Carnarvon Harbour Master will then contact the Department of Marine and Harbours at Perth. Their representative on the State Oil Pollution Combat Committee will mobilise equipment and personnel as per the National Plan (WA Supplement) from Perth (by air charter) and Geraldton (by air charter and road) to Useless Loop or Carnarvon, which ever is closer to the spill;

- a Marine and Harbours representative will also travel to the site and assume responsibility for combating the fuel spill, since this department is responsible for the Carnarvon Port Authority area, which includes Useless Loop;

- the clean up operation would be co-ordinated by an OSC ('On-Site Co-ordinator' - in this case the Marine and Harbours representative on the State Combat Committee);

- if the spill occurred near Useless Loop, the OSC would require SBS resources, particularly boats and personnel for deploying the containment booms. The action priorities are to (1) contain the fuel; (2) protect environmentally sensitive areas; and (3) protect commercial interests;
- at the completion of the fuel spill clean up, the shipper would be billed for the costs.

With these points in mind, it is recognised that in the event of a fuel spill near Useless Loop, the efficiency of the following actions:

- on-site communication,
- co-ordination and deployment of boats and equipment, and
- protection of environmentally sensitive areas,

could be improved by implementing a fully-developed oil spill contingency action plan (OSCP) that specifically addresses the swinging and berthing area at Useless Loop and the nearby Denham Channel.

6.3.9 Public access

While public 4WD access to existing recreational and tourist attractions via the Clough's Bar causeway will not be interrupted during the construction of the new levee, its completion will remove boating access to the open waters of Useless Inlet via existing routes. However, continued 4WD access to open water shoreline angling and the occasional beach launching of recreational fishing boats (Section 5.4.5) could continue if the temporary haulage track to be located on the western shoreline (between Clough's Bar and the new levee; Fig. 5) is not rehabilitated but left open after bar completion.

This route would allow boats to be beach launched at the western side of the new levee and provide access to the causeway along the new levee, thereby permitting public vehicles along most of the new levee for angling and sightseeing activities. Vehicular access will be blocked at the point where the tidal gate is located, i.e. on the eastern portion of the new levee (Fig. 3). Vehicular access will not be permitted down the eastern shore of the new pond for both safety and operational reasons. Pedestrian access will be permitted to the eastern shore.

Therefore access to open waters of Useless Inlet for recreational fishing need not be impeded. SBS is amenable to providing improved amenity and access across their leases where practical. However this option is dependent on advice from CALM, and SBS will be happy to facilitate this matter if requested. The present responsibility is to rehabilitate the temporary access track.

6.3.10 Ecologic and conservation values of area of proposed pond

The proposed pond will not reduce the conservation value of Shark Bay nor will it adversely affect the Bay's marine ecosystem. The impact of the pond will be to modify an extremely small portion of available marine habitat. The 26 km^2 area of the pond comprises 18% of the existing open waters of Useless Inlet, and 0.16% of the 15,780 km^2 of Shark Bay's water area.

Comparative surveys of the benthos and fish life within Useless Inlet, Freycinet Reach and Boat Haven Loop have been conducted to determine the relative ecological value of the proposed pond area. These surveys are detailed in Appendix 3 and 7. In summary they indicate that biological productivity (as appraised by standing crop indices) in the proposed pond area is no greater, and in some instances is less than, that of comparable habitats elsewhere in the study area.

None of the marine organisms which occur within the pond area (see Section 5) are either rare or restricted in distribution. Whilst the pond does provide nursery area for juvenile marine biota, particularly fish and prawns, the actual habitats within the proposed pond area are no more biologically productive than other comparable habitats of Useless Inlet or other inlets of the Edel Land Province.

In addition, the proposed pond area does not contain any of the following marine conservation resources of the region:

- stromatolites or other sedimentary deposits (such as Fragum coquina) of scientific. or cultural significance.
- mangrove stands or dugong foraging grounds (Amphibolis or Halodule seagrass beds).

The use made of the proposed pond area by dugongs appears to be negligible (Appendix 9), but there is little pertinent aerial survey data available to confirm this. It is therefore acknowledged that an aerial survey will be required.

6.3.11 Commercial fishing value of proposed pond

The proposed pond does not provide either commercial prawn trawling grounds, trap or line fishing grounds or oyster culture lease areas. It does not provide important nursery or breeding grounds for pink snapper, brown tiger prawns or scallops. However the shallow sublittoral edges of the pond area do contribute to or lie within the following:

- part of the fishable waters presently utilised by some of the licensed beach seine fishermen operating out of Denham (Fig 16);
- the nursery requirements of some of the fish species utilised by this modest but traditional industry;
- the nursery requirements of western king prawns which are subsequently taken as adults from the trawling ground in Denham Sound by the Carnarvon prawn fishery (Figs. 16 and 17).

The impact of the proposed pond on both these fisheries is appraised below based on the result of intensive fish surveys presented in Appendices 2 and 3.

(a) King prawn fishery

Edel Land inlets provide part of the nursery area for those juvenile western king prawns which are subsequently caught as adults on the Denham Sound trawling ground (Section 4.4.2.2). This ground has yielded a varying annual catch of western king prawns that has averaged some 170 tonnes over the past eight years, and represents some 15% of the annual total Shark Bay catch in the same period (Appendix 3).

King prawns cannot complete their life cycle in the shallow metahaline parts of Shark Bay and must spawn in the deep waters of the trawling grounds (Fig. 16). Their planktonic larvae are dispersed back to the metahaline embayments to the south.

The shallow nursery area of the proposed pond represents less than 1% of the total nursery area for western king prawns which are subsequently caught in Denham Sound. A survey was undertaken to investigate the potential effects of the new pond on this annual catch (Appendix 3). Data from this survey showed that the number of juvenile western king prawns in the proposed pond area in summer was no higher than at other sites in Useless Inlet, and that juveniles of these prawns were common in all other sites sampled along Freycinet Reach and inside Boat Haven Loop, another Edel Inlet (Appendix 3).

Densities of western king prawns in the existing pond system were much lower than in the rest of Useless Inlet. The drop in density immediately behind Clough's Bar can be related to the very small size (less than 14 m width) and operational characteristics of the tidal gates through which the larval prawns must pass to become trapped inside the ponds (Appendix 3).

The densities recorded in this survey indicate that future reduction to the annual Denham Sound catch caused by 'trapping' can be no more than 6.3% in the worst theoretical case. Such a reduction is far less than the annual fluctuations in the Denham Sound catch (Section 5.4), and represents less than 1% of the total catch of western king prawns landed at Carnarvon. Moreover, the assumptions listed below and used for this estimation are highly conservative:

- density of larval and postlarval king prawns drifting into the proposed pond area will not be reduced by the presence of the levee wall;
- king prawn density throughout the proposed pond (including the deep basin area) will be as high as that recorded from the favoured shallow bank habitat (which represents only 43% of the total area);

- king prawn density throughout the remainder of Useless inlet and the other Edel Land and Freycinet areas is taken as zero in areas greater than 2 m; and

- density is no more than the lowest recorded outside the ponds over the preferred shallow areas (i.e. a value less than 30% of that in the proposed pond; Appendix 3).

A more realistic prediction can be made if the deep part of the pond area is also ignored and assuming that the entrance of prawns into the new pond will be halved whilst the average density of prawns in the rest of the Edel/Freycinet nursery area is 50% of that recorded in Useless Inlet (Appendix 3). These are not unreasonable assumptions which indicate a 0.8% reduction, a figure representing a potential reduction of less than 0.12% of the total western king prawn catch from Shark Bay (i.e. some 1,800 kg of landed prawn worth approximately $20,000 on today's market).

Therefore it is considered most unlikely that the prawn fishery will be adversely affected to a significant level.

(b) Beach seine fishery

Surveys of the scale fish in Useless Inlet and nearby areas show that the area of the proposed pond does not form a regionally-distinct or unusually substantial nursery area compared to other similar areas within Useless Inlet, Freycinet Reach and Boat Haven Loop. They also show that large numbers of both the juvenile and adults of the same commercially important fishes occur in the existing primary ponds, as well as two species of bait fish (Appendices 2 and 3).

The fish distribution surveys and the commercial fish down exercise to estimate in-pond population sizes indicate that stocks within the existing primary pond have been enhanced through increased primary production owing to the managed nutrient regime of the ponds, rather than because they have simply escaped the effects of commercial fishing (Appendix 3).

These surveys also demonstrated that the existing primary ponds contain stocks of fish whose quality and market value are no different to those of open waters (Appendix 2).

Since post-larval juveniles of whiting and other commercial species are supported by the existing primary ponds P0 and P1, conversion of the proposed pond area into a primary salt pond is not expected to reduce the value or amount of habitat and food utilised by these fish. The new pond is therefore expected to continue to support juveniles and adults of existing commercial species (Appendix 3).

The results of the fish surveys imply that fish either do not escape from these ponds and/or have no desire to do so, and that existing fish production in the proposed pond area may be enhanced rather than degraded following its conversion to a primary concentration pond (Appendices 2 and 3).

The commercial fishing exercise within primary ponds P0 and P1A has demonstrated the viability of commercial seining operations within a primary concentration pond, and so while the new pond could act as a 'trap' for those juvenile fishes which move towards more saline and sheltered areas, this resource need not be lost to the beach seine fishery.

Substantial catches of high quality whiting were taken during the commercial fish down exercise (Appendix 2), and a very high level of whiting recruitment occurred in the existing pond system in 1990 (Appendix 3). However, it is recognised that the existing database is too limited to determine whether sufficient in-pond spawning and recruitment of whiting occur each year to sustain an intensive level of harvesting based solely on these species.

On the other hand, the surveys do show that the existing ponds also contain large amounts of other commercial species including bream, tailor, mullet and clupeid bait species. Thus a controlled harvesting programme based on all of these species should be both sustainable and commercially attractive to local fishermen, and at the same time would yield valuable data for refining and selectively improving future catches (Appendix 3).

Therefore the potential exists to not only maintain the size of the commercial fish stocks of the species traditionally caught by beach seine fishermen but also to enhance the fishery by increasing both the size of the stocks and the range of fish caught. For this to happen however, traditional fishermen of the Inlet would need to be granted access to the new pond.

If access is not granted, the loss to the fishery is estimated to be $21,000 based on the premise that the present shores of the pond area provide some 3% of total whiting catch which is worth some $700,000 per annum. Given that increased salt production will generate an extra A$10 m worth of export earnings per annum, the potential loss to the fishery is disproportionately small compared with the benefits that will be accrued to the larger community.

Furthermore, if a management plan can be implemented which incorporates commercial harvesting of fish from areas behind the new levee without affecting efficient salt production, there would be no affect on the fishery.

6.4 POTENTIAL IMPACTS REQUIRING MANAGEMENT

Many of the effects and concerns assessed in the preceeding sections will either not eventuate or not cause significant adverse impact on the Shark Bay ecosystem or community. Some however, will require management to ensure potential impacts are minimised. These are as follows:

- quarry sites (Sections 6.2.2.1 and 6.3.3);
- marine mammals and turtles within new pond [Section 6.2.3.2 (b)];

- bitterns disposal (Section 6.3.6);
- ballast water discharge (Section 6.3.7);
- risk of oil spill (Section 6.3.8);
- public access (Section 6.3.9);
- dugong usage (Section 6.3.10);
- commercial fisheries (Section 6.3.11).

The proposed management actions for these potential impacts are outlined in the following section of this report.

7 ENVIRONMENTAL MANAGEMENT PROGRAMME

7.1 INTRODUCTION

The previous section of this report identified several potential impacts which require management to minimise their imposition on the environment. The following Environmental Management Programme (EMP) is proposed. The objectives of the EMP are to:

- prevent or minimise adverse impacts on the environment from the proposed project; and

- validate important predictions made during the assessment of this project.

The first objective will require management actions, the second requires monitoring actions. These are described in Sections 7.2 and 7.3 respectively, with a summary of management commitments provided in Section 7.4. The scope of the proposed programme varies from the provision of assistance to Authorities to implementing or continuing monitoring programmes.

The following list of management and monitoring actions has been proposed by Agnew Clough Ltd, which manages the solar salt project at Shark Bay on behalf of the joint venturers, and in accordance with the terms and provisions of the Shark Bay Solar Salt Industry Agreement Act 1983 (see Secton 1.3).

7.2 PROPOSED MANAGEMENT ACTIONS

7.2.1 Rehabilitation of quarry sites and access track

Apart from a 1-2 ha portion of the eastern quarry site which will be retained for maintenance purposes, both quarry sites will be rehabilitated using the methods adopted by SBS at numerous sites within its lease area. These methods comprise:

- modification of quarry topography to blend into landscape;
- contour trenching where appropriate;
- spreading of stockpiled top soil and local vegetation;
- appropriate placement of brush matting.

These techniques have proven successful in the past. Based on past experience of this arid region, regrowth of natural vegetation is expected to commence within three years of average rainfall and complete rehabilitation is anticipated within 10-15 years.

The access track along the western shore of the proposed new pond will either be rehabilitated in a similar manner or it may be left in a useable form, depending on Local and State Authority preference.

7.2.2 Public access

The Clough's Bar causeway provides the most reasonable access to Steep Point and other tourist attractions west of Useless Inlet. This Bar will remain open to public traffic during and after construction of the new levee.

The cleared area by the foreshore on the western end of Clough Bar is occasionally used by tourists and anglers for overnight camping and the launching of boats which are then used to fish the Steep Point and South Passage areas. Advice will be sought from CALM as to what facilities should be provided.

SBS is prepared to continue to provide access but recognises this must be consistent with Government strategies and policies. The western access road to the new bar could be left open to traffic if required. Should this be agreed SBS will then allow public access along the western and middle sections of the new levee. No recreational boat fishing or netting will be permitted in the ponds. Shoreline angling will however be permitted.

7.2.3 Prevention of trapping of marine mammals and turtles

At the time of the levee closure an inspection will be made by boat and aircraft to ensure no marine mammals or turtles remain inside the new pond area. Advice and assistance will be sought from CALM regarding any necessary shepherding or transfer techniques.

7.2.4 Ballast water discharge

If required SBS will assist the Commonwealth Government in the development of any ballast water monitoring programme that covers the Shark Bay area.

7.2.5 Oil spill contingency plan

If required SBS will liaise with the Department of Marine and Harbours and any other State agency to develop and implement an oil spil contingency plan for the Useless Loop area.

7.2.6 Beach seine fishery

It is recognised that a controversial impact of the proposal is the right to exclude access to a small part of the traditional fishing grounds currently worked by the Denham beach seine fishermen.

In the past, and in accordance with the terms of the Shark Bay Solar Salt Industry Agreement Act, 1983, SBS has utilised ponded areas exclusively for salt production. The reason for this is that careful biological husbandry of the ponds is necessary to ensure that a precise sequence of plants and animals occur in the various stages of the pond system (refer Section 2.3).

However, studies of the fish stocks in the existing ponds conducted for this project have shown not only that the ponds support a wide range of quality commercial fish, but also that these fish can be periodically removed without compromising the efficiency of salt production. In addition fish stocks within the ponds may have been enhanced as a result of the managed nutrient application regime implemented by SBS as part of their husbandry of the pond system.

Therefore the opportunity now exists to either or both:

(i) allow access to the fish within the ponds for traditional fishermen of the area; and/or

(ii) conduct research aimed at improving the yield of commercial species in the ponds.

In recognition of the recent findings, SBS is prepared to accommodate both commercial fishing and research activities within the existing and proposed new pond areas. However, neither activity can be allowed to jeopardise the efficiency of salt production which must remain the primary objective of pond management. Therefore in-pond fishing and/or experimentation will need to be regulated and SBS must retain the right to control access, the amount or frequency of fertilizer application and water flux through the primary pond system.

SBS is therefore prepared to:

(i) develop a fishing programme which may permit commercial beach seine fishing activities within the primary pond system, in association with the WA Department of Fisheries and WAFIC; and/or

(ii) contribute to research programmes developed by the Fisheries Department to monitor various aspects of the pond systems, for the purposes of aquaculture or fisheries enhancement.

Furthermore, while the Agreement Act legally inhibits application of the Fisheries Act to the ponded waters, SBS is prepared to accept Fisheries Department regulations of commercial fishing activities within the pond system.

SBS therefore proposes to liaise with the WA Department of Fisheries and WAFIC in an effort to develop a pond management programme whereby local seine fishermen can obtain regulated access to the fish stocks in the pond system, and if required, the Fisheries Department can obtain research data into the potential for fish aquaculture in Shark Bay.

7.3 PROPOSED MONITORING ACTIONS

Monitoring is proposed to determine the accuracy of predictions regarding effects which have the potential for adverse impact. Such predictions made in this document are:

(i) the probability of discernible adverse impacts arising from increased bitterns disposal is considered to be low;

(ii) the use made of the proposed pond area by dugongs appears to be very limited;

(iii) it is considered unlikely that the commercial beach seine fishery will be adversely affected to a significant level if access to pond waters is denied.

Details of the monitoring programmes proposed to substantiate these predictions are outlined below.

7.3.1 Bitterns Discharge

The present monitoring programme will continue. This includes colour aerial photography of seagrass cover in the Useless Loop area. The density and ionic composition of the groundwater adjacent to the Useless Loop levee will be used to provide a benchmark to monitor any change in the dilution pattern of bittern leaching through the shoreline at the intertidal area.

7.3.2 Dugong use of inlet

The conclusion regarding the very limited dugong usage of the proposed pond area is based on local observations and opinion obtained from available dugong specialists and fishermen.

Present aerial survey data on Usless Inlet are too limited to confirm that large numbers of dugongs do not regularly frequent the proposed pond area in the spring/early summer period of each year (Appendix 9).

It is therefore proposed to undertake the aerial surveys of the Inlet during the appropriate periods that have been requested by the EPA (Appendix 9). Two aerial surveys of Useless Inlet between September and December 1990 will be arranged, using observers from the Department of Conservation and Land Management (see Appendix 9 for details on the methods of these low-speed aerial surveys).

The results of this study will be provided to the EPA, and will be made available free-of-charge to anyone who has purchased a copy of this PER during the public submission period. Construction of the levee will not be started before the EPA has reviewed the results of these surveys.

7.3.3 Fish monitoring

The Agreement Act enables SBS to preclude fishing in ponded areas. This had been the case in Pond 0 because SBS believed that nets would disturb the fine sediment that had been cultivated to reduce permeability. However, these studies have shown that with time, animals in the pond cause good mixing within the sediments of the pond floor. Occasional harvest of fish stocks from the primary ponds is unlikely to upset salt production. SBS are therefore amenable to some form of harvest by fishermen, but also wish to retain prior rights to the fish stocks should the joint venture wish to develop a substantial aquaculture programme.

Four options exist:

(i) If the Denham fishermen decline SBS offers of regulated access to fish stocks in the pond system, then no monitoring is required.

(ii) If the SBS offer is accepted, then some form of monitoring of stocks will be implemented as a means of regulating access to the ponds.

(iii) If the Fisheries Department requests assistance with research into general aquaculture potential, then SBS will assist with any such programme.

(iv) If SBS identify an opportunity for aquaculture either for commercial or recreational use, the joint venture will initiate a research and development programme.

The development of any fisheries programme in the pond will be in liaison with the Department of Fisheries. SBS will routinely collect data on the ponds for salt production. SBS is prepared to make available environmental data from both within and outside the ponds including water levels, volumes and time of water influx, water temperatures, salinity profiles, nutrient levels and nutrient input. Some aspects of the husbandry of the algal/brine shrimp purification stage are the intellectual property of SBS and will not be available.

7.4 SUMMARY OF COMMITMENTS

The following commitments summarise the environmental management programme outlined in this document.

7.4.1 Pre-construction phase

(i) Determine the occurrence and use made of the proposed pond area in Useless Inlet by dugongs during the spring/early summer by aerial survey.

7.4.2 Construction phase

(i) Locate levee 400 m south of Lease Boundary to avoid containment of the large mangrove embayment in Useless Inlet.

(ii) Minimise vehicular traffic along the western access track.

(iii) Ensure continued use by tourists and recreational fishermen of the Clough's Bar access to Steep Point.

(iv) Transfer any marine mammal or turtle from the pond area to open water prior to completion of the levee and pond closure.

7.4.3 Post construction phase

(i) Continue to provide public access to Steep Point across Clough's Bar.

(ii) Continue to provide cleared areas at the ends of Clough's Bar for overnight camping by tourists.

(iii) Rehabilitate or vacate the construction access track along the western foreshore if required. Contour quarry sites to configuration prescribed by appropriate Government Agencies. Revegetate by agreed methods to approved standards. Manage the residual maintenance quarry site.

(iv) If directed by EPA or requested by CALM, provide camping areas and boat launching ramp at the western end of the new bar for recreational fishing purposes.

(v) If considered appropriate by CALM and/or Fisheries Department, allow public access to the new bar to tourists, fishermen, bird watchers, etc.

(vi) If considered appropriate by CALM and/or Department of Fisheries, enable vehicular access on the proposed levee from the western side to some agreed point to the west of the intake structures.

(vii) Install appropriate termination/s to vehicular access at agreed locations.

7.4.4 Operations phase

(i) Continue to monitor groundwater salinities and ionic composition in the Useless Loop area together with seagrass distribution to ensure adequate dilution of bitterns.

(ii) Develop and implement an oil spill contingency plan in conjunction with the appropriate authorities.

(iii) Assist in the implementation and operation of any routine ballast water monitoring programme established by the Port Authority.

(iv) Subject to Section 7.3.3, enable regulated access to fishermen for commercial fish harvesting within the pond system.

(v) If requested pursuant to Section 7.3.3, assist in aquaculture research programme under the auspices of the Department of Fisheries and the Western Australian Fisheries Industry Council (WAFIC).

(vi) Validate the essential and relevant items by field survey as requested and directed by the appropriate Government agencies that have responsibility for ongoing environmental regulation.

7.4.5 Termination of project

There is no predictable lifetime to a solar salt field and production can continue while demand provides for commercially viable continuance. The project could continue for hundreds of years.

Whenever the project does reach the end of its practical life the following shall occur:

(i) breach levees and remove all pipes and gate structures so that tidal flushing of the whole ponded area can resume;

(ii) remove infrastructure such as pump station, flume, washery, jetty, shiploader and townsite facilities, unless otherwise required by the State, all in accordance with Clause 27(b) of the 1983 Lease Agreement.

8 CONCLUSION

The proposal does not involve the alienation or adverse alteration of a pristine environment with high conservation value, and its potentially deleterious social effects are amenable to management. It is the culmination of some eighteen months work aimed at identifying the potential effects of the project and resolving associated concerns. A staged approach was adopted, wherein there has been regular liaison with relevant local and state authorities aimed at identifying concerns. This approach is entirely consistent with the recommendations of Shark Bay Region Plan, and it is considered that the proponent has fulfilled his obligations in that regard.

The proposed Environmental Management Programme will minimise the potential for adverse impacts arising from the proposed expansion and is evidence of the proponent's responsible approach to the project. Examples of the proponents commitment to minimise the potential effects of the proposal are:

- The location of the new levee some 400 m to the south of the existing mining lease boundary to avoid containment of a mangrove embayment of the eastern shore of the Inlet.
- The offer to provide additional public access and recreational facilities on the western shore of Useless Inlet subject to approval and request by relevant State authorites.
- The offers to co-operate with State and Commonwealth authorities in developing and implementing both an oil spill contingency plan and a ballast water monitoring programme.
- The offer of regulated access to commercial stocks of fish within the new pond.
- The offer to assist in aquaculture research programme aimed at improving in-pond fish stocks.

No resources of identified conservation value have been found which rely on the proposed pond area, and the ecological value of the proposed pond is no higher than that of other similiar habitats within Edel Land Inlets and elsewhere in Shark Bay. Construction of the pond will not adversely affect the remainder of the Useless Inlet ecosystem.

The proposal will therefore not lead to significant adverse impacts on either the regional marine ecosystem of Shark Bay or the regional community who derive benefit from the marine resources within the Bay.

The main potentially adverse effect identified in the assessment of the proposal is the trapping of commercial fish and prawn stocks within the proposed new pond. This impact, however, is considered to be of minor significance to both the Denham beach seine fishery and the Shark Bay prawn fishery, with the impact on the Denham beach seine fishery being largely mitigated by the management proposals referred to earlier. It is less simple to ameliorate the small reduction in western king prawn numbers predicted for the Denham Sound trawling ground, although management of the tidal gates might help minimise the trapping potential of the new pond. However it must be remembered that even the worst-case estimate indicates that the small reduction in prawn numbers will not be discernible above natural annual fluctuations in size of the annual prawn catch from the Denham Sound trawling grounds.

Important background considerations that are also worth noting are:

- Useless Inlet is not a pristine unmodified environment but one which appears to have been modified prior to the initiation of the salt project as a result of earlier pearling activities.

- The present pond system does not represent an 'ecological desert'. To the contrary it supports enhanced numbers of many marine biota (including fish), and is an important refuge for local avifauna and trans-equatorial migratory wading birds.

- The proponent does have an existing agreement with the State which foreshadowed the proposed expansion by granting of the mining lease. The proposed new levee is within the existing lease boundary. The proponent has fulfilled all his obligations under that Agreement.

- The Shark Bay Region Plan and subsequent submissions, and the EPA evaluation of the Plan, all support the continuation of the solar salt project and, the proposed expansion, subject to its environmental acceptability.

- The Shark Bay Salt Project is an optimally environmental friendly industry in that is based on a sustainable resource produced by harnessing a combination of solar, wind and tidal energies. It does not require the consumption of large of fossil fuels to produce the salt, and does not produce hazardous toxic wastes or greenhouse gases.

Furthermore, the following potential benefits will accrue to the regional community as a result of the proposal proceeding:

- Shark Bay Salt will remain economically viable and continue to provide employment opportunities in the region as well as its management of convenient public access to Steep Point.

- The nation will receive an additional A$10 m of foreign earnings per annum that will help reduce the present foreign debt.

- The State and Commonwealth governments will benefit from increased receipts from taxes and royalties.

- Regional fisheries may benefit from the offer to participate in aquaculture research. Studies conducted for this assessment have shown that pond husbandry techniques can enhance fish production within the ponds, and that these fish are highly production within the ponds, and that these fish are highly marketable. An opportunity exists to develop these findings further by researching the potential for commercial aquaculture within Shark Bay. Such an opportunity is consistent with recommendations of the Shark Bay Region Plan.

It is therefore concluded that the benefits of the proposal substantially outweigh its imposition on the environment, and as such the proposal should be allowed to proceed subject to resolution and acceptance of the proposed Environmental Management Programme.

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GLOSSARY

Abbreviations of Measures

%	- percentage
cm	- centimetres
cm/km	- centrimetres per kilometre
cm/s	- centimetres per second
DWT	- dead weight (ships load capacity in tonnes)
g	- grams
g/L	- grams per litre (i.e. parts per thousand)
ha	- hectares (square kilometres)
kg	- kilogrammes
kL	- kilolitre (thousand litres)
km/h	- kilometres per hour
km^2	- square kilometres
m	- metre
m/s	- metres per second
m^2	- square metres
m^3	- cubic metres (equivalent to kL)
mm	- millimetre
^oBe	- degrees in Baume (industry standard for measurement of density)
ppb	- parts per billion
ppm	- parts per million
ppt (or $^o/oo$)	- parts per thousand (equal to kg/m^3 and g/L)
tonne	- one thousand kilogrammes
ug/L	- micrograms per litre (i.e. parts per billion)

Acronyms

BU	- Beneficial Use
CALM	- Department of Conservation and Land Management
DMH	- Department of Marine and Harbours
DRDNW	- Department of Regional Development for the North West
DRD	- Department of Resources Development
EPA	- Environmental Protection Authority
IUCN	- International Union for the Conservation of Nature
LSC	- LeProvost, Semeniuk & Chalmer
MHHW	- mean higher high water (mean height of the higher two daily high waters over a long period)
MHW	- mean high water (height of the mean high water level over a long period)
MLLW	- mean lower low water (mean height of the lower of the two daily low waters over a long period)
MLW	- mean low water (height of the mean low water level over a long period)
MSL	- mean sea level (average level of the sea surface over a long period)
OSCP	- Oil Spill Contingency Plan
PER	- Public Environmental Report
SBS	- Shark Bay Salt Joint Venture
SPC	- State Planning Commission
WAFIC	- Western Australian Fishing Industry Council (Inc.)

Chemical names

$CaCO_3$	- calcium carbonate ('lime')
$CaSO_4$	- calcium sulphate (gypsum)
$MgCl_2$	- magnesium chloride
$MgSO_4$	- magnesium sulphate
N	- nitrogen
NaCl	- sodium choloride (common salt)
P	- phosphorus
PO_4	- phosphate
potash	- potassium chloride

Scientific Terms

aeolianite	- rock formed from deposits of wind blown sediments
alluvial	- material transported by a river and deposited
aquatic macrophytes	- large aquatic plants (e.g. seaweeds)
avifauna	- bird life
benthos	- animals and plants living in bottom sediments
bitterns	- waste brine after salt has crystallised out
brine	- concentrated salt solution
bryozoans	- aquatic colonial animals
calcilutite	- rock with limestone grains less than 1/16 mm
carapace	- the shield covering the head and thorax of prawns (part of its exoskeleton)
carbonate	- limestone
Clupeidae	- family of bony fish including herring, pilchard and sardine

codiacean aglae	- a type of green algae
coquina	- limestone of cemented coarse shell debris
coralline algae	- a type of calcareous green algae
Cretaceous	- geological period beginning 135 million years before present and lasting approximately 70 million years.
crustaceans	- class of aquatic arthropods including crabs, shrimps and barnacles
crystallising pond	- where salt is crystallised from brine
cyanobacteria	- blue-green algae
dendritic	- branching (tree like)
detritus	- organic debris from decomposing plants and animals
diurnal	- occuring daily
epibiota	- plants and animals that live or grow on the surface of other organisms such as seagrasses
fauna	- animals
filamentous	- in the form of filaments
flora	- plants
foraminiferans	- group of Protozoa, mostly marine, which form shells usually of lime
gastropods	- class of molluscs often having a single shell (e.g. snails)
geomorphology	- the description and interpretation of landforms
halophyte	- plant which grows in soil containing a high concentration of salt (e.g. samphire)
herbivore	- plant eating animal
Holocene	- youngest subdivision of the Quaternary period; following the Pleistocene, from 10,000 years ago to the present

hydrology	- study of water movements
hypersaline	- much saltier than the ocean
indurated	- hardened
intertidal	- area periodically exposed between low and high tide marks
inturbated	- mixed up
lithified	- sediment consolidated and hardened into sedimentary rock
lithoclasts	- particles, grains or stones which have been eroded from rocks, moved and subsequently redeposited
littoral zone	- area between the highest storm surge level and lowest level of spring tide
littorinid mollusc	- type of marine snail usally found on rocky shore lines
marine angiospersm	- flowering plants which grow underwater (e.g. seagrasses)
megaripples	- conspicuous sand waves up to 60 cm in height
metahaline	- slightly saltier than the ocean
micro-organism	- any plant or animal too small to see with the naked eye
mytilids	- a group bivalve molluscs, including mussels
nekton	- animals that can swim faster than the prevailing currents
oolids	- calcerous grains (concentrically layered) formed where currents roll around sand size deris in evaporating shallow waters
Palaeozoic	- era of ancient geological time occurring between the Precambrian and Mesozoic
panamax	- maximum size of ship that can navigate the Panama Canal
passerines	- perching birds with bivalve shells such as mussels and oysters

pelagic	- applied to organisms which live, swim or float in the open sea and not on the sea floor
pelecypod	- a class of molluscs with bivalve shells
phytoplankton	- small unicellular algae that form the 'plant life' of the plankton
plankton	- usually small animals and plants which float or drift at the mercy of the prevailing currents
Pleistocene	- older subdivision of the Quaternary preceeding the Holocene from about two million years ago to 10,000 years ago
polychaetes	- order of annelids including bristle worms, tube worms and fan worms
polysaccharides	- large molecules or carbohydrate such as cellulose produced by combination of many molecules of monosaccharide
Quaternary	- geological time since the end of the Pliocene, including the Pleistocene and Holocene subdivisions
raptor	- bird of prey
seine net	- fishing net that hangs vertically in the water by means of floats at the tope and weights at the bottom
stromatolite	- a 'rock' formed by the trapping and binding and/or precipitation of lime as a result of the activity of micro-organisms, including cyanobacteria
sublittoral	- shallow zone of sea below the low water spring mark
supratidal	- area above normal high tide mark
Tamala Limestone	- type of limestone formed along the Western Australian coast during the Pleistocene
Tertiary	- geological period from the end of the Cretaceous to the beginning of the Quaternary

tube worm	- type of polychaete worm
unicellelar algae	- single celled plants
winnowing	- a sorting and sifting process produced by currents of air or water
zooplankton	- animals of the plankton

Plate 1A: Western quarry site. View looking northwest across depression between the two longtitudinal dunal ridges.

Plate 1B: Eastern side of west quarry site looking north. Emergent limestone bench and narrow sand plain separate first longtitudinal dunal ridge from Useless Inlet.

Plate 1C: View of eastern quarry site from top of main dunal ridge looking west towards the parallel ridge that will partially mask quarry from Useless Inlet.

Plate 1D: Outcrop of Tamala limestone underlying the main dunal ridge of the eastern quarry site.

TABLE 1

PRODUCTION AND CONSTITUENTS OF BITTERNS

	PRESENT ANNUAL PRODUCTION	PREDICTED PRODUCTION
	(with current salt production at 650,000 tonnes per annum)	(after boosting salt production by 85% to 1,200,000 tonnes per annum)
Mass	338,000 tonnes	625,000 tonnes
Volume	940,000 cubic metres	1,74 0,000 cubic metres

Constituents:

NaCl	104 g/l	**After top-ups to extract additional salt (NaCl)** (almost exclusively used by SBS)
MgCl2	135 g/l	
MgSO4	82 g/l	
KCl	35 g/l	
MgBr	4 g/l	
CaSO4	0.3 g/l	
Total	360 gms per litre (360 kilograms per cubic metre)	

BITTERNS PRODUCTION WITHOUT USING TOP-UPS

Constituents:

NaCl	182 g/l	**Without top-ups** (rarely used by SBS)
MgCl2	89 g/l	
MgSO4	55 g/l	
KCl	24 g/l	
MgBr	3 g/l	
CaSO4	1 g/l	
Total	354 grams per litre (354 kilograms per cubic metre)	

NB Production without top-ups would lead to an annual discharge of 496,000 tonnes (ie. 1,400,000 cubic metres). Following expansion, this would rise to 917,600 tonnes (ie. 2,590,000 cubic metres)

TABLE 2

SALINITY AND DENSITY REGIME IN THE PRIMARY CONCENTRATION PONDS IN USELESS INLET

POND	EXISTING RANGE	PREDICTED RANGE	
Proposed pond	**42-49**	**44-52**	g/L
	4.0-4.7	4.2-5.3	o Be
Pond PO	**45-54**	**48-58**	g/L
	4.6-5.5	4.9-6.0	o Be
Pond P1A	**48-58**	**50-75**	g/L
	4.9-6.0	5.1-7.7	o Be
Pond P1B	**53-78**	**70-85**	g/L
	5.5-8.0	7.2-8.8	o Be
Pond P2	**88-105**	**95-120**	g/L
	9.4-11.1	10.0-13.5	o Be
Pond P3A	**95-140**	**106-160**	g/L
	10.0-12.5	11.0-15.0	o Be
Pond P3B	**106-160**	**130-200**	g/L
	11.0-15.0	12.5-18.0	o Be

NB. Ranges are due mainly to winter/summer variations in evaporation

Units: Salinity (g/L) = grams of total dissolved salts per litre
Density (o Be) = degrees Baume

(a density increase by one degree Baume is almost equivalent to an additional 10 g)

TABLE 3

ANTICIPATED WORKS PROGRAM

EVENT	TIMING
Call for tenders for plant, equipment and labour (or lump sum contract for construction)	**1st month**
Site preparation (quarry sites & access track; and accommodation at Useless Loop)	**2nd month**
Mobilisation of plant to site; commence levee (further progressive mobilisation as levee is extended)	**3rd month**
Call for tenders for tidal gates (materials, fabrication, installation - lump sum or separate)	**12th month**
Work on tidal gates commences	**13th month**
Tidal gates installed	**15th month**
Complete levee; commence rehabilitation of quarries and western shoreline access track	**16th month**

(maximum anticipated salt production and export attained 3 years after levee is completed)

TABLE 4

CONCENTRATION OF TOTAL NITROGEN (^{o}/oo) IN SHARK BAY ENVIRONMENTS*

ENVIRONMENT	OCEANIC	META-HALINE	HYPER-SALINE
Sublittoral platform	0.08-0.2	0.08-0.2	0.8
Seagrass meadow	0.40-1.0	0.40-1.0	-
Open strait or reach	0.15-0.7	0.30-0.8	-
Restricted channel	0.18	0.30	-
Channel fan or delta	0.70	1.10-1.7	2.0
Basin	-	0.80	1.4
Mean total nitrogen	0.4	0.75	1.3

* Logan & Cebulski (1970).

TABLE 5

ANNUAL CATCH OF SCALEFISH CAUGHT BY BEACH SEINE IN SHARK BAY*

COMMON NAME	TONNES LIVE WEIGHT		
	1986	1987	1988
Whiting	180	124	90
Mullet	70	122	130
Tailor	18	20	16
Bream	6	13	20

* Data from Mr G. Finlay, Fisheries Inspector at Denham, Shark Bay.

TABLE 6

COMPOSITION OF MARINE ASSEMBLAGES WITHIN EDEL LAND INLETS*

COMMUNITY	MOLLUSCA	FORAMINIFERA	ALGAE	OTHERS	SEAGRASSES
Amphibolis	Mainly small gastropods: Alaba, Zaffra hedleyi, Diala, Bittium, Clanculus, Gibbula, Elachorbis tatei; minor pelecypods.	Peneroplis planatus, Discorbis vesicularis var. dimidiata, Vertebralina striata, Elphidium crispum, encrusting nubecularids, Triloculina oblonga, T. rotunda, Quinqueloculina vulgaris, Q. neostriatula.	Coralline algae: Metagoniolithon, Corallina, Melobesia.	Bryozoans, tube worms, sponges.	Cymodocea, minor Posidonia.
Pinna-Pinctada	Pelecypods & minor gastropods.	Minor foraminifers: peneroplids, miliolids, rotalids.		Serpulids, bryozoans.	Stunted Posidonia, minor Cymodocea.
Posidonia		Marginopora vertebralis, Peneroplis planatus, Vertebralina striata, Discorbis vesicularis var. dimidiata.	Coralline alga: Melobesia.		Posidonia.
Cerithium-Penicillus	Cerithum sp. Small gastropods: Clypeomorus, Parcanassa jonasi, Diala, Merelina. Pelecypods: common Fragum hamelini, Gafrarium intermedia, Hemicardium hemicardium.	Marginopora vertebralis, Peneroplis planatus, Spirolina arietina, Triloculina spp.	Codiacean alga: Penicillus nodulosus.		Posidonia australis, Zostera sp. Halophilia spp.
Costacallista-Anomalocardia	Mainly thick-shelled Pelecypods: Costacallista impar, Anomalocardia squamosa.	Minor foraminifers.			
Algal-mat			Algal mats of cyanobacteria	Unicellular green alga, purple sulphur bacteria and scattered halophytes.	
Halophytes				Halophytes: Pachycornia sp., Arthrocnemum arbuscula, Wilsolia humilis, Agianthus cunninghamii.	

* Modified from Logan & Cabulski 1970; Read, 1974a.

TABLE 6

COMPOSITION OF MARINE ASSEMBLAGES WITHIN EDEL LAND INLETS*

COMMUNITY	MOLLUSCA	FORAMINIFERA	ALGAE	OTHERS	SEAGRASSES
Archaias	Mainly small gastropods: Alaba, Zafra medleyi, Diala, Bittium, Lamellus, Gibbula, Liachorbis [illegible]; minor pelecypods.	Peneroplis planatus, Discorbis vesicularis var. dimidiata, Vertebralina striata, Elphidium crispum, encrusting nubecularids, Triloculina oblonga, T. rotunda, Quinqueloculina vulgaris, Q. neostriatula.	Coralline algae: Metagoniolithon, Corallina, Melobesia.	Bryozoans, tube worms, sponges.	Cymodocea, minor Posidonia.
Pinna-Pinctada	Pelecypods & minor gastropods.	Minor Foraminifera: peneroplids, miliolids, rotaliids.		Serpulids, bryozoans.	Sparse Posidonia, minor Cymodocea.
Posidonia		Marginopora vertebralis, Peneroplis planatus, Vertebralina striata, Discorbis vesicularis var. dimidiata.	Coralline algae: Melobesia.		Posidonia.
Cerithium [illegible]	Lithopoma sp. Small gastropods: Clypeomorus, [illegible] [illegible], Diala, Merelina. Pelecypods: common Fragum hamelini, [illegible] intermedia, [illegible] [illegible].	Marginopora vertebralis, Peneroplis planatus, Spirolina arietina, Triloculina spp.	Codiacean algae: Penicillus nodulosus.		Posidonia australis, Zostera sp., Halophila spp.
Costacallista-Anomalocardia	Mainly thick-shelled Pelecypods: Costacallista [illegible], Anomalocardia squamosa.	Minor Foraminifera.			
Algal mat			Algal mats of cyanobacteria	Unicellular green algae, purple sulphur bacteria and scattered halophytes.	
Halophytes				Halophytes: Pachycornia sp., Arthrocnemum arbuscula, Wilsonia humilis, [illegible] cunninghamii.	

* Modified from Logan & Cebulski 1970; Read, 1974a.

Table 7: POTENTIAL ADVERSE IMPACTS PREDICTED, PROBABILITY OF OCCURRENCE, SIGNIFICANCE AND PROPOSED MANAGEMENT PROGRAMME TO MITIGATE IMPACTS FOR SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET

POTENTIAL ADVERSE IMPACTS	PROBABILITY OF IMPACT OCCURRENCE	SIGNIFICANCE OF IMPACT	ENVIRONMENTAL MANAGEMENT PROGRAMME AND COMMITMENTS
PHYSICAL ENVIRONMENT			
Construction of the proposed pond will modify the following topography of the project area:			
- the shoreline at each end of the proposed levee;	Inevitable	Low	
- 15ha of limestone and dunal ridge on the eastern side of Useless Inlet;	Inevitable	Low	The quarry sites will be rehabilitated once the levee has been completed except for a small portion of the eastern quarry to be reserved for maintenance purposes. Much of the eastern quarry will be masked from view by a dunal ridge.
- 4ha of dunal ridges on the western of Useless Inlet; and	Inevitable	Low	
- slight modification to parts of the western shoreline between Clough's Bar and the western abutment to create an access track (0.5ha).	Inevitable	Low	The access track will be either rehabilitated or left open for public 4WD vehicular access to new levee.
A temporary sediment plume of carbonate fines (that will vary in size, duration and direction on a daily basis) will be generated during construction of the levee.	Certain	Low	
The proposed new levee will alienate the southern end of Useless Inlet. This will shorten the length of the Inlet by 6km and reduce the volume capacity of the Inlet by 18%.	Inevitable	Low	The proposed levee has been located 400m to the south of the lease boundary to avoid containment of 15ha of mangroves within an embayment on the eastern shore of the Inlet.
Piloted shipping movements at Useless Loop will increase from 33 to about 60 vessels per year. This will double the risk of an accidental fuel oil spillage (only by ship wreck).	Remains very low	Medium	There are no fuelling facilities on (or planned for) the ship loading jetty. The proponent will assist with the development of an oil spill contingency plan in conjunction with appropriate authorities.

Table 7: (cont'd) **POTENTIAL ADVERSE IMPACTS PREDICTED, PROBABILITY OF OCCURRENCE, SIGNIFICANCE AND PROPOSED MANAGEMENT PROGRAMME TO MITIGATE IMPACTS FOR SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET**

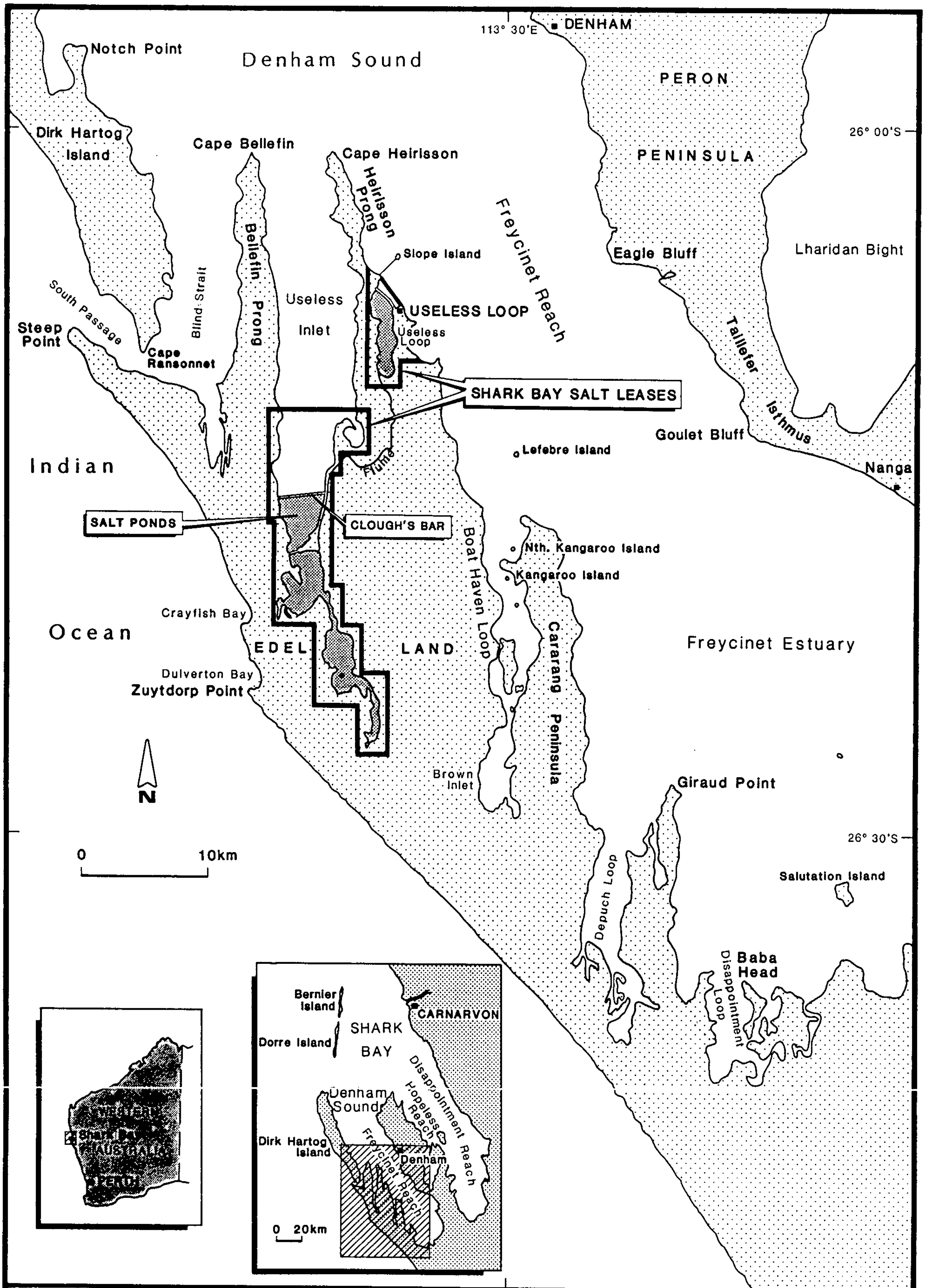
POTENTIAL ADVERSE IMPACTS	PROBABILITY OF IMPACT OCCURRENCE	SIGNIFICANCE OF IMPACT	MANAGEMENT PROGRAMME AND COMMITMENTS
BIOLOGICAL ENVIRONMENT			
Construction of the levee will alienate approximately 26km^2 (18%) of existing marine habitat in Useless Inlet.	Inevitable	Low	
Increased bitterns discharge has a potential to impact on adjacent biota if below-ground dilution is not adequate.	Very low	Medium	The proponent will continue to monitor.groundwater salinities and ionic composition in the Useless Loop area, together with extent of seagrass distribution.
Increased shipping movements at Useless Loop increase the potential for introducing undesirable foreign biota via the discharge of ballast water.	Low, provided ships continue to arrive from nearby SE Asian ports	High	The proponent will assist in the implementation and operation of any routine ballast water monitoring programme that may be established by the Carnarvon Port Authority and Australian Quarantine Service.
Closure of the levee has a potential to trap marine mammals and/or turtles within the proposed pond.	Low	Medium	At the time of levee closure, a final inspection will be made by boat and aircraft to ensure these animals do not remain inside the new pond area. Any trapped animals will be transferred to the inlet.
The new levee may alienate important feeding or breeding habitat for dugongs.	Very low	Medium	Aerial surveys of Useless Inlet will be undertaken before project commencement to confirm that area of proposed pond does not contain an important dugong habitat

Table 7: (cont'd) **POTENTIAL ADVERSE IMPACTS PREDICTED, PROBABILITY OF OCCURRENCE, SIGNIFICANCE AND PROPOSED MANAGEMENT PROGRAMME TO MITIGATE IMPACTS FOR SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET**

POTENTIAL ADVERSE IMPACTS	PROBABILITY OF IMPACT OCCURRENCE	SIGNIFICANCE OF IMPACT	MANAGEMENT PROGRAMME AND COMMITMENTS
SOCIAL ENVIRONMENT			
Completion of the proposed levee will remove public access to the open waters of Useless Inlet via existing route.	Inevitable	Medium	It is proposed that the temporary haulage track located on the western shore could be left open to provide 4WD vehicle access to the new levee. Open water shoreline angling and beach launching of recreational fishing boats would thus be maintained.
The proposed pond will occupy part (~ 1.5%) of fishable waters presently utilised by some of the licensed beach seine fishing operators from Denham.	Inevitable	Low	The proponent will liaise with WAFIC and the WA Department of Fisheries in order to develop a pond management programme which can lead to regulated fish harvesting in the new pond.
The proposed pond will alienate 0.8% of the nursery grounds of western king prawns, which are taken from trawling grounds in Denham Sound by prawn trawlers based at Carnarvon.	Inevitable	Very Low	

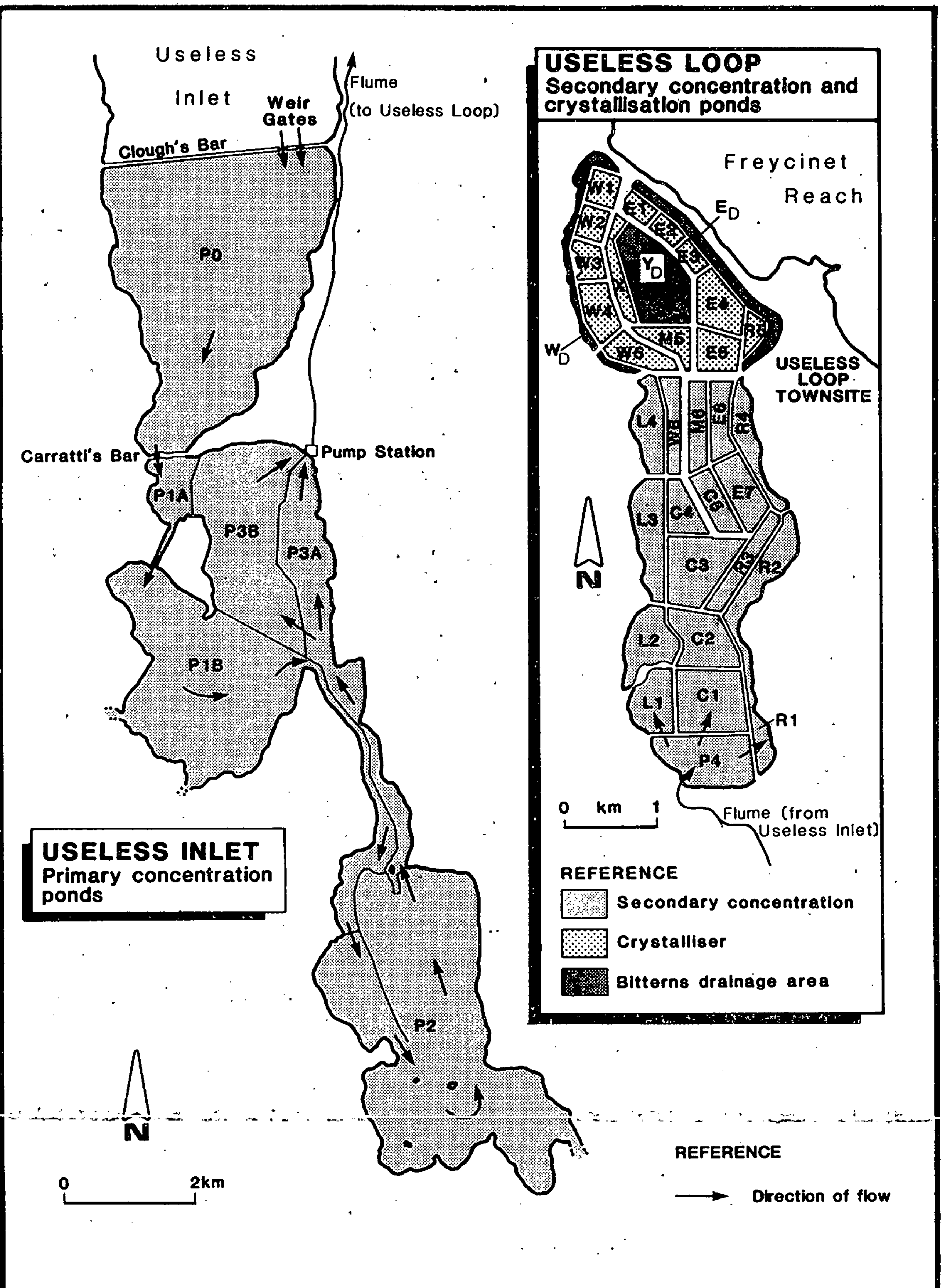
TABLE 8: BENEFICIAL IMPACTS PREDICTED TO RESULT FROM PROPOSED SHARK BAY SALT EXTENSIONS OF SALT PONDS, USELESS INLET

BENEFICIAL IMPACTS	COMMENTS
The proposed salt production extensions will provide additional export earnings estimated at A$10.4 million per annum.	Increased salt production is required to ensure the future viability of the Shark Bay salt works.
The proposed salt production extensions will provide employment for 25 construction workers during the 14 month construction period and an additional 15 full time staff during the operation of the expanded development.	All employees will be housed at the company town at Useless Loop.
The proposed pond will expand the area in the southernmost section of Useless Inlet presently used by migratory wading birds.	The existing primary salt ponds P2 and P3 currently provide an important waterfowl refuge of high conservation value.
The access track to the proposed levee can provide 4WD vehicle access to a boat launching and overnight camping area at the western end of the proposed levee, with public access along the new levee (as well as Clough's Bar) improving recreational angling, boating and bird watching opportunities in Useless Inlet.	The cleared area by the foreshore on the western end of Clough's Bar is currently used by tourists for these purposes. The proponent is prepared to allow public access to the western sector of the new levee and to provide camping areas and a boat launching ramp at the western end, subject to approval by CALM and Fisheries Dept.
The abundance of commercial teleost fish species within the proposed pond area is expected to increase, thereby leading to enhanced commercial fishing opportunity.	Regulated commercial harvesting of fish appears logistically viable within both the new and existing (PO) primary ponds, and may be an economically attractive operation.
The new pond has the potential for use as a site for aquaculture research in the Shark Bay region.	If required the proponent will assist in an aquaculture research programme for the Department of Fisheries and the Western Australian Fisheries Industry Council.



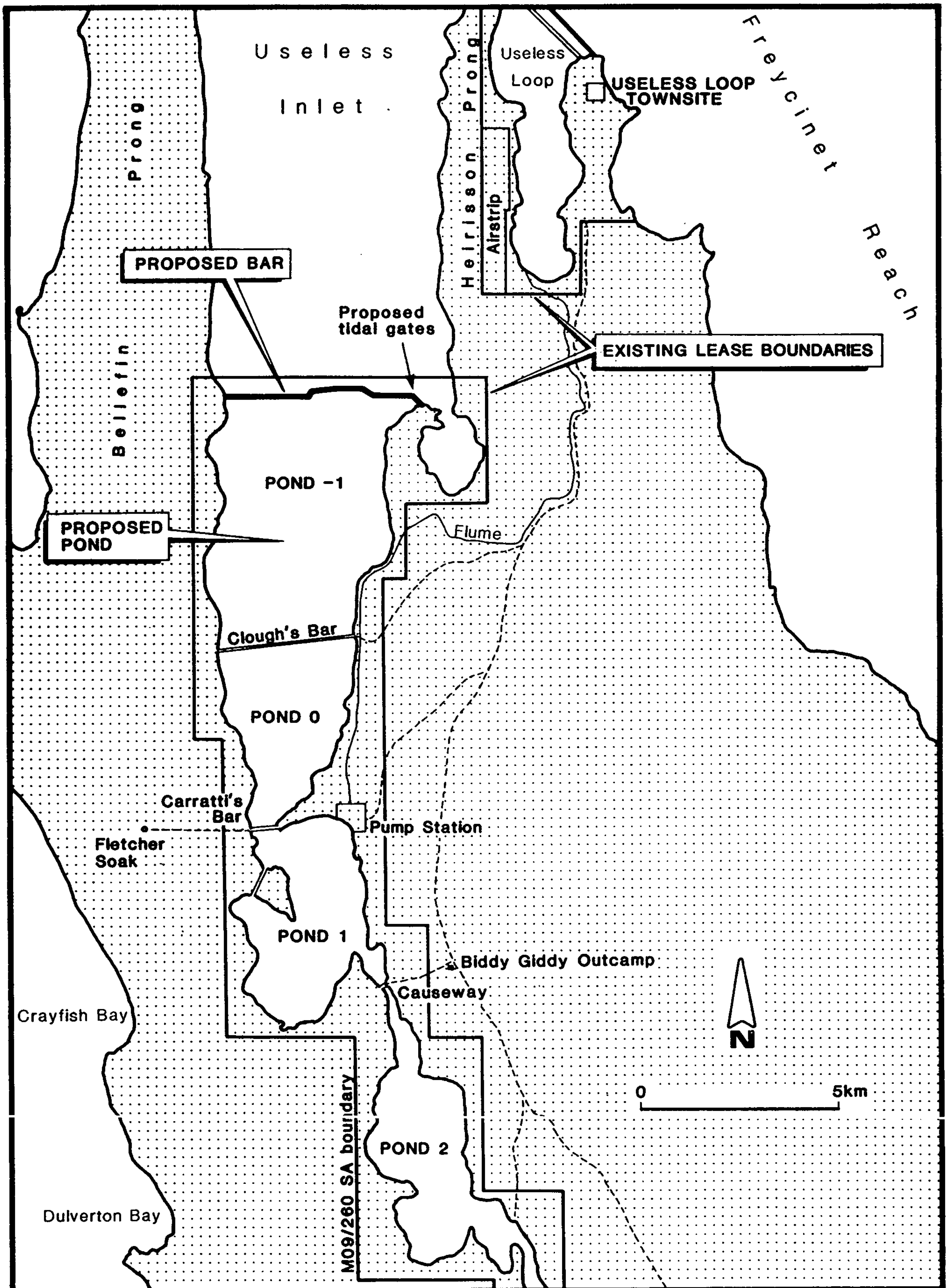
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	**EXISTING FACILITIES AND MINING LEASE**	**1**
	Date : June 1990		

J171 R303



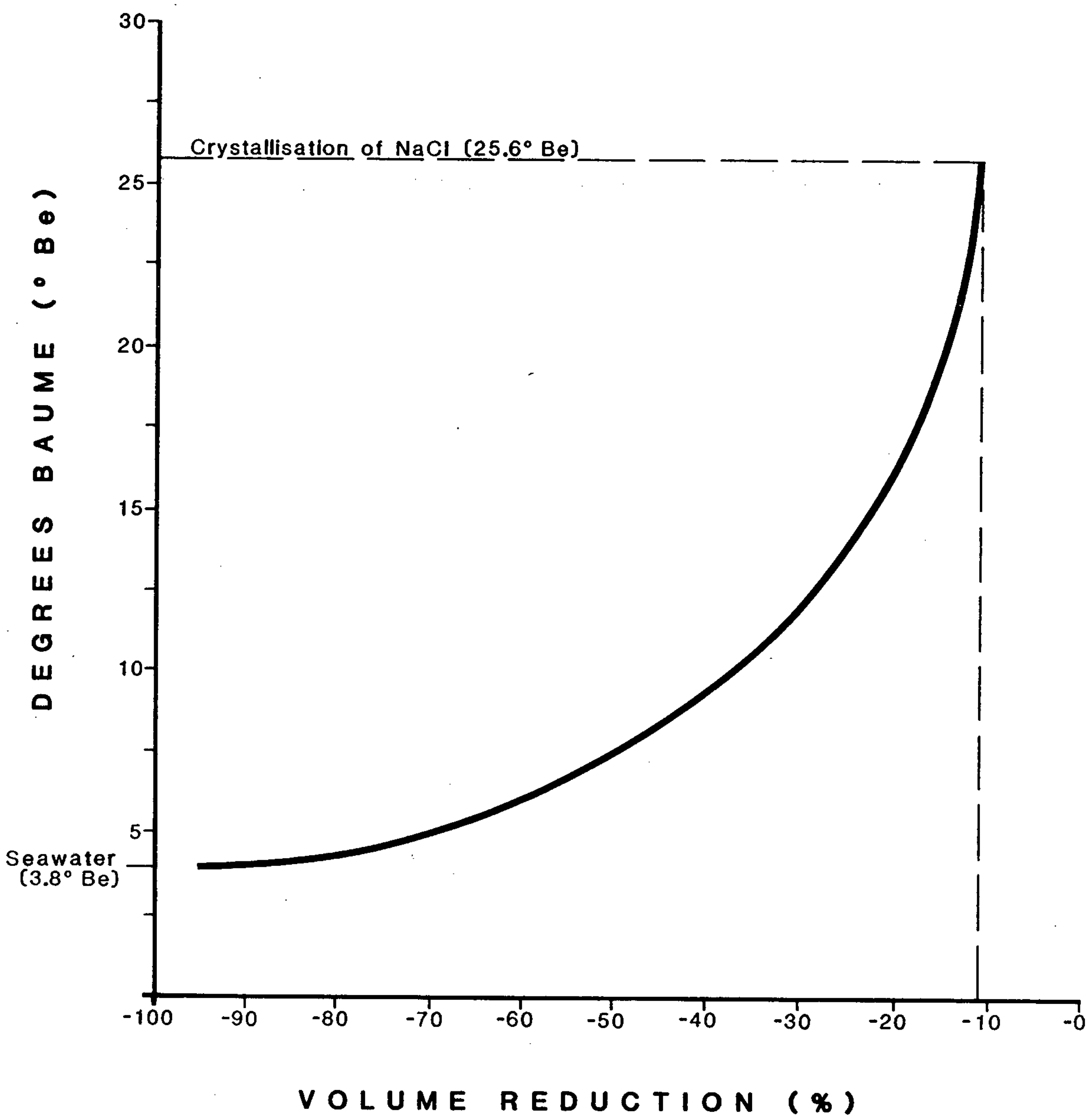
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn: Environmental	**POND NOMENCLATURE AND WATER FLOW**	**2**
	Date: June 1990		

J171 R303



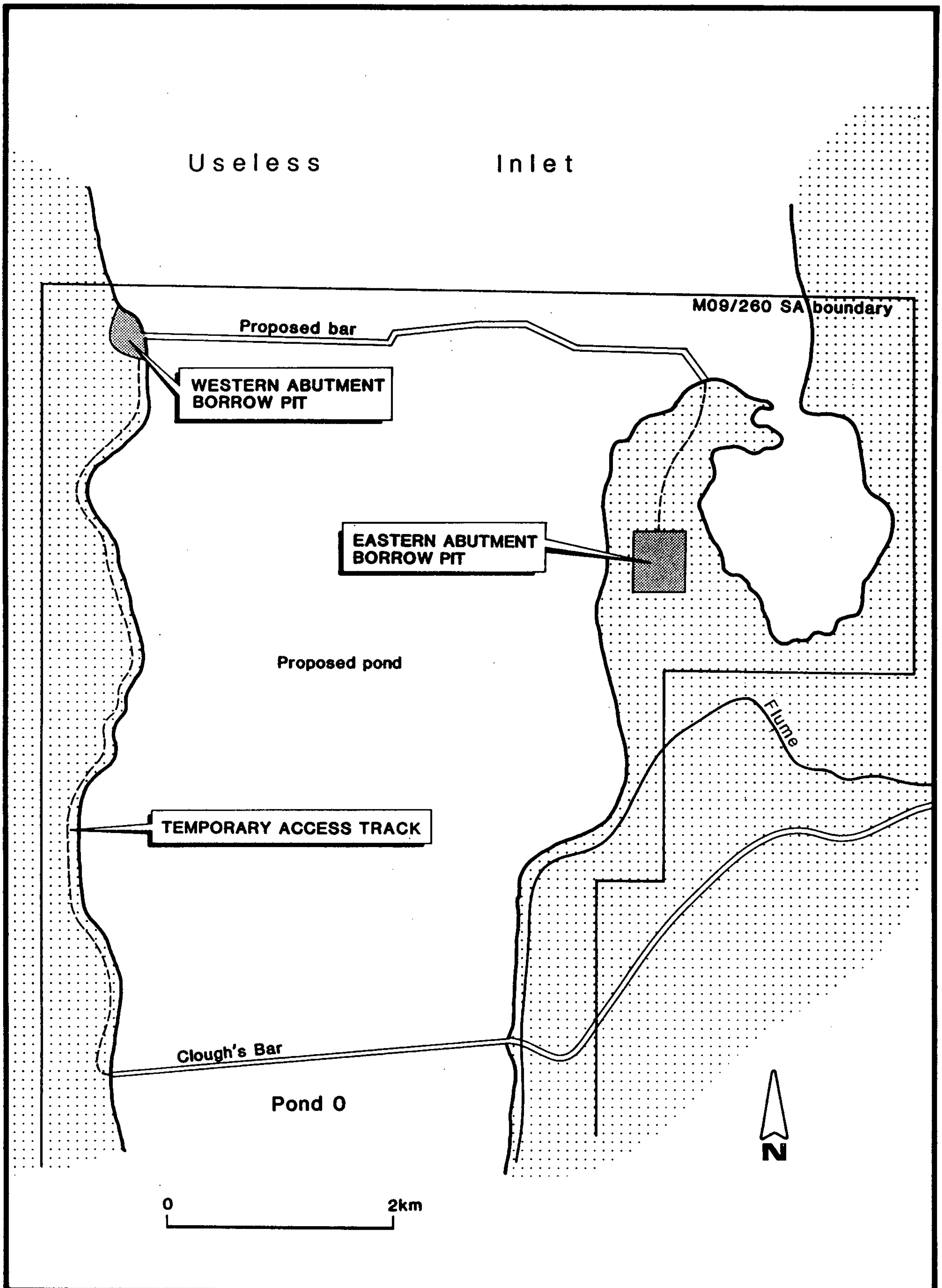
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	LOCATION OF PROPOSED POND	3
	Date : June 1990		

J171 R303



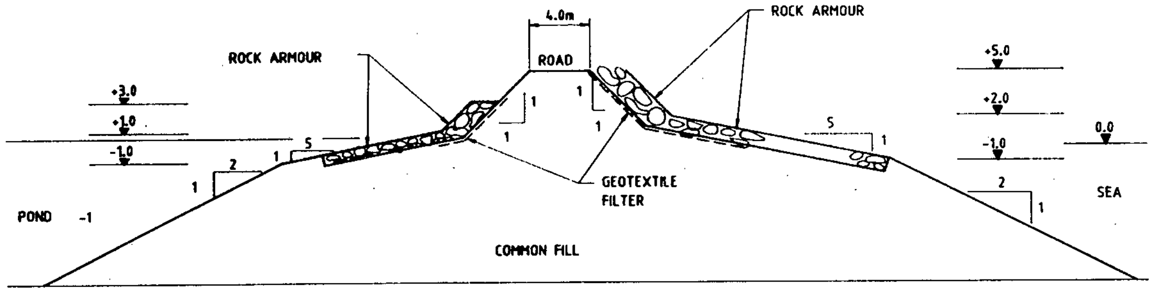
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	**SEAWATER VOLUME Vs SALT CONCENTRATION**	**4**
	Date : June 1990		

J171 R303



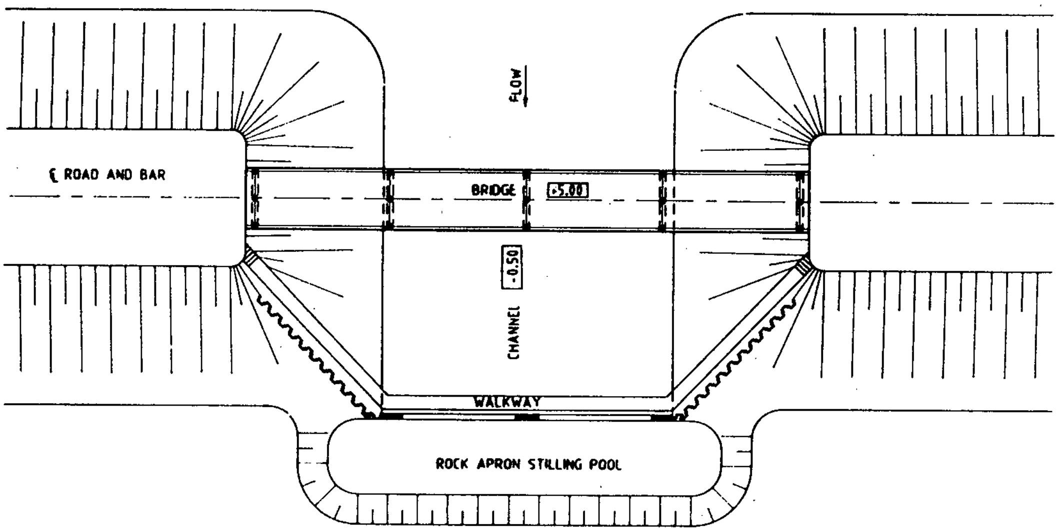
LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	**LOCATION OF BORROW PITS AND TEMPORARY ACCESS ROAD**	**5**
	Date : June 1990		

J171 R303

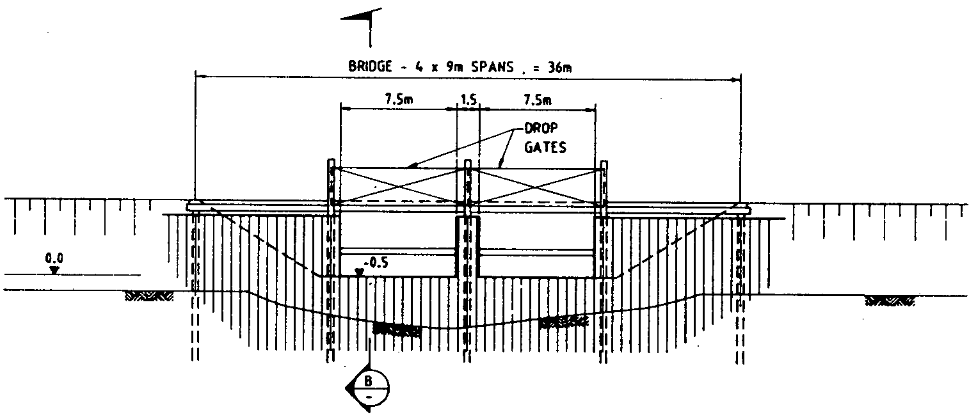


LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard Drawn : Environmental Date : June 1990	SHARK BAY SALT JOINT VENTURE **CROSS SECTION OF PROPOSED BAR**	Figure **6**

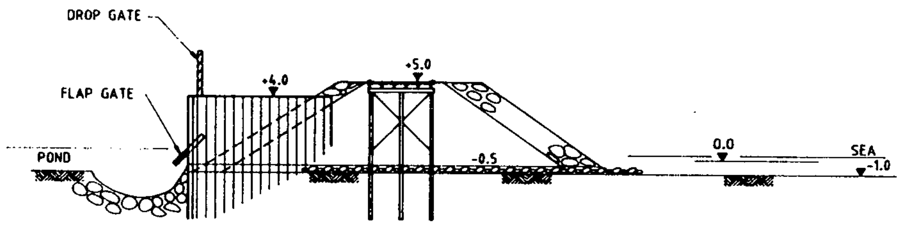
J171 R303



POND -1 PROPOSED BAR INTAKE PLAN



INTAKE STRUCTURE



INTAKE CROSS SECTION

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : **R.Hilliard**	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	**WATER INTAKE STRUCTURE**	**7**
	Date : **June 1990**		

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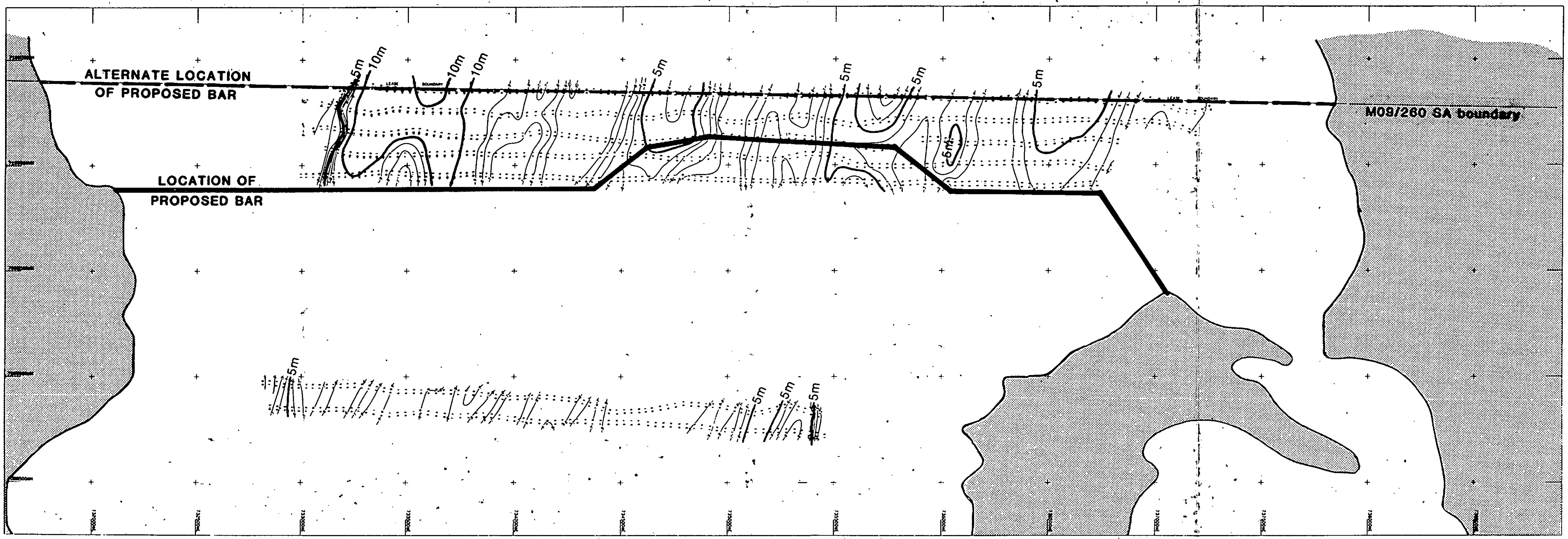
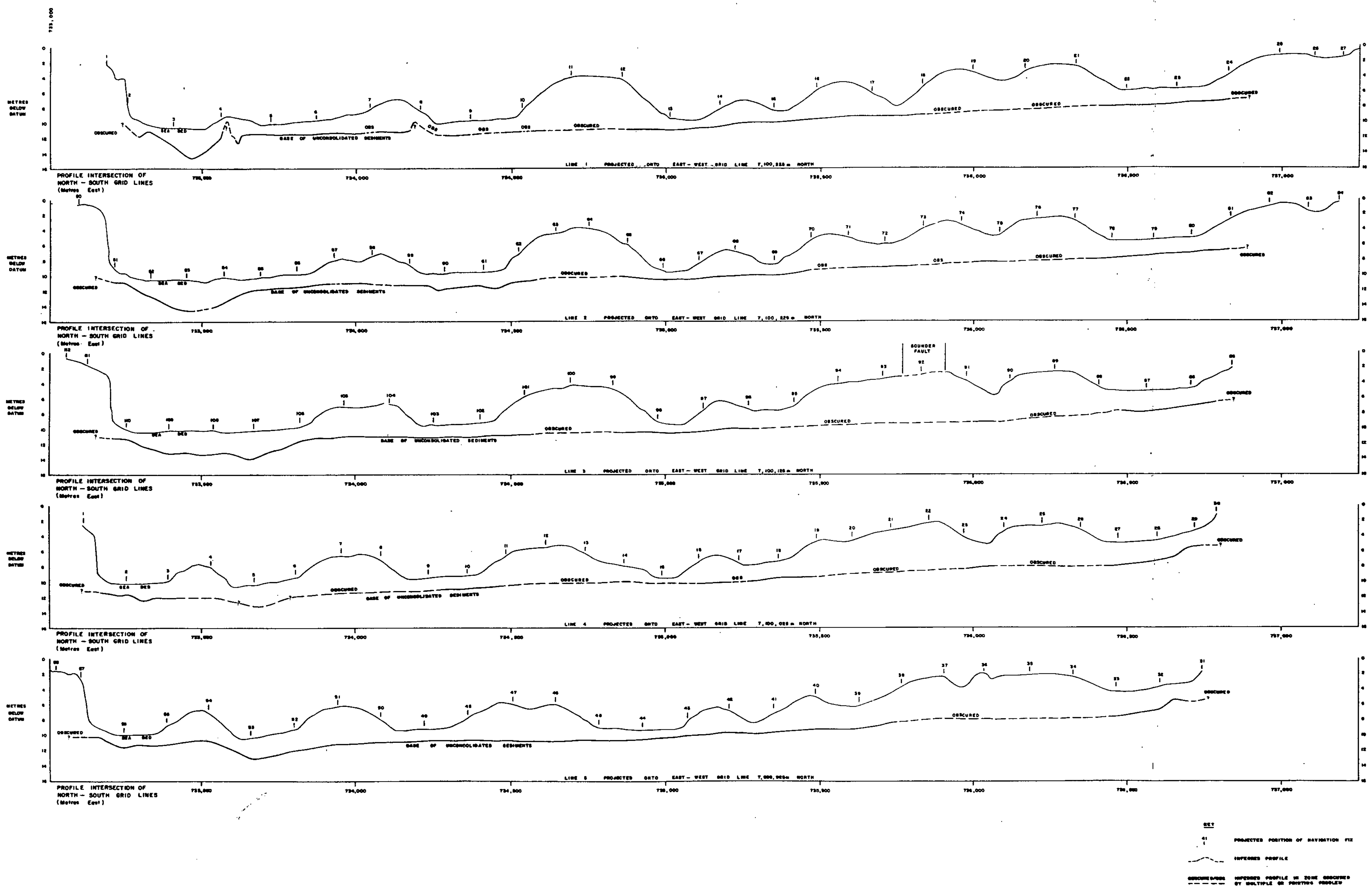
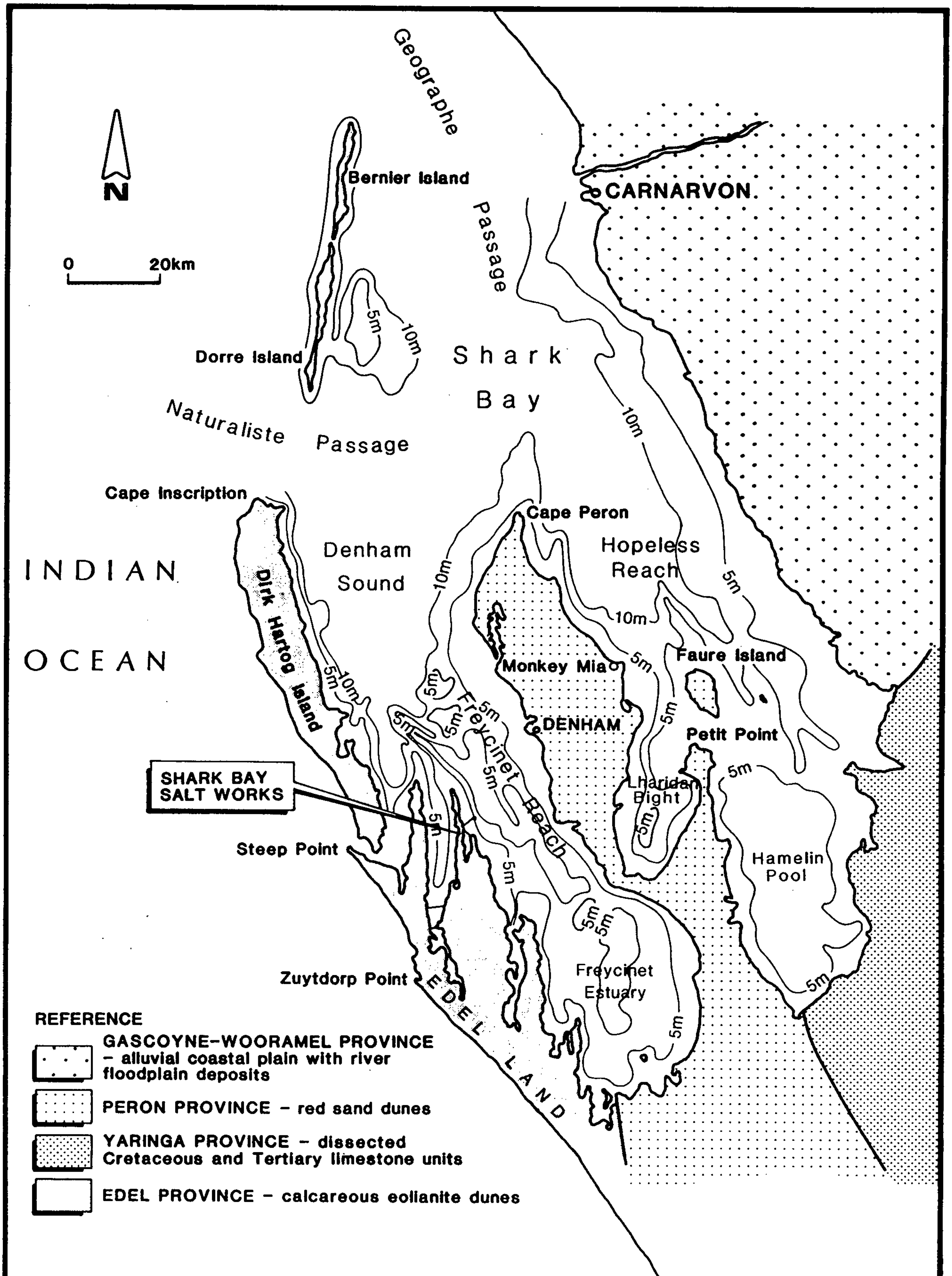


LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard Drawn: Environmental Date: June 1990	SHARK BAY SALT JOINT VENTURE **BATHYMETRY AT LOCATIONS OF PROPOSED BAR**	Figure **8**

J171 R303



LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn: Environmental	**SUB BOTTOM PROFILES AT PROPOSED BAR**	**9**
	Date: June 1990		



Source : Logan and Cebulski 1970

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : R.Hilliard Drawn : Environmental Date : June 1990	SHARK BAY SALT JOINT VENTURE **GEOMORPHOLOGY AND BATHYMETRY**	Figure **10**

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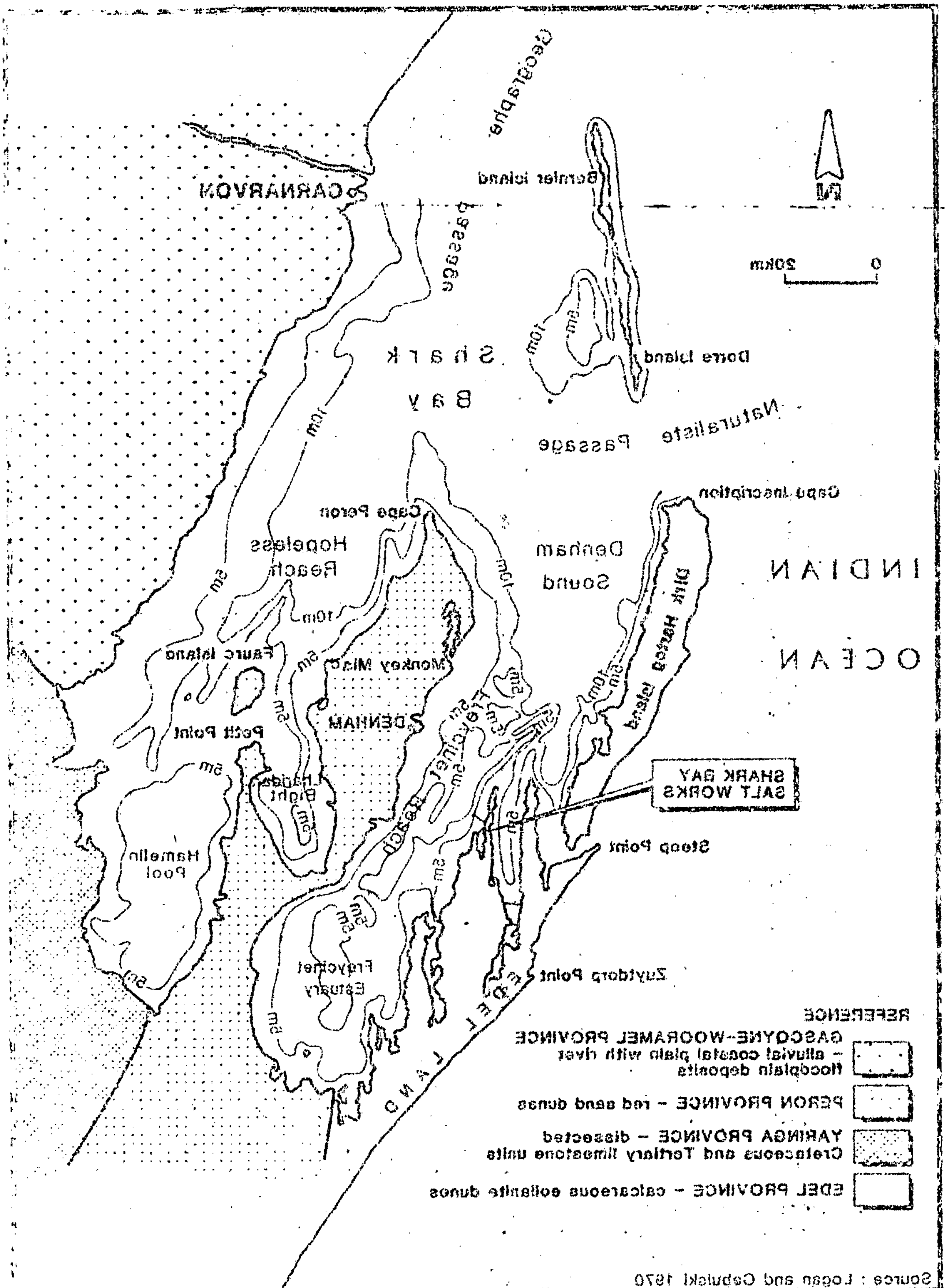
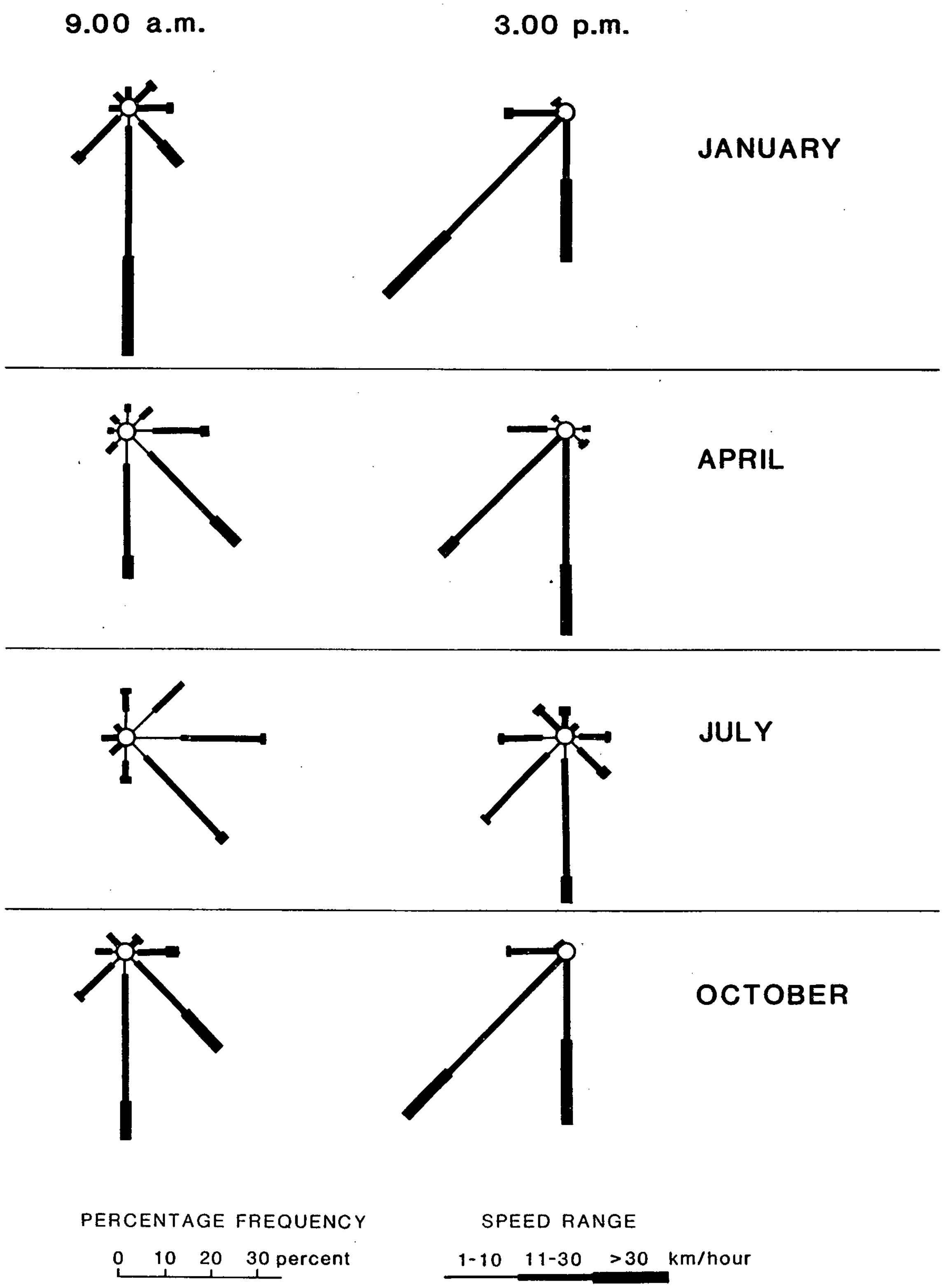


Figure	SHARK BAY SALT JOINT VENTURE **GEOMORPHOLOGY AND BATHYMETRY**	Comp. R.Hillard Drawn Environmental Date June 1990	LeProvost Semeniuk & Chalmer Environmental Consultants



Frequency of calms (wind speed less than 1km/hour) is less than 10% for all roses.
Percentages measured from circumference of circle.

Source : Bureau of Meteorology from records to 1976

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard Drawn : Environmental Date : June 1990	SHARK BAY SALT JOINT VENTURE **WIND ROSES FOR CARNARVON**	Figure **11**

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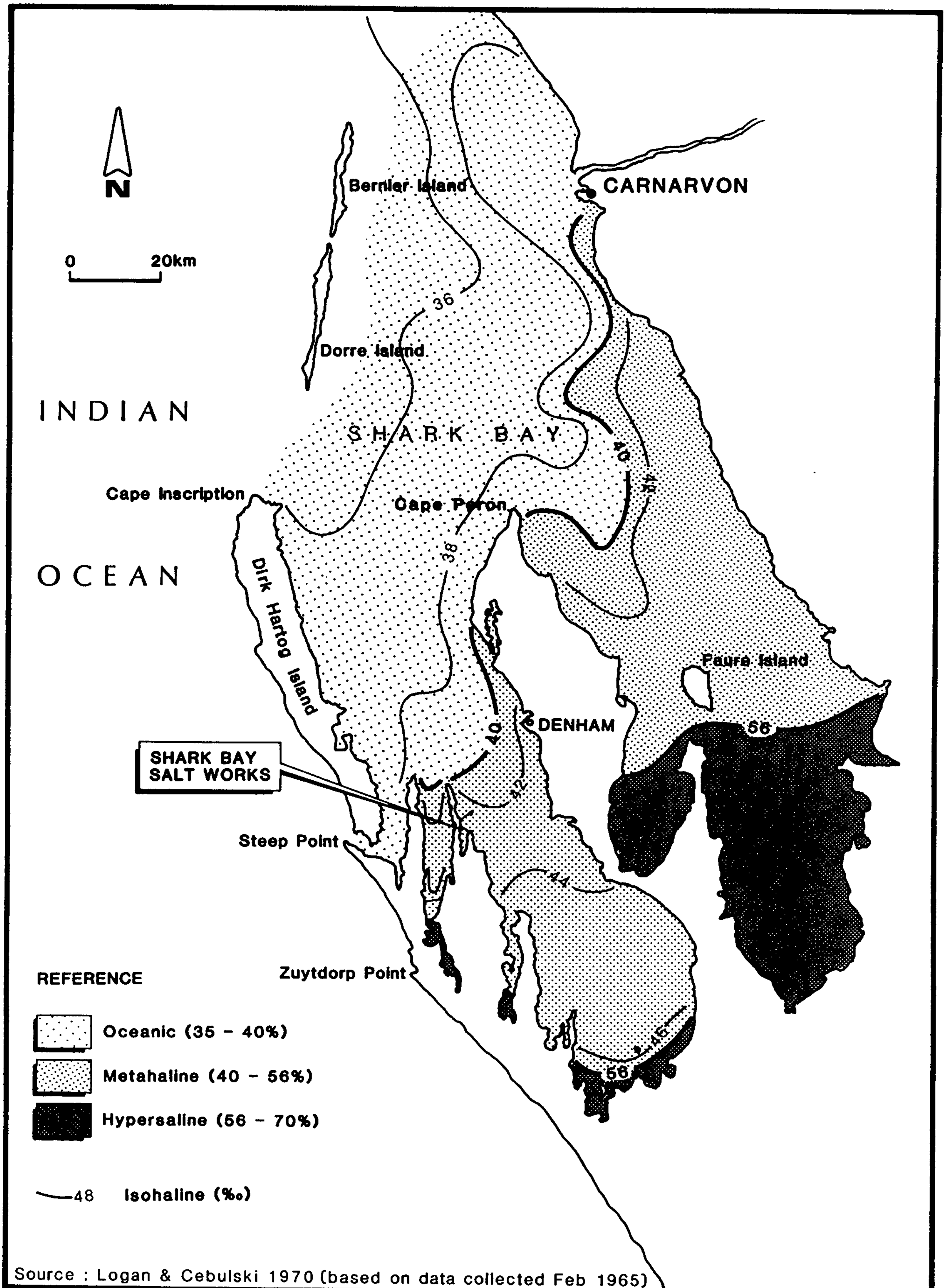

Source : Logan & Cebulski 1970 (based on data collected Feb 1965)

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	BOTTOM SALINITY	12
	Date : June 1990	GENERALISED WATER SALINITY SHARK BAY	

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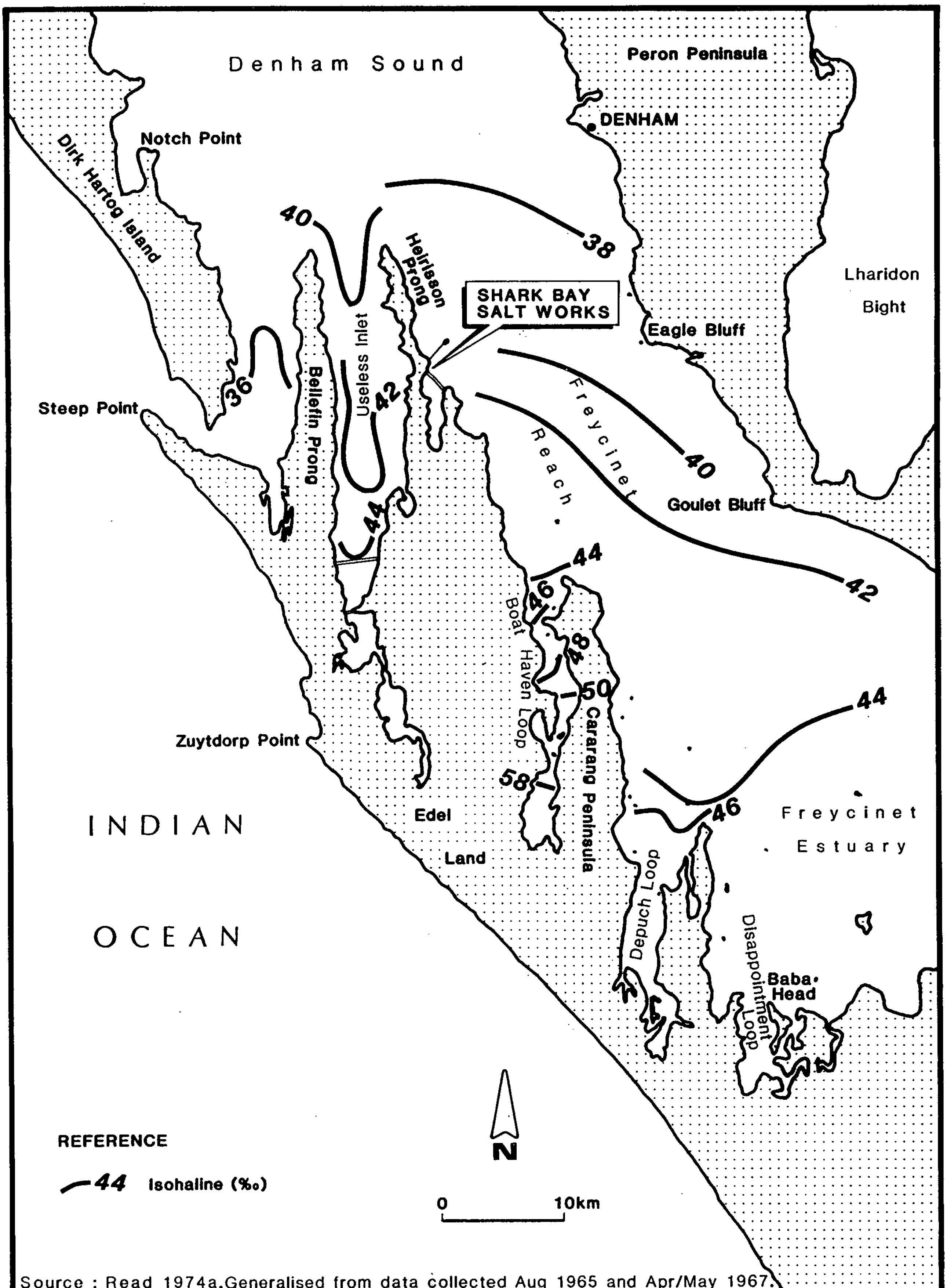

Source : Read 1974a.Generalised from data collected Aug 1965 and Apr/May 1967.

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	SURFACE SALINITY	13
	Date : June 1990	GENERALISED WATER SALINITY EDEL LAND INLETS	

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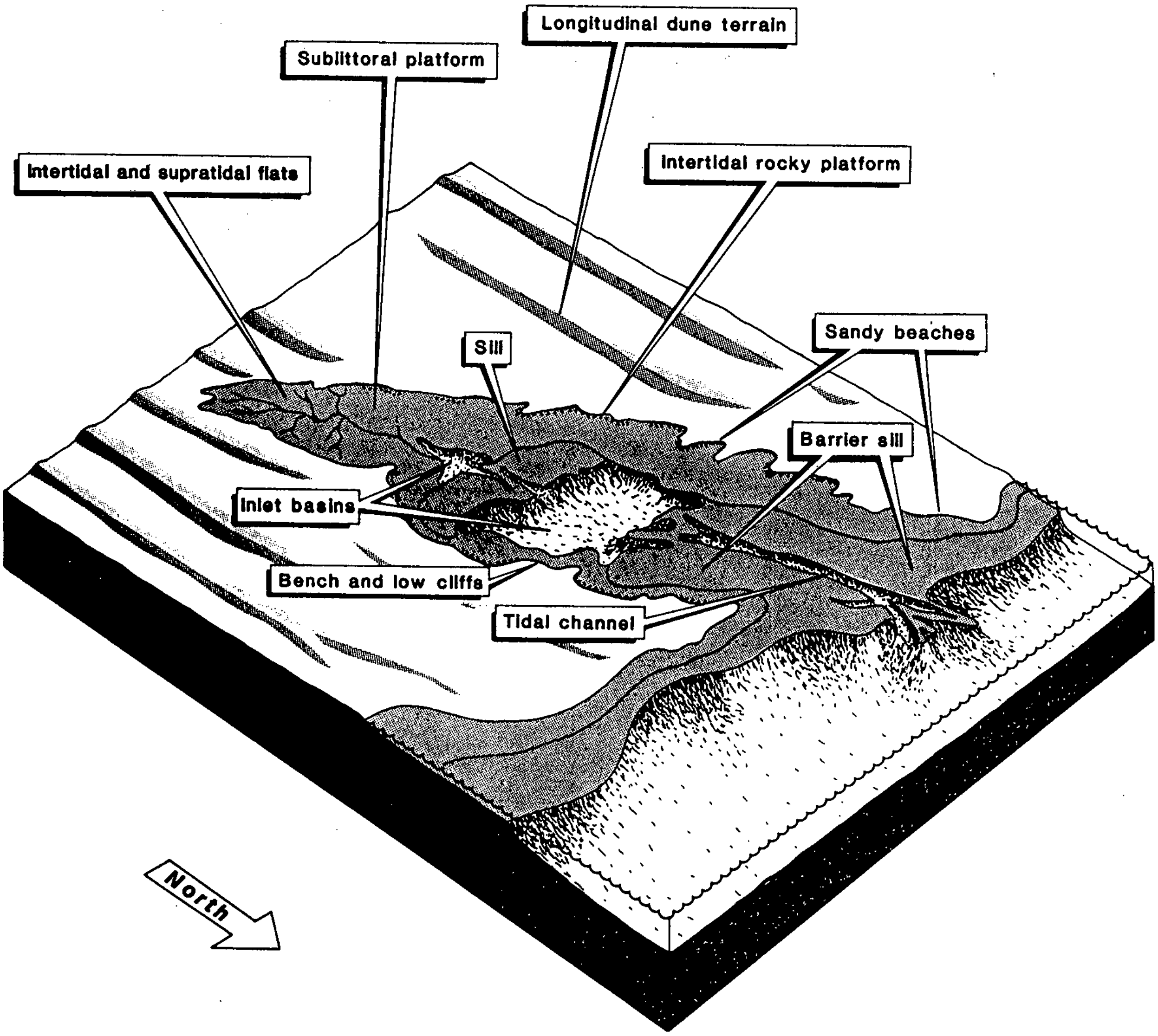

Note : schematic only ; not to scale

Source : Read 1974a

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R. Hilliard Drawn : Environmental Date : June 1990	SHARK BAY SALT JOINT VENTURE SCHEMATIC GEOMORPHOLOGY OF AN EDEL LAND INLET	Figure 14

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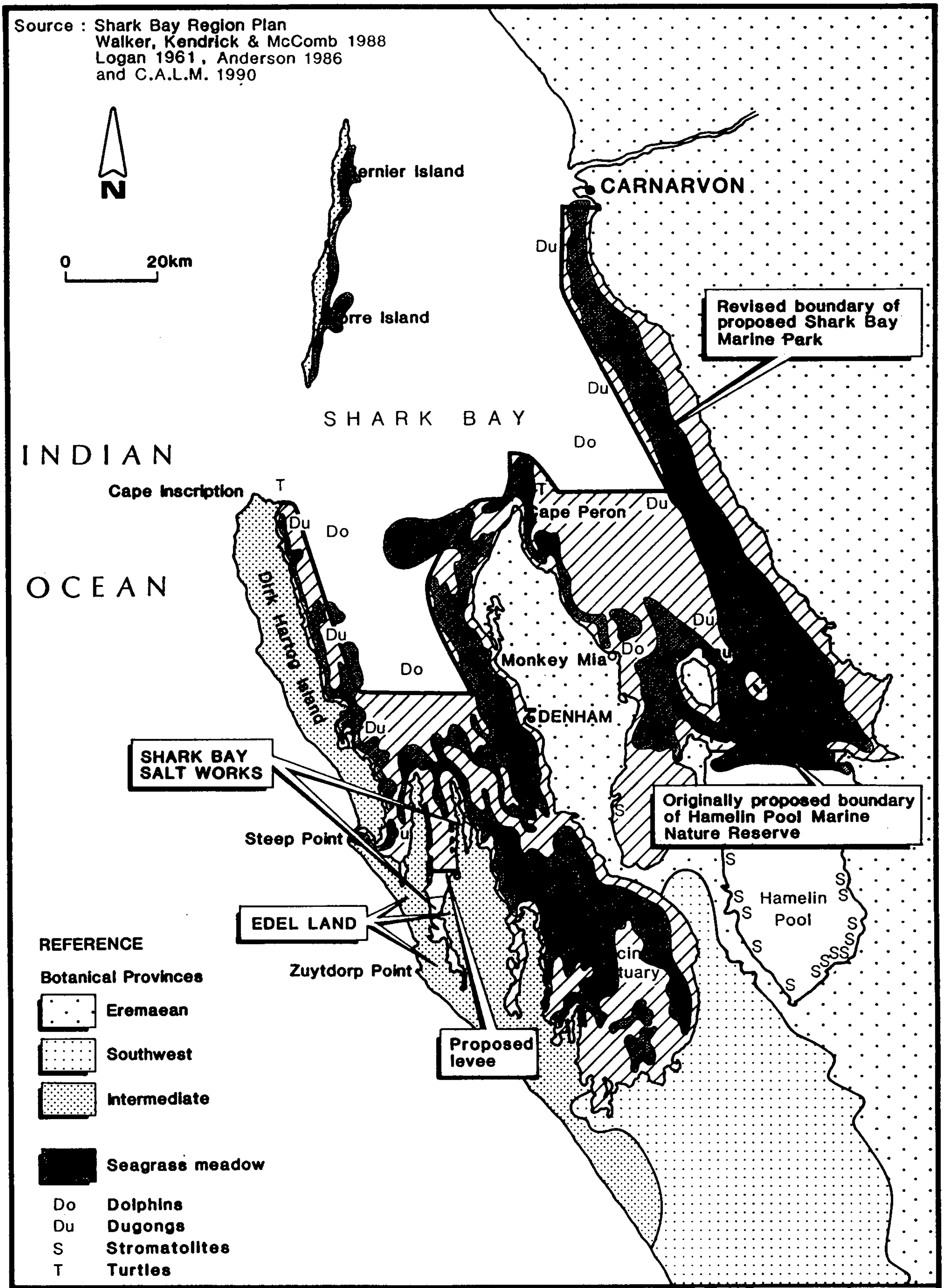

LeProvost Semeniuk & Chalmer Environmental Consultants | Comp : R.Hilliard | Drawn : Environmental | Date : June 1990

SHARK BAY SALT JOINT VENTURE

MARINE AND BOTANICAL RESOURCES

Figure **15**

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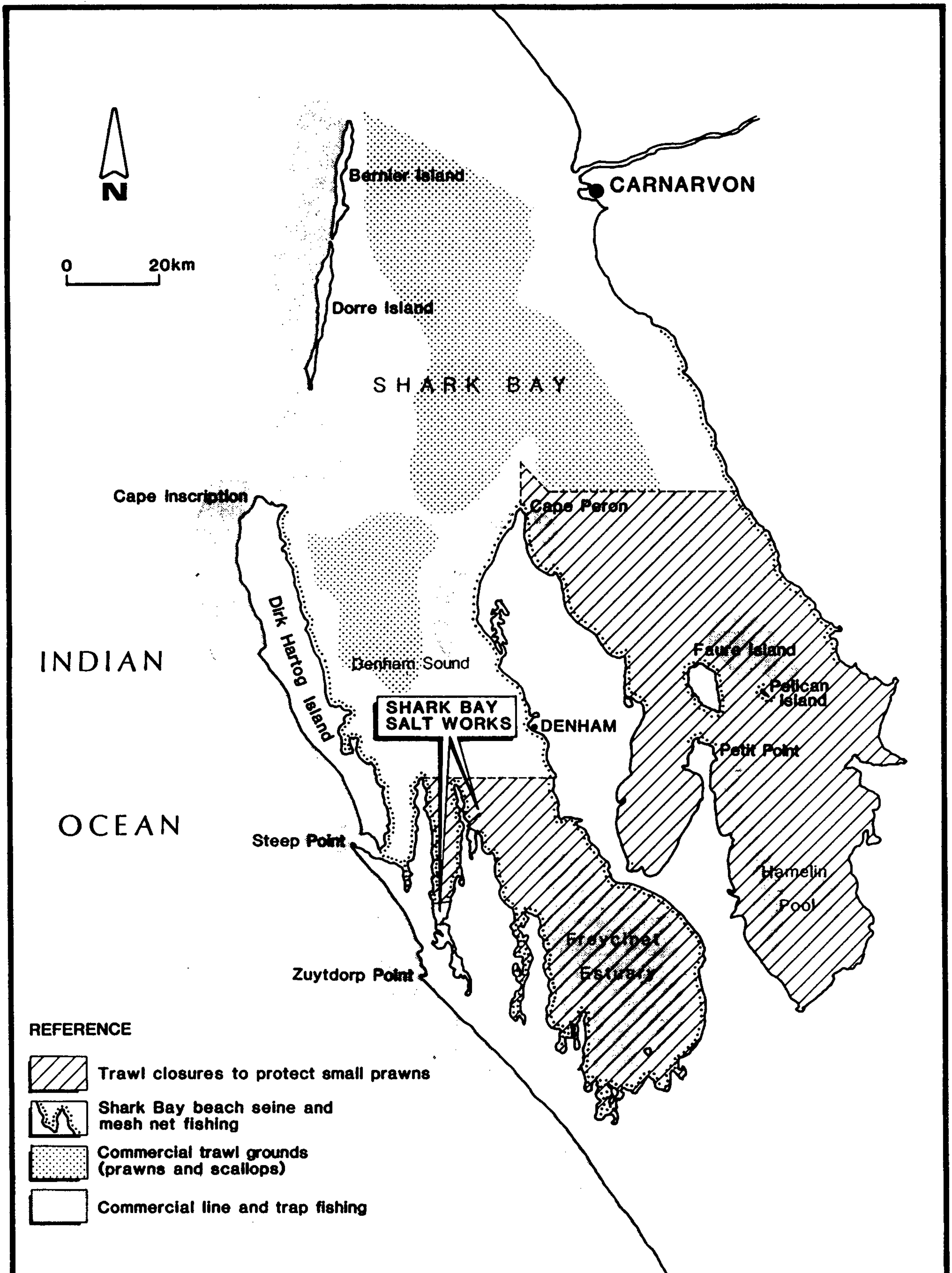

Source : Shark Bay Region Plan

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : R.Hilliard Drawn : Environmental Date : June 1990	SHARK BAY SALT JOINT VENTURE **COMMERCIAL FISHERIES**	Figure **16**

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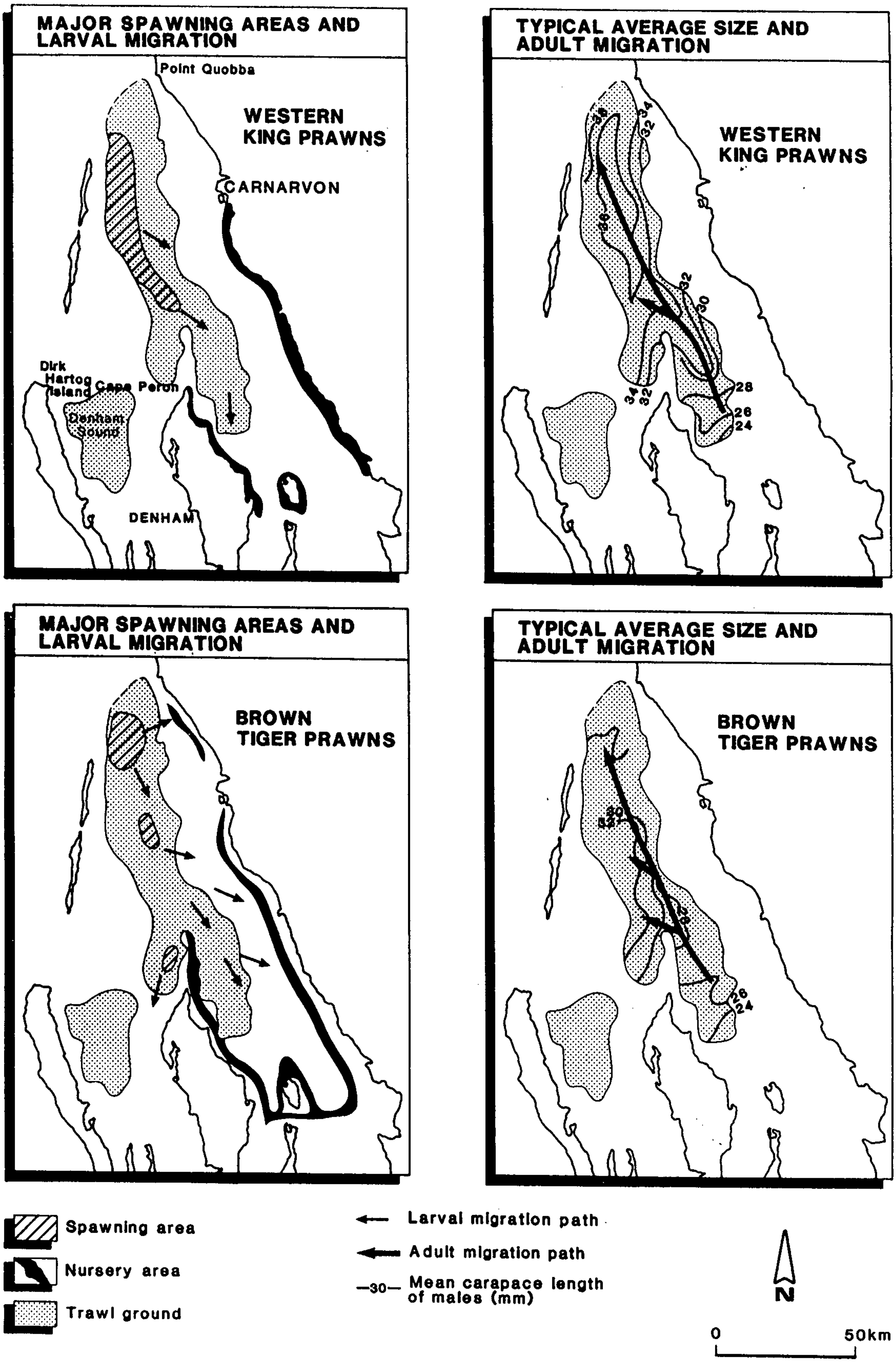

Source : Penn & Stalker 1979
and Shark Bay Region Plan

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp : R. Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	PRAWN SPAWNING, MIGRATING AND TRAWLING AREAS	17
	Date : June 1990		

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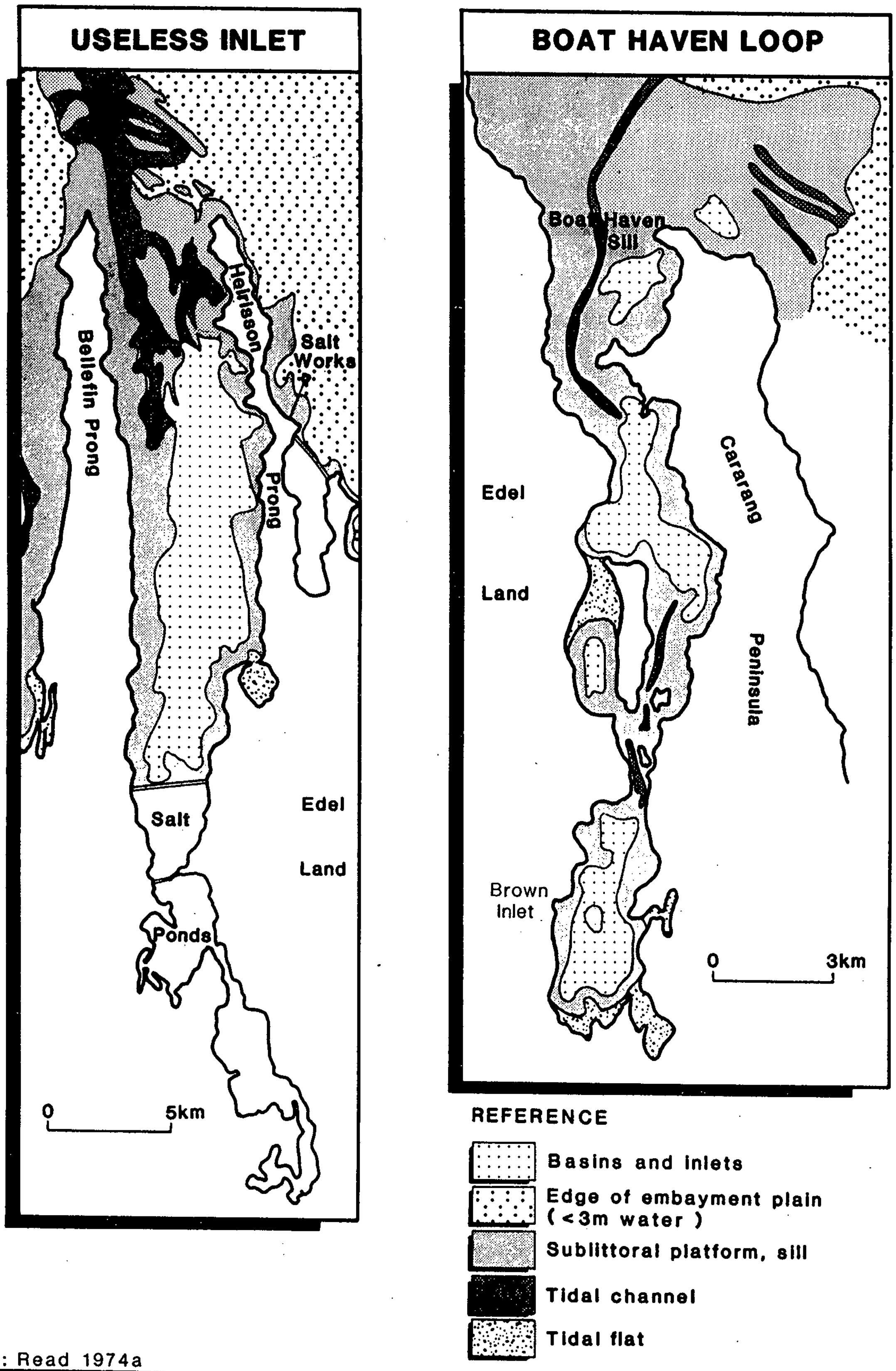

Source : Read 1974a

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	**GEOMORPHIC UNITS**	**18**
	Date : June 1990		

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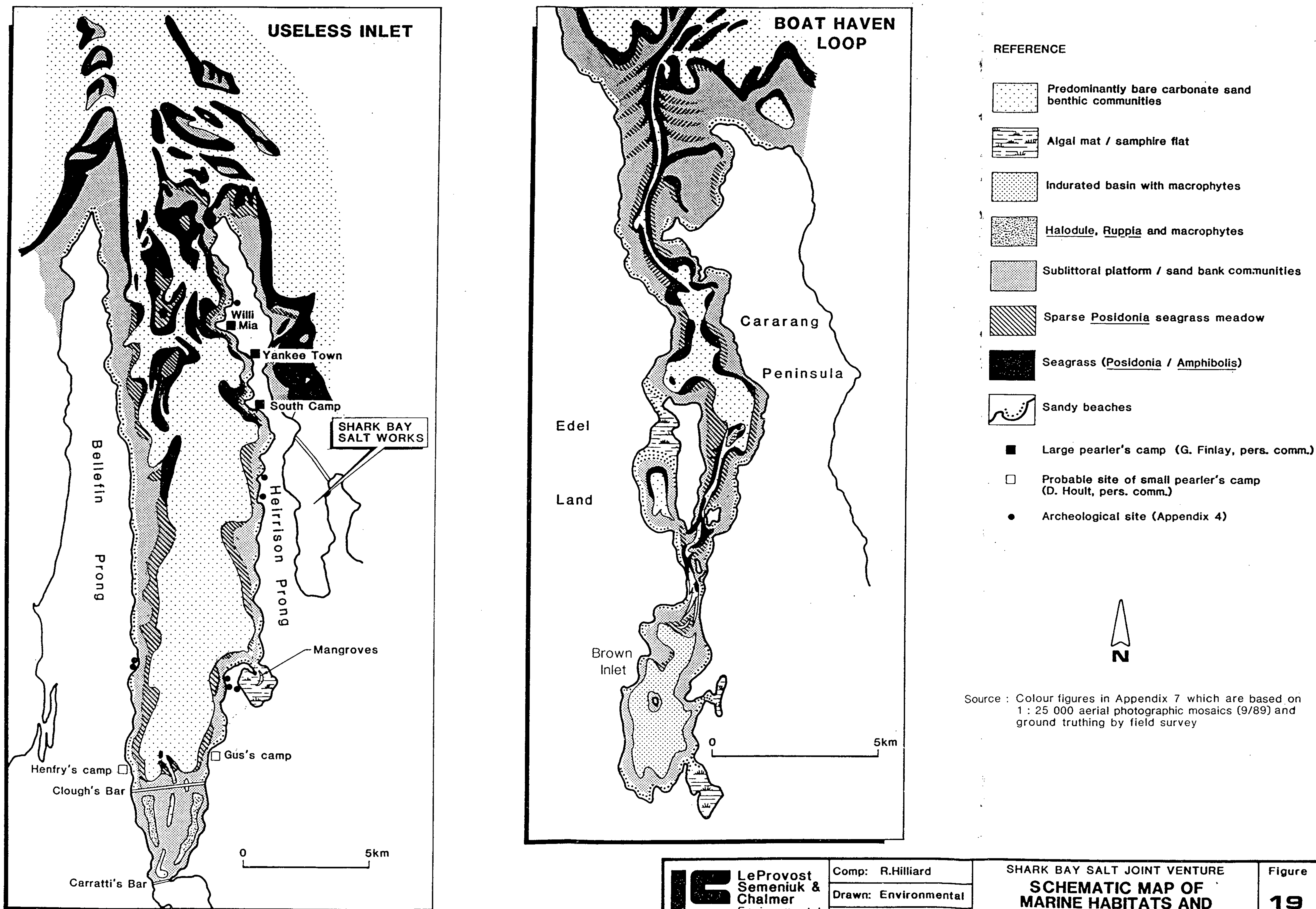

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard Drawn: Environmental Date: June 1990	SHARK BAY SALT JOINT VENTURE **SCHEMATIC MAP OF MARINE HABITATS AND PEARLER'S CAMPS**	Figure **19**

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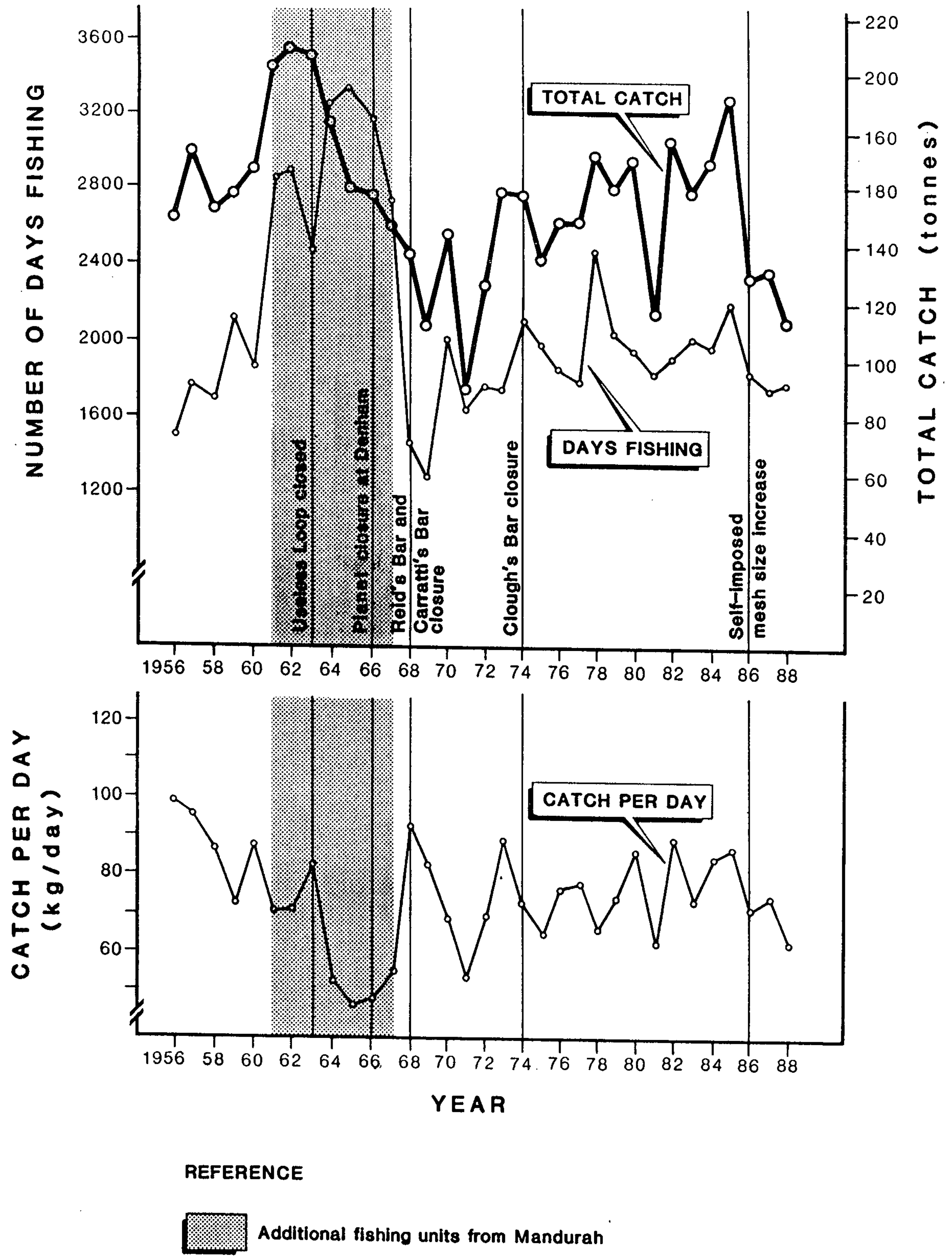

Source : Slack-Smith 1978, Fry 1988 and Lenanton & Cliff (Unpublished data) 1989.

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	**ANNUAL WHITING CATCHES AT DENHAM (1958 TO 1988)**	**20**
	Date June 1990		

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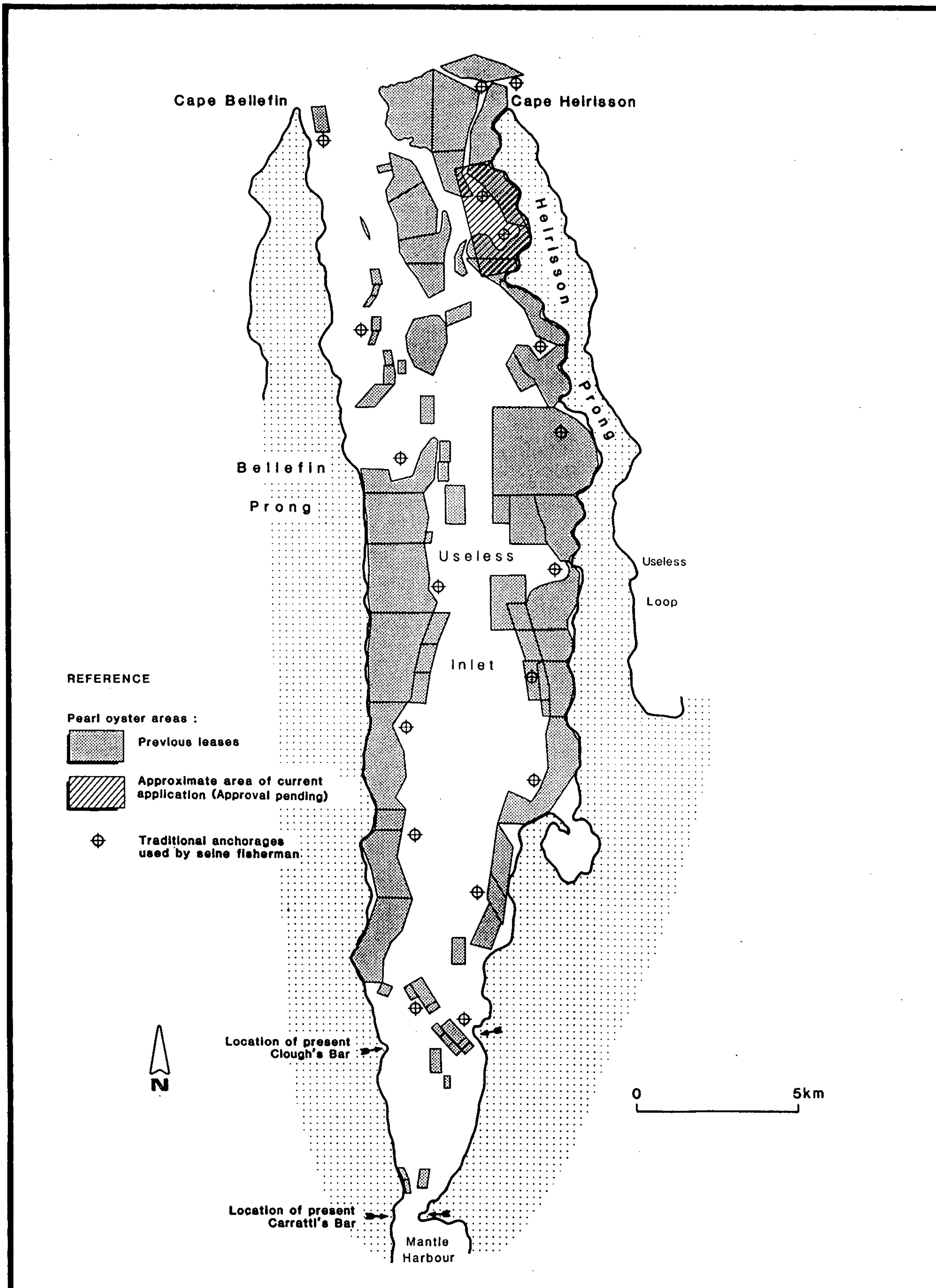

Source : Hancock 1989 and McClaughlan (W.A. Fisheries)

LeProvost Semeniuk & Chalmer Environmental Consultants	Comp: R.Hilliard	SHARK BAY SALT JOINT VENTURE	Figure
	Drawn : Environmental	**OYSTER LEASE AREAS AND FISHERMAN'S ANCHORAGES**	**21**
	Date : June 1990		

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