Yannarie Solar
a **Straits** initiative

ENVIRONMENTAL REVIEW &
MANAGEMENT PROGRAMME

VOLUME ONE

Environmental Review

NOVEMBER 2006

Yannarie Solar
a Straits initiative

ENVIRONMENTAL REVIEW & MANAGEMENT PROGRAMME

VOLUME ONE

Environmental Review

November 2006

Straits Salt Pty Ltd
1st Floor, 35 Ventnor Avenue
West Perth WA 6005
ACN: 107 118 570

Cover Photograph Acknowledgements
Biota: Sandpipers
Oceanica: Whales

INVITATION

Straits Salt Pty Ltd (Straits) is proposing to construct and operate a nominal 10 million tonne per annum (Mtpa) solar saltfield (known as the Yannarie Solar Project) on the eastern margin of the Exmouth Gulf (the Gulf) in Western Australia.

The Environmental Protection Authority (EPA) invites people to participate in the environmental assessment process for the Yannarie Solar Salt proposal. Most of the information about this proposal is included within the main Environmental Review and Management Programme (ERMP) document, which is open for public comment for twelve (12) weeks from **4 December 2006,** closing on **26 February 2007**.

Additional information about:

- Flora and vegetation;
- Subterranean fauna; and,
- Subtidal benthic communities

will be published in the first half of 2007. These supplementary reports will be made available for a further four (4) week public submission period.

Comments from government agencies and from the public will assist the EPA to prepare an assessment report in which it will make recommendations to government. If you are able to, the EPA would welcome electronic submissions in particular, emailed to the project assessment officer or via the EPA's Website (see address below).

WHERE TO GET COPIES OF THIS DOCUMENT

Printed copies of this document may be obtained from Mr James Barrie at Straits Salt Pty Ltd, Level 1, 35 Ventnor Avenue, WEST PERTH WA 6872, (61 8) 9480 0500 at a cost of $10.00.

Copies may also be obtained from http://www.straits.com.au

WHY WRITE A SUBMISSION?

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

All submissions received by the EPA will be acknowledged. Electronic submissions will be acknowledged electronically. The proponent will be required to provide adequate responses to points raised in submissions. In preparing its assessment report for the Minister for the Environment, the EPA will consider the information in submissions, the proponent's responses and other relevant information. Submissions will be treated as public documents unless provided and received in confidence subject to the requirements of the Freedom of Information Act, and may be quoted in full or in part in each report.

WHY NOT JOIN A GROUP?

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

DEVELOPING A SUBMISSION

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

When making comments on specific elements of the ERMP:

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

POINTS TO KEEP IN MIND

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

- attempt to list points so that issues raised are clear. A summary of your submission is helpful;
- refer each point to the appropriate section, chapter or recommendation in the ERMP;
- if you discuss different sections of the ERMP, keep them distinct and separate, so there is no confusion as to which section you are considering; and
- attach any factual information you may wish to provide and give details of the source. Make sure your information is accurate.

Remember to include:

- your name;
- address;
- date; and
- whether and the reason why you want your submission to be confidential.

The closing date for submissions is: 26 February 2007

The EPA prefers submissions to be sent in electronically. You can either e-mail the submission to the following address:

eia@dec.wa.gov.au

OR

use the submission form on the EPA's website:

www.epa.wa.gov.au/submissions.asp

and click on the EIA Assessment Submission option

OR you can post your submission to:

The Chariman
Environmental Protection Authority
PO Box K822
PERTH WA 6842
Attention: Dr Sue Osborne

TABLE OF CONTENTS

CHAPTER 1 INTRODUCTION AND ENVIRONMENTAL ASSESSMENT PROCESS 1-1

1 BACKGROUND 1-1

1.1 PROJECT OVERVIEW 1-1

1.1.1 Salt production 1-1

1.1.2 Production stages 1-2

1.2 ENVIRONMENTAL REVIEW AFTER 10 YEARS 1-2

1.3 THE PROPONENT 1-4

1.4 PURPOSE OF THIS DOCUMENT 1-6

1.4.1 Structure of this document 1-6

2 ENVIRONMENTAL IMPACT ASSESSMENT PROCESS 1-7

2.1 COMMONWEALTH AND WESTERN AUSTRALIAN IMPACT ASSESSMENT AND APPROVAL 1-7

2.1.1 Referral and level of assessment 1-7

2.1.2 Public review and EPA assessment of ERMP 1-7

2.1.3 Ministerial consideration 1-8

2.2 OTHER RELEVANT COMMONWEALTH AND WESTERN AUSTRALIAN LEGISLATION, REGULATIONS AND POLICIES 1-9

2.2.1 Commonwealth legislation and policies 1-9

2.2.2 State Legislation, policies and guidelines 1-10

CHAPTER 2 SUSTAINABILITY, STAKEHOLDER CONSULTATION AND THE PROPOSAL 2-1

1 SUSTAINABILITY 2-1

1.1 NATIONAL APPROACH TO SUSTAINABILITY 2-1

1.2 WESTERN AUSTRALIAN APPROACH TO SUSTAINABILITY 2-1

1.3 PROJECT SUSTAINABILITY 2-2

1.3.1 Project sustainability principles and outcomes 2-2

2 STAKEHOLDER CONSULTATION 2-13

2.1 CONSULTATION PROGRAM 2-13

2.2 FUTURE CONSULTATION 2-17

3 THE PROPOSAL 2-19

3.1 PROJECT JUSTIFICATION 2-19

3.1.1 Markets, demand and supply 2-19
3.1.2 Sources of salt 2-20

3.2 STATE AND REGIONAL BENEFITS 2-21

3.3 EVALUATION OF ALTERNATIVE SITES 2-21

3.3.1 The no development option 2-22

3.4 KEY CHARACTERISTICS 2-23

3.5 SALT PRODUCTION PROCESS 2-26

3.6 SITE ACCESS AND HAUL ROADS 2-29

3.7 SEAWATER AND FRESHWATER WATER SUPPLIES 2-31

3.7.1 Freshwater source 2-31
3.7.2 Seawater supply for ponds and processing 2-31
3.7.3 Seawater conveyance 2-33

3.8 CONCENTRATOR AND CRYSTALLISER PONDS 2-34

3.8.1 Sea level change 2-34
3.8.2 External and internal levee design 2-34

3.9 SOURCE OF LEVEE CORE AND SURFACE AND ROAD MATERIALS 2-37

3.9.1 Clay 2-37
3.9.2 Rock armour 2-37
3.9.3 Barge harbour and barge and ship loading 2-39
3.9.4 Location of barge harbour 2-39
3.9.5 Ship loading/unloading 2-39
3.9.6 Fuel storage 2-41
3.9.7 Power 2-41
3.9.8 Salt Harvesting and Materials Handling 2-41

CHAPTER 3 ENVIRONMENTAL IMPACT ASSESSMENT AND MANAGEMENT 3-1

1 IMPACT ASSESSMENT APPROACH 3-1

1.1 SCOPING OF THE ASSESSMENT 3-1

1.1.1 Departure from approved Scoping Document 3-3

1.2 ENVIRONMENTAL REVIEW STRUCTURE FOR RELEVANT ENVIRONMENTAL FACTORS 3-3

2 STRAIT'S ENVIRONMENTAL MANAGEMENT APPROACH 3-5

2.1 ENVIRONMENTAL POLICY 3-5

2.2 ENVIRONMENTAL MANAGEMENT SYSTEM 3-5

2.3 PROJECT SPECIFIC SUSTAINABILITY PRINCIPLES 3-5

2.4 PUBLIC REPORTING, TRANSPARENCY AND COMMUNITY INVOLVEMENT 3-6

3 MINOR ENVIRONMENTAL FACTORS 3-7

3.1 GREENHOUSE GASES 3-7

3.1.1 Management 3-7

3.2 WORLD HERITAGE AREA NOMINATION 3-8

3.3 SUBTERRANEAN FAUNA 3-8

3.3.1 EPA objective 3-8

3.3.2 Legislative policy and context 3-8

3.3.3 Background 3-8

3.3.4 Investigations 3-9

3.3.5 Management 3-9

3.3.6 Proponent commitment 3-10

3.4 SOLID AND LIQUID WASTE DISPOSAL 3-10

CHAPTER 4 OVERVIEW OF THE REGION AND ECOSYSTEM 4-1

1 OVERVIEW OF THE REGION 4-1

1.1 SOCIO-ECONOMIC SETTING 4-1

1.1.1 Gascoyne Region 4-1

1.1.2 Existing land uses 4-1

1.1.3 Aboriginal heritage 4-6

1.1.4 European heritage 4-6

2 OVERVIEW OF EXMOUTH GULF ECOSYSTEM – INTEGRATION OF KEY ENVIRONMENTAL FACTORS 4-7

2.1 SEA LEVEL CHANGE AND LANDFORM DEVELOPMENT 4-7

2.2 GULF WIDE PROCESSES 4-7

2.2.1 Linkages between Exmouth Gulf and Ningaloo Marine Park 4-7
2.2.2 Influence of tides and winds 4-9
2.2.3 Influence of extreme storm events 4-10
2.2.4 Long-term sea level change 4-10
2.2.5 Hydrology, hydrogeology and groundwater system on the eastern side of the Gulf 4-11
2.2.6 Nutrient inputs and cycling 4-14
2.2.7 Potentially significant anthropogenic influences 4-15

2.3 GULF AREA BELOW LOW TIDE MARK 4-17

2.3.1 Bathymetry 4-17
2.3.2 Benthic habitat and Gulf fauna 4-17
2.3.3 Water and sediment quality 4-18

2.4 INTERTIDAL ZONE – AREA BETWEEN THE LOW AND HIGH TIDES 4-18

2.4.1 Algal mats and mangroves 4-20
2.4.2 Tidal creeks 4-21

2.5 SUPRATIDAL SALT FLATS 4-21

2.5.1 Hinterland (dunefield and outwash plain) 4-22

CHAPTER 5 TERRESTRIAL FACTORS 5-1

1 SOILS AND LANDFORMS 5-1

1.1 EPA OBJECTIVES 5-1

1.2 LEGISLATIVE AND POLICY CONTEXT 5-1

1.2.1 Relevant guidelines 5-1

1.3 DESCRIPTION OF LANDFORM AND SOILS 5-2

1.3.1 Investigations 5-2
1.3.2 Outwash plain 5-4
1.3.3 Dunefield 5-4
1.3.4 Supratidal salt flat 5-6

1.4 IMPACT ASSESSMENT AND MITIGATION 5-9

1.4.1 Environmental aspects and potential impacts 5-9

1.4.2 Assessment and management 5-10
1.5 MONITORING AND ASSESSMENT OF PERFORMANCE 5-13
1.6 PROPONENT COMMITMENTS 5-13
1.7 ENVIRONMENTAL OUTCOME 5-14
2 GROUNDWATER 5-15
2.1 EPA OBJECTIVE 5-15
2.2 LEGISLATIVE AND POLICY AND CONTEXT 5-15
2.2.1 Abstraction 5-15
2.2.2 Environmental water provisions 5-15
2.2.3 Water quality 5-16
2.3 DESCRIPTION OF GROUNDWATER 5-16
2.3.1 Investigations 5-16
2.3.2 Outwash Plain 5-16
2.3.3 Dunefield 5-18
2.3.4 Supratidal salt flat 5-18
2.4 IMPACT ASSESSMENT AND MITIGATION 5-21
2.4.1 Environmental aspects and potential impacts 5-21
2.4.2 Relevant aspects and potential impacts 5-21
2.4.3 Assessment and management 5-22
2.5 MONITORING AND ASSESSMENT OF PERFORMANCE 5-26
2.6 PROPONENT COMMITMENTS 5-26
2.7 ENVIRONMENTAL OUTCOME 5-27
3 SURFACE WATER 5-29
3.1 EPA OBJECTIVES 5-29
3.2 LEGISLATIVE AND POLICY CONTEXT 5-29
3.2.1 Pollution prevention 5-29
3.2.2 Environmental water provisions 5-29
3.2.3 Water quality 5-30
3.3 DESCRIPTION OF SURFACE WATER 5-30
3.3.1 Investigations 5-30
3.3.2 Overall 5-30
3.3.3 Watercourses 5-30
3.3.4 Flood plain 5-35

3.3.5 Discharge outlets 5-35
3.3.6 Supratidal saltflat 5-38
3.3.7 Water quality 5-39
3.4 IMPACT ASSESSMENT AND MITIGATION 5-39
3.4.1 Environmental aspects and potential impacts 5-39
3.4.2 Assessment and management 5-39
3.5 MONITORING AND ASSESSMENT OF PERFORMANCE 5-49
3.6 PROPONENT COMMITMENTS 5-49
3.7 ENVIRONMENTAL OUTCOME 5-49
4 TERRESTRIAL VEGETATION AND FLORA 5-51
4.1 EPA OBJECTIVE 5-51
4.2 LEGISLATIVE AND POLICY AND CONTEXT 5-51
4.2.1 Significance 5-51
4.2.2 National policy 5-51
4.2.3 EPA position statements 5-52
4.2.4 Statutory requirements 5-53
4.3 DESCRIPTION OF TERRESTRIAL VEGETATION AND FLORA 5-53
4.3.1 Baseline surveys 5-53
4.3.2 General vegetation description 5-54
4.3.3 Species representation 5-58
4.3.4 Vegetation and flora of conservation significance 5-59
4.3.5 Vegetation condition 5-61
4.3.6 Exotic flora 5-61
4.4 IMPACT ASSESSMENT AND MITIGATION 5-62
4.4.1 Environmental aspects and potential impacts 5-62
4.4.2 Assessment and management 5-62
4.5 MONITORING AND ASSESSMENT OF PERFORMANCE 5-69
4.6 PROPONENT COMMITMENTS 5-69
4.7 ENVIRONMENTAL OUTCOME 5-69
5 TERRESTRIAL FAUNA 5-71
5.1 EPA OBJECTIVE 5-71
5.2 LEGISLATIVE POLICY AND CONTEXT 5-71
5.2.1 Environment Protection and Biodiversity Conservation Act 1999 5-71

5.2.2 Statutory requirements 5-72
5.2.3 International agreements 5-72
5.2.4 EPA Guidance Statement No. 56 5-72
5.3 DESCRIPTION OF TERRESTRIAL FAUNA 5-72
5.3.1 Investigations 5-72
5.3.2 Fauna habitat 5-77
5.3.3 Summary of fauna abundance 5-77
5.3.4 Birds 5-78
5.3.5 Mangrove fauna 5-84
5.3.6 Mammals 5-85
5.3.7 Reptiles 5-85
5.3.8 Amphibians 5-86
5.3.9 Invertebrates 5-86
5.3.10 Significant species 5-86
5.3.11 Exotic species 5-90
5.4 ASSESSMENT AND MITIGATION OF POTENTIALLY SIGNIFICANT IMPACTS 5-91
5.4.1 Potential impacts 5-91
5.4.2 Assessment and management of potential impacts 5-91
5.5 MONITORING AND ASSESSMENT OF PERFORMANCE 5-94
5.6 PROPONENT COMMITMENTS 5-94
5.7 ENVIRONMENTAL OUTCOME 5-95

CHAPTER 6 MARINE FACTORS 6-1

1 MARINE WATER AND SEDIMENT QUALITY 6-1
1.1 SEDIMENT QUALITY 6-1
1.2 LEGISLATIVE AND POLICY AND CONTEXT 6-1
1.2.1 National Water Quality Management Strategy Australian and New Zealand Guidelines for Fresh and Marine Water Quality 6-1
1.2.2 EPA Environmental Quality Management Framework and protection for Exmouth Gulf 6-2
1.3 DESCRIPTION OF CIRCULATION, CURRENTS AND MARINE WATER AND SEDIMENT QUALITY 6-3
1.3.1 Regional context 6-3
1.3.2 Circulation and currents 6-6
1.3.3 Sediment quality 6-9

1.3.4 Water quality 6-14
1.4 IMPACT ASSESSMENT AND MITIGATION 6-16
1.4.1 Current human influence 6-16
1.4.2 Environmental aspects and potential impacts 6-16
1.4.3 Assessment and management of turbidity arising from dredging and ship and barge movements 6-17
1.4.4 Assessment and management of potential oil spills 6-18
1.5 MONITORING AND ASSESSMENT OF PERFORMANCE 6-18
1.5.1 Dredging and ship and barge movements 6-18
1.6 PROPONENT COMMITMENTS 6-19
1.7 ENVIRONMENTAL OUTCOME 6-19
2 BENTHIC PRIMARY PRODUCER HABITAT AND ECOLOGICAL INTEGRITY 6-21
2.1 BENTHIC PRIMARY PRODUCERS AND HABITAT 6-21
2.2 MARINE WETLANDS 6-22
2.3 LEGISLATIVE AND POLICY CONTEXT 6-23
2.3.1 Statutory framework 6-23
2.3.2 Recommended marine conservation areas 6-23
2.4 DESCRIPTION OF INTERTIDAL HABITAT (MANGROVES & ALGAL MATS) 6-24
2.4.1 Pre-existing impacts on habitat 6-24
2.4.2 Mangroves 6-25
2.4.3 Algal mats 6-32
2.5 DESCRIPTION OF SUBTIDAL HABITAT (SEAGRASSES, ALGAL BEDS, SPONGES & CORALS) 6-37
2.5.1 Investigations 6-37
2.5.2 Description 6-39
2.6 IMPACT ASSESSMENT AND MITIGATION 6-42
2.6.1 Proposed management units for assessment of impact on BPPH 6-42
2.6.2 Environmental aspects and potential impacts 6-44
2.6.3 Assessment and management of clearing impacts on mangroves and algal mats (intertidal BPPH) 6-44
2.6.4 Assessment and management of potential hydrodynamic changes caused by infrastructure and pumping of seawater 6-50
2.6.5 Assessment and management of impacts arising from changes to water flows on subtidal BPPH 6-60
2.6.6 Assessment and management of saline water seepage from the saltfield on mangroves and algal mats 6-69

2.6.7 Assessment and management of impacts from changes to surface hydrology and water contamination on mangroves and algal mats 6-70
2.6.8 Assessment and management of clearing and dredging impacts on subtidal BPPH 6-70
2.6.9 Assessment and management of turbidity impacts on subtidal BPPH 6-72
2.6.10 Assessment and management of salt spills 6-83
2.6.11 Assessment and management of oil spills on subtidal BPPH 6-83
2.6.12 Conformance with principles in EPA Guidance Statement No. 29 6-86
2.7 MONITORING AND ASSESSMENT OF PERFORMANCE 6-89
2.8 PROPONENT COMMITMENTS 6-89
2.9 ENVIRONMENTAL OUTCOME 6-90
3 MARINE FAUNA 6-93
3.1 EPA OBJECTIVE 6-93
3.2 LEGISLATIVE POLICY AND CONTEXT 6-93
3.2.1 Statutory framework 6-93
3.2.2 Policy framework 6-93
3.3 DESCRIPTION OF MARINE FAUNA 6-94
3.3.1 Protected marine fauna 6-94
3.3.2 Sea turtles 6-96
3.3.3 Whales 6-100
3.3.4 Dugongs 6-108
3.3.5 Sharks and rays 6-109
3.3.6 Sea snakes 6-111
3.3.7 Fish 6-111
3.3.8 Prawns 6-112
3.3.9 Benthic macrofauna 6-114
3.4 IMPACT ASSESSMENT AND MITIGATION 6-115
3.4.1 Pre-existing impacts on marine fauna 6-115
3.4.2 Environmental aspects and potential impacts 6-117
3.4.3 Assessment and management of habitat loss and modification 6-117
3.4.4 Assessment and management of dredging 6-118
3.4.5 Assessment and management of seawater pumping 6-119
3.4.6 Assessment and management of the effects of noise and vibration from barge and ship movements 6-127
3.4.7 Assessment and management of marine vessel avoidance 6-131
3.4.8 Assessment and management of water contamination due to loss of anti-foulants from vessels 6-133

3.4.9 Assessment and management of potential introduction of non-indigenous marine species by marine vessels 6-134
3.4.10 Assessment and management of light spill 6-140
3.5 MONITORING AND ASSESSMENT OF PERFORMANCE 6-141
3.6 PROPONENT COMMITMENTS 6-141
3.7 ENVIRONMENTAL OUTCOME 6-142

CHAPTER 7 SOCIAL SURROUNDS 7-1

1 COMMERCIAL FISHING AND AQUACULTURE 7-1
1.1 LEGISLATIVE AND POLICY CONTEXT 7-1
Legislation 7-1
1.2 DESCRIPTION OF COMMERCIAL FISHING AND AQUACULTURE 7-2
1.2.1 Commercial fishing 7-2
1.2.2 Aquaculture 7-4
1.3 IMPACT ASSESSMENT AND MITIGATION 7-5
1.3.1 Environmental aspects and potential impacts 7-5
1.3.2 Assessment and management 7-5
1.4 MONITORING AND ASSESSMENT OF PERFORMANCE 7-10
1.5 PROPONENTS COMMITMENTS 7-10
1.6 ENVIRONMENTAL OUTCOMES 7-10
2 RECREATION AND ECOTOURISM 7-11
2.1 EPA OBJECTIVE 7-11
2.2 LEGISLATIVE POLICY AND CONTEXT 7-11
2.2.1 Relevant guidance 7-11
2.3 DESCRIPTION OF RECREATION AND ECOTOURISM 7-11
2.3.1 Recreational use 7-11
2.3.2 Ecotourism 7-14
2.3.3 Landscape and aesthetics 7-14
2.4 IMPACT ASSESSMENT AND MITIGATION 7-14
2.4.1 Environmental aspects and potential impacts 7-14
2.4.2 Assessment and management 7-14

2.5 MONITORING AND ASSESSMENT OF PERFORMANCE 7-16
2.6 PROPONENTS COMMITMENTS 7-16
2.7 ENVIRONMENTAL OUTCOMES 7-16
3 CULTURAL HERITAGE AND CONSERVATION VALUES 7-17
3.1 EPA OBJECTIVES 7-17
3.2 LEGISLATIVE AND POLICY CONTEXT 7-17
3.2.1 Aboriginal heritage 7-17
3.2.2 European heritage 7-18
3.3 DESCRIPTION OF CULTURAL HERITAGE AND CONSERVATION VALUES 7-18
3.3.1 Background 7-18
3.3.2 Aboriginal heritage 7-19
3.3.3 European heritage 7-24
3.3.4 Conservation values 7-24
3.4 IMPACT ASSESSMENT AND MITIGATION 7-28
3.4.1 Environmental aspects and potential impacts 7-28
3.4.2 Assessment and management – Aboriginal heritage 7-28
3.4.3 Assessment and management – Conservation values 7-28
3.5 MONITORING AND ASSESSMENT OF PERFORMANCE 7-29
3.6 PROPONENTS COMMITMENTS 7-29
3.7 ENVIRONMENTAL OUTCOME 7-29
4 REFERENCES 7-31
5 SHORT TITLES AND ACRONYMS 7-47

LIST OF TABLES

Table 1-1 Key contact details 1-4
Table 2-1 Scope of environmental and socio-economic investigations 2-4
Table 2-2 Mitigation measures to achieve sustainability outcome 2-5
Table 2-3 Comparison with EPA provisional sustainability criteria 2-10
Table 2-4 Key stakeholder concerns 2-14

Table 2-5	Membership of the stakeholder liaison groups	2-14
Table 2-6	Meetings with Non Government Organisations	2-15
Table 2-7	State Government consultation	2-16
Table 2-8	DEH consultation	2-17
Table 2-9	Salt applications	2-19
Table 2-10	Total salt imported into the Asian market in 2005	2-20
Table 2-11	Key project characteristics	2-25
Table 2-12	Seawater requirements for reverse osmosis plant and dust suppression	2-31
Table 2-13	Estimated material quantities for 10 Mtpa saltfield construction	2-37
Table 3-1	Scoping document and ERMP relevant environmental factors and investigations	3-1
Table 3-2	Summary of potential environmental impacts associated with solid and liquid waste production	3-10
Table 4-1	Profile of the human environment in Shire of Exmouth and Town of Onslow	4-2
Table 5-1	Acid sulphate soil generating potential for each geomorphic zone (Parsons Brinkerhoff 2005n)	5-12
Table 5-2	Estimated peak flows and volumes of Yannarie River and Rouse Creek	5-33
Table 5-3	Outlet discharge summary to supratidal flat during major storms	5-35
Table 5-4	Outlet discharge summary to supratidal flat during minor storms	5-38
Table 5-5	Species rich flora families in the project area (brackets represent number of weed species)	5-59
Table 5-6	Reservation priority ecosystems within the Cape Range subregion as they relate to the project area	5-60
Table 5-7	Condition of vegetation types surveyed within the project area	5-61
Table 5-8	Estimated clearing of vegetation types (excluding mangroves) surveyed by Biota (2005a) for northern saltfield and saltfield infrastructure	5-64
Table 5-9	Estimated clearing of vegetation types interpolated from Land Systems Mapping for southern saltfield and hinterland infrastructure (other than that surveyed by Biota, 2005a)	5-65
Table 5-10	Summary of survey sites by broad habitat units present in the project area and native mammals	5-77
Table 5-11	Number of vertebrate fauna species recorded during the Yannarie Solar fauna surveys	5-78

Table 5-12	Littoral birds recorded and maximum count for each species	5-80
Table 5-13	Fauna species of conservation significance potentially occurring and the likelihood of occurrence within the project study area	5-87
Table 5-14	Predicted habitat clearing for infrastructure requirements for the Yannarie Solar Project	5-91
Table 6-1	Tidal levels (values above Chart Datum in metres) at Exmouth and Hope Point	6-5
Table 6-2	Summary of nutrient sediment results (Oceanica 2006a)	6-11
Table 6-3	Summary of nutrient and carbon in sediment (mg/kg)	6-11
Table 6-4	Acid sulphate soil analyses	6-11
Table 6-5	Summary of metal concentrations in sediments (mg/kg)	6-12
Table 6-6	Summary of metal concentrations in sediments	6-13
Table 6-7	Summary of east Gulf coast salinity results (ppt)	6-14
Table 6-8	Mangrove associations recorded from the Yannarie Solar Project area in 2005	6-29
Table 6-9	Average algal mat and mangrove vertical ranges and inundation	6-36
Table 6-10	Estimated clearing of mangrove associations and algal mat for permanent saltfield infrastructure	6-45
Table 6-11	Suspended sediment concentrations recorded on the east coast of Exmouth Gulf	6-73
Table 6-12	Characteristics and movements of vessels associated with the Straits Solar Project	6-80
Table 6-13	Summary of shipping activity and hydrocarbons associated with the Straits Solar Project	6-84
Table 6-14	Current areas and losses of intertidal BPPH in proposed management units along the east coast of Exmouth Gulf	6-87
Table 6-15	Marine species listed under State legislation and marine species listed as Matters of National Significance under Commonwealth legislation (accessed July 2005) for Exmouth Gulf region (excluding birds)	6-94
Table 6-16	Results of Exmouth Gulf aerial dugong surveys	6-109
Table 6-17	Summary of pumping for southern seawater intake at full production of 10 Mtpa (Dean's Creek)	6-120
Table 6-18	Summary of pumping for northern seawater intake at fill production of 10 Mtpa (Naughton Creek)	6-120
Table 6-19	Summary of local and regional impacts of seawater pumping on entrainment at full production of 10 mtpa (expressed as percentage of tidal prism)	6-122

Table 6-20	Fish species captured in Dampier Salt's Port Hedland concentrator ponds	6-124
Table 7-1	Previously recorded archaeological sites within the project area	7-19
Table 7-2	Aboriginal heritage surveys completed	7-20
Table 7-3	Short titles and acronyms	7-47

LIST OF FIGURES

Figure 1-1	Location of proposal	1-3
Figure 1-2	Study and project areas	1-5
Figure 1-3	Commonwealth and State environmental assessment and approval process	1-8
Figure 2-1	Mitigation hierarchy based on EPA (2006)	2-3
Figure 2-2	Proposed location and layout of Yannarie Solar Project	2-24
Figure 2-3	Solar salt production flowchart	2-28
Figure 2-4	Proposed location of construction camp	2-30
Figure 2-5	Proposed location of northern intake pump at Naughton Creek	2-32
Figure 2-6	Proposed location of southern intake pump at Dean's Creek	2-32
Figure 2-7	Typical seawater intake structure from a saltfield in north west Western Australia	2-33
Figure 2-8	Typical levee and flume cross-sections	2-36
Figure 2-9	Proposed sources of construction materials and location of existing access roads	2-38
Figure 2-10	Proposed barge harbour design	2-40
Figure 2-11	Proposed Main Island layout	2-43
Figure 2-12	Proposed conveyor and services causeway alignment	2-44
Figure 3-1	Assessment framework for environmental factors	3-4
Figure 4-1	Mining tenements and pastoral leases in the Exmouth Gulf region (Aug 2006)	4-3
Figure 4-2	Boundaries of the Exmouth Gulf prawn fishery	4-4
Figure 4-3	Time-stratigraphic relationships between landform units of the study area	4-8

Figure 4-4	Leeuwin current in Northwest Cape region (a) sea surface temperature (b) generalised summer flows	4-8
Figure 4-5	Summer and Winter 9:00 AM and 3:00 PM wind roses for Learmonth	4-9
Figure 4-6	Current models predicting global average sea level rise (1990 – 2100). The mean of the models predicts 0.38 m in sea level rise	4-10
Figure 4-7	Cyclone Vance debris line relative to the fuel storage location at Hope Point	4-13
Figure 4-8	Conceptual hydrogeological model of the east coast of the Gulf	4-14
Figure 4-9	Conceptual diagram of the Exmouth Gulf ecosystem	4-16
Figure 4-10	Bathymetry of (a) eastern coast of Exmouth Gulf and (b) Exmouth Gulf	4-17
Figure 4-11	Conceptual diagram of the ecosystem at tidal creek scale on the east coast of the Gulf	4-19
Figure 4-12	Salinity and inundation gradient in mangrove communities	4-20
Figure 4-13	(a) View of salt flat area and (b) example of mainland remnant	4-21
Figure 4-14	View of longitudinal dunefield towards the Yannarie River South and supratidal salt flats	4-22
Figure 5-1	Landscape elements of the Yannarie Solar Project	5-3
Figure 5-2	Claypans and interdunal swales in the dunefield landscape element	5-5
Figure 5-3	Mouth of the Yannarie River South where it discharges to the supratidal salt flat	5-6
Figure 5-4	Tidal creek and fringing mangroves with algal mat visible in lower right foreground	5-7
Figure 5-5	Sand sheet with dunes at Locker Point	5-8
Figure 5-6	(a) limestone forming low cliffs on western end of Hope Point and (b) limestone pavement in nearshore environment immediately north of Tubridgi Point	5-9
Figure 5-7	Bore locations and superficial aquifer groundwater contours	5-20
Figure 5-8	View of Yannarie River downstream from the North West Coastal Highway	5-31
Figure 5-9	View downstream of Rouse Creek from North West Coastal Highway	5-32
Figure 5-10	Yannarie River 100-year 24-hour hydrograph	5-34
Figure 5-11	Rouse Creek 100-year 24-hour hydrograph	5-34
Figure 5-12	Exmouth surface hydrology after Tropical Cyclone Vance	5-36

Figure 5-13	The mouth of the Yannarie River South at its discharge point onto the supratidal salt flats	5-37
Figure 5-14	Pre-development hinterland surface hydrology	5-41
Figure 5-15	Surface hydrology following installation of diversion weir for Yannarie North channel	5-42
Figure 5-16	Cross section of the 'choke' point	5-43
Figure 5-17	Flooding footprint upstream of diversion weir for 2 year ARI event	5-45
Figure 5-18	Flooding footprint upstream of diversion weir for 5 year ARI event	5-46
Figure 5-19	Flooding footprint upstream of diversion weir for greater than 5 year ARI events	5-47
Figure 5-20	Vegetation types 1a to 3a within the Yannarie Solar project area	5-58
Figure 5-21	Location of flora and vegetation survey quadrats and extent of survey	5-63
Figure 5-22	Terrestrial remnants that are greater than 5 m AHD elevation	5-68
Figure 5-23	Location of fauna survey sites	5-74
Figure 5-24	Wader count locations within the project area	5-76
Figure 5-25	Photographs of migratory waders	5-79
Figure 5-26	Wader roost sizes for south west Gulf to Hope Creek	5-82
Figure 5-27	Wader roost sizes north east gulf - Hope Point to Tent Island	5-83
Figure 6-1	EVs, EQOs and LEPs for Exmouth Gulf	6-4
Figure 6-2	Tidal currents in the Gulf: Peak ebb (a), and +3 hours after peak ebb (b)	6-7
Figure 6-3	Tidal currents in the Gulf: Peak flood (a), and +3 hours after peak flood (b)	6-7
Figure 6-4	Flushing of Exmouth Gulf	6-8
Figure 6-5	Marine sediment and water sampling locations	6-10
Figure 6-6	Median salinity at locations within creeks showing 80th and 20th percentiles	6-15
Figure 6-7	Dissolved inorganic nutrient and chlorophyll-a concentrations	6-16
Figure 6-8	Sediment impacts on Avicennia marina and Rhizophora stylosa	6-25
Figure 6-9	Photographs of mangroves in project area	6-27
Figure 6-10	Mangrove associations and algal mat near the Yannarie Solar Project	6-28
Figure 6-11	Representative salinity gradient in the mangrove systems and response of Avicennia marina	6-30

Figure 6-12	Simplified conceptual carbon cycle for mangrove/algal mat ecosystems	6-32
Figure 6-13	Simplified conceptual nitrogen cycle for algal mat/mangrove ecosystem	6-34
Figure 6-14	Photographs of algal mats	6-35
Figure 6-15	Photographs of algae from algal mats in project area	6-36
Figure 6-16	Percentage of (a) seagrass cover in June 1999 and (b) December 2001	6-38
Figure 6-17	Percentage cover of algae on Hope Point transects	6-40
Figure 6-18	Proposed management units for the intertidal BPPH and eastern Exmouth Gulf	6-43
Figure 6-19	Infrastructure footprint at Hope Point	6-46
Figure 6-20	Infrastructure footprint at Main Island	6-47
Figure 6-21	Pump station and channel footprint at Naughton Creek	6-48
Figure 6-22	Pump station and channel footprint at Dean's Creek	6-49
Figure 6-23	Naughton Creek pump station, benthic habitat results and habitat type	6-52
Figure 6-24	Deans Creek pump station, benthic habitat results and habitat type	6-53
Figure 6-25	Habitat types, habitat coverage survey and proposed channel layout (impact area) within Hope Point 04 Management Unit	6-54
Figure 6-26	Predicted percentage change to tidal wetting and drying regimes in the mangrove zone at the Hope Point infrastructure corridor crossing	6-55
Figure 6-27	Tidal submergence curve for existing conditions at Hope Point crossing and predicted curve for the saltfield scenario	6-56
Figure 6-28	Predicted percentage change to tidal wetting and drying regimes in the mangrove zone at the northern pump station (Naughton Creek)	6-58
Figure 6-29	Tidal submergence curve quantifying predicted maximum reduction in tidal flushing in mangrove and algal mat zones at the Naughton Creek pump station	6-58
Figure 6-30	Predicted change to percentage time wet in the mangrove zone at the southern pump station (Dean's Creek)	6-59
Figure 6-31	Effects of the southern portion of the saltfield on residual currents	6-61
Figure 6-32	Effects of the northern portion of the saltfield on residual currents	6-62
Figure 6-33	Modelled typical peak ebb tidal currents for Dean's Creek (pre-development conditions)	6-64

Figure 6-34	Modelled typical peak flood tidal currents for Dean's Creek (pre-development conditions)	6-65
Figure 6-35	Residual depth-averaged current differences between pre-development and post-development conditions at Naughton Creek	6-67
Figure 6-36	Difference between maximum current speeds for pre-development and post-development conditions at Naughton Creek	6-67
Figure 6-37	Hope Point dredging channel and barge harbour	6-72
Figure 6-38	Modelled maximum suspended sediment concentrations caused by excavation and dredging at Hope Point	6-74
Figure 6-39	Modelled deposition of sediment following excavation and dredging activity at Hope Point	6-75
Figure 6-40	Suspended sediment concentrations vs. horizontal distance from dredge/excavator	6-76
Figure 6-41	Predicted thickness of deposition due to dredging and excavation activity at Hope Point	6-77
Figure 6-42	Zone of turbidity influence levels compared to background levels	6-79
Figure 6-43	Proposed ship transit passage and anchorage areas	6-82
Figure 6-44	Distribution of dolphins, turtles, sharks and rays in Exmouth Gulf based on aerial surveys from October 2004 to July 2005	6-102
Figure 6-45	Aerial survey sightings of Humpback Whales during the northern migratory period (June to early August) in 2000 and 2001	6-103
Figure 6-46	Aerial survey sightings of Humpback Whales during the transition phase (mid-August to early September) in 2000 and 2001	6-103
Figure 6-47	Aerial survey sightings of Humpback Whales during the southern migratory period (mid-September to December) in 2000 and 2001	6-104
Figure 6-48	Flight plan for megafauna surveys of Exmouth Gulf	6-105
Figure 6-49	Preferred Humpback Whale resting area as measured by boat surveys from 1996-97 (Oct) and 1998 (8 Aug–4 Oct)	6-106
Figure 6-50	Location of all pods of whales sighted during all flights to July 2005	6-107
Figure 6-51	Location of all pods of dugongs sighted during all flights to April 2005	6-110
Figure 6-52	Northern Prawn Fishery life cycle	6-114
Figure 6-53	Benthic macrofauna sampling locations	6-116
Figure 6-54	Example of a pump station	6-118
Figure 6-55	Example of acoustic modelling output	6-128

Figure 6-56 Potential mechanisms for introduction and translocation of marine species in Exmouth Gulf 6-138
Figure 7-1 Boundaries of the Exmouth Gulf prawn fishery 7-3
Figure 7-2 Example of VMS data for four trawlers (June 2004) 7-8
Figure 7-3 Distribution of recreational fishing in Exmouth Gulf (Apr 1998 to Mar 1999) 7-12
Figure 7-4 Current recreational fishing activity in the Exmouth Gulf region 7-13
Figure 7-5 Archaeological survey Area 7-21
Figure 7-6 Aboriginal archaeological sites within the Thalanyji native title claim area 7-22
Figure 7-7 Aboriginal archaeological sites within the Gnulli native title claim area 7-23
Figure 7-8 Artefacts collected from one site, prior to being recorded 7-24
Figure 7-9 Existing and nominal reserve boundaries in the Exmouth Gulf region 7-26

LIST OF APPENDICES

Appendix 1 Bitterns Resource Recovery Strategy

Appendix 2 Scoping Document

Appendix 3 Physical Environment of the Yannarie Salt Project Area (DC Blandford and Oceanica 2005)

Appendix 4 Mangrove and coastal ecosystem study – baseline ecological assessment (Biota 2005d)

Appendix 5 Fauna and fauna assemblages survey (Biota 2005b)

Appendix 6 Flora and vegetation assessment – baseline botanical survey (Biota 2005a)

Appendix 7 Marine and coastal environment of the eastern Exmouth Gulf (Oceanica 2006a)

Appendix 8 Surface hydrology for the Yannarie Salt Project (Parsons Brinkerhoff 2006b)

Appendix 9 Straits Environmental Policy

Appendix 10 Example of oil spill contingency plan

Chapter 1

Introduction and environmental assessment process

Chapter 1 Introduction and environmental assessment process

1 BACKGROUND

1.1 PROJECT OVERVIEW

Straits Salt Pty Ltd (Straits) is proposing to construct and operate a nominal 10 million tonne per annum (Mtpa) solar saltfield on the eastern margin of the Exmouth Gulf (the Gulf) in Western Australia (Figure 1-1). Known as the Yannarie Solar Project, the operation will meet the rapidly growing demand for salt stemming from the Asia-Pacific region. Conventional solar salt production involves natural evaporative processes to crystallise sodium chloride salt from seawater, and does not involve any chemical processing or hazardous chemicals.

1.1.1 Salt production

Seawater will be pumped into a series of large, shallow concentration ponds where solar energy evaporates water and concentrates the dissolved salts as it proceeds through the ponds. In the last concentrator pond the brine is salt-saturated (sodium chloride), and is transferred to a series of smaller crystalliser ponds where the salt then crystallises out of solution. The residual brine (called bitterns) is continually discharged from the crystalliser ponds at a specific gravity (SG) of 1.25 resulting in 75% of the sodium chloride available in seawater being crystallised at this point.

A further 18% of the original sodium chloride will be crystallised out as pavement in crystalliser ponds until Stage 2 of the saltfield is fully operational (production rate of 4.7 Mtpa). When pavement build up is complete for stages 1 and 2, further processing of bitterns to remove the 25% remaining sodium chloride will be accomplished by existing technology including the construction of additional crystalliser ponds.

The brine left over after recovery of sodium chloride from the bitterns will be stored and then processed through additional ponds to extract a complex mixture of salts (principally potassium) which will vary according to the local characteristics of the saltfield. The specific gravity of the brine residue will increase to 1.35 and the remaining volume will be about 20% of the original bitterns volume. The economic recovery of these salts is anticipated when Stage 1 of the saltfield is fully operational. Site specific research work will be required to confirm the technical and economic options.

Recovery of magnesium values from the residual mixed salt production would result in full resource recovery from bitterns, but requires further evaluation of feasibility.

Straits is not seeking approval for discharge of bitterns, and has set a goal of zero discharge and maximum resource recovery through a continuous improvement process. The financial and technical feasibility of achieving zero discharge will be assessed within in the first ten years of operation of the saltfield (about 13 years from the commencement of construction). An initial feasibility study by the CSIRO on the technical capacity for bitterns re-use and the potential value of bitterns products has identified significant long term opportunities (CSIRO 2004).

Any new value-adding processes will be referred to the Environmental Protection Authority (EPA) for consideration on completion of the final assessment of bitterns resource recovery feasibility. A separate referral to the EPA would also be made for the disposal of any bitterns not able to be practicably re-used or contained.

Appendix 1 addresses in detail the proposed bitterns resource recovery strategy. This resource recovery strategy involves a new level of best practice for saltfield operation in Western Australia.

The salt from the crystallisers will be loaded onto barges, which transport the salt offshore for loading into a bulk carrier which would be anchored in Exmouth Gulf.

1.1.2 Production stages

The proposal is intended to be developed in four distinct stages with Stages 1 and 2 taking at least ten years (13 years after the commencement of construction) to fully establish:

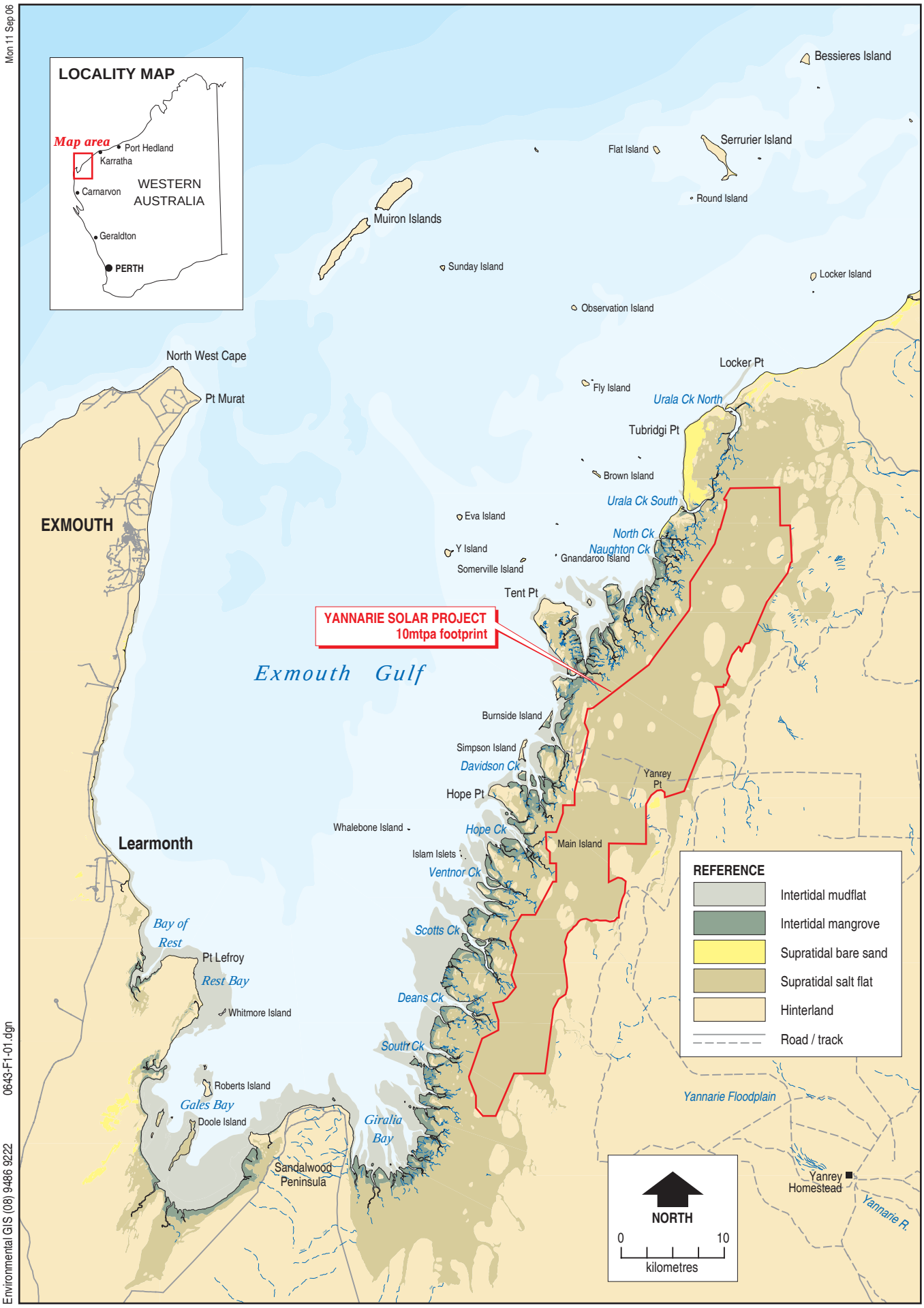
- Stage 1 – establish a saltfield at the southern end of the lease having a nominal capacity of 3.1 Mtpa.
- Stage 2 – increase the capacity of the southern end to a nominal 4.7 Mtpa.
- Stages 3 and 4 – establish a saltfield at the northern end of the lease having an ultimate capacity of 5.8 Mtpa. The combination of the southern and northern end fields gives a total capacity of 10 Mtpa.

1.2 ENVIRONMENTAL REVIEW AFTER 10 YEARS

The proponent is willing to accept as a condition of approval or upon request of the Minister for Environment pursuant to section 46 of the *Environmental Protection Act 1986* (EP Act) to conduct an environmental review of the project before commencing stages 3 and 4. This review would consider all environmental impacts and how they are being managed as well as a review of any social issues associated with the project.

The scoping for this review will be determined in consultation with the EPA and the review submitted to the Minister for the Environment. The EPA would assess the review and provide advice to the Minister on any new or amended environmental conditions needed to ensure the project continues to proceed in an environmentally acceptable manner.

The proposed solar salt project will be designed and managed such that the existing economic, cultural, social and environmental values of the region will not be compromised. A major goal of the project is for the local community and the State economy to share in economic and social benefits of the project.



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 1-1 Location of proposal

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

The study area

The term "study area" is used this document and is defined by the green line in Figure 1-2 for the purposes of this document. This area is inclusive of all the areas where investigations and sampling were undertaken for the terrestrial flora and fauna surveys, marine ecosystem modelling and fauna studies, and physical environment surveys.

The "project area" or project footprint is defined by the black line in Figure 1-2. This is the area potentially affected, directly or indirectly, through construction and operation of the proposed Yannarie Solar Project.

1.3 THE PROPONENT

The proponent and owner of the proposed solar saltfield will be Straits Salt Pty Ltd. Key contact details are presented in Table 1-1.

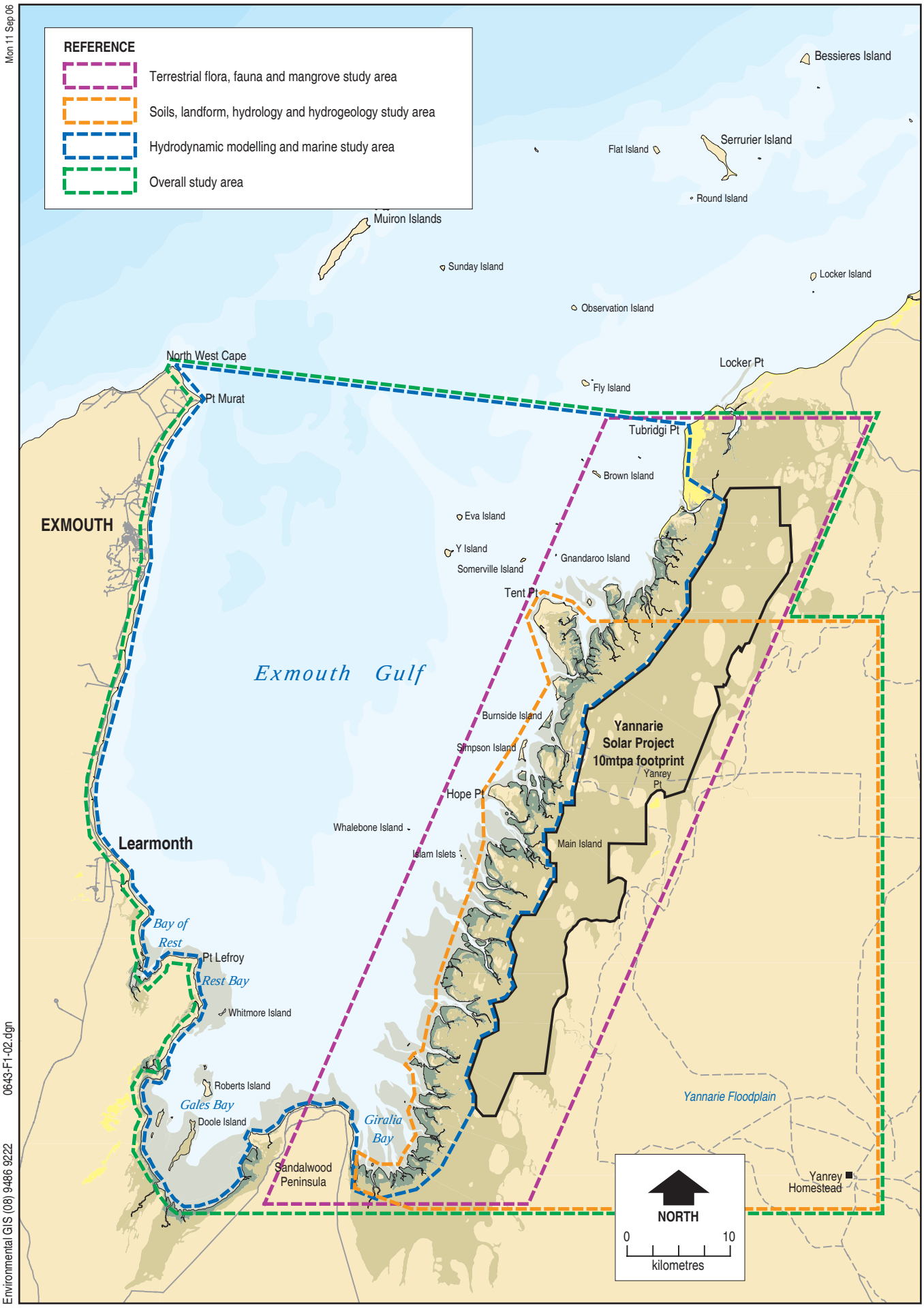
Table 1-1 Key contact details

Organisation	Proponent representative
Straits Salt Pty Ltd First Floor, 35 Ventnor Ave West Perth WA 6005 http://www.straits.com.au/ Telephone: (61 8) 9480 0500 Facsimile: (61 8) 9480 0520 ACN: 056 601 417	Mr James Barrie Project Manger – Yannarie Solar Project Telephone: (61 8) 9480 0500 Facsimile: (61 8) 9480 0520 Email: rbarrie@straits.com.au

Straits Salt Pty Ltd is a wholly owned subsidiary of Straits Resources Limited. Straits Resources is a diversified Australian resource company that was founded in 1992 and has been listed on the Australian Stock Exchange since 1994. Based in Perth, the company is focused on acquiring and developing assets within the gold, copper and bulk commodities sectors. Straits Resources controls and operates the Whim Creek Copper Operation in Western Australia, Sebuku Coal and Mt Muro Gold Mines in Indonesia, and is currently redeveloping the Hillgrove Gold Operation in New South Wales.

Straits Resources is a resource development company that has:

- a Western Australian presence (corporate office is located in West Perth) and a desire to continue operating in this State
- local knowledge of the Pilbara, through its Whim Creek assets (and previous ownership of the Nifty Copper Operation) and
- bulk commodity and marine/shipping expertise developed at Sebuku.



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 1-2 Study and project areas

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

1.4 PURPOSE OF THIS DOCUMENT

The purpose of this document is to present both an environmental review and a prospective environmental management programme for the Yannarie Solar Project in the form of an Environmental Review and Management Programme (ERMP). The ERMP together with community and agency submissions received during the public review of the ERMP will be considered by the EPA who will then provide an assessment report to the Minister for Environment. The Minister for the Environment will then decide whether or not the proposal should be implemented and if so under what conditions.

The proposal has also been determined to be a controlled action under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) for listed threatened species and communities and migratory species. The Commonwealth has accredited the Western Australian impact assessment process under the bilateral agreement between the Commonwealth and Western Australian Governments. This ERMP has also been prepared to specifically address the potential impacts on these listed species.

1.4.1 Structure of this document

This ERMP is divided into three volumes, Volume 1 describes the proposal and salient features of the environment and addresses potential environmental impacts on relevant environmental factors associated with the implementation of the proposal. The ERMP also provides a description of how these impacts will be mitigated through a combination of engineering modifications and environmental management measures in accordance with a mitigation hierarchy (EPA 2006).

This document (Volume 1) is divided into the following Chapters:

1. Introduction and Environmental Assessment Process
2. Sustainability, Stakeholder Consultation and the Proposal
3. Environmental Impact Assessment and Management
4. Overview of the Region and Ecosystem
5. Terrestrial Factors
6. Marine Factors
7. Social Surrounds Factors

Volume 2 outlines the Environmental Management Program. The Environmental Management Program provides the basis for which comprehensive management plans will be developed.

Volume 3 (compact disk) contains the Appendices referred to in the ERMP document.

2 ENVIRONMENTAL IMPACT ASSESSMENT PROCESS

2.1 COMMONWEALTH AND WESTERN AUSTRALIAN IMPACT ASSESSMENT AND APPROVAL

2.1.1 Referral and level of assessment

Under the Western Australian EP Act, proposals that may have a significant effect on the environment are referred to the EPA for consideration. The EPA then determines whether a proposal shall be assessed and if it is to be assessed at what level. The EPA has set an ERMP level of assessment (which the proponent recommended) for the Yannarie Solar Project and under the EPA administrative procedures the proponent was required to prepare:

1. An acceptable scoping report which outlines the environmental factors to be addressed, investigations to be conducted, the methodologies for the conduct of investigations, stakeholder consultation and a timetable for the assessment process (Appendix 2).
2. An ERMP document, suitable for public review, which provides a detailed review of potential environmental impacts and management measures for the relevant environmental factors outlined in the scoping report for public and government agency review and subsequent assessment by the EPA.

The ERMP is intended to provide the EPA, other government agencies and the public with an understanding of the proposal, its potential environmental impacts, and the environmental management measures and commitments required to ensure EPA objectives are met for each relevant environmental factor.

The key steps in the Yannarie Solar Project environmental impact assessment and approval process are summarised in Figure 1-3.

The project was also referred to the Department of the Environment and Heritage (DEH) in accordance with the EPBC Act. The DEH confirmed that the project was to be treated as a controlled action and an Environmental Impact Statement (EIS) will be required for assessment under the EPBC Act. This assessment will, however, be conducted in accordance with the bilateral agreement between the Commonwealth and the State Governments.

The Commonwealth has accredited the Western Australian impact assessment process under this agreement such that this ERMP document will be satisfying the requirements of both the Commonwealth and State assessment processes.

2.1.2 Public review and EPA assessment of ERMP

This ERMP is subject to a 10-week public review period and at the end of this period, issues raised in written submissions from the public and Government agencies are collated and transmitted to Straits (the proponent) by the EPA Services Unit. An opportunity then exists for the proponent to provide responses to the submissions for the EPA's consideration before finalising its assessment report. The proponent's responses are conveyed along with the EPA's report (EPA Bulletin) to the Minister for the Environment.

The DEH will also review the ERMP, public submissions and Straits' responses to prepare environmental assessment reports and recommendations for the Commonwealth Minister.

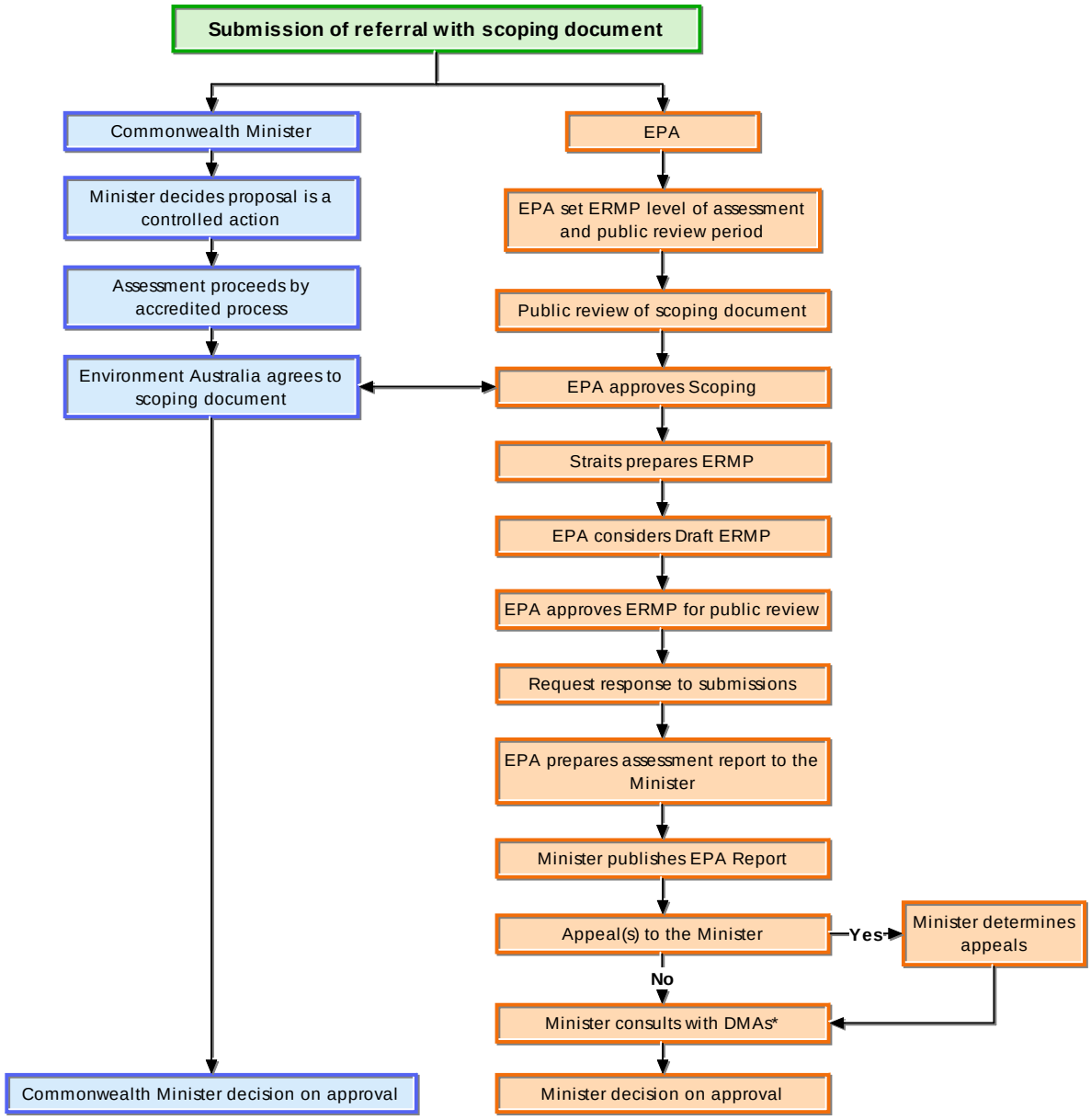


Figure 1-3 Commonwealth and State environmental assessment and approval process

2.1.3 Ministerial consideration

Once the EPA bulletin is released by the Minister for the Environment, the public or any person has the right to appeal against the contents of that report. The Appeals Convenor collates any appeals, consults where required and provides advice to the Minister for the Environment.

The Minister for the Environment is required to consult with relevant Decision Making Authorities before making a final determination on whether the Yannarie Solar Project should be implemented and the conditions under which implementation may proceed.

2.2 OTHER RELEVANT COMMONWEALTH AND WESTERN AUSTRALIAN LEGISLATION, REGULATIONS AND POLICIES

Straits will take into consideration and adhere to requirements of all applicable legislation and regulations relevant to the Yannarie Solar Project. In addition to existing legislation, there are a number of Commonwealth and State policies and strategies that are of relevance to the environmental assessment and management of this proposal.

2.2.1 Commonwealth legislation and policies

Legislation

Environmental Protection and Biodiversity Conservation Act 1999

This Act provides for the protection of the environment, promotion of ecologically sustainable development and conservation of biodiversity.

Environmental Protection (Sea Dumping) Act 1981

This Act regulates the dumping of waste and all other materials in Australian waters.

Protection of the Sea (Prevention of Pollution from Ships) Act 1983

This Act and the *Navigation (Protection of the Sea) Amendment Act 1983* give effect to the International Convention for the Prevention of Pollution from Ships (MARPOL[1]).

The Coastal Waters (States Powers) Act 1980 and Coastal Water (States Titles) Act 1980

This Act gives the States power over 'coastal waters'.

Policies and agreements

The following international agreements and conventions are relevant to the project:

- Convention on Biological Diversity (1992)
- Convention on the Conservation of Migratory Species of Wild Animals (Bonn Convention) (1979)
- United Nations Convention on the Law of the Sea 1982

[1] MARPOL refers to the International Convention for the Prevention of Pollution from Ships. The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes (International Maritime Organisation 2002).

- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention) 1982
- Convention for the Prevention of Marine Pollution from Ships (International) (1973) and Protocol (1978) (MARPOL 73/78)
- Ramsar Convention (in reference to fauna rather than a listed wetland)
- ANZECC/ARMCANZ Guidelines (1996 and 2000)
- Towards Sustainability: Achieving Cleaner Production in Australia (ANZECC 1998).

2.2.2 State Legislation, policies and guidelines

Legislation

Environmental Protection Act 1986

This Act provides for the control and licensing of potentially polluting activities, environmental impact assessment, enforcement and appeals.

Conservation and Land Management Act 1984

This Act provides for the administration and management of conservation reserves within the State of Western Australia and for the management of marine parks and reserves in State waters.

Acts Amendment (Marine Reserves) Act 1997

This Act amended the *Conservation and Land Management Act 1984* to provide for the establishment of a Marine Parks and Reserves Authority to oversee the management of Western Australia's marine parks and nature reserves.

Land Act 1933 and the Land Administration Act 1997

The *Land Act 1933* previously provided for the administration of land title within the State of Western Australia. The *Land Act 1933* was repealed and replaced by the *Land Administration Act 1997*.

Fish Resources Management Act 1994

This Act is used to manage the commercial and recreational exploitation of all fishes in State Waters and demersal fisheries on the continental shelf to the 200 m isobath.

Wildlife Conservation Act 1950-1979

Within Western Australia and State Waters, flora and fauna, including marine species occurring in State waters, are protected under this Act. Special provisions apply to those species which are listed under schedules to the Act as rare or endangered, or otherwise in need of special protection.

Aboriginal Heritage Act 1972

This Act provides for the protection of Aboriginal cultural materials and places of significance.

The Heritage Act WA 1990

The Heritage Council of WA operates under this Act. The Heritage Council of WA maintains the State Register, which provides official recognition of a place's cultural heritage significance to WA. Protection is achieved through the requirement under the Heritage Act that all development proposals regarding a registered place be referred to the Heritage Council for advice.

Maritime Archaeology Act 1973

This Act provides for the preservation of historic shipwrecks and relics located in State waters.

Rights in Water and Irrigation Act 1914

The abstraction of groundwater is subject to a licence issued by the Water and Rivers Commission under this Act.

Draft Waste Avoidance and Resource Recovery Bill 2006

One of the features of this draft Bill is allowing for regulation to effect waste avoidance and resource recovery in Western Australia. The draft Bill also has a range of supporting objectives, including:

- 'To create effective frameworks and structures to coordinate and facilitate waste avoidance, resource recovery and the safe management of remaining wastes'
- 'To provide for the continuous reduction (continuous improvement) in waste generation'
- 'To optimise resource recovery from waste' (DEC 2006).

Relevant policies and guidelines

A number of non-statutory policies and guidelines which apply to management of the Gulf region are relevant to the proposed Yannarie Solar Project. These include, but are not limited to, the following:

Western Australian State Sustainability Strategy

The Western Australian State Sustainability Strategy (Government of Western Australia 2003) promotes the establishment of sustainability principles, guidelines and codes to be implemented by industries and Government agencies.

EPA Guidance Statement No. 1 Tropical Arid Zone Mangroves

Guidance Statement No. 1 specifically addresses the protection of tropical arid zone mangroves, habitats and dependent habitats along the Pilbara coastline from Cape Keraudren (at the southern end of Eighty Mile Beach) to Exmouth Gulf.

Draft EPA Guidance Statement No. 6 Rehabilitation of Terrestrial Ecosystems

Draft Guidance Statement No. 6 was released for stakeholder and public review and comment in January 2006. The Guidance Statement promotes the use of completion criteria and definitions for the rehabilitation of natural ecosystems.

EPA Guidance Statement No. 29 Benthic Primary Producer Habitat Protection

Guidance Statement No. 29 provides a set of principles to be applied by proponents and the EPA when considering development proposals that may result in removal or destruction of, or damage to, marine benthic primary producer (BPP) communities or the habitats which support them.

EPA Guidance Statement No. 41 Assessment of Aboriginal Heritage

Guidance Statement No. 41 provides guidance on the process for the assessment of Aboriginal heritage as an environmental factor. This guidance statement also details those actions that may be pertinent to the factor of Aboriginal heritage, including undertaking surveys and consulting local Aboriginal people.

EPA Guidance Statement No. 51 Terrestrial Flora and Vegetation Surveys

The primary purpose of Guidance Statement No. 51 is to provide guidance and information on the expected standards and protocols for terrestrial flora and vegetation surveys.

EPA Guidance Statement No. 54 Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia

Guidance Statement No. 54 specifically addresses the conservation of stygofauna in groundwater systems and troglofauna and stygofauna in subterranean caves.

EPA Guidance Statement No. 56 Terrestrial Fauna Surveys

Guidance Statement No. 56 provides direction and information on general standards and protocols for terrestrial fauna surveys.

EPA Position Statement No. 4 Environmental Protection of Wetlands

Position Statement No. 4 outlines the environmental protection of wetlands and issues considered to be important by the EPA when providing its advice to Government.

In terms of the Yannarie Solar Project, it is recognised that this Position Statement does not apply to 'tidal wetlands'.

EPA Position Statement No. 9 Environmental Offsets

Position Statement No. 9 presents a decision framework for the use of environmental offsets.

Pilbara Coastal Waters Quality Consultation Outcomes (DoE 2006)

A plan for protecting and managing the quality of marine waters from Exmouth to Port Hedland and out to the limit of State waters.

State Policy on Environmental Water Provisions

The Statewide Policy on Environmental Water Provisions protects ground and surface water dependant ecosystem values through the establishment of ecological water requirements.

State Water quality Management Strategy

The objective of the State Water Quality Management Strategy is 'to achieve sustainable use of the Nation's water resource by protecting and enhancing their quality while maintaining economic and social development'.

Western Australian Cleaner Production Statement

The Western Australian Sustainability Industry Group (WASIG) (2001) developed this statement, which provides a vision on how all key stakeholders can promote cleaner production and eco-efficiency in the state.

Chapter 2

Sustainability, stakeholder consultation and the proposal

Chapter 2 Sustainability, stakeholder consultation and the proposal

1 SUSTAINABILITY

The Commonwealth and State Governments have developed strategies to incorporate sustainability values and principles into a range of development projects.

This chapter describes how the principles of sustainable development have been applied to the Yannarie Solar Project to achieve beneficial outcomes for the environmental (addressed in detail in Chapter 3), social and economic values of the region.

1.1 NATIONAL APPROACH TO SUSTAINABILITY

Australia developed the National Strategy for Ecologically Sustainable Development (ESD) between 1989 and 1991. The strategy establishes a common goal for the nation, supported by a framework of core objectives and guiding principles.

All Australian State/Territory Governments agreed to the Intergovernmental Agreement on Environment in 1992 which embedded the need for:

- a precautionary approach
- intergenerational equity
- conservation of biological diversity ecological integrity
- improving valuation, pricing and incentive mechanisms.

The Commonwealth Government took a further step towards integrating economic activity with environmental integrity and social concerns by including the principles of ESD in section 3A of the EPBC Act.

Australia has recognised that resource efficiency and cleaner production are integral components of sustainable development. A strategy to increase adoption of cleaner production in Australia was developed in 1998 (ANZECC 1998).

The ANZECC 1998 strategy adopted the United Nations Environment Programme definition of Cleaner Production which includes conserving raw materials and energy, eliminating the use of toxic raw materials and reducing the quantity and toxicity of all emissions and wastes (UNEP 1994).

1.2 WESTERN AUSTRALIAN APPROACH TO SUSTAINABILITY

The development of 'sustainability' thinking in Western Australia began in 1992, when the State Government signed up to the Intergovernmental Agreement on the Environment. This was followed by the State of Environment Report for Western Australia in 1992, and again in 1998 (Centre for Water Research 2004).

The West Australian Government released the WA Sustainability Strategy in September 2003, the first of its kind in Australia.

The Western Australian State Sustainability Strategy contains a commitment to develop a Sustainability Act to:

- establish the principles of sustainability that can be incorporated by reference into relevant legislation
- support the development of guidelines or codes for the implementation of sustainability principles into the operation of relevant Government agencies, including reporting.

A Draft Sustainability Bill was released for public comment in 2004.

The State Government amended the EP Act to include a set of principles which underpin the environmental protection component of sustainability.

The WASIG released a Cleaner Production Statement for WA (WASIG 2001).

This Statement provides a vision on how all key stakeholders can promote Cleaner Production in WA. The goal of cleaner production is "to increase resource efficiency and to minimise (and/or where possible) prevent wastes and emissions being generated in the production, distribution and use of goods and services."

1.3 PROJECT SUSTAINABILITY

The Yannarie Solar Project is different from many other mining operations because the source of the product is renewable (seawater from the Indian Ocean) and the production method is based upon naturally occurring processes (solar evaporation).

Significant environmental, social and financial responsibilities exist for the implementation and management of any project proposed in an area of environmental importance. Addressing sustainable development is critical to the long-term viability of the Yannarie Solar Project and to ensure continued delivery of shareholder value.

The concept of sustainability, as defined by the Western Australian Sustainability Strategy, has been embedded in the project definition and planning stages, and will continue to be the focus of construction, operation and potential future decommissioning of the proposed project.

The Yannarie Solar Project has been designed specifically to accommodate cleaner production and resource efficiency through the application of the bitterns resource recovery strategy for various residual salts and other value added compounds.

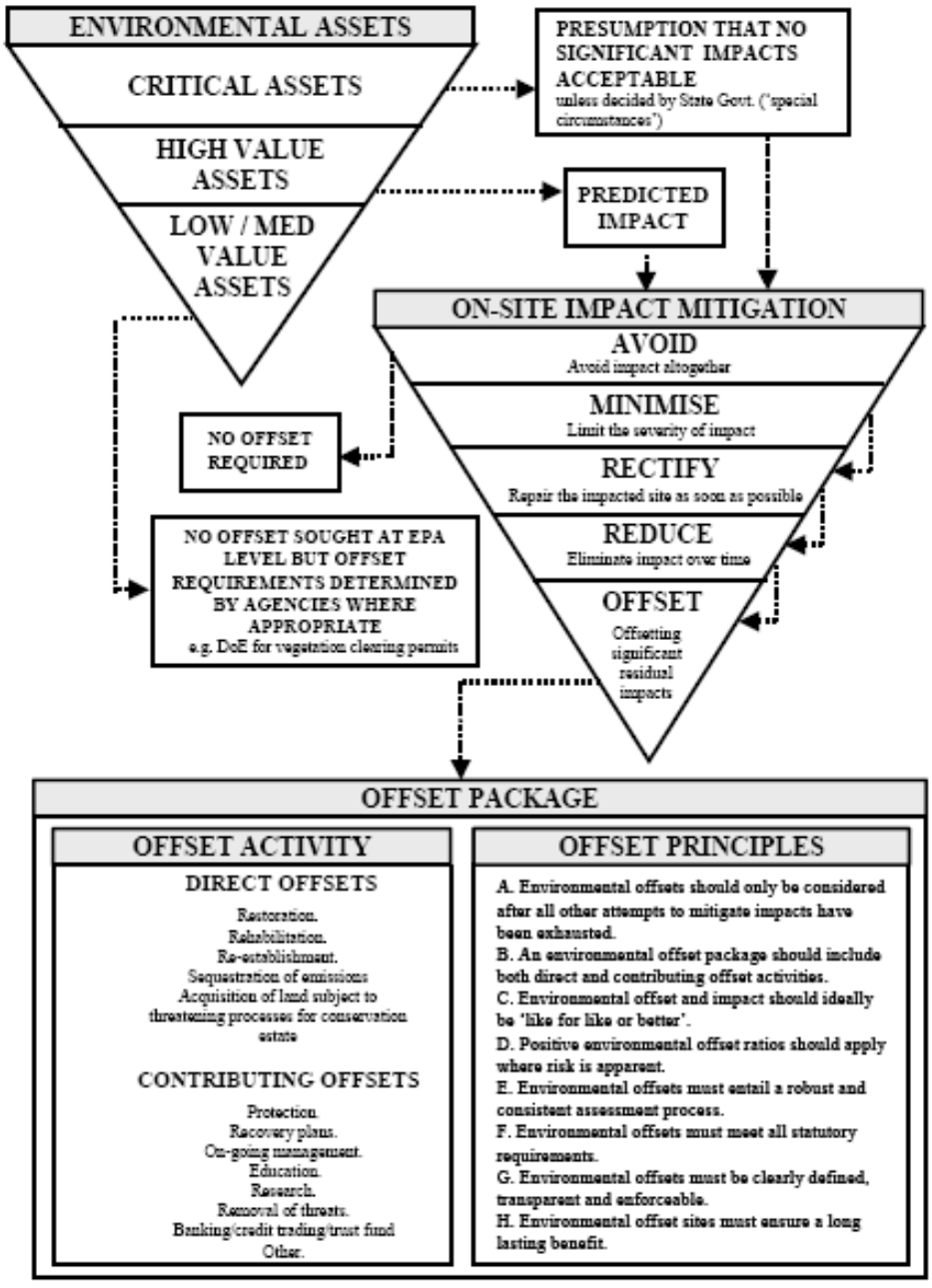
The scope of the environmental and socio-economic investigations is set out in Table 2-1.

1.3.1 Project sustainability principles and outcomes

A series of project specific principles were derived from the National Strategy for Ecologically Sustainable Development, the WA Sustainability Strategy and stakeholder consultation. Sustainability outcomes or objectives were developed from these principles taking into consideration stakeholder input and concerns. An iterative process for the impact assessment of the proposal as it developed was conducted to mitigate impacts of the proposal (particularly to address environmental aspects of the

proposal) to ensure that sustainability outcomes were achieved and stakeholder concerns were addressed.

This mitigation was conducted in accordance with the mitigation hierarchy outlined in EPA (2006) (Figure 2-1).



Source: EPA 2006

Figure 2-1 Mitigation hierarchy based on EPA (2006)

This process resulted in a number of changes to the project (summarised in Table 2-2) and the development of offset measures to mitigate impact on important ecosystem processes to achieve sustainability outcomes. These measures were also based on a detailed scientific understanding of the eastern Exmouth Gulf ecosystem derived from numerous investigations conducted as part of the environmental assessment process. A conceptual model of this ecosystem was developed enabling impacts not only to be considered on individual environmental factors but on ecological processes and the ecosystem as a whole (Chapter 3, Figure 4-9).

A comparison of the project's sustainability outcomes against the EPA provisional sustainability checklist was also conducted (Table 2-3).

Table 2-1 Scope of environmental and socio-economic investigations

Environmental	Social	Economic

• Terrestrial baseline flora surveys to identify keynote species and their spatial and temporal extent
• Terrestrial fauna surveys to identify representative fauna habitats, community types and any areas of particular conservation significance
• Desktop studies to identify the potential for impact to subterranean faunal species
• Geological mapping and geotechnical investigations to identify geomorphological processes, landforms, soils, surface stability, erosion potential and potential acid sulphate soils
• Hydrodynamic modelling to identify nutrient flows within the Gulf system, the wetting and drying of the intertidal system and the likely impacts on these flows from the proposed project
• Water and sediment quality assessments in the Gulf itself to identify baseline characteristics and hydrodynamic modelling to identify the potential fate of oil spills
• Surface and groundwater assessments to define hinterland catchments, identify the contribution of the catchment to surface flow during a range of rainfall events, and to characterise the groundwater regime.
• Benthic habitat surveys of algae, corals and ephemeral sea grass species to determine baseline characteristics and to advise on the best options for the location of project infrastructure
• Mangrove community and algal mat field surveys to map current spatial and temporal extent, geomorphological conditions, tidal channels and inundation regimes to identify natural systems critical to their existence
• Marine fauna surveys to identify species present, their temporal and spatial extent and potential impacts upon them and acoustic modelling of shipping activities
	• Cultural heritage surveys to identify areas of significant heritage value and potential impacts upon the integrity of them, including:
	  • archaeological surveys;
	  • ethnographic surveys;
	  • European heritage surveys.
	• Social impact assessment to identify concerns and potential impacts on the local and regional communities, including:
	  • population and demographic impacts;
	  • education and employment impacts;
	  • industry participation;
	  • infrastructure and service delivery impacts;
	  • amenity issues and environmental values considerations;
	  • recreational activities;
	  • safety and security impacts;
	  • community development opportunities and impacts;
	  • accommodation and land use impacts;
	  • culture and heritage impacts; and
	  • communication.
		• Assessment of potential economic impacts on the local, regional industries and the state economy, including:
		  • Fisheries and aquaculture;
		  • Tourism;
		  • Pastoral activities;
		  • Retail and suppliers;
		  • Contribution to the GDP of the Gascoyne Region;
		  • Royalty contribution to the State Economy;
		  • Induced local expenditure based on construction workforce wages;
		  • Induced local expenditure based on operation workforce wages.

Table 2-2 Mitigation measures to achieve sustainability outcome

Sustainability factor	Potential impact	Phase[2]	Mitigation measure	Sustainability outcome	Relevant sustainability principle(s)
Environmental					
Terrestrial and intertidal habitat	Clearing of mangrove and algal communities for project infrastructure	D	Inland relocation of proposed salt ponds behind the intertidal zone.	Retention of regionally and nationally important biological communities. Provision of pond habitat for migratory and shorebirds.	Protection of biological diversity, maintenance of essential ecological processes and life-support systems (National ESD Strategy) Protect and value the environment and ensure the sustainable management and use of natural resources (WA State Sustainability Strategy, Goal 3)
		D	Re-design of salt conveyor system to minimise mangrove/algal mat disturbance.		
		D	Relocation of proposed saltwater intake pump stations to minimise mangrove/algal mat clearance requirements.		
		D	Adjustments to seawall locations to avoid mangrove/algal mat communities.		
		D	Location of barge harbour on area denuded of vegetation		
	Impacts to mangrove and algal communities from disturbance to tidal creek flows	D	Re-design of salt conveyor system to reduce the number of creek crossings required (reducing from 2 to 1).	Preservation of regionally and nationally important biological communities.	
		D	Re-design of creek crossing to include culverts to avoid impact to tidal flows.		
Sub tidal flora	Lethal and sub-lethal impacts to benthic primary producers from the discharge of bitterns	O	Investigate commercial re-use options for bitterns, with the intention of achieving nil bitterns discharge.	Minimisation of impact to benthic primary producer communities (seagrasses, corals, algae).	
		O	Construction of bitterns resource area for re-use and storage. Goal of zero discharge based on bitterns resource recovery strategy. Any future proposal for bitterns discharge would be referred to the EPA for assessment.		
	Smothering and shading of seagrasses, coral and algae communities from channel dredging activities	C	Modification of project design to include conveyance of salt via barge to salt ships in the Gulf.	Reduction in the length of channel from 5.5 km (under original project design) to approximately 1.3 km and minimisation of impacts to benthic primary producers.	

[2] D – Design, C – Construction, O – Operation, DC - Decommissioning

Sustainability factor	Potential impact	Phase[2]	Mitigation measure	Sustainability outcome	Relevant sustainability principle(s)
		D,O	Modification of barge design to reduce draft by 0.5 m.	Reduction in the volume of material to be dredged and minimisation of impact to benthic primary producers.	
		C	Use of channel excavation spoil as land based deposition sites.	Minimisation of impacts to benthic primary producers.	
	Clearance of benthic flora during construction of the barge channel	C	Dredging to be completed during winter months when seagrass is dormant. Proposed location of barge channel route in an area of low percentage coverage of benthic flora	Minimisation of impacts to benthic primary producers.	
Sub tidal flora	Impacts to benthic primary producers from non-indigenous marine species (NIMS) in ship ballast water	O	Salt export activities will be required to be undertaken in accordance with IMO Guidelines (Resolution A.868 (20)), the Commonwealth Quarantine Act, 2000 and AQIS Ballast Water Management Requirements.	Decreased risk of NIMS introduction and subsequent impacts to benthic primary producer communities.	
		O	Commitment to monitor the performance of export ships and captains via the use of 'Ship Right' programme and to implement a marine monitoring programme. Transfer from barge to ship occurs at anchor in natural deep water. This minimises the chances of species survival as no shallow or tidal depth permanent structure will exist for species to establish 'roost' site.		
Marine fauna (humpback whales, Dugongs, turtles)	Collision or noise disturbance from vessel movements	D, O	Modification of project design to include movement of construction and operational workforce via aircraft, as opposed to fast ferries. All ships to be piloted within Exmouth Gulf. Speed to be minimised and alternate routes implemented. Anchorage locations are sited at suitable water depth and removed from high population densities of marine fauna.	Minimisation of disturbance to marine mammal species.	
Other faunal Marine species	Lethal and sublethal impacts arising from bitterns discharge	O	Goal of zero discharge of bitterns.	Minimisation of impact to marine faunal species. Conservation and storage of bitterns resource while determining options to achieve goal of zero discharge.	
		O	Storage of residue while determining option to achieve goal of zero discharge of bitterns.		
	Lethal and sub-lethal impacts arising from NIMS in ballast water	O	Salt export activities will be required to be undertaken in accordance with IMO Guidelines (Resolution A.868 (20)), the Commonwealth Quarantine Act, 2000 and AQIS Ballast Water Management Requirements.	Decreased risk of NIMS introduction and subsequent impacts to marine faunal species.	

Sustainability factor	Potential impact	Phase[2]	Mitigation measure	Sustainability outcome	Relevant sustainability principle(s)
		O	Straits commitment to monitor the performance of export ships and captains via the use of 'Ship Right' programme and to implement a marine monitoring programme.		
Hydrodynamics and ecosystem integrity	Disruption to hydrodynamic flows, coastal processes and associated nutrient flows with resultant impacts on ecosystem functioning within the Gulf	C, O	Inland relocation of proposed salt ponds behind the intertidal zone (including mangroves and algal mat).	Minimal disturbance to hydrodynamic flows, coastal processes and nutrient flows.	Protection of biological diversity, maintenance of essential ecological processes and life-support systems (National ESD Strategy) '..all life has intrinsic value and is interconnected…biodiversity and ecological integrity are part of the irreplaceable life support systems upon which the earth depends' (WA State Sustainability Strategy, Foundation Principles)
		D	Modification of the saltfield layout to enable sporadic flows from the Yannarie River to reach the Gulf.		
		O	Modification of conveyor creek crossing to include culverts to enable tidal flushing.		
Ecosystem integrity and ecological sustainability	Positive contribution to regional research	D, C & O	Straits commitment to funding ongoing research into regional ecology, including mangrove systems and the systems which influence the functioning of the Gulf ecosystem. Funding has commenced through an Australian Research Council Linkage Project grant to the University of Queensland which is looking at the links between the algal mats, mangroves and the Gulf with regard to nutrient transfers.	Increased understanding of ecological functions and opportunities to improve ongoing environmental management practices.	
Ecosystem integrity and ecological sustainability	Positive contribution to regional research	O	Straits commitment to correctly identify the high water mark to define the boundary of the proposed conservation area.	Improvement of the ongoing management of the Gulf ecosystem.	
Social					
Community well-being	Minimal opportunities for social and community benefits from Fly-in/Fly-out workforce	O	Proposed location of residential workforce in Exmouth, as opposed to fly-in/fly-out of Perth.	Increased participation in community activities, increased resourcing for community services, thereby enhancing community sustainability.	To enhance the individual and community well-being and welfare by following a path of economic development that safeguards the welfare of future generations (National ESD Strategy) '…planning for the common good requires equitable distribution of public resources' (WA State Sustainability Strategy, Foundation Principles)
		O	Employment and training opportunities for local people. Proposed employment of locally based people. Where specific skills do not currently exist, training will be provided or skilled personnel will be relocated to Exmouth.	Access to employment and training.	
Community cohesion	Negative social and community impacts from introduction of a construction workforce with differing demographic characteristics to those of	C	Ongoing consultation with the local community to assess the need for an on-site construction camp.	Minimisation of potential community conflict and cohesion impacts.	

Sustainability factor	Potential impact	Phase[2]	Mitigation measure	Sustainability outcome	Relevant sustainability principle(s)
	local community	C	Use of site inductions, contracting terms and contractor management plans to manage construction workforce behaviour. Proposed use of locally based personnel wherever possible for construction workforce.		
Local community recreation	Restricted access to former fishing spots in immediate environs of proposed salt production facility	O	New recreational fishing opportunities through guided access to first concentrator ponds.	Enhancement of recreational activities for local community.	
		O	No present recreational areas will be restricted. Restricted areas will be the barge harbour and pump station sites (for safety) which are newly constructed components of Straits infrastructure.		
Community cohesion	Ongoing social and community impacts from salt production facility and introduced residential workforce	D, C & O	Commitment to ongoing community engagement to identify potential issues and appropriate mitigation measures.	Continued community engagement during project lifecycle.	Decisions and actions should provide for broad community involvement on issues which affect them (National ESD Strategy) '…public engagement lies at the heart of all sustainability principles' (WA State Sustainability Strategy, Process Principles)
Economic					
Prawn and aquaculture industries	Disruption to trawling activities via export ship movements	O	Modification of project design to include multiple anchorage areas for salt export ships. No permanent ship mooring locations. Where possible, export ships will not anchor in active trawling area.	Minimisation to impact on prawn and aquaculture activities.	The need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection (National ESD Strategy) '…the need of current and future generations for long-term economic health, innovation, diversity and productivity of the earth' (WA State Sustainability Strategy, Foundation Principles)
		O	Potential to load export ships to 75% capacity in shallow waters in the East of the Gulf and load final volumes in deeper water in the Gulf to minimise impact on night trawling activities		
	Impact to commercial fish species nursery grounds from bitterns discharge	O	Goal of zero discharge of bitterns.	Minimisation of impact to commercial fish species. Investigation of potential synergies between solar ponds and aquaculture activities.	Protection of biological diversity, maintenance of essential ecological processes and life-support systems (National ESD Strategy) Protect and value the environment and ensure the sustainable management and use of natural resources (WA State Sustainability Strategy, Goal 3)
		O	Investigate commercial re-use options for bitterns, with the intention of achieving nil bitterns discharge. Pre-dilution of bitterns prior to discharge into barge harbour. Discharge in an area with sparse seagrass habitat (nursery flora). Discharge is hydraulically disconnected and well away from existing southern Gulf pearling operations.		
Prawn and aquaculture industries	Impact to commercial fish species nursery grounds from disruptions to	C	Location of site ponds outside the coastal intertidal zone (including mangroves and algal mat).	Impact on nutrient flows negated.	

Sustainability factor	Potential impact	Phase[2]	Mitigation measure	Sustainability outcome	Relevant sustainability principle(s)
	nutrient flows				
	Impact to commercial fish species nursery grounds from NIMS in export ship ballast water	O	Salt export activities will be required to be undertaken in accordance with IMO Guidelines (Resolution A.868 (20)), the Commonwealth Quarantine Act, 2000 and AQIS Ballast Water Management Requirements	Decreased risk of NIMS introduction and subsequent impacts to prawn and aquaculture industries.	
		O	Straits commitment to monitor the performance of export ships and captains via the use of 'Ship Right' programme and to implement a marine monitoring programme that would allow action to be taken should NIMS be introduced.		
Local economic benefits	Moderate local economic benefit from salt production facility	O	Proposed location of operational workforce in Exmouth (190 full time employees (FTE) at 10 Mtpa and 70 FTE at 3 Mtpa)	Additional local expenditure and economic benefits to local communities	The need to develop a strong, growing and diversified economy which can enhance the capacity for environmental protection (National ESD Strategy) '…the need of current and future generations for long-term economic health, innovation, diversity and productivity of the earth' (WA State Sustainability Strategy, Foundation Principles)
		O	Use of local Exmouth service providers and maintenance contractors (at least 500 indirect jobs through construction and operational phases – significant new non seasonal employment opportunities)		
		C, O	Proposed procurement of local goods and services wherever possible and economically viable during the construction and operation of the salt production facility (value of services and purchases from local businesses is estimated at over $7 M per year; estimated $10 M per year direct employee expenditure into local economy at full production of 10 Mtpa and $3 M per year at 3 MTPA production; attraction of additional Government services to region)		
		O	Tourist access to designated evaporation ponds once operational, using local tour operators		
Regional economic benefits	Contribution of an estimated $230 million per annum to the regional GDP.	O	-	Positive contribution to regional Gross Domestic Product and regional economic sustainability	
State economic benefits	Contribution of an estimated $5 million per annum in Royalty Contribution.	O	-	Positive contribution to State Economy and economic sustainability via Royalty Contributions	
Federal economic benefits	Increases Australia's export earning's.	O	-	Positive contribution to Federal government economy	

Table 2-3 Comparison with EPA provisional sustainability criteria

Provisional sustainability criteria	Yannarie Solar Project
Does the proposal deplete non-renewable resources significantly?	Solar salt production uses the natural and renewable resources of sunlight and seawater. Therefore it does not deplete non-renewable resources
Does the proposal deplete assimilative capacity significantly?	Bitterns will be stored and processed with the goal of zero discharge. Research and investment activities will be undertaken to identify viability of product recovered from bitterns. If discharge of bitterns is required in the future, referral of such a proposal to the EPA will be made.
Does the proposal use natural resources responsibly?	The solar salt process relies almost entirely upon the use of natural process and a renewable resource, and is a relatively passive process.
Does the proposal satisfactorily restore any disturbed land?	The majority of the Project is located on an unvegetated salt flat; and involves flooding the salt flat with seawater, thereby creating minimal disturbance to the underlying land. Straits will prepare a preliminary decommissioning plan to ensure land within the project footprint is reinstated in an acceptable manner.
Does the proposal follow the waste hierarchy and manage satisfactorily any waste produced?	The waste minimisation and mitigation hierarchies were followed (refer to Figure 2-1). Waste minimisation opportunities will be sought for all project waste streams.
Does the proposal incorporate best practice in water and energy efficiency?	The project's salt production energy requirements will be solar sourced. Reverse osmosis facilities will be utilised for all fresh water needs to avoid water abstraction from bores.
Does the proposal make good use of best practice to prevent pollution?	Potential for pollution will be prevented through a combination of mitigation measures including engineering modifications and management. All areas where hazardous and dangerous goods are to be transferred, handled, stored and used will be designed and managed in accordance with relevant environmental and occupational health and safety legislation and Australian Standards.
Does the proposal increase use of non-renewable transport fuels?	Straits propose to export the salt to the Asia-Pacific region via bulk carrier, and this will lead to an increase in non-renewable fuels but the most efficient system of transport will be used. There are currently no other viable transport alternatives.
Does the proposal use energy efficient technologies?	The salt production process relies on the use of solar evaporation. All equipment associated with the transport and distribution of the salt product will be regularly serviced and maintained to ensure ongoing energy and resource efficiency.
Does the proposal result in net improvements in biodiversity?	Through a number of significant modifications in engineering design, Straits has minimised the loss of regionally important algal mat and mangrove communities. A commitment has been made to plant mangroves to offset losses from construction of the proposal.
Does the proposal increase greenhouse gas emissions?	Diesel will be used in the operation of the seawater pumps, generators and for the transport and distribution of the finished salt product. This will result in the emission of greenhouse gases (GHG's). GHG emissions will be offset to an extent by the biomass creation and resultant carbon sequestration in the concentrator ponds.
Does the proposal involve acceptable levels of risk?	A number of significant engineering modifications and identified a range of mitigation and monitoring measures to reduce the potential for environmental and socio-economic impact. Through the application of engineering management measures and ongoing monitoring programmes to adaptively change management as required, the level of risk associated with the project is at an acceptable level.
Does the proposal have a secure foundation of scientific understanding of its impacts?	A thorough investigation of the existing natural and socio-economic environment and the key interactions between these factors was undertaken before and during project design (Table 2-1). This provided a sound understanding of the environmental characteristics of the region and ensured the proposed facility was designed from an informed position. Ongoing research in the region will be conducted in order to build upon the scientific assessments undertaken as part of the environmental approvals process.
Does the proposal minimise the ecological footprint?	The Project requires a large area for salt concentration and crystallisation. However, opportunities to minimise the ecological footprint have been achieved by moving the saltfield behind the intertidal zone, thereby limiting mangrove clearance, minimising potential impacts to hydrodynamic regimes, coastal and ecological processes. The saltfield is also located over existing unvegetated and non-primary productive supratidal salt flats.

Provisional sustainability criteria	Yannarie Solar Project
Does the proposal avoid or minimise adverse impacts and promote beneficial impacts on the surrounding community?	Comprehensive consultation activities were undertaken to identify community concerns and potential social impacts. A number of project modifications were made, including the location of a residential operational workforce in Exmouth. This will lead to a number of beneficial impacts on the local community, including increased social networks, community activities and contribution to community services.
Does the proposal produce sustainable net economic benefits?	Solar salt production is a sustainable process, allowing the proposed project to be developed with a long-term lifespan. The project will have a number of beneficial impacts on the local, regional and state economy through the purchase of local goods and services, increased local expenditure from construction and operational wages and royalty contributions. The Project will also provide local employment opportunities and increase industry diversity. This will decrease some vulnerability resulting from the seasonal nature of existing industries.
Does the proposal produce sustainable net social benefits?	The creation of local employment, training opportunities and economic benefits will result in net social benefits. The introduction of an operational residential workforce in Exmouth will provide social benefits, such as increasing social networks, community activities and contributions to community resources.
Does the proposal add to heritage protection and provide a sense of place?	Archaeological and ethnographic surveys have been undertaken to understand and minimise potential heritage impacts. These surveys have added a number of sites previously unidentified as sites of significance to the current knowledge base. These sites will be protected, or where this is not possible, appropriate consultation and clearances will be obtained.
Does the proposal produce net environmental benefits?	Through a number of significant modifications in engineering design, Straits has minimised the loss of regionally important algal mat and mangrove communities. A commitment has been made to plant mangroves to offset losses from construction of the proposal. Additionally, a monitoring program for NIMS will be implemented, the saltfield will provide waterbird habitat and research will be conducted to improve scientific knowledge of dugong distribution and its relationship with benthic habitat.
Does the proposal contribute to a more equitable and just society?	Straits is an equal opportunity employer and the social and economic benefits of the proposal will be distributed locally and regionally.
Does the proposal interact positively with other likely developments?	Extensive consultation was undertaken to identify the key concerns of existing business and industry groups. A number of modifications to engineering design have been made to minimise potential impacts to these industries, such as the inclusion of several alternate anchorage areas to reduce impacts to seasonal prawn trawling fleets. Tours of the facility will be encouraged through the use of local operators.
Does the proposal provide new opportunities (social, economic or environmental)?	The proposed project will provide employment opportunities for the local community, increase social networks and will provide direct economic benefits. Straits consider that the increase in local industry diversity will serve to decrease some of the vulnerability resulting from the seasonal nature of existing industries. Funding ongoing research into the area will increase knowledge of the regional ecology and ecological interactions.

2 STAKEHOLDER CONSULTATION

Engaging all stakeholders throughout the life of the project and in particular during the environmental investigations stage is an important step in the development of any project and achieving sustainability. Straits recognised the need for proactive, two-way consultation for the Yannarie Solar Project and implemented an inclusive community consultation program.

2.1 CONSULTATION PROGRAM

A number of consultation tools were used in the consultation program to improve the effectiveness and opportunities for collecting feedback and dissemination of project information. These tools included:

- Stakeholder Liaison Groups (SLGs)
- a part time office in Exmouth
- a project brochure
- monthly project updates
- a "Frequently Asked Questions" sheet
- regularly published Fact Sheets
- information displays in the Ross Street Mall in Exmouth
- presentation at the Harold E Holt Naval Base in Exmouth
- presentation at an Exmouth Chamber of Commerce and Industry regular meeting
- meetings with Exmouth residents at their houses or in the Straits office
- meetings with aquaculture lease holders within Exmouth Gulf
- presentations to the Shires of Exmouth and Ashburton
- presentation at the Exmouth High School
- presentations to MG Kailis Group
- Straits website.

A wide range of environmental aspects were raised throughout the consultative process and have helped focus on issues that are important to various stakeholders. Key stakeholder concerns arising during the consultation process are listed below in Table 2-4.

Each of these concerns was addressed during SLG meetings and is further addressed in this ERMP.

Table 2-4 Key stakeholder concerns

Key stakeholder concerns	ERMP Reference
Protection of the mangroves and algal mats	Chapter 6, Section 2
Potential impacts on the daily tidal movements	Chapter 6, Section 1
Potential effects on marine mammals such as whales, Dugongs and turtles	Chapter 6, Section 3
Protection of the fisheries habitats including seagrass beds and mangroves	Chapter 7, Section Chapter 7
Potential for acid sulphate soils to be disturbed	Chapter 5, Section 1
Potential to introduce non-indigenous marine species	Chapter 6, Section 3
Potential interruption of surface water flows and the nutrient transfer processes from the coastal strip to the Exmouth Gulf	Chapter 5, Section 3
Changes to sediment transport and potential impacts to benthic habitats, including seagrass beds	Chapter 6, Section 2
Management of excavation and/or dredge spoil and the potential for increased sediment loads during dredging operations	Chapter 6, Section 3
Bitterns management and the potential impacts to marine flora and fauna	Chapter 6, Sections 2 and 3
Effects of storm surge and cyclones on the saltfield	Chapter 3, Section 2
Potential impacts on Ningaloo Reef	Chapter 4, Section 2.2.1
Potential impacts on recreational fishing and tourism	Chapter 7, Section 2

Stakeholder liaison groups

Stakeholder liaison groups were established in Exmouth and Onslow with representatives from a wide variety of stakeholder groups (Table 2-5). The SLGs have been meeting regularly since September 2004.

The purpose of the SLGs was to provide forums to disseminate the latest information about the project and to seek and record concerns and obtain input. Feedback from the SLGs and other forums has been addressed throughout the ERMP and was used to guide the design of the saltfield.

Table 2-5 Membership of the stakeholder liaison groups

Exmouth	Onslow
Shire of Exmouth	Onslow Employment Project
MG Kailis Group	Thalanyji People
Department of Fisheries (DoF)	Shire of Ashburton
Exmouth Visitors Centre	Ashburton Fisheries
Department of Conservation and Land Management (CALM)	Onslow Chamber of Commerce and Industry
Exmouth Indigenous Representative	Onslow Visitors Centre
Exmouth Game Fishing Club	
Cape Conservation Group	
Exmouth Bluewater Tackle	
Exmouth Chamber of Commerce and Industry	
Exmouth residents	
Gascoyne Development Commission	
Morgan & Co	
Workbase	

Community and non-government organisations

A part-time office was established and attended by a senior Straits representative for one week each month in Exmouth to facilitate contact with the local community.

The Exmouth based Cape Conservation Group (CCG) participated in the consultation program and was an inaugural member of the Exmouth SLG. Consultation was undertaken in an open and transparent manner and positive feedback received about the consultation process from those that participated.

Consultation with the Conservation Council of Western Australia (CCWA) and Wilderness Society proved unsuccessful with these NGOs not responding to invitations to meet and discuss the Yannarie Solar Project beyond the initial contact in 2003. Table 2-6 provides a summary of the consultation undertaken with various non-government organisations between December 2003 and December 2005.

Table 2-6 Meetings with Non Government Organisations

NGO	Date	Method	Purpose
Conservation Council of Western Australia (CCWA)	18-Dec-03	In person	Meeting
Coastal Community Network	18-Dec-03	In person	Meeting
	8-Aug-05	In person	Meeting
The Wilderness Society	18-Dec-03	In person	Meeting
WWF Australia	08-Jun-05	In person	Meeting
Cape Conservation Group	30-Sep-04	In person	Meeting
	25-Nov-04	In person	Plane trip over project area
	25-Nov-04	In person	Meeting
	07-Jun-05	In person	Meeting
	08-Jun-05	In person	Meeting
	04-Aug-05	In person	Meeting
	04-Oct-05	In person	Meeting
	06-Dec-05	In person	Meeting

State Government agencies

Ongoing consultation with State Government departments has occurred since project inception. Table 2-7 summarises the key consultation events for each of the Government departments.

Table 2-7 State Government consultation

Department	Date	Method	Purpose
Department of Environment (DoE)	26-Aug-03	In person	Project briefing
	05-Jul-04	In person	Project update
	30-Jul-04	In person	Environmental survey work
	23-Aug-04	In person	Project update
	11-Oct-04	In person	Finalisation of ESD
	15-Feb-04	Letter	Straits responds to submissions
	16-Feb-05	In person	Acid sulphate soil management
	15-Mar-05	In person	Marine investigations update
Department of Conservation and Land Management (CALM)	26-Aug-03	In person	Project briefing
	11-Aug-04	Letter	Invitation to join SLG
	27-Aug-04	In person	Project update
	19-Nov-04	In person	Marine issues
	25-Nov-04	In person	Plane trip over project area
	25-Nov-04	In person	SLG meeting
	09-Dec-04	In person	Project update
	02-Feb-05	In person	Project update
	22-Jul-05	In person	Project update
	07-Dec-05	In person	Project update
Environmental Protection Authority (EPA)	26-Jul-04	In person	Project briefing
	18-Nov-04	In person	Project briefing
Department of Fisheries WA	11-Aug-04	Letter	Invitation to join SLG
	25-Nov-04	In person	Plane trip over project area
	07-Feb-05	Email	Project information
	18-Mar-05	In person	Fishery advice
	31-Mar-05	In person	SLG meeting
	04-Aug-05	In person	SLG meeting
	11-Aug-05	In person	Interaction with trawlers
	13-Oct-05	In person	Project update
Department of Industry and Resources	Regular contact	In person	Project update
Tourism WA	11-Apr-05	In person	Project update

Commonwealth Government

The Department of Environment and Heritage (DEH) is the primary Commonwealth Government department and decision making authority. The DEH was first contacted on 10 May 2004 to discuss the Yannarie Solar Project. The project was formally referred to the DEH on 22 July 2004. Table 2-8 summarises the key contact dates for the DEH.

Table 2-8 DEH consultation

Date	Method	Purpose
10-May-04	Telephone	Initial consultation
14-Jul-04	In person	Meeting
15-Jul-04	Email	Follow-up meeting
02-Aug-04	Letter	Submission of draft Terms of Reference
15-Sep-04	In person	Project briefing

Outcomes of Consultation

The consultative process resulted in a series of iterative changes to the project infrastructure design, layout and the development of management measures to address unavoidable impacts.

These changes have been summarised previously in Table 2-2.

2.2 FUTURE CONSULTATION

This ERMP document is subject to a 10-week public review period and at the end of this period, issues raised in written submissions from the public and government agencies are transmitted to Straits for an opportunity to provide responses to the submissions.

Additionally, Straits will prepare an Annual Environmental Report (AER) for the Yannarie Solar project. This review will report on the environmental commitments, including monitoring results, management responses and environmental performance.

A Tripartite Stakeholder Liaison Group (TSLG) has been established and will continue to provide a public forum for transparent environmental management.

The TSLG will be provided with all monitoring data resulting from management commitments as well as helping to develop and implement the respective community based monitoring programs.

Meetings of the TSLG will be open to the public and the group will include representatives from:

- community environment organisations
- local Government
- Government agencies
- Chamber of Commerce and Industry
- Recreation fishing sector
- Commercial fishing sector
- Tourism
- Straits Resources.

3 THE PROPOSAL

3.1 PROJECT JUSTIFICATION

3.1.1 Markets, demand and supply

World demand for salt in 2005 was around 225 million tonnes per annum (Mtpa). The main consumer of salt (sodium chloride) is currently the chemical industry (60%), 30% is produced for edible salt and 10% for de-icing. Salt is the key raw material for the production of caustic soda and chlorine and is also one of the two major chemicals used in the production of soda ash. These three chemical products are important for the manufacture of thousands of downstream products (Table 2-9).

Table 2-9 Salt applications

Salt derivative	Applications
Caustic soda	Pulp and paper, textiles, petroleum refining, bauxite digestion, in the manufacture of aluminium, dyes, soaps and the synthesis of organic and inorganic chemicals.
Soda ash	Glass, pulp and paper, soap, detergents and water treatment.
Chlorine	Poly vinyl chloride, bleaches, water treatment, hydrochloric acid, vinyl chloride resins, plastics and the synthesis of numerous organic and inorganic chemicals.
Sodium	Cosmetics, ore refining, pharmaceuticals and metal plating salts.
Sodium sulphate	Ceramics, detergents, dyes and fertilisers.
Hydrogen	A by-product of chlorine manufacturing. Used during the production of ammonia

Source: CSIRO 2004

Australia is a major exporter of bulk solar salt, as the international trade for bulk salt is limited and the majority of the demand is in the Asia – Pacific Rim region. Solar salt facilities in Australia need to be large integrated facilities to ensure that competitive unit costs of production and sufficient market volume can be achieved and maintained to service this demand. They must also be capable of producing salt of a consistently high quality.

The demand for high quality solar salt in the Asia-Pacific region has been driven by both population growth and industrial demand. The 2005 market demand for imported solar salt into the major markets of China, Japan, South Korea, Taiwan and Indonesia, plus other minor markets is approximately 21 million tonnes (Table 2-10). If solar salt is not available for the expanding market, then the chlor-alkali producers will be forced to use vacuum salt as one of the main alternatives. This will increase the global consumption of fossil fuel.

Although China has abundant resources of salt, there has recently been a shortage of salt supplies. A surge in industrial projects in China created a demand for salt in quantities beyond its domestic supply capacity. This increase in demand prompted plans to construct a new solar salt operation in Western Australia, which if constructed, could satisfy some of the salt demand of China.

Table 2-10 Total salt imported into the Asian market in 2005

Country	Imports of Salt (Mtpa)
Japan	8.0
South Korea	2.6
Taiwan	2.4
Indonesia	2.1
China	4.5
Others	1.0
Total	20.6

Source: SSJV 2006

Western Australia and Mexico are currently the two dominant producers of solar salt which is exported to the Asia-Pacific area.

Western Australia currently exports more than 10 million tonnes of solar salt to Asia, with Mexico supplying more than 5 million tonnes. This business is dominated by two producers. In Western Australia, Dampier Salt Limited operates three of the five major saltfields in WA at Dampier, Port Hedland and Lake Macleod. Dampier Salt exports more than 70% of salt produced in WA. There is only one major supplier from Mexico, Exportadora de Sal (ESSA). It will be necessary for Straits to establish a capacity in the same order of magnitude as these major producers (i.e. up to 10 Mtpa) to be competitive over the long term.

The existing WA saltfields produce salt containing more than 99.7% sodium chloride on a dry basis. Most Western Australia saltfields produce this grade of salt which is set by the specifications of the chlor-alkali customers.

Western Australia has the advantage of being the closest major solar salt producing state to the various Asia-Pacific customers. Additional sources of salt from Western Australia would therefore be attractive to potential customers in the region.

The existing salt producers in Western Australia exporting to the Asia-Pacific region have limited expansion capacity and are likely to achieve close to their maximum potential capacities by 2010. Beyond then, the continued increase in China's demand for high quality salt for chemicals in the Asia-Pacific region is unlikely to be satisfied by the current producers. The Straits Yannarie Solar Project is currently the only major solar salt proposal in the region capable of meeting this demand.

3.1.2 Sources of salt

Worldwide, salt is recovered from underground rock salt deposits, from seawater and from naturally occurring brines. The most economically viable and sustainable salt production method is through solar evaporation of seawater in a region with favourable climatic conditions. The north west coast of Western Australia has already been proven to be one of the world's most suitable regions for solar salt production due to its regional climatic conditions of very high evaporation rates and very low rainfall.

3.2 STATE AND REGIONAL BENEFITS

The Yannarie Solar Project will be constructed and operated such that the environmental, social and economic values of the region will not be compromised. The project will generate financial and employment benefits for the local community and State economy.

The detailed engineering design of the saltfield is proposed to be completed in 2007 with the first significant salt harvest and sales in 2009/2010. The Yannarie Solar Project would generate revenues of over $230 million per annum at the 10 Mtpa production capacity. The projected revenue is significant on a regional scale for Exmouth. For example, commercial fishing in Exmouth Gulf produces revenue of $10-15 million per annum. The project will provide 190 full time jobs at full production capacity. The project will also create up to 500 indirect jobs through the construction and operational phases. Employees will be housed locally in Exmouth and will invest significant money into the local economy. Additionally, Straits will be contributing to the local community through the payment of residential and commercial rates to the Shires of Exmouth and Ashburton.

The saltfield itself could provide tourism opportunities in the form of guided tours of the facilities. The predicted value of providing services and purchases from local businesses is over $7 million per annum (Q & A Communications 2005).

The Yannarie Solar Project will also indirectly contribute positively on the Exmouth school community through the enrolment of employee's children, as well as contributions to local social activities and networks by permanently increasing the number of residents in Exmouth.

The Exmouth region relies on seasonal tourism, commercial fishing and pastoral grazing as its main sources of revenue. Consequently, the Yannarie Solar Project provides an opportunity to significantly increase the diversity of industry underpinning the local economy, with no reliance on seasonal income sources.

3.3 EVALUATION OF ALTERNATIVE SITES

The area proposed for the Yannarie Solar Project is currently set aside as a Ministerial Temporary Reserve for the potential future production of salt and gypsum. Nonetheless, Straits investigated 20 potential locations for a solar saltfield on the north west coast of Western Australia. The site selection criteria used included:

- environmental sensitivities
- area available
- topographic information
- maritime survey map data
- tenement information
- general site characteristics
- distance from transport routes (road, port facilities, and airfield facilities)
- distance to population centres
- location of existing salt operations.

After applying the selection criteria to the 20 possible sites, the five most suitable sites identified were:

- Balla Balla Port area
- Mardie Station
- Tubridgi Point
- Talandji Salt Evaporator
- East Exmouth Gulf—North of Giralia Point.

All of the locations individually were considered to have insufficient area to establish a saltfield of a commercially viable size. However, combining Tubridgi Point, Talandji Salt Evaporator and East Exmouth Gulf (North of Giralia Point) sites met requirements for the development of a saltfield with potential expansion capabilities. The large area also provides significant flexibility in design and layout to allow for environmental, heritage and engineering constraints. The combined site has also previously been identified by the State Government as being suitable for future solar salt production.

A pilot study was conducted in the late 1960s with the construction of the Talandji Salt Evaporator within the boundary of the combined site. Subsequent to this, Ministerial Temporary Reserve 70/5350 was set aside over this entire area for the potential production of solar salt, gypsum and limestone from seawater.

The Yannarie Solar Project site meets all of the key area and production criteria (e.g. high evaporation rates, flat terrain, low rainfall). Straits have been granted exploration licences covering the area selected for the Yannarie Solar Project.

3.3.1 The no development option

The regional and State economies will lose a sustainable, long term operation if the project does not proceed.

The region will lose opportunities for enhancement of social networks, improvements to transport, supply services, health and school services all created as a result of the increased labour requirements from the project. These opportunities include:

- 190 full-time, non-seasonal permanent jobs based in Exmouth
- 500 indirect jobs based in Exmouth
- reduced economic dependence on seasonal industries
- $230 million/yr in revenue contributing to the Gross Domestic Product (GDP) of the region
- $10 million/yr in local expenditure
- increased training and opportunities for apprenticeships
- increased school population resulting in greater interaction and learning opportunities
- potential for a bitterns value adding industry
- significant opportunity for diversification of industry for employment of the local community.

The State Government would not benefit from the royalties and taxes that Straits will contribute to the Western Australia economy, both through the direct payment of taxes by Straits and workers, and by

businesses associated with the project. This would deny Western Australians the associated social benefits such as an increase in community services and employment opportunities.

3.4 KEY CHARACTERISTICS

Solar saltfields are classified as extractive mines under the *Western Australian Mining Act 1978*, although the extraction of the resource is renewable.

The proposal is intended to be developed in four distinct stages with Stages 1 and 2 taking up to ten years to fully establish:

- Stage 1 – establish a saltfield at the southern end of the lease having a nominal capacity of 3.1 Mtpa
- Stage 2 – increase the capacity of the southern end of the lease to a nominal 4.7 Mtpa
- Stages 3 and 4 – establish a saltfield at the northern end of the lease having an ultimate capacity of 5.8 Mtpa. The combined southern and northern ends give a total of 10 Mtpa.

The proponent is willing to accept as a condition of approval or upon request of the Minister for Environment pursuant to section 46 of the EP Act to conduct an environmental review of the project before commencing stages 3 and 4. This review would consider all environmental impacts and how they are being managed as well as a review of any social issues associated with the project.

The scoping for this review will be determined in consultation with the EPA and the review submitted to the Minister for the Environment. The EPA would assess the review and provide advice to the Minister on any new or amended environmental conditions needed to ensure the project continues to proceed in an environmentally acceptable manner.

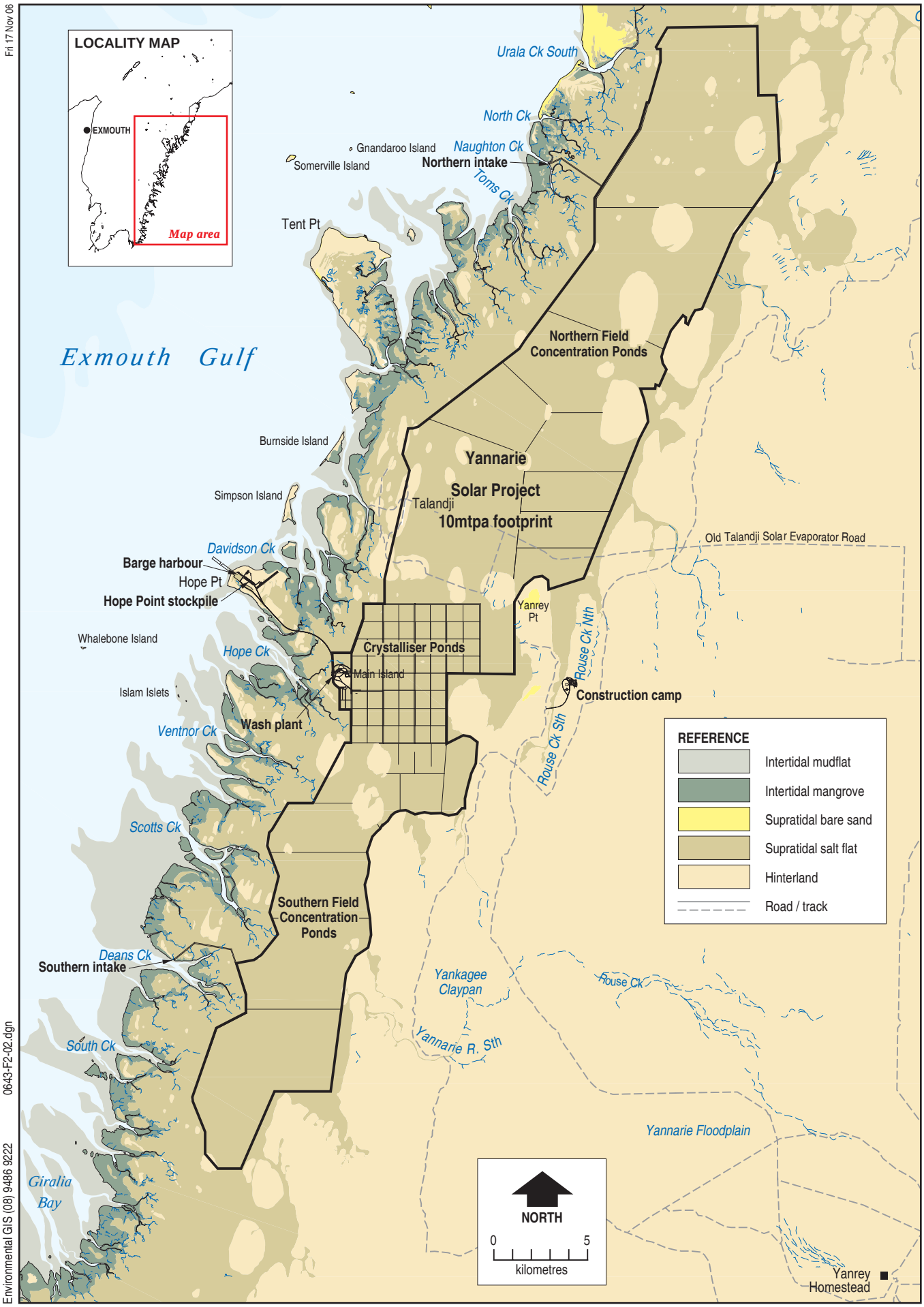
Straits is not seeking approval to discharge bitterns and has set a goal of zero discharge and maximum resource recovery through a continuous improvement process. The financial and technical feasibility of achieving zero discharge will be assessed within in the first ten years of operation of the saltfield (about 13 years from the commencement of construction). An initial feasibility study by the CSIRO on the technical capacity for bitterns re-use and the potential value of bitterns products has identified significant long term opportunities (CSIRO 2004).

Any new value-adding processes will be referred to the Environmental Protection Authority (EPA) for consideration on completion of the final assessment of bitterns resource recovery feasibility. A separate referral to the EPA would also be made for the disposal of any bitterns was not able to be practicably re-used or contained.

Appendix 1 addresses in detail the proposed bitterns resource recovery strategy. This resource recovery strategy involves a new level of best practice for saltfield operation in Western Australia.

Figure 2-2 illustrates the proposed location and layout of the pond levee system.

The key characteristics of the proposal are listed in Table 2-11.



Fri 17 Nov 06

0643-F2-02.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-2 Proposed location and layout of Yannarie Solar Project

Table 2-11 Key project characteristics

Characteristic	Description
Proposal location	Refer Figure 2-2
Production	Up to 10 Mtpa
Current reservation of project area	Ministerial Temporary Reserve for potential future solar salt and gypsum production.
Site disturbance (ha)	
Terrestrial Vegetation	Approximately 461 ha of terrestrial vegetation to be removed for infrastructure
Mangroves	Approximately 5.4 ha
Algal mat	Approximately 30.8 ha
Quarries	Approximately 26.9 ha
Salt flat	Approximately 411 km^2
Proposal location	Refer Figure 2-2
Concentrator and crystalliser ponds	
Location	Refer Figure 2-2
Quantity	64 crystalliser ponds, 16 concentrator ponds, 1 bitterns management area
Levee banks	
Materials	Approximately 5,700,000 m^3 embankment material
	Approximately 1,100,000 m^3 rock armour
	Approximately 145,000 m^3 road base materials
Length	Approximately total of 300 km
Prospective quarry sites	Refer Figure 2-9
Salt stockpile	
Location	Refer Figure 2-12
Quantity	Approximately 1 million tonnes
Length	Approximately 1 km
Duration of the project	>60 years
Seawater pump stations	
Location	Refer Figure 2-2, Figure 2-5 and Figure 2-6 Hope Point, Dean's Creek, Naughton Creek
Harbour	
Area	12 ha
Location	Hope Point
Dredge volume	284,500 m^3 for harbour and 20,500 m^3 for channel
Dredge channel	approximately 1.3 km long
Construction camp	
Size	Modular transportable living quarters for 100 workers
Water supply	Reverse osmosis unit producing 30 kL per day
Sewerage treatment plant	Activated sludge sewage treatment system
Power generation	8 MW (4 x 2 MW) diesel generators
Roads	Primary access road running 55 km from the existing Yanrey Station access road to the site boundary
	General site access roads within Hope Island
Site facilities	Airstrip at Hope Point for general site access and emergency evacuation
	Bunded fuel storage area
	Truck service bays and wash, parts store and tyre change and storage
	Mobile plant workshop
	Offices and laboratory
Workforce	
Construction	100 personnel
Operation	Up to 190 personnel

3.5 SALT PRODUCTION PROCESS

Normal seawater has a specific gravity of 1.0247 g/ml (measured at 20^{o}C), and contains 26.61 grams of salt (sodium chloride) per 1000 grams of seawater (Baseggio 1974). The combined weight of all salts in seawater is 34.2 grams per 1,000 grams. Exmouth Gulf seawater has a marginally higher specific gravity than normal seawater due to localised higher evaporation in the Gulf.

Seawater intake and concentration

Seawater will be pumped from Dean's and Naughton Creek into a series of concentrator ponds (Figure 2-3). As the seawater (now called brine) flows through the series of concentrator ponds, solar energy evaporates water, increasing both the density of the brine and concentration of the dissolved salts. Calcium salts begin to precipitate out of the brine at an early stage, initially as calcium carbonate ($CaCO_3$) and then as calcium sulphate ($CaSO_4.2H_2O$) in the form of gypsum. The calcium salts remain on the floors of the concentrator ponds increasing the sealing of the ponds.

At the exit point of the final concentrator pond, the brine has achieved a specific gravity approaching 1.216 g/ml. At this density the brine is saturated with salt (sodium chloride) and 85% of the gypsum has been removed.

Crystalliser ponds

The saturated brine would then be pumped into the crystalliser ponds where salt (predominantly sodium chloride) precipitates out as crystals.

The crystalliser ponds will consist of multiple ponds arranged in pairs. The brine moves continually through each of the pairs (via passive movement) and at the exit point of the second crystalliser pond the specific gravity of the brine reaches approximately 1.25 gm/ml. At this density about 75% of the sodium chloride and most of the remaining calcium in the incoming brine has been precipitated.

The precipitated salt forms an even bed on the floor of the crystalliser pond and under average meteorological conditions the bed thickness after one year will be approximately 25 cm.

Initially, this salt bed will be left in place as a permanent pavement and subsequently harvesters and haulage equipment will extract salt that precipitates out on top of this pavement.

Bitterns resource recovery

The residual brine leaving the crystalliser ponds (termed bitterns) contains up to 25% of the sodium chloride of the brine initially fed to the crystalliser. This bitterns resource is then transferred to new or purpose built crystalliser ponds where further crystallisation of sodium chloride takes place to provide pavement material or harvestable salt. After this stage about 7% of the original sodium chloride is left in solution, which has a specific gravity of about 1.3.

After recovery of sodium chloride, the remaining bitterns will be concentrated and then processed through ponds to extract a complex mixture of salts (principally potassium) which will vary according to the local characteristics of the saltfield. The specific gravity of the brine residue will increase to 1.35 and the volume will be about 20% of the original bitterns volume. The economic recovery of these salts is anticipated when Stage 1 of the saltfield is fully operational. Site specific research work will be required to confirm the technical and economic options.

Recovery of magnesium values from the residual of the mixed salt production would result in full resource recovery from bitterns but requires further evaluation of feasibility.

Technology already exists for the further processing of bitterns to extract further sodium chloride and other salts from bitterns.

In 2004, CSIRO was commissioned to prepare a preliminary assessment of the options for processing bitterns. The objective was to identify potential commercial products that could be extracted from the bitterns (CSIRO 2004). The study concluded that bitterns produced from the Yannarie Solar project could potentially be made into a range of products including:

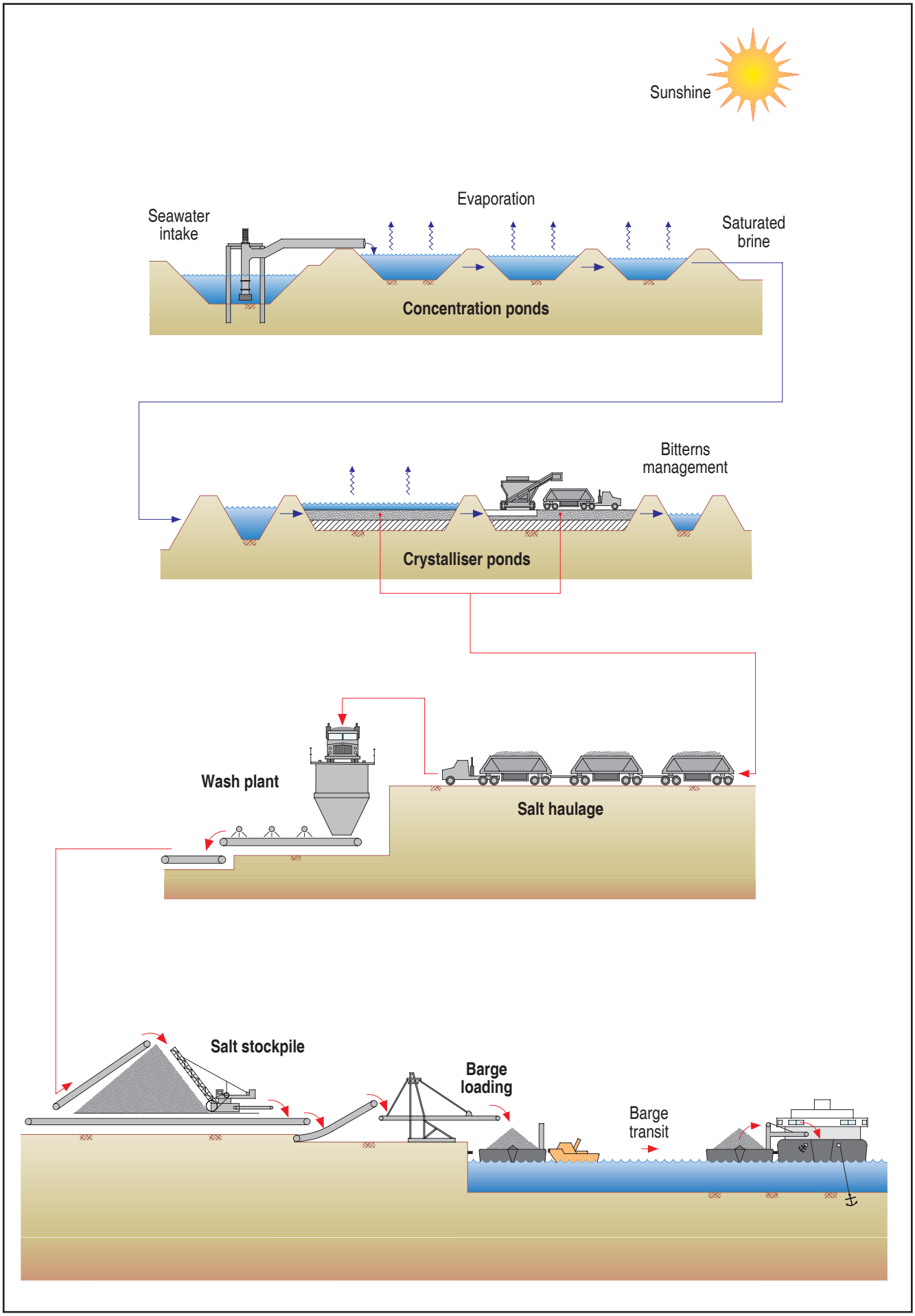
- magnesium oxide
- hydrochloric acid
- magnesium hydroxide
- magnesium sulphate
- magnesium chloride
- potassium chloride
- potassium sulphate
- bromine
- epsom salts.

These products can be marketed both domestically and around the world, with opportunities such as:

- supply of potassium sulphate, potassium chloride and magnesium sulphate to fertilizer producers
- supply of magnesium oxide to refractory brick producers and cement industries
- supply of products for niche markets such as flame-retardant grade magnesium hydroxide
- supply of feedstock to magnesium metal producers
- supply of hydrochloric acid (a by-product of magnesium oxide production) to e.g. fertiliser manufacturers, plastics producers, nickel ore processors.

A final assessment of the technical and economic options for resource recovery from the bitterns will be completed within ten years of the commissioning of Stage 1. While financial viability is essential for any potential processing opportunity, the major benefit of limiting the need to discharge residue into Exmouth Gulf will be a prominent consideration in a decision on reuse options.

Appendix 1 addresses in detail the proposed Bitterns Resource Recovery Strategy. This resource recovery strategy involves a new level of best practice for saltfield operation in Western Australia.



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-3 Solar salt production flowchart

Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

Harvesting and washing

Harvesting of the crystallised salt will be conducted on a continuous basis with each crystalliser pond being drained and harvested into haulage vehicles. Once each crystalliser pond is harvested it is re-flooded to return back into production for another year.

The harvested salt is transported by truck to the washplant and upgraded by the removal of most of the solid or liquid impurities present to achieve export quality grade salt. All washing brine is recirculated through settling ponds, with any overflow of brine being directed back to the concentrator ponds (refer to Section 3.9.8 for further detail).

Transport and export

The washed salt is then transported by conveyor to the storage stockpile at Hope Point. The dry salt is reclaimed from this stockpile and conveyed to barges in the barge harbour which then transport the salt to ships in the Gulf.

The export quality salt will primarily be used in chemical plants in the Asian region. A small proportion of the salt exported will be used for edible purposes after further processing offshore.

3.6 SITE ACCESS AND HAUL ROADS

Onsite staff transfer options considered for this proposal included fast speed ferry, helicopter and fixed wing aircraft. Fixed-wing transportation of personnel was selected as it will be fast, efficient, economical and avoids noise disturbance to marine megafauna (whales, dugongs etc.) and remove the risk of boat strike. Staff and contractors will be flown to site and back to Exmouth for each work day of the operation.

An access road will be established to link the Project area to the existing Yanrey Station access road, which in turn links to the North West Coastal Highway.

Haul roads (with access restrictions) will be established to access quarry areas during the construction of the project.

Construction

A temporary camp for about 100 contract workers is required during the construction phase. The site is proposed to be located east of the supratidal flats in the hinterland and approximately central to the proposed northern and southern fields (Figure 2-4).

The camp will be serviced by a compact activated sludge unit for wastewater treatment. Treated water will be used for irrigation of landscaped areas around the construction camp site and sludge will be taken off-site for disposal at an approved facility.

The power requirements (about 200 kVA) for the construction camp will be supplied by a diesel generator.

Environmental GIS (08) 9486 9222 0643-F2-04.dgn Fri 17 Nov 06

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

Figure 2-4 Proposed location of construction camp

YANNARIE SOLAR PROJECT ERMP/EIS

Operation

The initial setup phase (Stage 1) consists of a 3 Mtpa saltfield and requires approximately 70 full time permanent personnel working various shifts. At design capacity, the 10 Mtpa saltfield will require approximately 190 full time permanent personnel.

Site facilities will include the production area, plant service area, parts store, administration complex, wash plant office and the visitor complex. The production area will comprise a production office and crib room, truck parking area and a truck wash down area. The plant service area will consist of a mobile plant area (truck service bays and a workshop) and a parts store for tyre change and storage. The administration complex will include administration and maintenance offices, laboratories and staff office facilities. The wash plant office will comprise an office area and a laboratory. The visitor complex will include eight single bedroom units for use as emergency accommodation.

3.7 SEAWATER AND FRESHWATER WATER SUPPLIES

3.7.1 Freshwater source

Seawater will be used as the supply to feed the reverse osmosis plant at Main Island for the construction camp and to provide water for dust suppression (Table 2-12). This will avoid the need to develop a groundwater supply within the hinterland on the eastern side of Exmouth Gulf.

The total consumption of water by the project is anticipated to be about 194 ML/yr.

Freshwater for the operations at Hope Point will be tankered from the reverse osmosis plant at Main Island.

Table 2-12 Seawater requirements for reverse osmosis plant and dust suppression

Item	Water from RO Plant	
Construction camp	30 kL/day	11.0 ML/year
Dust suppression	500 kL/day	183 ML/year
Total	**530** kL/day	**194** ML/year

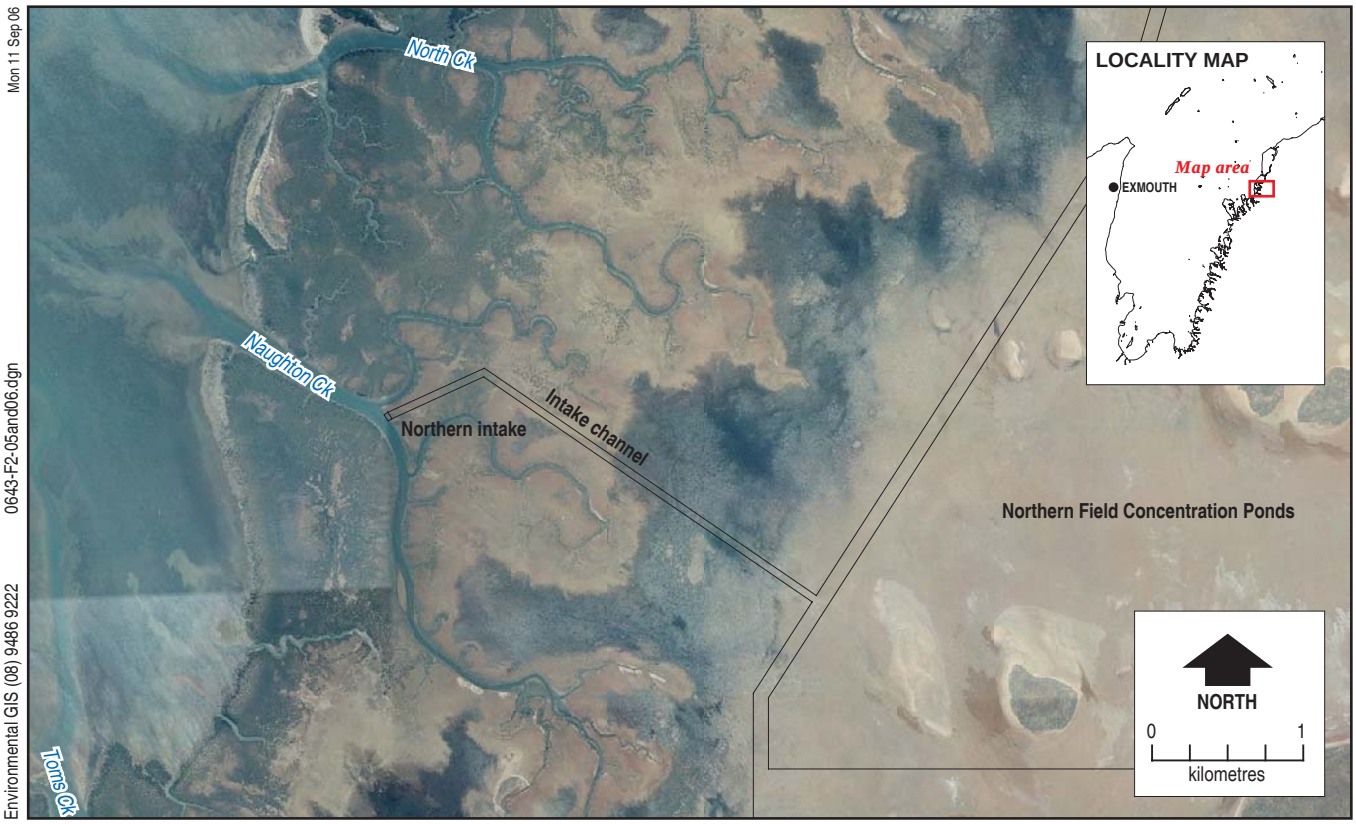
3.7.2 Seawater supply for ponds and processing

Seawater pump stations

The nominal 10 Mtpa saltfield seawater intake requirements for the southern intake pump station (about 202 x 10^6 m^3/year) and northern pump station (about 304 x 10^6 m^3/year) will be sourced from creeks with suitable tidal ranges and physical characteristics.

A number of potential seawater intake sites were investigated and it is proposed to source seawater for the northern field from Naughton Creek, and from Dean's Creek for the southern field (Figure 2-5 and Figure 2-6).

Seawater requirements for the production of freshwater for operation staff requirements, met through a reverse osmosis process, will be drawn from an intake south of Hope Point. Seawater requirements for process purposes (100 kL/day) will also be drawn from the same area, and transported to a seawater holding pond adjacent to Main Island.



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-5 Proposed location of northern intake pump at Naughton Creek

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-6 Proposed location of southern intake pump at Dean's Creek

Seawater intake structures

The intake chambers will be open to the creek so that seawater can flow directly to the pumps via a bar screen (Figure 2-7).

The primary objective of the screens is to prevent floating debris and marine megafauna entering the pump intake. The velocity of seawater flowing through the screens (0.95 m/s) will also be low enough to prevent the entrapment of marine megafauna against the screens.

The pump stations will be designed to prevent bank and creek bed erosion caused by the tidal pumping of large seawater volumes.

Figure 2-7 Typical seawater intake structure from a saltfield in north west Western Australia

3.7.3 Seawater conveyance

The conveyance of seawater for both pond systems and process requirements has been designed to avoid mangrove and algal mat areas as far as practicable. This has been achieved by selecting the shortest possible length and width for the required seawater conveyance corridors, as well as avoiding mangroves and algal mat communities.

The southern and northern seawater intakes and the pump stations will be located to ensure adequate delivery of water over the extended tidal range and depth of water over intake. The pump stations will also be located to reduce conveyance distance and mangrove and algal mat disturbance.

The seawater will discharge via a flume to the first (southern and northern) concentrator ponds (Figure 2-8).

The proposed pipeline from the Hope Point process wash water pump station to the seawater holding pond will be within the services corridor between Hope Point and Main Island.

3.8 CONCENTRATOR AND CRYSTALLISER PONDS

All the ponds have been designed to be located to the east (landward) side of mangroves and algal mat communities, and are totally contained within the extent of the supratidal salt flat. Pumped seawater will flood the areas within the ponds to a depth of up to 1.5 m.

The layout of concentrator ponds and brine flow has been optimised to suit the natural topography of the supratidal salt flats so as to maintain efficient hydraulic gradients over the saltfield area.

The perimeter levees of the concentration and crystalliser ponds will be keyed with clayfill through the less impervious mudflat layers into underlaying impervious layers to prevent seepage. A permanent pavement of crystallised salt will be laid down in crystalliser ponds before salt harvesting to enable heavy machinery to work on the pond surface once the bitterns have been drained away. The pavements also ensure that the high grade salt is recovered by providing a barrier between the harvested salt and the salt flat sediments. The pavement also acts as a seepage mitigation barrier on the crystalliser floor.

The fully developed saltfield will comprise of 50 crystalliser ponds, covering a flooded area of approximately 40 km^2 and 16 concentration ponds with a flooded area of approximately 310 km^2.

3.8.1 Sea level change

For the purpose of determining a set back limit to accommodate future sea level rise, it was considered appropriate to utilise the Bruun Rule (Bruun 1962). This model has been adopted by the Western Australian Planning Commission (WAPC 2003) policy for sea level rise and states that:

> "The vertical change predicted by the current model between the years of 2000 and 2100 is 0.38 m".

Via the Bruun Rule, this translates to a shoreline retreat of 38 m.

To accommodate this retreat, the bund walls and all other non-marine infrastructure have been set back a minimum of 40 m from the inland edge of the algal mat boundary. Therefore, the impacts from sea level rise and the frequency of over-topping of bund walls by sea water are considered to be inconsequential within the lifespan of the project.

3.8.2 External and internal levee design

Concentrator and crystalliser ponds will be formed by construction of levee walls, consisting of perimeter seawall levees and internal levees (Figure 2-8), totalling approximately 300 km at 10 Mtpa capacity (Stage 4).

The levee system will be designed to contain and protect the brine and crystallised salt during normal operational and meteorological conditions, and during cyclonic activity and severe storm events. The levees will be designed to withstand, at a minimum, a 1 in 25 year Annual Recurrence Interval (ARI) storm event. Storm events exceeding the 1 in 25 ARI event may result in overtopping, but the structural integrity of the levees will be maintained.

The height of the external seawalls is determined by cyclone sea level elevation and associated seawater set-up (elevation of seawater from storm surge) and wave run-up. The heights of the internal concentrator pond levees are determined by the design level of the contained brine, plus an allowance for rainfall, and associated wave run-up resulting from wind-generated brine set-up. The same design criteria are applied to the design of the crystalliser pond levees.

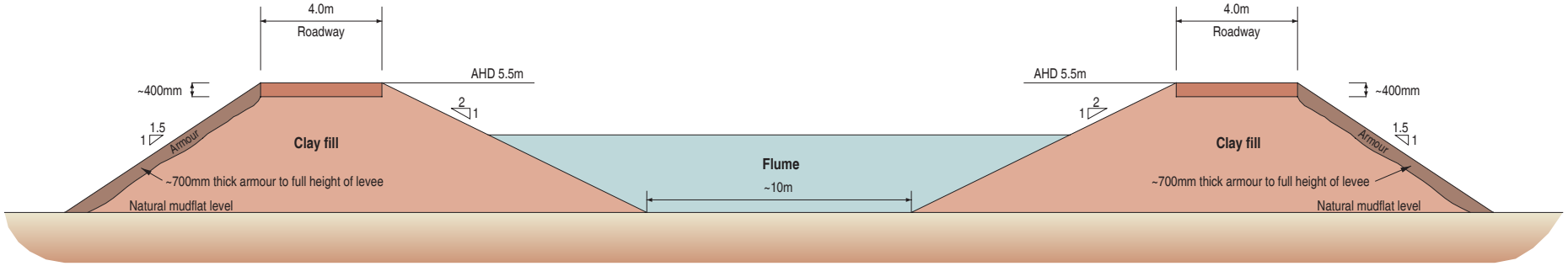
All levees will be constructed of low permeability clay fill core material to ensure cohesive strength against erosion and to prevent loss of brine through seepage. Levees will be protected by a blanket of rock armour designed to prevent displacement during storms.

During events that exceed the design standards, some overtopping of seawater and stripping of armour from the levees is possible, but catastrophic failure of the levees is highly unlikely. Correctly engineered and constructed levees at other Western Australian solar salt operations have not catastrophically failed during cyclonic events to date.

All concentrator pond levees are located well inland from the main Gulf area itself (between 4 and 8 km away), which provides additional protection of levees against storm damage.

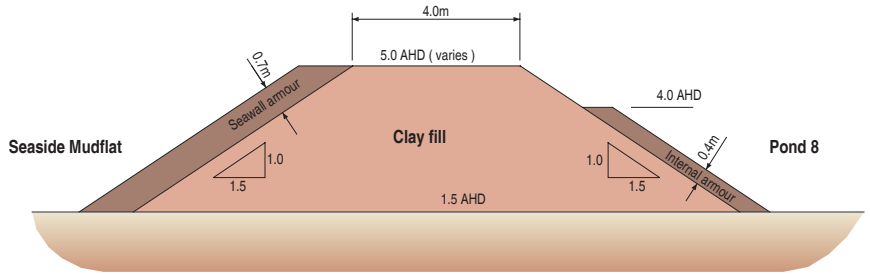
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

Yannarie Solar
a Straits initiative



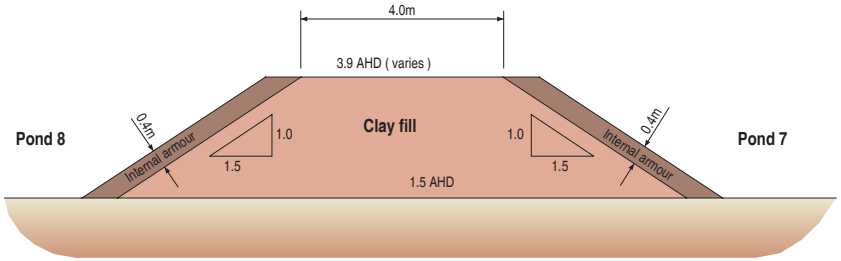
A. CONCEPTUAL SEAWATER DELIVERY FLUME

Not to scale



B. TYPICAL SEAWALL LEVEE

Not to scale



C. TYPICAL CONCENTRATOR INTERNAL LEVEE

Not to scale

Figure 2-8 Typical Levee and flume cross - sections

YANNARIE SOLAR PROJECT ERMP/EIS

3.9 SOURCE OF LEVEE CORE AND SURFACE AND ROAD MATERIALS

3.9.1 Clay

Clay will be used as the major constituent for the core of the levees because it provides strength and low permeability, the key prerequisites for effective levee functionality.

Clay materials will be sourced from claypans scattered across the lease area, primarily in the hinterland east of the salt flats and within remnant landforms on the supratidal salt flats (Figure 2-9).The estimated quantities of material required are shown in Table 2-13 for the full field capacity (10 Mtpa).

3.9.2 Rock armour

Rock material is required for batter armour on all levees, service causeways and flume walls. The armour material limits the effects of wave action, and will be of sufficient weight, grading and quality (strength, hardness and durability) that it can withstand storm events and prevent erosion.

All levees will have a running surface of limestone gravel suitably designed for maintenance or production traffic.

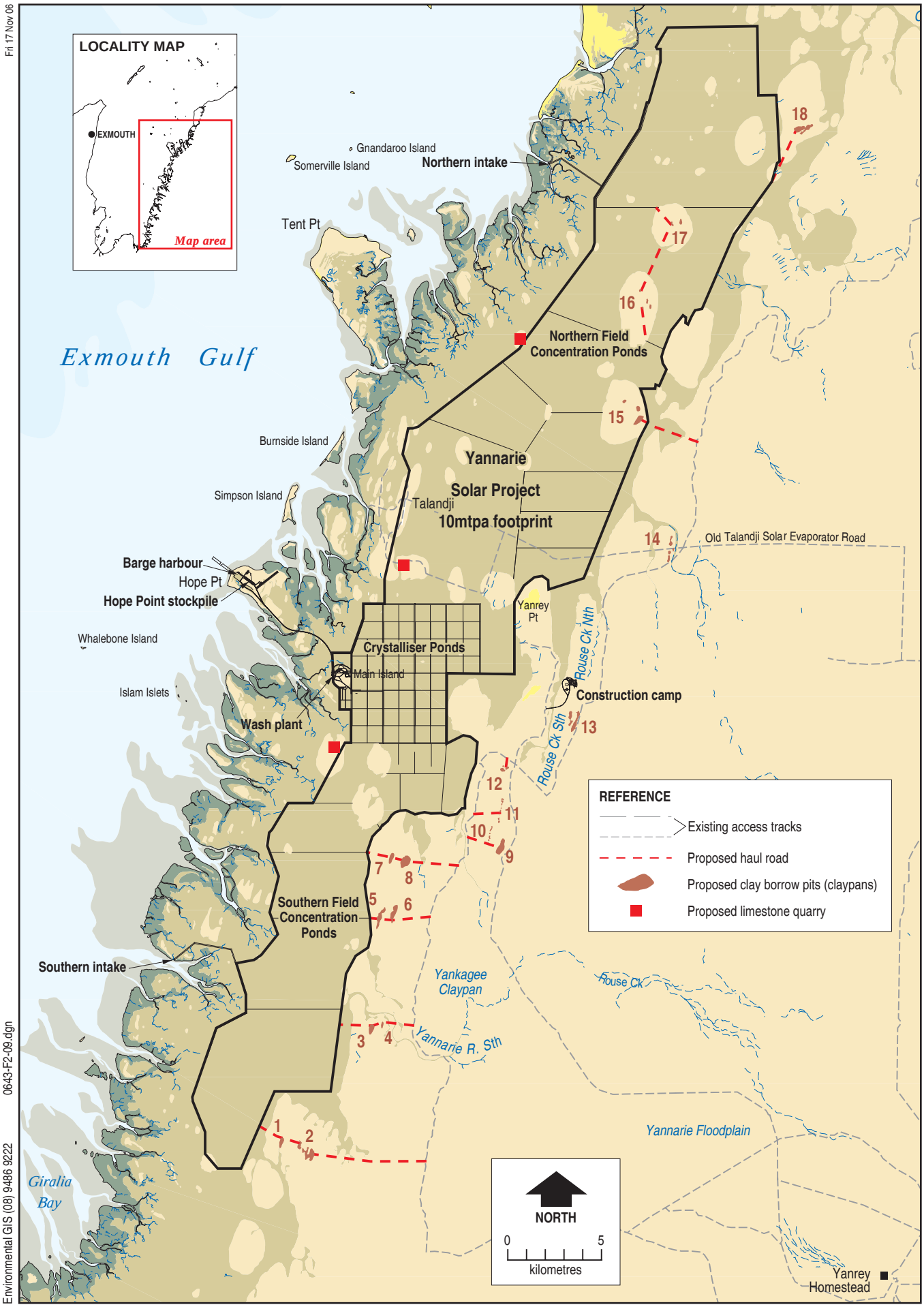
Local limestone has been identified as being potentially abundant in the project lease area. This limestone will likely suffice as armour material for the project pending further investigation. It is proposed, where suitable, to use limestone rock material sourced from the excavation and construction of the barge harbour at Hope Point in order to minimise the area of vegetation disturbance.

Approximately 600,000 m^3 of limestone rock material will be sourced from the excavation of the barge harbour (Table 2-13). The remaining quantity will be obtained from up to three limestone quarries, yielding approximately 600,000 m^3 of additional rock (Figure 2-9).

Road base material will be sourced from undersize material resulting from armour material production.

Table 2-13 Estimated material quantities for 10 Mtpa saltfield construction

Item	Required embankment material (m^3)	Required armour material (m^3)	Required road base material (m^3)
Seawall, concentrator and crystalliser	5,760,000	1,067,000	141,000
Roads, airstrip, building platform	933,000	133,000	153,000
TOTAL	**6,693,000**	**1,200,000**	**294,000**



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-9 Proposed sources of construction materials and location of existing access roads

3.9.3 Barge harbour and barge and ship loading

3.9.4 Location of barge harbour

The barge harbour will be located at a site on Hope Point that will avoid mangrove habitat (Figure 2-10). Positioning of seawater pumps, water transport routes and the conveying system have been designed to achieve the shortest possible length and width of a required transportation corridor between Hope Point and Main Island. Additionally, detailed hydrodynamic modelling was undertaken to optimise designs in order to prevent, as far as practicable, effects on the tidal flows essential to the health of mangroves that occur in areas south of the barge harbour.

The excavation of the barge harbour is anticipated to provide material for the rock armouring of levees.

The draft of the laden barges has been reduced by approximately 1.5 m, greatly shortening the length of channel excavation and dredging that will be required to provide access to the harbour. The dredge length required for construction of the barge channel has been reduced from 5.5 km to 1.3 km. All spoil will be deposited on land and used for stockpile foundation fill, road base, airstrip and levee wall construction.

The barge harbour will be excavated to 5 m Chart Datum and 12 ha in area to provide an area where barges can be secured during loading behind the limestone beach and sand dunes. The barge harbour will also provide a safe haven for operational vessels during severe weather events should the need arise. A navigation channel will be excavated within the Exmouth Gulf from the barge harbour for a length of approximately 1.3 km and to a depth of 3.5 m below Chart Datum.

3.9.5 Ship loading/unloading

Barges will be loaded in the harbour and moved by tug boats into the deeper Gulf waters where the salt will be transferred to the bulk transport ships for export. Alternative anchorage locations for the transport ships have been proposed to allow for multiple loading location options, to avoid potential for noise impacts on humpback whales and interruption to commercial fishing operations.

Fri 17 Nov 06

0643-F2-10.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-10 Proposed barge harbour design

3.9.6 Fuel storage

A diesel fuel storage facility will be installed with a storage capacity of approximately 250 kL. This facility will be constructed above the 1 in 25 year storm event contour and will be designed and operated in accordance with *AS1940:2004* (for the storage and handling of flammable and combustible liquids) and the *Dangerous Goods Regulations 1999.*

3.9.7 Power

Four 2 MW diesel power stations will be required for 10 Mtpa capacity at the following locations:

- Dean's Creek pump station
- Main Island
- Hope Point
- Naughton Creek pump station.

A small 200 kVa diesel power generation facility will service the construction camp.

3.9.8 Salt Harvesting and Materials Handling

Harvesting and haulage

Harvesting of the salt crop is a continuous operation using specialist harvesting machines which elevate the salt into haulage trucks travelling adjacent to the harvester.

The haulage trucks transport the salt from the crystalliser to the washplant on Main Island, where they discharge the salt through a grid into storage hoppers (Figure 2-11). The salt is transported on a conveyor to a stockpile at Hope Point.

Wash Plant

The function of the washplant is to beneficiate the salt from the crystallisers to an acceptable export quality. This is achieved by washing with a specially formulated wash brine to remove liquor impurities. These impurities consist mainly of residual organic and inorganic (calcium, magnesium, potassium, sulphate) solids.

All washing brine is recirculated through settling ponds, with surplus overflow brine being directed back to the production pond system.

Conveyor

The washed salt is then transported by conveyor from the washplant to the stockpile on Hope Point (Figure 2-12).

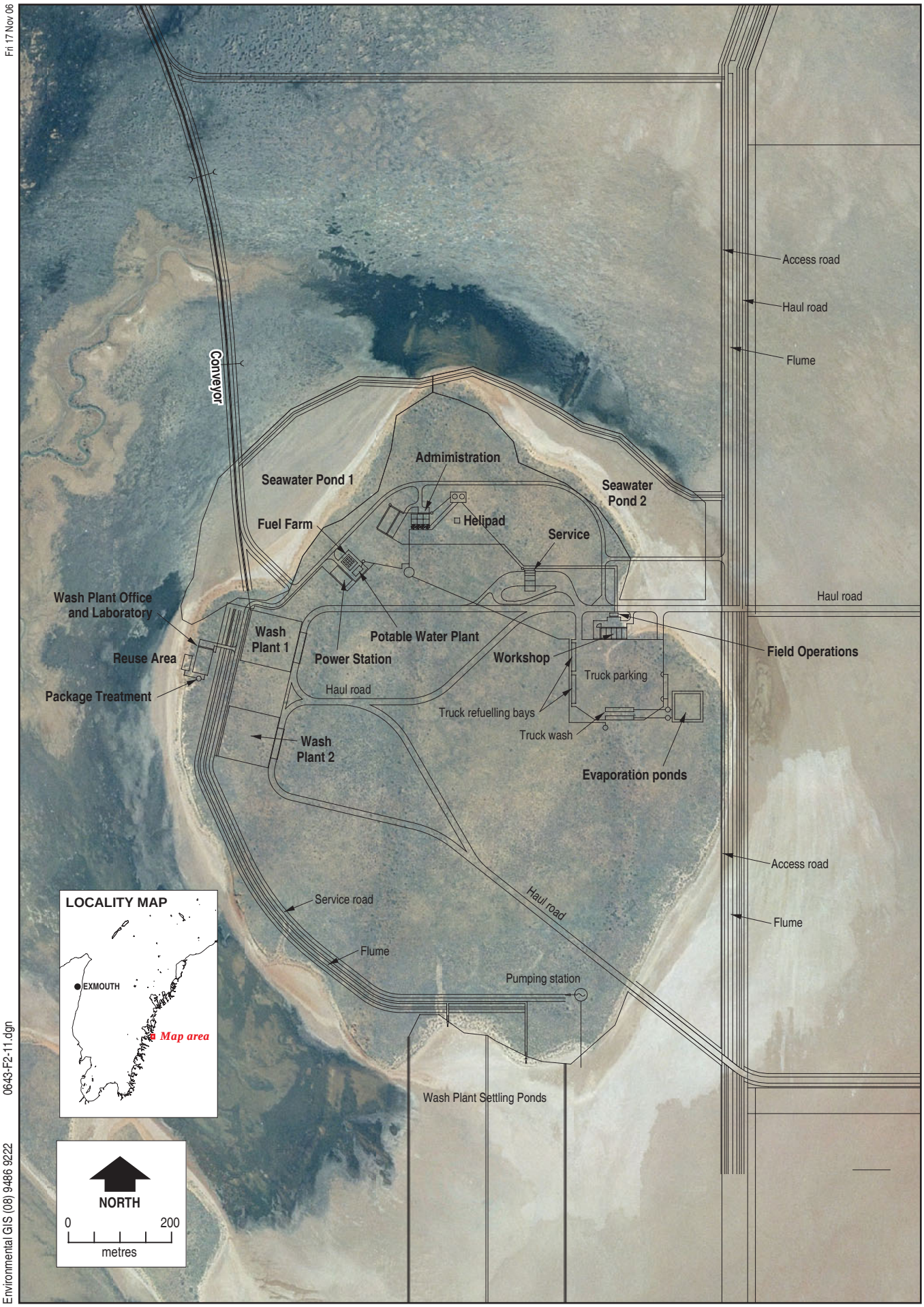
The conveyor alignment and services causeway were selected to avoid as far as practicable the footprint of the corridor on mangrove, algal mat and creek zones. The corridor crosses one tidal creek and has culverts designed to maintain creek water flow.

The cyclical tidal flooding of the algal mat north of Main Island will be maintained by a number of culverts through the services corridor.

Stacker, stockpile and reclaim area

A stockpile area will be established for both salt drainage and inventory holding purposes as required, at Hope Point. The stockpile will be up to 1000 m in length, with a storage capacity of nominally 1 million tonnes, when the field is operating at its ultimate capacity. The maximum height of the stockpile will be 25 m.

A reclaimer will recover the salt from the stockpile and transfer it by conveyor to the barge loader. Brine runoff from the stockpile area will be diverted to, and contained in special storage area. Periodically the salt crystallised within this area will be reclaimed and recovered as export salt.

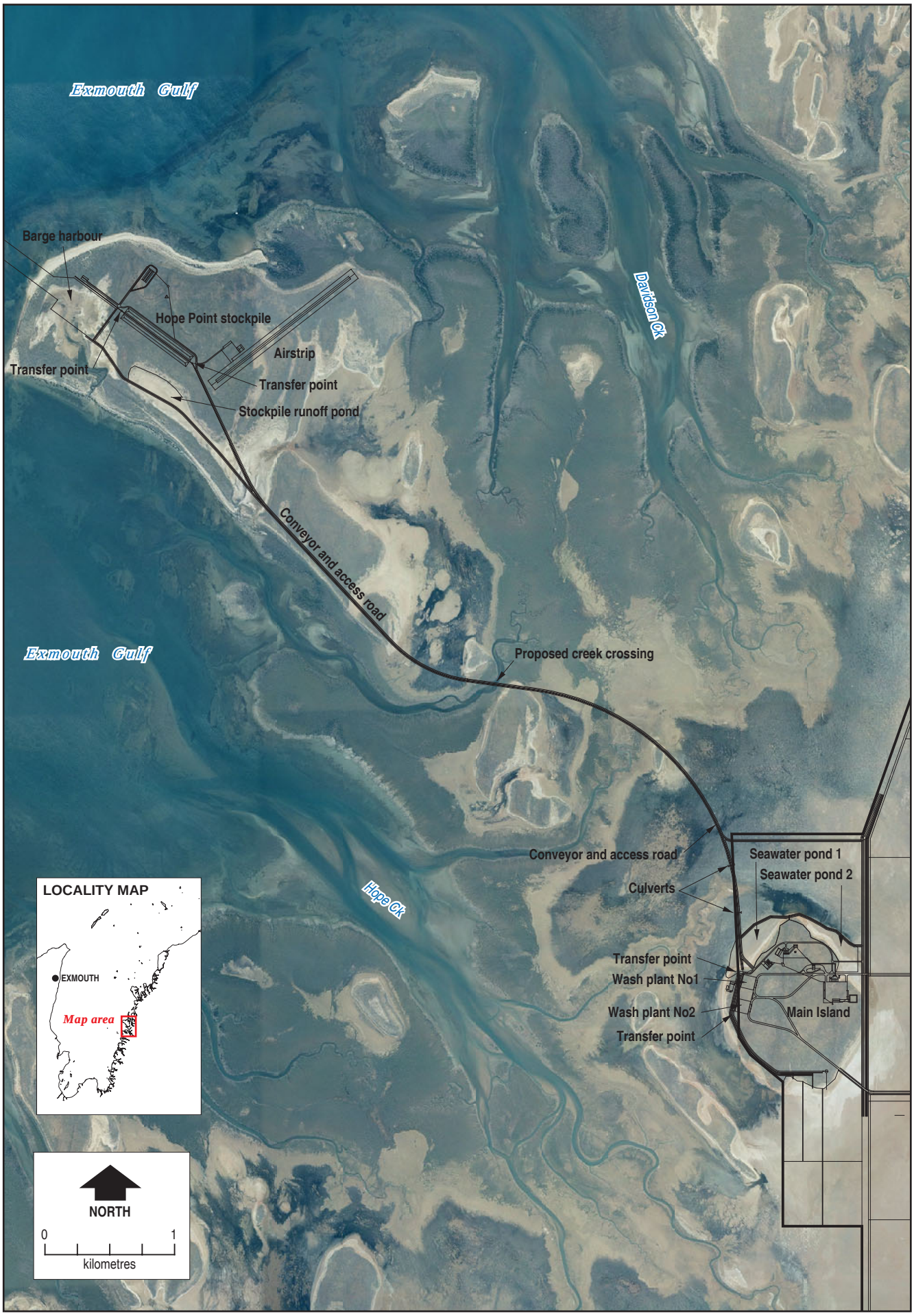


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-11 Proposed Main Island layout

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006



Fri 17 Nov 06

0643-F2-12.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 2-12 Proposed conveyor and services causeway alignment

Chapter 3

Environmental impact assessment and management

Chapter 3 Environmental impact assessment and management

1 IMPACT ASSESSMENT APPROACH

1.1 SCOPING OF THE ASSESSMENT

A Scoping Document (Appendix 2) was prepared to meet both Western Australian and Commonwealth legislative requirements and in accordance with:

- *Environmental Impact Assessment Act 1986*—Environmental Impact Assessment (Part IV Division 1) Administrative Procedures, and
- Environment Protection and Biodiversity Conservation Regulations 2000, Schedule 4.

The scoping process involved preliminary identification of environmental aspects and an environmental risk assessment to identify key environmental issues and factors associated with the project. Once key factors were identified, investigations required to understand these factors and predict impacts were developed.

A Draft Environmental Scoping Document and Terms of Reference were released for public comment between 20 December 2004 and 10 January 2005.

The finalised Environmental Scoping Document and Terms of Reference were submitted to the EPA and DEH on 15 February 2005, addressing public submissions on the draft document.

Table 3-1 outlines the environmental factors in the Environmental Scoping Document that were to be addressed, the investigations conducted and the sections of this ERMP that address each factor.

Table 3-1 Scoping document and ERMP relevant environmental factors and investigations

Relevant environmental factor	Supporting investigations	ERMP section
Integrated factors		
Ecosystem integrity (addressed under Benthic primary producer habitat)		Chapter 4, Section 2 and Chapter 6, Section 2
Ecological sustainability (addressed under Sustainability)		Chapter 2, Section 1
Proposed world heritage (factor no longer relevant)		Chapter 3, Sections 1.1.1 and 3.2 and Chapter 7, Section 3.3.4
Cumulative impacts (addressed under terrestrial and marine environmental factors in ERMP)		Chapter 4, Chapter 5, Chapter 6 and Chapter 7
Terrestrial biophysical		
Landforms and soils	Physical Environment of the Yannarie Salt Project area (D C Blandford and Oceanica 2005a) (Appendix 3)	Chapter 5, Section 1
Groundwater (includes hazards and spills in ERMP)	Superficial Aquifer Hydrogeology of the Yannarie River Delta (Parsons Brinckerhoff 2005b) Groundwater Supply Options—Yannarie Salt Project (Parsons Brinckerhoff 2006) Yannarie Salt Project Environmental Risk Assessment Workshop (International Risk Consultants 2006)	Chapter 5, Section 2

Relevant environmental factor	Supporting investigations	ERMP section
Surface water (includes hazards and spills in ERMP)	Surface Hydrology for Yannarie Salt Project—Supporting Information for Application for a Clearing Permit (Parsons Brinckerhoff 2005a) Yannarie Salt Project Environmental Risk Assessment Workshop (International Risk Consultants 2006)	Chapter 5, Section 3
Wetlands	Yannarie Salt Project: Mangrove and Coastal Ecosystem Study–Baseline Ecological Assessment (Biota 2005d) (Appendix 4)	Chapter 6, Section 2
Mangroves/algal mats (addressed under Benthic primary producer habitat in ERMP)	Yannarie Salt Project: Mangrove and Coastal Ecosystem Study–Baseline Ecological Assessment (Biota 2005d)	Chapter 4, Section 2 and Chapter 6, Section 2
Terrestrial fauna	Straits Salt Project: Fauna and Fauna Assemblages Survey (Biota 2005b) (Appendix 5)	Chapter 5, Section 5
Subterranean fauna	Investigations yet to be completed	Chapter 3, Section 3
Terrestrial flora and vegetation	Yannarie Salt Project: Flora and Vegetation Assessment (Biota 2005a) (Appendix 6)	Chapter 5, Section 4
Marine biophysical		
Hydrodynamics and coastal processes (addressed under Marine water and sediment quality and Benthic primary producer habitat in ERMP)	Model Results to Aid in the Selection of Pump Location in Dean's Creek (WorleyParsons 2005a) Straits Resources Limited: Yannarie Salt Project Hydrodynamic Modelling Mangrove Inundation Analysis—Southern Region (WorleyParsons 2005b) (Appendix 7) Straits Resources Limited: Yannarie Salt Project Hydrodynamic Modelling Mangrove Inundation Analysis—Northern Region (WorleyParsons 2005c) (Appendix 7) Yannarie Salt Project: Regional-scale modelling: Phase 1 progress report (APASA 2005a) Yannarie Salt Project: Regional-scale circulation of Exmouth Gulf (APASA 2005b) Storm Tide and Wave Climate Investigations Exmouth Gulf Solar Salt Project (Cardno Lawson Treloar 2005)	Chapter 4, Section 2 and Chapter 6, Sections 1 and 2
Subtidal flora (addressed under Benthic primary producer habitat in ERMP)	Yannarie Salt Project: Marine and coastal environment of eastern Exmouth Gulf (Oceanica 2006a) (Appendix 7) Yannarie Salt Project, Benthic Habitat mapping: Image Analysis (Oceanica 2005b)	Chapter 4, Section 2 and Chapter 6, Section 2
Water and sediment quality (includes hazards and spills)	Yannarie Salt Project: Marine and coastal environment of eastern Exmouth Gulf (Oceanica 2006a) (Appendix 7) Yannarie Salt Project Environmental Risk Assessment Workshop (International Risk Consultants 2006)	Chapter 4, Section 2.3.3 and Chapter 6, Section 1
Marine fauna	Current State of Knowledge: Humpback Whale (Megaptera novaeangliae) Survey for Exmouth Gulf 1995-2004 (Centre for Whale Research 2004a) (Appendix 7) Final Report Distribution and abundance of Humpback Whales and other megafauna in Exmouth Gulf, Western Australia, during 2004/2005 (Centre for Whale Research 2004b) (Appendix 7) Yannarie Salt Project: Modelled underwater noise in Exmouth Gulf from proposed Yannarie marine activities (McCauley and Maggi 2005) Yannarie Salt Project, Non-Indigenous Marine Species: Assessment of the risk of introduction and potential management measures (Oceanica 2005d) Yannarie Salt Project, Eastern Exmouth Gulf Benthic Macrofauna Assemblages Data Report (Oceanica 2005e) The Dugong (*Dugong dugon*) of Exmouth Gulf, Western Australia (Oceanwise 2005)	Chapter 6, Section 3
Pollution Management		
Solid and liquid waste disposal (addressed under relevant environmental factors in ERMP)	Desktop investigation of the economic potential of bitterns from Exmouth Gulf (WA) (CSIRO 2004) (Appendix 1) Straits Ecotoxicity Project—Direct Toxicity Assessment of Bitterns Using Resident Species (Parsons Brinckerhoff 2005h) Yannarie Salt Project, Quantification of mixing zones for proposed discharge of salt bitterns (APASA 2006)	Chapter 2, Chapter 3, Chapter 5, Chapter 6, Chapter 7 and Appendix 1

Relevant environmental factor	Supporting investigations	ERMP section
Hazards and spills (addressed under relevant environmental factors in ERMP)	Yannarie Salt Project Environmental Risk Assessment Workshop (International Risk Consultants 2006)	Chapter 5, Chapter 6 and Chapter 7
Social surroundings		
Cultural heritage (includes conservation values in ERMP)	A report of an Aboriginal Archaeological Heritage Assessment of the Straits Resources proposed Yannarie Salt project northern field boundary, Giralia Gulf, Western Australia (Archae-Aus 2005)	Chapter 7, Section 3
Existing fishing and aquaculture opportunities (addressed as Commercial fishing and aquaculture and Recreation and ecotourism in ERMP)	Yannarie Salt Project, Exmouth Gulf Fisheries and Aquaculture: Potential Impacts and Management (Oceanica 2005b) Salt Export from Hope Point, Exmouth Gulf, Western Australia—Marine transit and anchorage options study (WA Mercantile Services 2005)	Chapter 7, Sections 1 and 2
Research (addressed in Marine factors in ERMP)	Yannarie Salt Project: Environmental Edge Effects of Pond Bunds (M.P. Rogers 2005)	Chapter 6, Sections 2 and 3 and Proponent Commitments table in Executive Summary (Volume 1)
Local community (addressed in Sustainability in ERMP)	Straits Salt Project: Social Impact Assessment (Q&A Communications 2005)	Chapter 2, Section 1 and Proponent Commitments table in Executive Summary (Volume 1)

1.1.1 Departure from approved Scoping Document

The proposal does not include the discharge of bitterns and this aspect is not addressed under marine water quality but Appendix 1 does describe in detail the proposed bitterns resource recovery strategy.

Ecosystem integrity and cumulative impacts on the current ecosystem are addressed under benthic primary producer habitat.

The Scoping Document originally envisaged access to groundwater for operational use and required consideration of the likely environmental impacts. The use of groundwater has now been replaced by reverse osmosis plants using seawater as a feedstock.

The Scoping Document required consideration of the potential World Heritage values which might be applied to the project area in any possible World Heritage nomination. The State Government has since progressed a boundary for World Heritage Area nomination for community consultation which excludes Exmouth Gulf and the Yannarie Solar Project Area.

Subterranean fauna was considered to be a relevant factor in the Scoping Document but is a minor factor in this ERMP. Greenhouse gases have also been included in this ERMP (was not in the Scoping Document) as a minor factor. Subtidal flora, mangroves and algal mats, wetlands and ecosystem integrity in the Scoping Document are addressed under benthic primary producer habitat in this ERMP.

Table 3-1 lists the environmental factors prescribed in the Scoping Document and where they are addressed in the ERMP.

1.2 ENVIRONMENTAL REVIEW STRUCTURE FOR RELEVANT ENVIRONMENTAL FACTORS

The assessment of relevant environmental factors is structured as follows (Figure 3-1):

- EPA objectives
- legislative policy and context

- description of factor
- impact assessment and mitigation
- monitoring and assessment of performance
- proponent commitments
- environmental outcome.

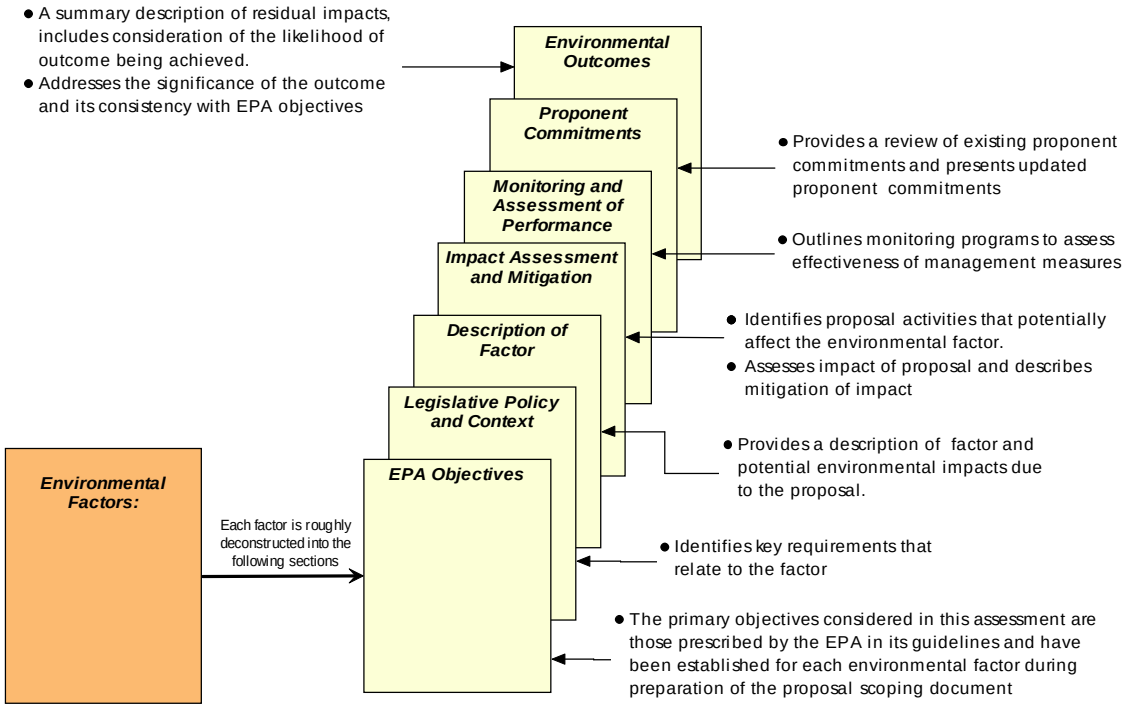


Figure 3-1 Assessment framework for environmental factors

2 STRAIT'S ENVIRONMENTAL MANAGEMENT APPROACH

2.1 ENVIRONMENTAL POLICY

Straits have developed an environmental policy which states the way in which Straits will approach and manage the project's effect on the environment (Appendix 9). The policy is the foundation on which all environmental management decisions will be made by Straits.

2.2 ENVIRONMENTAL MANAGEMENT SYSTEM

Straits will establish an environmental management system (EMS) for the construction and operation phases of the project in accordance with the principles of AS/NZ ISO 14001:1996. The purpose of the EMS is for document control and contingency planning to ISO standard.

The structure of the EMS will reflect the structure of this standard, namely:

1. Corporate environmental policy (refer above);
2. Planning instruments. The establishment of procedures to identify and assess risk to the environment (including consideration of stakeholder values) of construction and operations or changes thereto. The procedures developed will follow the framework and principles of the Australian Standard for Risk Management AS/NZS 4360:2004.
3. Implementation and operation
4. Performance monitoring
5. Review and improvement mechanisms

The intention is to seek independent certification by an accredited auditor of the EMS that will address operational aspects of the project.

Core components of the EMS will be the preparation and implementation of:

1. Environmental impacts and aspects register which will list all aspects of Straits construction and operational phases of the project that may present a risk to the environment.
2. An overarching Environmental Management Plan (EMP) for project operations which would include the environmental factor management plans outline in Chapter 7 and prescribed in proponent commitments
3. An overarching Construction Environmental Management Plan (CEMP) which will address those environmental aspects that arise from the construction of the project. The CEMP will include those components of the environmental factor management plans that are relevant to construction.

2.3 PROJECT SPECIFIC SUSTAINABILITY PRINCIPLES

Refer to Chapter 2, Section 1.

2.4 PUBLIC REPORTING, TRANSPARENCY AND COMMUNITY INVOLVEMENT

The community were consulted in a number of ways including the establishment of stakeholder liaison groups and providing information through presentations, brochures, information displays and via a website. Straits have committed to annual reporting which should maintain correspondence with the local community.

3 MINOR ENVIRONMENTAL FACTORS

Environmental factors considered 'minor' in the scope of this ERMP include:

- greenhouse gases (included in Pollution Management)
- world heritage area nomination (included in Social Surroundings)
- subterranean fauna (included in Terrestrial biophysical).

These factors and their associated management requirements (where applicable) are described in the following sections.

3.1 GREENHOUSE GASES

The greenhouse gas (GHG) emissions for the Yannarie Solar Project will be predominantly from combustion sources as carbon dioxide (CO_2). Other greenhouse gases will be emitted in quantities small enough to be considered negligible.

The major source of greenhouse gases is from electricity generation. The Yannarie Solar Project will require approximately 8 MW of power for its operation, consumed in the form of electricity sourced from diesel fuelled generators. The supply of this electricity will result in an increase in regional GHG emissions associated with combustion and the release of CO_2. The estimated load of the construction camp is 200 kVA based on accommodation for 100 people, a reverse osmosis (RO) plant and site lighting.

Australian Greenhouse Office (AGO) methods were used for calculating GHG emissions from the proposed electricity generation (AGO 2004a). Emission calculation involves multiplying appropriate emission factors by the amount of fuel used within the diesel generating sets. The AGO calculation uses a factor of 3.1 tonnes of CO_2 equivalent GHG for 1 kL (1,000 L) of diesel consumed (AGO 2004a).

The GHG emissions for the Yannarie Solar Project under the proposed form of power generation by 2 MW Diesel Generators will be 14,508 tonnes CO_2 equivalent/year, with a fuel throughput of 4680 kL/year (Parsons Brinkerhoff 2005s). Total GHG emissions generated by the project have been estimated to be 58,032 tonnes CO_2 equivalent/year, using 4 Diesel Generators.

3.1.1 Management

The estimated GHG emissions (Chapter 3, Section 3.1) will be offset to some degree by energy saving initiatives incorporated into the design of the project, to achieve an overall improvement in the GHG emission rates. These initiatives will include:

- preservation of native vegetation
- rehabilitation of degraded areas.

The implementation of the Yannarie Solar Project will result in an increase in greenhouse emissions, however proposed mitigation measures and a commitment to use renewable energy sources (where feasible) will minimise the production of greenhouse gases. Further, organic matter (algae) will grow on the bottom of the primary concentrator ponds (as seen at existing solar saltfields in WA), resulting in some carbon sequestration.

3.2 WORLD HERITAGE AREA NOMINATION

The State Government was considering nominating the Ningaloo/North West Cape area for World Heritage Listing. Sites recognised as having outstanding universal value may be included within the World Heritage List if they meet one of ten criteria. Four of these criteria consider natural values, as follows:

1. To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance.
2. To be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.
3. To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.
4. To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation (UNESCO World Heritage Centre 2005).

The World Heritage Consultative Committee recommended that the Ningaloo/North West Cape area could be nominated under all four natural environment criteria.

The State Government has recently delineated a boundary for World Heritage Area nomination for community consultation, and the area nominated for World Heritage excludes the Exmouth Gulf and the Project Area located on the eastern coast of the Gulf.

3.3 SUBTERRANEAN FAUNA

3.3.1 EPA objective

- To maintain the abundance, diversity, geographic distribution and productivity of subterranean fauna at the species and ecosystem levels through the avoidance or management of adverse impacts and improvement in knowledge.

3.3.2 Legislative policy and context

- EPA Guidance Statement No. 54 (specifically addresses the conservation of stygofauna in groundwater systems and troglofauna in subterranean caves)
- *Wildlife Conservation Act 1950-1979* (provides for the protection of all species of native fauna, including subterranean fauna).

3.3.3 Background

Subterranean fauna are animals that inhabit underground habitats, and comprise stygofauna and troglofauna.

Stygofauna are fauna that inhabit groundwater, sometimes occurring very close to the surface. They are highly specialised, obligate dwellers of subterranean groundwater habitats (Humphreys 2000). Stygofauna are known to be present in a variety of rock types including karst (limestones), fissured

rock (e.g. granite) and porous rock (e.g. alluvium) (Marmonier *et al.* 1993). The types of animals that have become stygal (groundwater-inhabiting) in Western Australia include a range of crustacean taxa (which normally dominate the fauna numerically), platyhelminthes, oligochaetes, water mites and water beetles (Humphreys 1999, Watts and Humphreys 1999).

Troglofauna are obligate terrestrial fauna that inhibit air chambers in underground caves or small humid air-filled voids. Troglofauna have previously been recorded in Western Australia from karstic limestone systems at Cape Range, Barrow Island and in the Kimberley (Harvey 1988, Biota 2002a, Humphreys 2001). Troglofauna have also since been discovered in a pisolitic mesa formation (Biota 2004, Strategen 2006). In the arid zone troglobitic fauna is considered to be relict rainforest litter fauna (Humphreys 1993).

Western Australian stygofauna and troglofauna exhibit high levels of endemism (EPA 2003a). Many species have restricted ranges, which is characteristic of subterranean fauna worldwide (Strayer 1994). An example of a species that is restricted in range is the millipede *Stygiochiropus peculiaris*, which is restricted to a single cave system at Cape Range (Humphreys and Shear 1993).

3.3.4 Investigations

Sampling for subterranean fauna in the project area has been limited as a clearance to drive a drilling rig into the area has only recently been received (July 2006), therefore preventing any detailed investigation. There are presently no records of stygofauna or troglofauna from the eastern margin of Exmouth Gulf. A search of the Western Australian Museum database showed no records within the study area, with the closest records being of a copepod and ostracod in two locations more than 50 km from Hope Point. Most records for the locality appear to be associated with the alluvial system of the Ashburton River (Western Australian Museum 2006).

The geology of the area proposed to accommodate the saltfield appears to have low potential for subterranean fauna. The area that will accommodate the field is comprised of an extensive plain of hypersaline mud, underlain by a hypersaline aquifer (Parsons Brinckerhoff 2005b, D C Blandford & Associates and Oceanica 2005), which would be unlikely to provide habitat for stygofauna or troglofauna. There are no major superficial drainage systems (with associated alluvial aquifers) in the locality and no palaeodrainages (with associated calcrete aquifers) in the area to be affected by the saltfield. With the extremely saline groundwater present beneath the Onslow Plain (up to ten times seawater concentration), and the clay-dominated stratigraphy, it appears very unlikely that any subterranean fauna utilise the area proposed to accommodate the ponds.

The two key activities that typically offset stygal communities are dewatering of mines, water quality impacts associated with discharge of dewatering fluids and borefield construction. The Yannarie Solar Project involves only limited dewatering associated with proposed limestone quarrying activities.

Considering the low likelihood of subterranean fauna occurring in the area, and the limited change to groundwater systems presented by the project, there is little risk of reduction in regional subterranean fauna values.

3.3.5 Management

The available data suggest that it is unlikely that subterranean fauna occur within the proposed saltfield footprint, however sampling and reporting will be undertaken at the time of installation of the dewatering system to verify the occurrence, or otherwise, of subterranean fauna.

3.3.6 Proponent commitment

Notwithstanding the low probability of stygofauna in the project area, the following commitment is:

1. Undertake a subterranean fauna survey in areas where dewatering will occur.
2. Results of the subterranean fauna survey will be made available for a four week public submission period during the first half of 2007.

3.4 SOLID AND LIQUID WASTE DISPOSAL

The solid and liquid wastes that may be generated through the construction and operation of the project are summarised in Table 3-2. The Construction and Environmental Management Plan (CEMP) and Operation Environmental Management Plan (OEMP) will address the issues of solid and liquid waste disposal.

Table 3-2 Summary of potential environmental impacts associated with solid and liquid waste production

Source of waste	Waste type	Estimated quantity	Proposed disposal	Potential impact
Domestic Waste				
Administration block and accommodation area	General litter and refuse	400 kg/person/year[1]	Litter and refuse will be collected onsite and removed and disposed offsite by a licensed contractor	Ingestion or physical impairment of marine and terrestrial animals
	Treated wastewater and sludge	Construction: 140 L/day/person Operation: 140 L/day/person	Wastewater to be disposed via the waste water treatment plant	Groundwater and surface water contamination
Workshop and vehicle washdown area	Waste oils and oil filters	6000 L/year[2]	Waste oils and filters will be removed by licensed contractors for recycling	Contamination of soil and water
	Degreasers and detergents	2000 L/year	Degreasers and detergents will be removed by licensed contractors for recycling	Contamination of soil and water
	Radiator fluid coolants	2000 L/year	Coolants will be removed by licensed contractors for recycling	Contamination of soil and water
	Brake fluid and brake pads	500 L/year	Brake fluids and pads will be removed by licensed contractors for recycling	Contamination of soil and water
	Batteries	20 truck batteries/year	Batteries will be removed by licensed contractors for recycling	Contamination of soil and water
	Tyres	1760 tyres per year	Tyres will be removed by licensed contractors for recycling	Contamination of soil and water

Source of waste	Waste type	Estimated quantity	Proposed disposal	Potential impact
Process Waste				
RO Plant	Reject water	70 kL/day[3]	Reject water will be discharged to the concentration ponds	Groundwater and surface water contamination
Construction Waste				
Construction activities	Soil rubble, concrete, bricks, tiles, timber, ferrous, plasterboard, paper, cardboard, textiles, packaging material, wiring, wastewater, plastics	<10 m^3 of solid construction waste materials	Non-hazardous solid waste will be collected and removed by a licensed contractor Liquid waste will be disposed via the wastewater treatment plant where appropriate	Solid waste - Ingestion or physical impairment of marine and terrestrial animals Liquid waste – contamination of surface and groundwater

Note: 1. Source: WSROC 2000
2. Estimation of vehicle wastes for 10MtPa operations: 100L/yr/truck degreasers/detergents, 500L brake fluid, 44 tyres per truck, 20 trucks, 2 sets per year, 300L/yr/truck waste oil, 100L/yr/truck radiator coolant, 1 battery per year/truck
3. Based on a requirement of 30 kL/day

Chapter 4

Overview of the region and ecosystem

Chapter 4 Overview of the region and ecosystem

1 OVERVIEW OF THE REGION

1.1 SOCIO-ECONOMIC SETTING

The area is located in the Gascoyne region off the north west coast of Western Australia. The nearest townships to the development location are Exmouth and Onslow.

1.1.1 Gascoyne Region

The most recent Australia-wide census, for which results are available, was on 7 August 2001. On this day, the population of the Gascoyne stood at around 10,300 people, with 17% of these being Indigenous (ABS 2001).

In 2001, the Australian Bureau of Statistics counted a residential population of 2069 for the Shire of Exmouth. Visitors to the region from local, interstate and overseas locations added a further 2199 temporary residents to the region which illustrates the significance of tourism in the region. Of the Shire's population, 40 people (approx 0.9%) identified themselves as being Indigenous Australians (ABS 2001). Currently, the town of Exmouth represents approximately 78% of the Shire's total population (Western Australian Planning Commission 2004).

In 2001, the population of the Shire of Ashburton was approximately 5258. Approximately 9% identified themselves as Indigenous Australians (ABS 2001).

The Shire of Ashburton is similar to the Shire of Exmouth (Table 4-1) in that it also experiences a large number of visitors to the region for tourism, employment and cultural purposes. Temporary visitors to the region added an additional 1626 individuals to the population (ABS 2001).

1.1.2 Existing land uses

Pastoral and mining leases

The hinterland is occupied by pastoral leases (Figure 4-1). Urala, Koordarrie and Yanrey Stations are active while the Giralia lease has recently been acquired by CALM (now Department of Environment and Conservation, DEC) to be managed as a conservation reserve.

The region was the location of Western Australia's first oil discovery at Rough Range and is considered to be highly prospective; as such almost the entire area is covered by petroleum exploration permits (Figure 4-1).

Table 4-1 Profile of the human environment in Shire of Exmouth and Town of Onslow

Indicator	Shire of Exmouth	Town of Onslow
Population	2069 residents (Increases by over 50% during peak tourist season with temporary visitors to the region)	497 residents
Proportion of population that are Indigenous	0.9% (Equivalent to 40 people)	22.8% (Equivalent to 182 people)
Area	6502.8 km^2	3.5 km^2
Median age	46	46
Mean household size	2.4	3.2
Mean individual weekly income	$300–$399	$300–$399
Male: Female ratio	1.08:1	1.05:1
Proportion of population that speaks only English (not including overseas visitors)	92.7%	87.0%
Marital status	23% never married	24% never married
Employment status	6.5% unemployed	4.7% unemployed
Number of dwellings	1850	361
Top 3 employment industries	Retail Accommodation, Café and Restaurants Property and Business Services	Health and Community Services Construction Transport and Storage and Property and Business Services

Source: ABS 2001

Notes: 1. This data is sourced from the Australian Bureau of Statistics 2001 Census data. Census data is calculated based on the total population present on Census night, which was 7 August 2001.

2. Detailed demographic charts for the Shire of Exmouth and for Onslow are included throughout this report.

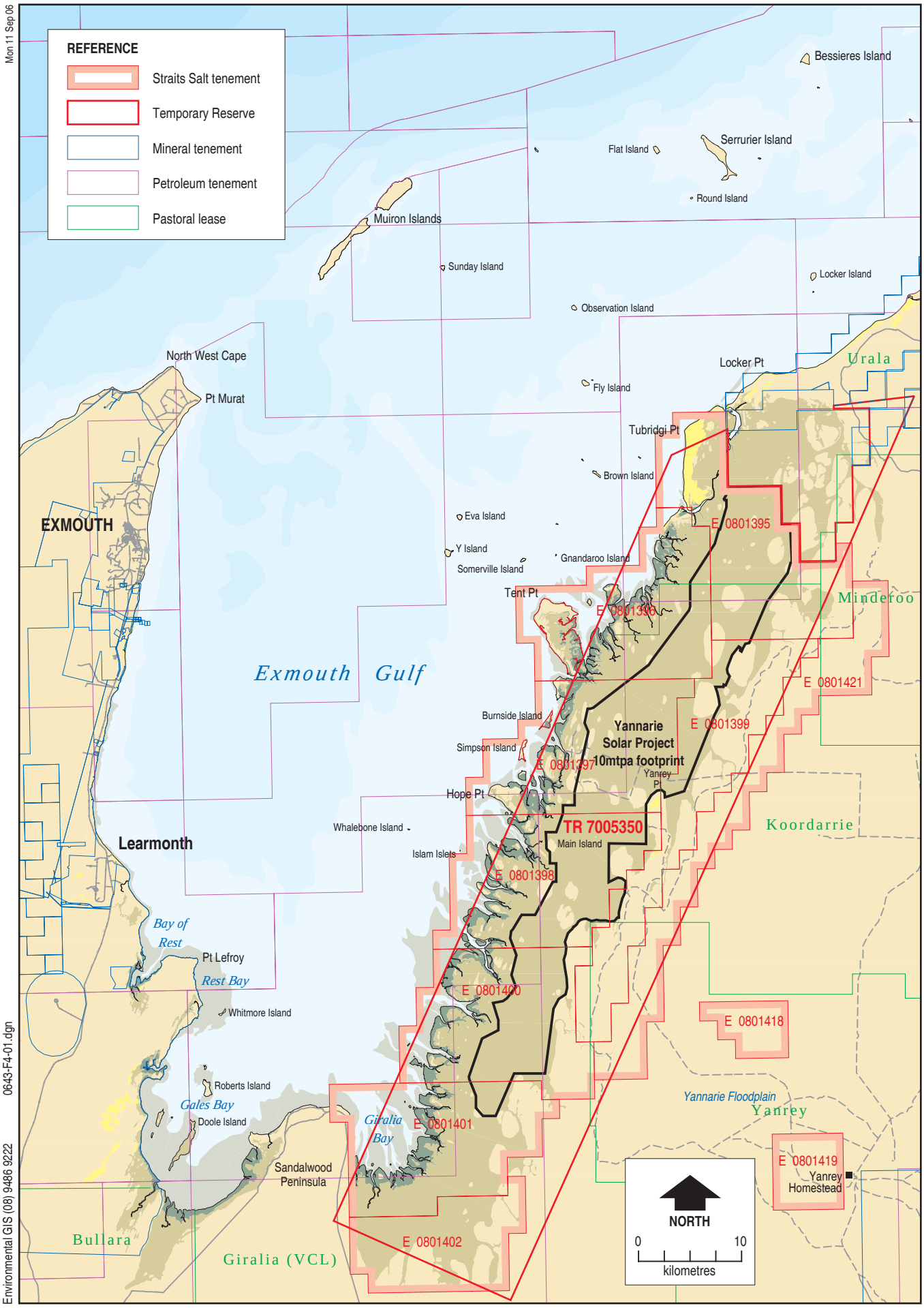
Ministerial Temporary Reserve 70/5350

Ministerial Temporary Reserve 70/5350 (TR 70/5350) (Figure 4-1) was granted on 9 September 1970 for the purpose of Solar Salt, Gypsum and Limestone production. The area was reserved by the Government of Western Australia in recognition of its value for solar salt manufacturing. TR 70/5350 remains in force (reserved for the future production of salt) under the jurisdiction of the *Mining Act 1978*.

TR 70/5350 was originally proclaimed to give occupancy rights to Gulf Holdings Pty Ltd under the *Exmouth Gulf Solar Salt Industry Agreement Act 1969* (Agreement Act). The Agreement Act was held by Gulf Holdings for the operation of the Talandji Salt Evaporator, which operated from c. 1969 for several years. Gulf Holdings no longer has any interests over this area. Historic workings (scrap and general refuse) from the salt evaporator are still visible. The old workings are within the proposed Yannarie Solar Project area.

Fisheries

Exmouth Gulf supports two key industries, the Exmouth Gulf Prawn (EGP) Managed Fishery (Figure 4-2) and Pearling.

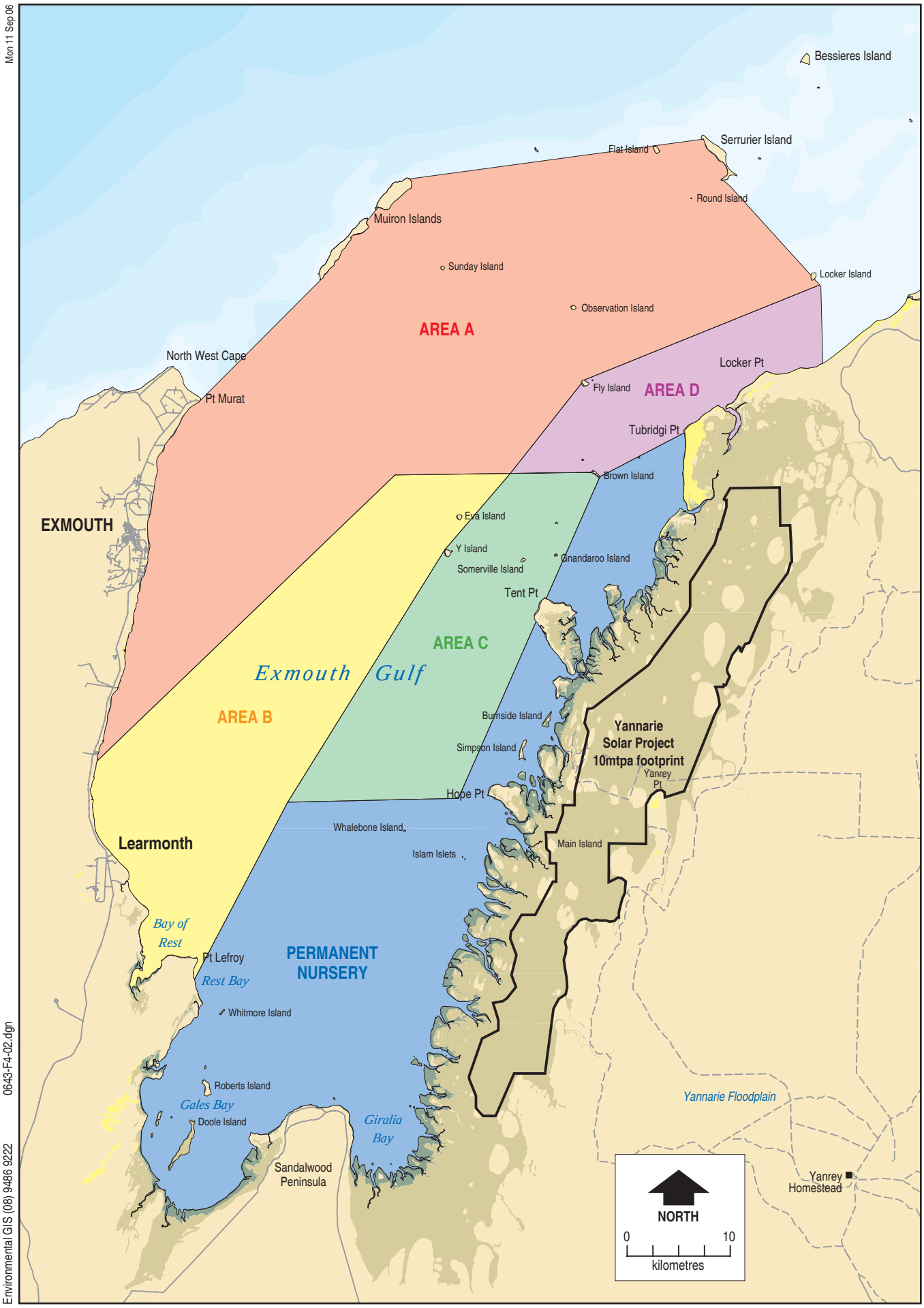


Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: DoIR, 2006 and DLI, 2006
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 4-1 Mining tenements and pastoral leases in the Exmouth Gulf region (Aug 2006)



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 4-2 Boundaries of the Exmouth Gulf prawn fishery

Datum: MGA Zone 50
Source: Dep't of Fisheries, 2006
Date: 11 Sep 2006

Oceanica (2006a) has identified and described the following industries occurring in Exmouth Gulf:

1. Exmouth Gulf Prawn Managed Fishery
2. Exmouth Gulf Beach Seine Fishery
3. Recreational Fishery
4. Aquaculture
5. Pearling
6. Blue Swimmer Crab Fishery
7. Tropical Rock Lobster
8. Marine Aquarium Fishery
9. Specimen Shell Managed Fishery.

Defence training area

The Royal Australian Airforce has a base at Learmonth and a bombing range on the Exmouth Peninsula. The airspace around Exmouth is used extensively for air combat training exercises.

Recreational use

Recreational activities within the project area itself are limited to fishing, camping and snorkelling, although utilisation of the area is limited. This is due in part to its isolation and limited road access; however the area is also quite inhospitable.

Tourism

In general, Exmouth's warm climate and extensive marine reef environment make it an extremely popular destination for tourists. However, the eastern side of Exmouth Gulf is remote from Exmouth (40 km boat trip) and largely inaccessible from land and is not a common tourist destination.

As at June 2003, there was one tourism project under construction in the Shire of Exmouth with a value of $3.4 million, which would provide 20 lettable units. There was one tourism project planned with a value of $15 million, which will provide for a further 179 lettable units (Department of Local Government and Regional Development).

Mining

Exmouth does not support any significant mining or petroleum projects apart from using Learmonth Airport for offshore oil and gas facility crew transfers. In contrast, a number of mining and petroleum projects are located within the vicinity of Onslow and includes BHP Billiton's Griffin Onshore Gas Treatment Plant, adjacent to the Tubridgi facilities[3], a gas pipeline linking the onshore facility to the Dampier to Bunbury Gas Pipeline and a solar salt project. Future plans for Chevron Texaco's Barrow Island facility could also see increased activity relating to mining in the Onslow area.

[3] Tubridgi is a Liquefied Petroleum Gas and Natural Gas plant operated by Origin Energy Ltd

The Onslow Solar Salt Project is expected to produce 2.5 million tonnes of salt per annum (Western Australian Planning Commission 2003).

Fishing and aquaculture

The Gascoyne Region, particularly the Exmouth Gulf, contains fishing and aquaculture industries. It is home to trawl fisheries of prawns and scallops in Shark Bay and Exmouth, and supports the Shark Bay Snapper Fishery and Shark Bay Beach Seine and Mesh Net Fishery.

1.1.3 Aboriginal heritage

According to the National Native Title register, there are two claims covering the area around the proposed development site. These are the Thalanyji Claimant Application (WC99/45) and the Gnulli Application (WC97/28) (National Native Title Tribunal Register 2004).

1.1.4 European heritage

There are no known significant European heritage sites within the project area. Although there are a number of shipwreck sites within the region, none have been identified in locations that are likely to be affected by the project (Oceanica 2006a).

2 OVERVIEW OF EXMOUTH GULF ECOSYSTEM – INTEGRATION OF KEY ENVIRONMENTAL FACTORS

The Gulf is one of the largest embayments (about 3000 km^2) on the Western Australian coast (Figure 1-1). The Gulf is located in a remote, tropical arid area enclosed by the Cape Range Peninsula to the west and the Yannarie Coastal Plain to the east (Biota 2005d). The catchment contributing runoff to the Gulf is relatively small resulting in an estuary dominated by marine processes (Oceanica 2006a) (Appendix 7).

The annual rainfall in the region, as recorded at Learmonth Airport, is highly variable with an annual average of 260 mm where peak rainfall occurs from January to March and between May and June (Bureau of Meteorology 2004a). The heaviest rainfall is generally associated with tropical cyclones and can cause extensive flooding in the area. Evaporation is high with annual average rainfall significantly exceeded by the mean annual evaporation of around 3140 mm.

The Gulf falls within the Carnarvon Bioregion as defined in the most recent update of the Interim Bioregionalisation of Australia (Thackway and Cresswell 1995, Environment Australia 2000). The Department of Environment and Conservation (DEC) places the project area in the CAR1 (Cape Range) biological subregion within this Bioregion (CALM 2002).

2.1 SEA LEVEL CHANGE AND LANDFORM DEVELOPMENT

At approximately 8000 years before present (BP) the sea level was approximately 20 m below present sea level while approximately 6300 years BP the sea level reached a height of approximately 3 m above present levels. Since that time sea level gradually declined to reach the present level approximately 1500 years BP (DC Blandford & Associates and Oceanica 2005).

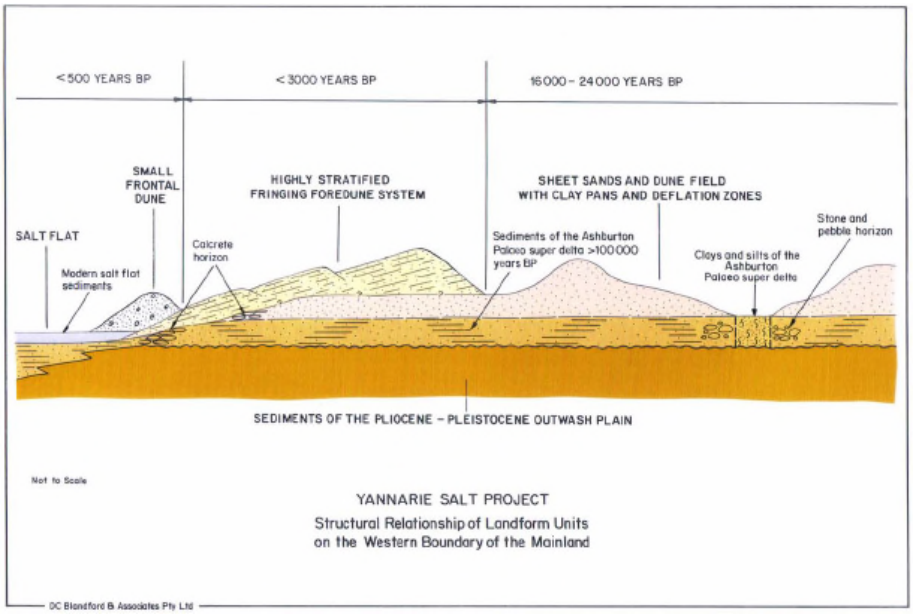
A suggested time-stratigraphic relationship for landform development in the study area was developed by DC Blandford & Associates and Oceanica 2005 and is shown in Figure 4-3.

2.2 GULF WIDE PROCESSES

Exmouth Gulf marks the start of the shallow Pilbara coastal waters region. At its deepest, the Gulf is 21 m in depth and the relatively narrow entrance between Point Murat and the Muiron Islands (which is crossed by a small sill) is at most, about 19 m in depth. The shallow protected waters of the Gulf provide a stark contrast to the waters of Ningaloo Reef which, outside the reef line, are exposed to the open ocean and rapidly drop off into waters approximately 1000 m deep. The Gulf is strongly influenced by the Leeuwin Current being in the region where it forms and starts to head south down the coast (Figure 4-4).

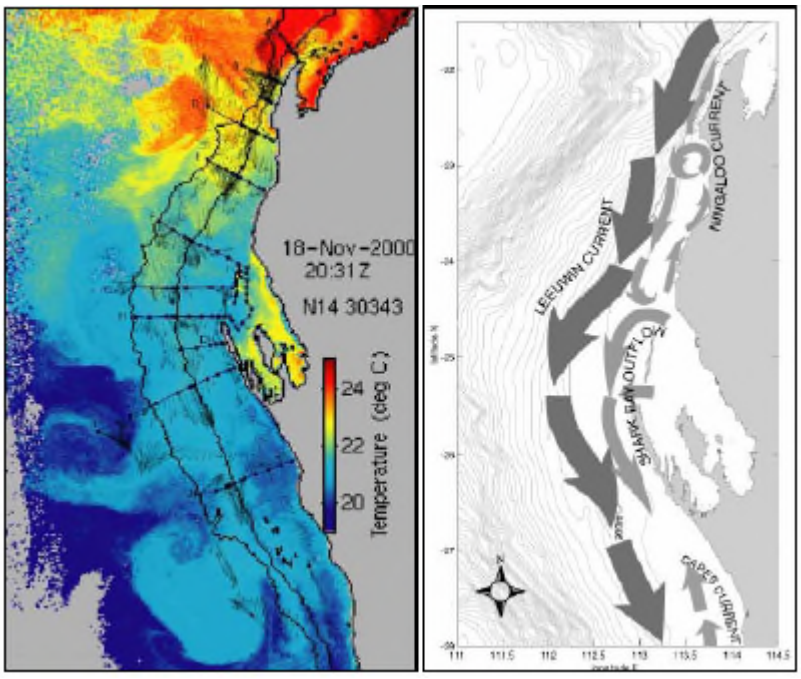
2.2.1 Linkages between Exmouth Gulf and Ningaloo Marine Park

There is no direct link of waters between the east coast of the Gulf and the Ningaloo Marine Park (Massel *et al.* 1997, APASA 2005a & b). The waters immediately east of Point Murat (but on the western side of the Gulf) are generally the only waters in the Gulf that can be transported directly into the Ningaloo reef area. The waters on the eastern side of the Gulf tend to stay in the vicinity of the east coast for several tidal cycles and tend to be driven by the prevailing winds northwards and parallel to the east Gulf coast.



Source: DC Blandford & Associates and Oceanica 2005

Figure 4-3 Time-stratigraphic relationships between landform units of the study area



Source: Woo and Pattiaratchi 2003, as cited in Oceanica 2006a

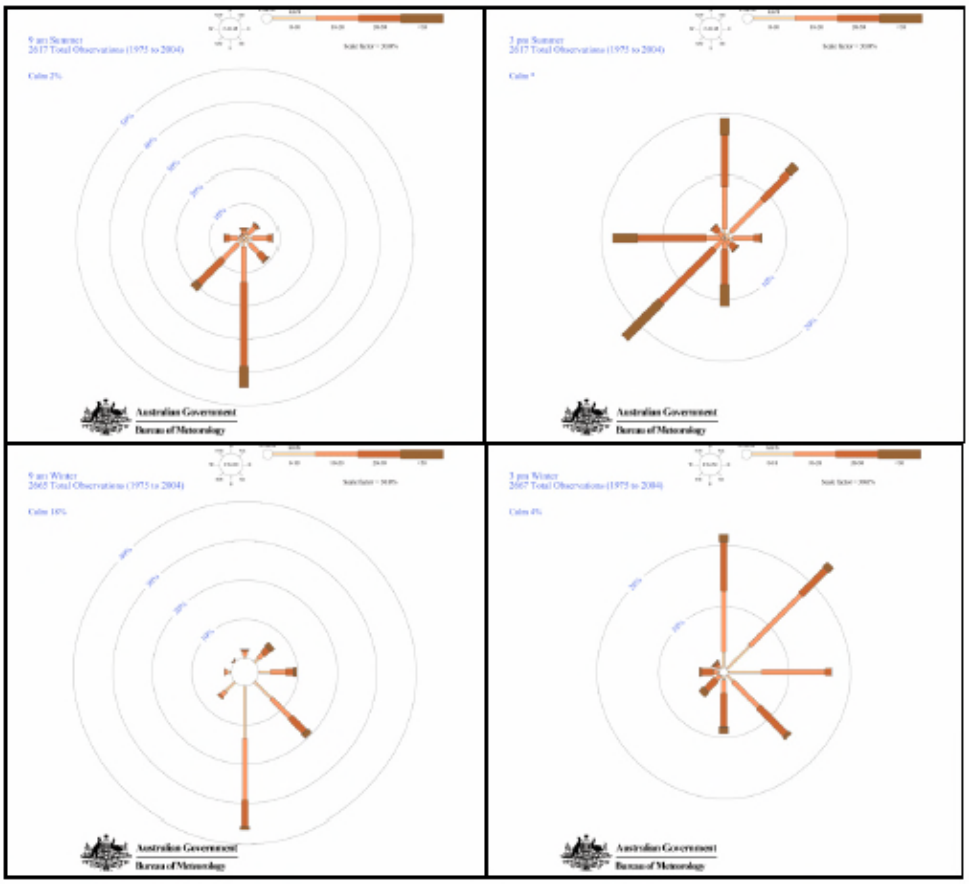
Figure 4-4 Leeuwin current in Northwest Cape region (a) sea surface temperature (b) generalised summer flows

2.2.2 Influence of tides and winds

The winds in the region are dominated by south westerlies and south easterlies (with the south westerlies being generally the strongest) resulting in water being driven out of the Gulf towards the north east (Figure 4-5). The land mass of North West Cape is sufficiently large to potentially set up a dual sea breeze regime with one sea breeze generated on the ocean side (south westerly) and the other on the Gulf side (north easterly) (Oceanica 2006a) (Appendix 7).

Circulation in the Gulf is affected by winds and tides (semi-diurnal) with tidal currents dominating the nearshore region of the east coast and winds tending to drive currents northwards parallel to the east coast. Tidal excursions are 5 km or less resulting in detritus, nutrients, spawn and plankton originating from the east coast staying in the vicinity of this area for several tidal cycles.

The mean spring tidal range at Exmouth is 1.8 m with a mean neap tide range of 0.6 m (Department of Defence 2002). The Gulf shallows in a southward direction which results in an increase in tidal range of at least 0.1m towards the southern end of the Gulf.



Source: Bureau of Meteorology 2004b

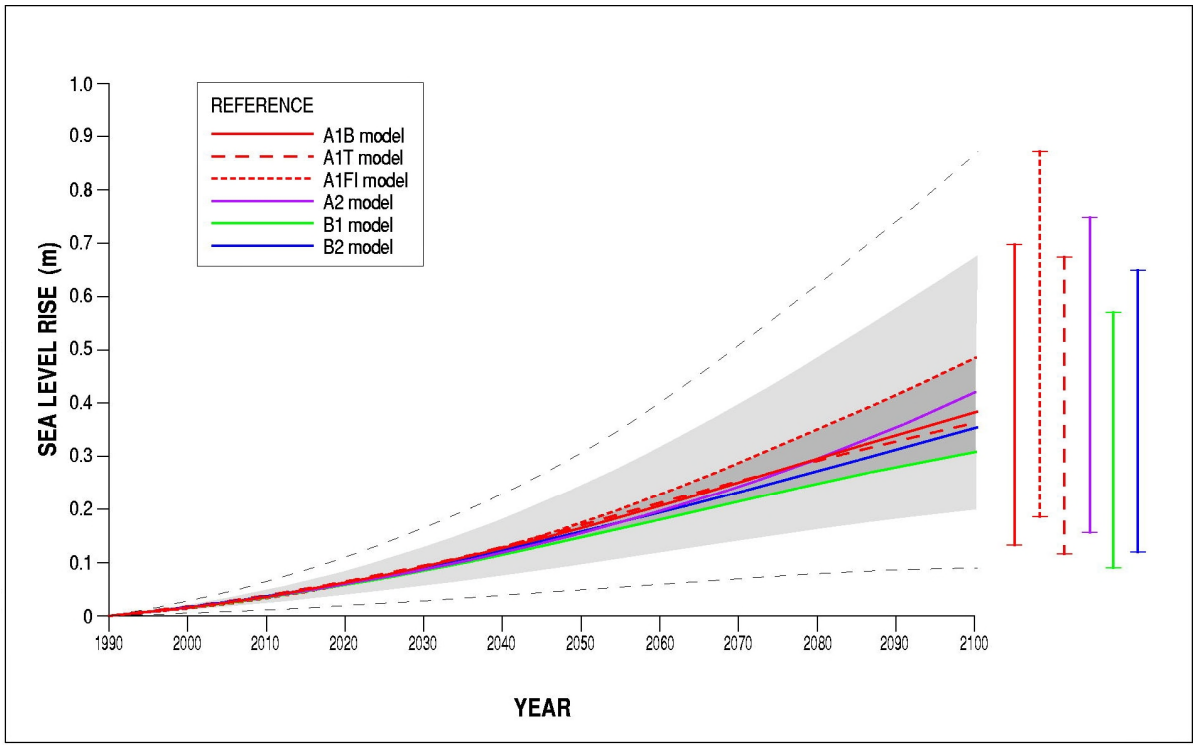
Figure 4-5 Summer and Winter 9:00 AM and 3:00 PM wind roses for Learmonth

2.2.3 Influence of extreme storm events

Severe cyclones occur approximately every 25 years and can permanently alter the coastline and cause wide-scale loss of benthic habitat including mangroves. Cyclone Vance removed approximately 5,700 ha, or 44%, of the estimated 1999 mangrove habitat (Paling *et al.* 2005). Some 1580 ha of mangrove recovered over the period 1999-2004 resulting in the total area of mangroves being 68% of their former coverage. The post Cyclone Vance recovery of this habitat is the most rapid observed in Australia (Paling and Kobryn 2005).

2.2.4 Long-term sea level change

Coastal planning in Western Australia is presently allowing for long-term sea level rise based on the mean of the latest models of the latest Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) Working Group (Department of Planning and Infrastructure 2003). Based on this method and application of the 'Bruun Rule' (Bruun 1962), sea level rise over the next 100 years is predicted to be 0.38 m (Figure 4-6).



Source: IPCC 2001

Figure 4-6 Current models predicting global average sea level rise (1990 – 2100). The mean of the models predicts 0.38 m in sea level rise

Vertical changes in sea level are often translated to horizontal shoreline retreat using the Bruun Rule which suggests a 1 cm rise in sea level equates to a 1 m retreat in shoreline position (Bruun, 1962). However, it should be noted that Clarke and Eliot (1983) and Clarke and Eliot (1987) have examined

this relationship using observations obtained from Scarborough Beach (Western Australia). The results of this analysis suggest that this ratio may vary from 1 cm rise to 1.1–1.24 m shoreline retreat for annual to triennial fluctuations in sea level and approximately 1 cm sea level rise to 80 cm shoreline retreat for half-yearly sea level fluctuations.

In addition, Stive *et al.* (1991) note that the Bruun Rule is over simplistic and suggests that the rate of shoreline retreat with sea level rise is time dependent. They note that the Bruun Rule may actually over-predict shoreline retreat rates. For sea level rise rates of approximately 0.2 m/100 years the shoreface processes are largely compensatory and there is no shoreline retreat. For rates greater than 0.6 m/100 years it is expected that shoreline retreat may become significant. Cox and Horton (1999) note that the Stive model has been qualitatively confirmed for the New South Wales Coast, where over the past 100 years with a sea level rise of approximately 0.1 m there has been effectively no overall shoreline retreat.

Further, Cahoon and Lynch (1997) reported that in muddy coastal environments, mangroves are excellent land-builders and by way of example, provided evidence that mangrove elevations in south-west Florida had kept pace with sea level rises over the previous 70 years (rise of 10–20 cm from 1930 to 1990). The implication is that long-term sea-level rise in the Exmouth Gulf will not necessarily result in an inland migration of the mangrove system from its current position.

In addition to the unknown manner of a response to gradual changes in sea-level, attempts to gain consensus on the future location of a mangrove shoreline due to long-term sea level changes are likely to be futile given the potential for variation in other long-term global factors such as ocean acidification and global temperatures.

For the purposes of determining a set back limit to accommodate future sea level rise, it is considered most appropriate to use the Bruun Rule with an acknowledgment that it may provide a conservative overestimate. This is the approach that has been applied elsewhere in Western Australia by the Department of Planning and Infrastructure and as such is the only current 'official' approach to the issue in Western Australia (there is no EPA policy or guideline on this issue). Using a planning horizon of 100 years it may be anticipated that the sea level may rise by 0.38 m, which, via the Bruun Rule, translates to a shoreline retreat of 38 m.

For comparison, the debris line from Tropical Cyclone Vance at Hope Point (Figure 4-7) shows that the fuel storage is located above the 100 ARI storm surge event. In the region of the Hope Point site, this debris line is approximately 200 m from the shoreline.

2.2.5 Hydrology, hydrogeology and groundwater system on the eastern side of the Gulf

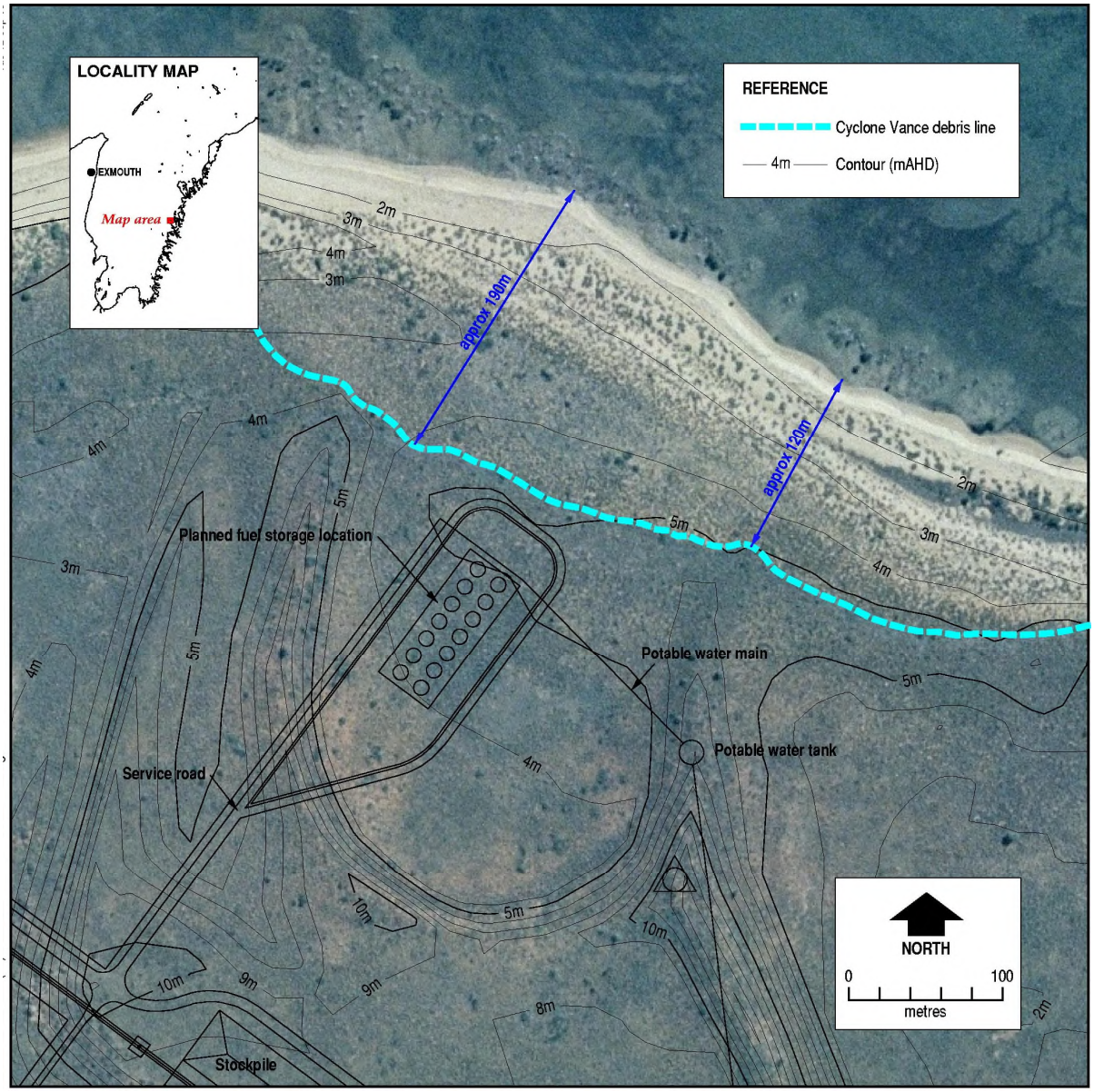
Overland flow from the hinterland to the eastern shoreline of the coast of the Gulf is usually only associated with cyclone events. The Yannarie River and Rouse Creek are the main watercourses in the area. Flood conditions result in sheetflow on outwash plains and interdunal basins in the hinterland to the east of the supratidal salt flats. Most of this flow is eventually lost through evaporation. Only under very high flow conditions does water discharge via Yannarie River South or Yannarie River North onto the supratidal salt flats (refer to Chapter 5, Section 3.3.5).

During high flow events some water from Rouse Creek may flow into the Ashburton River to the north and onto the supratidal salt flats via Rouse Creek South and Rouse Creek North.

The extent of flow from the hinterland to the supratidal salt flat to the west of the coastal dunes is dependent on the period and intensity of rainfall into the catchment of these streams. No significant runoff to the supratidal flat is expected from annual and 2-year rainfall events. The discharge characteristics of the Yannarie River drainage system suggest that there is no hydrologic link between the hinterland drainage systems and the mangrove ecosystems. If runoff were to reach this zone, it would be accompanied by higher sea levels from extreme storm events resulting in inundation of the supratidal salt flat with seawater (Biota 2005d) (Appendix 4).

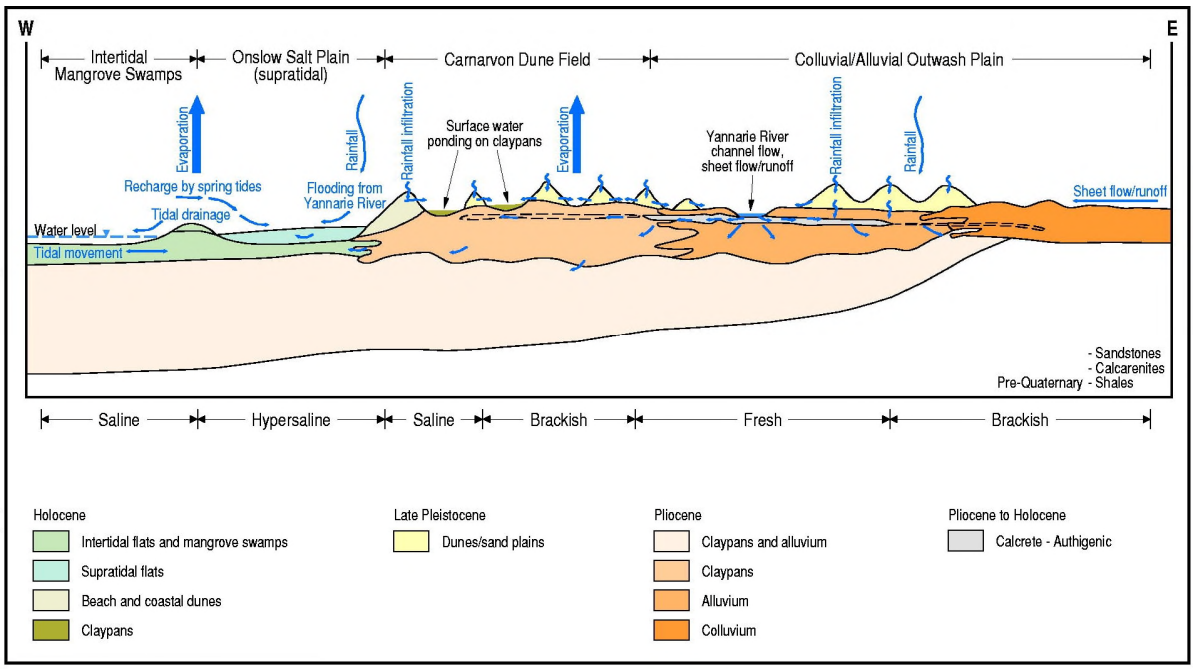
The supratidal salt flat has a very thin unconfined aquifer of sand, silt and clay above a low permeability clay layer (Parsons Brinkerhoff 2005b) (Appendix 7). The depth to water beneath the salt flat ranges from 0.2 to 1 m and the hydraulic gradient is extremely low due to negligible topographic variation and recharge by throughflow from the claypan deposits in the dune field. The elevation of the underlying clay layer is generally above sea-level, hydraulically isolating the water levels beneath the salt flat from tidal influences. The supratidal salt flat is intermittently recharged by sea level rises above the normal astronomical tidal range events and flood events from the Yannarie and Rouse river systems.

A conceptual hydrogeological model for the east coast of the Gulf is provided in Figure 4-8.



Source: Parsons Brinkerhoff 2006

Figure 4-7 Cyclone Vance debris line relative to the fuel storage location at Hope Point



Source: Parsons Brinckerhoff 2005b

Figure 4-8 Conceptual hydrogeological model of the east coast of the Gulf

Groundwater and soil water salinity, together with the frequency of tidal inundation, strongly influence the distribution of mangrove communities and species (Biota 2005d) (Appendix 4).

2.2.6 Nutrient inputs and cycling

The Gulf is a marine estuary, dominated by marine exchange and coastal scavenging of nutrients from the shallow vegetated banks, mangroves and algal mats on the eastern side. Productivity in the Gulf is nitrogen limited with no appreciable inputs of terrestrial freshwater and nutrients except during periods of cyclonic activity (Oceanica 2006a) (Appendix 7).

The primary external source of nitrogen to this Gulf ecosystem is from intertidal zone algal mats which transform nitrogen from the atmosphere into biologically available nitrogen which then is cycled within the ecosystem. Carbon dioxide from the atmosphere is converted by algal mats, mangroves, seagrass and algal mats through the process of photosynthesis to compounds that are then cycled through the Gulf ecosystem.

Algal mats, mangroves, seagrass and algal beds are the key primary producers in the Gulf ecosystem.

Despite the lack of terrestrial nutrient inputs, the Gulf supports a significant prawn fishery and an important Dugong population (Oceanica 2006a) (Appendix 7). The productivity in the Gulf is maintained through contributions from the large system of algal mats and mangroves on the eastern shoreline and vegetated banks on the eastern side of the Gulf (Figure 4-9).

2.2.7 Potentially significant anthropogenic influences

Large areas of the Gulf form part of trawl grounds that have been intensively trawled for approximately 30 years (Oceanica 2006a) (Appendix 7). Trawling has had the most impact on the Gulf ecosystem but is now restricted to deeper areas of the Gulf where the seabed now is primarily a muddy bottom. Trawling can result in changes to the sea floor and does result in a significant by-catch of fin fish and other marine life which has amounted to about 2-5 times the catch of prawns (Department of Fisheries 2002). Recently the industry has adopted mandatory by-catch reduction devices and fish escape devices to reduce the by-catch.

Recent Fisheries research into by-catch suggests that trawling is operating in a sustainable manner in that there are still significant quantities of by-catch and that the by-catch does not include significant quantities of commercial species (Department of Fisheries 2003). However, there are no long-term quantitative data on the effects of trawling on the benthic structure and ecology of the Gulf (Oceanica 2006a) (Appendix 7).

A variety of aquaculture activities take place in the Gulf and there are currently 21 aquaculture and pearl licences in the Gulf. The environmental impacts of these operations are believed to be relatively minor (Oceanica 2006a).

Recreational boating is mostly confined to the western side of the Gulf in the vicinity of Exmouth and is associated with fishing and diving. Recreational fishing pressure is believed to have contributed to declines in target species such as coral trouts, Malabar rock cod, tuskfish and members of the emperor and sea perch families in the vicinity Muiron Islands (Hutchins *et al.* 1996). In response, the State Government has introduced closures to protect stocks.

Tourism ventures include charter operators conducting whale watching tours during August to November in the western part of the Gulf. Exmouth is increasingly visited by cruise ships with an anticipated 14 ships due to berth at Exmouth between October 2005 and March 2006. Western shore-based tourism activities include fishing and diving at the Naval jetty and snorkelling at Bundegi Reef.

Tue 12 Sep 06
Environmental GIS (08) 9486 9222 0643-F4-09.dgn

Yannarie Solar
a Straits initiative

Source: Sherri Brown, 2006
Date: 11 Sep 2006

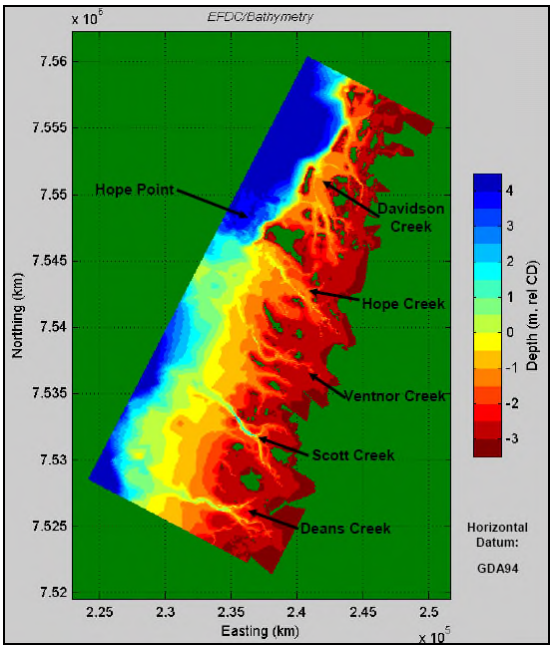
YANNARIE SOLAR PROJECT ERMP/EIS

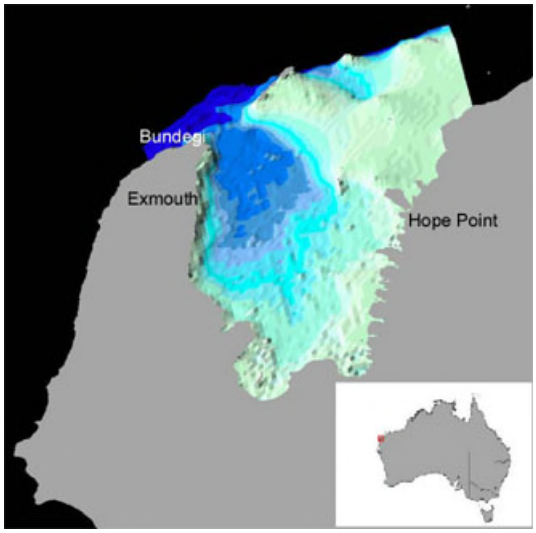
Figure 4-9 Conceptual diagram of the Exmouth Gulf ecosystem

2.3 GULF AREA BELOW LOW TIDE MARK

2.3.1 Bathymetry

The Gulf has two distinct bathymetric regions; the deeper waters >10 m in the west (maximum of 21 m) and shallows of the eastern portion which tend to regulate the flora and fauna found in each region (Figure 4-10). The deep region does not support seagrasses while the eastern portion is not frequented by whales. The shallow protected waters of the Gulf are in contrast to the water of Ningaloo Reef which outside the reef line are exposed to ocean waters and rapidly drop off to 1000 m deep.





(a) Source: WorleyParsons 2005b

(b) Source: Centre for Whale Research 2004a

Figure 4-10 Bathymetry of (a) eastern coast of Exmouth Gulf and (b) Exmouth Gulf

2.3.2 Benthic habitat and Gulf fauna

There are extensive vegetated (ephemeral seagrasses, sponges and macroalgae) shallow banks extending predominantly south of Hope Point generally 0.5 to 1.5 m below mean sea level which support the majority of marine fauna on the east coast of the Gulf.

This benthic habitat is a very important foundation for the Gulf ecosystem through the fixing of carbon and providing shelter and food for organisms higher in the food chain (Figure 4-9). Many of the fauna that are reliant on this habitat are of conservation or commercial value. These banks are the primary feeding ground for the Gulf dugong population (about 1000) with the greatest numbers being in the south east corner of the Gulf (Oceanica 2006a) (Appendix 7). These banks are also likely to be important feeding ground for turtles and are key component for the lifecycle of the tiger prawn which is of commercial interest.

The eastern banks produce significant quantities of seagrass detritus and the supply of this material to the remainder of the Gulf may be an important contributor of nutrients to the ecosystem (McCook *et al.* 1995).

The Gulf is an important resting ground for nursing humpback whales on their southward migration between September and November (Centre for Water Research 2004b). Large numbers of whales and their calves gather in the deeper waters along the west coast of the Gulf and near point Murat. The Gulf is also visited by other whale species.

Benthic habitat communities and marine fauna are addressed in detail in Chapter 6, Section 2 and 3 respectively.

2.3.3 Water and sediment quality

Water quality in the Gulf is naturally turbid and primary production (phytoplankton biomass) is low and is limited by the availability of nitrogen. Water temperatures vary between 18˚C and 30˚C and salinities between 34 and 36 ppt outside tidal creek areas (Oceanica 2006a) (Appendix 7).

There are greater nutrient (particularly nitrogen) and chlorophyll-*a* concentrations on the eastern shore of the Gulf with highest concentrations occurring in tidal creeks (Oceanica 2006a).

The quality of sediments in the eastern side of the Gulf show negligible, if any, anthropogenic influence. The maximum concentrations of nitrogen and organic carbon occur along the eastern mangrove coastline (Oceanica 2006a) (Appendix 7). Naturally elevated levels of total arsenic could exceed the EPA environmental quality guidelines, however the bioavailable fraction of arsenic will be substantially lower (Oceanica 2006a) (Appendix 7). The acid neutralising capacity of the sediments layer is high owing to high calcium carbonate content.

The water and sediment quality of the Gulf is addressed in more detail in Chapter 6, Section 1.

2.4 INTERTIDAL ZONE – AREA BETWEEN THE LOW AND HIGH TIDES

This area includes mudflats, mangroves and algal mats which experience periodic inundation by tides and hypersaline groundwater or soil. Ecological processes of nitrogen (algal mats only) and carbon fixation in the algal mat and mangrove communities are key sources of nutrients to the eastern Gulf ecosystem in addition to sustaining organisms higher in the food chain through the provision of shelter and food (Figure 4-11, Figure 6-12 and Figure 6-13). The input of nutrients from the supratidal salt flats to the mangroves and algal mats is insignificant (Biota 2005d and Brunskill et al. 2001) (Appendix 4).

The distribution of the mangroves and algal mat communities is governed by a combination of groundwater salinity and inundation frequency (Figure 4-12).

Surface and groundwater flows from hinterland have negligible influence on the maintenance of salinities in the intertidal zone (Biota 2005a, Brunskill *et al.* 2001).

Tue 12 Sep 06

Environmental GIS (08) 9486 9222 0643-F4-11.dgn

Yannarie Solar
a Straits initiative

Source: Sherri Brown, 2006
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 4-11 Conceptual diagram of the ecosystem at tidal creek scale on the east coast of the Gulf

2.4.1 Algal mats and mangroves

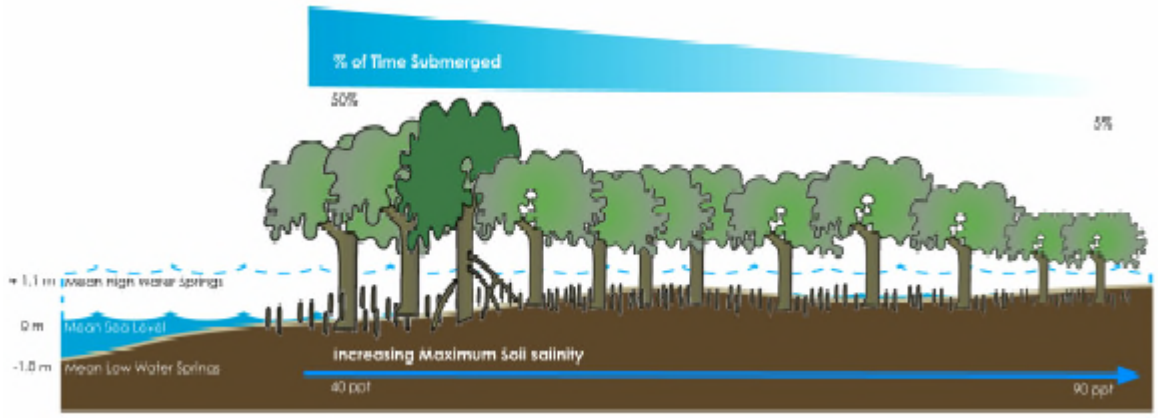
The cyanobacteria algal mats form the inland margins of the intertidal zone to the east of the mangrove communities above the Mean High Water spring tides. These are generally wet from tidal inundation for only 1-3% of the time during spring tides (Biota 2005d).

The mats are an important component of the ecosystem as they fix nitrogen and carbon from the atmosphere and contribute nutrients, particularly organic nitrogen and organic matter to the down-gradient mangrove communities and the east coast of the Gulf (Figure 6-12 and Figure 6-13). The mats together with mangroves are believed to be the source of much of the nutrients in the sediments along the east coast and a foundation for the prawn fishery within the Gulf (Brunskill *et al.* 2001, CALM 1994). Nitrogen fixed by algal mats is lost principally as organic nitrogen during tidal inundation and localised intertidal runoff from rainfall.

The east coast of the Gulf is dominated by one of the most extensive stands of arid zone mangroves in WA (Biota 2005d) (Appendix 4). Mangrove communities stabilise the coast and fix carbon from carbon dioxide in the atmosphere and receive nutrients predominantly from algal mats up the tidal gradient from them. The mangroves contribute nutrients and organic matter to eastern Gulf system as well as providing shelter for a wide range of fauna. Sediment dwelling fauna (such as crabs) in mangrove communities typically process particulate nitrogen which is not exported to the Gulf by ebb tides.

The distribution and range of mangrove species is governed by a combination of groundwater salinities and period of tidal inundation. Groundwater salinities in mangroves vary typically between 40 and 90 ppt and tidal inundation of mangroves varies between 5 to 50% of the time (Figure 4-12).

Algal mats and mangrove communities are addressed in detail in Chapter 6, Section 2.



Source: Biota 2005d. Note: heights in m AHD

Figure 4-12 Salinity and inundation gradient in mangrove communities

2.4.2 Tidal creeks

Tidal creeks facilitate the inundation and draining of mangrove and algal communities and therefore convey nutrients and carbon to offshore areas of the eastern Gulf. These creeks are characterised by turbid water and strong tidal currents.

The salinity at the inland end of tidal creeks is in the range of 50-70 ppt with salinities in the main body of a creek ranging from 40-50 ppt. The concentrations of inorganic nitrogen in these creeks tend to be higher than offshore waters indicating the export of nitrogen to the eastern Gulf subtidal areas.

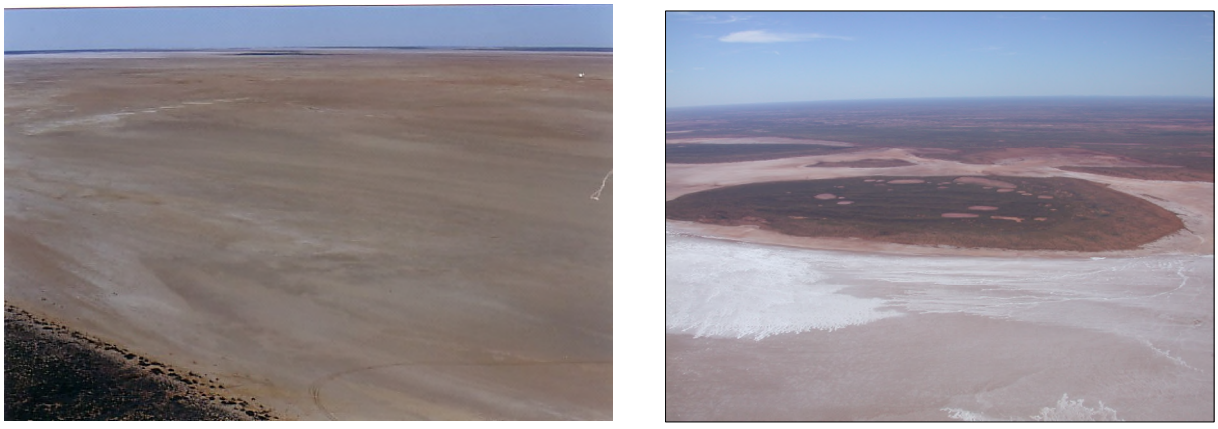
The creeks perform an important ecological function as a refuge for juvenile fish and prawns as well as attracting fauna that use the local conditions or are larger predators.

The benthic communities of the intertidal zone and tidal creeks and fauna reliant on them are addressed in more detail in Chapter 6, Sections 2 and 3.

2.5 SUPRATIDAL SALT FLATS

This area adjoins the eastern side of the algal mat communities, has a lack of vertical relief and is occasionally inundated by seawater during storm surges or spring tides coincidental with the passage of low pressure systems (Figure 4-13a). The supratidal salt flats are up to 10 km wide and in the north they slope away from the ocean. In all cases, slopes are 1:5000 to 1:10,000 and the total relief across the flats is of the order of 20–30 cm higher than the edge of the algal mats. Within the supratidal flat there are occasional mainland remnants (Figure 4-13b) and very slight depressions, channels and ridges where water ponds in broad sheets when the area floods through rain, storm surges or exceptional tidal events.

The environment of the salt flats is generally extremely hostile to life due to hypersaline groundwater and salt in the near surface sediments. The area is devoid of flora and vegetation (except for occasional mainland remnants within the flats) and biological activity and is not utilised by terrestrial fauna on any regular basis (Biota 2005a) (Appendix 5).



(a) **(b)**

Source: D. C. Blandford & Associates Pty Ltd and Oceanica 2005

Figure 4-13 (a) View of salt flat area and (b) example of mainland remnant

2.5.1 Hinterland (dunefield and outwash plain)

This area adjoins the eastern side of the supratidal salt flats and may be affected by exceptional storm or cyclonic events. The dunefield landscape comprises a sheet of sand base over which a longitudinal dune system has formed which ranges in height from four to seven metres and interdunal swales and claypans (Figure 4-14) (Biota 2005b). Further inland is an outwash plain which has a low overall east west gradient and is composed of alluvial and coalluvial sediments.

The Yannarie River is the major river system in the area and has a catchment area of 4300 km^2 (Parsons Brinkerhoff 2006a). There is no major incised drainage across the outwash plain as the Yannarie River loses its identity at the entrance to the plain. During flood conditions this river discharges as sheet flow onto the supratidal salt flats with the majority of this flow lost to evaporation and a small amount infiltrating to the groundwater system.

There appears to be no direct hydrologic link between discharge from the mainland drainage systems and the ecosystems of the intertidal zone (Biota 2005d, D C Blandford & Associates and Oceanica 2005). If runoff reaches the intertidal zone, it would be aided by higher sea levels resulting from extreme storm events flooding the supratidal salt flats. Given the long time frame and periodicity of these events it is most unlikely that the coastal zone ecosystems rely on carbon and nutrient flows generated by mainland discharge (Biota 2005b).

Source: D. C. Blandford & Associates Pty Ltd and Oceanica 2005

Figure 4-14 View of longitudinal dunefield towards the Yannarie River South and supratidal salt flats

Chapter 5

Terrestrial factors

- Soils and landforms
- Groundwater
- Surface water
- Terrestrial vegetation and flora
- Terrestrial fauna

Chapter 5 Terrestrial factors

1 SOILS AND LANDFORMS

1.1 EPA OBJECTIVES

The EPA objective relevant to this assessment is:

- *To maintain the integrity, ecological functions and environmental values of soils and landform.*

1.2 LEGISLATIVE AND POLICY CONTEXT

1.2.1 Relevant guidelines

EPA Position Statement No. 5

EPA Position Statement No. 5, "*Environmental Protection and Ecological Sustainability of the Rangelands in Western Australia*"(EPA 2004e), outlines the environmental attributes and values of rangelands, their pressures and environmental condition, management issues, principles and objectives for the environmental protection and ecological sustainability of the rangelands and management responses required. This Position Statement identifies grazing, horticulture (in the floodplains), fire, feral animals and weeds, mining and climate change as pressures on the rangeland environment.

EPA Guidance Statement No. 4

EPA Guidance Statement No. 6, "*Rehabilitation of Terrestrial Ecosystems*" (EPA 2006c), recognises that a key aim of rehabilitation is to ensure the long-term stability of soils, landforms, and hydrology required for the sustainability of sites. When discussing abiotic factors, the Guidance Statement describes the maintenance of soil properties as being a key aspect of rehabilitation to ensure vegetation establishment and resistance to erosion. It also states that effective topsoil and subsoil management is essential to ensure adequate plant growth and normal root distribution patterns.

EPA Position Statement No. 8

EPA Position Statement No. 8, "*Environmental Protection in Natural Resource Management*" (EPA 2005b), outlines the EPA's role in NRM with respect to evaluating environmental performance. The EPA has been given the task of environmental performance evaluation of NRM agencies by Government. This task will link closely with WA's State of the Environment Reporting Program.

Planning Bulletin No. 64

The Western Australian Planning Commission Planning Bulletin No. 64, "*Acid Sulphate Soils*" (WAPC 2003b), provides advice on matters that should be taken into account in the development of lands that contain acid sulphate soils (ASS). The Bulletin provides planning guidelines for ASS and refers proponents to the Acid Sulphate Soils Guidelines Series, prepared by the Department of Environment (now DEC), which assist developers and individuals to manage development in areas where ASS may, or will be affected.

1.3 DESCRIPTION OF LANDFORM AND SOILS

The project area is located within the Cape Range Province (Figure 5-1) and can be roughly divided into four parallel geomorphic landscape elements that trend north east to south west (Oceanica 2006a) (Appendix 7) (Figure 5-1). These geomorphic units include:

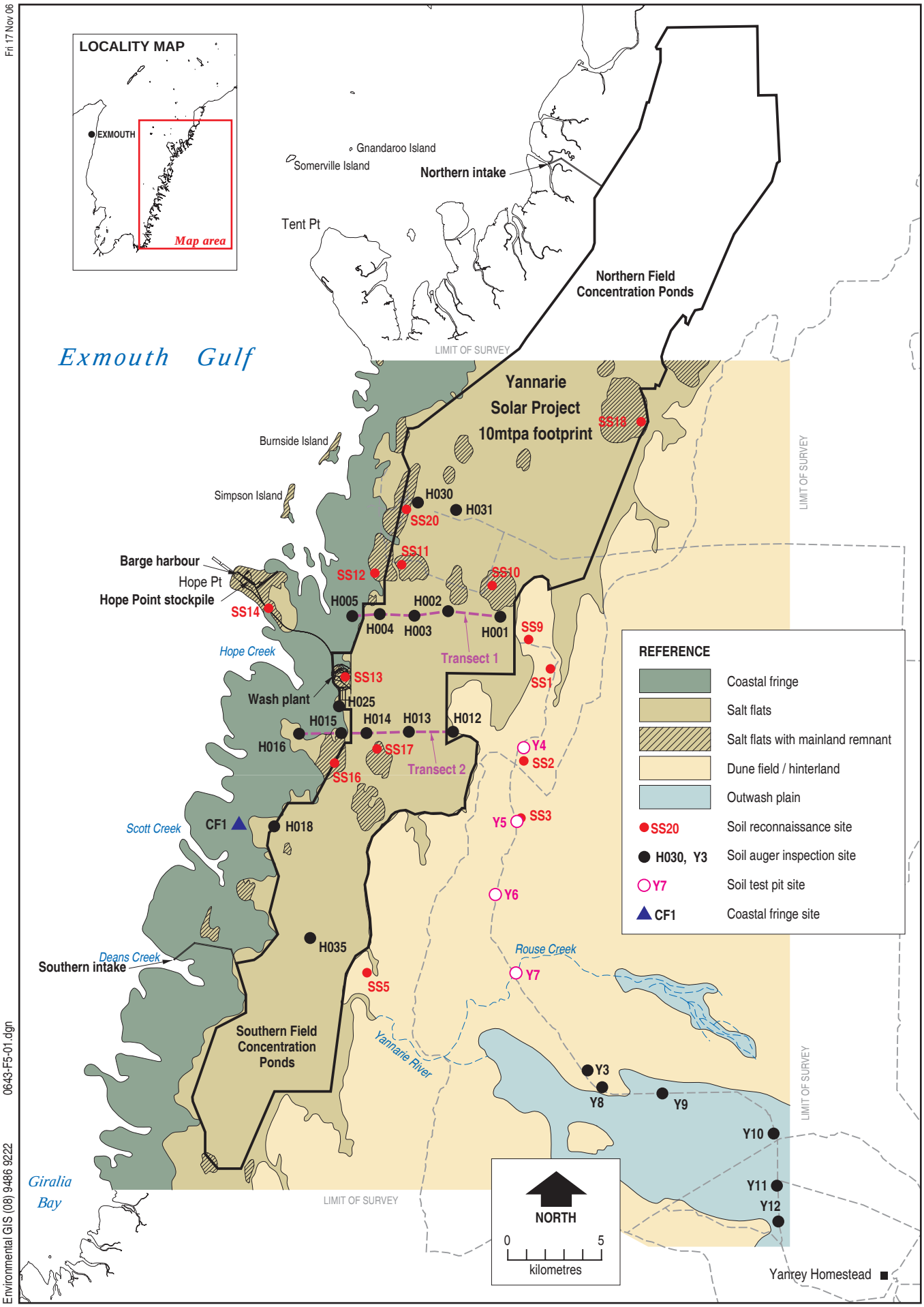
1. *Outwash Plain* - Alluvial/colluvial outwash plain of the Yannarie River and Rouse Creek systems. The plain is generally of low topographic relief, with sparse dune ridges up to 10 m high. Dominated by alluvial processes, sheet deposits of sand and gravel are often present on the surface resulting from sheet flow during flood events. The outwash plain itself is incised by channels near the course of the Yannarie River and Rouse Creek systems.
2. *Dunefield* - Carnarvon Dune Field. Dominated by aeolian processes, this landscape unit features sand dune ridges up to 25 m high with inter-dunal claypans. The dune field is up to 15 km wide in the study area, adjacent to the Onslow Salt Plain. Flood channels draining water from the Yannarie River and Rouse Creek systems dissect the dune field.
3. *Salt Flats* - Onslow Salt Plain. This supratidal flat is of extremely low relief, varying little in elevation over its 10–15 km width. The supratidal salt flat is elevated above the reach of regular high tides but is inundated during storms and spring tide events coincident with periods of extended low pressure.
4. *Coastal Fringe* - Intertidal Flats and Mangrove Swamps. Mangrove swamps form in the upper reaches of the intertidal areas with mudflats. Local dendritic drainage patterns are present between low tide and high tide levels.

The distribution of these landscape elements has been historically governed by fluvial and aeolian processes (rather than pedological processes) occurring in the Yannarie River and Rouse Creek systems in the east and the coastline in the west. Landscape elements are shown in Figure 5-1 and described below.

1.3.1 Investigations

A soil investigation of the project area was undertaken by D. C. Blandford & Associates and Oceanica (2005) (Appendix 3). This investigation comprised three methodologies:

- literature review – revealed no site-specific information about the project area, available data was at the regional scale
- desktop appraisal and photo interpretation – conducted to determine the major soil landscapes and morphologic units of the project area and surrounds
- field inspection and soil profile description – soils were described using soil reconnaissance sites, soil auger sites and test pits.



Fri 17 Nov 06

0643-F5-01.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: D.C. Blandford & Ass and Oceanica, 2006
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-1 Landscape elements of the Yannarie Solar Project

1.3.2 Outwash plain

The outwash plain comprises both alluvial and colluvial sediments. The areas of alluvial sediments are mostly composed of massive clays (generally fine) and sands and are closely associated with the flood discharge of the Yannarie River. The areas of colluvial sediments are composed of coarse sand and gravels and were formed in response to sheet flooding. The plain has a low overall gradient from east to west and very low local relief. Subtle changes in the surface material and depositional characteristics are indicated by changes in vegetation communities.

1.3.3 Dunefield

The dunefield system is known as the Carnarvon Dunefield (Jennings and Mabbutt 1986), and extends both north and south from the outwash plain. The dunefield landscape is highly variable and comprises of longitudinal dunes, vegetated interdunal swales and claypans and sand sheets.

Longitudinal dunes

The longitudinal and network dunes formed during more arid conditions when vegetation cover was sparser than present. The current day dunes in the study area are generally earthy sands which are largely vegetated (see Figure 4-14). These dunes are oriented north/south to the north of the Yannarie River and north west/south to the south of the Yannarie River. The dunes range in height from 4 m to 7 m and display network patterns of great variability. Much of the contemporary surface form of the longitudinal dunes is a function of degradation and historical sand mobilisation.

Interdunal swales and claypans

The interdunal areas of the dunefield landscape are either stable/vegetated or form deflation zones and claypans (Figure 5-2). The soils are mostly duplex in nature. In some areas, particularly where the interdune is extensive, the deflation zones and claypans dominate the landscape. The floor of the claypans is up to 1.5 m below ground level and the series of claypans often link to form a discontinuous network of storage and high runoff areas. These areas are a major factor in the complexity of the surface drainage patterns. The largest of these claypans, the Yankagee Claypan, is immediately north of the Yannarie River outwash plain.

Source: D.C. Blandford & Associates and Oceanica 2005

Figure 5-2 Claypans and interdunal swales in the dunefield landscape element

Yanrey Point sand sheet

An isolated area (approximately 100 ha) of unvegetated red sand is located at Yanrey Point. The Yanrey Point sand sheet has been formed into a series of complex ridges under the influence of the prevailing southerly winds. The dune heights in this area are approximately 14 m and the northern edge of this sand sheet appears to be moving northwards and engulfing vegetated areas. Several swale areas within the sand sheet have a sparse cover of low vegetation.

Fringing dunes

The western edge of the dunefield landscape sharply abuts the supratidal salt flats. In several areas along this boundary (and on several mainland remnants), a fringing dune landform unit has formed. This unit consists of two elements which may occur together or separately and include:

- larger highly-stratified fringing foredune
- a smaller frontal dune to the west.

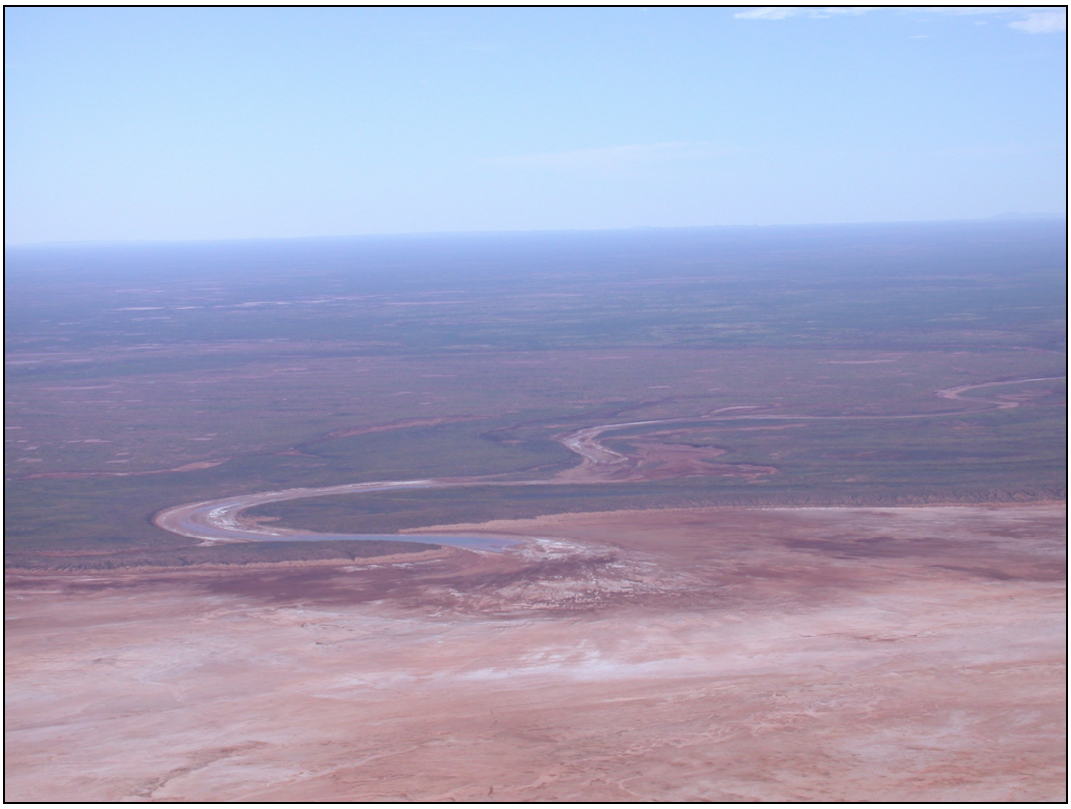
The fringing foredunes have formed from the deposition of wind-blown sands sourced from the supratidal salt flat and the frontal dune has been formed by storm surge. Storm debris lines are often observed within the fringing dune landform and are more common on the mainland remnants towards the west.

1.3.4 Supratidal salt flat

The supratidal salt flat landscape element is also known as the Onslow Plain (Jennings and Mabutt 1986). This plain is only rarely inundated by marine waters and only then under cyclonic surge events. The supratidal salt flat landscape includes the landform units described below.

Salt flats

The salt flat landform is dominated by terrestrial sediments and covers the largest area of all the landforms units in the study region. This landform extends from the fringing dunes of the dunefield landscape to the coastal fringe and ranges from 4.5 - 13 km in width. The salt flats extend from Sandalwood Peninsula to Locker Point and form a flat featureless plain (see Figure 4-13[a]). There is very little evidence of significant fluvial sediment deposition along the eastern edge of the salt flats (Figure 5-3). Some areas, generally towards the eastern edge of the salt flats, show the faint impression of previous tidal creeks which have been infilled. The salt flats are only inundated by marine waters under major storm events.



Source: D.C. Blandford & Associates and Oceanica 2005

Figure 5-3 Mouth of the Yannarie River South where it discharges to the supratidal salt flat

Mainland remnants

The supratidal salt flat landform unit contains a number of mainland remnants (see Figure 4-13[b]). These features are remnants of the dunefield landscape which once extended to the eastern shore of Exmouth Gulf. Hence, the majority of the remnants contain a physical framework typical of the

dunefield landscape, in particular, longitudinal dunes, interdunal swales/claypans and fringing foredunes. However, the interdunal swales/claypans do not exhibit the same degree of erosion as those within the dunefield landscape. A foredune unit (with occasional debris lines) is located on the southern and western edge of some of these mainland remnants, and is generally better developed on the remnants located towards the western edge of the supratidal salt flat landscape.

Coastal fringe

The coastal fringe landscape element lies along the western edge of the study area and forms the eastern fringe of Exmouth Gulf. The soils within this element are highly variable and are generally associated with tidal creeks, foredunes, sand sheet, beaches and limestone outcrops.

Tidal creeks

Tidal creeks and associated intertidal mangroves form a major biophysical system along the western boundary of the project area. The tidal creek unit is characterised by sinuous tidal creeks, mud/sand flats and depositional sediments (Figure 5-4). This unit extends along the eastern shore of Exmouth Gulf from Sandalwood Peninsula to Locker Island. The tidal creek unit is most extensive in the sheltered environments south of Hope Point. North of Hope Point this unit is most developed in the sheltered lee of the offshore islands and points, including Hope Point, Simpson Island, Burnside Island and Tent Island.

Tidal creeks are associated with relatively high tidal ranges with low gradient shores. The tidal creeks typically form a wide mouth which narrows and shallows upstream via a sinuous channel which becomes dendritic towards the landward (eastern) end.

Source: D.C. Blandford & Associates and Oceanica 2005

Figure 5-4 Tidal creek and fringing mangroves with algal mat visible in lower right foreground

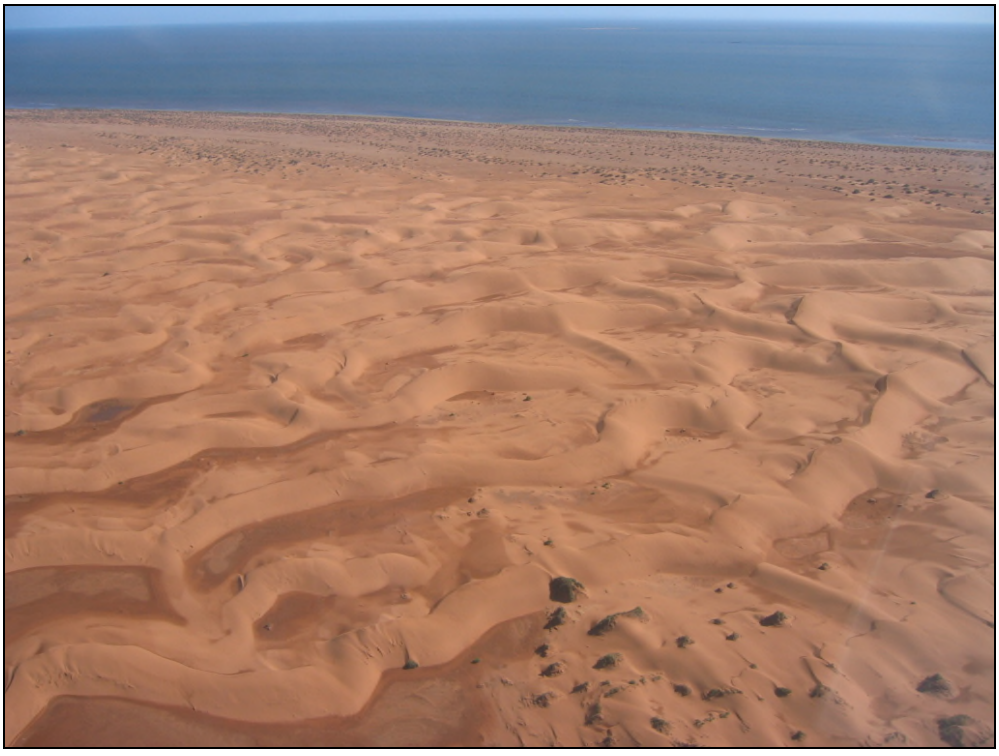
Dune ridges

Low dune ridges composed of sands are occasionally present along the eastern shore of Exmouth Gulf. It is likely that these dune ridges are formed as a result of storm events as they are typically associated with exposed coastal areas. In places, migration of these dune ridges has decreased the extent of tidal creek mouths.

Sand sheet

The sand sheet landform occurs to the north of the region at Locker Point and is similar in morphology to the Yanrey Point sand sheet. The sand sheet forms an extensive area of unconsolidated mobile sands which cover the majority of Locker Point (Figure 5-5). Within the sand sheet, dunes exhibit a transverse/barchan form indicating a relatively constant wind direction (from the south/south west). A deflation zone occurs along the western edge of this sand sheet and areas of deflation are also present in several of the dune swales. The dunes within the sand sheet have an average height of 3 m ranging up to maximum heights of 6 - 7 m.

During Tropical Cyclone Vance, dunes along the western edge of the dunefield were significantly affected. The lower dunes were completely removed by overtopping waters whereas erosion and scarping occurred in areas associated with the higher dunes (Nott and Hubbert 2003).



Source: D.C. Blandford & Associates and Oceanica 2005

Figure 5-5 Sand sheet with dunes at Locker Point

Beaches

Sandy beaches are relatively uncommon across the study area but increase in occurrence to the north of Hope Point. In essence, the distribution of sandy beaches is inversely related to the intertidal mangrove landform and indicates the increased exposure to wind and wave energy with distance northwards. The most extensive sandy beaches occur along the south western flanks of Hope Point, Tent Island and Locker Point. These locations have the greatest exposure (fetch length) to the prevailing south/south westerly wind waves. These beach forms are characteristic of tide dominated beach systems with a relatively large tidal range and a surplus of sediments.

Limestone outcrops

South of Hope Point, rock outcrops are present along the shore at Islam Islets and Whalebone Island. However, from Hope Point northwards, rock outcrops are more prevalent and occur at Hope Point, Simpson Island, Burnside Island, Tent Island and Tubridgi Point. These outcrops are associated with limestone which is exposed to form low relief cliffs and platforms along the western shores.

(a) **(b)**

Source: D.C. Blandford & Associates and Oceanica 2005

Figure 5-6 (a) limestone forming low cliffs on western end of Hope Point and (b) limestone pavement in nearshore environment immediately north of Tubridgi Point

1.4 IMPACT ASSESSMENT AND MITIGATION

1.4.1 Environmental aspects and potential impacts

Key activities or aspects of the proposal that may potentially affect soils and landforms include:

- **site preparation** potentially increasing erosion including removal of topsoil and changes in surface water flows
- **landform removal or modification** through sourcing materials for earthworks of ponds, bunds and associated infrastructure including the barge harbour
- **exposure of potential acid sulphate soils** on the supratidal salt flat and the hinterland through the construction of infrastructure and dredging.

1.4.2 Assessment and management

Increases or changes in erosion from site preparation

The landforms most affected through destabilisation of soil will be the salt flat and the coastline. Within the salt flat landform unit, impacts will be restricted to the surface sediments as there will be no large scale excavation works. Erosional events within this area have the greatest potential to occur during storm events and inland flows of the Yannarie River drainage area, as drainage on the salt flats is typically very slow due to the flat nature of the area. The coastline is already predisposed to erosional events during storms, which may be exacerbated through soil disturbance required for infrastructure development. The hinterland area adjacent to the project footprint has historically had little impact from erosion, other than in isolated areas resulting from grazing pressures, fencing and access tracks.

Soil erosion can also be initiated and accelerated through the loss of perennial vegetation, which plays a pivotal role in stabilising soil structure within the project area. The majority of vegetation clearing will occur for:

- site access roads and haul roads
- saltfield concentrator and crystalliser ponds (where vegetation occurs)
- on the access tracks to proposed 'borrow' pits and limestone quarries (materials sourcing areas)
- within areas proposed for infrastructure (e.g. washplant, stockpiles, workshops, construction camp, air strip, administration buildings, seawater flume, barge harbour, conveyor) such as Hope Point.

Examples of potential degradation within the project area resulting from erosion include:

- stripping of the surface soil, particularly of the sandy surface layer, and its transport during flood events
- sealing of surface soils and inability of rainfall to infiltrate, contributing to increased runoff and flooding
- dust emissions
- elimination of perennial cover in some plant communities
- invasion of exotic perennial grass species and/or woody weeds after erosional events.

Management measures addressing soil erosion and sediment mobilisation

Measures that can be employed to prevent soil erosion and sediment mobilisation within construction areas and in areas where vegetation is cleared (Chapter 5, Section 4), include the following:

1. Clearing and exposed soil working surfaces are kept small and protected from stormwater erosion as far as practicable.
2. Siting infrastructure above natural ground level.
3. Accurately defining and marking areas of native vegetation to be cleared to avoid inadvertent clearing.
4. Rehabilitation of cleared areas not required for the operation of the project to a condition compatible with adjoining land.

5. Utilisation of materials from the construction of the barge harbour to offset requirements from borrow pits and quarries.
6. Construction of a flood protection weir to divert hinterland flows away from saltfield construction areas during major rainfall events.

Landform modification

Two types of construction material will be sourced onsite within the project area including clay for the construction of levee banks, and limestone for lining levee bank walls and causeways (Chapter 2, Section 3).

Clay will be sourced potentially from 15 claypans (i.e. borrow pits) distributed across the project area primarily within the hinterland east of the salt flats and within remnant forms on the supratidal salt flats (Figure 2-9). Limestone will be sourced from three quarries located within the coastal fringe and from excavation of the barge harbour located at Hope Point (Figure 2-9).

Landform modification is one of the potential impacts relating to the removal of construction materials from within the project area, which may result in:

- disturbance of vegetation surrounding the bare claypans (primarily Vegetation Types 2a, 2c and 2d (Chapter 5, Section 4)
- changes to the hydrological balance (e.g. inundation of excavated claypans).

The construction of the saltfield may have a potential impact on the geo-heritage values of the Yannarie River delta, this is addressed in Chapter 7, Section 3.

The construction of the solar saltfield will occupy approximately 410 km^2 at full production, which is about 32% of the salt flat landform within the Ashburton Land System (approximately 127,000 ha total). The ecological significance of this landform to the mangrove and algal communities and the east Gulf coast is negligible.

The barge harbour will be excavated on Hope Point and will be 5 m CD (Chart Datum) deep. The harbour will provide an area where barges can be secured during loading and will be approximately 300 m x 400 m in size. The barge harbour will be located at a site devoid of living mangroves.

Management measures addressing removal of soil

Measures that can be employed to minimise removal of soil and soil disturbance within construction areas and in areas where vegetation is cleared (Chapter 5, Sections 3 and 4), include:

- clearing and exposed soil working surfaces kept to a minimum
- utilisation of materials from the construction of the barge harbour to offset requirements from borrow pits and quarries.

Acid sulphate soils

The acid generating potential of soils within geomorphic units of the project area has been assessed by Parsons Brinkerhoff (2005n). The volume of excavation material which may be potentially acid generating is small compared with the total volume of material proposed to be removed in earthworks for the project as a whole (Parsons Brinkerhoff 2005n).

In general, sensitive ecological receptors within the project area which may be affected from acid sulphate soils include:

- mangrove and algal mats
- invertebrate populations within mangrove algal mat areas.

The geology of the project area is locally constrained to three distinct geomorphological provinces including the intertidal and intertidal/supratidal transitional, the supratidal and the hinterland zones. The acid sulphate soil generating potential for these geomorphic zones has been determined by Parsons Brinkerhoff (2005n) and are summarised in Table 5-1.

Table 5-1 Acid sulphate soil generating potential for each geomorphic zone (Parsons Brinkerhoff 2005n)

Geomorphic zone	Sediment types	Environment of deposition	Acid generating capacity	Interval thickness	Historical field tests
Intertidal and Intertidal/Supratidal transitional					
Intertidal	Sands, shell debris, silts, minor clays, associated with algal mats	Shallow marine, intertidal	Low to moderate (depending on presence of algae and organic debris)	Up to 1.3 m, locally variable (Brunskill *et al*. 2001)	No
Supratidal - Intertidal Boundary	Sands, silts, mud proximal to mangrove stands	Shallow marine, tidal creeks, mangroves, beaches, aeolian dunes	Moderate to high (depending on proximity to mangroves and tidal creeks)	Up to 3 m, locally variable (depending on sediment accretion from tidal creeks), dunes occur on headlands	No (for surface tidal creeks and mangroves) Yes (for mangrove sediment at depth and dunes)
Supratidal					
Supratidal Salt Plain	Sands, silty sands and sandy clays which are red to orange, brown and terrestrial in origin	Terrestrial, aeolian	Low	0.3 to 1 m thinning to the east (average thickness ~0.7m)	Yes
Supratidal Salt Plain	Sands, sandy silts and silty clays which are green, blue, grey, fine sands/silts marine in origin and increasing in clay content with depth	Shallow marine, beach	Low to moderate	0.3 to 1.8 m generally thickening to the west and locally absent	Yes
Supratidal Salt Plain	Sandy clay and clay which is brown to dark brown, possibly terrestrial in origin	Shallow marine, mangroves	Moderate to high	Locally variable, up to 2 m	Yes
Hinterland					
Carnarvon Dune System	Clays that are brown and terrestrial in origin. Contains authigenic carbonates (formed in situ)	Terrestrial	Low	1 to 6 m and up to 10 m in some locations	No

Management measures for addressing acid sulphate soils

An Acid Sulphate Soil Management Plan (ASSMP) will be prepared and implemented which will address the following management strategies for acid sulphate soils:

1. Further sampling within areas of high and moderate risk:
    - soil bores installed over representative areas
    - soil testing
    - logging of soil bore lithologies
    - identification of depth interval in bores with the highest acid generating potential
2. Sediment handling and treatment
3. Reuse of neutralised soils.

1.5 MONITORING AND ASSESSMENT OF PERFORMANCE

A monitoring and investigation program will be implemented to assess:

- performance of rehabilitation in disturbed areas
- sampling of areas of moderate to high risk of acid sulphate soils
- sampling of dredge spoil before disposal
- occurrence of acid sulphate soils.

1.6 PROPONENT COMMITMENTS

Refer also to commitments for environmental factors for vegetation and terrestrial fauna which include the preparation and implementation of:

- Terrestrial Vegetation Management Plan (which addresses the impact of aspects of the proposal on vegetation)
- Rehabilitation Plan (which addresses the control of erosion and the establishment of native vegetation cover in disturbed areas).

1. An Acid Sulphate Soil Management Plan will be prepared and implemented and will address the following:
    - assessment of areas of moderate to high risk of acid sulphate soils
    - management measures to control the generation of ASS
    - sampling of dredge spoil.

1.7 ENVIRONMENTAL OUTCOME

The construction of the Yannarie Solar project will require landform modification through the sourcing of construction materials for the saltfield and associated infrastructure. The largest landform modification will be construction of the ponds on the salt flats landform. A mainland remnant in this flat and at Hope Point will be modified to accommodate the processing plant and construction of the barge harbour respectively.

The area of the supratidal flat landform occupied by the project will be 410 km^2, which represents 32% of the Ashburton Land System. This loss of landform is ecologically insignificant and there is still sufficient area remaining for geo-heritage values to be retained.

Rehabilitation of landforms and vegetation will be conducted on areas (if not required for operational activities) disturbed by construction activities and quarry operations to the satisfaction of the EPA. The overall environmental outcome will be that erosional events will be limited to those naturally expressed within the region and that the disturbance of low quantities of potentially acid generating soils will be minimised or otherwise managed in accordance with an Acid Sulphate Soil Management Plan.

2 GROUNDWATER

2.1 EPA OBJECTIVE

The EPA objective relevant to this assessment is:

- *To maintain the quantity and quality of water so that existing and potential environmental values, including ecosystem function, are protected.*

2.2 LEGISLATIVE AND POLICY AND CONTEXT

2.2.1 Abstraction

The abstraction of groundwater is subject to licensing by the Water and Rivers Commission (now Department of Water) under the *Rights in Water and Irrigation Act 1914*. Licences specify the maximum abstraction rate and include conditions for monitoring.

2.2.2 Environmental water provisions

ANZECC/ARMCANZ 1996 Guidelines

In 1996 the Australian and New Zealand Environment and Conservation Council (ANZECC) together with the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) developed the National Principles for the Provision of Water for Ecosystems (1996). These national principles aimed to improve the approach to water resource allocation and management, and to incorporate the needs of the environment in the water allocation process. The overriding goal of the principles is to provide water for the environment to sustain, and where necessary restore, ecological processes and biodiversity of water dependent ecosystems.

State Policy on Environmental Water Provisions

In Western Australia, the Statewide Policy on Environmental Water Provisions (WRC 2000) protects ground and surface water dependant ecosystem values through the establishment of ecological water requirements. The policy was guided by State water and environmental legislation, the National Strategy on Ecologically Sustainable Development and the National Principles for the Provision of Water for Ecosystems (ANZECC/ARMCANZ 1996).

Ecological water requirements are determined on the basis of the best scientific information available. A conservative approach is taken to the estimation of ecological water requirements in allocation planning and licensing processes where scientific knowledge of ecosystem requirements is limited. Soil water requirements are elements of the existing or historic water flow regime that are required to sustain key social values such as recreation and Aboriginal heritage and culture.

2.2.3 Water quality

ANZECC/ARMCANZ Guidelines

ANZECC and ARMCANZ have also released a set of water quality guidelines for the protection of marine and freshwater ecosystems (ANZECC/ARMCANZ 2000). The ANZECC/ARMCANZ guidelines provide a comprehensive list of recommended low-risk trigger values for physical and chemical stressors in water bodies, broken down into five geographical regions across Australia and New Zealand.

State Water Quality Management Strategy

The Government of Western Australia developed the State Water Quality Management Strategy with the objective 'to achieve sustainable use of the Nation's water resource by protecting and enhancing their quality while maintaining economic and social development'.

2.3 DESCRIPTION OF GROUNDWATER

The hydrogeological component of the physical environment is important in understanding the links between surface water drainage, claypan recharge and discharge, and the washout features observed from the dunefields onto the supratidal salt flats (Figure 4-8). Hydrogeological processes often play a significant role in controlling or buffering surface water flows in this type of environment (Parsons Brinkerhoff 2005a).

2.3.1 Investigations

Parsons Brinkerhoff completed a study on the hydrogeology of the superficial aquifer of the Yannarie River delta (Parsons Brinkerhoff 2005a) and assessed groundwater supply options for the project (Parsons Brinkerhoff 2006a).

The hydrogeological investigations included:

1. Desk study: collating background information on the hydrogeological infrastructure in the area, aerial photos and geological maps.
2. Field investigations: establishment of baseline hydrogeological conditions and a groundwater monitoring network across the study area.
3. Reporting: development of a conceptual hydrogeological model using the findings of the field investigations.

The investigation concentrated on the superficial aquifer formations in the project area (as opposed to confined hydrogeological formations) as potential issues concerning hydrogeological processes relevant to the proposed development are generally limited to the superficial aquifer formations (Parsons Brinkerhoff 2005a).

2.3.2 Outwash Plain

Water levels in superficial aquifer wells and bores on the outwash plain are between 8 m and 20 m below ground level. Watering points on Yanrey Station are generally excavated to the base of the calcrete horizon within alluvial and colluvial outwash plain sediments, where groundwater flows freely into the well (Parsons Brinkerhoff 2005a).

Flows in the Yannarie River channel are considered to recharge the superficial aquifer. Parsons Brinkerhoff (2005a) outlines the evidence for this to include:

1. The thickness, cementation and lateral continuity of the calcrete horizon decreases with distance from the Yannarie River suggesting the calcrete is precipitated from recharge waters from the river channel.
2. A locally, relatively steep hydraulic gradient is observed between the Yannarie River channel and the greater outwash plain area, indicating the river is a source of groundwater recharge (Figure 5-7). The hydraulic gradient flattens past Wanjacootharra Well, delineating the western extent of the competent calcrete horizon and associated alluvial sediments. Drilling reveals the calcrete to the west of this point is present as thin, discontinuous lenses.
3. The electrical conductivity (EC) of groundwater in bores and wells closest to the Yannarie River channel is fresh to transitional, ranging between 1000 and 3000 µS/cm and increasing in EC with distance from the Yannarie River channel. Fresh water is recharged into the calcrete aquifer during times of flow in the river, and by sub-surface flow in the permeable river channel sediments.
4. Anecdotal evidence suggests that the quality of the non-potable water supply to the Yanrey Station homestead improves significantly during periods of flow in the Yanarrie River. The wells supplying the homestead with non-potable water exploit groundwater resources within the calcrete horizon.

The Yannarie River represents the most significant source of recharge to the superficial aquifer in the study area (Parsons Brinkerhoff 2005a). Water level fluctuations are negligible during periods of no flow in the Yannarie River. Contributions to recharge by direct rainfall infiltration are minimal as the majority of rainfall is lost to either surface runoff or evaporation and evapotranspiration (Parsons Brinkerhoff 2005a).

Recharge occurs across a significantly broader front than is represented by the present day channel as suggested by groundwater contours (Figure 5-7) (Parsons Brinkerhoff 2005a). The calcrete is the most hydraulically conductive unit in the outwash plain profile. Recharge water from the Yannarie River flows through the calcrete and is disseminated at the western extent of the calcrete horizon. The alluvium and claypan deposits present beneath the calcrete horizon are of low hydraulic conductivity. However isolated lenses of high permeability river gravels and sands, deposited in channels and as sheet flow during flood events, may provide additional sources of preferential through flow and recharge in the outwash plain profile. Such deposits were observed at an unidentified bore approximately 2.5 km south of Noogara Bore (WIN ID 20004298) where coarse rounded gravels were observed on the ground surface over a width of up to 400 m. Additionally, recharge takes place along the length of the Yannarie River up-catchment from the study area. Changes in hydraulic gradient are a function of recharge and decay of residual head through the western portion of the outwash plain (Parsons Brinkerhoff 2005a).

Low conductivity (salinity) groundwater was found near the recharge source along present day channels of the Yannarie and Rouse river systems (Figure 5-7) (Parsons Brinkerhoff 2005a). Groundwater quality in bores and wells decreases significantly following periods of high abstraction due to up-coning of saline water, indicating that water recharged from the Yannarie River is present as a lens overlying a more saline regional groundwater system. The quality of groundwater in the regional outwash plain system is brackish, ranging from 3000 to 15,000 µS/cm (Parsons Brinkerhoff 2005a).

Discharge from the superficial formations in the outwash plain system is by through flow towards the west, and a small component of leakage into the underlying pre-quaternary sandstones, calcarenites and shales (Parsons Brinkerhoff 2005a).

2.3.3 Dunefield

Groundwater in the dunefield was encountered between 4 and 8 m below the level of the claypans coincident with thin, discontinuous lenses of calcrete (Parsons Brinkerhoff 2005a). Groundwater yields within the calcrete and claypan deposits are low; the monitoring bores installed during the current investigation were bailed dry at a rate of approximately 0.25 L/s. Groundwater gradients within the dunefield landscape unit are consequently flat (0.0002), with groundwater recharged by a small component of through flow from the outwash plain (Parsons Brinkerhoff 2005a).

The electrical conductivity of the groundwater is brackish to saline, with EC's ranging from 10,000 to 55,000 µS/cm at the water table, reflecting the distance of the dunefield from the recharge source at the Yannarie River (Parsons Brinkerhoff 2005a).

Parsons Brinkerhoff (2005a) states that 'as with the outwash plain, rainfall recharge to the watertable is negligible, largely due to high evaporation rates and the low permeability of the claypan deposits'. The following micro-hydrogeological processes were observed during a rainfall event on the 28 July 2004 (Parsons Brinkerhoff 2005a):

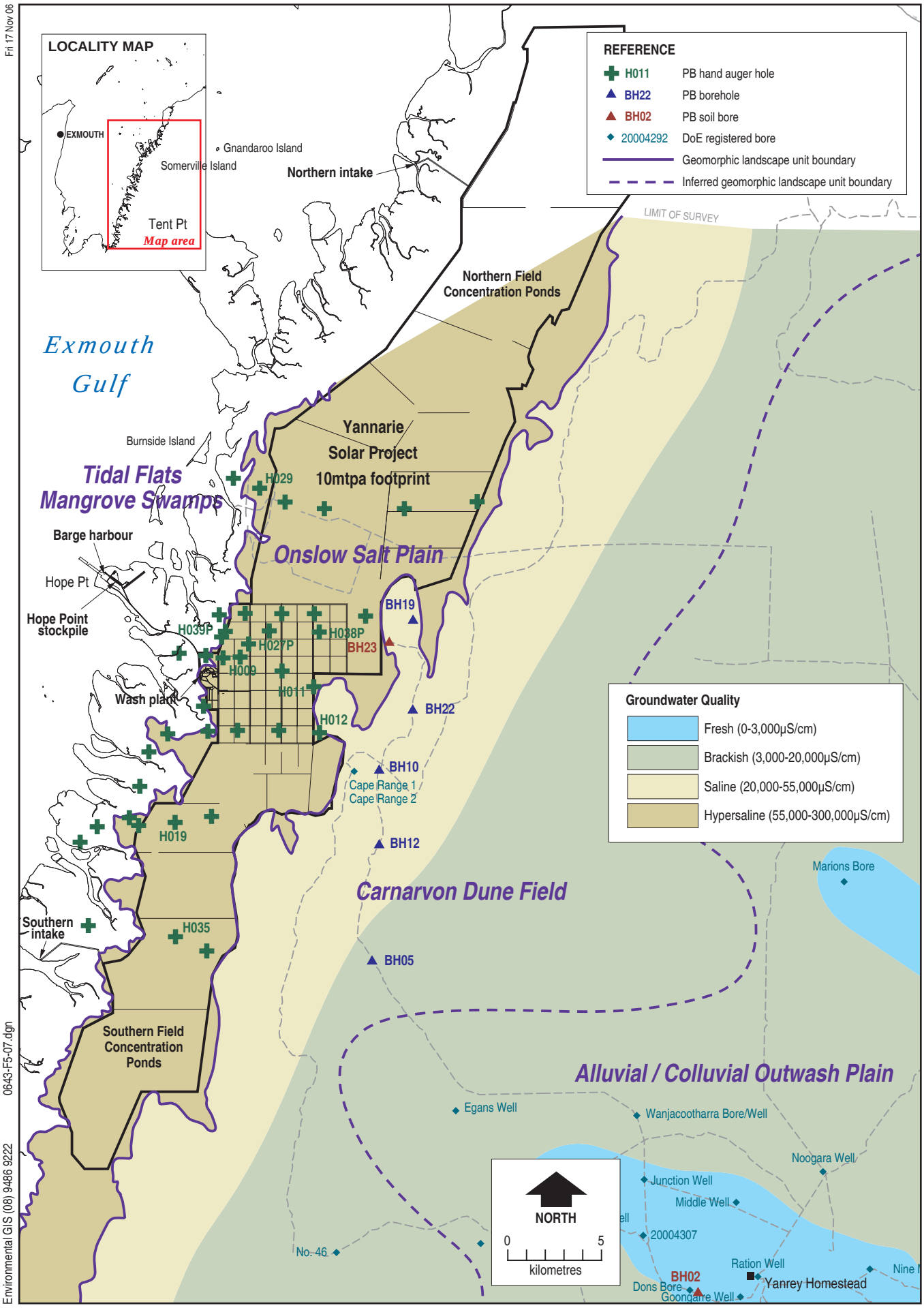
1. Rainfall infiltrates into the dunes surrounding each claypan, discharging at the base of the dune as a wetting front. Infiltrated rain water then flows onto the claypan surface.
2. Rainwater collects in the topographic lows of the claypans where it is lost to evaporation following the rainfall event. The depth of rainwater on the claypan surface following the observed rainfall event was between 5 and 50 mm deep, with electrical conductivities as low as 190 µS/cm.
3. Evidence of breaching of the dunes surrounding some of the larger claypans was observed, suggesting that the interconnection of the claypans form an important component in the surface water drainage system within the dunefield.

2.3.4 Supratidal salt flat

The supratidal salt flat is commonly characterised by sediment accumulation (including authigenic gypsum, anhydrite and carbonate minerals), an ephemeral halite crust and laminated saltpan deposits (Parsons Brinkerhoff 2005a). Parsons Brinckerhoff drilled 37 auger holes in the salt flat and found that a heavy clay layer occurred at depths ranging from 1.5 to 2.5 m with dry, plastic clays preventing deeper hand augering. The hydraulic conductivity of the material was measured in the laboratory and found to be around 10^{-9} m/sec, which represents very low permeability and slow rates of vertical water movement (years rather than days). Above the tight, dry clays, there was a shallow perched aquifer of hypersaline water (soil profiles included in Appendix 3, p 43, 44). The perched water table is 0.2–1 m deep with an extremely low hydraulic gradient (0.00009) due to the extremetly flat topography (Parsons Brinkerhoff 2005a).

The dry conditions in between depths of 1.0 m to 2.5 m indicate that these clays are not within the capillary zone of the deep groundwater table. Combined with the very low hydraulic conductivities measured it is concluded that surface evaporation of deep groundwater does not take place on the Onslow Salt Plain.

The elevation of the clay layer is generally above sea-level and the perched watertable is hydraulically isolated from tidal influences (Parsons Brinkerhoff 2005a). However, the supratidal salt flats are intermittently inundated by spring tide events coincident with a period of extended low pressure. The majority of the water evaporates, concentrating salts in the surficial sediments as halite crusts. These are subsequently dissolved by infiltrating surface water to produce hypersaline groundwater, with electrical conductivities of 120,000 to 263,000 µS/cm (Parsons Brinkerhoff 2005a).



Fri 17 Nov 06

0643-F5-07.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2006
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-7 Bore locations and superficial aquifer groundwater contours

2.4 IMPACT ASSESSMENT AND MITIGATION

2.4.1 Environmental aspects and potential impacts

Pre-existing impacts

The Department of Environment (now DEC) WIN Database revealed approximately 90 bores/wells within a 50 km radius of the proposed construction camp. Up to 50 of these bores/wells were reported to be accessible or operational, occurring mainly along drainage lines such as the Yannarie River and Rouse Creek however, very few points were located within the Carnarvon Dune Field or on the Onslow Salt Plain (Parsons Brinkerhoff 2005a).

Groundwater resources within the fine-grained superficial sediments of the Carnarvon Dune Field are generally limited and saline. However, groundwater within the alluvial/colluvial outwash plain can yield reasonable quantities of fresh to brackish groundwater supplies. This aquifer has been previously developed at the following locations:

- Egans Well, located approximately 25 km south of the camp, with an electrical conductivity of 1757 µS/cm
- Wanjacoothara Well, located approximately 28 km south-south east of the camp, with an electrical conductivity of 9670 µS/cm
- Leonie's Bore, located approximately 23 km east-south east of the camp, with an electrical conductivity of 11,880 µS/cm
- Marion's Bore, located approximately 27 km east-south east of the camp, with an electrical conductivity of 1147 µS/cm.

Existing groundwater quality impacts are considered to be negligible as a result of the low level of anthropogenic impact in the study area.

2.4.2 Relevant aspects and potential impacts

The following aspects have the potential to adversely impact on the quality and/or quantity of groundwater resources within the project area:

- **dewatering** during construction could potentially impact water quality and groundwater-dependent ecosystems (including subterranean fauna)
- **spills** pose a potential threat to water quality
- **seepage** from the salt ponds
- **saline groundwater intrusion** into groundwater of mainland remnants resulting from construction of salt ponds
- **effluent disposal** from wastewater treatment plants could potentially affect water quality
- **discharge of tailwater** from reverse osmosis plants could potentially affect water quality.

2.4.3 Assessment and management

Dewatering during construction

Dewatering will be required for the construction of the barge harbour and establishment of limestone quarries associated with the supply of rock armour (refer to Chapter 5, Section 1 for the location of limestone quarries). Full geotechnical surveys of these sites have not yet been possible due to site access constraints, however it is envisaged that excavation will be to a depth of approximately 9 m and 5 m below ground level for the barge harbour and limestone quarries, respectively. No other dewatering is contemplated for the project.

Water quality

Dewatering could alter groundwater quality through drawdown causing saline intrusion or exposure of ASS. The likelihood of generating acidic discharges associated with dewatering for limestone quarrying will be negligible because of the acid neutralising capacity of karstic terrains. The disposal of dewatering fluids could potentially affect the receiving environment through increased turbidity, salinity or metals (possible if acid is generated from ASS disturbance).

Groundwater-dependent ecosystems

The available data suggest that it is unlikely that subterranean fauna occur within the proposed saltfield footprint (Chapter 3, Section 3.3). However, subterranean fauna are known to be present in a variety of rock types including karst (limestones), fissured rock (e.g. granite) and porous rock (e.g. alluvium) (Marmonier *et al*. 1993). There is the possibility that subterranean fauna might exist in the areas of proposed limestone quarrying. The limestone habitat of Hope Point is not unique to the project area and also occurs at Simpson Island, Burnside Island, Tent Island and Tubridgi Point to the north as well as at Islam Islets and Whalebone Island to the south. Any subterranean fauna occurring at Hope Point is likely to also occur at other limestone outcrops in the project area.

Nonetheless, Straits has committed to determining the presence of subterranean fauna in these limestone areas.

There is the potential for saline intrusion and/or drawdown to adversely affect ecosystems dependent upon localised lenses of groundwater as dewatering may be required to quarry limestone at a number of coastal locations (refer to Chapter 5, Section 1). However, it is considered unlikely that vegetation in these areas would be groundwater-dependent but reliant upon soil moisture for its survival (Chapter 5, Section 4) rather than groundwater.

Management measures addressing dewatering

A Groundwater Management Plan will be prepared and will describe measures that will be employed to reduce impacts from dewatering including:

- a sampling program to determine the occurrence of subterranean fauna in the groundwater
- dewatering will be undertaken only for the construction of the barge harbour and establishment of limestone quarries
- passing dewatering discharges through sedimentation ponds to reduce their turbidity such that it will not adversely affect sensitive receiving environments. These discharges will either be evaporated, re-infiltrated or reused, with no direct discharge to the marine environment
- monitoring vegetation in areas potentially sensitive to groundwater drawdown.

Oil and fuel spills

Fuel will be barged in to Hope Point before being further distributed by tanker to the four fuel storage facilities located within the project area. The fuel storage facilities include one each for the Northern pump station (Naughton Creek), Southern pump station (Dean's Creek) and Main Island and a main fuel storage facility located at Hope Point.

The secondary fuel storage at Main Island will be constructed above the 1 in 100 year storm surge event. Fuel storage at the pump stations will be set on top of a levee wall on a raised platform and anchored in place to protect against any overtopping which might be associated with the 1 in 100 year storm surge event. These tanks will also be double skinned. The nature of the landforms within the project area means fuel storage facilities will be located on mainland remnants. The highly permeable nature of the soils in the coastal area means the superficial groundwater would be vulnerable to contamination should a spill occur.

Management measures addressing oil and fuel spills

Bunds will be constructed to contain spills and leaks from fuel storage and handling. The bunds will be constructed of impervious material to prevent the inflow or outflow of liquids in accordance with Australian Standard *AS 1940-2004: The storage and handling of flammable and combustible liquids.*

The net capacity of each bunded fuel storage facility will be at least 110% of the net capacity of the largest tank.

In addition to bunding, the risk of fuel spills entering the environment will be addressed through:

- regular inspections of valves, pumps, pipes and hoses (e.g. drain valve remains in the fully closed position at all times when not in use)
- preventative maintenance (bund walls/floor are routinely maintained to ensure it is always impervious to liquids)
- spillages of solid or liquid material within the bunded area being cleaned up immediately and disposed at an appropriately licensed solid/liquid waste treatment facility
- on-site and off-site emergency procedures and preparedness
- all bunds being emptied as soon as possible after rainfall, to maintain full capacity
- spill response and cleanup (e.g. identify personnel responsible for cleanup, notification of relevant authorities, define timing of response and level of response according to severity of spill, identifying appropriate cleanup material and procedures, list personal protective equipment for cleanup personnel)
- storage and maintenance of spill recovery and cleanup equipment at Hope Point.

Seepage from the salt ponds

Permeability tests conducted on the near-surface soils of the supratidal salt flat show that these soils have very low to extremely low hydraulic conductivities (conductivity of 10^{-9} m/s). The elevation of the underlying clay layer is generally above sea level, hydraulically isolating the salt ponds from tidal influences and deeper groundwater systems.

The low permeability of the clays underlying the salt flat provides a suitable foundation for construction of the seawalls and will also ensure that seepage losses from the ponds to the underlying groundwater system will be insignificant.

Detailed geotechnical investigations were carried out to characterise the local materials planned for bund construction (Parsons Brinckerhoff 2005b). One of the key issues considered was the amount of seepage that might occur through the saltfield bund walls which are to be constructed from locally sourced clays. In the context of mangroves and algal mats, it is horizontal seepage from the western boundary of the field that is of interest.

Seepage testing was carried out on local clay materials and found that seepage rates through this material would be very low (a maximum of 3.09×10^{-7} m^3/sec/m of wall length) (Parsons Brinckerhoff 2005b). Given the very low seepage rates associated with the local clay material, only very gradual seepage is anticipated from the saltfield ponds to adjacent areas.

Groundwater underlying the salt flat is naturally hypersaline as a result of evapo-concentration (evaporation is approximately 3,000 mm/yr). As seepage losses from the salt ponds can be expected to be minimal, the likely egress and impact of any seepage is considered to be insignificant. Also, the salinity of water in the majority of the ponds is less than that of the groundwater. Therefore, if seepage occurs, it would result in a slight reduction in groundwater salinity.

The Groundwater Management Plan will address the management measures and monitoring to be applied.

Saline groundwater intrusion

The flooding of the saltfield will result in the terrestrial habitats of the mainland remnants becoming surrounded by water of varying salinity (becoming true 'islands'). Dependent on the stratigraphy of the individual islands, this may lead to saline water intrusion from the surrounding concentrator ponds into the groundwater lens present on these mainland remnants. A general elevation of groundwater levels may also arise, driven by a combination of hydrostatic pressure of the large volume of water within the surrounding ponds and associated capillary rise of moisture through the soil profile.

This may have a direct impact on existing vegetation complexes and indirectly affect fauna abundance and distribution through alterations to their habitat and food availability.

Vegetation assemblages and flora

This is addressed in Chapter 5, Section 4.

Fauna abundance and distribution

There is also the potential for long-term change to fauna habitats through saline groundwater rise and intrusion on the mainland remnants. This loss or modification of habitat will be restricted to those mainland remnants that occur within the central area of the proposed saltfield. Predictions suggest that less than 16% of the terrestrial habitats of these central remnants may be affected by this process, depending on their position in the landscape (Chapter 5, Section 4).

The gradual decline in *Triodia* habitats that may arise from saline groundwater intrusion will also affect fauna habitats. It is likely that any decline in vegetation will ultimately lead to modifications in the lower terrestrial fauna community trophic levels and declines in invertebrate biomass. In the

longer term this will probably lead to some localised reductions in vertebrate fauna populations and species richness in the affected area. However, the areas most likely to be affected are currently saline claypans. These are mostly devoid of vegetation and do not show any evidence of routine terrestrial fauna use (Biota 2005a and 2005b), therefore, the overall impact is not considered significant.

The Groundwater Management Plan will address monitoring of vegetation communities low-lying areas on islands potentially affected by saline water intrusion.

Treated wastewater disposal

Wastewater from the construction camp will be treated using a package activated sludge unit. This unit will be selected to meet Health Department of WA performance criteria and be sized for a workforce of 100 person equivalence. These units produce effluent equivalent to an upper secondary treatment standard and are suited to instances where there may be fluctuations in loadings, as may be expected from the variable work force at the construction camp.

Once the construction phase of the project is completed, the construction camp will be decommissioned and the site rehabilitated.

Wastewater from Main Island will also be treated using a package activated sludge unit and sized to meet Health Department of WA performance criteria for a peak full-time workforce of 150 person equivalence. The operational workforce will, however, commute between Exmouth and the site on a daily basis.

The workforce at Hope Point is expected to be minimal and largely associated with barging and stockpile operations. Accordingly, it is proposed to use modern composting toilets to serve approximately 10 person equivalence. These will be located on elevated ground to reduce groundwater interaction and maximise nutrient attenuation. The use of dry composting systems is preferred as water supplies for Hope Point will also be required to be carted from Main Island.

The biosolids from the wastewater systems will be disposed at an appropriate offsite disposal facility (e.g. Exmouth landfill). Treated wastewater will be disposed in sealed evaporation ponds. Only overflow/excess volumes will be used to irrigate landscaped areas to improve amenity and dust control. Some localised infiltration of treated wastewater is expected, however no significant impacts on surface and groundwater quality is anticipated given the loading rates, level of treatment, high evaporation rates and soils of the area.

Management measures addressing discharge of treated wastewater

Management measures that will be employed to reduce impacts from wastewater include:

- installing a domestic wastewater treatment system that meets the Health Department of WA requirements
- appropriate maintenance of the treatment system
- testing water quality of any treated water to be used for irrigation purposes
- monitoring groundwater quality in the vicinity of disposal areas or receiving environments (particularly nutrients).

The Groundwater Management Plan will address management measures described above and monitoring of groundwater quality.

Discharge of tailwater from reverse osmosis plants

Tailwater from the reverse osmosis plant at Main Island will be disposed of to the concentrator ponds and become part of the salt making process.

Tailwater from the reverse osmosis plant at the construction camp will be discharged to evaporative ponds. As the superficial aquifer is saline in this area, any short-term term impact associated with groundwater infiltration will be highly localised and insignificant.

Management measures addressing discharge of tailwater

The Groundwater Management Plan will address management measures for tailwater to be applied including monitoring of groundwater quality in the vicinity of the evaporation ponds (particularly salinity).

2.5 MONITORING AND ASSESSMENT OF PERFORMANCE

A monitoring program will be developed (described in the Groundwater Management Plan) and implemented that will include monitoring of:

- water quality of dewatering fluids (including turbidity and TSS) following treatment through sedimentation ponds
- groundwater levels and quality of the shallow aquifers in the vicinity of concentrator and crystalliser ponds
- wastewater used for irrigation (including pH, EC, N and P)
- vegetation on the fringes of mainland remnants and potentially influenced by dewatering activities.

The monitoring program for groundwater will be described in detail in the Groundwater Management Plan.

2.6 PROPONENT COMMITMENTS

Refer also to commitments for environmental factors of vegetation, fauna and surface hydrology which require the preparation and implementation of:

1. Terrestrial Vegetation Management Plan (addresses the effects of saline intrusion into mainland remnants)
2. Fauna Management Plan (addresses investigation of subterranean fauna prior to dewatering)
3. Surface Water Management Plan
4. Preparation and implementation of a Groundwater Management Plan that will address the following:
    - dewatering
    - spills
    - effluent disposal
    - seepage from salt ponds to groundwater system in the supratidal flat
    - monitoring of groundwater quantity and quality.

2.7 ENVIRONMENTAL OUTCOME

Construction of the saltfield will require dewatering, potentially affecting groundwater quantity and quality and any subterranean fauna (if they exist). Sampling and reporting the presence or otherwise of subterranean fauna will be undertaken and the results will be made available for a four week public submission period during the first half of 2007. Given the replication of limestone habitat across the project area it is not expected that any subterranean fauna will be limited to the proposed quarry locations.

Groundwater quality may also be affected by oil and fuel spills, seepage losses from the salt ponds and discharge of treated wastewater or tailwater from reverse osmosis plants. The risk of this happening will be reduced through the development of appropriate procedures and monitoring and if they occur, impacts prevented.

The flooding of the saltfield may lead to limited saline water intrusion and hydrostatically elevated groundwater levels for the isolated mainland remnants within the concentrator ponds. The low lying areas that may be affected mostly comprise claypans and halophytic vegetation and these are least likely to be affected by an increase in salinity or waterlogging over the longer term. Straits will develop and implement a monitoring programme targeting low-lying areas on the islands identified as being at potential risk within the saltfield.

The EPA objective to maintain the quantity and quality of groundwater and maintaining ecosystem function will be achieved.

3 SURFACE WATER

3.1 EPA OBJECTIVES

The EPA objectives relevant to this assessment include:

- *To maintain the quantity of water so that existing and potential environmental values, including ecosystem function, are protected.*
- *To minimise the potential for displacement of flood values and erosion due to stormwater flows.*

3.2 LEGISLATIVE AND POLICY CONTEXT

3.2.1 Pollution prevention

Environmental Protection Act 1986

The EP Act is the principle statute relevant to environmental protection in Western Australia. The Act makes provision for prevention, control and abatement of pollution and for the conservation, preservation, protection, enhancement and management of the environment. Surface water discharges and potentially polluting activities are managed under a licence issued under the EP Act.

3.2.2 Environmental water provisions

ANZECC/ARMCANZ 1996 Guidelines

In 1996 the Australian and New Zealand Environment and Conservation Council (ANZECC) together with the Agricultural and Resource Management Council of Australia and New Zealand (ARMCANZ) developed the *National Principles for the Provision of Water for Ecosystems* (1996). These national principles aimed to improve the approach to water resource allocation and management, and to incorporate the needs of the environment in the water allocation process. The overriding goal of the principles is to provide water for the environment to sustain, and where necessary restore, ecological processes and biodiversity of water dependent ecosystems.

State Policy on Environmental Water Provisions

In Western Australia, the Statewide Policy on Environmental Water Provisions (WRC 2000) protects ground and surface water dependent ecosystem values through the establishment of ecological water requirements. The policy was guided by State water and environmental legislation, the National Strategy on Ecologically Sustainable Development and the National Principles for the Provision of Water for Ecosystems (ANZECC/ARMCANZ 1996).

Ecological water requirements are determined on the basis of the best scientific information available. A conservative approach is taken to the estimation of ecological water requirements in allocation planning and licensing processes where scientific knowledge of ecosystem requirements is limited. Soil water requirements are elements of the existing or historic water flow regime that are required to sustain key social values such as recreation and Aboriginal heritage and culture.

3.2.3 Water quality

ANZECC/ARMCANZ 2000 Guidelines

ANZECC and ARMCANZ have also released a set of water quality guidelines for the protection of marine and freshwater ecosystems (ANZECC/ARMCANZ 2000). The ANZECC/ARMCANZ guidelines provide a comprehensive list of recommended low-risk trigger values for physical and chemical stressors in water bodies, broken down into five geographical regions across Australia and New Zealand.

State Water Quality Management Strategy

The Government of Western Australia developed the State Water Quality Management Strategy (2003) with the objective 'to achieve sustainable use of the Nation's water resource by protecting and enhancing their quality while maintaining economic and social development'.

3.3 DESCRIPTION OF SURFACE WATER

3.3.1 Investigations

Investigations into surface water hydrology were undertaken by Parsons Brinkerhoff (2006b) (Appendix 8). To determine the volumetric flows in the catchments, a "top-down" approach was undertaken using topographic maps, aerial photos, satellite imagery, artificially generated digital ground elevation and limited field surveys. Collectively these sources developed a robust picture of the overall hydrology model for the hinterland (Parsons Brinkerhoff 2006b).

3.3.2 Overall

Surface water flows within the study area are the result of a complex interrelationship between the water courses, floodplain and an intricate maze of dunal ridges. In addition, due to the arid climate and very high evaporation rates, the occurrence of overland flow is rare and usually only associated with tropical cyclone events. There are a number of watercourses in the hinterland to the east of the project area in the study area. These include Chinty Creek, Rouse Creek and Yannarie River (Figure 1-1), with the majority of freshwater flows occurring within the latter two.

During very high flow conditions, the Yannarie River and Rouse Creek discharge as sheet flow onto the alluvial plain (Parsons Brinkerhoff 2006b). As the depth of flow increases, adjacent but smaller interdunal basins, including claypans, also become flooded. The majority of the water discharged to these storage areas is eventually lost through evaporation and to a lesser extent through infiltration. Under very high flow conditions water discharges via four outlets (Yannarie South, Yannarie North, Rouse South and Rouse North) onto the supratidal salt flats (Parsons Brinkerhoff 2006b).

3.3.3 Watercourses

Yannarie

The Yannarie River is the major river system of the study area, its catchment area is approximately 4,300 km^2, being about 185 km in length (Parsons Brinkerhoff 2006b). The Yannarie River system, which is generally linear, rises in High Range, approximately 140 km south east of the North West

Coastal Highway (NWCH). It is approximately 260 m wide at the North West Coastal Highway (Figure 5-8). This width decreases to approximately 140 m immediately downstream from Yanrey Homestead before losing its identity on the outwash plain just downstream from the homestead. The average stream gradient from the headwaters to the flood-out on Yanrey Station is approximately 0.2%.

Source: DC Blandford & Associates and Oceanica 2005

Figure 5-8 View of Yannarie River downstream from the North West Coastal Highway

Rouse Creek

Rouse Creek, which parallels the Yannarie River system, has a catchment area of 1,700 km^2 and a stream length of 75 km (Parsons Brinkerhoff 2006b). The defined channel of Rouse Creek is approximately 95 m wide at the crossing of the North West Coastal Highway (Figure 5-9), but then loses its identity approximately 10 km downstream of the Highway flowing into the floodplain and interdunal basins. During high flow events, some of the water from Rouse Creek has been reported to flow into the Ashburton River. Some water from Rouse Creek may also flow into the Yankagee Claypan (Parsons Brinkerhoff 2006b).

Source: DC Blandford & Associates and Oceanica 2005

Figure 5-9 View downstream of Rouse Creek from North West Coastal Highway

Stream discharge

Annual events are usually generated by thunderstorms, the occasional scattered rainfall depressions or residual depressions dispersed from elsewhere. The larger flood events, such as the 1 in 20 years ARI floods are usually generated by cyclones or by rain bearing depressions (Parsons Brinkerhoff 2006b).

Peak flows and annual flow for average recurrence intervals (ARI) of 1 in 2, 5, 10, 20, 50 and 100 years have been estimated using a runoff routing programme (RORB) (Parsons Brinkerhoff 2006b). The results of this modelling show that no significant runoff occurs in either the Yannarie or Rouse systems from the annual and 2-year ARI rainfall events, a result consistent with site observations. These more common rainfall events are usually very localised and may cover only a small proportion of the catchment areas (Parsons Brinkerhoff 2006b).

Modelling using RORB estimated that peak flows at the bridges on the NWCH are greater than the peak flow downstream near Yanrey Station for both the Yannarie and the Rouse systems (Parsons Brinkerhoff 2006b). This reduction in peak flows is due to attenuation brought about by factors such as flatter slopes, the streams becoming less defined, shallower and wider flow (Parsons Brinkerhoff 2006b). A summary of discharge for the Yannarie River and Rouse Creek is presented in Table 5-2.

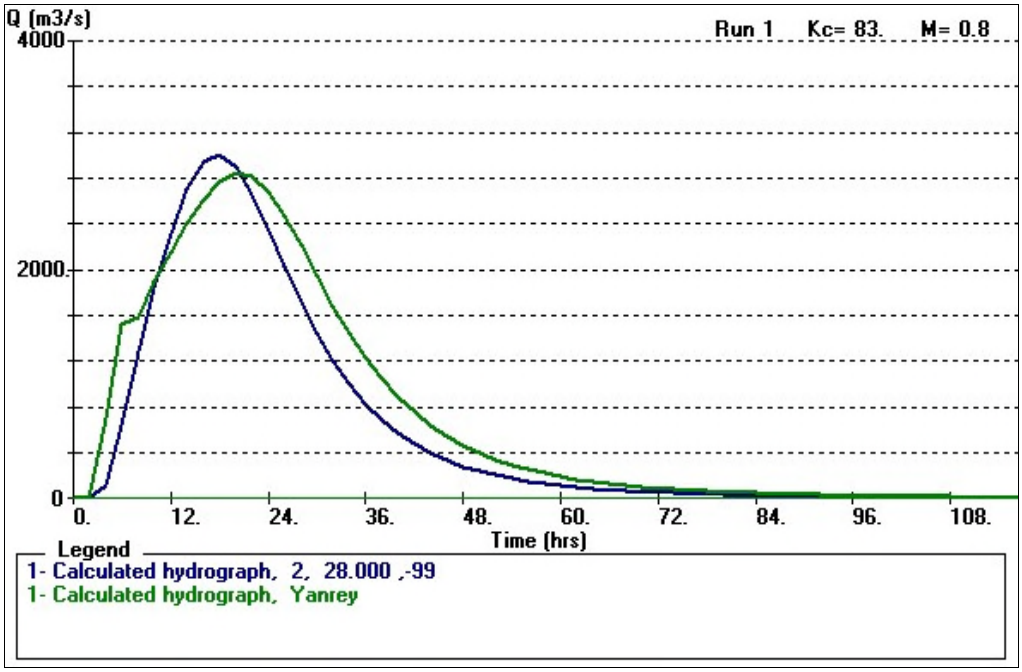
Table 5-2 Estimated peak flows and volumes of Yannarie River and Rouse Creek

Design Flow	12 hour				24 hour			
	Peak Flow Hwy Bridge (m^3/s)	Volume (million m^3)	Peak Flow Yanrey (m^3/s)	Volume (million m^3)	Peak Flow Hwy Bridge (m^3/s)	Volume (million m^3)	Peak Flow Yanrey (m^3/s)	Volume (million m^3)
Yannarie River								
Q5	0	0	0	0	0	0	0	0
Q10	14	3.0	13	3.4	20	4.2	19	5
Q20	83	13.4	78	15.8	514	60	484	71.6
Q50	503	64.3	483	76.6	1714	106	1620	192
Q100	879	103	851	124	3000	256	2848	306
Rouse Creek								
Q5	0	0	0	0	0	0	0	0
Q10	18	1.5	12	1.9	27	2.0	18	2.7
Q20	110	6.3	72	8.4	577	27.6	442	37.2
Q50	405	29.7	379	39.9	1731	73.6	1427	99.3
Q100	701	47.6	663	64.2	3072	148	3033	200

Source: Parsons Brinkerhoff 2006b

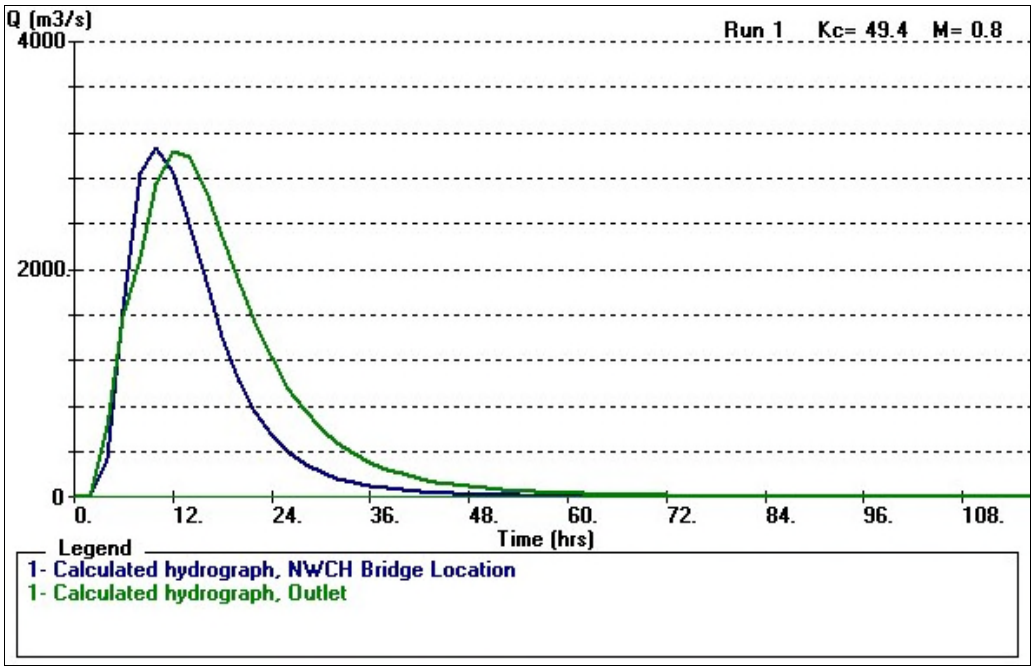
Both catchments produced similar peak flows for the 24-hour, 100-year storms, even though the Yannarie catchment is approximately 2.5 times larger than Rouse (Parsons Brinkerhoff 2006b). This is a result of catchment characteristics where the Yannarie catchment is typically more elongated compared to Rouse. The greater runoff distance offsets the time of concentration of the subcatchments at the discharge outlet (i.e. flows dissipated in the nearest subcatchments by the time the furthest subcatchment has contributed). This results in a 'flatter' discharge hydrograph (Parsons Brinkerhoff 2006b).

For the concentric Rouse catchment, the time of contribution from the subcatchment is closer aligned, thus responds more rapidly (i.e. narrower discharge hydrograph) (Parsons Brinkerhoff 2006b). Figure 5-10 and Figure 5-11 show the hydrographs of Yannarie River and Rouse Creek at the bridges on the NWCH and further downstream.



Source: Parsons Brinkerhoff 2006b

Figure 5-10 Yannarie River 100-year 24-hour hydrograph



Source: Parsons Brinkerhoff 2006b

Figure 5-11 Rouse Creek 100-year 24-hour hydrograph

However, anecdotal observations of two flood events (March 1999 and 2004) indicate that the hydrological modelling of the catchments was not completely accurate for the 50 and 100 year flood events (Parsons Brinkerhoff 2006b).

This is a very complex surface hydrological system that converts a 1:100-year peak flow in the Yannarie and Rouse systems at the bridge on the North West Coastal Highway of 3,000 m^3/s to a 990 m^3/s peak flow at the mouth of the Yannarie South channel where it discharges to the supratidal salt flat (Parsons Brinkerhoff 2006b).

3.3.4 Flood plain

The existing watercourses and outlets to the supratidal salt flats are inter-connected by a 200 km^2 flood plain (Parsons Brinkerhoff 2006b). A satellite image recorded shortly after Tropical Cyclone Vance crossed the area was used to establish the following flow characteristics (Figure 5-12):

1. Flows that breakout from Rouse Creek during major storm events spread north and westwards. Flows travelling north are either contained within the local dunal systems or make their way out towards the supratidal salt flat. Flows that are west bound appear to predominantly continue on to meet the Yannarie system, though some is contained within local depressions and channels (Parsons Brinkerhoff 2006b).
2. Flows that discharge from the Yannarie River are temporarily stored within the flood plain before continuing west or dispersing northwards into claypans and interdune depressions according to the hydraulic head generated (Parsons Brinkerhoff 2006b).

3.3.5 Discharge outlets

Discharge from major storms

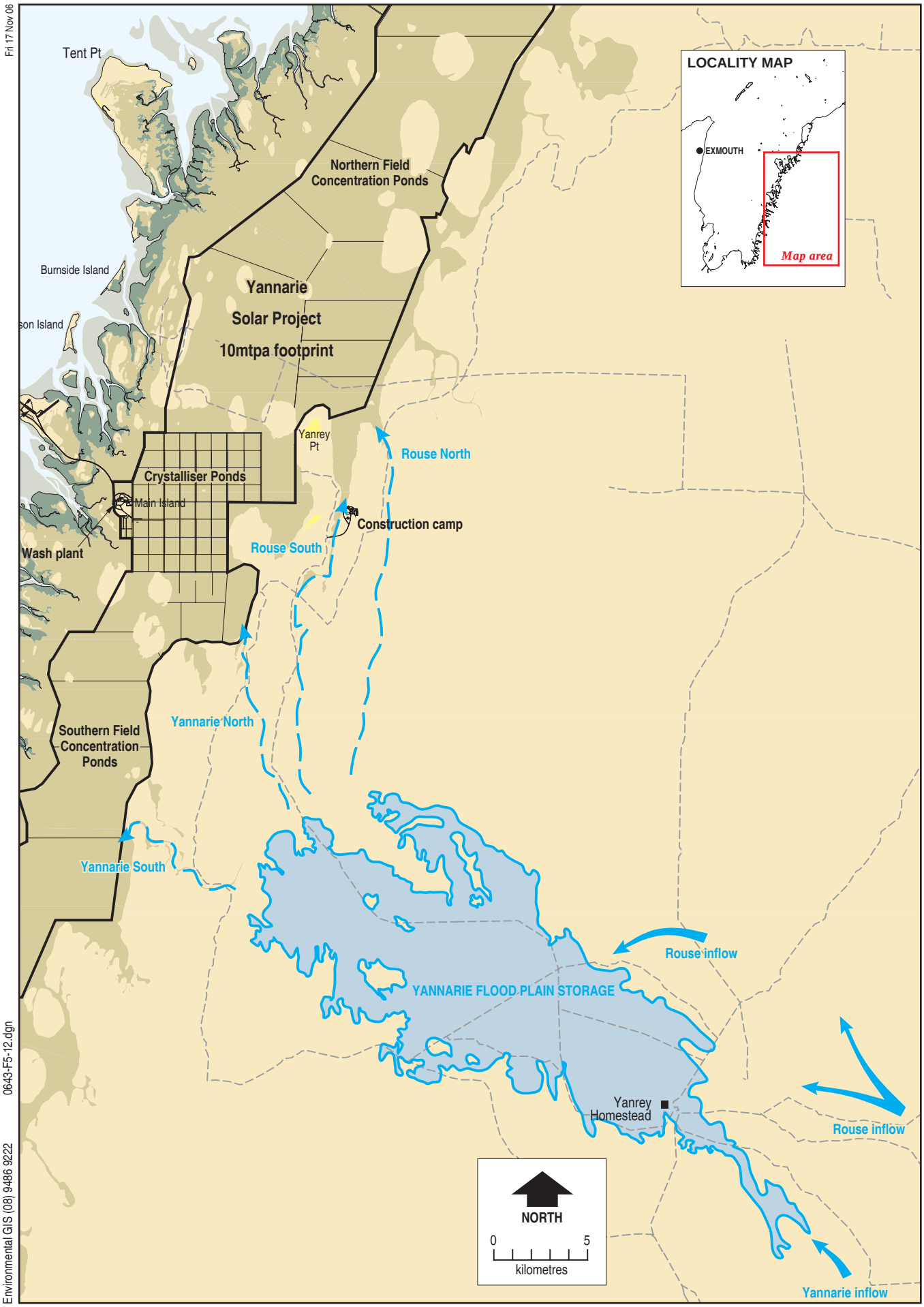
Flood plain and interdunal basin storages, including claypans, greatly influence discharge at the four main outlets (Yannarie River north and south, Rouse Creek north and south) (Parsons Brinkerhoff 2006b). Outflows have been conservatively estimated on the assumption that inflows from the Yannarie River and Rouse Creek are fed directly into the flood plain as storage, however in reality only a portion of the Rouse Creek flows enter the flood plain (Parsons Brinkerhoff 2006) (Table 5-3).

Table 5-3 Outlet discharge summary to supratidal flat during major storms

Location	20-Year			100-Year		
	Q (m^3/s)	H (m)	V (m/s)	Q (m^3/s)	H (m)	V (m/s)
Yannarie South	150	0.7	2.2	1010	2.2	4.5
Yannarie North	50	0.4	1.5	780	1.8	4.3
Rouse South	15	0.2	0.8	490	1.8	2.7
Rouse North	10	0.2	0.7	460	1.9	3.0

Source: Parsons Brinkerhoff 2006b

As expected from field inspections of the drainage line outlets, the above results indicate that Yannarie South is the dominant outlet (Figure 5-13). It comprises approximately 35% of total outflow for 100 year ARI events but is expected to increase to 80% for the lesser storms such as the 10-year ARI (Parsons Brinkerhoff 2006b).



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2006
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-12 Exmouth surface hydrology after Tropical Cyclone Vance - discharge evidenced from March to April

The Yannarie North outlet accounts for approximately 25% of the total outflows for both the 20- and 100-year ARI storm events. Rouse South and Rouse North outlets each account for approximately 10% of the total outflows (Parsons Brinkerhoff 2006b).

Source: DC Blandford & Associates and Oceanica 2005

Figure 5-13 The mouth of the Yannarie River South at its discharge point onto the supratidal salt flats

Discharge from minor storms

The losses incurred from overland flows within the Yannarie and Rouse systems greatly limits the discharge at the outlets and based on the recommended losses in Pilgrim (1987), these systems will not generate sufficient rainfall excess for the lesser storm events to produce any runoff. This suggests that during minor storms, these systems are effectively disconnected from the outlet sub-catchments (Parsons Brinkerhoff 2006b).

The estimated peak flows discharging to the supratidal flat from the outlets for the 1 and 2 year ARI storms is outlined in Table 5-4 and shows the only flow dispels from Yannarie South (Parsons Brinkerhoff 2006b). This volume of water equates to a maximum water depth of 30 mm across the supratidal flat, being even shallower once evaporation has been taken into account. The flow depth and velocity for the minor storms are unlikely to have sufficient energy to reach the Gulf even if evaporative losses were ignored (Parsons Brinckerhoff 2006b).

Table 5-4 Outlet discharge summary to supratidal flat during minor storms

Location	1 year, 24 hour		2 year, 24 hour	
	Peak flow (m^3/s)	Volume (m^3)	Peak flow (m^3/s)	Volume (m^3)
Yannarie South	0	0	0.3	15,000
Yannarie North	0	0	0	0
Rouse South	0	0	0	0
Rouse North	0	0	0	0

Source: Parsons Brinkerhoff 2006b

3.3.6 Supratidal saltflat

The supratidal salt flat, onto which stream discharge occurs, has its genesis in a Holocene marine transgression which resulted in erosion, in part, of the original Quaternary/Pliocene outwash plain. The result, following a return to pre-transgression sea level, was the formation of a broad, flat, featureless plain up to 13 km wide extending from the mainland to the newly formed shoreline of the mangrove zone. The destruction of the original outwash plain, and its superimposed sand sheet and dunefield was incomplete as areas of the plain with elevated relief remained behind when the regression phase finished. These areas, which now appear as mainland remnants across the supratidal salt flat, generally contain all the physical attributes of the mainland dunefield systems.

In terms of drainage, the supratidal flat will receive discharge from the outlets resulting from 1 in 2 year ARI events up to 1 in 100 year ARI events, but with vastly different volumes of water (Parsons Brinkerhoff 2006b). Parsons Brinkerhoff (2006b) states that "the performance of any single discharge event is dependent on a number of factors, key among which are the sediment load of the discharge, the depositional patterns of sediment resulting from the last discharge event, the degree of re-working of supratidal salt flat sediments by storm surges, and the simple relationship of the presence of water on the supratidal salt flat at the time of discharge and the depth of this water."

As the width of flow increases, the depth and velocity of flow decreases to the point where, at approximately 1.6 km from the discharge point, the flow is 1500 m wide, is less than 1 cm deep, and is flowing at approximately 0.01 m/s (for a 2-year ARI) (Parsons Brinkerhoff 2006b).

In addition to the dynamics of the discharge event, the existing surface hollows and depressions across the supratidal salt flat cause ponding of water and channelling of flows. When flows of such dimensions, i.e. 1 cm deep and flowing at 1 cm/sec, are subject to strong winds, these winds can stop the discharge and cause it to travel down wind. In this scenario, southerly winds can blow the water back across the supratidal salt flat towards the mainland (Parsons Brinkerhoff 2006b).

Parsons Brinkerhoff (2006b) states that 'for this flow to continue to the coast, it would require sustained discharge such as those from the 20 and 100-year ARI storms. The modelling indicates that under conditions of discharge to a 'dry' supratidal salt flat, runoff from the 100-year event will not reach the mangrove zone. However, if the rainfall event is associated with a local cyclone, then the supratidal salt flat will most likely be saturated from rainfall and may also be subject to storm surge. Under these circumstances of storm surge, the depth and nature of water at the mangrove zone and across the supratidal salt flat will be determined by tidal effects and storm surge, rather than by stream discharge.

On the other hand, there is also a complex relationship between when rainfall occurs, the duration of the event, the timing of a storm generated surge, and ultimate stream discharge. Anecdotal evidence indicates that, as a result of low surface gradients, it can take up to a week for flood waters at Yanrey Station homestead to reach the supratidal salt flat. Such a delay suggests that any storm surge may be well passed prior to discharge occurring.

Based on the discharge characteristics of the Yannarie South drainage system (as this outlet generates the highest peak flow and is considered to represent the worst case scenario), there appears to be no direct hydrologic link between discharge from the mainland drainage systems and the ecosystems of the project area mangrove zone (Parsons Brinkerhoff 2006b). If runoff were to reach this zone, it may coincide with higher sea levels, resulting from extreme storm events, transgressing the supratidal salt flat.

3.3.7 Water quality

Owing to the infrequent flows within the Yannarie River near the project area, water quality data has not been collected. The salinity and other chemical parameters are likely to be lower than levels in the groundwater underlying the outwash plain. A baseline water quality monitoring program will be implemented before commissioning of the saltfield.

3.4 IMPACT ASSESSMENT AND MITIGATION

3.4.1 Environmental aspects and potential impacts

Key activities or aspects of the proposal that may potentially affect surface water include:

- **diversion or redirection of Yannarie River flows** will alter local hydrology patterns downstream of the diversion weir
- **impoundment and inundation** as a result of construction of diversion weir may alter vegetation and affect sediment and nutrient transmission pathways
- **spills** pose a potential threat to water quality and the aquatic flora and fauna that inhabit this environment
- **effluent disposal** poses a potential risk to water quality and the aquatic flora and fauna that inhabit this environment.

3.4.2 Assessment and management

Diversion or redirection of Yannarie River flows

The saltfield needs to be protected from freshwater inflows from the hinterland during major storms events (Figure 5-14). A concentrator pond abuts the Yannarie North channel outlet and diversion of flows from major storms (such as the 100-year ARI event) is required to prevent breaching of the pond levee wall and entry of freshwater.

A diversion weir is proposed to prevent this freshwater influx along the Yannarie North channel. The proposed location of the diversion weir is between the banks of two dunal ridges (Figure 5-15). This location will ensure that flows can be diverted to other outlets with sufficient capacity to accommodate the increased streamflow for major storm events (Parsons Brinkerhoff 2006b).

The proposed diversion weir is to be 5 m in height to prevent overtopping for the 100-year ARI storms. Diverted flow will be encouraged to flow towards the Rouse channel outlets. Initially flow will discharge to Rouse South before enough hydraulic head is generated and then water will spill over to Rouse North. To facilitate the diverted flow, some minor earthwork is required at the 'choke' point north of the diversion weir (Figure 5-16).

Establishment of the saltfield will also result in construction of a levee wall near the eastern margin of the salt flat in proximity to the outlet of the Yannarie South channel. The levee will not constrict flow, but rather will merely serve to direct discharge from the Yannarie South outlet across the salt flat in a southerly direction and then to the Gulf.

Local hydrology patterns

Diverting flows from the Yannarie North channel is expected to cause an increase in the peak discharge in the Rouse South and Rouse North channels. For 20 year ARI storms, the diverted flow from the Yannarie North channel will be fully diverted through to the Rouse South channel. However for the 100 year ARI storms, the diversion will cause an increase in the peak discharge for Rouse South and Rouse North channels from 490 m^3/s to 800 m^3/s and from 460 m^3/s to 900 m^3/s respectively.

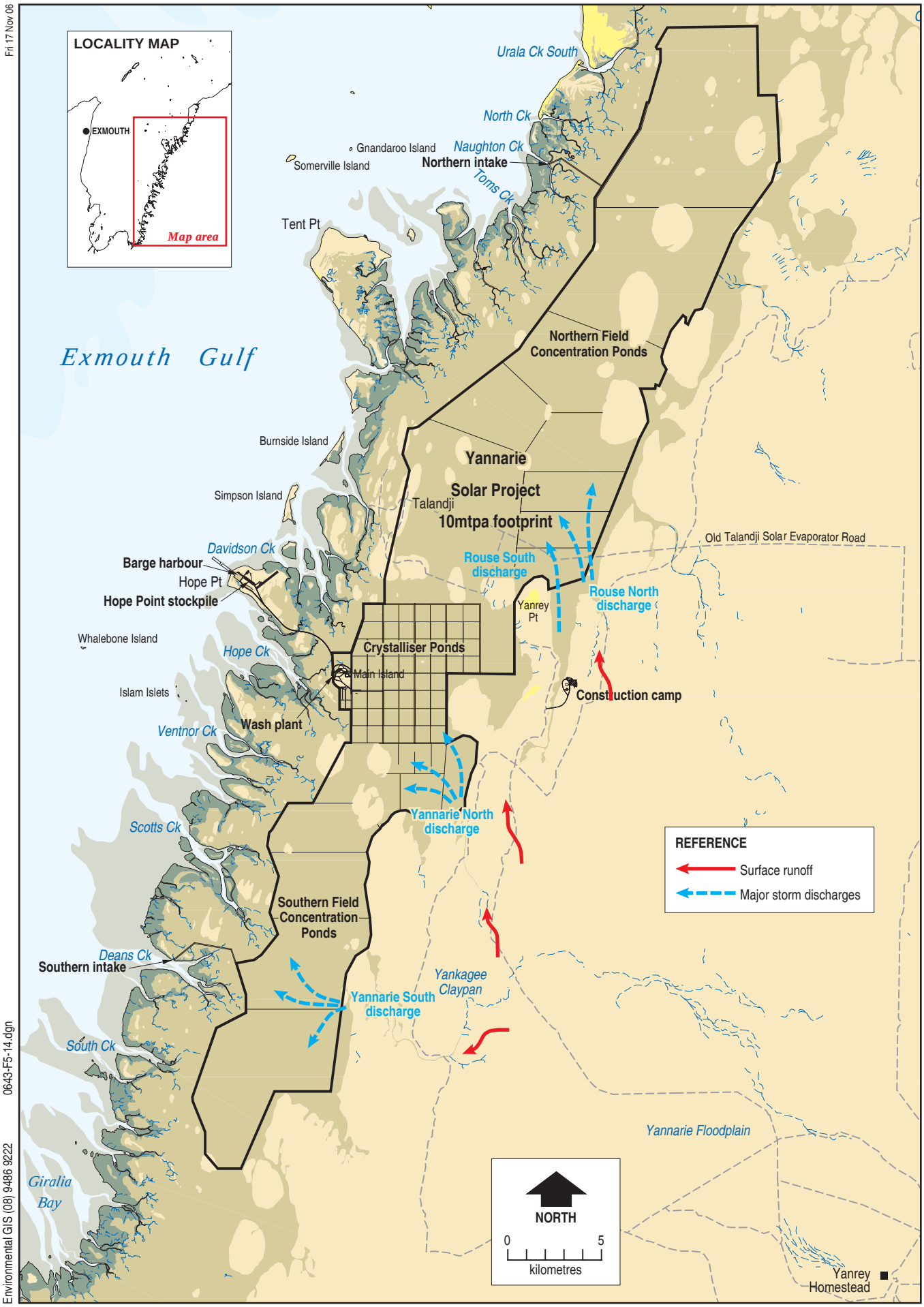
Some ponding will also occur downstream of the diversion weir however this will be contained within the existing Yannarie North channel itself and therefore the impacts on the saltfield are predicted to be insignificant (Parsons Brinkerhoff 2006b).

Alteration to watercourse morphology

Watercourse morphology may be both directly and indirectly affected by the installation of the weir and levee banks. Excavation will directly affect the watercourse, whilst diversion of flows may result in scouring and erosion of watercourse banks. These impacts are discussed in Chapter 5, Section 1.

Finlayson and McMahon (1988) note that Australia has highly variable annual river flows and annual floods compared to the rest of the world's continents. Over decadal time scales, regional rainfall and river discharge are also modulated by the strength and duration of the summer monsoon, which, in turn is coupled to El Ninõ Southern Oscillation (ENSO) variability. Thus rainfall and runoff vary considerably, both between and within years across river basins draining the area.

As well as more variable flow, extreme floods occur more often in Australia than in the rest of the world (Finlayson & McMahon 1988). Thus, the catchments in the project area generally exhibit very low annual flows – yet with a propensity for very large, but highly infrequent, floods. The inherently high variability and infrequency of large streamflows in the project area means that the proposed increase in peak flows and velocities within the Rouse North and South channels is unlikely to result in adverse impacts within these drainage systems.

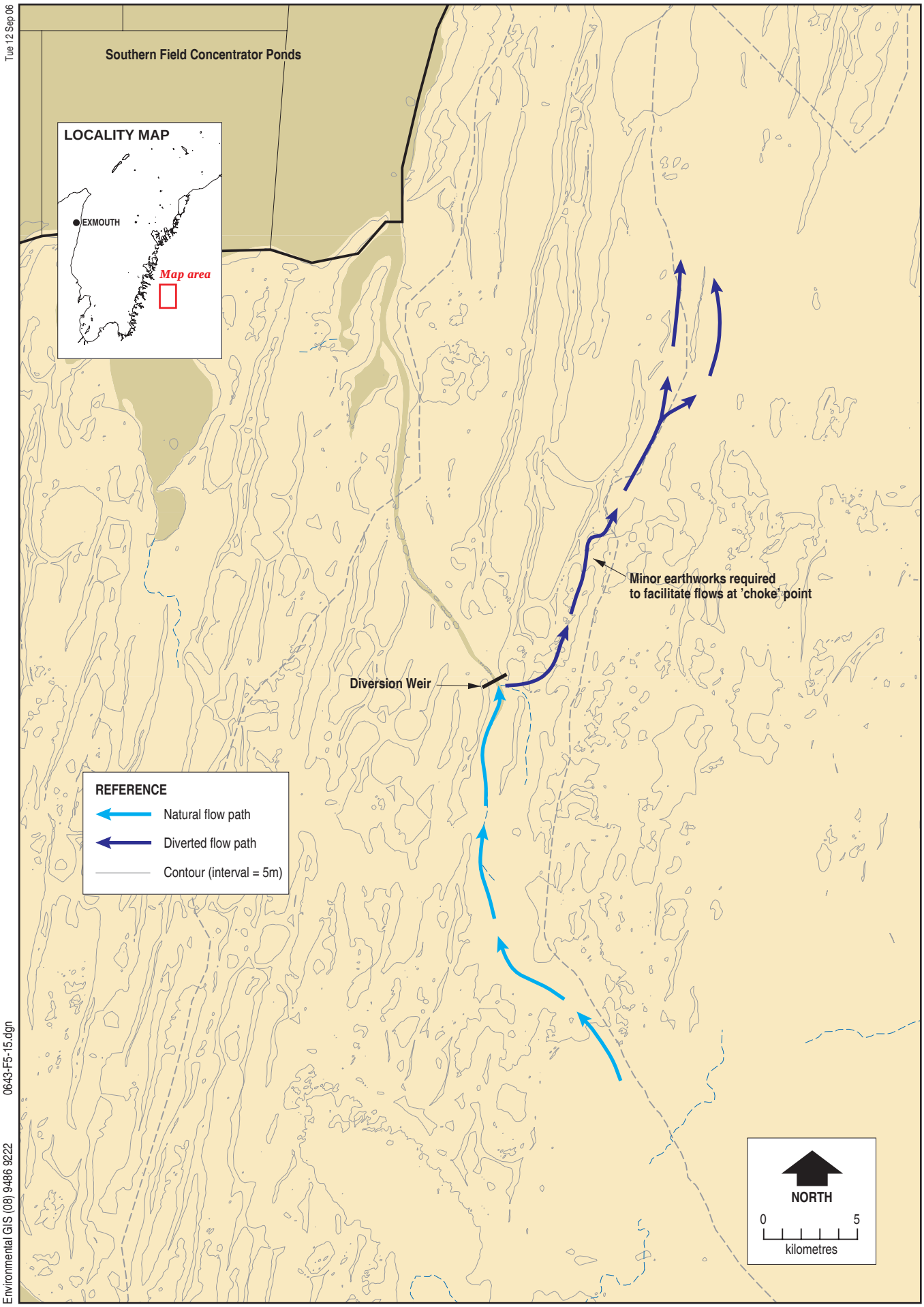


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-14 Pre - development hinterland surface hydrology

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2005
Date: 11 Sep 2006

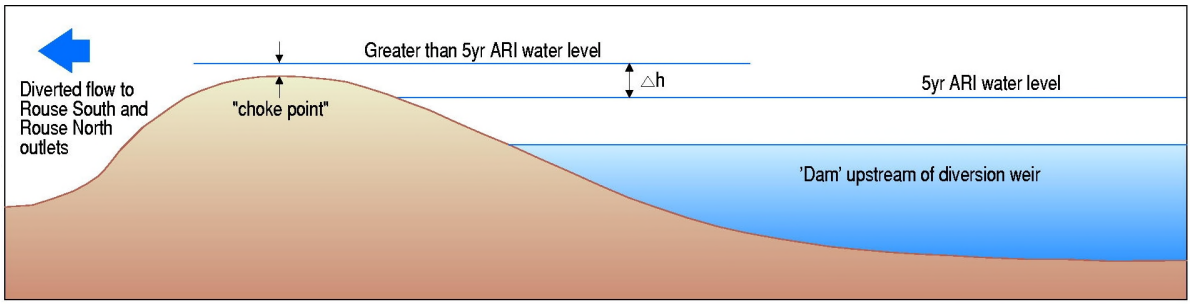


Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-15 Surface hydrology following installation of diversion weir for Yannarie North channel



Source: Straits Salt Pty Ltd 2006

Figure 5-16 Cross section of the 'choke' point

Management measures addressing impacts from diversion and redirection

Management measures that will be employed to reduce impacts to the watercourses include:

- limiting excavation
- limiting extent of levee bank construction
- geotechnical monitoring of levee banks, in conjunction with the Surface Water Management Plan, which includes:
    - a rainfall-based geotechnical storm monitoring program will be conducted via field survey after all major rainfall events, particularly when floodwaters reach the constructed levee banks. Field surveys will be conducted immediately after the rainfall event when it is safe to observe the area; and after all flood waters have disappeared
    - an annual field-based geotechnical monitoring program will be conducted at a set time once a year. An overall assessment will be made of all the bunds and recordings will also be made from set bench mark locations
- monitoring erosion/scouring and installing erosion control measures where required.

The preparation and implementation of a Surface Water Management Plan which will address management measures and monitoring of flows and quality the Yannarie River and Rouse River and discharges from outlets to the supratidal salt flat will facilitate the management of impacts on these watercourses.

Impoundment and inundation

The extent of inundation will be dependent upon the severity of the storm event and any previous wetting of the catchment. Discharges for minor storms (i.e. up to 5-year ARI) are localised in nature (Figure 5-17). The footprint of inundation resulting from ponding upstream of the diversion weir for a 5 year ARI rainfall event or greater is approximately 151 ha (Figure 5-18), within the Yanrey Land System. However, this represents a very small amount (0.14%) of this land system within the Ashburton Land System. A one in 2 year event would inundate a 43 ha subset of this larger area (Figure 5-17).

Storms greater than the 5-year ARI will overtop the 'choke' point and result in runoff being diverted through the dunal systems via the Rouse channel outlets to the north (Parsons Brinckerhoff 2006b) (Figure 5-19).

The period of inundation will be greatly dependent on evaporation rates and the pre-existing state of the soils of the area (i.e. the weather conditions before and after the flood event). It is not possible to meaningfully predict these variables for any given event, however it is likely that the area would be flooded for a period of several days longer than they would have been in the unmodified system. Under high evaporation rates and dry soil profile this may be 2–3 days, whereas this period could exceed 2-4 weeks under high humidity and ongoing rainfall.

Should impoundment increase periods of inundation, it is likely that recharge to groundwater would be greater in those areas where the inundation is occurring. However, the extent of recharge would depend on the soil type.

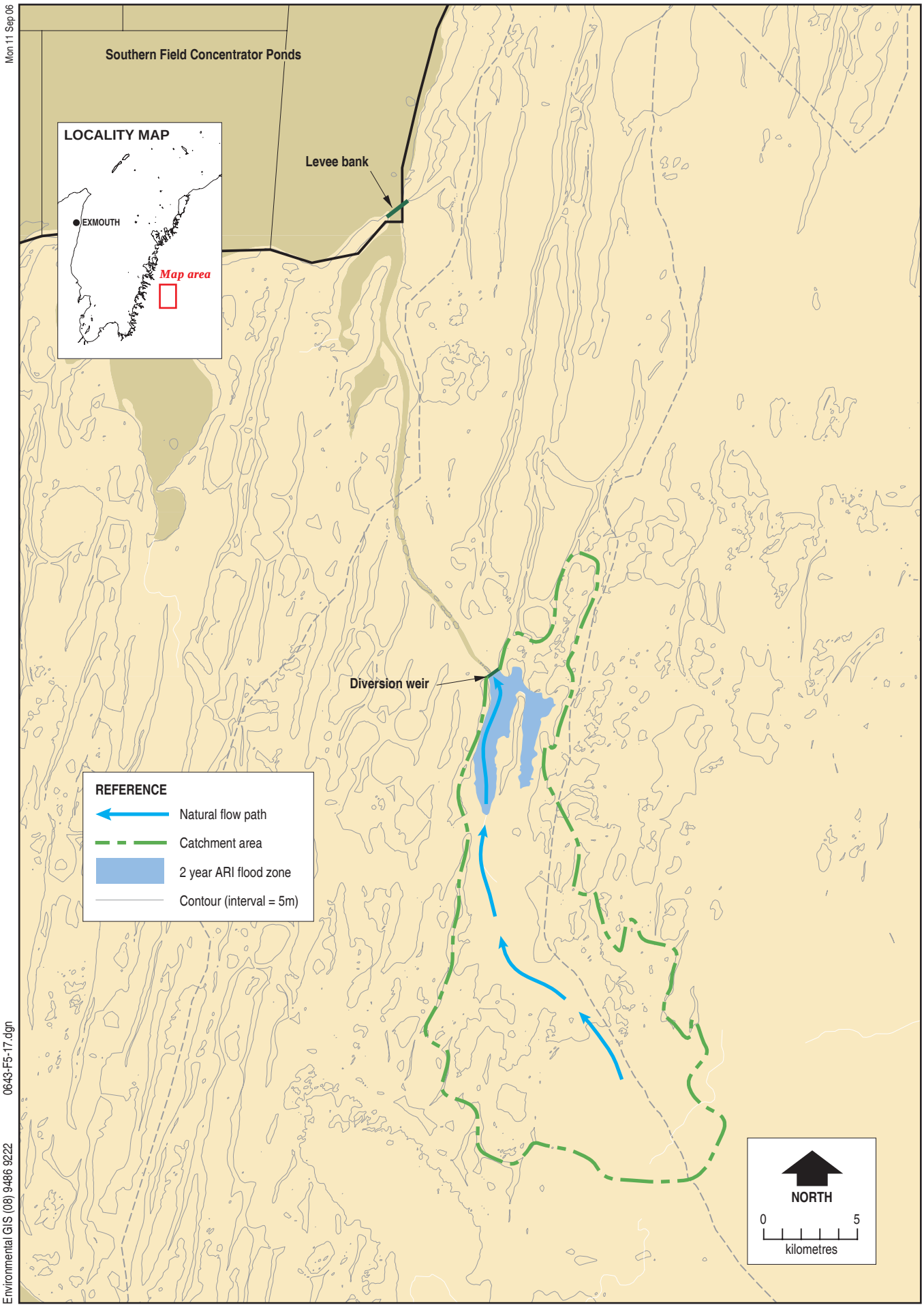
Sediment and nutrient transmission pathways

Diversion of the Yannarie North flows into the Rouse North and South channels will effectively serve to alter the point of discharge outlet to the Gulf. As these systems only infrequently 'break out' to the Gulf and then only under high flow conditions (expected to be >1 in 20 year) any alteration in the flow route and point of outlet is not expected to adversely affect freshwater, sediment and nutrient fluxes to the Gulf. There will be some minor losses from the system associated with evaporation and sedimentation arising from impoundment, but these losses will be insignificant in terms of events >1:20 years.

The potential for the bunded saltfield to prevent nutrient distribution processes (e.g. wind-blown sediment deposition) from occurring may affect vegetation communities fringing the landward side of the salt flats, but this is considered to be unlikely, based on observations at other Western Australian saltfields.

Tidal flows are the primary vector responsible for transporting nutrients and organic material out from the mangrove/algal mat region. The scale of nutrient inputs to the Gulf will not be affected and alteration to the point of entry to the Gulf is not anticipated to affect mangroves or the shallow benthic habitat on the eastern site of the Gulf. In summary:

- the small catchment, lack of riverine inputs and low and extremely intermittent rainfall means that freshwater inflows are negligible (Brunskill *et. al.* 2001, Parsons Brinckerhoff 2005a)
- the soils in the catchment beyond the mangrove/supratidal salt flat area are ancient and nutrient poor and any freshwater inflows are unlikely to carry significant nutrient loads (Brunskill *et al.* 2001, D.C. Blandford & Associates and Oceanica 2005)
- tidal exchange volumes are at least four orders of magnitude (i.e. approximately 10,000 times greater) than any freshwater inflows (including Ashburton River flows, which do not actually enter the Gulf) (Brunskill *et al.* 2001, Parsons Brinckerhoff 2005a)
- tidal inundation of the algal mats creates the vector for transport of organic material back into the mangrove zone.

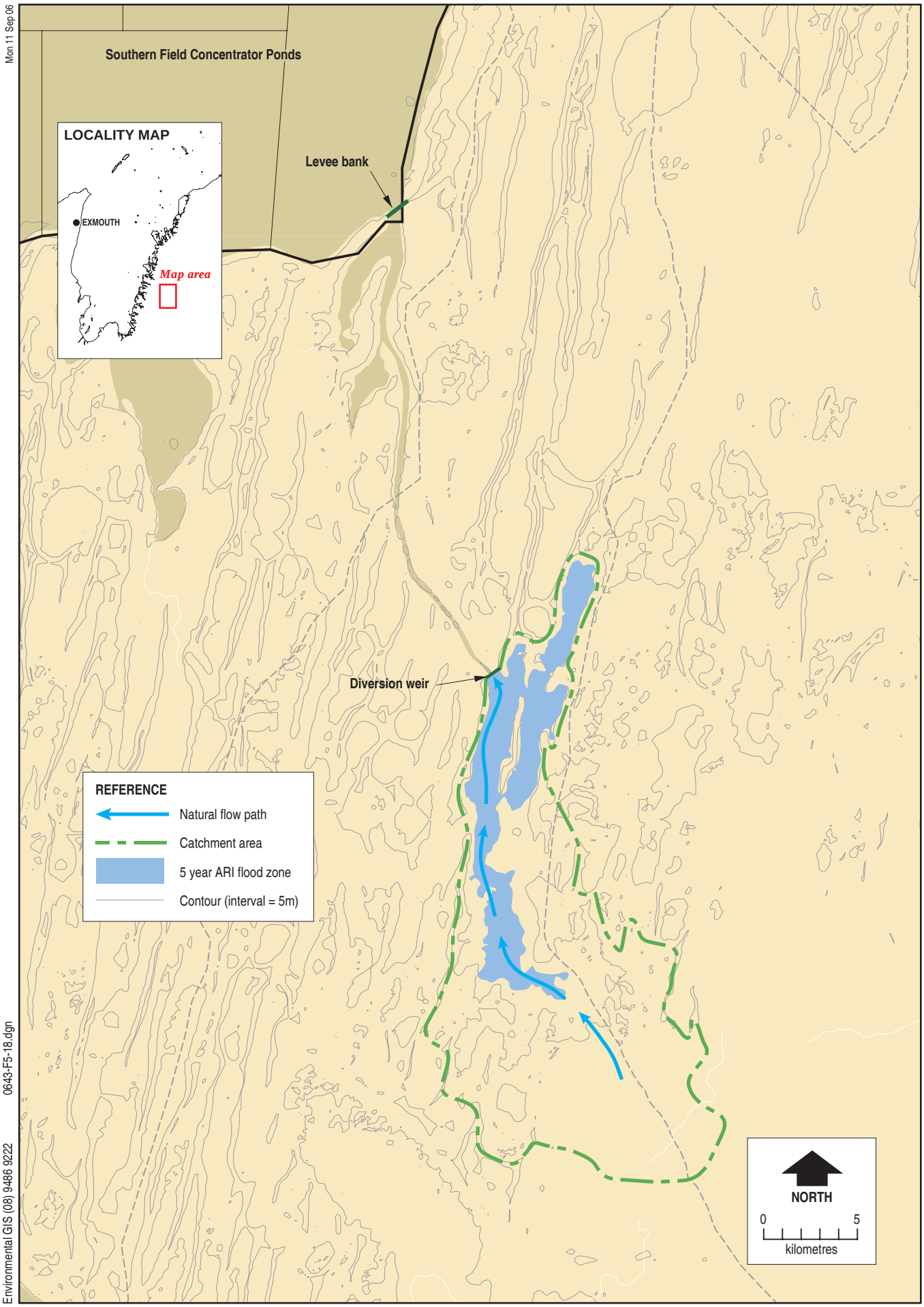


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-17 Flooding footprint upstream of diversion weir for 2 year ARI event

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2005
Date: 11 Sep 2006

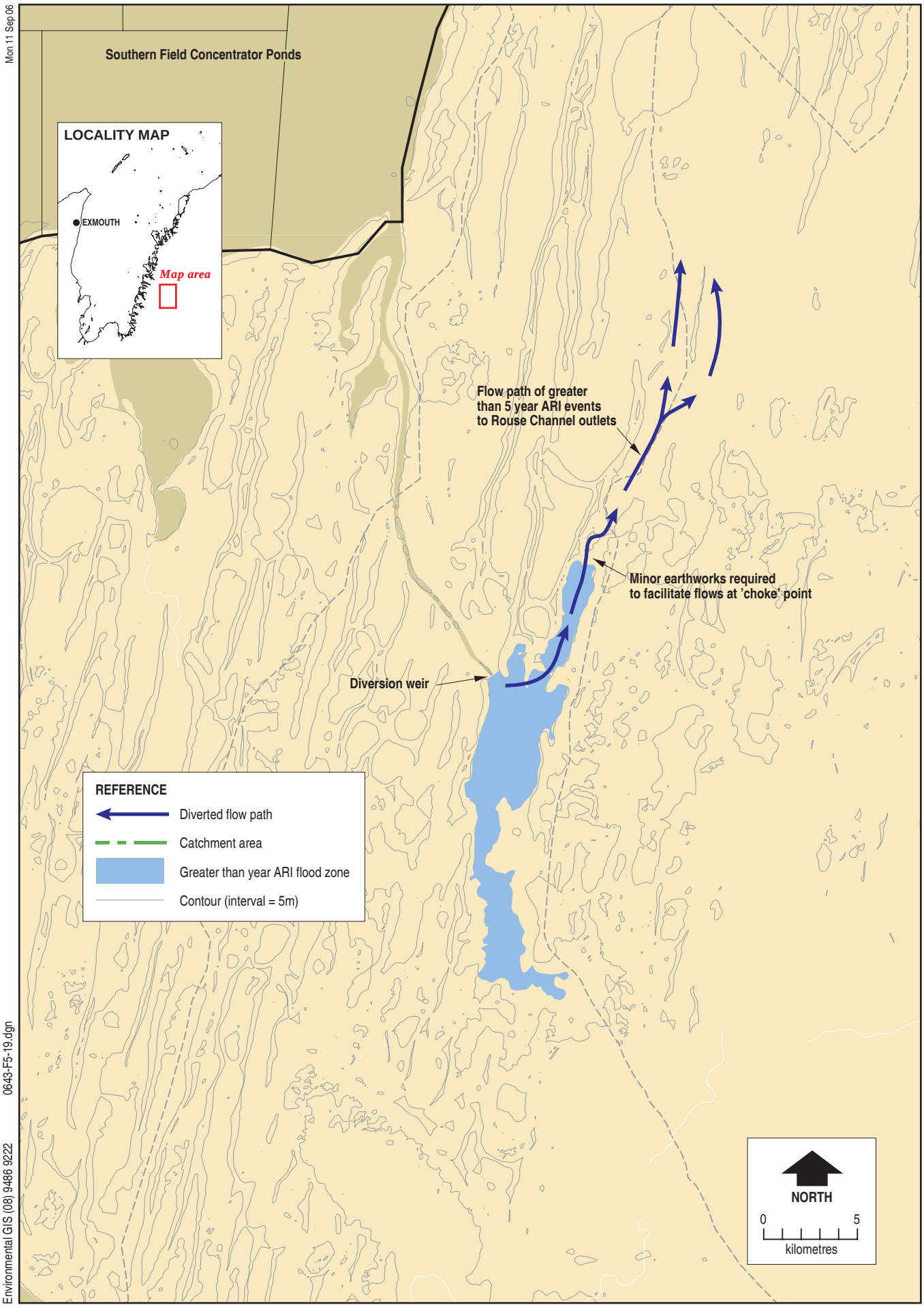


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-18 Flooding footprint upstream of diversion weir for 5 year ARI event

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2005
Date: 11 Sep 2006



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-19 Flooding footprint upstream of diversion weir for greater than 5 year ARI event

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2005
Date: 11 Sep 2006

Flora and vegetation

Terrestrial vegetation in the hinterland may be affected by the increased submergence caused by installing a weir in the Yannarie North channel. The vegetation of the Yanrey Land System comprises Gilgai floodplains; coolibah woodland with weeping grass and other tussock grasses in fair condition.

The vegetation types in this land system are typically subject to flood events under natural conditions and some of the units in the footprint, including drainage lines and claypans are unlikely to be affected by the increased flooding. Other vegetation types however, such as tussock grasslands and hummock grasslands, may be affected by the increased residence time of the floodwaters. Should vegetation be inundated for 2-4 weeks it is possible that some of the terrestrial vegetation would die-off as a result of the prolonged submergence.

The condition and long-term survival of the mangroves of the project area are not dependent on large-scale surface water flood events from the hinterland. It is therefore only local runoff patterns from supratidal land in the intertidal zone contributing to mangroves that may be affected by project changes to surface hydrology. This process generally only occurs in locations where mangroves adjoin supratidal mainland remnants and localised runoff and freshwater seepage from perched groundwater lenses assists mangroves to survive (Biota 2005d) (Appendix 4). The infrastructure of the field is generally set well back from the mangrove zone so no impacts on mangroves are expected from changes to small-scale surface hydrology.

The vegetation along the Yannarie North channel downstream of the diversion weir will be deprived of surface flow from upstream of the weir, but will still experience local runoff and thus is not anticipated to be substantially affected.

There are potential impacts to aquatic and terrestrial fauna from changes to surface hydrology. These are addressed in Chapter 6, Section 3 and Chapter 5, Section 5 respectively.

Management measures addressing impacts from impoundment and inundation

Management measures that can be employed to minimise impacts to the surrounding environment from impoundment and inundation include:

- developing and undertaking a vegetation monitoring program to assess and adequately respond to alleviate inundation impacts on vegetation
- stream water quality monitoring.

A Surface Water Management Plan will be prepared and implemented describing the management measures and monitoring to be applied.

Spills and effluent disposal

Oils and fuel spills or effluent disposal are unlikely to have a significant impact on the surface water quality. These issues and control measures are addressed in detail under oil and fuel spills and treated wastewater disposal in Chapter 5, Section 2.4.3.

Measures that will be employed to avoid spills if they occur and manage effluent disposal will be addressed in the Surface Water Management Plan.

3.5 MONITORING AND ASSESSMENT OF PERFORMANCE

A surface water monitoring program will be prepared and implemented that will include monitoring of:

- water quality (including TDS, N, P and TSS, and pH) of the Yannarie and Rouse watercourses
- flow of the Yannarie and Rouse watercourses
- discharges from Rouse and Yannarie outlets to the supratidal salt flat
- vegetation within the inundation area
- erosion

The monitoring program for surface water will be addressed in detail in the Surface Water Management Plan.

3.6 PROPONENT COMMITMENTS

Refer also to commitments for environmental factors of vegetation which requires the preparation of:

- Terrestrial Vegetation Management Plan (addresses the effects of inundation on the vegetation)

1. The preparation and implementation of a Surface Water Management Plan which will address the following:
    - fuel spills and handling
    - hazardous materials handling
    - incident response
    - drainage management
    - effluent disposal
    - management measures to prevent and ameliorate any erosion that may occur as a result of the proposal
    - water quality monitoring of streams adjoining the project
    - monitoring of streamflow and discharges to the supratidal flat from the Rouse and Yannarie river systems.

3.7 ENVIRONMENTAL OUTCOME

Diversion of Yannarie North flows will increase flow volumes to Rouse North and South channels. The weir will increase the area inundated to approximately 151 ha (for a 1 in 5 year event), being flooded for about 2-4 weeks.

As these systems only infrequently 'break out' to the Gulf, any alteration in the flow route and point of outlet is not expected to adversely affect freshwater, sediment and nutrient fluxes to the Gulf. Additionally, the intertidal ecosystem of the east coast of the Gulf does not rely on hinterland flows as a source of nutrients and thus diversion of flows is not expected to have a significant impact. There will be some minor losses from the system associated with evaporation and sedimentation arising from impoundment, but these losses will be insignificant in terms of events >1 in 20 years.

Some vegetation types may be affected by the increased residence time of the floodwaters and reduction in flow down the Yannarie North channel below the diversion weir. However, the area of potential impact represents a very small amount of the Yanrey Land System.

The net quantity of water flows to the Exmouth Gulf will remain the same, however the quantity of water flowing in various watercourses and outlets will be affected. Water quality is not expected to be affected by the diversion of flow and operation of the saltfield.

4 TERRESTRIAL VEGETATION AND FLORA

4.1 EPA OBJECTIVE

The EPA normally applies the following objective to the assessment of proposals that may affect vegetation and flora. This objective is considered relevant to this assessment:

- *To maintain the abundance, diversity, geographic distribution and productivity of flora at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge.*

4.2 LEGISLATIVE AND POLICY AND CONTEXT

4.2.1 Significance

For this assessment, the significance of the loss or disturbance of vegetation and flora by the proposal was determined by considering:

- any special ecological functions of the vegetation
- regional and local abundance of the vegetation communities
- representation in existing or proposed conservation reserves
- condition of the vegetation
- the presence of Priority or Declared Rare Flora species
- important fauna habitat functions
- the presence of threatening processes (e.g. weeds).

The assessment of the significance of impacts (following the application of management measures) on significant flora was on the basis of:

- change in the local and regional distribution and abundance of Declared Rare and Priority Flora species and species genotypes
- compliance with the *Wildlife Conservation Act 1950*.

4.2.2 National policy

The State and Commonwealth Governments have endorsed *the National Strategy for Conservation of Australia's Biodiversity 2001 - 2005* and the *National Strategy for Ecologically Sustainable Development*. The strategies address the conservation of Australia's biological diversity by defining guiding principles.

A recent development in Federal Government policy on protection of native vegetation is the publication, *National Objectives and Targets for Biodiversity Conservation* stemming from the *National Strategy for the Conservation of Australia's Biodiversity 2001 – 2005*. In this document, the Commonwealth Government and the majority of the States, including Western Australia, have agreed to pursue the target of ensuring that all jurisdictions have clearing controls in place that will have the effect of reducing the net national rate of land clearance to zero.

4.2.3 EPA position statements

Position Statement No. 2

EPA Position Statement No. 2, *Environmental Protection of Native Vegetation in Western Australia* (EPA 2000), provides an overview of the EPA's position on the clearing of native vegetation in Western Australia. Principles and related objectives and actions in this Position Statement have been adopted from the above mentioned national strategies. In assessing a proposal, the EPA's consideration of biological diversity will include the following basic elements:

- comparison of development scenarios or options of biodiversity at the species and ecosystems level
- no known species of plant or animal is caused to become extinct as a consequence of the development and the risks to threatened species are considered to be acceptable
- no association or community of indigenous plants or animals ceases to exist as a result of the proposal
- there is a comprehensive, adequate and secure representation of scarce or endangered habitats within the project area, and/or in areas which are biologically comparable to the project area, protected in secure reserves
- if the project is large (in the order of 10 ha to 100 ha or more, depending on where in the State) the project area itself should include a comprehensive and adequate network of conservation areas and linking corridors whose integrity and biodiversity are secure and protected
- the on-site and off-site impacts of the project are identified and the proponent demonstrates that these impacts can be managed.

Position Statement No. 3

EPA Position Statement No. 3, *Terrestrial Biological Surveys as an Element of Biodiversity Protection* (EPA 2002b), discusses the principles the EPA would apply when assessing proposals which may impact on biodiversity values in Western Australia. The outcomes sought by this Position Statement are intended to:

- promote and encourage all proponents and their consultants to focus their attention on the significance of biodiversity and therefore the need to develop and implement best practice in terrestrial biological surveys
- enable greater certainty for proponents in the environmental impact assessment process by defining the principles the EPA will use when assessing proposals which may impact on biodiversity values.

EPA Guidance Statement No. 51

The EPA determined that several separate guidance statements were warranted to address the range and complexity of issues pertaining to biological surveys, as described in EPA Position Statement No. 3. To this end, EPA Guidance Statement No. 51, *Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia* (EPA 2003b), provides guidance on standards and protocols for terrestrial flora and vegetation surveys, particularly those undertaken for the environmental impact assessment of proposals.

4.2.4 Statutory requirements

In a legislative context, the preservation and conservation of flora is covered primarily by the following Western Australian and Commonwealth statutes:

- *Wildlife Conservation Act 1950* (Western Australia)
- *Conservation and Land Management Act 1984* (Western Australia)
- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth).

Recorded conservation flora will either be Declared Rare Flora (which, under the Wildlife Conservation Act, it is illegal to remove), or defined as Priority Flora.

Declared Rare Flora – Extant Taxa are specifically scheduled for protection under the Wildlife Conservation Act and are species that have been adequately searched for and are deemed to be rare, in danger of extinction, or otherwise in need of special protection.

Priority species are those listed by DEC (CALM 2004a) as potentially threatened. They range from Priority 1 to Priority 4 species, as follows:

- Priority 1: Poorly Known Taxa. Taxa, which are known from one or a few (generally <5) populations, which are under threat
- Priority 2: Poorly Known Taxa. Taxa which are known from one or a few (generally <5) populations, at least some of which are not believed to be under immediate threat
- Priority 3: Poorly Known Taxa. Taxa which are known from several populations, at least some of which are not believed to be under immediate threat
- Priority 4: Rare Taxa. Taxa which are considered to have been adequately surveyed and which whilst being rare, are not currently threatened by any identifiable factors.

4.3 DESCRIPTION OF TERRESTRIAL VEGETATION AND FLORA

4.3.1 Baseline surveys

Previous investigations

Previous investigations within and adjacent to the project area include:

- Bioregional Summary of the 2002 Biodiversity Audit for Western Australia – Carnarvon Bioregion: Cape Range Subregion (CAR1). Department of Conservation and Land Management, Perth (CALM 2002).
- An Interim Biogeographic Regionalisation for Australia: a framework for setting priorities in the National Reserves System Cooperative Program Version 4. Australian Nature Conservation Agency, Canberra. (Thackway and Cresswell 1995).
- An inventory and condition survey of rangelands in the Ashburton River Catchment. Western Australian Department of Agriculture Technical Bulletin No. 62, 1988 (Payne *et al.* 1988).
- Vegetation Survey of Western Australia. Map Sheet 5 – Pilbara. 1:1,000,000 Vegetation Series. University of Western Australia Press, Perth (Beard 1975).

Recent investigations

A recent flora and vegetation investigation included *Yannarie Salt Project Flora and Vegetation Assessment – Baseline Botanical Survey* (Biota 2005a) (Appendix 6). This concentrated on the northern expansion area. Botanical surveys have been commissioned to be completed by April 2007.

4.3.2 General vegetation description

CALM (2002), places the project area in the CAR1 (Cape Range) biological subregion within the Carnarvon Bioregion. The CAR1 subregion[4] is 2,547,911 ha in size and is described as:

"Cape Range and Giralia dunefields form the northern part of Carnarvon Basin. Rugged tertiary limestone ranges and extensive areas of red aeolian dunefield, Quaternary coastal beach dunes and mud flats. Acacia *shrublands over* Triodia *on limestone (*Acacia stuartii *or* A. bivenosa*) and red dunefields,* Triodia *hummock grasslands with sparse* Eucalyptus *trees and shrubs on the Cape Range. Extensive hummock grasslands (*Triodia*) on the Cape Range and eastern dune-fields. Tidal mudflats of sheltered embayments of Exmouth Gulf support extensive mangroves. Beach dunes with* Spinifex *communities. An extensive mosaic of saline alluvial plains with samphire and saltbush low shrublands along the eastern hinterland of Exmouth Gulf. Islands of the Muiron, Barrow, Lowendal and Montebello groups are limestone-based. Climate is arid, semi-desert to sub-tropical climate, with variable summer and winter rainfall. Cyclonic activity can be significant, and cyclonic systems may affect the coast and hinterland annually."*

Due to the inaccessibility of the coastline of the Yannarie Coastal Plain during a vegetation survey by Beard (1975), the area was not visited and the vegetation community types identified at this time were interpreted from aerial photography. The three main vegetation types identified by Beard (1975) included:

1. Mangrove vegetation on the coastline and covering the intertidal zone, *Avicennia marina* listed as the principal species, with some *Rhizophora stylosa.*
2. Behind the intertidal zone is a belt of bare hypersaline mud, which sometimes floods with spring tides. This zone is quite devoid of any vegetation, but some samphire communities occur locally (*Halosarcia* species).
3. Behind the saline tidal mud flats area is a zone mapped as shrub steppe on sandhills with numerous small claypans. The shrub steppe is typically dominated by *Triodia* species (*T. epactia/pungens*) with *Acacia bivenosa, A. synchronicia, A. tetragonophylla* and *A. xiphophylla* the most common shrub species present.

The potential impacts to the mangrove system within the intertidal zone is addressed in Chapter 6, Section 2.

[4] Note that the parts of this description relating to *'Rugged tertiary limestone ranges...'* relate to the Cape Range Peninsula rather than the eastern portion of the subregion which contains the current project area.

Site vegetation types

A recent ground-based flora/vegetation survey identified eleven vegetation types within the northern project area and the vicinity, representing three broad groupings based on landform position (Biota 2005a). The main vegetation types included:

1- Vegetation of Saline Flats

1a - Samphire on Mainland Remnant Margins and Inland Saline Flats. Low, open heath of samphire species, dominated by *Halosarcia indica* but also including up to six other *Halosarcia* species (Biota (2005a) (Figure 5-20). Other typical shrub species included *Neobassia astrocarpa*, *Lawrencia viridigrisea, Frankenia pauciflora, Suaeda arbusculoides* and *Muellerolimon salicorniaceum*. Scattered tussock grasses of *Eragrostis falcata* were usually present, with some dense patches of Marine Couch *Sporobolus virginicus*. Herbs were sparse but *Cyperus bulbosus* and the annual pea *Swainsona pterostylis* occurred occasionally.

Within the salt flats, there are occasional scattered individual samphires (Vegetation Type 1a) close to mainland remnant islands and the hinterland, but otherwise entirely devoid of vegetation cover.

2- Vegetation of Coastal Dune Systems

2a – *Acacia* Shrubland over *Triodia epactia* Hummock Grasses/Buffel grass *Cenchrus ciliaris*[5] Tussock Grasses on Eroded Dune Slopes of the Hinterland Margin (Figure 5-20). This vegetation consisted of a scattered to open shrubland of *Acacia sclerosperma* over scattered low shrubs of *Acacia stellaticeps* over a tussock grassland of Buffel grass *Cenchrus ciliaris* or hummock grassland of *Triodia epactia* Other species typically present included *Acacia coriacea* subsp. *coriacea*, *Solanum lasiophyllum* or *Cassia glutinosa* x *luerssenii*. The understorey included scattered or occasional, *Rhagodia eremaea* and *Lawrencia viridigrisea*. Two variants of this vegetation type were recognised (2a.1 and 2a.2), based on the extent of degradation from erosion and Buffel grass invasion (Biota 2005a).

2b - *Melaleuca cardiophylla* Shrubland over *Triodia epactia* on Limestone Outcroppings in Coastal Dunes (Figure 5-20). This vegetation type comprised a low open shrubland of *Melaleuca cardiophylla*, with other species including *Acacia gregorii*, *A. bivenosa*, *Cassia artemisioides* subsp. *oligophylla* and *C. glutinosa* x *luerssenii* over a mid-dense hummock grassland of *Triodia epactia*. Other associated species included *Acanthocarpus preissii, Indigofera brevidens, Enchylaena tomentosa* var. *tomentosa, Boerhavia coccinea, Rhynchosia minima* and *Solanum cleistogamum*. This vegetation type was only recorded on Hope Point.

2c - Vegetation of Dune Swales and Interdune Flats (Figure 5-20). This typically comprised a low, open shrubland including *Acacia synchronicia* and/or *A. coriacea* subsp. *coriacea*, *A. sclerosperma*, *A. tetragonophylla*, *Scaevola spinescens* and/or *Stylobasium spathulatum*. Understorey strata included *A. gregorii*, *A. stellaticeps* and/or *Solanum lasiophyllum*, over *Triodia epactia*, and less widespread *T. lanigera*, with localised infestations of Buffel Grass *Cenchrus ciliaris*. This vegetation type was very widespread in the survey area including dune swales, small islands and coastal flats. Termite mounds were often present in this vegetation type, predominantly on the mainland.

[5] Indicates weed species

The composition of the overstorey varied slightly from site to site but the single dominant feature of this vegetation type was a mid-dense hummock grassland of *Triodia epactia* in the understorey.

The Dodder Laurel *Cassytha racemosa* and Prickle lily *Acanthocarpus preissii* were often present, along with a range of other herb species (Biota 2005a). Generally this vegetation type was in Excellent condition, with the exception of isolated infestations of Buffel grass *Cenchrus ciliaris*.

2d – Vegetation of Longitudinal Red Sand Dunes (Figure 5-20). Shrubland to open shrubland dominated by *Acacia murrayana, A. coriacea* subsp. *coriacea, Hakea stenophylla* subsp. *stenophylla, Grevillea stenobotrya* and *Scaevola sericophylla* but also including *Acacia tetragonophylla, Grevillea eriostachya* and *Scaevola spinescens*. Other species present include *Santalum lanceolatum, Corymbia zygophylla* or *Stylobasium spathulatum*. The lower shrubland was dominated by *Pityrodia loxocarpa, Acacia stellaticeps* and *Solanum lasiophyllum*, but also included a range of other species (Biota 2005a). Mid-dense hummock grassland of *Triodia epactia* was present on dune slopes, with *T. schinzii* often occurring along the dune crest.

Ephemeral herbs were present as a scattered to open herbland, including *Brachyscome ciliocarpa, Euphorbia tannensis* subsp. *eremophila, Nicotiana occidentalis* subsp. *occidentalis, Rhodanthe psammophila* and the sedge *Bulbostylis barbata*.

2e - Mobile Sand Sheet (Figure 5-20). This vegetation type was only represented in two locations in the vicinity of the project area including the red dune field at 'Yanrey Point' and a smaller, similar formation on another headland on the hinterland. Most of the dune field was devoid of vegetation, but where present comprised a sparse cover of *Acacia murrayana* and/or *A. coriacea* subsp. *coriacea* over *Trichodesma zeylanicum* var. *grandiflorum, Tephrosia rosea* var. *clementii* and the grass species *Paractaenum refractum*, with scattered *Triodia epactia* or *T. schinzii*. Other associated species included *Acacia stellaticeps, A. synchronicia, Abutilon dioicum, Eriachne aristidea, Rhagodia eremaea* and *Salsola tragus*.

3 - Vegetation of Claypans

3a - Bare Claypans with Fringing Plant Communities (Figure 5-20). Unvegetated claypans were a conspicuous feature of the landscape in the project area and the surrounding locality. Two variants were identified from the project area, which varied in the composition of fringing vegetation:

> 3a.1: Fringing *Eucalyptus victrix* and *Melaleuca leiopyxis* over *Triodia epactia* surrounding bare claypan. The claypan itself was completely devoid of vegetation. This vegetation type was more typical of areas further inland and the eastern edge of the hinterland part of the project area only just included the outliers of this association
>
> 3a.2: Bare pans with *Triodia epactia*, herbs and grasses on fringe (where the claypans were small or shallow, herbs and grasses were often present across the surface as an open herbland or tussock grassland). Herb species typical of these claypans included *Swainsona pterostylis, Trianthema triquetra, Evolvulus alsinoides, Crotalaria medicaginea, Angianthus acrohyalinus* and *Gnephosis arachnoidea*. Grasses recorded included *Eragrostis dielsii, E. pergracilis, E. setifolia, Dactyloctenium radulans, Eulalia aurea* and *Sporobolus mitchellii*.

3b - Vegetated claypans of Coolibah *Eucalyptus victrix* Low Woodland over Grassland. Open woodland to woodland of Coolibah *Eucalyptus victrix* over grassland on heavy clay soils in vegetated claypan (Biota 2005a).

Vegetation Type 1a: Narrow strip of samphire typical of edges of mainland remnants

Vegetation Type 2a.1: *Acacia sclerosperma* over *Acacia stellaticeps* over *Triodia epactia*

Vegetation Type 2a.2: *Acacia sclerosperma* over *Acacia stellaticeps* over Buffel **Cenchrus ciliaris*

Vegetation Type 2b:*Melaleuca cardiophylla* over *Triodia epactia* in patches of exposed limestone

Vegetation Type 2c: Sparse Mixed shrub and *Acacia* species over *Triodia epactia*

Vegetation Type 2d: Mixed shrubs over *Triodia epactia* and *T. schinzii* on longitudinal dunes

Vegetation Type 2e: Unconsolidated mobile dune with sparse shrubs and herbs. Photo shows *Acacia murrayana and A. coriacea* with miscellaneous shrubs (Site SS120)

Source: Biota 2005a

Vegetation Type 3a.1: Bare claypans with fringing Paperbarks *Melaleuca leiopyxis* and stunted Coolibah *Eucalyptus victrix*

** Indicates a weed species*

Figure 5-20 Vegetation types 1a to 3a within the Yannarie Solar project area

4.3.3 Species representation

A total of 192 taxa of terrestrial vascular flora representing 100 genera and 41 families were recorded from the project area (Biota 2005a). Of this total, approximately 50 taxa (26%) were represented by ephemeral species and two taxa (1%) were represented by introduced weed species (Buffel Grass, *Cenchrus ciliaris* and Mesquite, *Prosopis pallida*).

The relatively low number of vascular flora recorded (compared to over 1200 native taxa recorded for the Swan Coastal Plain – Department of Environmental Protection, 1996) reflected the following factors:

- a relatively low diversity of plant habitat types present in the project area
- low numbers of constituent species in the project area due to the harsh environment (e.g. hypersaline supratidal salt flats and claypan areas, windblown deep red sand dunes)
- low summer and winter rainfall resulting in few annual or ephemeral perennial species
- the general paucity of the flora of the coastal environments in the Cape Range sub-region of the Carnarvon Bioregion.

The flora families with the greatest number of taxa are shown in Table 5-5. The families and genera that numerically dominated the project area are typical of the coastal areas of the Carnarvon and Pilbara Bioregions (Biota 2005a).

Table 5-5 Species rich flora families in the project area (brackets represent number of weed species)

Family	Number of Native Taxa
Poaceae (Grass family)	26 (1)
Chenopodiaceae (Saltbush, Bluebush family)	23 (0)
Asteraceae (Daisy family)	16 (0)
Papilionaceae (Pea family)	15 (0)
Mimosaceae (Wattle family)	12 (1)
Malvaceae (Hibiscus family)	9 (0)
Goodeniaceae (Leschenaultia family)	7 (0)

Source: Biota 2005a

Species richness (per survey quadrat) ranged from four to 39 taxa (Biota 2005a). Habitats in comparatively 'good' condition such as sand dune swales (i.e. deep, well-drained soils with some available water) typically had much greater species richness than habitats with less favourable soils (i.e. high salinity, wind exposure or tidal influence).

4.3.4 Vegetation and flora of conservation significance

Historical studies

It was difficult to conclusively determine the conservation significance of vegetation in the project area region due to the lack of contextual information historically (Biota 2005a). In the absence of extensive survey data with which to compare results of the Biota (2005a) study, the following discussion of vegetation conservation significance utilises information from the DEC IBRA subregion audit (CALM 2002).

The survey area is situated within the Carnarvon Bioregion and the 2002 Subregional Biodiversity Audit (CALM 2002) split this Bioregion into two sub-regions of which the study is in the Cape Range sub-region. Currently, only 2-3% of this sub-region is protected within reserves.

The CALM (2002) audit of the Cape Range subregion identified those ecosystems that had low, medium or high priority for reservation. Several medium to high priority ecosystems were identified within the survey area (Table 5-6).

Bare claypans have been listed as having a high reservation priority. There are numerous vegetated and bare claypans within the study area, mostly on the hinterland but also mainland remnant islands in the saltfield. There is very little data available to determine uniqueness of vegetation associated with these claypans. The linear parallel red sand dunes that are located on islands in the supratidal flats are fairly widespread in the Cape Range Subregion, but have coastal influences in their floristics which possibly makes them unique at a floristic level.

Coolibah (*Eucalyptus victrix*) communities that are still relatively intact have conservation significance. This community will not be affected.

Table 5-6 Reservation priority ecosystems within the Cape Range subregion as they relate to the project area

Ecosystem (CALM 2002)	Reservation priority	Equivalent vegetation type within the project area	Location and likely impacts
Medium Woodland; Coolibah (*E. microtheca**)	High	Ambiguous community description. Possible equivalent to 3b: Coolibah *Eucalyptus victrix* Low Woodland over Grassland on vegetated claypans. There were some patches of *E. victrix* also within dune swales (Vegetation Type 2c).	Mainly inland. May be minimally affected by access road construction. Borrow pits have not been selected but are likely to be along the access track and these areas will be avoided.
Bare Areas: mudflats	High	Ambiguous community description. Possible equivalent to 4: Saline mudflats (devoid of vegetation). Could also refer to tidal mudflats.	Salt located in this area. Soil will be disturbed and salt flats inundated. The study area covers a large proportion of the largest expanse of supratidal salt flats in the Cape Range sub-Bioregion.
Succulent Steppe: samphire	High	1a: Island and coast margins and inland saline flats: Samphire.	Island margins and saline flats on islands will be inundated. Inland samphire flats should only be minimally affected by access road.
Open Dwarf Scrub, waterwood (*Acacia coriacea*) on recent dunes	High	Ambiguous community description. Probably equivalent to 2d: Semi-consolidated Linear and Parallel Dunes.	Mainly in the centre of islands and inland. Minimal impact expected, although these areas are vulnerable to slow decline through Buffel grass invasion. Increased fires or soil disturbance may aid Buffel spread.
Bare Areas: claypans	High	3a: Bare Claypans.	Some island claypans may be inundated. Inland claypans may be affected by quarries and construction of access track or borrow pits, which are likely to be located at intervals along the access track.
Shrublands: *Acacia sclerosperma* and *A. victoriae*** scrub	Medium	2c: Sparse Mixed shrub and *Acacia* species over *Triodia epactia*.	This vegetation type is widespread in the study area, occurring on islands and the mainland. Low lying areas may be inundated on islands. Level of disturbance on mainland will depend on where quarries and borrow pits are to be located. This area will be vulnerable to Buffel grass infestation if disturbed.

Source: adapted from Biota 2005a

* *Eucalyptus microtheca* in this area is now *E. vitrix*

** *Acacia victoriae* in this area is now *A. synchronicia*

Threatened Ecological Communities

No vegetation types within the project area represent Threatened Ecological Communities (TECs) or communities of special conservation significance. Most vegetation types were widespread within the project area and were consistent with the regional framework provided by the Department of Agriculture land system studies (Payne *et al.*, 1988) and the regional scale vegetation mapping of Beard (1975). Due to the lack of suitable reference data for coastal vegetation in the region, a PATN analysis has not yet been completed to further refine and confirm this assessment.

Declared and Priority Flora

A search of CALM's Threatened (Declared Rare) and Priority database and the Western Australian Herbarium Specimen database was commissioned for the project area by Biota (2005a). This search identified three Priority 1 (P1), eight Priority 2 (P2), eleven Priority 3 (P3) and four Priority 4 (P4) species, although none of these plant species have been recorded closer than 10 km from the project area.

No plant species identified within the project area were found to be listed as Declared Rare (DRF) or Priority at State or Federal level (Biota 2005a). There are two Declared Rare Flora species *Lepidium catapycnon* and *Thryptomene wittweri* currently listed as 'Vulnerable' (EPBC Act) within the Carnarvon IBRA Bioregion, however these were located 50 km from the project area (G. Humphreys, 2006, pers. comm.).

4.3.5 Vegetation condition

The majority of vegetation within the project area was generally in Very Good to Excellent condition, with little ground disturbance and very few weed species (Biota 2005a). There were some areas where infestations of Buffel grass (*Cenchrus ciliaris*) occurred and these areas were classified as being in Very Poor condition. This highly invasive species was also present throughout the study area as scattered individuals and could be considered a 'sleeper' weed species within the study area. Buffel grass is currently at low levels, but processes such as soil disturbance or a fire during construction may cause it to proliferate. It was recorded mainly along the edge of the hinterland coast where erosive processes had disturbed the soil.

The condition of the main vegetation types within the project area are outlined in Table 5-7.

Table 5-7 Condition of vegetation types surveyed within the project area

Type	Description	Condition rating
1a	Samphire on mainland remnant margins and inland saline flats	Excellent
2a	Vegetation of eroded dunes on the edge of the hinterland	Very Good to Excellent
2b	*Melaleuca cardiophylla* shrubland over *Triodia epactia* on Limestone outcroppings in coastal dunes	Excellent
2c	Vegetation of dune swales and interdune flats	Excellent, with isolated infestations of Buffel grass
2d	Vegetation of longitudinal red sand dunes	Very Good to Excellent, with isolated infestations of Buffel grass
2e	Unconsolidated sandsheet	Excellent, with isolated infestations of Buffel grass
3a	Bare claypans with fringing plant communities	Very Good to Excellent, with isolated infestations of Buffel grass
3b	Vegetated claypans of Coolibah *Eucalyptus victrix* low woodland over grassland	Very Good
4	Saline mudflats (vegetative cover absent)	N/A

Source: Biota 2005a

4.3.6 Exotic flora

Two species of introduced flora were recorded from the project area (Biota 2005a):

1. Buffel grass (*Cenchrus ciliaris*) is widespread in the Pilbara and Carnarvon Bioregions and similarly throughout the project area. While this invasive species has demonstrated allelopathic capacities (release of chemicals inhibiting the growth of other species), it is not listed as a Declared Plant species by the Department of Agriculture and Food Western Australia due to its importance to the pastoral industry. Portions of the project area associated with mainland remnants or hinterland edges (disturbed from erosive processes and/or grazing by cattle) had the greatest density of Buffel Grass.

2. Mesquite (*Prosopis pallida*) has been recorded from various locations along the Pilbara coast and three mature trees were recorded from a single location in the north of the project area.

4.4 IMPACT ASSESSMENT AND MITIGATION

4.4.1 Environmental aspects and potential impacts

Key activities or aspects of the proposal that may potentially affect vegetation and flora include:

- **site preparation** and **construction of infrastructure** will involve removal or disturbance of terrestrial vegetation, with associated primary and secondary effects (e.g. habitat loss and risk of weed spread)
- **salt water intrusion** from operation of the ponds
- **hydrological changes** (e.g. flooding, inundation or reduced stream flow) could lead to the loss of vegetation in certain soil types.

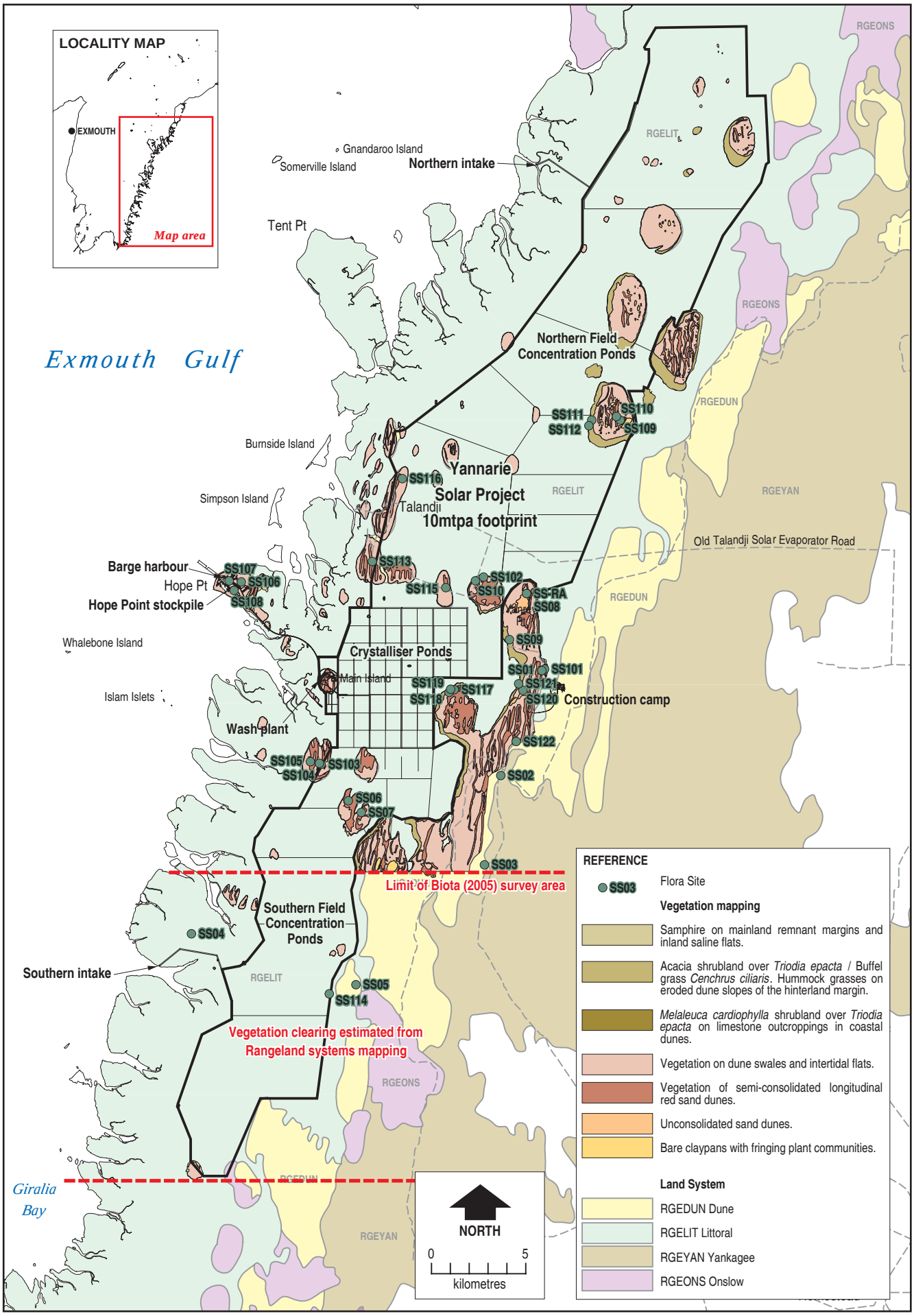
4.4.2 Assessment and management

Disturbance of native vegetation (excluding mangroves)

Clearing of vegetation will be required to accommodate various infrastructure for the project, including the washplant, stockpiles, conveyor, workshops, construction camp and administrative buildings. Clearing will also be required for site access roads, a landing strip for aircraft and haul roads.

A flora and vegetation survey was conducted by Biota (2005a) prior to the finalisation of the conceptual design and preliminary identification of materials sourcing areas, therefore some of the proposed ground disturbance extends beyond the mapped area (Figure 5-21). For the purpose of the ERMP, the extent of vegetation clearing within the whole project footprint has been determined by combining data from:

- estimates of clearing within areas surveyed by Biota (2005a) corresponding to the northern saltfield, crystalliser ponds and Hope and Main Island infrastructure (Table 5-8)
- estimates of clearing within areas not surveyed by Biota (Figure 5-21), which have been interpolated from Land Systems Mapping for the southern saltfield and hinterland quarries and infrastructure (Table 5-9).



Fri 17 Nov 06

0643-F5-21.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-21 Location of flora and vegetation survey quadrats and extent of survey

Datum: MGA Zone 50
Source: Biota, 2005 and Dep't of Agriculture, 2002
Date: 11 Sep 2006

Table 5-8 Estimated clearing of vegetation types (excluding mangroves) surveyed by Biota (2005a) for northern saltfield and saltfield infrastructure

Vegetation Type	Total area mapped (ha)	Indicative clearing within the project footprint (ha)	% of disturbance within each vegetation type
1a – Samphire on Mainland Remnant Margins and Inland Saline Flats	420.7	0.7 (Access roads) 1.0 (Conveyor) 0.3 (Haul roads) 11.6 (Hope Point) 0.1 (Southern pump station) 0.8 (Settling ponds)	3.4
		14.5 ha total	
2a – *Acacia* shrubland over *Triodia epactia* Hummock Grasses/Buffel grass *Cenchrus ciliaris* Tussock Grasses on Eroded Dune Slopes of the Hinterland Margin	1384.5	4.1 (Access roads) 1.1 (Haul roads) 0.2 (Settling ponds)	0.4
		5.4 ha total	
2b – *Melaleuca cardiophylla* Shrubland over *Triodia epactia* on Limestone Outcroppings in Coastal Dunes	2.1	0.02 (Hope Point)	1.0
		0.02 ha total	
2c – Vegetation in Dune Swales and Interdune Flats	6946.4	22.8 (Access roads) 0.1 (Camp and access) 4.9 (Conveyor) 25.3 (Haul roads) 39.7 (Hope Point) 0.1 (Southern pump station) 18.9 (Quarries) 0.6 (Settling ponds)	1.6
		112.4 ha total	
2d – Vegetation of Red Longitudinal Sand Dunes	1945.5	5.6 (Access roads) 4.1 (Haul roads) 9.2 (Hope Point) 8.1 (Quarries)	1.4
		27.0 ha total	
2e – Vegetation of Mobile Sand Sheet	73.4	0	0
3a – Bare claypans with fringing plant communities	124.8	0.1 (Access roads) 1.9 (Haul roads) (0.003 ha for Quarries)	1.6
		2.0 ha total	
TOTAL	**10,897.4**	**161.32* ha**	

Note: * indicative clearing as surveyed by Biota (2005a) is 1.5 % of the total area within the project footprint

Within the area surveyed by Biota (2005a), 33.9 ha of terrestrial native vegetation will be cleared for access roads, 5.9 ha cleared for the conveyor, 7.4 ha cleared for haul roads, 60.5 ha cleared for the Hope Point infrastructure, 0.2 ha cleared for the southern pump station, 1.3 ha cleared for the settling ponds, 0.07 ha cleared for the camp and camp access, and 26.9 ha cleared for the proposed quarry sites.

Table 5-9 Estimated clearing of vegetation types interpolated from Land Systems Mapping for southern saltfield and hinterland infrastructure (other than that surveyed by Biota, 2005a)

Rangeland Unit	Total area mapped within the project footprint (ha)	Indicative clearing within the project footprint (ha)	% of disturbance within each unit
RGEDUN	240	60.3	25
RGELIT	41,091.9	222.4	0.5
RGEONS	22.3	4.9	22
RGEYAN	10.5	10.5	100
Total	**41,364.7**	**298.1***	

Note: * indicative clearing estimated from Land Systems Mapping is 0.7 % of the total area within the project footprint (other than that surveyed by Biota, 2005a)

The combination of data from both the clearing estimates of the Biota (2005a) survey (Table 5-8) and Land Systems Mapping (Table 5-9) estimates that a total of 461 ha of vegetation will be cleared within the whole project footprint for infrastructure. This estimate amounts to less than 1% of the total project area, which is 41,364.7 ha in size.

Management measures addressing disturbance of vegetation

Straits will manage its operations to avoid, reduce and offset impacts on vegetation and flora as far as practicable. Straits will apply the vegetation protection strategies (to be detailed in Terrestrial Vegetation and Flora Management Plan) detailed below:

- surveying flora prior to construction
- identifying areas of conservation significance and avoiding these whenever practicable
- restricting the majority of the operating area of the project to the barren salt flats
- supporting vegetation surveys to further knowledge of local and regional flora and vegetation communities (jointly with DEC)
- recalcitrant species research and rehabilitation
- educating the workforce on conservation values of flora and vegetation
- monitoring impacts of project footprint
- rehabilitation of areas temporarily disturbed
- exclude significant communities in the hinterland from disturbance

Straits will also establish a process with DEC to ensure floristic data collected in surveys is compatible with existing and planned floristic databases for the Exmouth region. Surveying and mapping of site vegetation types outside of the proposed project area will be conducted to enable assessment of impact on site vegetation types in the regional context.

Rehabilitation will be consistent with current best practice.

Disturbance of Declared Rare and Priority Flora

The disturbance of vegetation may directly affect flora species of conservation significance. Although no Declared Rare Flora (DRF) was identified by Biota (2005a) during surveys within the project area, there are three Priority 1 (P1), eight Priority 2 (P2), eleven Priority 3 (P3) and four Priority 4 (P4) which could potentially occur within the area, as they have been recorded in similar vegetation communities more than 50 km away from the project area (G. Humphreys, 2006, pers. comm.).

Potential for spread of weeds

The two species of introduced flora recorded within the project area include Buffel grass (*Cenchrus ciliaris*) and Mesquite (*Prosopis pallida*) (Biota 2005a).

Management measures addressing spread of weeds

A weed management strategy will be developed (and detailed in the Terrestrial Vegetation and Flora Management Plan) with the aim of minimising the introduction and spread of weeds. Management measures include:

- weed mapping will be completed in areas where soil is to be disturbed to differentiate between clean and weedy soil
- soil removed for construction purposes that is identified as a potential source of weeds will be stored separately to clean soil
- monitoring of rehabilitated and adjacent areas for the presence of weeds
- implementation of weed control measures in areas of weed infestations
- prompt rehabilitation of temporarily disturbed areas.

Saltwater intrusion

The flooding of the saltfield will result in terrestrial habitats of the mainland remnants becoming surrounded by water of varying salinity, creating islands in some cases. Depending on the stratigraphy of the individual islands, saltwater has the capacity to intrude from the surrounding concentrator ponds into the groundwater lens present within these mainland remnants.

The long-term impact of saltwater intrusion is difficult to quantify. A general elevation in groundwater levels may arise, driven by a combination of hydrostatic pressure of the large volume of water within the surrounding ponds and associated capillary rise of moisture through the soil profile. This phenomenon has been previously described at the Onslow solar saltfield (Biota 2003), where the depth of salt ponds was no more than 2 m below the ground level of adjacent islands of vegetation. Investigations indicated that the root zone of Spinifex (*Triodia* spp.) extended to approximately 1 m depth within these islands and a saturated vadose zone of capillary rise extended to 1 m above the water level of the adjacent salt ponds. Therefore, it was generally expected that vegetation growing on ground that was less than 2 m above the level of adjacent ponds may be considered at risk from salt water intrusion.

The low-lying portions of the mainland remnants situated within the centre of the Straits saltfield are most likely to be susceptible to saltwater intrusion. Evidence from Onslow suggests that areas on the perimeter of the saltfield are unlikely to be affected by this process. There are 15 mainland remnants within the Yannarie footprint (potential 'islands') that may be affected by the intrusion of saltwater,

however an analysis of the elevation levels of the mainland remnants (>5 m AHD, Figure 5-22) and future salt ponds (current level of salt flats averages 1.41 m AHD + pond depth of 1.5 m = 2.91 m AHD) indicate that the islands within the Yannarie saltfield are less likely to experience widespread vegetation loss from saltwater intrusion than their counterparts at Onslow due to their generally greater elevation (+ 2 m above the water level within the ponds) (Figure 5-22).

Some hummock grassland areas located on mainland remnants may become converted to halophytic samphire shrublands from saltwater intrusion (i.e. long-term successional change in vegetation), although this is considered to be a low risk and will be confirmed through more extensive stratigraphic investigation.

Management measures addressing saltwater intrusion

The effects of saltwater intrusion will be managed through:

- further stratigraphical investigations to identify areas within mainland remnants that are most at risk from intrusion of saltwater
- baseline flora and vegetation surveys conducted on mainland remnants
- long-term monitoring of flora and vegetation on the mainland remnants to assess changes to species composition, abundance and condition.

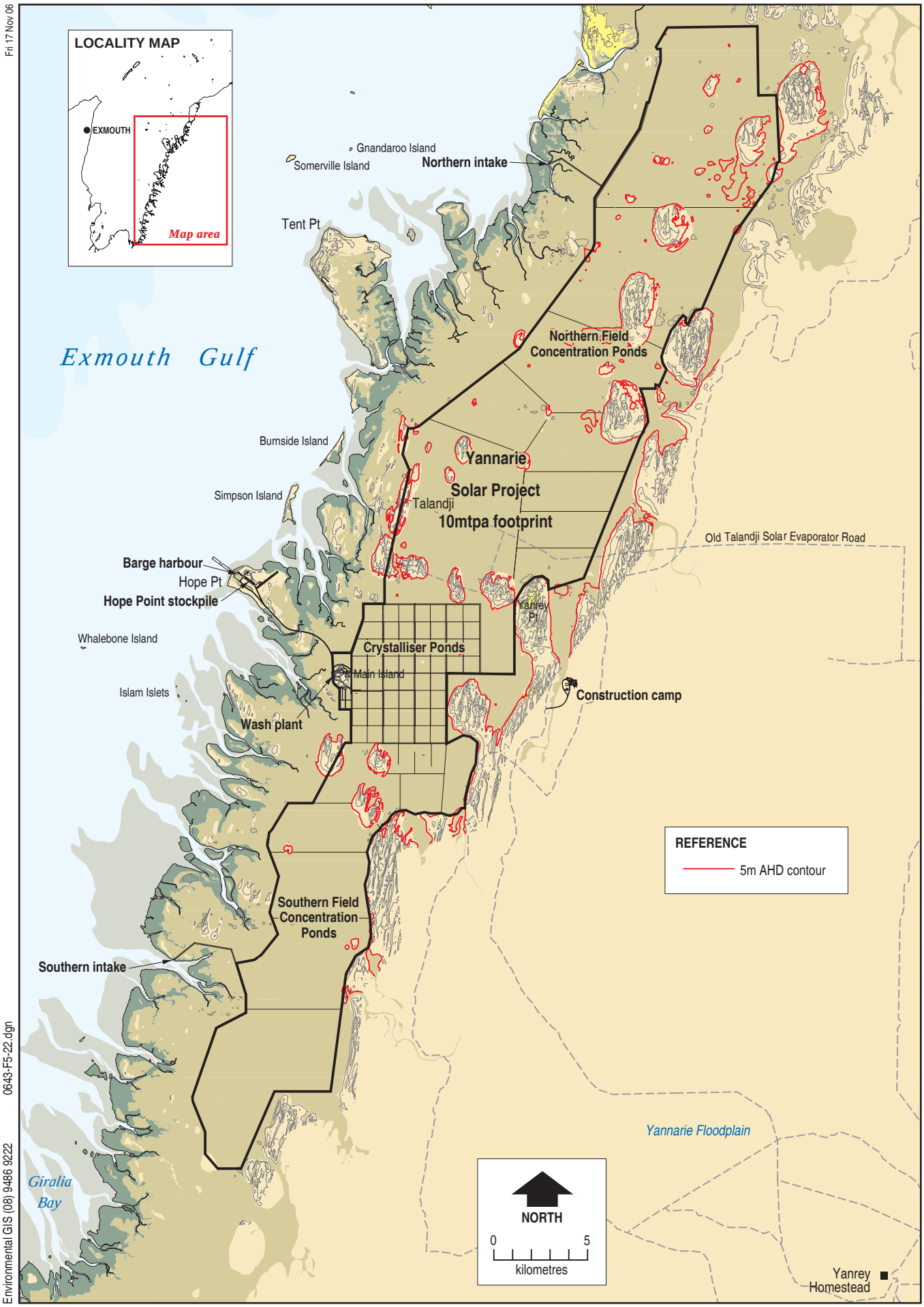
Hydrological changes (flooding and inundation)

Part of the saltfield design includes the construction of a flood protection weir to divert hinterland flows away from the concentrator ponds during major rainfall events. The presence of the weir may result in increased ponding of floodwaters and inundation of areas inland (upstream) of these bunds. Terrestrial vegetation on the hinterland may be affected by the increased submergence.

Parsons Brinkerhoff (2006b) reviewed the potential impacts that the project may have on hydrology and identified that:

- small-scale storm events (less than 2 years ARI) result only in localised runoff and ponding and are not driven by inputs from the wider Yannarie and Rouse catchments. For these flood events, floodwaters would pond upstream of the weir (see Chapter 5, Section 3)
- larger storm events (greater than 5 year ARI) would generate sufficient flow to over-top the weir, with the floodwaters discharging through an interdunal 'choke point' to the north (see Chapter 5, Section 3).

Under normal conditions, local floodwaters would discharge relatively rapidly out of the Yannarie North, leaving the vegetation and soil in this area wet but not submerged (Parsons Brinkerhoff 2006b). The construction of the weir may result in detained floodwater dissipating only via infiltration or evaporation after a flood event. The rate of this dispersal would be dependent on weather conditions (e.g. evaporation rates and humidity) and the pre-existing state of the soils throughout the area. Parsons Brinkerhoff (2006b) were not able to meaningfully predict these variables for any given event, however it is likely that the area contained by the weir will be flooded for a period of several days longer than they would have been in the unmodified system.



Fri 17 Nov 06

0643-F5-22.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Straits Salt Pty Ltd
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-22 Terrestrial remnants that are greater than 5m AHD elevation

Management measures addressing hydrological changes

Management measures to reduce the affect of hydrological change on flora and vegetation communities are further discussed in Chapter 5, Section 3.

4.5 MONITORING AND ASSESSMENT OF PERFORMANCE

A monitoring program for vegetation will be developed within and adjacent to the project area to determine changes to flora abundance and vegetation distribution as a result of the project. Periodic monitoring within rehabilitation areas will also be conducted. These programs will assist Straits in monitoring the effectiveness of its flora and rehabilitation management measures.

4.6 PROPONENT COMMITMENTS

The following commitments to protect vegetation are:

1. Conduct a baseline terrestrial vegetation and flora and vegetation survey within and adjacent to the southern portion of the project area and in vegetation adjacent to this area, inundation area and potential quarry and borrow pit locations before ground disturbance in these areas.
2. Conduct a baseline terrestrial vegetation and flora survey of the mainland remnants and implement a monitoring program to assess changes to species composition, abundance and condition resulting from saltwater intrusion.
3. The results of the surveys outlined in commitments 1 and 2 above will be made available for a four week public submission period during the first half of 2007.
4. Preparation and implementation of a Terrestrial Vegetation Management Plan.
5. Develop and implement a survey program to increase knowledge of native flora and vegetation locally and within the region in conjunction with DEC.

4.7 ENVIRONMENTAL OUTCOME

Through regular monitoring of vegetation and flora within and adjacent to the project area, Straits will increase the knowledge of vegetation communities, plant ecology and function in the region. Similarly, Straits commits to further research on these communities so that significant flora and vegetation communities are identified.

Approximately 461 ha of terrestrial vegetation within the project area will be cleared for infrastructure such as access and haul roads, the conveyor, Hope Point infrastructure, southern pump station, settling ponds and quarries. This clearing is not considered significant as it is less than 1% of the project area (which is 41, 364 ha in size) and no Declared Rare Flora or Priority Flora species have been identified by surveys within the project area.

Straits will progressively rehabilitate temporarily disturbed areas arising from construction.

With construction, there is an increased risk of the spread of weeds, which will be managed through weed control and management procedures.

There is a low risk of saltwater intrusion impacting vegetation within the mainland remnants located throughout the proposed pond areas due to differences in elevation between pond water and height of remnants (> 2 m).

A flood protection weir will be primarily utilised for diverting hinterland flows of water away from the concentrator ponds during major rainfall events. Hydrological impacts (flooding and inundation) to vegetation within the project area from the weir is difficult to quantify at this stage, however vegetation condition, abundance and species diversity will be monitored particularly during large rainfall events.

5 TERRESTRIAL FAUNA

5.1 EPA OBJECTIVE

- *To maintain the abundance, diversity, geographic distribution and productivity of fauna at species and ecosystems levels through the avoidance or management of adverse impacts and improvement in knowledge.*
- *To protect species listed under the EPBC Act 1999, and Schedule and Priority Fauna consistent with the Wildlife Conservation Act 1950.*

5.2 LEGISLATIVE POLICY AND CONTEXT

5.2.1 Environment Protection and Biodiversity Conservation Act 1999

The *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) utilise 'significance levels' for fauna, which are recommended by the International Union for the Conservation of Nature and Natural Resources (IUCN). The WA *Wildlife Conservation Act 1950* uses a set of schedules but also classifies species using some of these IUCN categories.

The EPBC Act lists migratory species that are recognised under international treaties such as the China Australia Migratory Bird Agreement (CAMBA), the Japan Australia Migratory Bird Agreement (JAMBA) and the Bonn Convention (Convention on the Conservation of Migratory Species of Wild Animals). Those species listed in JAMBA are also protected under Schedule 3 of the WA *Wildlife Conservation Act*. In addition, the Department of the Environment and Heritage (DEH, formerly Environment Australia) has supported the publication of reports on the conservation status of most vertebrate fauna species e.g. reptiles (Cogger *et al.* 1993), birds (Garnett & Crowley 2000), monotremes and marsupials (Maxwell *et al.* 1996), rodents (Lee 1995) and bats (Duncan *et al.* 1999).

Fauna species included under conservation acts and/or agreements are formally recognised as of conservation significance under State or Federal legislation. Species listed only as Priority by DEC, or those included in publications such as Garnett and Crowley (2000) and Cogger *et al.* (1993) but not in State or Commonwealth Acts, are also of recognised conservation significance. Species that are at the limit of their distribution, those that have a very restricted range, and those that occur in breeding colonies (such as some waterbirds) can also be considered of conservation significance. Although this level of significance has no legislative or published recognition, and is based on interpretation of distribution information, the Government of Western Australia (2000b) used this interpretation to identify significant bird species in the Perth metropolitan area as part of *Bush Forever*.

On the basis of the above, three 'significance levels' of conservation are recognised in this assessment:

- *Conservation Significance (CS) 1*: Species listed under State or Commonwealth Acts
- *Conservation Significance (CS) 2*: Species not listed under State or Commonwealth Acts, but listed in publications on Threatened Fauna or as Priority species by DEC
- *Conservation Significance (CS) 3*: Species not listed under Acts or in publications, but considered of at least local significance because of their pattern of distribution.

5.2.2 Statutory requirements

State

In Western Australia, DEC has produced a supplementary list of Priority Fauna, being species that are not considered Threatened under the *Wildlife Conservation Act 1950* but for which DEC feels there is cause for concern. Some Priority species, however, are also assigned to the IUCN Conservation Dependent category. Rare or endangered species in WA are protected by the *Wildlife Conservation (Specially Protected Fauna) Notice 2003*, under the *Wildlife Conservation Act 1950*. Schedules 1 and 4 in this notice are relevant to this assessment, providing a listing of those species protected by this Notice.

The DEC Priority Fauna List also nominates conservation species from Priority level 1 to 4 as described for flora in Chapter 5, Section 4. The Priority Fauna List does not confer any additional legal protection apart from the normal protection afforded to most native fauna. It is expected however, that the potential impacts from a proposal on these Priority listed species should be managed so that the species do not meet the IUCN criteria for threatened species.

Commonwealth

In 1974, Australia signed the Convention on International Trade in Endangered Species of Wild Fauna and Flora. As a result, an official list of endangered species was prepared and is regularly updated. This listing is administered through the Commonwealth EPBC Act. The current list differs from the various State lists but there are some species that are common to both.

5.2.3 International agreements

A range of shorebirds are listed under the Japan–Australia (JAMBA) and China–Australia (CAMBA) Migratory Bird Agreements. Most of these are associated with saline wetlands or coastal shorelines and have little relevance to the proposal area. However, some migratory birds not associated with water are also listed on these international treaties.

5.2.4 EPA Guidance Statement No. 56

The EPA determined that several separate guidance statements were warranted to address the range and complexity of issues pertaining to biological surveys, as described in EPA Position Statement No. 3. To this end, EPA Guidance Statement No. 56, *Terrestrial Fauna Surveys for Environmental Impact Assessment in Western Australia* (EPA 2004c), provides guidance on standards and protocols for terrestrial fauna surveys, particularly those undertaken for the environmental impact assessment of proposals.

5.3 DESCRIPTION OF TERRESTRIAL FAUNA

5.3.1 Investigations

Previous investigations

The Yannarie Solar Project area falls into the Carnarvon IBRA Bioregion (Thackway and Cresswell 1995, Environment Australia 2000). Regional level mapping of broad fauna habitat units is available

from the mapping of Beard (1975) and later work completed on land system units by the Department of Agriculture (Payne *et al.* 1988) (Chapter 5, Section 4). Systematic fauna surveys have also been recently conducted by DEC at Giralia Station to the south of the project area, and the results of this work were considered on the basis of specimens lodged with the WA Museum from this survey (Biota 2005b).

Prior to the current study, the only other systematic surveys completed in the locality comprise:

- terrestrial fauna survey collecting work completed along the Tubridgi gas pipeline corridor to the north of the current project area by the WA Museum (WA Museum 2005)
- ongoing systematic sampling of terrestrial fauna on islands within the Onslow Salt solar saltfield to the north of the current project area (Biota 2002b, 2005c).

The majority of the other terrestrial fauna information available is at a more regional scale of consideration (e.g. the Herpetofauna of the Exmouth and Onslow—Ashburton Regions) (Storr and Hanlon 1980, Storr and Harold 1985).

Recent investigations

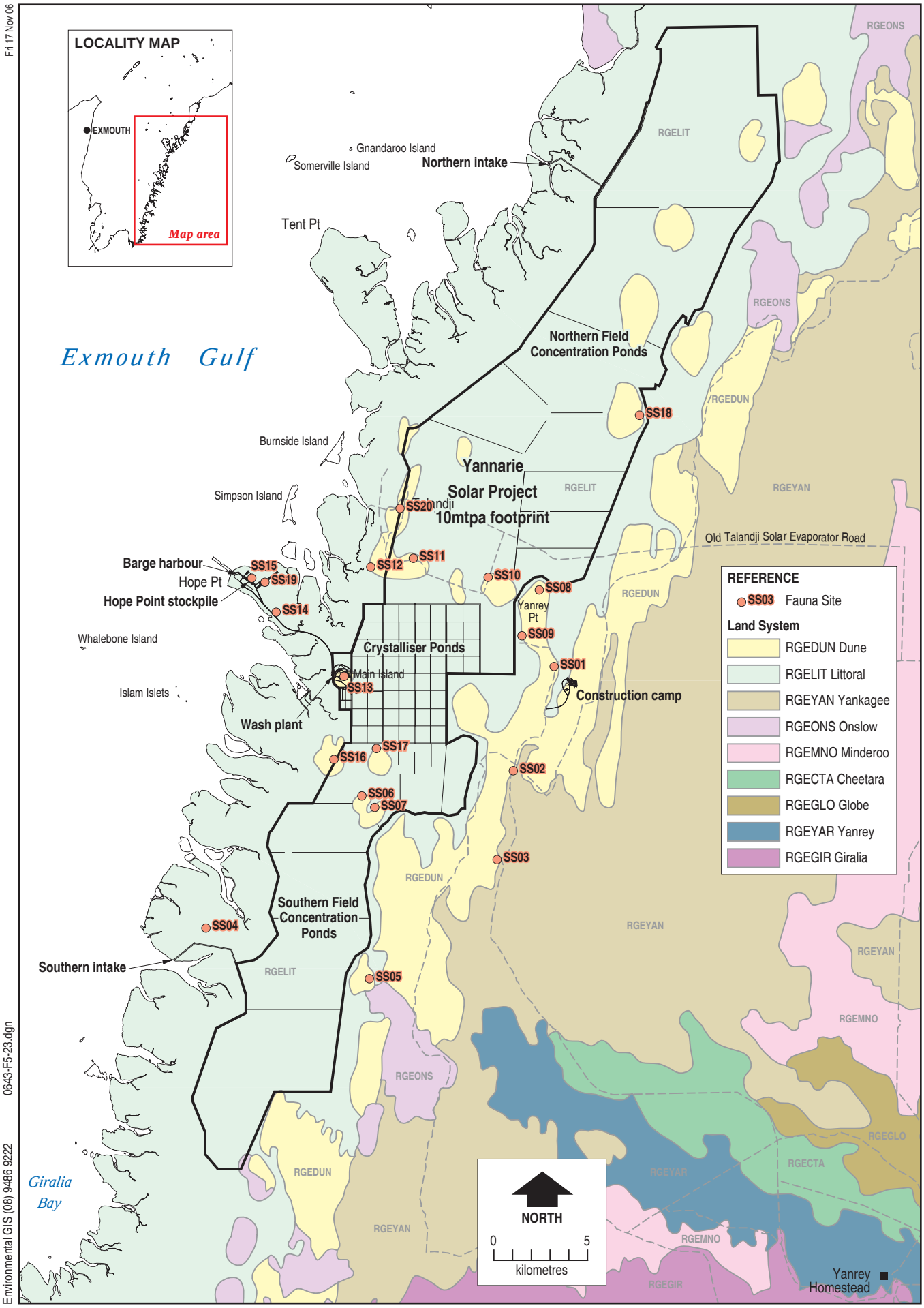
The terrestrial fauna investigations for the Yannarie Solar project area comprised of systematic and non-systematic surveys and were conducted over a 10-day period between 15/08/2004 and 24/08/2004.

The central component of the systematic survey consisted of 20 fauna trapping grids, each located within a defined habitat (Figure 5-23) (Biota 2005b) (Appendix 5). Fauna survey sites were selected so that they sampled:

- a representative set of the fauna habitat types within the project area
- any areas of perceived potential conservation significance
- across the geographic extent of the project area, with some sampling emphasis on known potential impact areas.

A range of non-systematic fauna survey activities were undertaken by the survey team to supplement the trapping and investigate additional habitats identified during the course of the survey. These included:

- habitat specific searches for evidence of Schedule and Priority listed fauna species
- searching (including raking and head-torching) of microhabitats for reptile, frog and small mammal species
- opportunistic sightings and records
- identification of animal remains
- recording and identification of secondary signs (where possible) including tracks, scats and diggings.



Fri 17 Nov 06

0643-F5-23.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-23 Location of fauna survey sites

Datum: MGA Zone 50
Source: Biota, 2005 and Dep't of Agriculture, 2002
Date: 11 Sep 2006

Mangrove dependent bird counts were conducted by Biota during the breeding (2–8 August 2004), non-breeding (29–30 January 2005) and northward migration (12–13 March 2005) periods. During each survey, three types of counts were conducted:

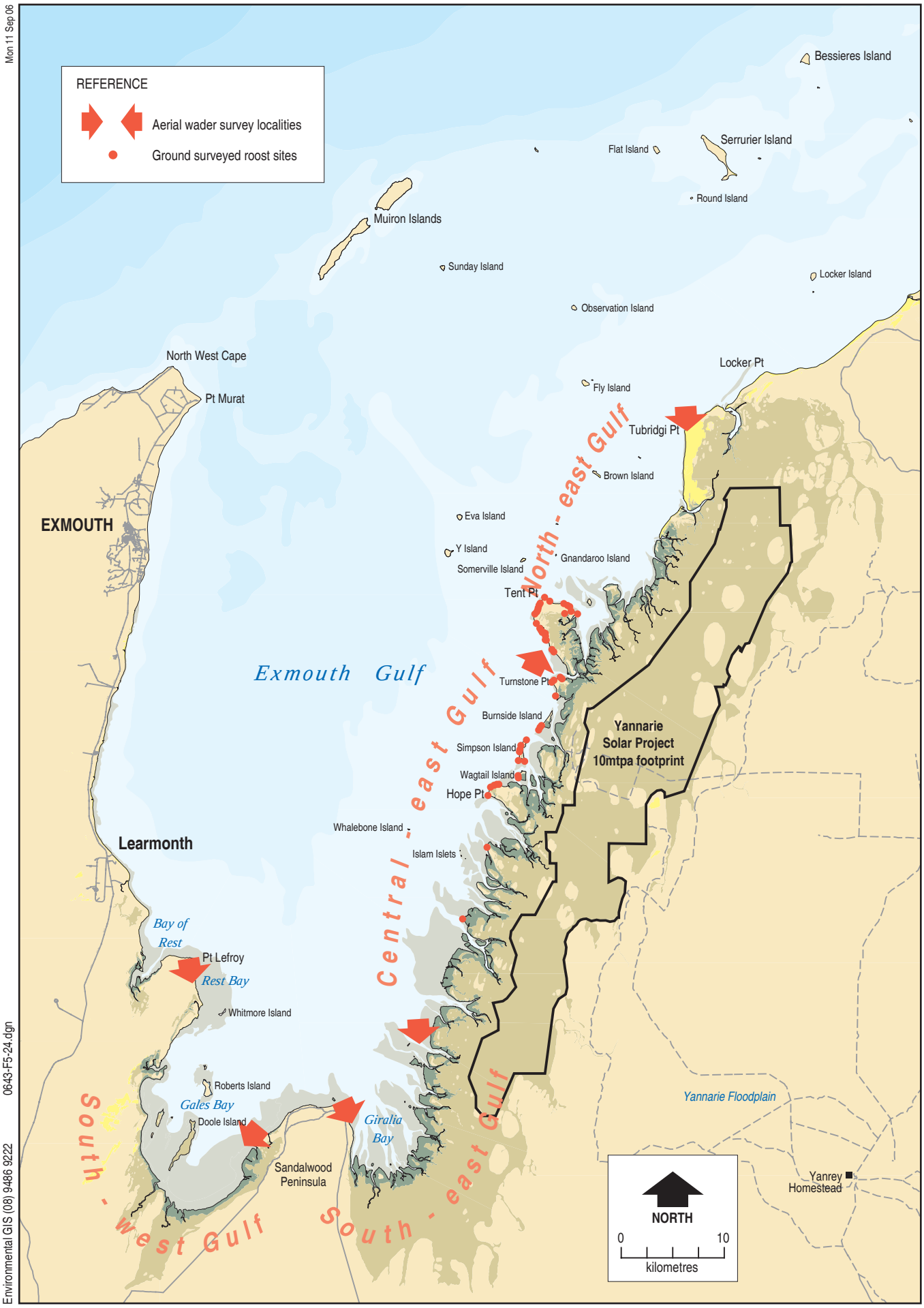
- high tide counts (conducted on foot)
- high tide counts (conducted from helicopter)
- low tide counts (conducted on foot).

Counts for each bird species were totalled for each survey and the maximum number of individuals present in the study area was recorded. The maximum number recorded was the greater of either:

1. the foot counts and aerial high tide counts combined, or
2. the foot counts at low tide.

The locations where wader species were located are shown in Figure 5-24 (Biota 2005d).

Thresholds to assess the international significance of shorebirds and waders in the area were based on proportions of the East Asia-Pacific flyway population present in the survey locations (Biota 2005d). If the location contained more than 1% of the population of a species during the breeding and non-breeding seasons, or more than 0.25% of the population of a species during the northward or southward migration seasons, then the area was deemed to be internationally significant by these criteria. The threshold is lower during the migration season because birds are staying for relatively short periods and passing through the site rapidly so any counts will only reflect a proportion of birds using that site during the migration (conservatively estimated to be about one quarter). The threshold criteria were supplied by Dr Mike Bamford (unpublished data).



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-24 Wader count locations within the project area

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006

5.3.2 Fauna habitat

Each survey site was broadly classified by landform type and position in the landscape. The sites were then described in more detail in terms of soils by DC Blandford & Associates and Oceanica 2005 and vegetation by Biota 2005a. Detailed descriptions are provided in Biota (2005b), while Table 5-10 provides a summary of survey sites grouped by broad landform habitat units, highlighting those situated on the hinterland from those on the mainland remnants. Representative photos of the various habitat types are provided in Chapter 5, Section 4.

Table 5-10 Summary of survey sites by broad habitat units present in the project area and native mammals

Habitat type	Survey sites
Linear red, sand dunes with mixed low shrublands over *Triodia* hummock grasslands	SS01*, SS04, SS07, SS10, SS11, SS15, SS17, SS20
Open shrublands over *Triodia* hummock grasslands on duplex soils in dune swales	SS03*, SS06, SS13, SS16
Low, open *Acacia* shrublands over dense *Triodia* hummock grasslands on duplex soils on interdune flats	SS05*, SS12, SS14
Open samphire shrublands on saline clay flats	SS02*, SS19
Margin of unconsolidated mobile dune	SS08*
Dune ridge on margin of claypan	SS18
Eroded coastal dune	SS09*

Source: adapted from Biota 2005b

* sites situated on the hinterland

At the broad scales of rangeland units and Beard's vegetation mapping, the habitat types present in the study area occur relatively widely in the locality. This includes areas on Giralia Station to the south of the project area which has recently been acquired by DEC and is being managed for conservation purposes.

Locally, the fauna habitats comprise similar units which are repeated and effectively replicated, both on the mainland (the Carnarvon dunefield) and to varying extents on each of the isolated mainland remnants on the Onslow Plain supratidal salt flat. The longitudinal sand dune formations, interdune flats and claypans are typical landscape features in this locality and these are all represented on both the mainland and the supratidal salt flat mainland remnants.

Five mangrove associations were defined from the mangrove vegetation of the project area (Biota 2005d). The area of live mangrove associations totals 11,154 ha and are discussed in Chapter 6, Section 2. Some fauna groups are strongly associated with mangroves and are essentially restricted to these habitats along the Pilbara coast (Biota 2005d). Mangrove dependent birds in particular are well recognised as a vertebrate group that is restricted to this habitat type along the arid zone coast (Biota 2005d).

5.3.3 Summary of fauna abundance

The surveys of the Yannarie Solar Project area recorded a total of 138 vertebrate taxa, including 57 bird species as discussed in Biota (2005d). Table 5-11 provides a summary of the number of species recorded from each major vertebrate group during the surveys. A range of invertebrate taxa were also recorded during surveys, as discussed below.

Table 5-11 Number of vertebrate fauna species recorded during the Yannarie Solar fauna surveys

Fauna group	Total number of Species
Terrestrial Avifauna	33
Migratory Waders/Littoral Avifauna*	48
Mangrove Avifauna*	9
Native Mammals	7
Introduced Mammals	5
Reptiles	34
Amphibians	2
Total	**138**

Source: Biota 2005b

* mangrove dependent birds and migratory waders

5.3.4 Birds

Terrestrial birds

Thirty-three species of terrestrial avifauna were recorded from the project area by Biota (2005b). The 33 terrestrial species recorded represented twenty families, with a more detailed account of the habitats and other observations for each species provided by family in Biota 2005b. None of the terrestrial bird species recorded represent endemic or regionally restricted taxa.

One Schedule listed avifauna species was recorded from the Yannarie Solar project area. The Rainbow Bee-eater, which is listed as a migratory species under the EPBC Act and the Japan-Australia Migratory Bird Agreement (JAMBA) and is listed as a Schedule 3 species, was recorded. In addition, a single Priority fauna species, the Australian Bustard, was recorded from mainland remnants on the salt flats:

- **Australian Bustard *Ardeotis australis* (Priority 4)** - This species has declined significantly in southern Australia but still remains common in northern Australia. The Australian Bustard is typically locally nomadic and seems to be particularly attracted to recently burnt areas. Two birds were seen in *Triodia* grassland on Simpson Island in August 2004 and the species probably occurs widely in similar habitats throughout the study area. Given its habitat preferences, it will be negligibly affected by the proposed development.
- **Rainbow Bee-eater *Merops ornatus* (Schedule 3/JAMBA**) - This species breeds in Australia and migrates to northern Australia and Indonesia (with one record from Japan) in the austral winter. It typically feeds on flying insects which it captures in short flights from prominent perches. It was recorded at a few sites in January 2005 and is probably quite common in the study area wherever there is suitable habitat (Biota 2005b). Given its habitat preferences, it will be negligibly affected by the proposed development.

Shorebirds and waders

Fifty-four species of mangrove and littoral birds were recorded from the project area and this included 49 species of non-passerines and five species of passerines (Biota 2005d). All the passerines recorded during the study were mangrove specialists. The most speciose families were the sandpipers and allies (Scolopacidae; 14 species), gulls and terns (Laridae; 9 species), herons (Ardeidae; 6 species) and

plovers (Charadriidae; 6 species). The most abundant species were three species of scolopacid (Grey-tailed Tattler, Bar-tailed Godwit and Red-necked Stint) and one species of charadriid (Greater Sand Plover).

Of the species recorded, 20 were migrants from breeding grounds in the northern hemisphere and would be only non-breeding visitors to the study area. Some of the other species recorded (e.g. Little Tern, Bridled Tern) breed in Australia but would be very unlikely to breed in the study area. Most of the remaining species probably do breed in the study area at certain times. No definite evidence of local breeding was recorded for any species, although the presence of several juvenile Striated Heron provided strong evidence that the species breeds in the area (Biota 2005d).

Of the 54 species of mangrove and littoral birds recorded from the project area, 48 species and over 20,000 birds were counted during the three wader surveys combined (Biota 2005d). Most of these records were during the non-breeding season with relatively fewer birds in the breeding and northward migration seasons (Figure 5-24).

Of the 48 migratory wader species recorded, 28 are listed as migratory species under the EPBC Act (Table 5-12). The most abundant species in the study area were the Grey-tailed Tattler, Red-necked Stint, Bar-tailed Godwit and Greater Sand Plover, in that order (Table 5-12). All of these numerically dominant species are listed under the EPBC Act.

The area was ranked as of international importance for five species, although for only one of these species, the Grey-tailed Tattler (Figure 5-25), it was of international importance in all three seasons (breeding, non-breeding and migration). For the remaining species, the area was ranked as internationally important for Greater Sand Plovers in the breeding season and was internationally important for the Bar-tailed Godwit (Figure 5-25), Ruddy Turnstone and Sanderling during northward migration.

(a) Grey-tailed tattler

(b) Bar-tailed Godwit

Figure 5-25 Photographs of migratory waders

Table 5-12 Littoral birds recorded and maximum count for each species

Species	Breeding	Non-breeding	Northward migration	Maximum*
Non EPBC Act listed species				
Darter	21	7	2	21
Pied Cormorant	93	180	377	377
Little Black Cormorant	0	2	6	6
Little Pied Cormorant	0	3	0	3
Australian Pelican	794	90	7	794
White-faced Heron	37	137	144	144
Little Egret	38	151	57	151
Nankeen Night Heron	40	2	7	40
Striated Heron	3	7	8	8
Black-necked Stork	0	1	2	2
Brahminy Kite	2	2	2	2
Beach Stone-curlew	1	0	5	5
Pied Oystercatcher	102	196	169	196
Sooty Oystercatcher	4	6	17	17
Red-capped Plover	66	249	150	249
Silver Gull	93	382	135	382
Gull-billed Tern	6	47	3	47
Crested Tern	36	185	346	346
Fairy Tern	0	1	8	8
Whiskered Tern	0	6	1	6
EPBC Act listed species				
Eastern Reef Egret	9	10	3	10
Great Egret	9	24	8	24
Osprey	4	5	7	7
White-bellied Sea-Eagle	4	4	4	4
Bar-tailed Godwit	647	1253	912	1253
Whimbrel	192	112	29	192
Eastern Curlew	189	48	9	189
Common Greenshank	10	109	51	109
Common Sandpiper	10	8	17	17
Grey-tailed Tattler	484	3184	2234	3184
Terek Sandpiper	0	48	53	53
Ruddy Turnstone	37	109	185	185
Great Knot	123	434	14	434
Red Knot	1	0	0	1
Sanderling	10	11	112	112
Red-necked Stint	1133	752	467	1133
Sharp-tailed Sandpiper	0	5	0	5
Curlew Sandpiper	44	34	1	44
Grey Plover	11	32	14	32
Pacific Golden Plover	0	4	7	7
Lesser Sand Plover	64	20	76	76
Greater Sand Plover	1036	420	116	1036
Oriental Plover	0	15	0	15
Caspian Tern	105	31	18	105
Lesser Crested Tern	36	61	14	61
Common Tern	0	70	0	70
Little Tern	0	38	1	38
Bridled Tern	0	1	0	1
Unidentified Waders	0	660	0	660
Total	**5494**	**9156**	**5798**	**11861**

Source: Biota 2005d

* maximum count from the three migratory waders surveys

Wader roosts

During foot surveys for migratory waders, roosts were recorded at all sites in all surveys, except on Wagtail Island in August (where no roosts were recorded). Survey results are shown in Figure 5-26 and Figure 5-27, and are summarised as follows:

- Wagtail Island recorded a small roost in January and March (Figure 5-26)
- Hope Point recorded a large roost in August with smaller roosts recorded during the other two seasons (Figure 5-27)
- Simpson Island recorded a large roost on the south east tip in all surveys and there were additional large roosts on the west coast and northern tip in August (Figure 5-27)
- Burnside Island recorded large roosts at its southern end in all surveys (Figure 5-27)
- Turnstone Point recorded few birds and roosts in all months (Figure 5-27)
- Tent Island recorded a roost at its north east corner in all months, although it was much smaller in March than in August or January
- North Tent Island recorded a consistently large roost in the western area
- Central Tent Island recorded a large roost in January, although none was recorded during the other two seasons
- North west Tent Island recorded good numbers of birds in March, although they were dispersed among a number of smallish roosts (Figure 5-27).

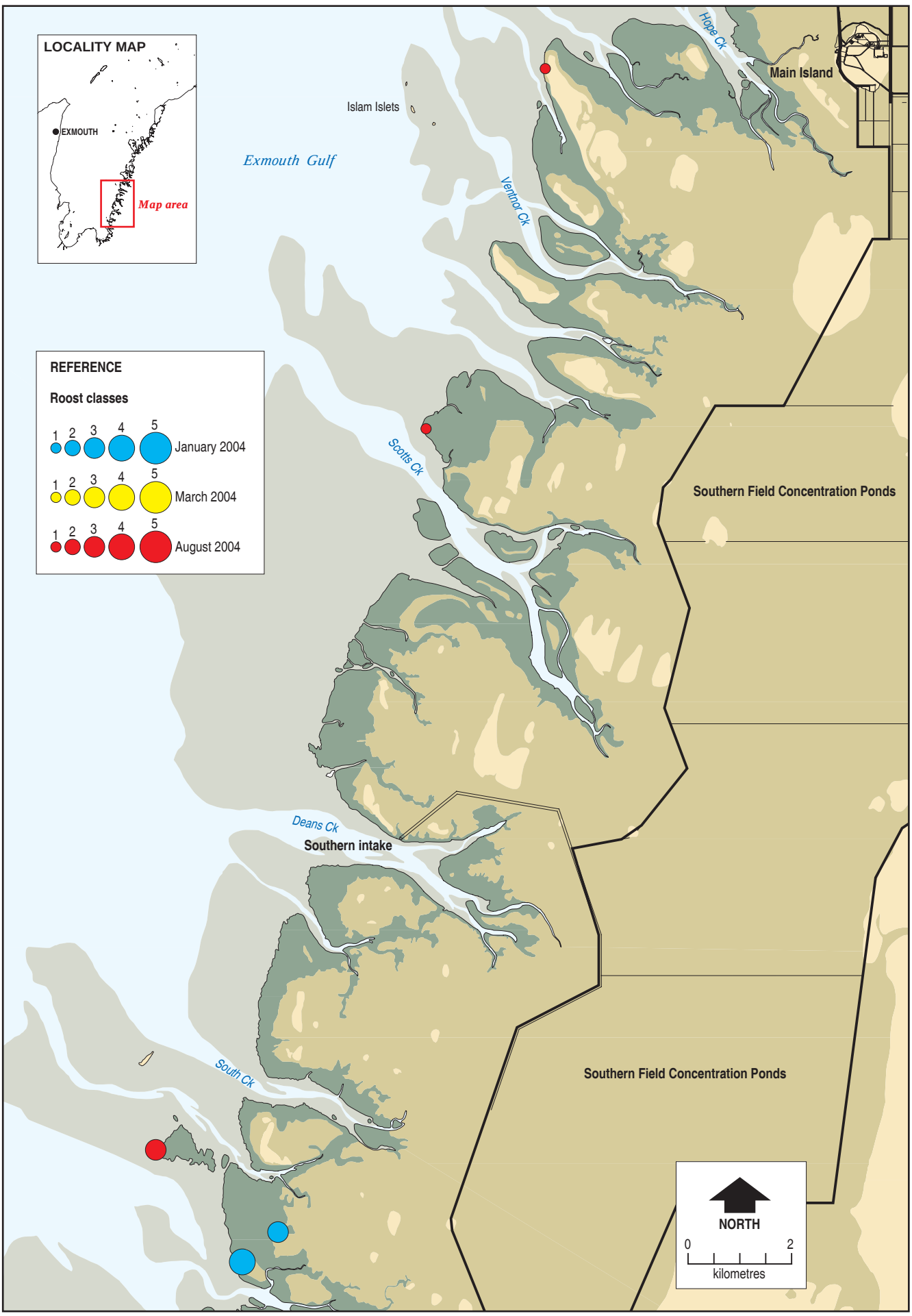
The number of individuals occurring in the Yannarie Solar Project area was relatively low considering the area involved and the number of individuals that some sites along the Pilbara coastline support (Biota 2005d). By way of comparison, Barrow Island supports twice as many birds in January and over twice as many birds in March, although numbers are more similar in August (Bamford and Biota 2005). This is despite the fact that the two areas are roughly similar in size.

The relatively low number of waders in the survey location is probably due to the extensive mangroves that line the shore of the Gulf (Biota 2005d). Most waders, except for Grey-tailed Tattlers (and to a lesser extent Whimbrels), are reluctant to roost in mangroves, preferring instead to roost on beaches, rocky promontories and other open areas. The reasons relate to increased predation risk in mangroves and the difficulties that these essentially terrestrial birds have in perching in trees. This is supported by the survey findings that the survey locations supports internationally significant numbers of Grey-tailed Tattlers in all seasons and this species commonly roosts in mangroves.

The survey locations were assessed as internationally significant for five species, although only during one season for four of those species (Biota 2005d). It was important for two species in the breeding/non-breeding season and four species on northward migration. In contrast, Barrow Island is important for four species in the breeding/non-breeding season and eight species on southward/northward migration against the same threshold criteria (Bamford and Biota 2005).

No avifauna of special conservation significance under the *Wildlife Conservation Act 1950-1979* were recorded in the study area, although 28 species are listed as migratory species under the EPBC Act. However, none of the migratory species is considered rare or threatened, although the Eastern Curlew is listed as Priority 2. The Eastern Curlew is far more abundant on the coastline between Port Hedland and Broome on passage and winters primarily in south eastern Australia, and therefore the study area is unlikely to be of critical importance to the species (Biota 2005d).

Whalebone Island



Mon 11 Sep 06

0643-F5-26.dgn

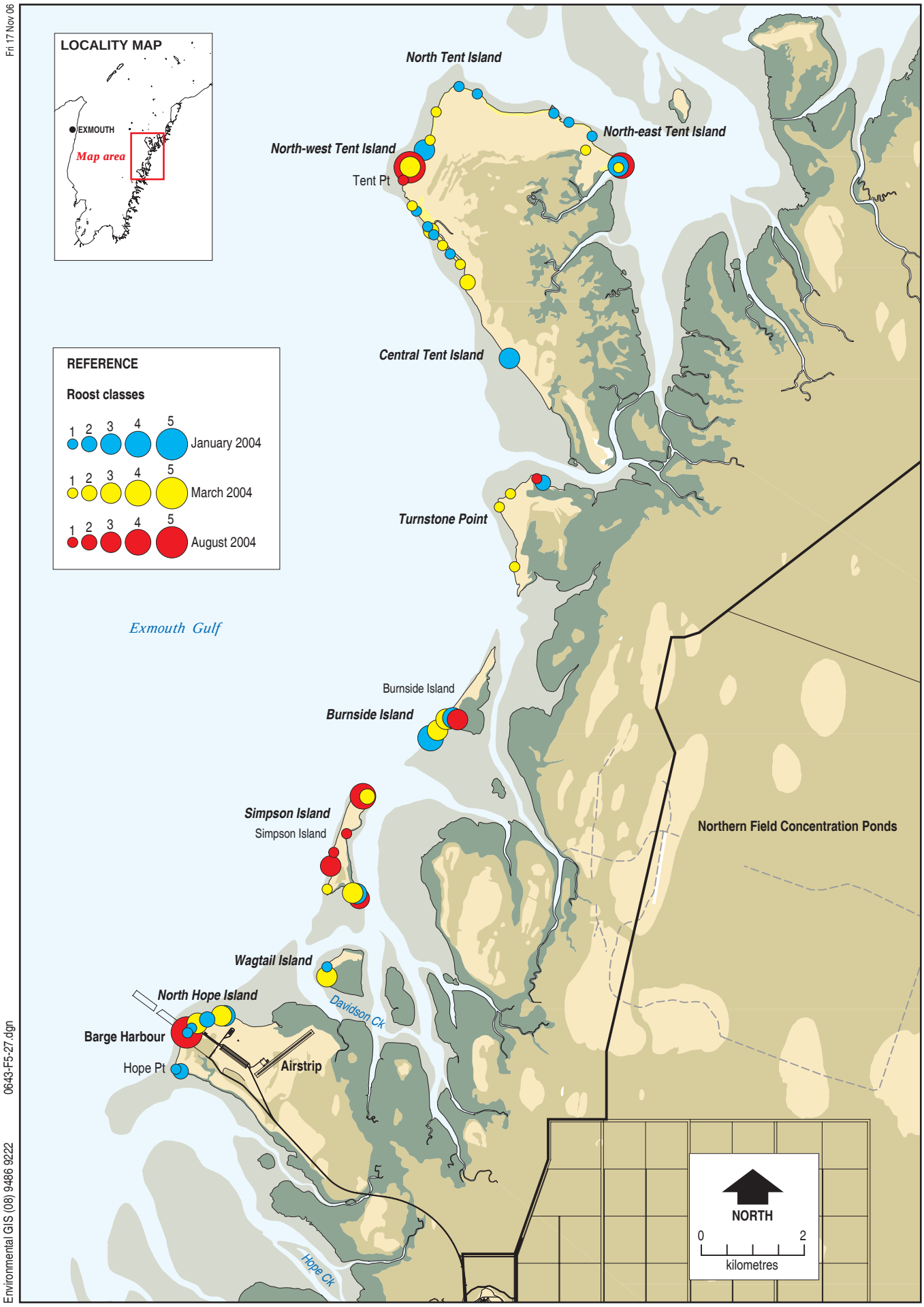
Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-26 Wader roost sizes south - west gulf to Hope Creek



Fri 17 Nov 06

0643-F5-27.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 5-27 Wader roost sizes north - east gulf - Hope Point to Tent Island

Hope Point was not an important roost site for any of the species for which the area was internationally important, except Greater Sand Plovers in August (Biota 2005d). Hope Point supported less than 7% of the Grey-tailed Tattlers present in the wider study area in all seasons and did not support any Bar-tailed Godwits or Sanderlings on the northward migration. The proportion of Ruddy Turnstones using Hope Point on northward migration was just over 2%. Almost half of the Greater Sand Plovers present in the survey location were roosting on Hope Point in August and this roost represents almost 0.5% of the estimated flyway population (Dr. M. Bamford, 2005, pers. comm.).

Large numbers of birds used the mudflats around the nominal pump stations sites and Hope Point in January and March (Biota 2005d). This is probably typical for most of the southward migration, non-breeding and northward migration seasons (September to March inclusive). The counts around Hope Point showed that this area is also important for foraging. The number of birds using the Hope Point Creek Mouth and North Hope Point was roughly similar (with seasonal variation). However, most birds in the Creek Mouth were foraging around the small island to the east of this location. In North Hope Point, most birds were foraging in the eastern half of the mudflats.

5.3.5 Mangrove fauna

In addition to the mangrove-dependent birds discussed above, a number of other fauna were recorded or likely to occur in mangrove habitats within the project area.

Evidence of Euro *Macropus robustus* was recorded from the upper limit of the mangrove zone in areas adjacent to terrestrial habitat and they probably visit this fringe when the tide is out (Biota 2005d).

Two mangrove snake species were recorded during the mangrove field surveys, the Mangrove Mud Snake *Ephalophis grayae* and the Banded Mangrove Snake *Hydrelaps darwiniensis* (Biota 2005d). Both species have previously been recorded from mangrove habitats at Onslow (Biota 2003) and are relatively widespread along the arid and tropical mangrove coast of Western Australia.

Due to logistical and technical difficulties with ultrasonic call recording equipment, sampling for bats was not completed in mangrove habitats. However, the Little North-western Mastiff Bat *Mormopterus loriae coburgiana* (a mangrove specialist) has previously been recorded in the region (Start and McKenzie 1992), and it is likely that this species occurs in the mangroves of the project area (Biota 2005d).

The Little North-western Mastiff Bat wider distribution encompasses Western Australian coastal areas from Derby to Exmouth. It is endemic to Australia (Churchill 1998) and is listed as a Priority 1 species by DEC. This species has been recorded as roosting in crevices in dead upper branches of the mangrove *Avicennia marina*. Individuals emerge above the mangrove canopy early in the evening in groups of up to 100, before dispersing to forage on insects alone or in pairs. They are restricted to mangrove forests and adjacent area. They give birth to single young, which are born in the wet season (summer) (Churchill 1998). It is unclear what effect (if any) Cyclone Vance may have had on bat populations in the study area (Biota 2005d).

5.3.6 Mammals

Seven native and five introduced mammal species were recorded from the study area during the fauna survey conducted by Biota (2005b). The mammals recorded include the echidna, three carnivorous marsupials, one kangaroo, three rodents, sheep, cattle, feral cat and fox. Sheep and cattle were widespread on the hinterland on Yanrey Station.

The 12 mammal taxa recorded (seven native and five introduced) can be compared with:

- 16 ground mammal species (nine native and seven introduced) recorded in total by the WA Museum over four seasonal collecting periods (from 1998 to 2000) at the Griffin Gas Plant area near Tubridgi Point north of the study area (WA Museum 2005)
- four phases of seasonal sampling over five years on similar mainland remnants at Onslow, which have yielded a total of 12 ground mammal species (eight native and four introduced) (Biota 2005c).

These comparison datasets from similar coastal habitats in the locality indicate that the mammal fauna of Yannarie Solar Project area was well sampled for a single survey phase. Removing overlaps, the combined mammal fauna documented for this section of coastal habitat from the three datasets (Biota 2005b and 2005c, WA Museum 2005), totals 12 native species. The five native ground mammal species recorded from other surveys not recorded from the Yannarie Solar Project area are the Northern Quoll *Dasyurus hallucatus*, Red Kangaroo *Macropus rufus*, Lakeland Downs Mouse *Leggadina lakedownensis*, *Ningaui Ningaui timealeyi* and Planigale—*Planigale* sp. (Biota 2005b).

Of these mammals, *Dasyurus hallucatus* and *Leggadina lakedownensis* are the only taxa of special conservation significance which may occur. The Red Kangaroo, Ningaui and Planigale are likely to occur in the habitats of the study area, and additional survey work would probably add these to the current tally.

5.3.7 Reptiles

Thirty-four reptile species were recorded from the Yannarie Solar Project area during the project fauna survey (Biota 2005b). This total included seven Gekkonids (geckos), two Pygpodids (legless lizards), four Agamids (dragon lizards), 13 Scincids (skinks), three Varanids (goannas), one Typhlopid (blind snake) and four Elapids (front-fanged snakes).

This total of 34 taxa compares with:

- 49 reptile species recorded by the WA Museum over four seasonal collecting periods (from 1998 to 2000), at the Griffin Gas Plant area near Tubridgi Point, north of the study area (WA Museum 2005)
- four phases of seasonal sampling over five years on similar mainland remnants at Onslow, which have yielded a total of 43 reptile species (Biota 2005c).

Removing overlaps, the combined reptile taxa documented for this section of coastal habitat from the three datasets totals 58 reptiles (Biota 2005b and 2005c, WA Museum 2005). Four of these are reptile species only recorded during the current survey and not previously collected from the locality by the WA Museum (2005) or Biota (2005c). All of the reptile species recorded from other surveys but not recorded during the current study, occur more widely in the Pilbara and Carnarvon Bioregions (Biota 2005b).

5.3.8 Amphibians

Two species of Myobatrachids (Australasian Ground Frogs), were recorded from the project area (Biota 2005b).

This total of two species compares with four species recorded by the WA Museum over four seasonal collecting periods (from 1998 to 2000), at the Griffin Gas Plant area near Tubridgi Point, north of the study area (WA Museum 2005). Four phases of seasonal sampling over five years on similar mainland remnants at Onslow failed to yield any amphibian species (Biota 2005c).

Removing overlaps, the combined amphibian taxa documented for this section of coastal habitat from the three datasets (Biota 2005b and 2005c, WA Museum 2005), totals five amphibian species (Biota 2005b).

5.3.9 Invertebrates

The survey of the Yannarie Solar project area collected 915 invertebrate specimens, representing 17 orders. (Biota 2005b). Only those taxa of conservation significance are discussed here.

Short-range endemics

Many recent publications have highlighted taxonomic groups of invertebrates with naturally small distributions at the species level (less than 10,000 km^2) (Harvey 2002, Ponder & Colgan 2002, Clark & Richardson 2002). These taxa are variously described as 'narrow range endemics' or 'short-range endemics' (Harvey 2002), and are in part characterised by poor dispersal capabilities, confinement to disjunct habitats and low fecundity (Harvey 2002, Ponder & Colgan 2002). Given the potential importance of short-range endemism to the conservation of biodiversity, the assessment of such invertebrate taxa is becoming an important component of impact assessment, as recognised by the EPA (EPA 2003).

Examples of taxonomic groups that show high levels of short-range endemism in this respect include millipedes, mygalomorph spiders, and freshwater and terrestrial molluscs.

Mygalomorph spiders

A total of four mygalomorph spider individuals were collected during the survey, all of which belonged to the family Nemesiidae (Biota 2005b).

Pulmonate snails

Samples of pulmonate snails (land snails) were collected as both live and dead specimens. Live specimens were collected by excavating beneath *Triodia* hummocks and were submitted to Associate Professor Mike Johnson (University of WA School of Animal Biology) for future genetic analysis and to the WA Museum (Garth Humphreys 2006, pers. comm.).

5.3.10 Significant species

One Schedule fauna species (Rainbow Bee-eater) was recorded during the survey of the project area (Biota 2005b), although database searches have confirmed that seven Schedule species may potentially occur within this area (Table 5-13). Summaries of Schedule fauna potentially occurring in the project area are provided below.

Only one Priority species was recorded during the survey of the project area (Biota 2005b), although database searches have confirmed that eight Priority species may potentially occur within this area (Table 5-13).

Table 5-13 Fauna species of conservation significance potentially occurring and the likelihood of occurrence within the project study area

Species	State level	Federal level	Likelihood of occurrence
Bilby *Macrotis lagotis*	Schedule 1	Vulnerable	Unlikely to occur in hinterland and would not occur on mainland remnants
Orange Leaf-nosed Bat *Rhinonicteris aurantius*	Schedule 1	-	Would not occur
Night Parrot *Pezoporus occidentalis*	Schedule 1	Endangered	Unlikely to occur
Pilbara Olive Python *Liasis olivaceus barroni*	Schedule 1	Vulnerable	Unlikely to occur
Mulgara *Dasycercus cristicauda*	Schedule 1	Vulnerable	Unlikely to occur
Peregrine Falcon *Falco peregrinus*	Schedule 4	-	May visit area occasionally
Rainbow Bee-eater *Merops ornatus*	Schedule 3	Migratory/ JAMBA	Recorded and likely to be common in study area
Lerista planiventralis maryani	Priority 1	-	May be present in study area
Little North-western Mastiff Bat *Mormopterus loriae coburgiana*	Priority 1	-	Likely to occur in mangroves
Lakeland Downs Mouse *Leggadina lakedownensis*	Priority 4	-	Unlikely to occur
Northern Quoll *Dasyurus hallucatus*	Not listed	Endangered	May occur
Western Pebble-mound Mouse *Pseudomys chapmani*	Priority 4	-	Unlikely to occur in study area
Grey Falcon *Falco hypoleucos*	Priority 4	-	May occur in coolibar woodland on Yannarie River
Star Finch (western) *Neochmia ruficauda subclarescens*	Priority 4	-	Unlikely to occur
Australian Bustard *Ardeotis australis*	Priority 4	-	Recorded and likely to occur at low densities
Bush Stonecurlew *Burhinus grallarius*	Priority 4	-	May occur

Source: adapted from Biota 2005b

Biota (2005b) completed a review of the likelihood of any of these species utilising the specific habitats to be affected by the proposed saltfield. This was based on documented distribution, ecology and field-based habitat assessments (Biota 2005b). Only one Priority species (Australian Bustard *Ardeotis australis,* Priority 4), was confirmed as occurring in the project area (recorded from Hope Point). Three other Threatened fauna species; Peregrine Falcon *Falco peregrinus* (Schedule 4), *Lerista planiventralis maryani* (Priority 1) and the mangrove specialist Little North-western Mastiff Bat *Mormopterus loriae coburgiana* (Priority 1), were considered likely to actually utilise the habitats of the study area (Biota 2005b).

Six federally listed species potentially occur within the project area (Table 5-13). Biota (2005b) completed a review of the likelihood of any of these species utilising the specific habitats to be affected by the proposed saltfield, as discussed below.

Description – Bilby (Macrotis lagotis)

Distribution

The former range of the Bilby included most of the semi-arid areas of mainland Australia, however it is now confined to *Triodia* hummock grassland and *Acacia* scrub across parts of northern Australia.

Ecology

The Bilby is a medium-sized ground mammal, ranging in weight from 1.0-2.5 kg. The species is apparently strictly nocturnal and constructs a substantial burrow system, which may be up to 3 m in length (Flannery 1990). Similar to the Mulgara, this species has been documented as showing temporary home ranges and relatively rapid changes in distribution in response to variation in habitat resources (Johnson 1995). Whilst fox and cat predation and the effect of rabbits and stock are thought to be the principle factors in the decline of the Bilby, fire regimes have also been suggested as an important factor in maintaining habitat diversity for this species (Johnson 1995).

Likelihood of occurrence

The managers of Yanery Station believe that there are historical records of this species on the pastoral lease. However, the DEC database only lists a single uncertain record over 30 years old from the locality. It is therefore considered unlikely that this species still persists on the hinterland and it would not occur in the isolated habitat remnants within the area proposed to accommodate the saltfield.

Description – Night Parrot (Pezoporus occidentalis)

Distribution

Night Parrots have been reported from every state on the Australian mainland. Apparently suitable habitat occurs, or has occurred, across most of the inland, covering at least half the continent. Records are sparsely distributed through this area. However, there does appear to be concentrations of records in western Queensland and the eastern Pilbara (Higgins 1999).

Ecology

Night Parrots inhabit areas where there is dense, low vegetation, which provides them shelter during the day. Most records come from hummock grasslands with Spinifex (porcupine grass, *Triodia*), from areas dominated by samphire or, particularly, where these two habitats are juxtaposed. It has been suggested that birds move into the grasslands when *Triodia* is seeding. They have also been reported in low chenopod shrublands with saltbush and bluebush and from areas of Mitchell grass Astrebla with scattered chenopods. Many records have come from waterholes, and almost all reports from areas of *Triodia* have noted the presence of nearby water. The species is secretive and almost all confirmed sightings of feeding or drinking birds have come after dark. Sightings during the day almost always have been birds flushed from hiding places by herds of stock, dogs or fire. Birds typically sit very tight, flushing only if the disturbance is very close, actually affecting the clump of vegetation in which it is hiding. Early observers stressed the dependence of the parrot upon dense Spinifex or samphire for daytime roosting spots and for nesting.

The Night Parrot is presumably like other arid zone birds in being markedly nomadic. The extent of the movements and the possibility of some seasonality in any part of the range are unknown. Several possible reasons have been proposed for the decline of this species in recent years including habitat

loss through clearing, changes in burning practices, stock and rabbit grazing, reduced availability of water holes or surrounding suitable food plants and predation from feral animals (particularly cats and foxes). The relative importance of these factors is unknown.

Likelihood of occurrence

Not recorded during the current survey. Just four records of this species dating back to 1967 were yielded from the DEC Rare Fauna database search for the locality. Given the age of these records, and the evidence of fox and cat activity recorded during the study, the species is considered unlikely to occur in the project area.

Description – Pilbara Olive Python (Liasis olivaceus baroni)

Distribution

Regarded as a Pilbara endemic, this subspecies has a known distribution that coincides roughly with the Pilbara Bioregion (Environment Australia 2000).

Ecology

This species shows a preference for rocky habitats near water, particularly rock pools. It may shelter in deep rock crevices, with a diet that includes birds, reptiles and mammals as large as rock wallabies.

Likelihood of occurrence

Suitable habitat for this species does not occur within the project area and it is not likely to be present.

Description – Mulgara (Dasycercus cristicauda)

Distribution

The Mulgara is a medium sized (60 – 120 g) carnivorous marsupial occurring in suitable habitat across the arid zone of Western Australia.

Ecology

This species apparently prefers mature Spinifex associations on sandy substrates. Populations are thought to contract to core habitat areas during harsh years and have also been documented as undergoing rapid expansions in response to good conditions (Woolley 1992).

Likelihood of occurrence

Pastoralists at Yanrey Station believe they may have sighted this species on the station. However, there was no evidence of Mulgara activity or suitable habitat within the project area (Roy Teale pers. obs., as cited in Biota 2005b).

Description – Northern Quoll (Dasyurus hallucatus)

Distribution

Endemic to Australia, where it occurs in the Hamersley Ranges, Kimberley, north west Austraila, Northern Territory and Queensland (Biota 2006a).

Ecology

The Northern Quoll is classed as a medium-sized marsupial, with adult weight ranging between 300 – 1200 g (Biota 2006a). It is considered a partially arboreal and aggressive carnivore, feeding on a varied diet of small invertebrates and vertebrates (Oakwood 1997, as cited in Biota 2006a). The Northern Quoll is mostly nocturnal, although it is also active at dawn and dusk (Biota 2006a).

The Northern Quoll is a short-lived mammal, with both sexes maturing at 11 months (Biota 2006a). Females reproduce once a year and all males die shortly after reproducing (Dickman and Braithwaite 1992, Oakwood 2000, as cited in Biota 2006a).

Likelihood of occurrence

May occur in the project area (Biota 2005b).

Description – Rainbow bee-eater (Merops ornatus)

Distribution

The Rainbow Bee-eater is relatively common in Western Australia, however is not common in eastern Australia. The species is a breeding visitor from northern Australia and Indonesia. It visits in late August to early April, mainly arriving in late September or early October and leaving in February or early March (Biota 2006b). The species occurs in lightly wooded, preferably sandy country near water (Biota 2006b).

Ecology

Rainbow Bee-eaters breed from late October to early December, usually in pairs, rarely small colonies. Nests consist of a burrow dug at a slight angle in flat ground, sometimes into sandy banks or cuttings, and often at edges of roads and tracks (Biota 2006b).

The species is usually recorded in small parties during southward migration in spring, in pairs (rarely small colonies) when breeding, and in small parties or flocks (up to 100 individuals) after breeding and during northward migration. It generally forages on insects especially hive bees, flies, dragonflies and grasshoppers (Biota 2006b).

Likelihood of occurrence

Recorded in January 2005 at Burnside and Simpson Islands (Biota 2005b).

5.3.11 Exotic species

Five species of introduced mammals were recorded from the study area. Sheep (*Ovis aries*) and cattle (*Bos taurus*) were widespread on the hinterland on Yanrey Station. Also recorded were the House Mouse (*Mus Musculus*), Cat (*Felis catus*) and Fox (*Vulpes vulpes*).

5.4 ASSESSMENT AND MITIGATION OF POTENTIALLY SIGNIFICANT IMPACTS

5.4.1 Potential impacts

Activities or aspects of the proposal that may potentially affect terrestrial fauna include:

- **site preparation** will involve removal or disturbance of fauna habitat from areas proposed for the Hope Point dredge harbour and infrastructure associated with buildings, site offices and the construction camp
- **vehicle and equipment movement** within the project area and haul roads could result in occasional fauna deaths
- **noise emissions** from the operations within the dredge harbour and associated infrastructure may make habitat close to the operations unsuitable for fauna foraging and/or habitat.

5.4.2 Assessment and management of potential impacts

Site preparation

Almost all native fauna relies on native vegetation for their needs for shelter, food and breeding sites. The loss or degradation of native vegetation will reduce its capacity to support the range of species it does in an undisturbed state. Six broad terrestrial habitat types were identified in the study area (Table 5-14), all of which are expected to support a range of fauna species. In addition to these habitat types, mangrove associations were also mapped, and these associations also support a range of fauna species.

A total of approximately 166 ha of fauna habitat will be cleared for the proposal. Approximately 160 ha of terrestrial fauna habitat will be permanently cleared to accommodate infrastructure for the saltfield and infrastructure (Chapter 5, Section 4). In addition to this, approximately 5.36 ha of mangrove habitat will be cleared to accommodate project infrastructure. A breakdown of this long-term disturbance area by the habitat types categorised for the Yannarie Solar Project area (Biota 2005b, 2005d), is provided in Table 5-14.

Table 5-14 Predicted habitat clearing for infrastructure requirements for the Yannarie Solar Project

Vegetation code	Habitat type	Extent mapped in study area (ha)	Area cleared (ha and % of extent mapped in study area)
1a	Samphire on mainland remnant margins and inland saline flats	420.7	14.5 (3.4%)
2a	Vegetation of eroded dunes on the edge of the hinterland	1384.5	5.4 (0.4%)
2b	*Melaleuca cardiophylla* shrubland over *Triodia epactia* on Limestone outcroppings in coastal dunes	2.08	0.02 (1.0%)
2c	Vegetation of dune swales and interdune flats	6946.4	112.4 (1.6%)
2d	Vegetation of longitudinal red sand dunes	1945.5	27.0 (1.4%)
2e	Unconsolidated sandsheet	73.4	0
3a	Bare claypans with fringing plant communities	124.8	2.0 (1.6%)
AM2	Low, dense *Avicennia marina* shrubland *	8485	1.51 (0.01%)

Vegetation code	Habitat type	Extent mapped in study area (ha)	Area cleared (ha and % of extent mapped in study area)
AM3	Low, open to very open *Avicennia marina* scrub on landward margins *	2058	3.85 (0.19%)
TOTAL		**21,440.38**	**166.68**

Source: adapted from Biota 2005a, 2005d

Note: 1) Values are for mapped area of vegetation types only.

2) The percentage clearing in areas where vegetation type mapping was not available was assessed through loss of land system units. This was principally associated with access tracks on the hinterland and the construction camp.

* A mosaic of moribund mangroves recovering from cyclone damage occurs within these units that could not be accurately mapped; the extent of this was instead assessed by imagery classification (Biota 2005d).

This loss of habitat (and the direct mortality of individuals during clearing activity) will be the principal impact on terrestrial fauna arising from this proposal. Impacts on selected species of conservation significance are discussed below:

- Wader and shoreline bird species – clearing will lead to the loss of approximately 5.36 ha of mangrove habitat which may potentially be used by wader and shoreline birds as feeding and breeding habitat. Breeding habitat may be replaced after rehabilitation although it may take time for new habitats to become established. Clearing of mangrove habitats will be minimised through project design and construction, to minimise impacts on wader and shoreline bird species.
- Australian Bustard *Ardeotis australis* (Priority 4 species) – this species has been recorded from the project area and probably occurs widely in similar habitats throughout the area, however given its habitat preferences, it will be negligibly affected by the proposed development (Biota 2005b).
- Rainbow bee-eater *Merops ornatus* (Migratory species/JAMBA) – this species has been recorded from the project area and is probably quite common in the areas wherever suitable habitat is available. Given its habitat preference it will be negligibly affected by the proposed development (Biota 2005b).
- Small mammals and reptiles – clearing may lead to some loss of feeding and breeding habitat, although most of these species are physically small, have localised home ranges and would rarely, if ever, venture from the terrestrial habitats of the remnants.

The similarity in fauna habitats throughout the area is reflected in the ground fauna assemblage, with most species recorded from the study area being represented in other sites locally or in the wider region (Biota 2005b). The mainland remnants are generally more intact from the perspective of fire history and weed invasion, and they are also somewhat isolated from the influences of pastoral grazing pressure and feral predators present on the hinterland (Biota 2005a). Although foxes and cats were both recorded from the saltflat mainland remnants, an opportunity exists to create small fauna reserves when the field is flooded and these remnants become isolated as true islands. The value of this, and the conservation value for fauna of each mainland remnant currently, is likely to be proportional to the size of the island and the array of habitat types represented.

Management measures to address loss of habitat

Straits flora and fauna conservation strategy will be developed in consultation with DEC, and aims to minimise impacts on fauna populations through management measures including:

- undertaking extensive fauna surveys on a seasonal basis
- retention of the majority of vegetated areas within the project area
- utilising the barren salt flat for the majority of the bunds and evaporator ponds
- collaborative feral animal control programs (e.g. fox control on mainland remnants)
- investigating options for maintaining or establishing wildlife corridors and linkages
- prompt rehabilitation of disturbed areas with re-creation of fauna habitats
- workforce environmental education programs and training.

Vehicle and equipment movement

The impacts from vehicle and equipment movement are difficult to quantify, but are likely to operate at a relatively low level compared to the distribution and abundance of the terrestrial species present across the wider project area and locality (Biota 2005b). Vehicle types and frequency of movement will be determined once the operation has been commissioned.

Management measures to address impact from vehicle and equipment movement

Straits fauna conservation strategy will be developed in consultation with DEC and aims to minimise impacts on fauna populations through management measures including:

- workforce environmental education programs and training (e.g. information brochures and workshops on fauna species of conservation significance)
- compliance with site speed limits.

Noise emissions

Noise will mainly be a factor within and adjacent to the barge harbour, loading area and port related infrastructure. Most of the impacts from noise are difficult to quantify, but are likely to operate at a relatively low level compared to the distribution and abundance of the terrestrial species present across the wider project area and locality (Biota 2005b).

Management measures to address impact from noise

Straits fauna conservation strategy will be developed in consultation with DEC and aims to minimise impacts on fauna populations through management measures including:

- workforce environmental education programs and training regarding noise regulations and limitations
- compliance with noise regulations
- minimisation of noise from loading operations during the breeding and nesting season of shore birds and waders
- incorporation of bunds to reduce noise
- retention of the significant majority of vegetated areas within the project area.

5.5 MONITORING AND ASSESSMENT OF PERFORMANCE

Baseline fauna surveys have been undertaken by Straits (Biota 2005b). Straits will regularly monitor the abundance and distribution of fauna in the vegetated and rehabilitated areas within the project site, to monitor the effectiveness of fauna management measures. These measures will be implemented in consultation with DEC to assess whether the project meets the environmental objectives and proponents commitments. The results from the monitoring will be used to improve future fauna management measures.

5.6 PROPONENT COMMITMENTS

Terrestrial fauna issues will be addressed by the following management commitments:

- undertake baseline fauna surveys of areas adjacent to the project area, prior to site disturbance. This will enable determination of transient species that may potentially be impacted through disturbance or vegetation loss
- regularly monitor the abundance and distribution of significant fauna species
- implement a feral animal control program
- trial re-creation of fauna habitats in areas to be rehabilitated.

Straits proposes to consolidate these commitments into the preparation and implementation of a Fauna Management Plan which would include:

- a program to conduct seasonal fauna surveys. These will contribute to existing knowledge of the distribution and extent of fauna of significance and associated habitats, and will:
    - determine habitat associations of fauna (especially short-range endemic invertebrates, reptiles and shoreline birds) in order to determine the local significance and impact of the proposed operations. This will include determination of any effects on fauna as a result of fragmentation and isolation of habitat
    - determine measures of abundance of significant species (especially critical weight range mammals)
- a collaborative feral animal program that integrates feral cat and fox control measures
- maintenance of wildlife corridors wherever practicable
- establishment of fauna habitat zones (e.g. mangrove, hinterland) to customise management regimes
- re-creation of fauna habitat in rehabilitation areas to encourage fauna re-colonisation
- monitoring of recruitment of fauna into rehabilitation areas
- management of vehicle and equipment movement within the project area
- further research into the extent and significance of fauna habitat within and adjacent to the project area.

5.7 ENVIRONMENTAL OUTCOME

The primary outcome that Straits aim to achieve in relation to terrestrial fauna is to reduce the risk of adverse impacts on the regional abundance of significant species. The successful rehabilitation of disturbed areas may encourage fauna to return to current abundance and distribution and the control of feral animals within and surrounding the project area will have positive benefits to fauna values.

Experience at other Western Australian saltfields has indicated a potential benefit for migratory birds and other shorebirds. Observations at the Port Hedland saltfield have been that the concentrator ponds have developed into a significant habitat attracting over twenty CAMBA and JAMBA listed migratory species (Dampier Salt Limited 2006).

The ongoing fauna surveys and associated monitoring and research will also increase the knowledge of fauna ecology in the region.

Chapter 6

Marine factors

- Marine water and sediment quality
- Benthic primary producer habitat and ecological integrity
- Marine fauna

Chapter 6 Marine factors

1 MARINE WATER AND SEDIMENT QUALITY

The proposal is located on the eastern coast of Exmouth Gulf and there are environmental aspects of the proposal that may lead to changes to water and sediment quality.

Originally the proposal included the discharge of bitterns which was one of the environmental aspects that gave rise to the most concern. A Bitterns Resource Recovery Strategy (Appendix 1) has been developed which aims to recover all resource values (other salts and magnesium) from the bitterns and result in no discharge of bitterns to the marine environment. If complete re-use is somehow not practicable, the discharge of bitterns will be referred to the EPA for consideration under Part IV of the EP Act.

Appendix 1 provides a description of the resource recovery strategy including the anticipated characteristics of bitterns at the various stages of the recovery process. Preliminary modelling results for new industry best practice discharge of various bitterns products is also provided for information purposes.

1.1 SEDIMENT QUALITY

The proposal does not involve the discharge of substances that may accumulate or change the chemical characteristics of marine sediments however, the loss of anti-foulant coatings has the potential to affect sediment quality. The effect of anti-foulants is addressed in Chapter 6, Section 3.4.8 and will not be addressed further in this section.

The potential changes to sediment regimes in some tidal creeks is addressed under Benthic Primary Producer Habitat (Chapter 6, Section 2) and Marine Fauna (Chapter 6, Section 3) environmental factors.

EPA objective

- *To maintain or improve marine water and sediment quality in compliance with sediment and water quality guidelines documented in Australian and New Zealand Water Quality Guidelines (ANZECC 2000).*

1.2 LEGISLATIVE AND POLICY AND CONTEXT

1.2.1 National Water Quality Management Strategy Australian and New Zealand Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment Conservation Council (ANZECC) together with the Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) released a set of water quality guidelines for the protection of marine and freshwater ecosystems (ANZECC & ARMCANZ 2000).

The framework for applying the guidelines involves the following:

1. Define primary management aims which may be a statement of environmental values (particular uses or values of the environment) and level of protection (water quality necessary to protect values) to maintain these values.
2. Determine appropriate water quality guidelines (concentration of substances) tailored to local conditions.
3. Define water quality objectives that indicate the water quality to be achieved and may be concentrations of substances or a descriptive statement.
4. Monitoring and assessment program to determine whether water quality objectives are being achieved.
5. Management response to attain or maintain water quality objectives.

The guidelines recognise a number of environmental values and assign "trigger values" for each value for substances that may impair water quality. If a trigger is exceeded or predicted to be exceeded further investigation or a management response may be initiated.

Two levels of guideline trigger values were recommended:

1. Low-risk guidelines below which there is low risk that adverse biological effects will occur.
2. High risk guidelines above which there is a significant risk that adverse biological effects will occur.

The guidelines provide a comprehensive list of recommended low trigger values for physical and chemical stressors broken down into five geographical regions across Australia and New Zealand.

1.2.2 EPA Environmental Quality Management Framework and protection for Exmouth Gulf

EPA Environmental Quality Management Framework

The EPA has developed an Environmental Quality Management Framework (EQMF) for marine waters which involves the development of the following hierarchy and has applied this to the Exmouth Gulf (DoE 2006):

1. Environmental values (EVs) using the five environmental values prescribed by the national guidelines relevant to Exmouth Gulf – ecosystem health, recreation and aesthetics, cultural and spiritual, fishing and aquaculture, and industrial water supply.
2. Environmental quality objectives (EQOs) are the outcomes required – equivalent to the management goals in ANZECC & ARMCANZ 2000.
3. Level of ecological protection (LEP) - maximum, high, moderate or low (relevant to ecosystem health value only).
4. Environmental quality criteria (EQC) are concentrations of substances.

The maintain ecosystem health EQO has four different LEPs each representing a different environmental quality condition and an associated limit of acceptable change that would apply across all areas including those areas where existing social uses have been recognised:

1. Maximum - no contaminants (pristine, no change from background conditions) and no detectable change from natural variation of biological indicators.
2. High - very low levels of contaminants and no detectable change from natural variation of biological indicators.
3. Moderate - elevated levels of contaminants and moderate changes from natural variation of biological indicators.
4. Low - high levels of contaminants and large changes from natural variation.

EPA interim EV, EQOs and LEPS for the Exmouth Gulf

The EPA has adopted interim EVs, EQOs and LEPs for the Exmouth Gulf since the referral and scoping of the environmental assessment of this proposal to the EPA (Figure 6-1).

The interim EQO (management goal) for the identified EV of ecosystem health for the east coast of the Gulf in proximity to the project area is defined as follows:

"Maintain Ecosystem Integrity – This means maintaining the structure (e.g. the variety and quantity of life forms) and functions (e.g. the food chains and nutrient cycles) of marine ecosystems."

The maximum level of ecosystem protection has been assigned for this EQO on the east coast of the Gulf adjoining the project area. This level of protection (which recognises conservation as a pre-eminent value of the area) does not either explicitly permit or disallow industry from the area but will significantly constrain discharge and disturbances from commercial and land use activities (Department of Environment 2006).

The interim framework has proposed low protection levels adjacent to large existing activities and population centres.

1.3 DESCRIPTION OF CIRCULATION, CURRENTS AND MARINE WATER AND SEDIMENT QUALITY

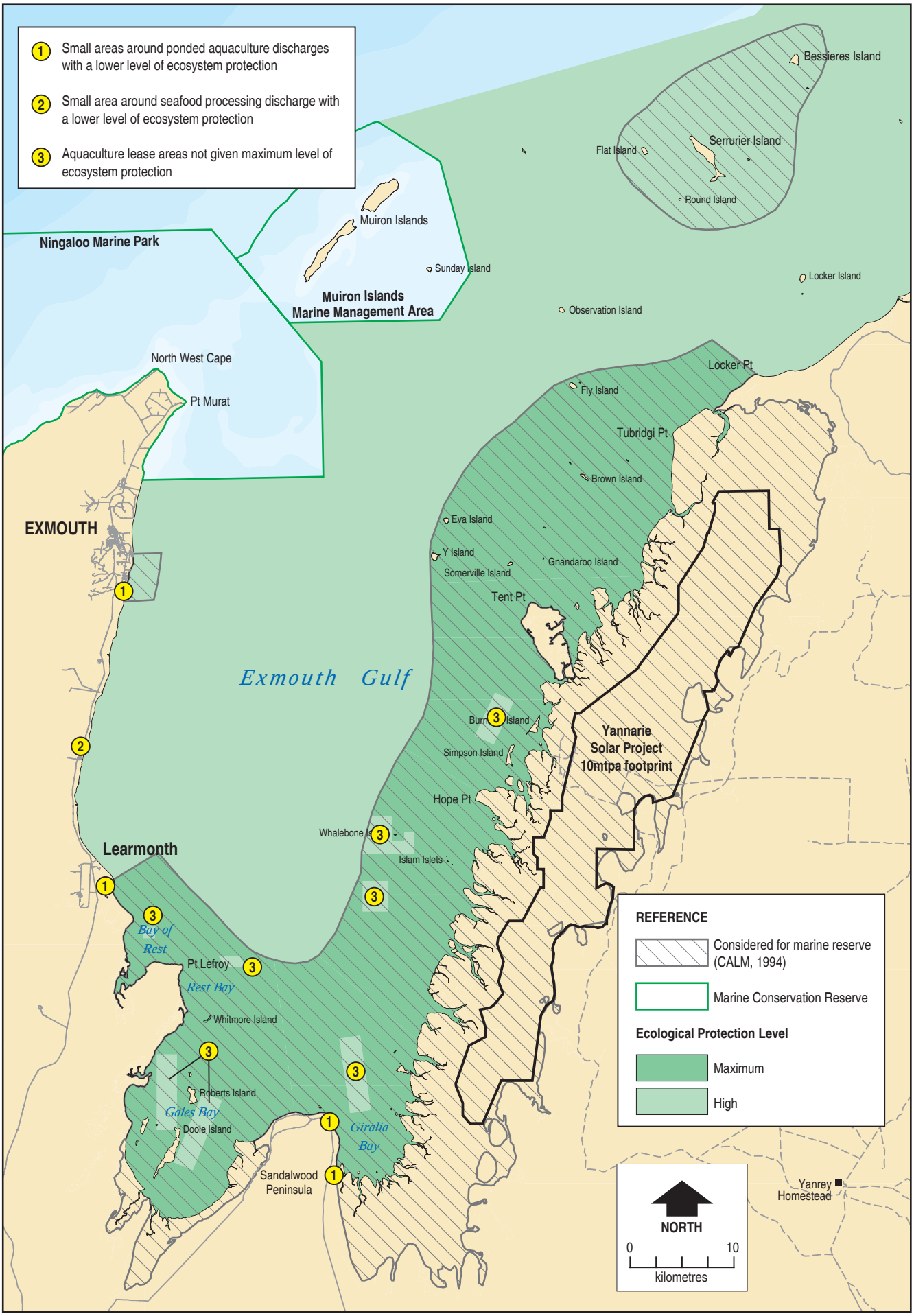
1.3.1 Regional context

Leeuwin Current

The Leeuwin Current is drawn from warm waters north of North West Cape. This relatively low salinity current flows along the outer North West Shelf most strongly between February and June. From the North West Cape south, the warm Leeuwin Current flows southwards along the continental shelf but can meander offshore and form large loops or eddies (Chapter 4, Section 2).

The current speed averages about 0.5-1 knot where the continental shelf narrows to about 10 km off the Ningaloo Coast. The Exmouth Gulf is at the head of the Leeuwin Current and is consistently affected by water waters flowing down from the north during summer months unlike the Ningaloo Reef which can be affected by colder northward longshore currents.

In the winter months consistent southerly winds create localised upwelling of colder water nearshore forcing the warmer waters away from coastal waters.



Tue 12 Sep 06

0643-F6-01.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-1 EVs, EQOs and LEPs for Exmouth Gulf

Datum: MGA Zone 50
Source: Dep't of Environment, 2004
Date: 11 Sep 2006

Waves

The Gulf is protected by the North West Cape from Indian Ocean wave energy, which arrives from the south west except during cyclone events where wave swell may be generated from the north west and attenuated by Muiron-Serrurier Island chain.

The primary form of wave energy in the Gulf comes from local wind generated waves predominantly from the south west and south east. The wave energy is greater in the northern section along the east coast because of the greater fetch and deeper waters. It appears that the dominant south westerly wind has played a key role in determining the habitat types along the east coast of the Gulf (Oceanica 2006a).

Water levels in the Gulf

Water levels in the Gulf are influenced by (Oceanica 2006a) (Appendix 7):

- astronomical tides
- barometric tides
- wind
- storm surge
- long-term sea level change
- tsunami.

There are two tides each day with the tidal range being above 1 m for a vast majority days in each month (Table 6-1). Tidal levels vary around the Gulf with the highest astronomical tide at Hope Point being about 0.4 m greater than at Exmouth.

Barometric pressure does significantly affect tides, sometimes causing 0.4 m increase in tides over the summers where low pressure systems may persist. In contrast, wind effects do not play a significant role in Gulf water levels or the ecology of the Gulf. Storm surges can a have a large impact on water levels with the maximum recorded storm surge levels estimated to be 4-6 m above mean sea level (Oceanica 2006a).

Table 6-1 Tidal levels (values above Chart Datum in metres) at Exmouth and Hope Point

	HAT	MHWS	MHWN	MSL	MLWN	MLWS	LAT	CD
Exmouth	2.8	2.3	1.7	1.4	1.1	0.5	0.0	0.0
Hope Point	3.17	2.67	2.06	1.74	1.24	0.62	~0.3	0.0

Source: Oceanica 2006a

HAT: Highest Astronomical Tide
MHWS: Mean High Water Springs
MHWN: Mean High Water Neaps
MSL: Mean Sea Level (long-term sea level)
MLWN: Mean Low Water Neaps
MLWS: Mean Low water Springs
LAT: Lowest Astronomical Tide
CD: Chart Datum

1.3.2 Circulation and currents

Previous studies

Massel *et al.* 1997 developed a preliminary computational hydrodynamic model and used it to run particle tracking exercise using wind data from Learmonth. The exercise showed that tidal excursion length was less than 5 km and that most of the particles had left the model domain within 28 days. This work also demonstrated that only a localised area of the Gulf, near Point Murat, exchanges directly with Ningaloo Reef.

Studies for the ERMP

Modelling

APASA developed a circulation model of the Gulf specifically to examine issues related to this proposal. The work was undertaken in two phases:

1. Phase I (APASA 2005a) reported the development and validation of a 2-dimensional tidal elevation and tidal circulation model to provide tidal elevation data as input to a tidal inundation model for the east cost of the Gulf developed by WorleyParsons (2005b and c). The Australian Institute of Marine Science (AIMS) supplied current and tidal data collected from 8 October to 16 December 1994 to validate the APASA model, which was found to replicate the measured tides throughout the Gulf.
2. Phase II (APASA 2005b) modelling incorporated varying wind fields. These wind fields were generated from two sources:
    - the University of NSW, Centre for Environmental Mathematics and Physics provided a two-dimensional wind field for the surface layer (10 m altitude) that was output from a local scale atmospheric model (HIRES)
    - a spatially varying windfield was generated by interpolating measurements of wind speed and direction made on the west coast (Learmonth) and east coast (Hope Point) of the Gulf. The wind field spanned a four month period of wind measurement during summer and autumn (December 2004 – April 2005). HYDROMAP simulations were produced using wind fields generated from a local scale atmospheric model and tidal forcing for October – December showing flushing of the Gulf (Figure 6-4).

Peer review of modelling studies

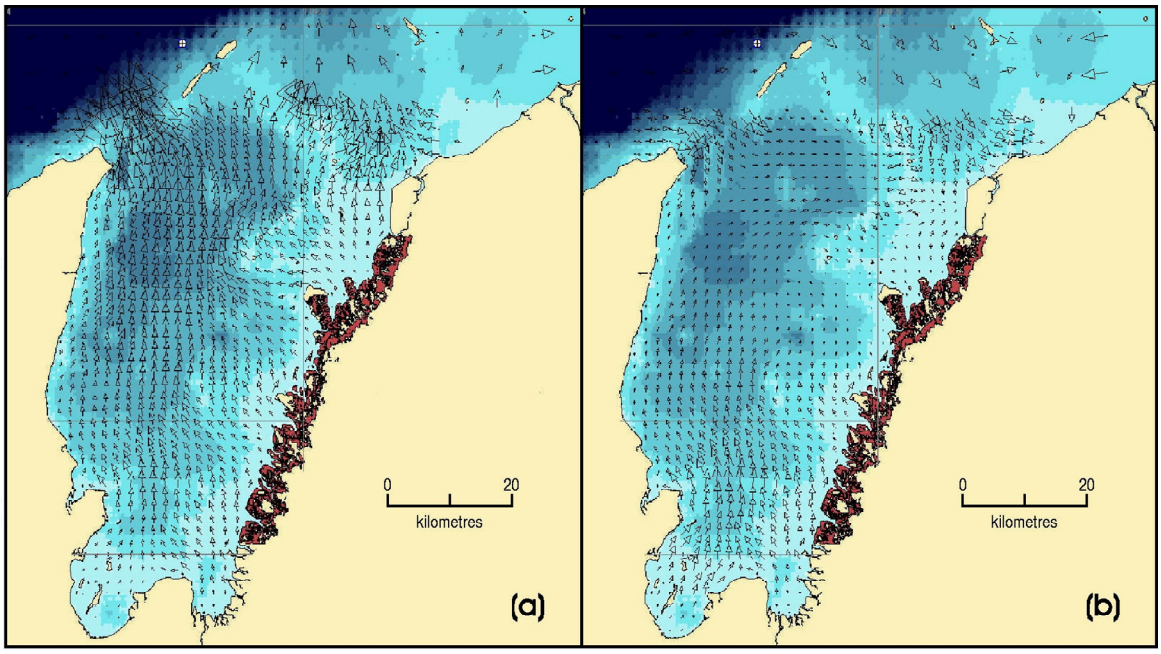
Dr Chris Fandry (CSIRO) and Dr Clifford Hearn (United States Geological Survey) reviewed the configuration of APASA (2005a & b) circulation model and its validation and concluded that the model configuration provided a sound basis for development of regional circulation model.

Current measurements

Current measurements were made by AIMS over the December 2004 – April 2005 period by AIMS along the eastern coast of the Gulf at three locations (APASA 2005b). Comparison of predicted and observed current vectors found that the model was producing tidal currents of similar magnitude and direction and that flow was synchronous (Oceanica 2006a).

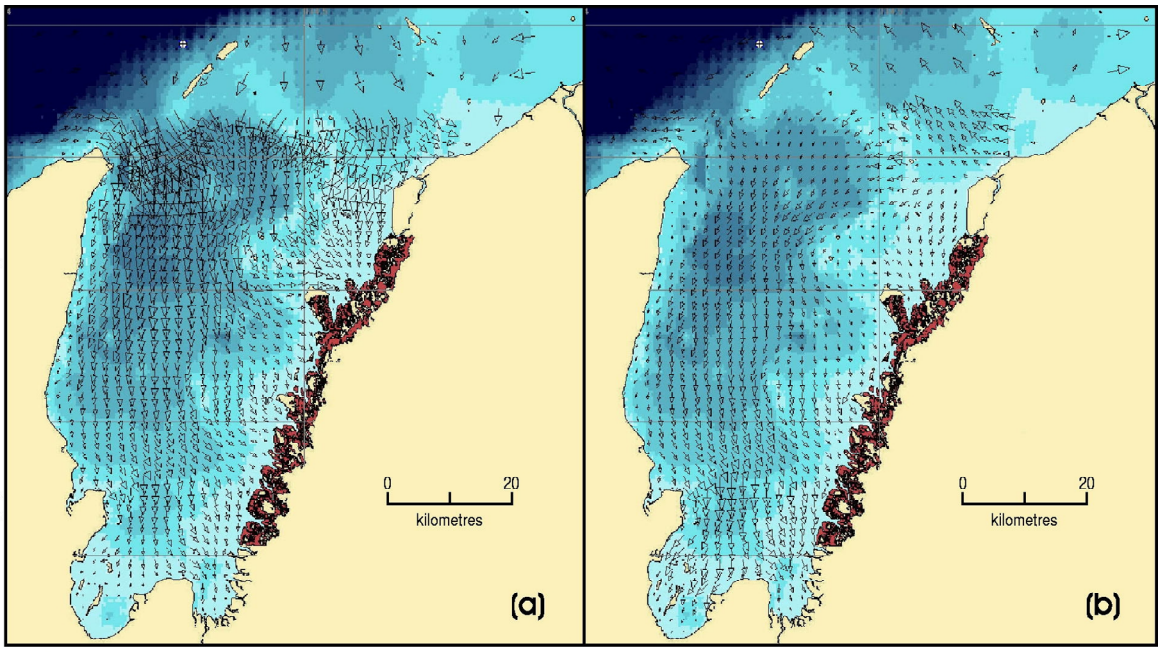
Results of modelling work

The tidal circulation along the deeper waters of the western margin, from tidal forcing alone are primarily oriented north-south, while tidal migrations along the eastern margin are more complex and steered by local topography (Figure 6-2 and Figure 6-3).



Source: APASA 2005a

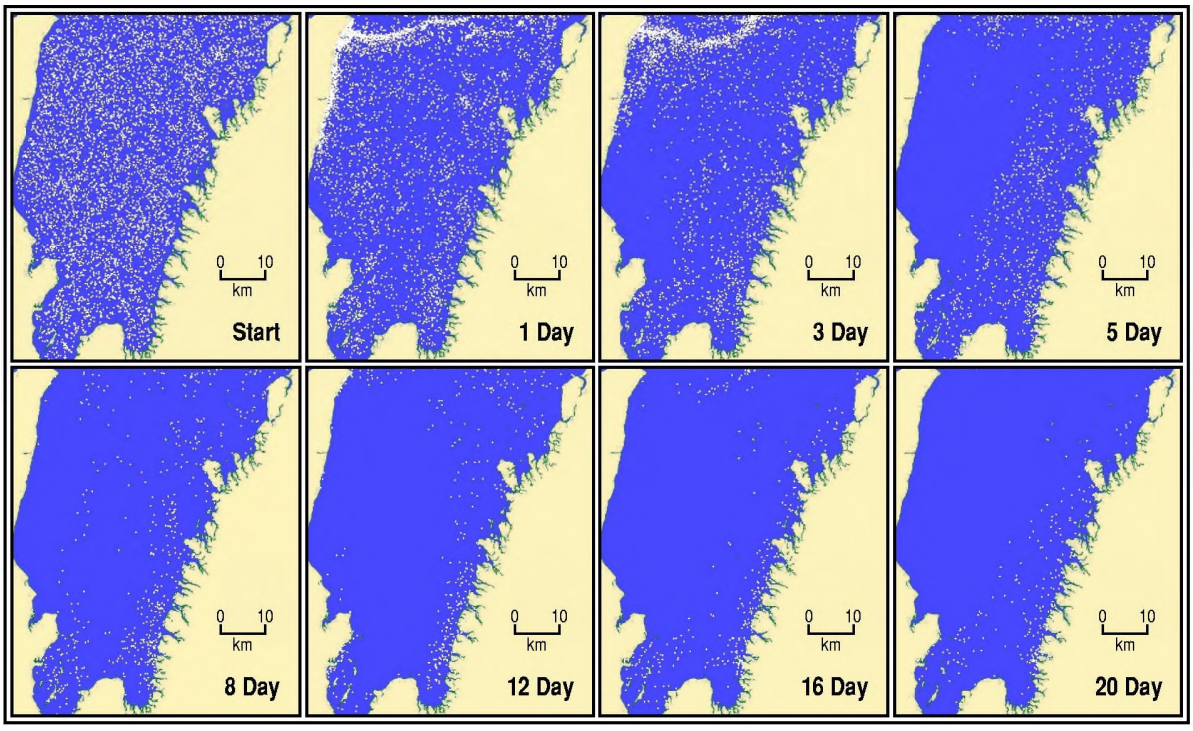
Figure 6-2 Tidal currents in the Gulf: Peak ebb (a), and +3 hours after peak ebb (b)



Source: APASA 2005a

Figure 6-3 Tidal currents in the Gulf: Peak flood (a), and +3 hours after peak flood (b)

The influence of regional-scale circulation on the likely transport of materials was investigated by particle tracking modelling. In these simulations conservative particles were released at uniform concentration throughout the Gulf and their movement was predicted over a period of 20 days. This modelling indicated that particles will tend to migrate backwards and forwards with tidal currents but undergo a net movement out of the Gulf (Figure 6-4).



Source: APASA 2005b

Figure 6-4 Flushing of Exmouth Gulf

The key conclusions from modelling in summary were:

1. Tidal excursion length was less than 5 km which is too short for to allow significant quantities of water to be drawn out the Gulf on any one tide. The indicative residence time of the Gulf is about 28 days.
2. A tidal "front" 5 km wide may develop about 5-10 km offshore which has been observed in Landsat imagery field (Oceanica 2006a).
3. The waters within about 2-5 km of the eastern shore tend to move into the tidal creek system with each tidal cycle, resulting in 'tidal trapping' of waters between shallow offshore areas and tidal creeks.
4. Only a localised area of the Gulf exchanges directly with Ningaloo region.
5. Tides and winds are important influences on circulation patterns within the Gulf.
6. The western side of the Gulf tends to flush out in a shorter time than waters on the eastern side of the Gulf. Flushing on the eastern side was the slowest with no obvious tendency for water to migrate from the eastern half to the northwest entrance to the Gulf but a tendency to migrate (forced by wind) along the eastern margin.

1.3.3 Sediment quality

Previous Studies

Brunskill *et al.* (2001) conducted a comprehensive survey of sediments of Exmouth Gulf and has provided the main basis for current understanding of sediment quality and origins in the Gulf.

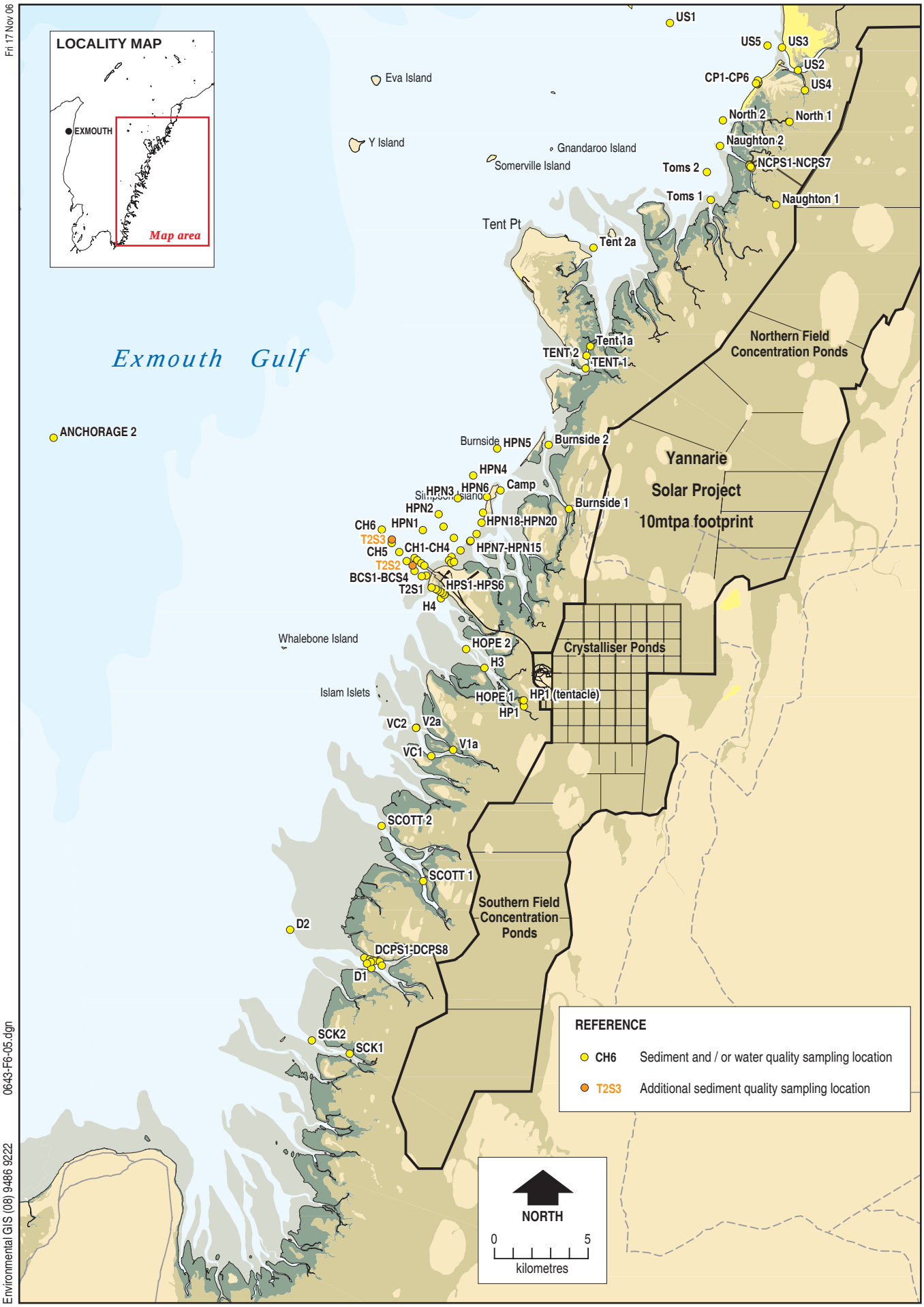
Studies for the ERMP

Oceanica (2006a) conducted sediment sampling for metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Hg) at all sites, particle size distribution at most locations and tributyltin and nutrients at some sites on the eastern side of the Gulf, to provide information suitable for a baseline monitoring program (Figure 6-5).

Key results of sediment studies

The key results of the above studies were:

1. Sediments of the Gulf are dominated by carbonate and quartz sand in a strongly oxidising environment to 50 cm depth.
2. There are no distinct geochemical or sedimentary plumes of riverine rich sediment within the basin.
3. Sediment accumulation rates are extremely small (<1 m for the Holocene) and some of the intertidal mangroves and salt flat regions appear to be zones of erosion rather than deposition.
4. The east coast mangrove and salt flat sediments have higher concentrations of organic carbon and nitrogen and lower phosphorus compared to open waters (Table 6-2 and Table 6-3).
5. The pH values for all samples analysed were greater than 9 indicating that none the samples were acidic. However, all reducible sulphur values exceeded the action criteria of 0.03% (DoE 2004) confirming that all samples were potential acid sulphate soils but their acid neutralising capacity was in excess of their acid forming potential (Table 6-4).
6. Trace metal chemistry showed little indication of anthropogenic input into the Gulf with all metal concentrations, except arsenic, below environmental quality guideline limits in EPA (2005). Cadmium concentrations vary widely with the highest concentrations occurring 0.1-0.2 m along the western coast of the Gulf (Table 6-5 and Table 6-6). Results from the two surveys (Oceanica 2006a, Brunskill *et al.* 2001) were consistent.
7. There were no consistent trends in the results of monitoring of sediment particle size distribution. Field observations showed that sediment characteristics varied considerably from coarse sand and shell grit to medium sand to fine mud (Oceanica 2006a). Offshore waters were similarly variable.
8. The calcium carbonate content of sediments was high varying from 6.3-43% as calcium carbonate.



Fri 17 Nov 06

0643-F6-05.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Oceanica, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-5 Marine sediment and water sampling locations

Table 6-2 Summary of nutrient sediment results (Oceanica 2006a)

Nutrient	Location	Median	80th Percentile	20th Percentile	Number
TKN[1]	Upper Creek	300	760	200	16
	Mouth of Creek	200	390	200	13
	Nearshore	300	n/a	n/a	1
TP[2]	Upper Creek	140	200	110	16
	Mouth of Creek	120	170	90	13
	Nearshore	380	n/a	n/a	1

Source: Oceanica 2006a

[1] Total kjeldahl nitrogen [2] Total phosphorus

Table 6-3 Summary of nutrient and carbon in sediment (mg/kg)

Location	No. of Samples	Parameter	Organic carbon	Carbonate carbon	Nitrogen	Phosphorus	Sulphur
Supratidal salt flat/Algal mat	5	Median			364	102	1603
		20th percentile			283	82	1231
		80th percentile			809	204	9182
Mangrove	11	Median	6.2	19.5	756	142	2661
		20th percentile	2.6	2.8	378	130	2212
		80th percentile	10.3	38.6	1120	198	3623
Intertidal	3	Median	0.7	17.0	84	118	289
		20th percentile			84	69	231
		80th percentile			126	127	327
Gulf	146	Median	2.2	65.9	378	347	1763
		20th percentile	1.8	49.2	322	304	1507
		80th percentile	2.8	82.5	476	455	1988

Source: derived from Brunskill et al. 2001, as cited in Oceanica 2006a

Table 6-4 Acid sulphate soil analyses

Site	pH	TAA[1] (molH$^+$/t)	Action criteria for soils (%S)	%S	ANC[2] (%$CaCO_3$)
BSC1	9.6	0	0.03	0.10	35
BSC2	9.7	0	0.03	0.05	26
BSC3	9.6	0	0.03	0.09	34
BSC4	9.6	0	0.03	0.08	43
CP6	9.5	0	0.03	0.17	33
DCP1	9.4	0	0.03	0.31	30
DCP2	9.4	0	0.03	0.61	28
DCP3	9.4	0	0.03	0.73	30
DCP4	9.3	0	0.03	1.20	29
NCPS1	9.2	0	0.03	0.58	8.0
NCPS2	9.2	0	0.03	0.45	15
NCPS3	9.3	0	0.03	0.17	6.3
NCPS4	9.1	0	0.03	0.92	21

Source: Oceanica 2006a

[1] TAA: total actual acidity [2] ANC: acid neutralising capacity

Table 6-5 Summary of metal concentrations in sediments (mg/kg)

Analyte	As	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Hg
Reporting limit	<1	<0.06	<0.2	<0.2	<0.2	<5	<0.05	<0.4	<1	<0.5	<0.01
Number of samples	60	60	60	60	60	60	60	53	60	60	60
Number of samples with values greater than reporting limit	60	15	60	60	60	60	60	53	34	60	2
Maximum	52	0.23	13	60	24	49000	640	30	7	46	0.03
Minimum	9	BRL*	1.1	7.2	1	5000	67	2.1	BRL*	3.7	BRL*
Median**	24	BRL*	3.5	17	2.8	18000	170	5.9	2	10.5	BRL*
20th percentile	17	BRL*	2.3	13	1.6	11000	125	3.8	BRL*	6.3	BRL*
80th percentile	29	BRL*	5.7	28	5.9	25300	315	10	4	16.5	BRL*
EQG Value	20	1.5		80	65			21	50	200	0.15
EQG Re-sampling	70	10		370	270			52	220	410	1

Source: Oceanica 2006a

Notes: *BRL: Below Reporting Limits
** In calculating descriptive statistical parameters, if more than 50% of samples analysed returned values greater than Laboratory Reporting Limits, then a value of half the Laboratory Reporting Limit was used in place of BRL values. If less than 50% of the samples analysed returned values greater than Laboratory Reporting Limits, then no calculations were made.

Table 6-6 Summary of metal concentrations in sediments

		Cd	Cu	Fe	Mn	Pb	Al	K	Ca	Mg	Sr	B	Li	Ba
		mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Supratidal salt flat/Algal mat	median	0.025	12.5	27,621	138	6.2	20,574		12	17,496	96	47	17	
	20th percentile	0.016	9.6	22,287	119	5.0	16,454		4	8529	42	29	12	
	80th percentile	0.040	18.8	38,502	313	8.8	32,573		51	21,831	357	62	22	
	number	5	5	5	5	5	5		5	5	5	5	5	
Mangrove	median	0.035	5.3	13,783	135	2.3	9045	2346	61	11,154	394	41	8	22
	20th percentile	0.035	2.7	11,383	100	1.7	7371	1799	11	6658	88	35	6	21
	80th percentile	0.035	7.8	21,371	149	3.1	13,986	3363	121	13,025	867	56	11	36
	number	1	11	11	11	11	11	11	11	11	11	11	11	11
Intertidal	median	0.014	2.2	7924	70	1.9	4104		50	2940	298	6	3	
	20th percentile	0.013	1.8	6685	67	1.6	3343		21	1686	130	4	3	
	80th percentile	0.015	2.7	8124	95	2.5	4946		53	3232	419	7	4	
	number	2	3	3	3	3	3		3	3	3	3	3	
Gulf	median	0.043	4.1	20,088	179	3.5	8762	1994	204	11,737	1288	27	11	25
	20th percentile	0.032	2.0	16,015	146	2.9	5697	1329	154	9258	1025	24	8	19
	80th percentile	0.071	6.0	23,492	213	4.6	11,934	2620	257	13,414	1928	30	15	32
	number	118	146	146	146	146	146	146	146	146	146	146	146	146

Source: derived from Brunskill et al. 2001, as cited in Oceanica 2006a

1.3.4 Water quality

Previous studies

McKinnon and Ayukjai (1996) and Ayukai and Miller (1998) sampled water quality for salinity, nutrients and primary productivity at a number of stations (17) across the Gulf.

Meekan *et al.* (2003) measured chlorophyll-*a* concentrations at four stations between Point Murat and the Muiron Islands.

Studies for the ERMP

Oceanica 2006a conducted a comprehensive survey of water quality on the eastern side of the Gulf measuring salinity, dissolved oxygen, temperature and pH at a number of locations (Figure 6-5).

Study results

Salinity, dissolved oxygen, pH and temperature

The salinity gradient increases from west to east across the Gulf with the median nearshore salinity on the east coast of the Gulf being 37.9 parts per thousand (ppt) and increasing further at tidal creeks where the upper, mid and mouth median salinities are all above 41.5 ppt (Table 6-7, Figure 6-6). The maximum recorded salinity of 75.4 ppt was recorded up a small tributary to Hope Creek and the maximum salinity recorded in the main body of the creek was 60.7 ppt.

The increased salinity of water drawn out of the creeks on the ebb tide may cause some localised density currents and vertical stratification within channels leading from creeks to nearshore. The tidal regime, wind effects and nearshore shallow waters are likely to rapidly dissipate any vertical gradient in the nearshore shallow regions.

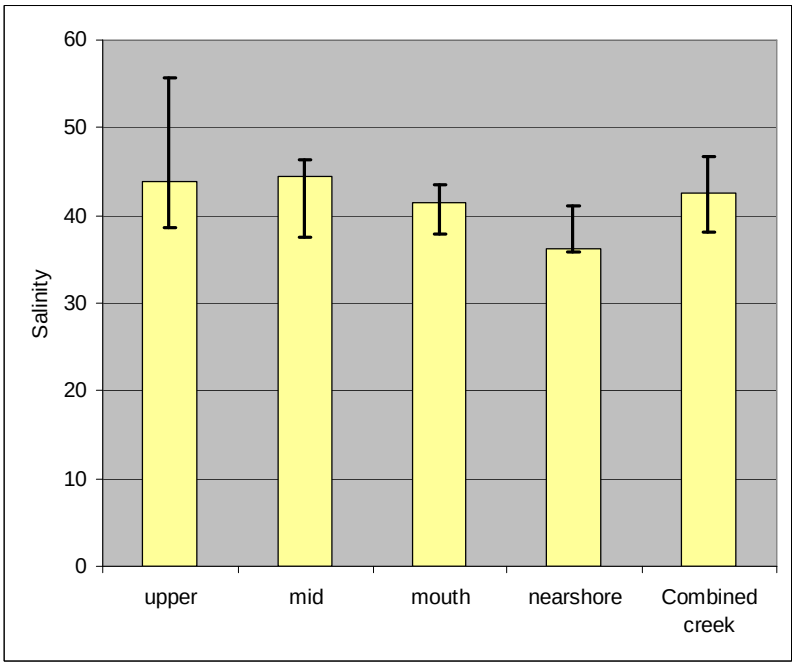
Dissolved oxygen levels were all at least 99% saturation and pH was 8.1-8.2 with location having no effect on the pH.

The temperature of waters of the east coast of the Gulf were surveyed by Oceanica (2006a) and were found to be cooler than measured by others (Ayuki and Miller 1998) probably reflecting inter-annual variation due to the influence of the Leeuwin Current. Minimum temperatures were recorded in September in the range of 18.1-20.6^{0}C and maximum temperatures were measured in mid-January, with a range of 27˚C to 32.4˚C.

Table 6-7 Summary of east Gulf coast salinity results (ppt)

Location	Median	80th percentile	20th percentile	Number
Upper Creek	43.8	55.61	38.59	17
Mid Creek	44.4	46.29	37.56	3
Mouth of Creek	41.5	43.49	37.79	14
Combined Creek data	42.6	46.64	38.15	34
Nearshore	37.9	41.13	35.89	7

Source: Oceanica 2006a



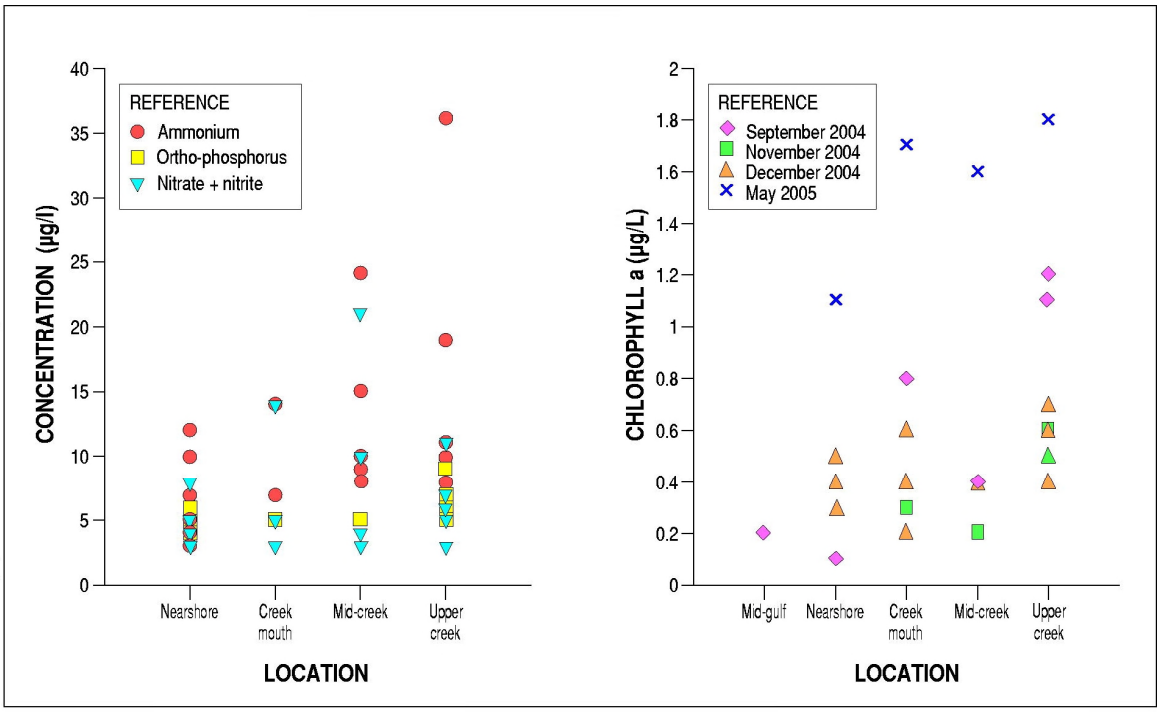
Source: Oceanica 2006a

Figure 6-6 Median salinity at locations within creeks showing 80th and 20th percentiles

Nutrients (including carbon)

Oceanica (2006a) conducted analyses of seawater samples from nearshore, creek mouth, mid creek and upper creek sites to ascertain any trends with location. There were not enough samples to assess any seasonal trends, but ammonium concentrations were generally higher in upper creek locations (Figure 6-7).

These results confirm that processes on the mangrove and algal mat communities are important for generating biologically available nutrients in seawater. This higher bioavailability of nutrients in creeks seemed to be reflected in the higher phytoplankton productivity (measured as chlorophyll-*a*) (Oceanica 2006a).



(a) (b)

Source: Oceanica 2006a

Figure 6-7 Dissolved inorganic nutrient and chlorophyll-a concentrations

1.4 IMPACT ASSESSMENT AND MITIGATION

1.4.1 Current human influence

The water quality of the eastern Gulf is unaffected by any significant anthropogenic current discharges or activities and essentially represents the natural background.

1.4.2 Environmental aspects and potential impacts

The discharge of bitterns is not part of this proposal. Refer Appendix 1 for detailed description of Bitterns Resource Recovery Strategy. This Appendix also describes preliminary modelling results for new industry best practice discharge scenarios based on greater resource recovery rates. Resource efficiency results in increasingly smaller volumes of bitterns and hence more rapid dilution back to seawater. The objective of the strategy is zero discharge resulting from complete resource recovery.

The proposal has the following environmental aspects that may result in environmental impacts:

- **storage of bitterns** for resource recovery on the site has the potential to affect water quality in the unlikely event that failure of the storage occurs. Bitterns will be stored in ponds of the same design as crystalliser ponds. Crystalliser ponds are designed to withstand extreme events (even cyclones) and to date, gross failure of similar structures at other saltfields has not occurred. In extreme events, ponds may be overtopped but are not expected to fail. Given the proposed security of bitterns storage this aspect will not be addressed further in this section

- **hypersaline water from reverse osmosis plants** will be discharged to the concentrator ponds (evaporator ponds in the case of the construction camp) and will become part of the salt-making process. This aspect will not be addressed further as there will not be any impact on the environment from its discharge
- **wastewater from waste water treatment plants in the construction camp** will be discharged in sealed evaporation ponds located well above tidal influences and any excess will be used to irrigate landscaped areas which are located in the hinterland well away (5-10 km) from the shoreline. Wastewater will be treated to upper secondary standard. Biosolids from the wastewater treatment plant will be deposited in an appropriate licensed offsite disposal facility. These facilities will pose negligible risk to the marine environment and further assessment of this aspect has not been conducted. Dry composting toilet facilities will be used at Main Island and will be located well above the watertable to reduce infiltration to local groundwater and facilitate nutrient attenuation
- **storage of hydrocarbons or fuels**, which could potentially result in a spill, as a result of ongoing operations can potentially affect water quality. This aspect has been addressed in detail in Chapter 6, Section 2 under the Benthic Primary Producer Habitat environmental factor and will not be addressed further in this section
- **dredging** can give rise to turbidity that may affect water quality and smothering of marine habitat. This aspect has been addressed in detail in Chapter 6, Section 2 under the Benthic Primary Producer Habitat environmental factor and will not be addressed further in this section
- **ship and barge movements** may give rise to turbidity that affect water quality and smothering of marine habitat. This aspect has been addressed in detail in Chapter 6, Section 2 under the Benthic Primary Producer Habitat environmental factor and will not be addressed further in this section.

1.4.3 Assessment and management of turbidity arising from dredging and ship and barge movements

The assessment of the impact of turbidity arising from these environmental aspects on benthic primary producer habitat and marine fauna are addressed in Chapter 6, Sections 2 and 3 respectively. The management measures to be applied is also described in these sections.

In summary the management to be applied to dredging is as follows:

1. A Dredging Management Plan will be prepared and implemented which will address the following:
    - Dredging will occur between 30 March and 30 October to coincide with the period of seagrass dormancy and when light requirements of benthic habitat are naturally at a minimum.
    - Ensuring that the type and size of dredge head used matches the performance and capacity of the suction pump.
    - collection of a set of baseline turbidity and suspended sediment data
    - appropriate criteria for protecting identified sensitive areas
    - sampling and analysis plan developed on the basis of *National Ocean Disposal Guidelines for Dredge Material* (Commonwealth of Australia 2002)
    - environmental management procedures relating to sediment mobilisation
    - reassessing dredging if wind speed and wave height exceed the operational parameters of the dredge.

2. A Marine Management Plan will be prepared and implemented which will address the following:
    - shipping and barge movements:
        - compulsory piloting of ships from outside the Gulf
        - tug piloting procedures
        - designated shipping routes
        - designated anchorage areas
        - maximum speed of restriction of ships of 10 knots within the Gulf
        - reporting to the DEC describing the fate, extent and duration of turbidity caused by barging in the first year of operation
        - aerial photography of the barging activities and measurements of turbidity and suspended sediments adjacent to the channel and adjacent to the closest seagrass and coral habitats
        - Ship Right – an international shipping accreditation program.

1.4.4 Assessment and management of potential oil spills

The assessment of the impact of oil spills arising from these environmental aspects on benthic primary producer habitat and marine fauna are addressed in Chapter 6, Sections 2 and 3 respectively. The management to be applied is also described in these sections.

In summary the management measures to be applied to prevent and manage oil spills is as follows:

- fuel handling procedures to prevent exposure to mangroves and other sensitive habitats located adjacent to fuel handling points and drainage from the development area
- environmental management controls which would be implemented in the event of a fuel spill or leak including establishing oil spill movement/trajectory and fate, response, cleanup, disposal and rehabilitation
- obtaining environmental sensitivity information and priority protection areas
- establishing roles, responsibilities and authorities for spill response tasks
- construct an inventory list of facilities, equipment and materials available for use in the event of a spill
- compulsory pilotage, establishment of speed limits and using established shipping routes and anchorage locations within the Gulf to reduce the risk of oil spills from ships.

1.5 MONITORING AND ASSESSMENT OF PERFORMANCE

1.5.1 Dredging and ship and barge movements

The Marine Management Plan and Dredging Management Plan will address monitoring programs for turbidity at key reference sites.

1.6 PROPONENT COMMITMENTS

Straits will prepare and implement the following to ensure water quality is protected:

1. A Dredging Management Plan will be prepared and implemented which addresses the following:
    - timing of dredging
    - baseline turbidity and benthic primary producer habitat surveys
    - criteria for protecting identified sensitive areas
    - development of a sampling and analysis plan based on the *National Ocean Disposal Guidelines for Dredge Material* (Commonwealth of Australia 2002)
    - environmental management procedures relating to sediment mobilisation
2. A Marine Management Plan which addresses the following:
    - monitoring program
    - baseline surveys of turbidity, suspended sediment and nutrient concentrations, shoreline and creek morphology/bathymetry, benthic primary producer habitat, marine fauna and non-indigenous marine species (NIMS)
    - ship and barge movements
    - oil and fuel spills precaution and management
    - fauna avoidance
    - marine fauna protection from seawater pumping
    - anti-foulant contamination
    - prevention of the introduction of NIMS
    - underwater noise emissions
    - light spill.

1.7 ENVIRONMENTAL OUTCOME

The implementation of the proposal poses only a minor risk to water and sediment quality in Exmouth Gulf. The proposed Marine Management Plan and Dredging Management Plan will ensure management procedures are in place to mitigate any adverse impact to the marine environment.

The Bitterns Resource Recovery Strategy aims to completely recover resource values from bitterns and to ensure there is no discharge of bitterns in the future.

2 BENTHIC PRIMARY PRODUCER HABITAT AND ECOLOGICAL INTEGRITY

This environmental factor addresses a number of marine environmental factors presented in the Scoping Document including:

- ecosystem integrity
- cumulative impacts (benthic primary producer habitat)
- wetlands (marine)
- mangroves and algal mats
- sub-tidal flora (seagrasses, corals and algae – sub-tidal benthic primary producer habitat).

The purpose of this amalgamation of factors was to facilitate the assessment of impact of the proposal, not only on the benthic habitat species themselves, but also on the ecological processes and functions of these communities and the role of these communities within the wider Gulf ecosystem.

In this way, the ERMP addresses the key environmental factors of ecosystem integrity and cumulative impact as well as policy considerations that arise out of EPA guidance statements on benthic primary producer habitat and mangroves (Chapter 6, Section 2.3).

Chapter 4, Section 2 includes an ecological overview which focuses on the eastern side of the Gulf as this area contains most of the habitat that is critical to the Gulf ecosystem.

Marine water quality is addressed separately (Chapter 6, Section 1) but any changes to water quality that may arise from the proposal and affect benthic primary producer habitat is addressed under this factor to ensure a comprehensive assessment of impact.

EPA objectives

The following EPA objectives apply to benthic primary producer habitat:

- *To maintain the integrity, ecological functions and environmental values associated with Exmouth Gulf, the intertidal zone and adjacent hinterland.*
- *To maintain the abundance, diversity, geographic distribution and productivity of mangroves and mangrove associations, through no loss of mangrove associations including algal mats.*
- *To maintain the ecological function, abundance, species diversity and geographic distribution of seagrass and algal communities.*
- *To meet the EPA's objectives with respect to Guidance Statement No.29 Benthic Primary Producer Habitat for Western Australia's Marine Environment.*
- *To maintain the integrity, ecological functions and environmental values of listed wetlands.*
- *To ensure that appropriate consideration is given to cumulative impacts on Exmouth Gulf.*

2.1 BENTHIC PRIMARY PRODUCERS AND HABITAT

Benthic primary producers 'are predominantly marine plants (e.g. seagrasses, mangroves, seaweeds and algal mats and beds) but also include invertebrates such as scleractinian corals, which acquire a

significant proportion of their energy from symbiotic microalgae that live in coral polyps. These organisms grow attached to the seabed (subtidal or intertidal), sequester carbon from surrounding seawater or air and convert it to organic compounds through photosynthesis' (EPA 2004a).

Benthic primary producer communities are biological communities including the plants and animals within which benthic primary producers dominate. Benthic primary producer habitats comprise benthic primary producer communities as well as the substrata that can/do support these communities (EPA 2004a).

Benthic primary producers undertake important ecosystem processes such as carbon fixing, cycling and nitrogen fixation in the case of algal mats. These producers also provide important ecological functions including shelter and food for other trophic levels in the ecosystem and stabilisation of marine and coastal sediments. Seagrasses, algal beds, algal mats and mangroves are important components in the nutrient and carbon cycles.

2.2 MARINE WETLANDS

Marine wetlands were a key environmental factor identified in the Scoping Document and were defined as extending from Giralia Bay to Urala Creek, Lockyer Point including waters less than 6 m at low tide, tidal mudflats and saline coastal flats.

The importance of the conservation of wetlands in the coastal zone ('marine wetlands') was recognised under the Ramsar Convention. The Department of Environment and Heritage (DEH) have developed a broad framework to aid the identification of 'marine wetland' habitats. The following presents a list of criteria of marine wetlands from the Ramsar Convention framework that have been identified as relevant to the project area:

- permanent shallow marine waters in most cases less than six metres deep at low tide (including sea bays and straits)
- marine subtidal aquatic beds (including kelp beds, seagrass beds, tropical marine meadows)
- coral reefs
- intertidal mud, sand or salt flats; intertidal forested wetlands (including mangrove swamps, nipah swamps and tidal freshwater swamp forest)
- karst and other subterranean hydrological systems, marine/coastal (DEH 2004).

Marine wetland systems that are relevant to the wetlands environmental factor for this assessment include a substantial proportion of the Gulf and include, in particular, the following communities on the eastern side of the Gulf:

- seagrass
- mangroves
- algal mats and beds.

2.3 LEGISLATIVE AND POLICY CONTEXT

2.3.1 Statutory framework

State and Commonwealth legislation are relevant to the consideration of the environmental impact on benthic primary producer habitats and their associated biota. These include:

- EPBC Act with regard to listed migratory and threatened species
- *Wildlife Conservation Act 1950–1979* (provides for the protection of all species of native flora and fauna, including mangroves and associated biota)
- *Conservation and Land Management Act 1982* (in respect of the recommended marine reserve).

2.3.2 Recommended marine conservation areas

The mangroves and coastal systems of the Yannarie Solar Project area have been addressed in other regional conservation value studies and Government reserve planning processes. These include the following.

Directory of important wetlands in Australia

The east coast of Exmouth Gulf is listed in the Commonwealth Department of the Environment and Heritage's *A Directory of Important Wetlands in Australia*, as a 'Directory Wetland' ("Exmouth Gulf East—WA007"). This listing is on the basis of the mangrove coast and intertidal area and is described as "An outstanding example of tidal wetland systems of low coast of north west Australia, with well developed tidal creeks, extensive mangrove swamps and broad saline coastal flats".

'Wilson Report' marine reserve recommendation

The Marine Parks and Reserves Selection Working Group (MPRSWG 1994; the 'Wilson Report') recommended that "the nearshore waters on the eastern and south western side of Exmouth Gulf be considered for reservation for the protection of mangal habitat, prawn and fish nursery areas, turtle and Dugong feeding areas, and coastal marine fauna and flora generally and for recreational fishing and such commercial fishing and mariculture and may be consistent with the former purposes".

EPA Guidance Statements

Two EPA Guidance Statements are relevant to the benthic primary producer habitats of the Yannarie Solar Project area:

1. *Guidance Statement No. 1 Protection of tropical arid zone mangroves along the Pilbara coastline* (EPA 2001).
2. *Guidance Statement No. 29 Benthic Primary Producer Habitat (BPPH) Protection for Western Australia's Marine Environment* (EPA 2004a).

EPA Guidance Statement No. 1 classified the mangroves of eastern Exmouth Gulf as a Guideline 1 area: 'Regionally significant mangroves - Outside designated industrial areas and associated port areas' (EPA 2001). The Guidance Statement identified a continuous management area from Sandalwood Peninsula (Giralia Bay) in the south to Tubridgi Point in the north.

This area was described as 'Area 2: Giralia Bay to Yanrey Flats, Exmouth East Shore' and the regionally significant mangrove areas were classified as being of 'Very High' conservation significance (EPA 2001). The Guidance Statement identified that for Guideline 1 areas, the EPA expects that 'no development should take place that would adversely affect the mangrove habitat, the ecological function of these areas and the maintenance of ecological processes which sustain the mangrove habitats' (EPA 2001).

The mangrove systems of the Yannarie Solar Project area are therefore considered to be regionally significant and to have very high conservation value.

EPA Guidance Statement No. 29 sets out a framework for the assessment of proposals that may affect Benthic Primary Producer Habitats (BPPH). Guidance Statement No. 29 identifies that the EPA expects a hierarchy of principles to be followed in assessing proposals that could damage BPPH (EPA 2004a). The first three of these four principles need to be demonstrated prior to evaluating the loss of BPPH against the management unit framework specified in the final principle of the Guidance. These three principles are discussed in relation to the project in Section 2.6.3.

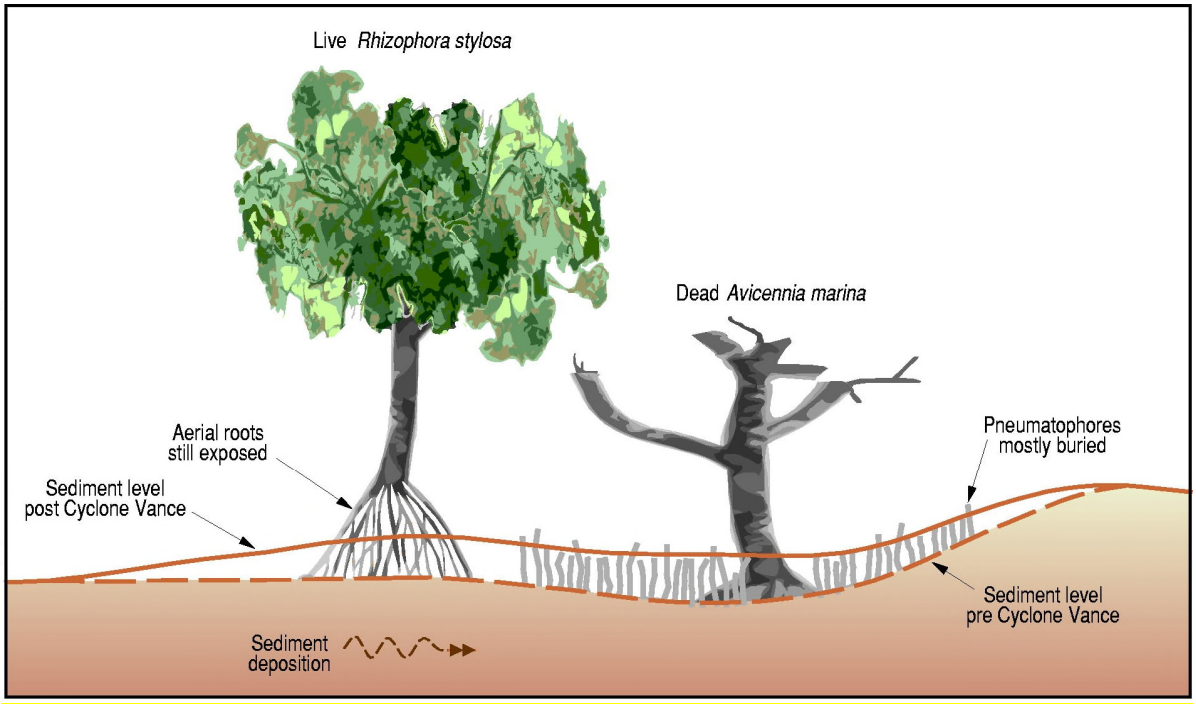
2.4 DESCRIPTION OF INTERTIDAL HABITAT (MANGROVES & ALGAL MATS)

2.4.1 Pre-existing impacts on habitat

In 1999 Tropical Cyclone Vance resulted in widespread damage to mangroves along the coast in the study area. Approximately 5700 ha or 44% of the 12,800 ha of mangroves estimated to be in the study area were removed by Vance (Biota 2005d, Paling *et al.* 2005). About 1580 ha of the mangroves damaged had recovered between 2002 and 2004 and at this rate of recovery it is estimated that the mangroves should have fully recovered by 2009.

This damage to mangrove areas has been attributed principally to large-scale sediment movement mobilised by Cyclone Vance. It was found that in most areas affected *Rhizophora stylosa* survived the cyclone whereas *Avicennia marina* did not (Figure 6-8). The more elevated and exposed root system of *Rhizophora stylosa* may have provided it with a greater tolerance to reworking of the sediment (Biota 2005d).

Apart from the occasional cyclone, there are unlikely to be any other natural events or human activities that are currently affecting the mangrove or algal mat communities.



Source: Biota 2005d

Figure 6-8 Sediment impacts on Avicennia marina and Rhizophora stylosa

2.4.2 Mangroves

Mangrove communities provide a range of keystone ecological functions on the Pilbara coast, including physical stabilisation of shorelines and sediments (Thom 1982, Semeniuk 1993a), provision of terrestrial and marine fauna habitats (Robertson and Duke 1987, Robertson 1991) and cycling inputs of carbon and nitrogen to coastal ecosystems (Semeniuk *et al.* 1978, Paling and McComb 1994). This is in addition to their intrinsic cultural and scientific value (Semeniuk 1999, EPA 2001).

Approximately 2507 km^2 of mangroves occur in the West Australian tropics (Robertson and Alongi 1995). While little of this extent is secured within formal conservation reserves, much of the Pilbara coastline, including mangrove areas on the eastern side of Exmouth Gulf, has been identified as regionally significant by the EPA (2001) and therefore have an implicit level of protection in the environmental assessment process for proposals. This area includes the proposed Yannarie Solar Project area.

Investigations

1. Field surveys

Two site-specific mangrove field surveys were completed at selected locations (Biota 2005d) (Appendix 4) on the basis of the following:

- representativeness of the apparent range of association types based on aerial photography and helicopter overflight

- areas of potentially higher biodiversity (as inferred from apparent association complexity and position in the landscape)
- areas that had been identified in the preliminary design as potentially accommodating saltfield infrastructure such as pump stations, trestleways and other facilities.

2. Mangrove association mapping

Field maps were prepared from georeferenced photomosaics and overlain with a coordinate grid to provide for spatial location of associations (Biota 2005d). The mangrove assemblages of the project area were mapped by cross-referencing to both types of photography. Mangrove assemblage categories were defined during the ground survey work according to dominant species, height and vegetation structure.

3. Satellite imagery analysis

Analysis of changes in mangrove distribution and extent from the period before Cyclone Vance to the time of the current study was carried out using historical satellite imagery (Biota 2005d, Paling *et al.* 2005). Three sets of Landsat TM images from 1999, 2002 and 2004 were used in this study, along with 2004 digital aerial photography.

Mangrove flora

The mangrove flora of the locality is more closely floristically linked with that of the Pilbara Bioregion coast notwithstanding that the mainland adjoining the Yannarie Solar Project area forms part of the Carnarvon Bioregion (Environment Australia 2000). This is reflected in both EPA Guidance Statement No. 1 and Semeniuk *et al.* (1978), which treat the current study area as part of the Pilbara coast.

Seven species of mangroves occur in coastal environments in the Pilbara Bioregion (Biota 2005d). The field surveys completed for the Yannarie Solar Project recorded six mangrove species from the study area, comprising:

- *Avicennia marina* (Forssk.) Vierh.—White (or Grey) Mangrove (Figure 6-9)
- *Rhizophora stylosa* Griff.—Spotted-leaved Red Mangrove (Figure 6-9)
- *Bruguiera exaristata* Ding Hou—Ribbed Mangrove
- *Ceriops tagal* (Perr.) C.B.Rob.—Spurred Mangrove
- *Aegialitis annulata* R. Br.—Club Mangrove
- *Aegiceras corniculatum* (Perr.) C.B.Rob.—River Mangrove.

By far the most abundant and widespread species in the study area was *Avicennia marina,* which was dominant across the great majority of the area. *Avicennia marina* is the most widespread mangrove in Western Australia and it is typically the dominant species along mangrove coastlines in the region (Semeniuk 1999). *Rhizophora stylosa* was the next most common and widespread species in the study area. *Rhizophora stylosa* formed dense stands in more seaward areas, either as a monospecific unit or in association with taller *A. marina.* This species is also relatively widespread along the Western Australian coastline and is typically locally dominant or co-dominant in mangrove habitats from the Kimberley to Exmouth Gulf.

(a) Avicennia marina (Forssk.) Vierh. – White (or Grey) Mangrove

(b) Rhizophora stylosa Griff. – Spotted-leaved Red Mangrove

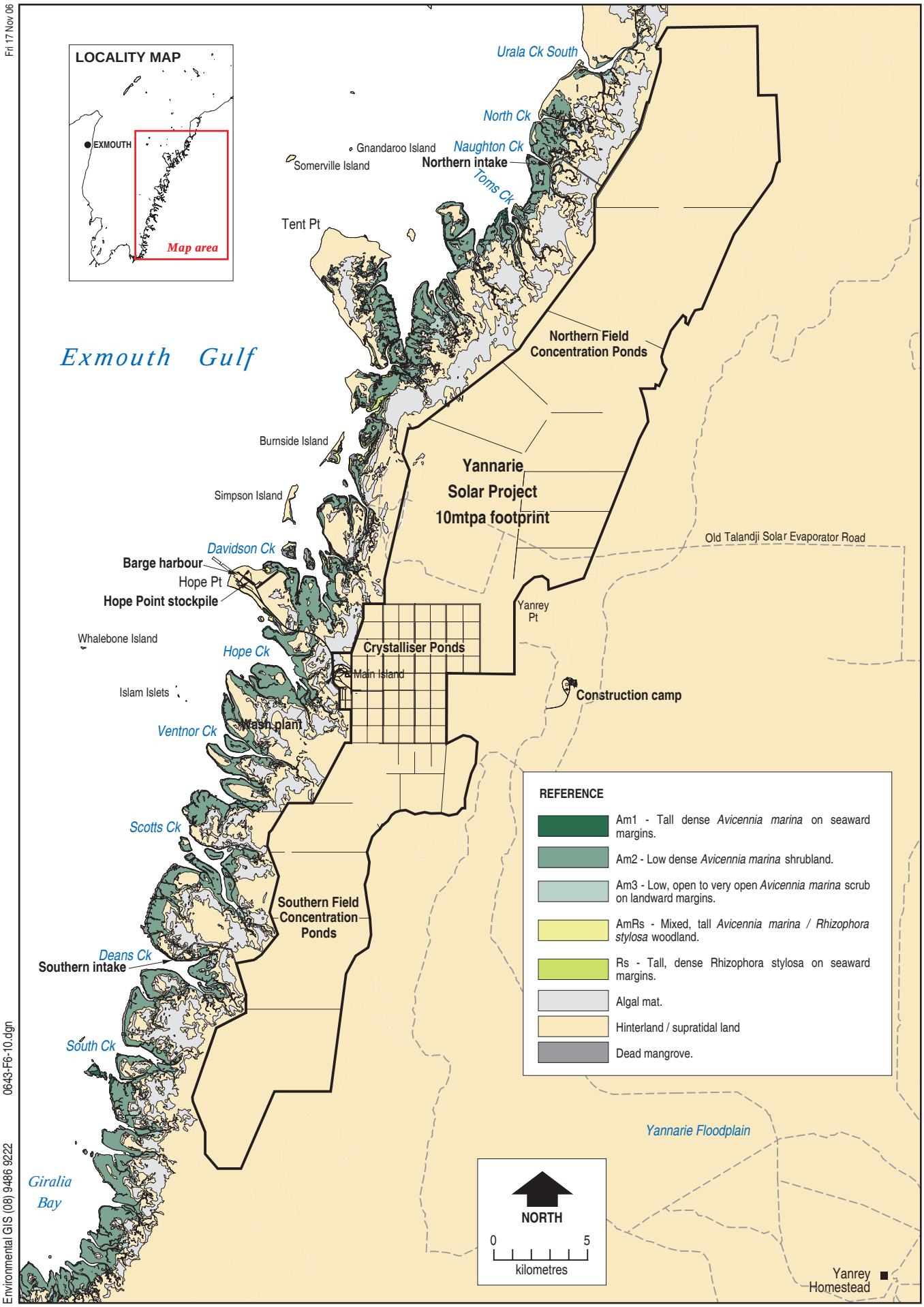
Source: Biota 2005d

Figure 6-9 Photographs of mangroves in project area

Ceriops tagal was recorded much less commonly than the two dominant mangrove species in the study area. The records of this species were restricted to more complex and sheltered mangrove creeks associated with Tent Island and Hope Point. *Ceriops tagal* typically occurred as small stands mixed with other species in the back of the mangrove creeks. The remaining three mangrove species, *Aegiceras corniculatum, Aegialitis annulata* and *Bruguiera exaristata* were only recorded from scattered individuals or small mixed stands. These records were all on Tent Island or associated with sheltered mangrove creeks to the west and immediate south west of this island. All three of these lower frequency species reach their southern documented range limits in Exmouth Gulf (Semeniuk 1999).

Mangrove assemblages

Five mangrove associations were defined from the project area, with live mangrove associations totalling 11,154 ha in extent (Figure 6-10 and Table 6-8). More detailed accounts of the mangrove associations and larger scale maps of their distribution are provided in Appendix 4 (Biota 2005d).



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-10 Mangrove associations and algal mat near the Yannarie Solar Project

Table 6-8 Mangrove associations recorded from the Yannarie Solar Project area in 2005

Code	Association	Area (ha)
Am1	Tall dense *Avicennia marina* on seaward margins	195
Am2	Low, dense *Avicennia marina* shrubland *	8485
Am3	Low, open to very open *Avicennia marina* scrub on landward margins *	2058
AmRs	Mixed, tall *Avicennia marina/Rhizophora stylosa* woodland	290
Rs	Tall, dense *Rhizophora stylosa* on seaward margins	126
	Live Mangrove Associations Subtotal:	**11,154**
D	Completely dead mangrove areas from historical cyclone damage	958
AlMa	Algal mat	8054

Source: Biota 2005d

Note: * A mosaic of moribund mangroves recovering from cyclone damage occurs within these units that could not be accurately mapped; the extent of this was instead assessed by imagery classification (Biota 2005d)

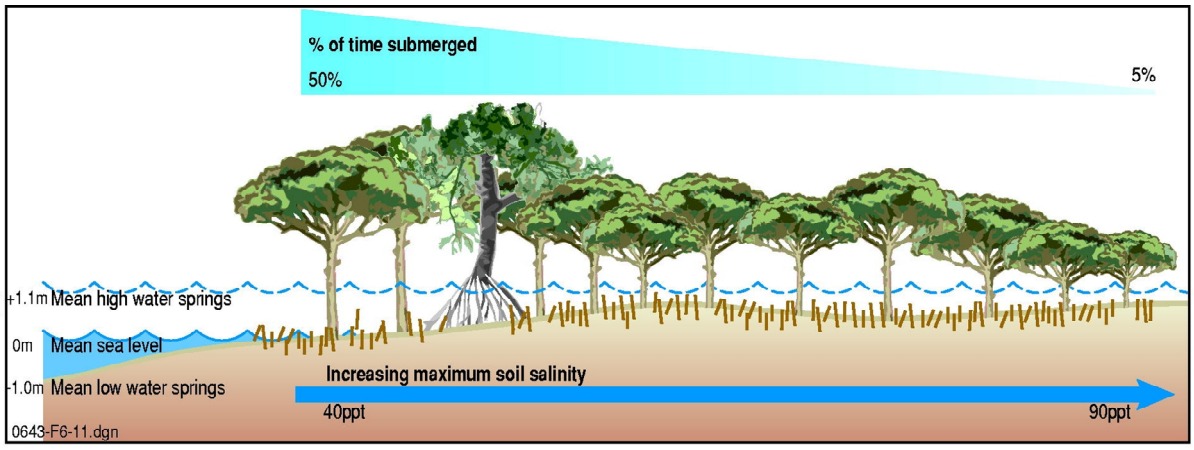
Factors controlling mangrove distribution

The types of specialisations developed by mangroves are generally a reflection of the physical environmental conditions they can tolerate. Common environmental variables in mangrove habitats in this respect include:

- cyclonic storms (with resultant groundwater salinity levels, can be up to double seawater in the upper mangrove zone)
- frequency and duration of tidal inundation (both in terms of too regular and too infrequent tidal inundation)
- anoxic sediments
- erosion and accretion of sediments (which change local creek geomorphology and therefore position in the tidal range)
- tidal currents and large scale redistribution of sediments.

The central factor affecting mangrove occurrence is the relationship between tidal elevation, daily seawater flooding and resultant control on groundwater salinity in mangrove sediments. The mangroves of the study area occur in a location where maximum daily temperatures are often very high and evaporation exceeds rainfall by a 10:1 ratio annually (Biota 2005d). This environment leads to conditions where mangrove soils are exposed to high evaporation rates and therefore increasing salinity levels once the tide has fallen and sediments are exposed. Groundwater salinity then increases steadily until the next incoming tide flushes the area, recharging the intertidal zone saline groundwater and reducing the salinity levels to close to seawater (Semeniuk 1983).

This pattern of daily tidal exchange and flushing of sediments creates a salinity gradient along the tidal range that affects both the occurrence of different mangrove species and the appearance and growth of individual plants (Figure 6-11). The various mangrove species occurring along the Pilbara coast have differing salinity tolerance limits. *Avicennia marina*, which has the greatest salinity tolerance, can occur in areas where groundwater salinity reaches up to 90 ppt (approximately 2.5 times seawater) (Gordon 1988). This is reflected in the species' distribution across the entire tidal elevation range of mangrove occurrence in the study area.



Source: Biota 2005d Note: heights in m AHD

Figure 6-11 Representative salinity gradient in the mangrove systems and response of *Avicennia marina*

The life form of *Avicennia marina* changes across this range however, in response to decreasing frequency of tidal flushing and consequent increased salinity levels up gradient. Plants occurring in the lowest parts of the tidal range develop into healthy trees and have to tolerate lesser magnitude and shorter-term increases in salinity. Further inland along the increasing salinity gradient, *Avicennia marina* forms tall shrubs through to low stunted shrubs in the most saline upper reaches of the tidal range (Figure 6-11).

Other mangrove species generally have lower salinity limits, with *Rhizophora stylosa* only occurring on average up to approximately 55 ppt and *Ceriops tagal* to 70 ppt (double seawater) (Semeniuk 1983, Gordon 1988).

Freshwater runoff during rainfall events can reduce groundwater salinities, but this is very unlikely to be a widespread or primary process in supporting mangroves in the project area, given the episodic nature of rainfall events and the duration of drought periods over the longer-term. Groundwater salinity in the upper tidal range can also be reduced by seepage from perched freshwater aquifers occurring as superficial lenses on mainland remnants (Semeniuk 1983). This is typically evidenced by the growth of larger mangrove trees at the upper end of the tidal range where this zone meets the terrestrial edge of a supratidal mainland remnant. There are no mangroves on the margin of the supratidal salt flat and the hinterland, indicating that this is a typical arid zone mangrove system as described by Semeniuk (1983), with no groundwater flow from the hinterland.

Other factors affecting distribution of mangroves include sediment physical characteristics and creek geomorphic processes (Biota 2005d). Biotic factors also play a part in controlling mangrove distributions, including propagule grazing and burrow establishment by crabs and shading by established mangroves (Robertson 1991, Clarke and Allaway 1993, Clarke 1995).

Influence of freshwater input from the hinterland

Freshwater input from hinterland flood events and groundwater seepage can also be important in reducing salinities and delivering nutrients to mangroves in more tropical locations (Semeniuk 1983). The importance of these factors in maintaining mangrove systems generally decreases with increasing aridity (Semeniuk 1983, Gordon 1988). In the current study area, hinterland flood events and groundwater seepage appear to be of negligible importance in the routine maintenance of mangrove

systems (Brunskill *et al.* 2001). The Gulf is a tidally dominated system, with freshwater flows and fresh groundwater seepage providing negligible contributions to the Gulf (Brunskill *et al.* 2001).

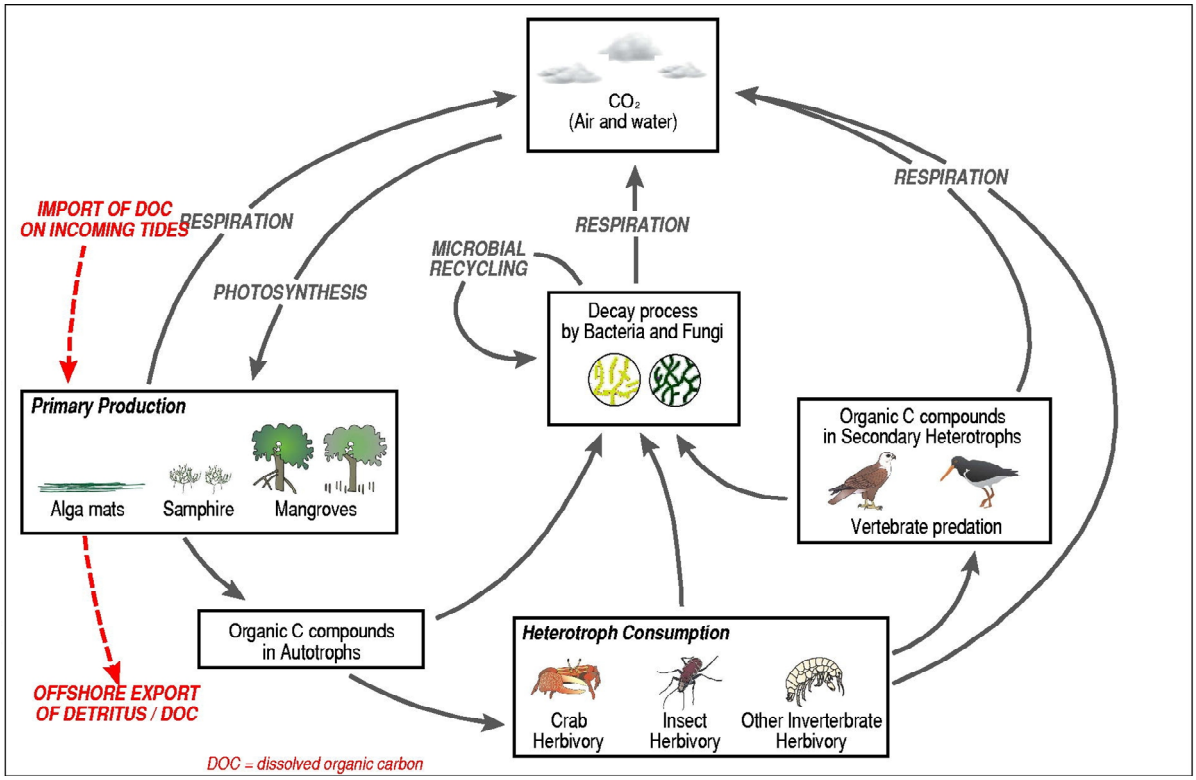
Hydrological modelling and review of historical rainfall data and flood records for the current study area indicated that most rainfall events do not generate enough runoff from the hinterland to cause the outlets of the Yannarie River and Rouse Creek to discharge onto the supratidal salt flat (Parsons Brinckerhoff 2005b). Modelling indicated that only the 1 in 20 and 1 in 100 year events generate significant outflow from the Yannarie River South and North and the Rouse Creek onto the supratidal salt flat to reach the Gulf (Parsons Brinckerhoff 2005b, D C Blandford & Associates and Oceanica 2005).

D C Blandford and Oceanica (2005) concluded that there was no direct hydrological linkage between the discharge from the mainland drainage systems and the mangrove zone along the coast. Observations on the supratidal salt flat support this hydrological model (Biota 2005d), with the available evidence (and earlier research work) supporting the concept of a hydrological disconnect between the hinterland and the mangrove zone of the project area. Mangroves in the current study area are therefore reliant on tidal flushing from Exmouth Gulf to reduce sediment salinity and provide inputs of dissolved organic carbon and other nutrients from offshore sources (Biota 2005d).

Carbon cycling in mangrove ecosystems

Carbon is a fundamental element in the structure and function of all living organisms. The relationship between inorganic and organic forms of carbon at different levels of the physical and biological environment is referred to as the carbon cycle (Figure 6-12). The key components of this process in mangroves include (Biota 2005d):

1. Conversion of atmospheric carbon dioxide to organic compounds via photosynthesis by mangroves (about 15,000 kg/ha) and algal mats.
2. Consumption of carbon compounds from mangrove leaf litter and algal mat by herbivores and grazing by macroinvertebrates.
3. Consumption of herbivores by carnivores.
4. Microbial decay of mangrove leaf litter and excretions and remains of herbivores and carnivores resulting in release of carbon dioxide to the atmosphere.
5. Animal respiration converting carbon compounds to carbon dioxide which is released to the atmosphere.
6. Export/import of carbon to and from offshore marine areas through tidal movement.



Source: Biota 2005d

Figure 6-12 Simplified conceptual carbon cycle for mangrove/algal mat ecosystems

2.4.3 Algal mats

Cyanobacterial mats are a common feature of the Pilbara arid zone mangrove coast, occurring north of the study area at Onslow, Mardie, Cape Preston, Port Hedland and Dampier. These mats have been demonstrated to fill an important ecological function in coastal arid zone systems, fixing atmospheric nitrogen into biologically available forms (Paling *et al.* 1989, Paling and McComb 1994, Biota 2005d).

Atmospheric nitrogen can also be converted into nitrates in rainfall by lightning, but this is likely to be a far less important contributor than nitrogen fixation by algal mats in the coastal ecosystem of the study area.

Nitrogen cycle in algal mat/mangrove communities

Export of biologically available nitrogen from algal mats occurs subsequent to the fixation of atmospheric nitrogen (Figure 6-13). The major pathways and components of the nitrogen cycle in algal mat/mangrove communities are as follows (Biota 2005d):

1. Fixation of atmospheric nitrogen by cyanobacteria into ammonia which can then be incorporated into organic nitrogen compounds.
2. Export of biologically available nitrogen from algal mats through tidal movement and incident rainfall. Paling and McComb (1994) showed that nitrogen is lost from algal mats during tidal inundation and localised intertidal runoff from incident rainfall. Export is principally organic

nitrogen and estimates for the Pilbara coast indicate export values of 68 kg of N/ha/yr (Paling and McComb 1994). Based on the Pilbara coast estimates of Paling and McComb (1994), and the area of algal mat (8054 ha) mapped for the study area, the mats probably contribute in the order of 547 tonnes of nitrogen per year to the mangrove and nearshore ecosystems of the eastern Gulf (Biota 2005d).

3. Uptake of nitrogen by plants through root systems. Plant uptake typically represents a relatively small component of available nitrogen with most nitrogen recycled in microbial processes or exported in tidal movement.
4. Consumption and excretion by herbivores.
5. Consumption of herbivores and excretion by carnivores.
6. Nitrification (conversion of ammonium nitrogen to nitrate) and denitrification (conversion of nitrate to nitrogen gas) which is believed to be low in mangroves.

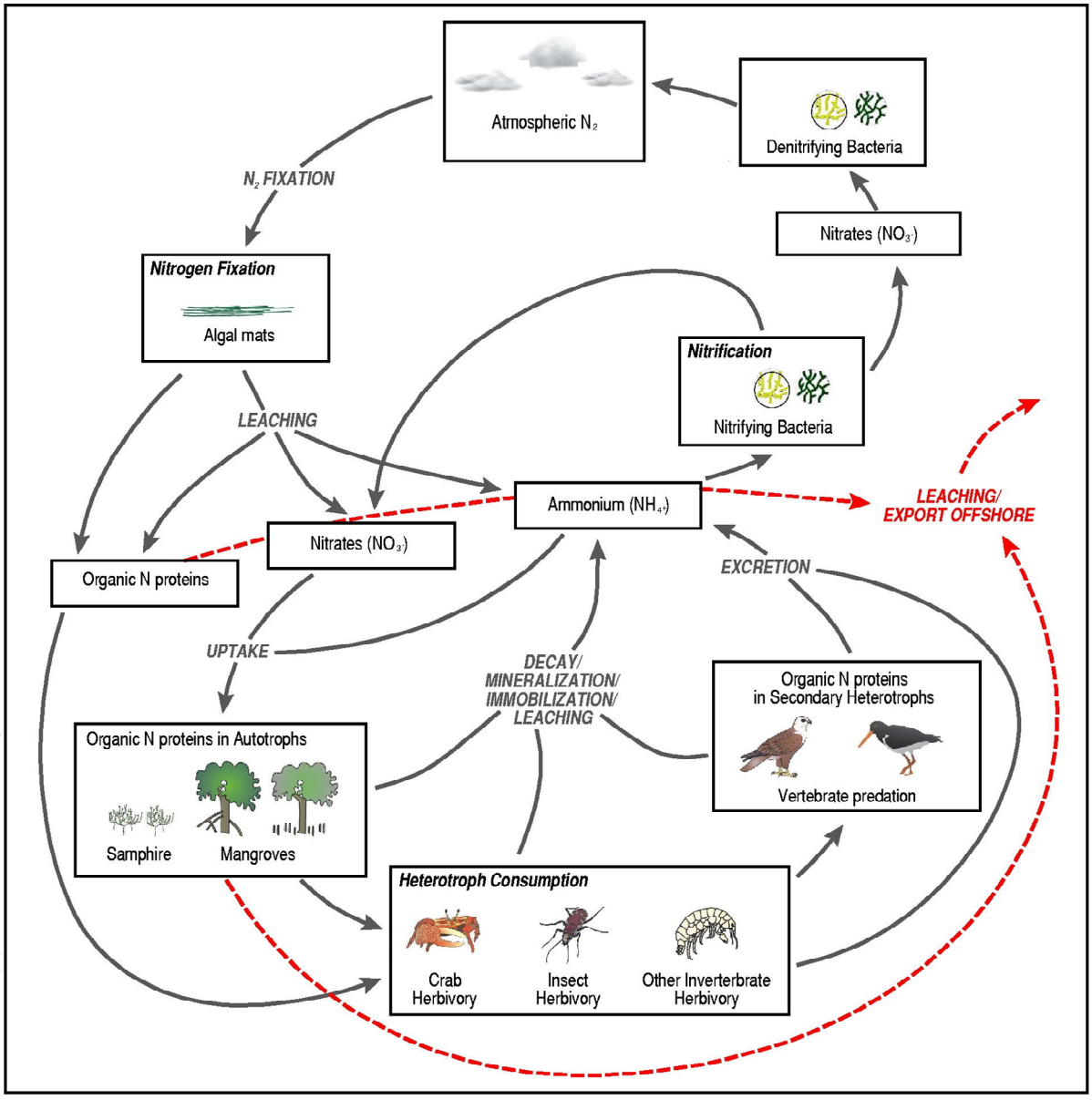
Organic nitrogen, nitrates and ammonium are all lost from the mats and enter a relatively complex cycle of offshore export, uptake by primary producers (mangroves and samphires) and geochemical mineralisation and immobilisation in intertidal sediments (Biota 2005d). Mats are also grazed directly by invertebrates in their lower tidal range limit, providing a direct source of organic nitrogen.

The algal mats are the key source of nitrogen to the nitrogen-limited Exmouth Gulf.

Investigations

Ground-truthing of algal mats in the project area was undertaken and observations on algal mat condition, thickness, structure and position in the tidal range were collected (Biota 2005d) (Appendix 4). Samples of mat from representative heights in the tide range were collected to determine species composition. Ground-truthing was used to relate different areas of algal mat (e.g. active algal mat, inactive and lithified mat) to aerial photography (Biota 2005d).

Maps of algal mat communities were produced from these investigations.



Source: Biota 2005d

Figure 6-13 Simplified conceptual nitrogen cycle for algal mat/mangrove ecosystem

Description

Mat occurrence and structure

Extensive areas of algal mats occur on the mudflats of the project area beyond the tidal limit of the mangrove zone. Approximately 8054 ha (~80 km^2) of algal mats were mapped during the field surveys (Figure 6-10) (Biota 2005d). Algal mats were generally similar in structure, condition and composition in equivalent tidal ranges across the project area. Active mat was dark grey to black on the surface and mat situated higher in the tidal range was flattish crustular/pustular in form and associated with little sediment input (Figure 6-14).

Mats occurring in areas lower in the tide range were more frequently inundated and were more pustular, with material wrapped over the top of the mat (Figure 6-14). The mat in these areas was approximately 8–10 mm thick and was often folded and showed evidence of having been moved and locally damaged by wind, currents and tidal action. Higher in the tidal range the mat was some 5 mm thick and consisted of dehydrated algal material on the surface with a deeper layer of more consolidated filaments (Biota 2005d).

The active mat typically disappeared relatively quickly into the upper limits of the monthly tidal range and on the edge of the supratidal salt flat further east. The exception to this general pattern arose in areas where localised depressions existed in the topography. Relatively small depressions appeared sufficient to provide shallow ponds for mats in some locations that are probably refilled by seawater only infrequently during a typical month's tidal cycle (Biota 2005d).

(a) Typical area of flat algal mat higher in the tidal range

(b) Thicker algal mat moved by tidal currents and wave action

Source: Biota 2005d

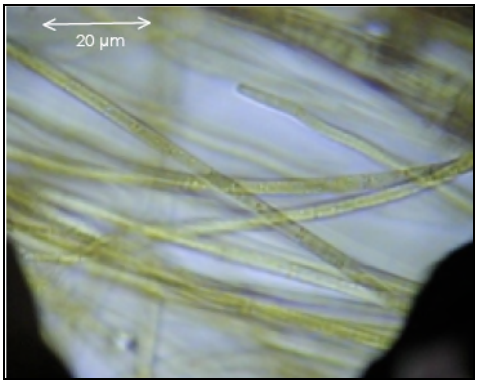
Figure 6-14 Photographs of algal mats

Mat composition

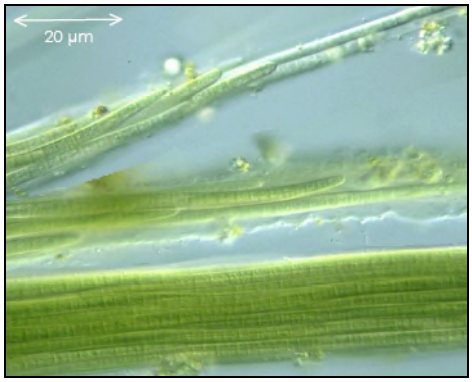
Mat from higher in the tidal range consisted mostly of *Oscillatoria* sp. as a tangled set of filaments and there were several species of this genus present (Figure 6-15a) (Biota 2005d). The dominant *Oscillatoria* sp. was approximately 5 µm wide. The remainder were freely associated with the mat (i.e. occurred individually within and around the tangled filaments) and were much smaller (~1 µm). There was also a small amount of *Microcoleus* sp. (Figure 6-15b), along with several diatom species.

More developed mat from lower in the tidal range consisted largely of *Microcoleus* sp. almost equally mixed with *Schizothrix* sp. The dominant cyanobacteria genera recorded in the mat samples were generally consistent with the dominant taxa in mats occurring in other coastal locations in the Pilbara (Paling *et al.* 1989).

The algal mat sampled in the study area was non-heterocystous. That is, its constituents did not contain specially differentiated cells formed for nitrogen fixation. Despite the absence of these structures, non-heterocystous microbial mats have previously been shown to be capable of significant nitrogen fixation (Paling and McComb 1994).



(a) Oscillatoria sp.



(b) Microcoleus sp.

Source: Biota 2005d

Figure 6-15 Photographs of algae from algal mats in project area

Factors controlling algal mat distribution

The distribution of active algal mat is limited to a relatively confined portion of the coastal zone in terms of tidal elevation but translates to a large spatial area due to the flatness of the terrain.

This distribution of algal mats in this environment is controlled by both biotic and abiotic factors (Biota 2005d). The key factors involved are:

- limits on the upper elevation imposed by dehydration and high salinity due to the low frequency of tidal flushing
- lower elevation limits where inundation is too frequent with less stable substrates and destabilising effect of tidal currents. Grazing by invertebrates in the upper tidal range also contributes to maintaining the mat's lower limit.

The shoreward boundary of the algal mat is inundated approximately 3% of the time (on 20 to 25 days of the month for a period of 1–2 hours).

The distribution of algal mats is determined by similar controlling factors to that of mangroves. Some quantification of the vertical ranges of these communities and mangroves in the project area was provided by relating elevation data from survey transects to the tidal submergence curve generated from the hydrodynamic model for the project area (Table 6-9) (Biota 2005d).

Table 6-9 Average algal mat and mangrove vertical ranges and inundation

Algal mat limit	Elevation (m AHD)	Tide range* (m)	~ % Time submerged
Algal mat upper limit	1.440	HR – 0.120	>1
Algal mat lower limit	1.336	MHWS + 0.270	>3
Mangroves upper limit	1.181	MHWS + 0.121	4
Mangroves lower limit	0.196	MSL + 0.156	45

Source: Adapted from Biota 2005d
Note: *HR = highest recorded tide; MHWS = mean high water of springs; MSL = mean sea level

Algal mats essentially occur in the narrow tidal range that is not so frequent that tidal currents are strong and sediments unstable, but also not so high that salinity levels are too great even for cyanobacteria to tolerate. This equates to an elevation range of about 10 cm on the average in the flat landscape of the study area, being submerged an average of 3% per month or less (Biota 2005d). Some variation also occurs at the upper range limit due to localised variation in topography and ponding effects.

Modelling of the inundation of the intertidal areas has confirmed that the shoreward extent of the algal mats is effectively equivalent to the High Water Mark. The landward extent of the algal mats therefore provides a distinct and clearly visible approximation of the High Water Mark (WorleyParsons 2005a).

2.5 DESCRIPTION OF SUBTIDAL HABITAT (SEAGRASSES, ALGAL BEDS, SPONGES & CORALS)

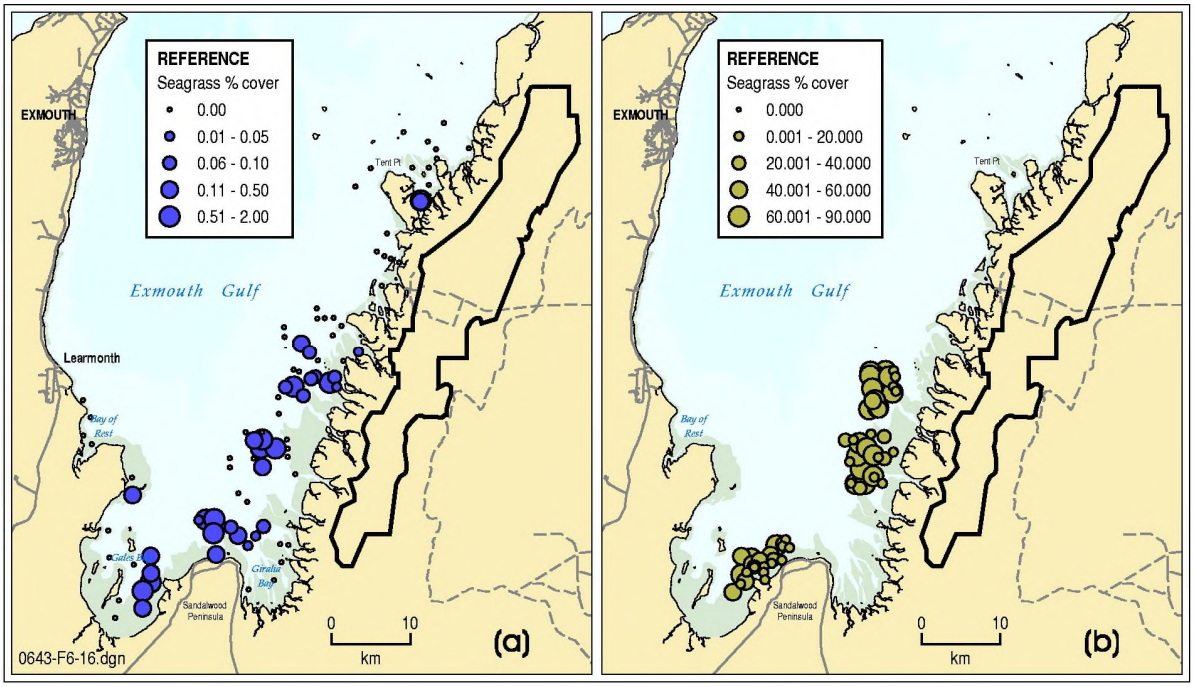
Exmouth Gulf contains a range of subtidal benthic primary producers and habitats, including seagrasses, algae, sponges and corals.

2.5.1 Investigations

Historically there have been a number of surveys targeting subtidal benthic habitats in the Exmouth Gulf, including McCook *et al*. (1995), Hutchins *et al.* (1996) and Loneragan *et al.* (2003). McCook *et al.* (1995) published the first survey of seagrass communities of the east coast of the Gulf. Loneragan *et al.* (2003) surveyed the region for a Fisheries Research and Development Corporation project and the Department of Fisheries (WA) has since been undertaking annual surveys which largely follow the methods and sites established by Loneragan *et al.* (2003).

The studies to date have revealed the following information about the subtidal benthic habitats of the Gulf:

1. The eastern side of Gulf south of Tubridgi Point contains extensive shallow waters that support seagrass and algae.
2. All the seagrass species found in the Gulf have tropical affinities and are predominantly fast growing ephemeral species.
3. The seagrasses in the Gulf undergo a marked seasonal cycle of growth and senescence. There have been observations of a significant increase in seagrass biomass from October to November/December. The seasonal cycle produces the least biomass from August to September and the most biomass from November to March.
4. There was very rapid recovery of seagrass following the nearly total destruction after Cyclone Vance in March 1999 (Figure 6-16).
5. Vegetated habitat is most abundant in waters less than 2.5 m deep.
6. Algae are most abundant throughout the year and are likely to have the greatest overall contribution to productivity.
7. Seagrass and algae provides critical nursery habitat for fish and prawns (particularly tiger prawns).



Source: Longeragan et al. 2003, as cited in Oceanica 2006a

Figure 6-16 Percentage of (a) seagrass cover in June 1999 and (b) December 2001

Benthic habitat surveys

Benthic habitat survey transects offshore from the project area were completed in January and December 2005 (Oceanica 2006a). Surveys focussed on the area immediately around Hope Point and were aimed at establishing baseline benthic habitats at the entrance to the proposed harbour and shipping channel on Hope Point. The surveys involved randomly placing a 0.5 m^2 quadrat on the seabed in four locations at each site, and recording the percentage cover of algae, seagrass and bare seabed (Oceanica 2006a).

Opportunistic visits to existing Department of Fisheries survey sites in the eastern area of Exmouth Gulf were also undertaken to determine species present and percent cover (Oceanica 2006a).

Mapping

Satellite imagery and aerial photography of Exmouth Gulf was collected with the aim of defining the benthic habitat types on the eastern side of the Gulf (Oceanica 2005a).

A number of image classification methods were employed on both satellite and aerial photomosaic images with the aim of producing a polygon dataset based on tonal differences between vegetated/reef habitat and bare substrate. However, lack of suitable image quality due to environmental and technical factors meant this ideal outcome could not be achieved. However, the analysis of the available imagery, coupled with the results from the Department of Fisheries, Loneragan *et al.* (2003) and field surveys still proved useful and enhanced the level of understanding regarding the distribution of the vegetated habitat on the Gulf east coast.

2.5.2 Description

Seagrass

Historically, the following seagrass species have been recorded for Exmouth Gulf:

- *Cymodocea angustata*
- *Cymodocea serrulata*
- *Halodule uninervis*
- *Halophila ovalis*
- *Halophila spinulosa*
- *Syringodium isoetifolium*
- *Thalassodendron ciliatum.*

McCook *et al.* (2005) found that seagrass encountered during surveys of the Gulf were neither extensive nor abundant in the areas surveyed. Seagrasses were rare or absent below 5 m depth and in the areas of greatest abundance, percent cover was rarely greater that 5%. Leaf blade lengths were generally about 5 cm and always less than 10 cm and sediment surveys found no evidence of roots or rhizomes (as indicator of dormant seagrass). The low abundance of seagrass in the areas surveyed was attributed to the lack of suitable substrate; with the observed substrate either hard or mobile coarse sediments (McCook *et al.* 2005 as cited in Oceanica 2006a).

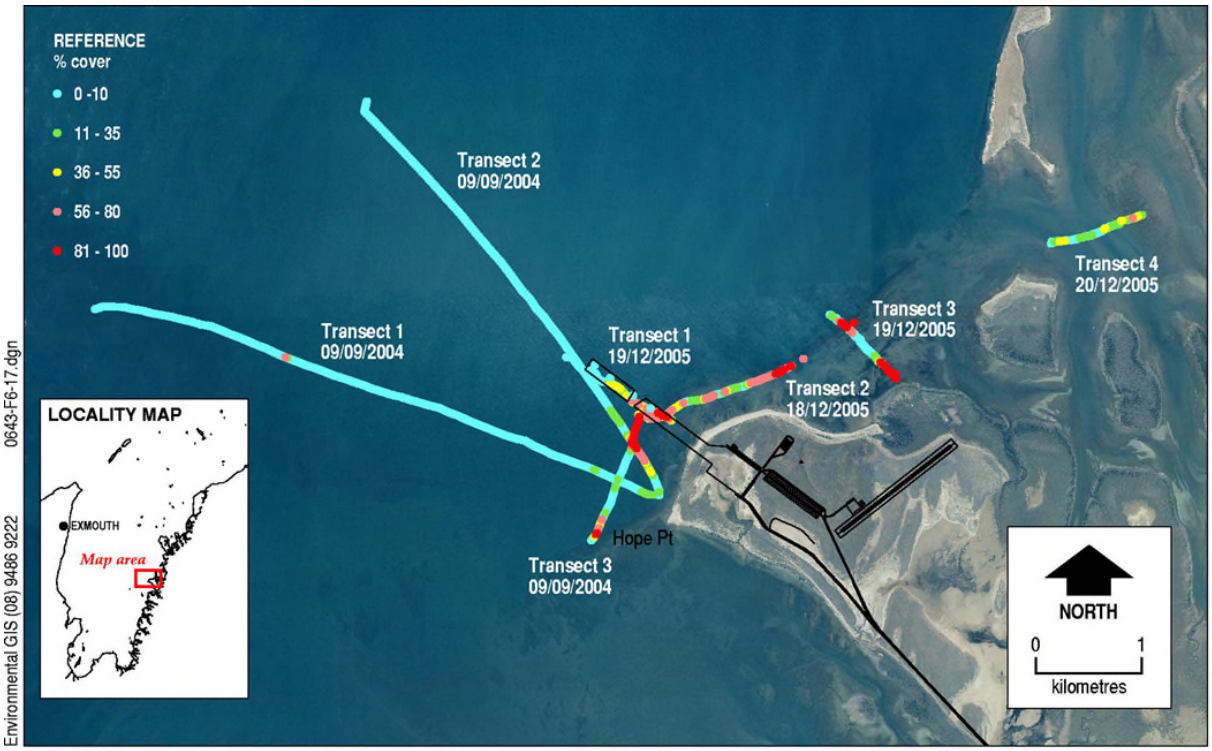
In the 2005 surveys, the majority of habitat on transects comprised sand and mud. Some seagrass was found close to shore, with seagrass cover of up to 20% in the first 100 m of transect 1; with only traces of seagrass beyond this distance (Oceanica 2006a).

Algal beds

McCook *et al.* (2005) concluded that algae are the dominant form of benthic flora and algal beds were most abundant from Tent Island to Whalebone Island/Islam Inlets. Algae in Exmouth Gulf included a wide range of groups, from filamentous epiphytes such as *Hydroclathrus, Padina*, *Sporochnus, Dictyota*, *Asparagopsis*, *Lauencia*, *Dictymenia tridens*, *Graciaria* and *Hypnea* to perennial macrophytes, notably *Sargassum decurrens* and other *Sargassum* species (McCook *et al.* 2005 as cited in Oceanica 2006a). The ephemeral phaeophyte *Hydroclathrus* was particularly abundant and there were large amounts of surface drift and attached algae present.

In the 2005 survey, algae dominated some areas, including an area of rocky pavement north of Hope Point and a shallow rock ledge that extends out in a north westerly direction from Hope Point. Up to 100% algal cover was observed in this area (Figure 6-17) (Oceanica 2006a) (Appendix 7).

Opportunistic surveys of three Department of Fisheries survey sites found that two sites were dominated by algae (species included *Penicillus nodulosus* and *Dictyota* sp.) and one site contained a mixed assemblage of algae and seagrass.



Source: Oceanica 2006a

Figure 6-17 Percentage cover of algae on Hope Point transects

Sponges

In the 2005 survey, sponges were observed in waters up to 3 m deep with up to 30% cover (Oceanica 2006a). Sponges are considered an important element of the Exmouth Gulf ecosystem especially in areas with stronger currents (such as the gap between Point Murat and the Muiron Islands). RPS Bowman Bishaw Gorham (2004) reported that diverse filter feeding communities occur in deeper, usually high current areas of Exmouth Gulf. The most extensive known area extends from near the Naval Pier to offshore between North West Cape and the Muiron Islands, which is the region of the Gulf where tidal currents are strongest. The community typically comprises sea whips, gorgonians, sponges, black corals, bryozoans, hard corals, ascidians and algae. The distribution of filter feeding communities throughout the Gulf has not been determined (Oceanica 2006a).

Coral

The region offshore and at Ningaloo is internationally significant for the scale and diversity of its coral reef communities (Oceanica 2006a). However, Exmouth Gulf does not support extensive coral reefs due to lack of suitable substrate and naturally high turbidity.

There are areas of limestone outcrops (Simpson and Burnside Island) and shoals (Whalebone and Campbell) which are most likely to support corals. The survey did not record extensive coral reef systems (Oceanica 2006a).

Mapping outcomes

The outcomes of the mapping exercise can be summarised as follows:

1. Confirmation that there is extensive vegetated habitat along the coast south of Hope Point to Giralia Bay and behind Simpson and Burnside Islands. The photography and the field surveys suggest that the habitat is most dense in the water depths to 2.5 m deep (CD).
2. Confirmation that the benthic survey transects offshore from Hope Point will be characteristic of the regions due east and north east of Hope Point and that vegetated habitat is not a key feature of the seabed in this area, although there is vegetated habitat close to Hope Point.
3. Hope Point marks a transition from the lower-energy, shallow mangrove dominated coast south to the higher-energy limestone dominated coast to the north.
4. It was impossible to differentiate between reef, algae and seagrass in any aerial photography, however, surveys and observations suggest that habitat south of Hope Point, will be dominated by algae and seagrass on shallow banks. North of Hope Point, the shoreline and coast is rockier and there are coral reefs seaward of Simpson and Burnside Islands. Behind the islands, there is extensive algae and seagrass habitat.
5. The area designated as a fish nursery or no trawl area accurately captures the vegetated benthic habitat which is of prime importance to the Gulf prawn fishery (Oceanica 2006a).

Estimation of BPPH on the east coast of the Gulf in vicinity of Hope Point

It was not practicable to accurately map the entire underwater habitat of the east coast of Exmouth Gulf for the following reasons (Oceanica 2006a).

1. Poor water clarity (turbidity) largely precludes the use of polygon classification from aerial or satellite photography.
2. Habitats are highly heterogeneous, with seagrass, reef and algal habitat frequently mixed.
3. Coverage and biomass of seagrass and algae varies significantly with season and any map produced is at best a 'snapshot', rather than a definitive reference map.

In the absence of detailed field mapping, the broad patterns observed by Loneragan *et al.* (2003) and Oceanica (2006b) have been used to define two habitat types in the vicinity of Hope Point:

1. Mixed Inshore Habitat (<2 m bathymetric contour). The substrate from the intertidal zone to about 2 m CD will largely comprise:

    a. limestone pavement, reef and rubble which will either be bare or support algae, sponges and small areas of hard corals

    b. shallow sandy banks in sheltered areas (i.e. south of Hope Point or in the lee of islands) which will support extensive seagrass and algae.

2. Offshore Habitat (>2 m bathymetric contour). The substrate deeper than about 2 m CD will generally be mud and sand. This will support sparse seagrass and algae in shallower areas (2–3 m CD) and be unvegetated in deeper areas (>3 m CD), with significant variation between coverage and biomass of seagrass and algae with time of year.

2.6 IMPACT ASSESSMENT AND MITIGATION

2.6.1 Proposed management units for assessment of impact on BPPH

EPA Guidance Statement No. 29 requires the identification of a management unit for benthic primary producer habitats (EPA 2004a). The guidance suggests the identification of an integrated area of marine habitat in the order of 50 km^2 in size, although other size units will be considered where justified (EPA 2004a).

Below is a summary of the basis for the selection of the proposed management units. A detailed geomorphological and ecological justification for these units is provided in (Biota 2005d) and Oceanica (2006a).

Historically human induced loss of BHHP in the intertidal and subtidal management units is considered to be zero.

Intertidal BPPH management units

The proposed four BPPH intertidal management units (M1to M4) ranging from 47 to 160 km^2 along the eastern margin of Exmouth Gulf reflect the smallest spatial scale of any of the studies that have examined geomorphology, mangrove community variation, conservation significance and management areas along the Pilbara Coast. The units are based on separating the east Exmouth Gulf by the only major geomorphic features present that may also indicate local connectivity in mangrove populations, tidal hydrodynamics and other relevant aspects. From north to south, these features are:

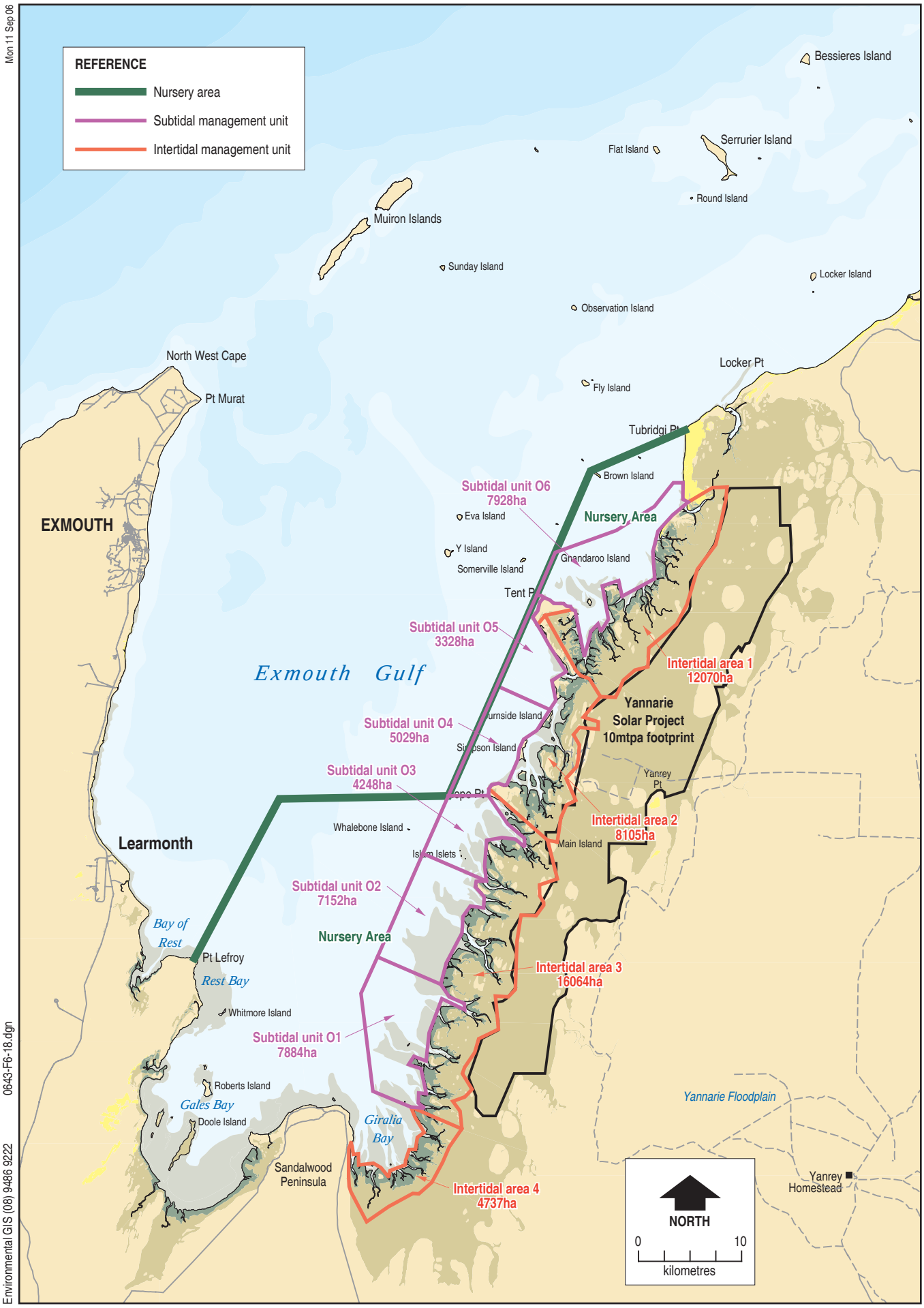
- the relatively enclosed and low wave energy environment of Giralia Bay, which marks the local southern limit of mangroves at Sandalwood Peninsula
- Hope Point – the next major headland, marking the southern boundary of the limestone barrier islands and associated creek systems, which also marks the general southerly limit of the more species-rich and complex mangrove association
- Tent Island – the next major headland south. This stretch of coast also includes a series of limestone barrier islands (Semeniuk 1993) sheltering more complex creeks
- Tubridgi Point – a clear boundary margin, representing the first expanse of sandy beach and the northern end of the mangrove habitats in east Exmouth Gulf (Biota 2005d).

Subtidal BPPH management units

There are four distinct geomorphic regions (which were also used as the basis for determining the for intertidal management units) along the east coast of the Gulf corresponding to:

- Giralia Bay
- Giralia Bay to Hope Point
- Hope Point to Tent Island
- Tent Island to Tubridgi Point.

These units were subdivided further to six units (O1 to O6) ranging from 33 to 79 km^2 to more closely match EPA guidance Statement 29 preferred area of 50 km^2 for a management unit (Figure 6-18). The units extend offshore to the boundary of the prawn nursery or no trawl zone corresponding roughly to the 5 m deep contour and the extent of subtidal benthic habitat.



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Biota, 2005 and Oceanica, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-18 Proposed management units for the intertidal BPPH and eastern Exmouth Gulf

2.6.2 Environmental aspects and potential impacts

Intertidal communities

Activities or aspects of the proposal that may potentially affect intertidal BPPH include:

- **site preparation** (including construction of ponds, pump stations, infrastructure corridor and seawater canals) leading to the physical removal/clearing of intertidal benthic primary producer habitats (mangroves and algal mat)
- **location of project infrastructure and pumping of water into ponds** could lead to hydrodynamic changes resulting in a reduction of tidal flushing in creeks and in extent of inundation during high tides. This may affect mangroves and algal mat extent in marginal fringing environments which have high salinities under natural conditions
- **impoundment of brine** at higher than natural surface levels potentially leading to seepage of saline water from the saltfield towards algal mat and mangrove communities
- **storage of hydrocarbons or fuels** with a risk of spills.

Subtidal communities

Activities or aspects of the proposal that may potentially affect subtidal BPPH include:

- **site preparation** (including dredging area and pump stations) leading to the physical removal/clearing of subtidal benthic primary producer habitat
- **dredging** leading to **increased water turbidity** potentially resulting in shading or smothering of benthic primary producer habitat
- **movement of marine vessels** leading to increased water turbidity potentially resulting in shading or smothering of benthic primary producer habitat
- **location of project infrastructure or operation of pump stations** potentially causing alterations to sediment dynamics and water flows potentially affecting BPPH
- **transport of salt**
- **storage of hydrocarbons or fuel** with a risk of spills.

2.6.3 Assessment and management of clearing impacts on mangroves and algal mats (intertidal BPPH)

Avoidance of mangroves and algal mats was a key design constraint for the Yannarie Solar Project. However, even with these design measures, some small areas of mangroves and algal mat will be unavoidably disturbed in order to accommodate the proposal. These areas will primarily be associated with the north and south pump stations and the infrastructure corridor for the conveyor from Main Island to Hope Point (Figure 6-19 to Figure 6-22). The impact of this clearing activity, while immediate and quantifiable represents a long-term (effectively permanent) loss of mangroves and algal mats in the areas of direct impact.

The estimated breakdown of the relative area of each mangrove association type that would be cleared for the proposal together with the area of mangroves mapped in the study area is provided in Table 6-10.

The project clearing requirements involve the removal of a very small percentage of the local extent of two mangrove associations (Table 6-10). The current mangrove extent of 11,154 ha will change to approximately 11,149 ha (or a reduction of 0.05%) as a result of the direct clearing for the proposal. Three of the five associations documented for the study area will not be affected at all by clearing for the proposed development (Table 6-10). The extent of proposed disturbance is less than the levels of accuracy of mapping and inter-annual variation in the extent of this habitat (Biota 2005d).

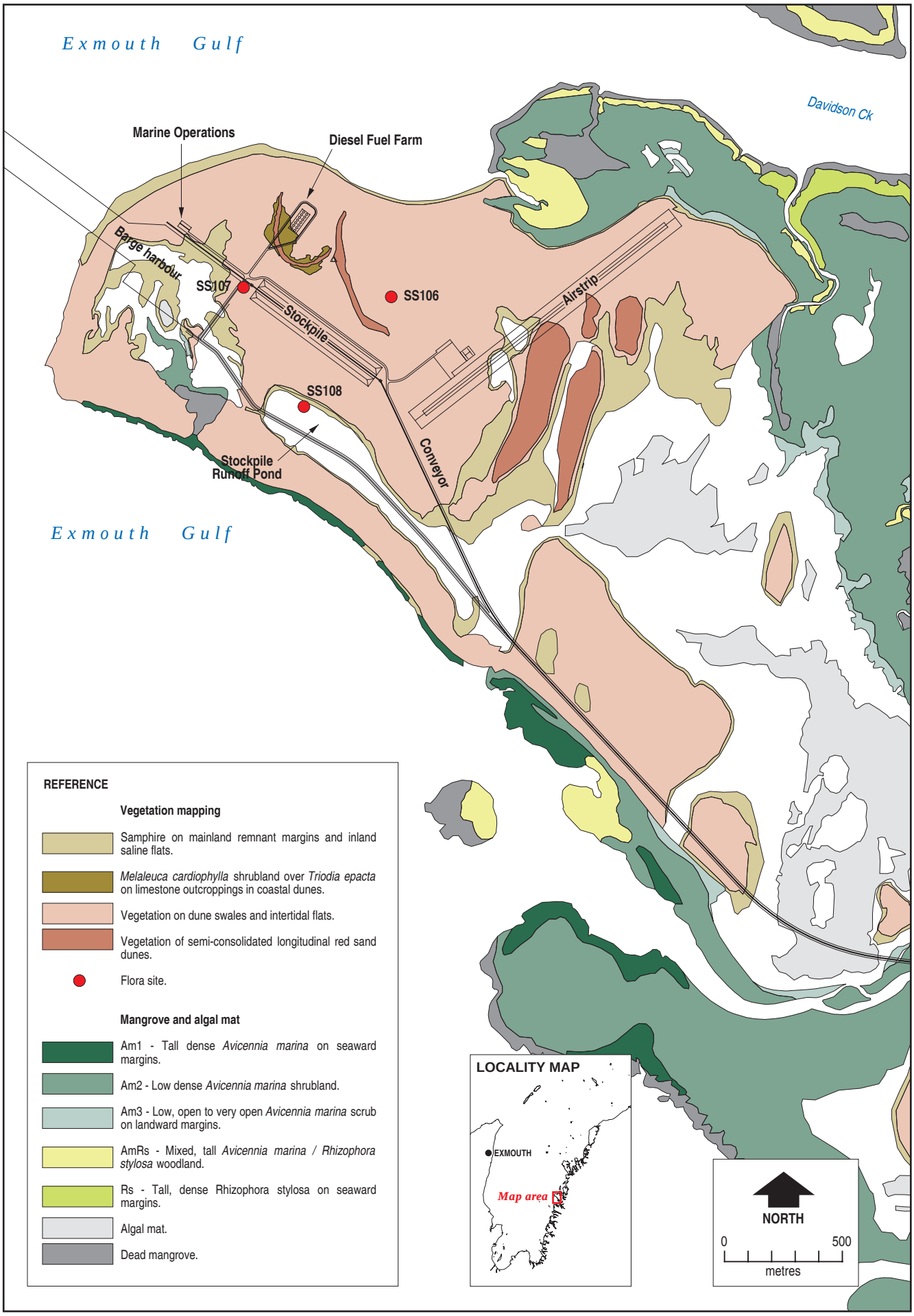
Three of the mangrove species recorded from the project area, *Aegialitis annulata, Aegiceras corniculatum* and *Bruguiera exaristata*, are at their documented southern range limits (Biota 2005d). All of the records of these species from the current assessment were associated with Tent Island or more sheltered and complex mangrove creeks along the main coastline to the west and immediate south west of this island. None of these areas will be directly affected by the project. The mangrove vegetation in the areas to be cleared comprised structural variants of monospecific *Avicennia marina*. There is expected to be no clearing of any mangrove species at their range limits as a result of this proposal.

The field surveys completed for this assessment also mapped 8054 ha of algal mats in the project area (Figure 6-18). The final design for the saltfield was also intersected with the algal mat extent in MapInfo and this GIS analysis indicated that 31 ha of algal mats will be removed by the construction of the field. This equates to 0.4% of the algal mat extent occurring along the eastern coast of Exmouth Gulf.

An assessment of the clearing of BPPH against EPA Guidance Statement No. 29 is provided in Section 2.6.12.

Table 6-10 Estimated clearing of mangrove associations and algal mat for permanent saltfield infrastructure

Mangrove association type	Area mapped in the study area (ha)	Predicted clearing (ha) and (% of area mapped)
Am1—Tall dense *Avicennia marina* on seaward margins	195	0 ha
Am2—Low, dense *Avicennia marina* shrubland	8485	1.5 ha (0.01%)
Am3—Low, open to very open *Avicennia marina* scrub on landward margins	2058	3.9 ha (0.19%)
AmRs—Mixed, tall *Avicennia marina/Rhizophora stylosa* woodland	290	0 ha
Rs—Tall, dense *Rhizophora stylosa* on seaward margins	126	0 ha
TOTAL Mangroves	**11,154**	**5.4 (0.05%)**
Algal mat	**8054**	**31 (0.4%)**



Fri 17 Nov 06

0643-F6-19.dgn

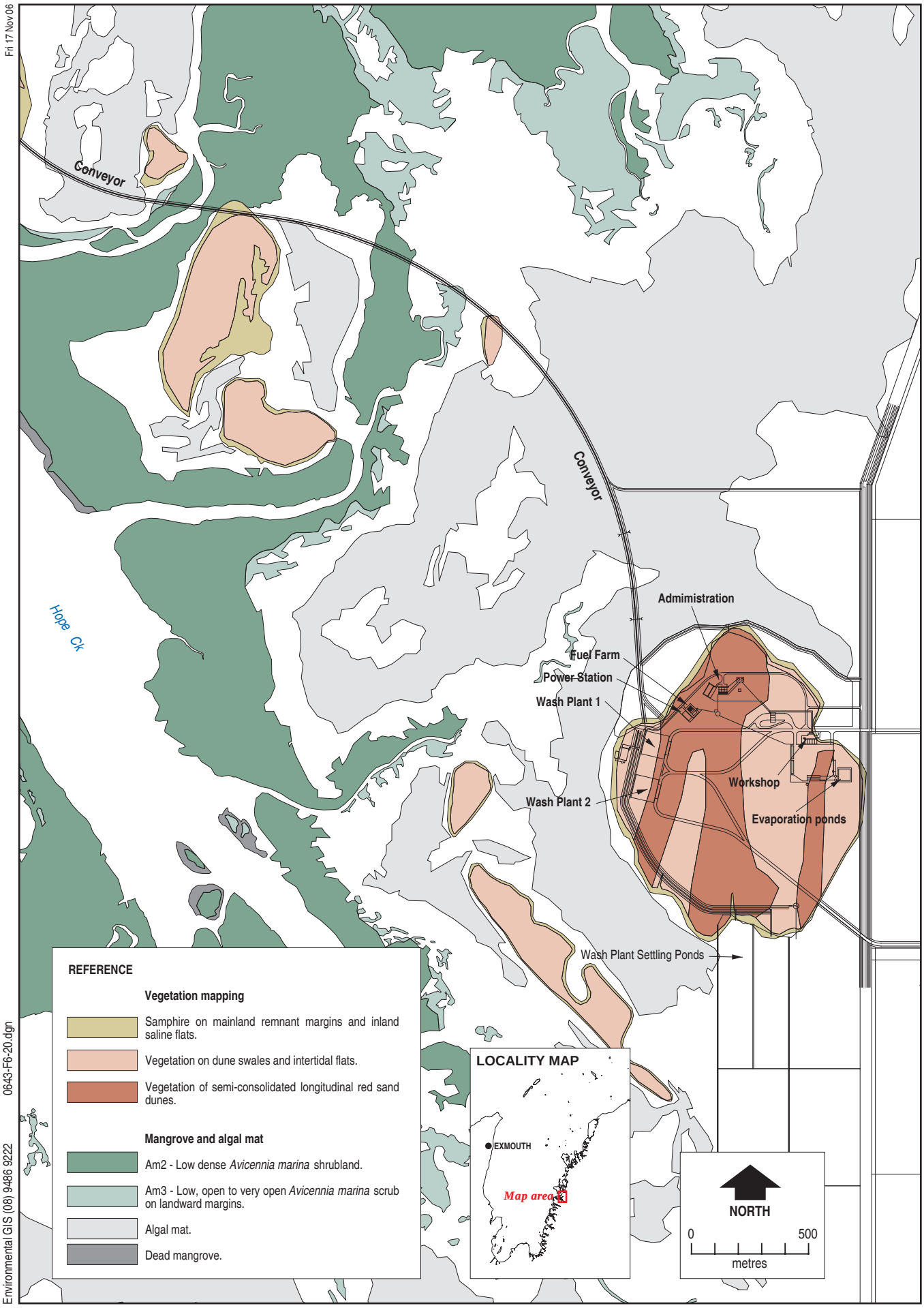
Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-19 Infrastructure footprint at Hope Point

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006

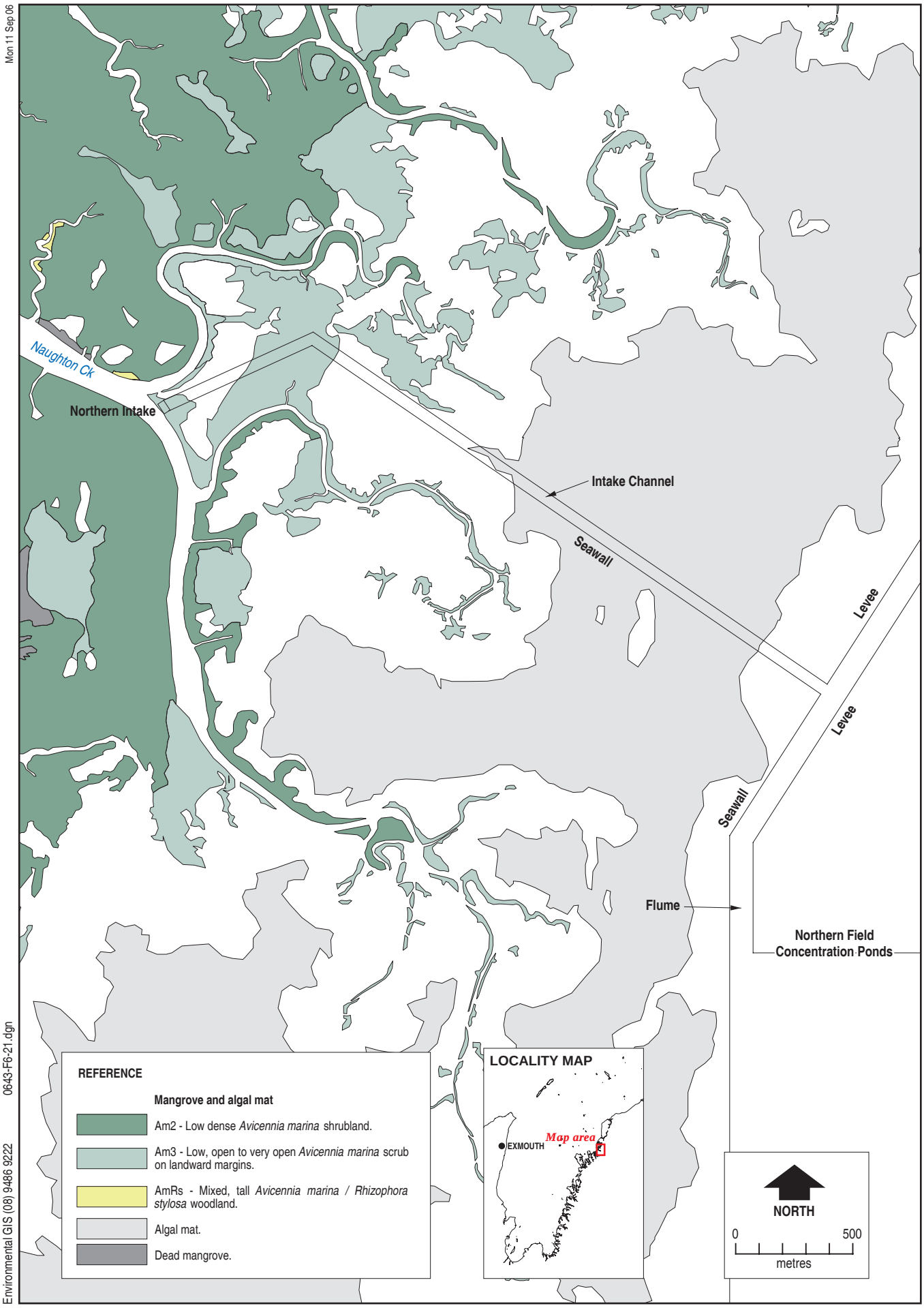


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-20 Infrastructure footprint at Main Island

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006

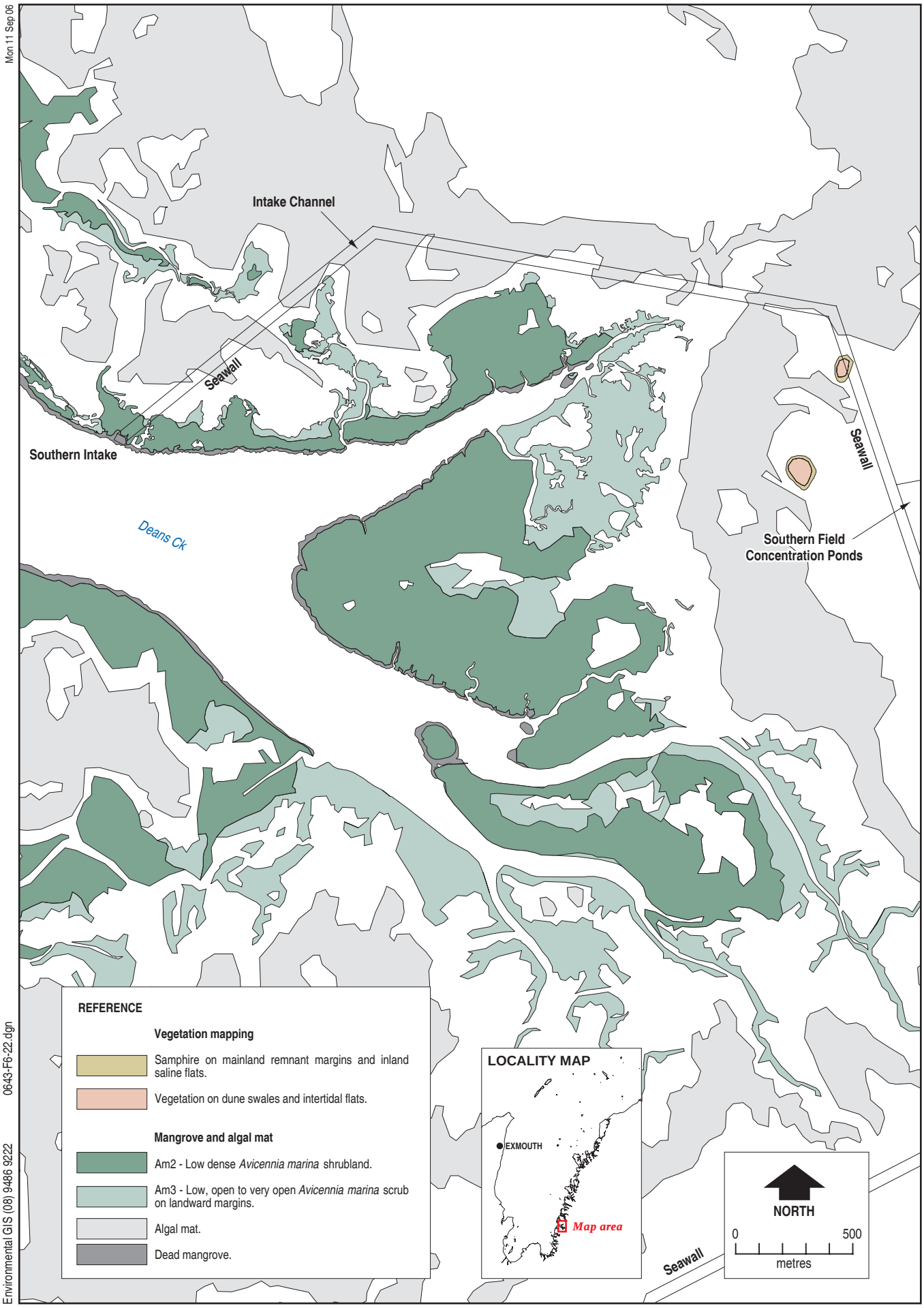


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-21 Pump station and channel footprint at Naughton Creek

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Biota, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-22 Pump station and channel footprint at Dean's Creek

Management

The following environmental management measures will be implemented to mitigate direct impacts to mangroves and algal mats:

1. **Detailed design**. Further consideration of reduction in clearing during detailed design.
2. **Mangrove vegetation clearing controls**. This will comprise definition of clearing limits on all design drawings and specifications, surveying in these limits in the field and erecting bunting or other clear boundary markers on-site. Any mangrove or algal mat clearing will constitute a hold point requiring written authorisation from the Site Superintendent prior to proceeding.
3. **Site environmental inductions**. All personnel working on the site will be required to complete an environmental induction. This will highlight the significance of the mangroves and algal mats of the project, particularly the need for sound day-to-day hydrocarbon management and to ensure that clearing activities remain within identified site limits.
4. **Mangrove ecosystem and algal mat monitoring program**. The development of a mangrove monitoring programme to monitor mangrove condition and demographic change in areas reliant on the hydrological design of the field for tidal flushing. This will primarily be in the areas that have been identified where potential hydrological changes from infrastructure crossing points could affect mangroves.

These measures will all be embodied in a construction and operational environmental management system and management plans. These will be written up as contractual specifications with construction and post-construction environmental auditing.

2.6.4 Assessment and management of potential hydrodynamic changes caused by infrastructure and pumping of seawater

Changes to tidal inundation regimes have the potential to result in more gradual, indirect impacts to mangroves and algal mats near the project area over the longer-term. Tidal flushing is the key mechanism that controls salinity levels within mangrove tolerance limits in intertidal sediments (Biota 2005d).

Hydrodynamic changes that have the potential to affect mangrove and algal communities fall into two categories:

1. Reduction of tidal flushing or inundation - the potential for newly constructed infrastructure to block incoming tidal flows or seawater pumping at Naughton Creek (Figure 6-21) and at Dean's Creek (Figure 6-22) to reduce tidal inundation of upgradient areas.
2. Increased ponding - the potential for tidal water to be trapped on the ocean side of infrastructure, resulting in more prolonged submersion of algal mats or mangrove pneumatophores (aerial roots).

A comprehensive hydrodynamic model of the project area was developed which predicted changes in percentage of the time that areas may be wet (WorleyParsons 2005b). The predicted changes were overlayed onto the mangrove and algal mat maps to ascertain the impact on these communities.

Effect of saltfield bunds

The wetting and drying model showed that the saltfield bund walls would result in no changes to the percentage of time the intertidal zone would be submerged primarily because the project was modified so that it was above the HWM and didn't interfere with tidal processes (WorleyParsons 2005b).

Effect of Hope Point infrastructure and pump stations

The outputs from the wetting and drying model also identified three areas where potential hydrodynamic changes may arise that could indirectly affect mangroves and algal mats:

- the conveyor and infrastructure crossing of the mangrove creek between Hope Point and the salt flat where the bulk of the field will be situated
- the northern field pump station and associated inlet channel on Naughton Creek tidal creek habitat (Figure 6-23)
- the southern field pump station and associated inlet channel on Dean's Creek tidal creek habitat (Figure 6-24).

The potential changes to tidal conditions in these areas, and any consequent effect on mangroves and algal mats, are discussed below.

Hope Point infrastructure

Some localised changes in maximum water velocity and percentage time inundated were predicted for the vicinity of Hope Point. These were primarily attributable to the crossing of the mangrove zone and a tidal creek by the conveyor infrastructure (Figure 6-25). The southern part of the project area was modelled under existing conditions and then subsequently with the saltfield imposed in the model, including a simulation of a tidally transmissive series of culverts in the Hope Point crossing (WorleyParsons 2005b).

Predicted changes in tidal current velocity between these scenarios were insignificant and unlikely to result in any changes to natural sedimentation patterns or increases in scour in these areas. WorleyParsons (2005b) concluded that these changes were small (of the order of a few cm/s occurring during the peak tidal ranges) and only occurred in very limited areas.

The hydrodynamic modelling indicated some small-scale and localised changes to the tidal wetting and drying regime in the area around the Hope Point crossing. The primary change identified comprised a small increase in percentage time wet on the seaward side of the Hope Point culverts of 1-2%, with no change in percentage time inundated predicted on the landward side of the crossing (Figure 6-26) (WorleyParsons 2005b). This change would amount to less than a day of extra submergence in the average month and would not be expected to result in any mangrove decline. A small decrease in the depth of the water on the landward side was predicted (approximately 2 cm under maximum tidal conditions) but these areas will still become submerged with the same frequency they currently experience (WorleyParsons 2005b).

This assessment was confirmed by more detailed inspection of tidal submergence curves at the Hope Point crossing area (WorleyParsons 2005b). These curves showed that the percentage of time a given elevation will be submerged under both the existing conditions and once the project is constructed. The submergence curves generated for this location confirmed that there is no significant difference predicted between the base case and the saltfield scenario (Figure 6-27) (WorleyParsons 2005b).

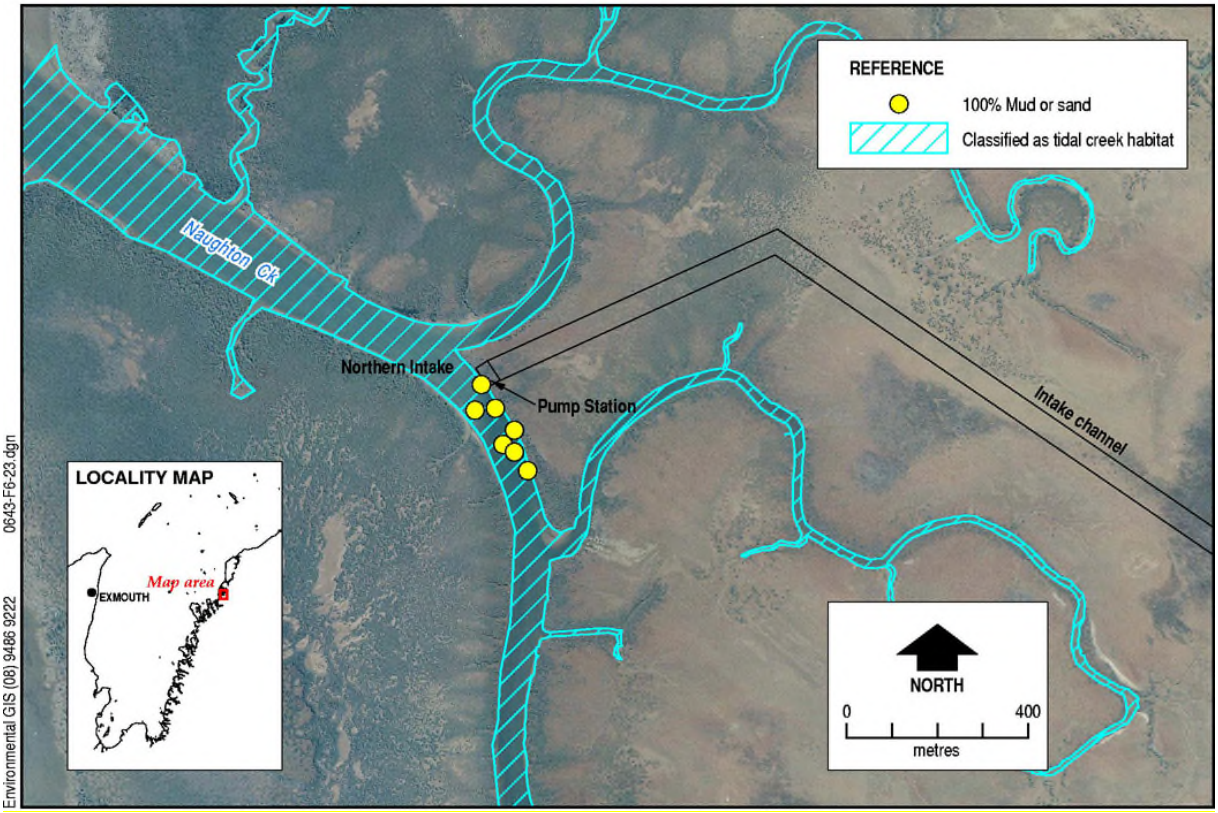


Figure 6-23 Naughton Creek pump station, benthic habitat results and habitat type[6]

[6] Habitat maps will be refined on the basis of additional habitat surveys. This information will be made available for a four week public submission period during the first half of 2007.

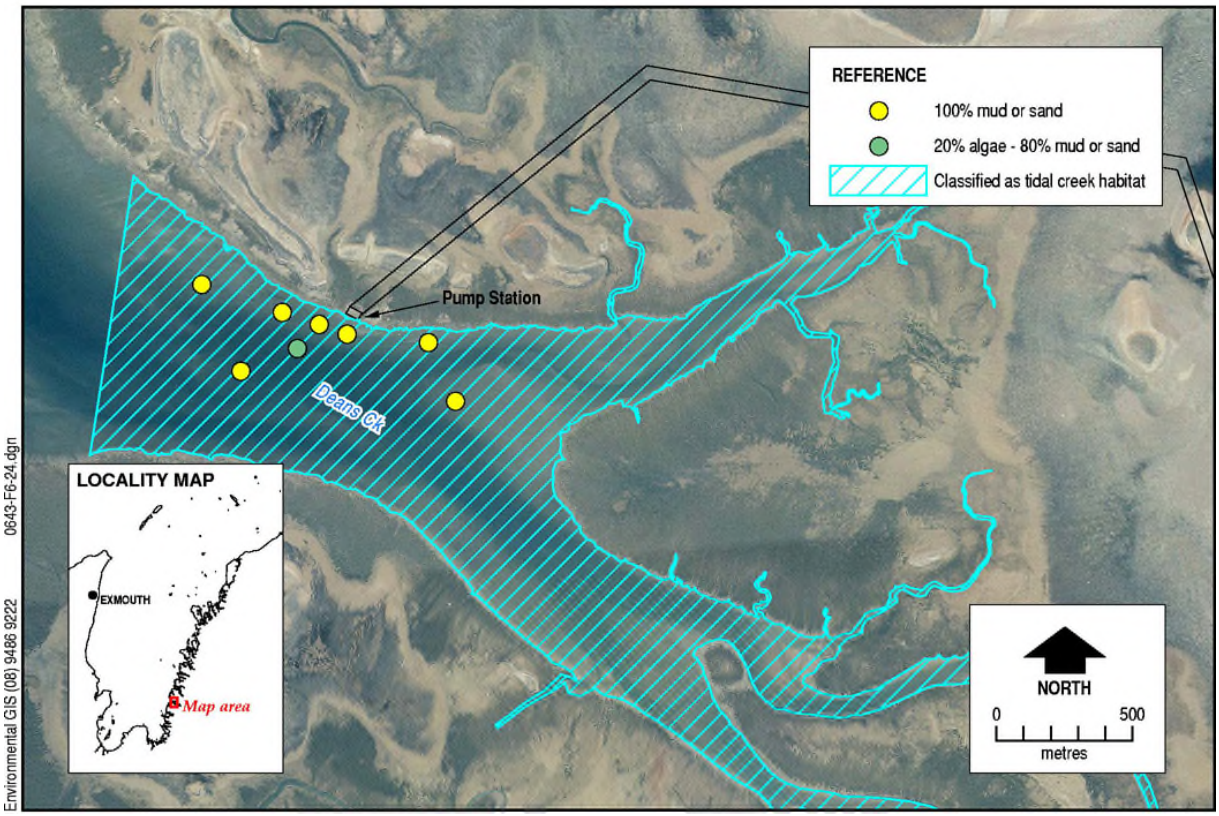
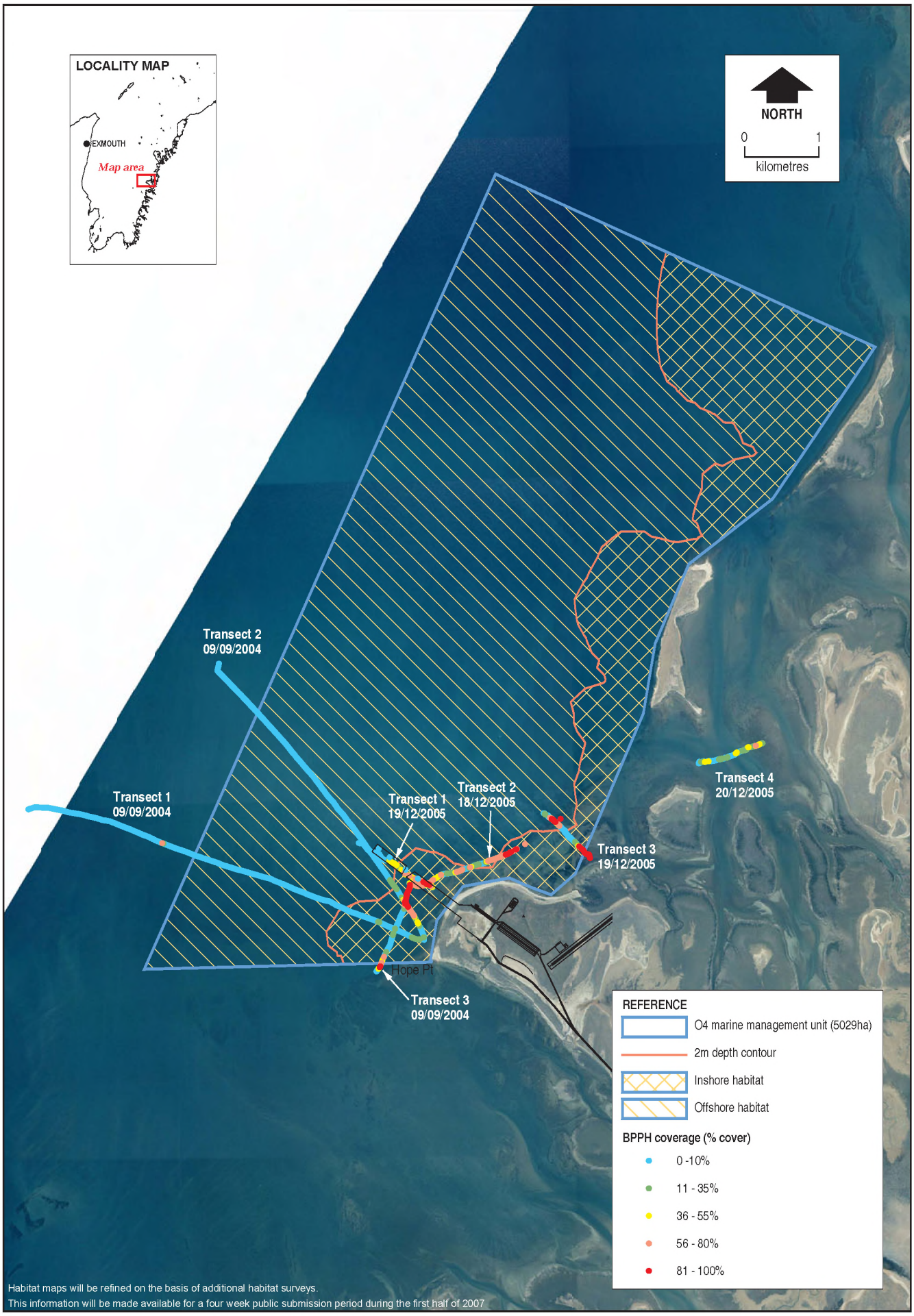


Figure 6-24 Deans Creek pump station, benthic habitat results and habitat type[7]

[7] Habitat maps will be refined on the basis of additional habitat surveys. This information will be made available for a four week public submission period during the first half of 2007.



Fri 17 Nov 06

0643-F6-25.dgn

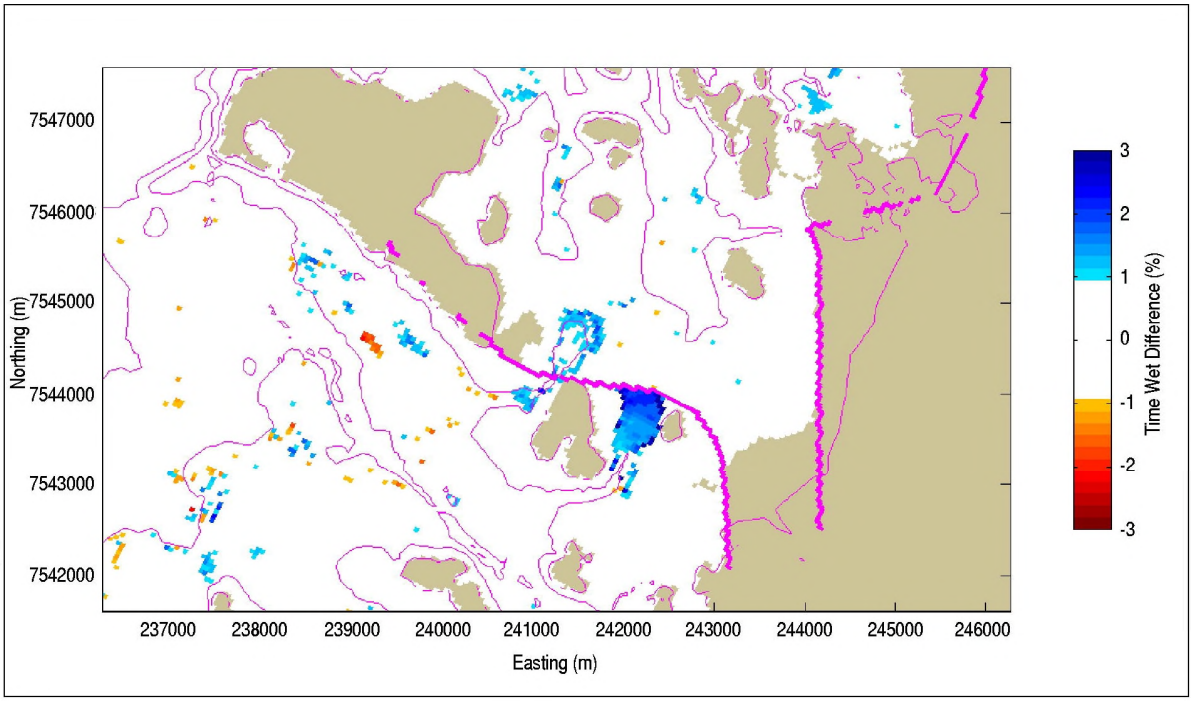
Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Oceanica, 2006
Date: 17 Nov 2006

YANNARIE SOLAR PROJECT ERMP/EIS

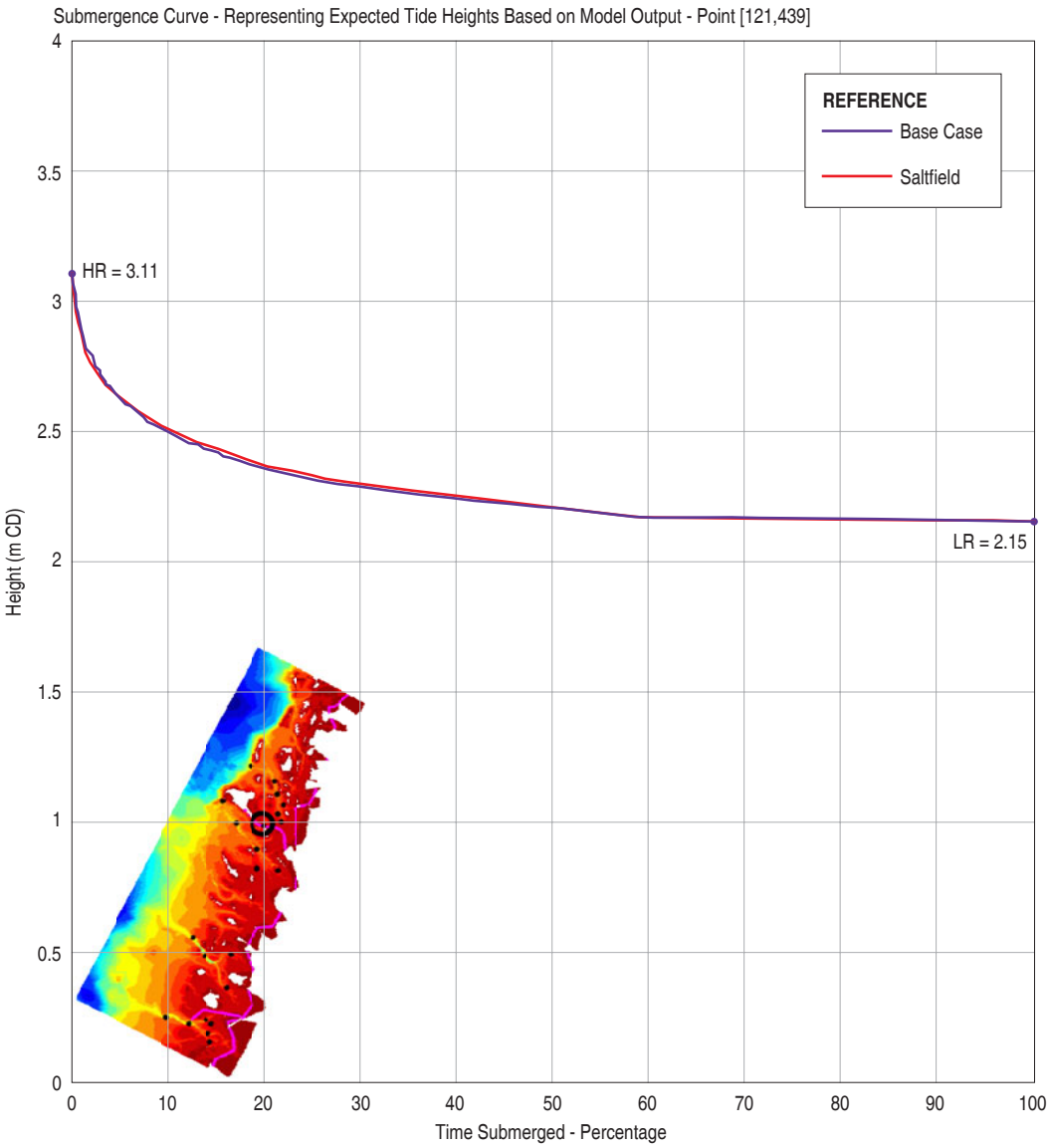
Figure 6-25 Habitat types, habitat coverage survey points and proposed channel layout within the 04 Management Unit



Source: WorleyParsons 2005b

Figure 6-26 Predicted percentage change to tidal wetting and drying regimes in the mangrove zone at the Hope Point infrastructure corridor crossing

The model period represents the highest astronomical tide ranges over the 18.6 year tidal cycle and therefore provides a worst case assessment at the upper end of the tidal range (WorleyParsons 2005b). Given that only very small scale and localised changes to the tidal regime are predicted, no indirect loss of mangroves or algal mats is expected in this area. This is based on the assumption that complete tidal exchange can be maintained across the creek crossed by the Hope Point infrastructure corridor. The size and spacing of the culverts have been designed in combination with the hydrodynamic modelling to ensure that this will be the case.



Time Submerged (%)	1	2	5	10	25	50	75	90	95	98	99
Base Case WL (m CD)	2.9	2.8	2.63	2.5	2.32	2.21	dry	dry	dry	dry	dry
Salt Field WL (m CD)	2.88	2.76	2.63	2.51	2.33	2.21	dry	dry	dry	dry	dry

0643-F6-27.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: WP, 2005
Date: 17 Nov 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-27 Tidal submergence curve for existing conditions at Hope Point crossing and predicted curve for saltfield scenario

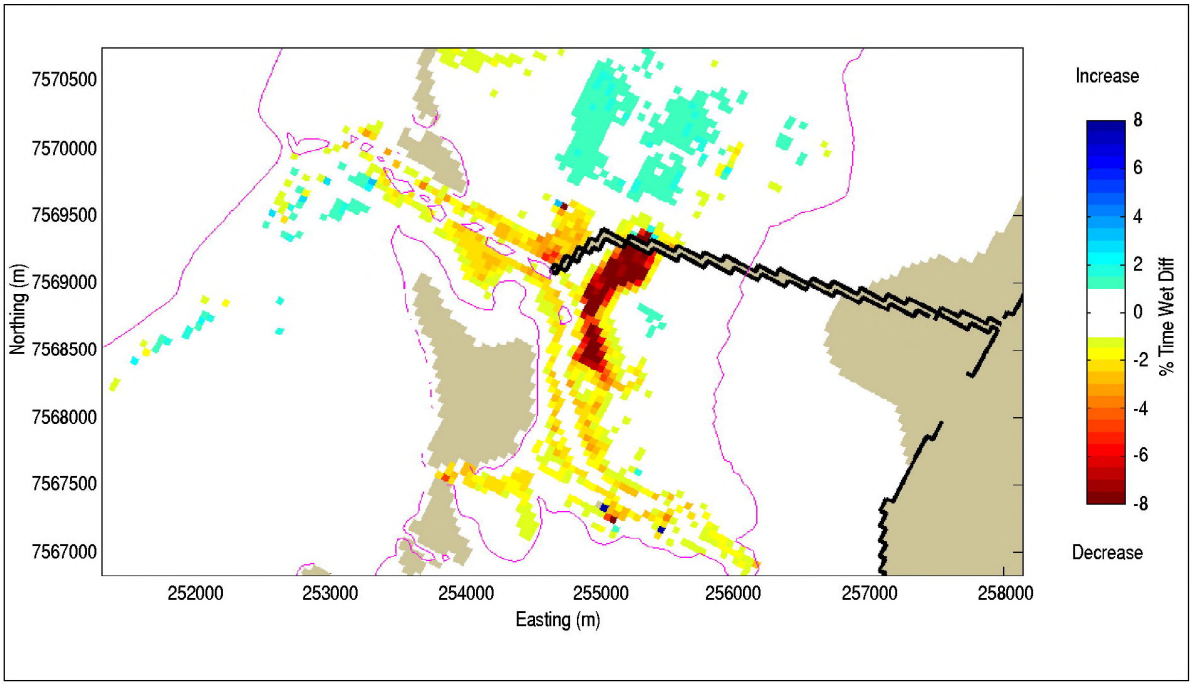
Northern pump station (Naughton Creek)

The Naughton Creek pump station will draw up to 120,000 m^3/hr for an average of 14 hours per day.

The hydrodynamic modelling showed some predicted reductions in percentage time wet at this pump station (Figure 6-28) (WorleyParsons 2005b). Most of the affected areas will experience a reduction in percentage time wet of approximately 2% or less. Algal mats are not expected to be affected by the hydrodynamic changes introduced by the operation of the Naughton Creek pump station as demonstrated by the tidal submergence curve for locations in the most affected areas (Figure 6-29) (WorleyParsons 2005c).

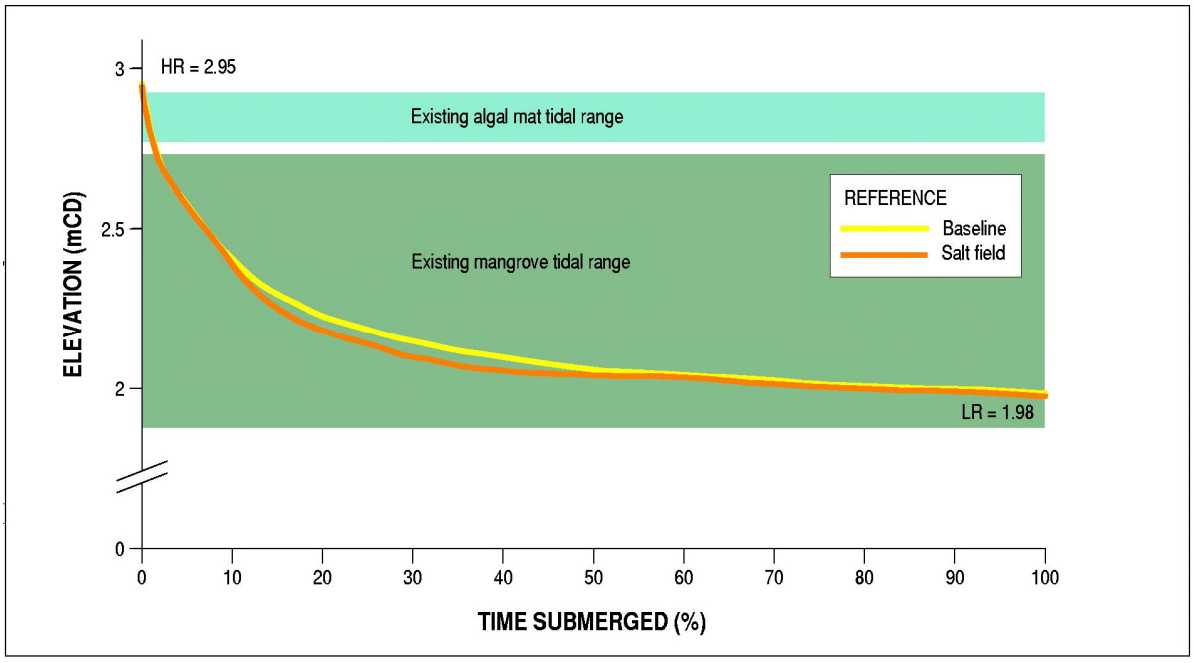
The submergence curves were determined for both the existing base case and the worst case conditions when the Naughton Creek pump station is operating (Figure 6-29). In the portion of the tide-affected area currently occupied by algal mats, there is no significant difference in the percentage time wet between the base case and development scenario (Figure 6-29). Mangroves higher in the tidal range would be more sensitive to changes in percentage time wet but will only be subject to very small changes in inundation. As with the algal mats, the percentage time wet for mangroves occurring in this uppermost portion of the mangrove tidal range under the development scenario will not differ significantly from the base case.

There is a relatively small area where the difference between the two curves is likely to be great enough to have the potential to affect mangroves through reduced tidal flushing. In this area two mangrove associations are affected: Am1 and Am2 (Biota 2005d). Both of which occur relatively low in the mangrove tidal range in this locality (Figure 6-29). The impact of a reduction in percentage time wet of 5–8% in this part of the tidal range would be less than for mangroves occurring in the top of the mangrove tidal range (where they are only inundated for less than 5% of the time). These mangroves may experience a change flushing from 40% to 32% of the time in the most affected areas (a change from approximately 12 days to 10 days of the month). These areas would still continue to receive regular tidal flushing and no loss of mangroves is likely to occur as a result of these localised hydrodynamic changes.



Source: WorleyParsons 2005b

Figure 6-28 Predicted percentage change to tidal wetting and drying regimes in the mangrove zone at the northern pump station (Naughton Creek)

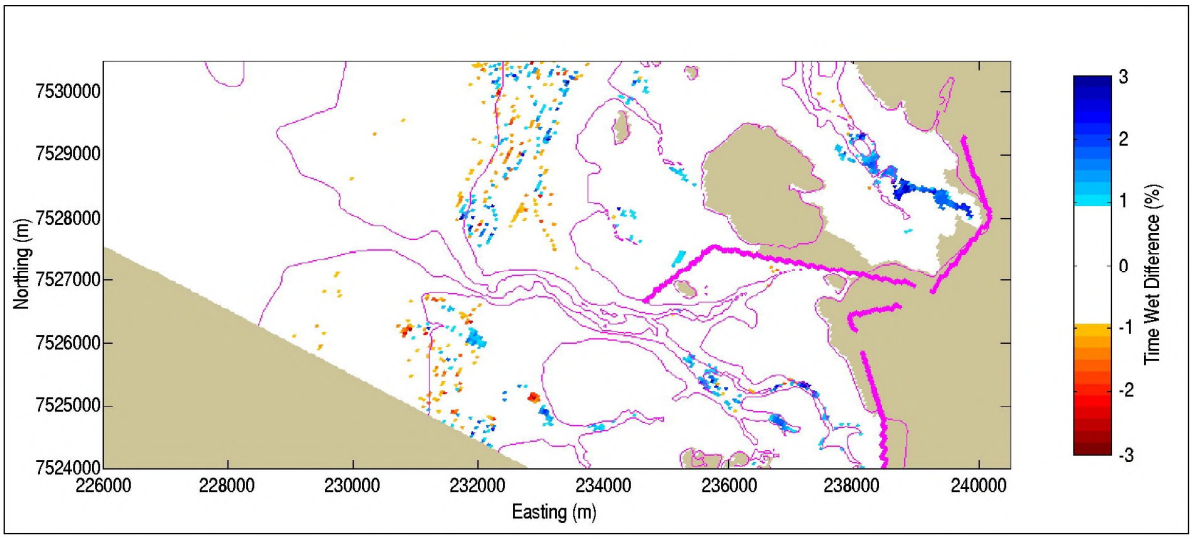


Source: WorleyParsons 2005b

Figure 6-29 Tidal submergence curve quantifying predicted maximum reduction in tidal flushing in mangrove and algal mat zones at the Naughton Creek pump station

Southern pump station (Dean's Creek)

The hydrodynamic modelling demonstrated that there was no detectable change in current velocities or percentage inundation time between the existing system and the scenario with the pump station operating in its proposed location (Figure 6-30) (WorleyParsons 2005b). This is largely due to the location of the proposed pump station intake, which is in a broad creek that opens directly into Exmouth Gulf. Tidal water levels in the area surrounding the pump station are not affected by pumping rates due to the dominance of the direct influence of oceanic water influx from the Gulf. No indirect impacts are therefore expected on mangroves or algal mats occurring in this area due to the operation of the southern pump station.



Source: WorleyParsons 2005b

Figure 6-30 Predicted change to percentage time wet in the mangrove zone at the southern pump station (Dean's Creek)

Summary of potential indirect impact from anticipated hydrodynamic changes

The results of hydrodynamic modelling of the effect of the saltfield ponds, northern (Naughton Creek) and southern (Dean's Creek) pump station and Hope Island infrastructure were overlayed on the mangrove and algal maps to determine any potential impacts on BPPH. The result of this assessment indicates that there will be no indirect loss of algal mats or mangroves as a result of hydrodynamic changes arising from the project. In particular:

1. The saltfield ponds will have no effect on wetting regime and tidal currents in mangrove and algal mat areas.
2. Small scale and localised changes may be anticipated in tidal wetting and drying regime resulting from the Hope Point infrastructure but will not result in any direct loss of mangroves or algal mats.
3. Some reductions in percentage wet are anticipated in some BPPH areas (but not algal mat areas) as a result of the operation of the northern pump station. A reduction of wetting time of 2% or less is anticipated in some mangrove associations of which those experiencing the greater reduction being low in the tidal range. The reduction of wetting mangrove in the uppermost tidal range is insignificant and no decline is anticipated. For those low in the tidal range the change in wetting is insignificant and not expected to decline.

4. No detectable change in current velocities or percentage inundation is anticipated at the southern pump station and therefore no indirect loss is anticipated of BPPH.

Management measures

A mangrove ecosystem monitoring programme will be designed and implemented for the project, with this locality identified as a potential impact site for monitoring.

A Marine Management Plan will be prepared and implemented that includes monitoring the impacts associated with the intersection of tidal flows including:

- a combination of aerial photography, site inspection and permanent survey transects will be used to establish whether the infrastructure crossing the intertidal areas is causing any change in sedimentation patterns with associated potential impacts on algal mats and mangroves.
- transect surveys will be undertaken before construction and every six months for the first two years following construction. If after two years of monitoring, there are no changes in sedimentation that can be related to the intertidal zone as a result of installed infrastructure, then monitoring will revert to surveys every two years.

2.6.5 Assessment and management of impacts arising from changes to water flows on subtidal BPPH

The effects of the proposal on water flows in the intertidal region and the waters immediately offshore were modelled (WorleyParsons 2005a, 2005b).

Bathymetric survey data was used in combination with aerial photography and mangrove mapping to locate the pump station locations in the deepest water possible while disturbing the least area of mangrove and algal mat.

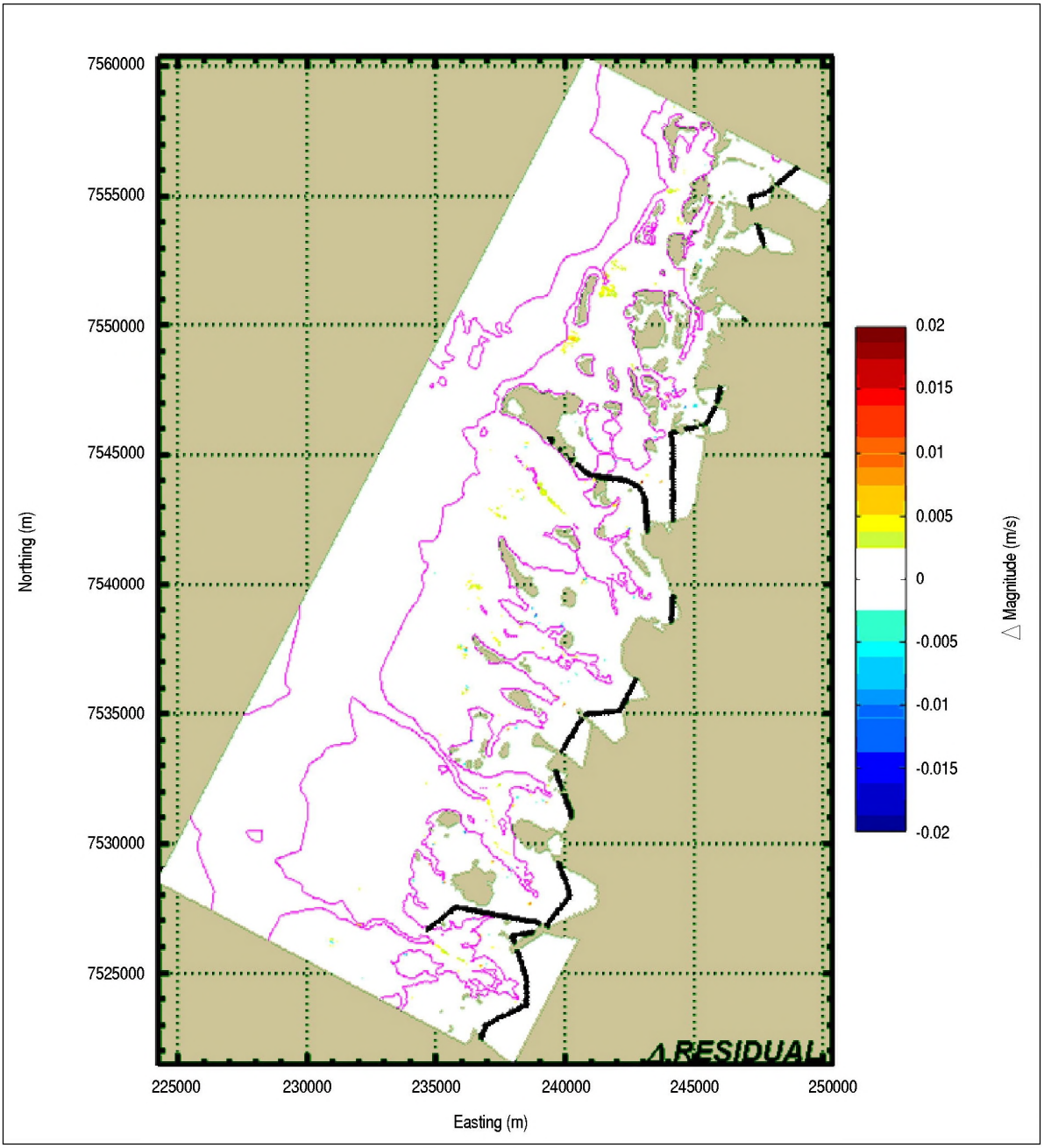
Saltfield bund walls have deliberately been located above the High Water Mark and consequently the majority of the project does not have any interaction with tidal flows and will not affect sediment movement or BPPH. The only components of the project which have any interaction with tidal flows are:

- the causeway from Main Island to Hope Point
- Dean's Creek pump station
- Naughton Creek pump station
- Hope Point barge harbour and channel.

Causeway and saltfield

In the southern section of the project area, there are only small changes in the velocities near the bund for the conveyor leading out to Hope Point and the culvert leading out to the Dean's Creek pumping station. Elsewhere, velocities are not affected (Figure 6-31).

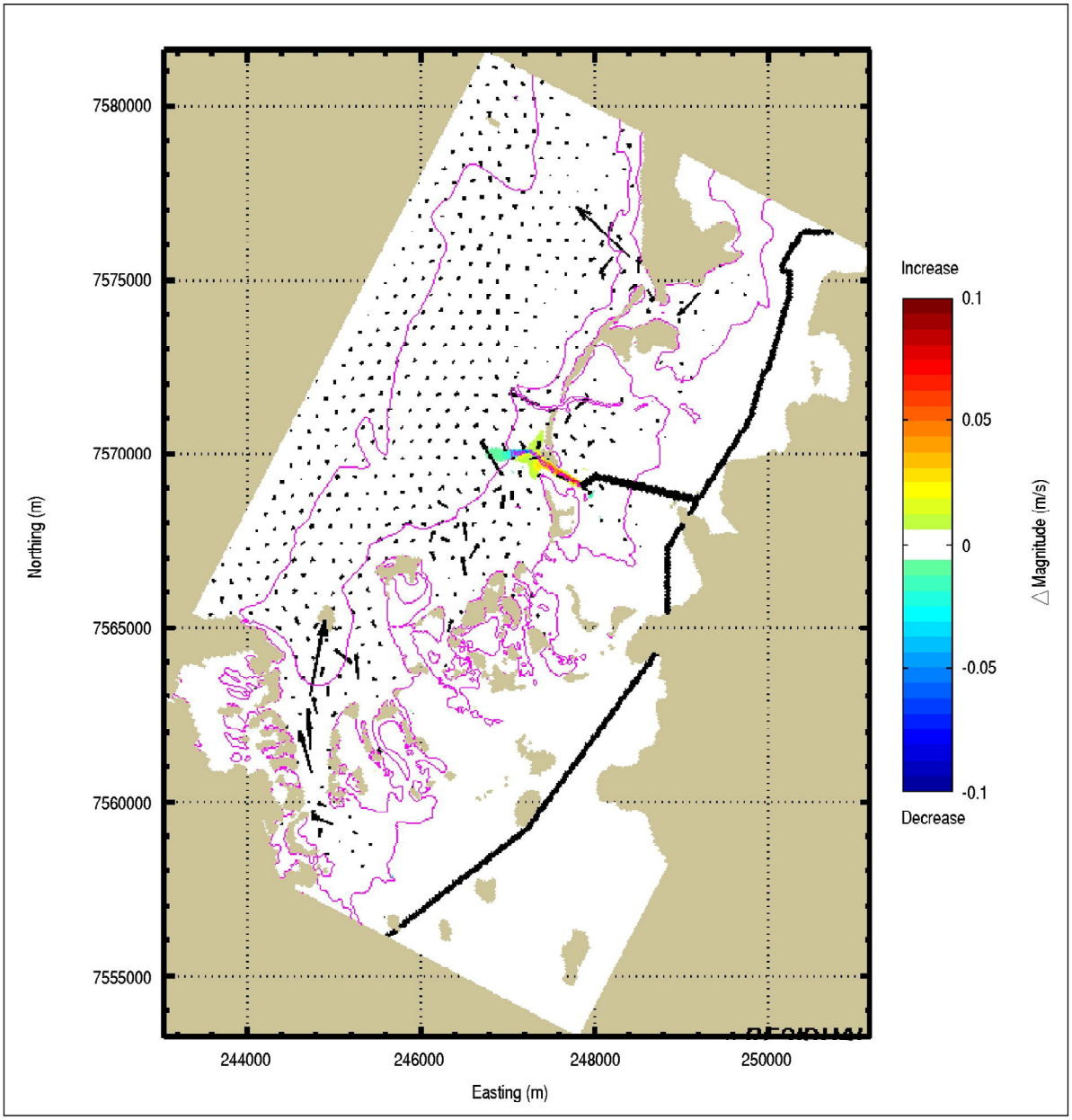
In the northern section of the project area, there is no difference (with the exception of the pumping impacts at Naughton Creek) between velocities with and without the project and as such there will be no project induced changes in sedimentation patterns away from Naughton Creek (Figure 6-32).



Source: WorleyParsons 2005a

Note: Maximum current differences between the base case and development case. Positive values represent an increase in the maximum current as a result of the proposal.

Figure 6-31 Effects of the southern portion of the saltfield on residual currents



Source: WorleyParsons 2005a

Note: Depth-averaged current differences between the baseline layout and the proposed saltfield facilities layout. Positive values represent an increase in residual current post-development. Residual current vectors (post-development) are overlain for reference.

Figure 6-32 Effects of the northern portion of the saltfield on residual currents

Dean's Creek (southern pump station)

This pump station has been located in an area that always has a water depth of at least 0.5 m under the full range of astronomical tides.

The Dean's Creek pumps will draw approximately 80,000 m^3/hr assuming an average favourable tidal 'window' for pumping of 14 hours/day and apportionment of this equally between the rising and falling tides. The pumps will be operating for about 3.5 hours during each rise or fall of the tide (for 2 tides per day), but this will vary to suit the tidal, rainfall and evaporation conditions.

Numerical modelling of pumping for a 29 day tidal cycle assuming a total maximum volume of pumping from the creek of 38.6 x 10^6 m^3 which is in excess of the projected peak rate of 32.1 x 10^6 m^3) (WorleyParsons 2005a). Without pumping, the natural flow past this point in the creek over a 29 day tidal cycle is 215 x 10^6 m^3 on the ebb and the same volume on the flood (a total of 430 x 10^6 m^3).

The pumping at Dean's Creek will draw about 4.3% of the monthly tidal prism of the creek, with the draw occurring during the higher portions of the tide. Although the pumps will draw a substantial volume of the tidal flow, there is little change in the total tidal flux in Dean's Creek with flood tide flux increasing slightly to 218 x 10^6 m^3 and ebb tide flux decreasing slightly to 213 x 10^6 m^3. The reason that these flows don't "total-up" is that fluxes were calculated across the creek immediately seaward of the pump station location and Dean's Creek is not a closed system, with flows coming in from the sides on high tides. The fluxes along the main channel of the creek remain similar to pre-pumping fluxes and ebb and flood volumes remain relatively symmetrical (about 1% change).

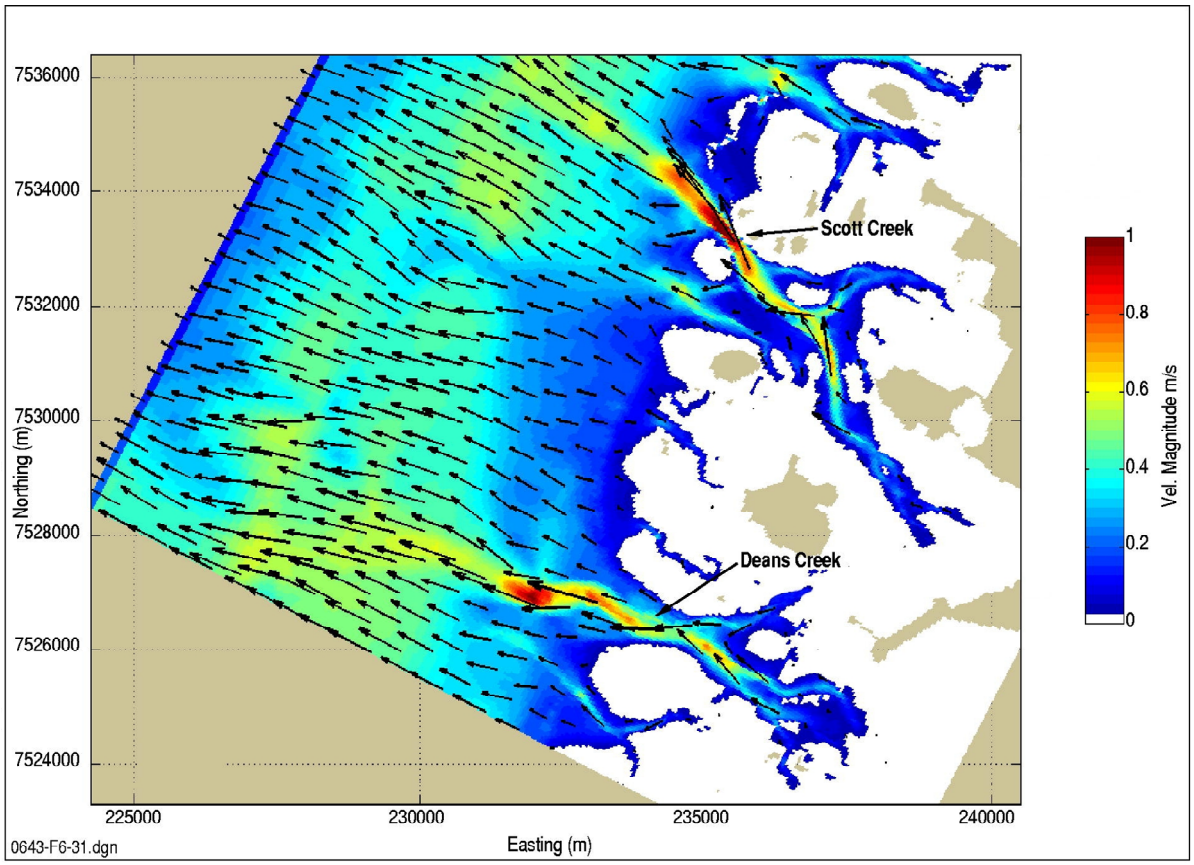
Pre-development peak currents in Dean's Creek were modelled and found these to be up to 1.4 m/s on the ebb tide and up to 1.2 m/s on the flood tides (Figure 6-33 and Figure 6-34). The asymmetry of the tidal speeds (with ebb flows creating stronger currents) is a key factor governing the morphology of mangrove creek systems (Wolanski *et al.* 1992). In order to quantify the potential impacts, the residual depth-averaged tidal currents over a 29 day tidal cycle were derived by comparing the modelled pre-development conditions with the modelled pumping scenario.

In general, the proposed pumping at Dean's Creek resulted in a negligible change in tidal velocities over the domain. The residual current direction was also not reversed, implying a dominance of the natural tidal regime over any pumping effects in Dean's Creek.

Modelling results showed no significant impact of the proposed saltfield development on maximum current magnitudes and residual currents over the model domain (WorleyParsons 2005a). The maximum currents induced by the pumps (approximately 0.63 m/s) within 50 m of the pump station, were an order of magnitude lower than the maximum currents resulting for the twice daily tidal flows.

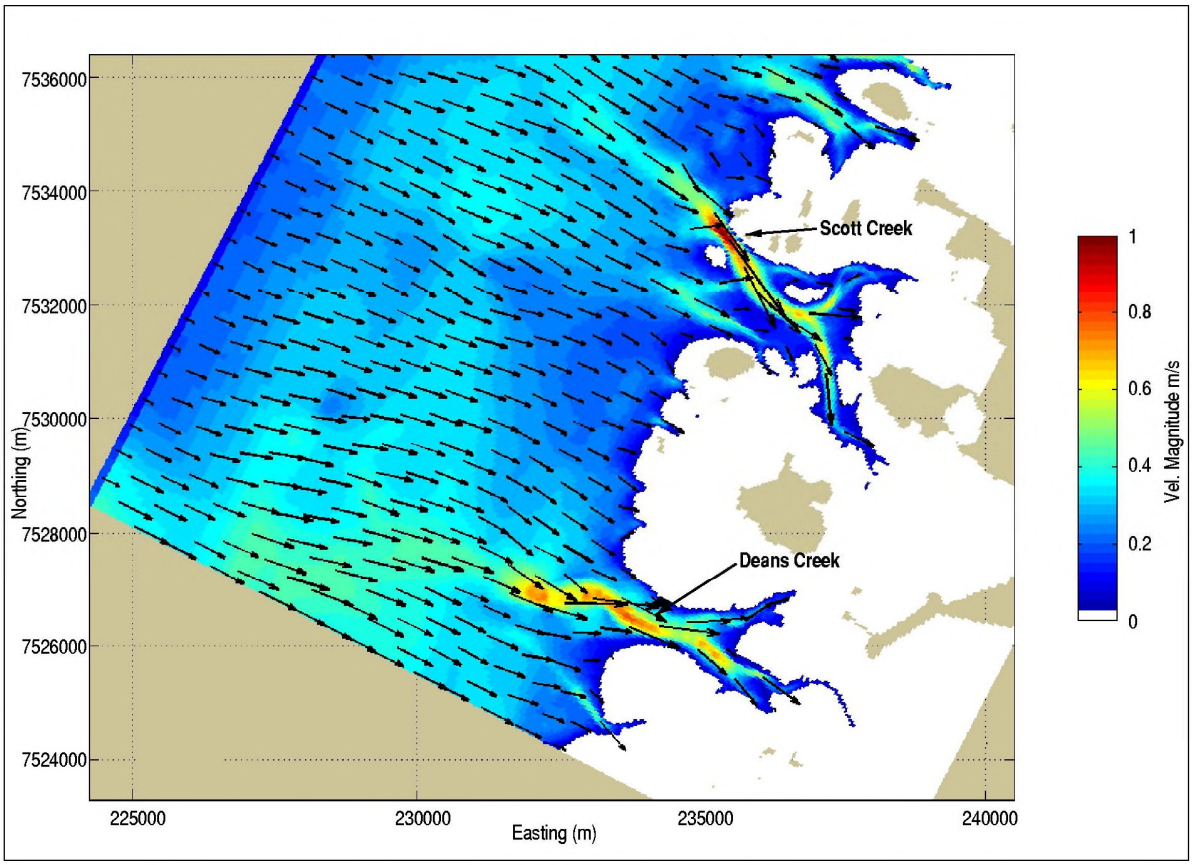
As pumping at Dean's Creek is not significantly affecting the currents or the fluxes in Dean's Creek, there will not be an impact on the sediment dynamics of the creek other than the possibility of highly localised effects in the vicinity of the pump station. There will be no loss of habitat due to pumping at Dean's Creek.

Detailed bathymetric cross-sections of the creek will be obtained before construction of the pumping station. Surveys will be repeated at one year intervals for the first 3 years of pumping to establish whether there is any change in the cross-sectional area of the creek. A nearby unaffected creek (possibly Scott Creek) will also be surveyed at the same time as a control.



Source: WorleyParsons 2005

Figure 6-33 Modelled typical peak ebb tidal currents for Dean's Creek (pre-development conditions)



Source: WorleyParsons 2005

Figure 6-34 Modelled typical peak flood tidal currents for Dean's Creek (pre-development conditions)

Naughton Creek (northern pump station)

The Naughton Creek pump station will draw up to 120,000 m^3/hr for an average of 14 hours per day, with the duration of pumping depending on tidal conditions, evaporation and rainfall.

The effects of pumping for a 29 day tidal cycle were similarly assessed through modelling (WorleyParsons 2005b). Naughton Creek would experience tidal flows of 96 x 10^6 m^3 on both the ebb and the flood tide. If the pumps were running continuously over a favourable tidal window of 14 hours for a 29 day cycle, the pumps would draw 59 x 10^6 m^3 which is greater than the expected peak monthly pumping rate of 48.4 x 10^6 m^3. The combination of high pumping rates and existing tidal fluxes in the creek results in a significant change in creek flows. After pumping, the summed 29 day flood flows in the creek would increase by 35% to 130 x 10^6 m^3 while ebb flows would decrease by 55% to 43 x 10^6 m^3 (WorleyParsons 2005b).

The net result is that pumping during tidal flows within the creek will become highly asymmetric, with flood flows 245% greater than ebb flows.

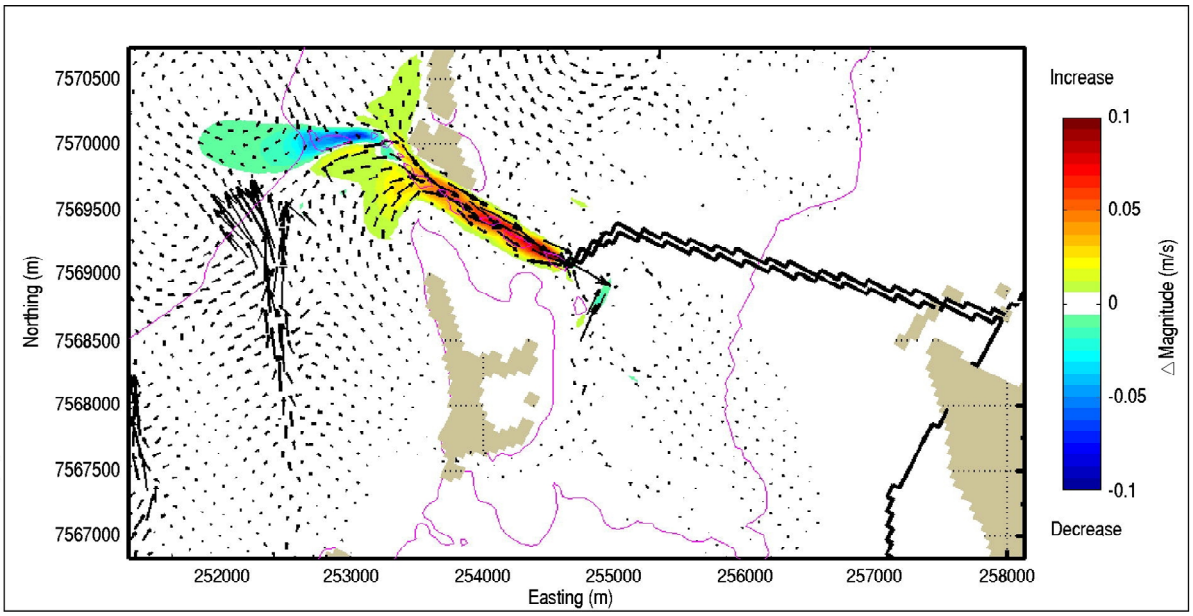
Typical peak flood tide and ebb tide currents for the northern region were modelled and peak tidal currents in the model ranged up to 1.6 m/s and were slightly larger on ebb tide than on flood tide. On both the ebb and flood tide, strong currents were evident along the creek channels. As the flow is constricted, these currents decay rapidly in the mangrove areas. The current magnitudes were generally lower in the nearshore waters where currents range up to 0.4 m/s.

Residual, depth-averaged currents were computed for a 29 day period for the pre-development and post-development conditions. The higher pumping rates at Naughton Creek will create a net or residual current movement upstream from the Gulf to the pump station. Figure 6-35 shows the difference between residual currents for the existing and post-development scenario. There will be changes of up to ±0.06 m/s in magnitude with positive values (yellow to red) showing an increase in residual current speed following development, negative values (light blue to dark blue) showing a decrease in current speed following development. White represents insignificant changes in current magnitude following development. The pumping will act to draw water into the creek from the Gulf, increasing flood currents and reducing ebb currents.

Peak current speeds in tidal creeks are a key part of maintaining the creek geometry (Wolanski *et al.*, 1992) and the proposal will change the maximum current speeds within Naughton Creek (Figure 6-35 and Figure 6-36). The change in maximum velocities is due to the pumping and as such, during periods of prolonged pumping, the creek may experience enhanced sedimentation. However, on cessation of pumping, creek velocities should return to normal and scouring of accumulated sediment may occur.

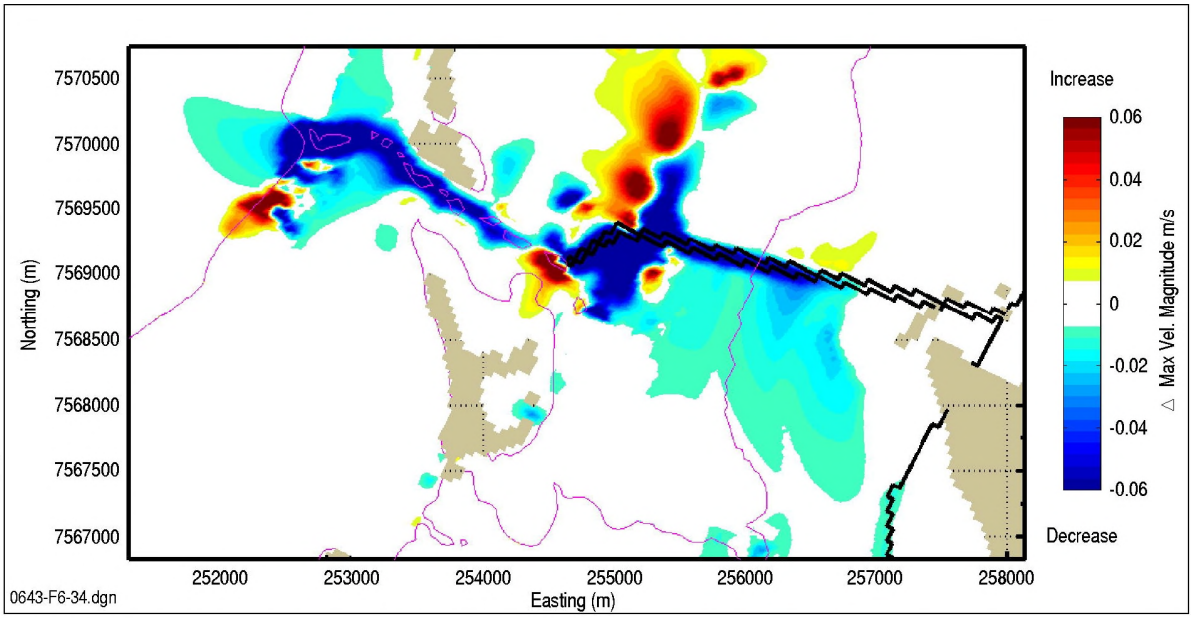
There is a reasonable risk that siltation in the creek will be enhanced but there is unlikely to be vegetated benthic habitat within Naughton Creek due to the combination of high velocities and turbid waters. However, potentially there could be impacts on mangrove and algal mat systems if sedimentation was significant. Creeks will be monitored to determine whether siltation is occurring above natural levels and corrective actions will be undertaken where required.

Detailed bathymetric cross-sections of the creek will be obtained prior to construction of the pumping station at Naughton Creek. Surveys will be repeated at one year intervals for the first 3 years of pumping to establish whether there is any change in the cross-sectional area of the creek. A nearby creek that will be unaffected by the proposal will also be surveyed at the same time as a control.



Source: WorleyParsons 2005

Figure 6-35 Residual depth-averaged current differences between pre-development and post-development conditions at Naughton Creek



Source: WorleyParsons 2005

Figure 6-36 Difference between maximum current speeds for pre-development and post-development conditions at Naughton Creek

Hope Point barge channel

Any channel perpendicular to a coast has the potential to intercept longshore sediment flows. However, the inshore part of the Hope Point barge channel is in limestone pavement and the area is generally devoid of mobile sediments, with the exception of one area of sandy beach.

The coastal morphology of the area in the vicinity of Hope Point suggests that there is no large-scale longshore sediment transport in the nearshore, with any such transport being trapped by the creek systems. The predominant particulate transport mechanism in the nearshore is perpendicular to the shore and is driven by tidal flows.

The barge harbour and channel will not affect sediment transport beyond the immediate vicinity of Hope Point and there will not be any significant impacts on benthic habitat due to any subsequent modified sediment transport processes.

Proposed management

A Marine Management Plan will be prepared and implemented to ensure minimal risk of impact by the project on coastal processes such as sediment transport and water flows. Management measures include:

1. Assessing alternative locations for the northern pump station.
2. Using aerial photography and shoreline profile monitoring at Hope Point to assess long-term shoreline change at Hope Point. Monitoring will be undertaken prior to construction and then annually for three years after construction. If there are no changes after the third year of monitoring the program will revert to a monitoring programme of every five years. Aerial photographs will be taken before commissioning and then annually for the first two years following commissioning with comparison of photographs between years used to establish any trends or changes in creek morphology. This work will be conducted in conjunction with the mangrove monitoring in the creeks.

   If, after two years of monitoring, there are no changes in creek bathymetry or morphology that can be related to the operation of the seawater pumps then monitoring will revert to bathymetric and aerial photography every two years. This reduction in frequency is proposed as the greatest period of pumping will occur in the first two years after commissioning. If there are no changes in this period, it is very unlikely that sudden changes due to the pumping would occur in following years.
3. Conducting bathymetric surveys to assess changes in localised and creek scale morphology/bathymetry due to change in tidal flows and velocities at pump stations. Surveys will be undertaken once prior to commissioning and then every year for the first two years following the commencement of seawater pumping.

   The survey results will be used to establish the cross-sectional area of the creeks at key locations. Any changes in cross-sectional area will be examined in terms of whether it is unique to the creeks with the pumping stations or whether any such changes are occurring in non impacted creeks. The survey results will also be used to establish any changes in bathymetry in the vicinity of the intake pumps.
4. Review pumping operations in the event that pumping is found to be causing siltation of the creeks over and above any natural effects and there is a significant risk of causing loss of mangroves or algal mats, posing a risk to the operation of the facility, or the functioning of the

creek. Based on the review, a corrective action programme may be proposed and implemented in consultation with the DEC.

5. Report the results of each survey to the DEC.
6. Assess any change in sedimentation patterns from infrastructure using a combination of aerial photography, site inspection and permanent survey transects.
7. Conduct transect surveys every six months for the first two years following construction. If after two years of monitoring, there are no changes in sedimentation that can be related to the intertidal zone as a result of installed infrastructure, then monitoring will revert to surveys every two years.

2.6.6 Assessment and management of saline water seepage from the saltfield on mangroves and algal mats

Horizontal seepage from the western boundary of the saltfield has the potential to affect mangroves and algal mats.

The experience in other saltfields in Western Australia has been that some seepage outside levee walls can occur, causing water logging. In these situations, levees are often very close, if not adjoining the mangroves.

The levee walls of the concentrator and crystalliser ponds will be keyed down to the clay layer below the surface sediments of the supratidal salt flat thereby reducing horizontal seepage BPPH habitat to the west. Permeability testing was carried out on local clay materials and found that seepage rates through this material would be very low - a maximum of 3.09×10^{-7} m^3/sec/m of wall length (Parsons Brinckerhoff 2005c).

The effect of precipitation of calcium salts in the concentrator ponds promotes the sealing of them and further reduces seepage potential.

The distance between the edge of mangroves at the top of creek systems and the western levee wall of the concentrator ponds in the northern field is about 500 m or greater with most being 1 km or greater, the distance between the crystalliser ponds and mangroves at the top of creek systems is about 600 m or greater and the distance between the concentrator ponds in the southern field is about 200 m or greater with most being 300-700 m.

The eastern edges of the algal mats are much closer, and in some cases touch these structures as they are located up the tidal range from the mangroves.

Algal mat distribution in the intertidal zone is controlled by dehydration and salinity. There will be a salinity gradient from the seawater in the concentrator pond (for their intake to the entry) to the crystallisers in the northern and southern saltfields. If seepage was to occur to the west of these ponds, it would be expected that this seepage would have a similar salinity gradient and this may encourage the development of algal mats near the levees until their salinity tolerance limit is reached.

Given the very low seepage rates associated with the local clay material, only very gradual seepage is anticipated from the saltfield ponds to adjacent areas. For most of the field, the seepage that will occur has a lower salinity to that of the shallow aquifer. There are no impacts to mangrove communities expected from the very low levels of seepage predicted due to the extent of the setback from the field walls to the mangrove zone along most of the field.

2.6.7 Assessment and management of impacts from changes to surface hydrology and water contamination on mangroves and algal mats

Surface hydrology

The condition and long-term survival of the mangroves in the project area is not dependent on large-scale surface water flood events from the hinterland. Only local runoff patterns from the supratidal land in the intertidal zone contributing to mangroves will be affected by project changes to surface hydrology. This process generally only occurs in locations where mangroves adjoin supratidal mainland remnants and localised runoff and freshwater seepage from perched groundwater lenses assists mangroves to survive (Biota 2005d). The infrastructure of the field is generally set well back from the mangrove zone so no decline in mangroves is expected from changes to small-scale surface hydrology.

Surface water contamination

Discharge of runoff water from stockpiles, drainage water from the plant site, fuel storage and other effluents has the potential to degrade mangroves in areas adjacent to the proposed saltfield. The main area of risk is in relation to potential contaminants from hydrocarbon storage and any saline drainage from the salt stockpiles. Stockpile runoff and infiltration will be captured into a dedicated drainage system and discharged back into the saltfield ponds.

The main fuel storage facility will be located at Hope Point. Fuel will be tinkered via trucks from Hope Point to three other storage locations (each with a capacity of 45 kL); Main Island, Naughton Creek pump station and Dean's Creek pump station. All fuel storage facilities will be constructed and managed according to industry best-practice (i.e. lined, bunded facilities) and compliant with Australian Standard *AS 1940-2004: The storage and handling of flammable and combustible liquids*.

The Marine Management Plan will be prepared and implemented and will address issues having the potential to contaminate surface water including those relating to fuel handling and storage and hazardous materials.

2.6.8 Assessment and management of clearing and dredging impacts on subtidal BPPH

Hope Point channel and barge harbour

The project will require a shallow channel to be dredged to a depth of approximately 3.5 m CD about 1.3 km long and 125 m wide. The area affected by the dredge channel is 16.4 ha and generates a dredging volume of about 20,500 m^3 comprising sand and mud. Most of the dredge material will be taken from near shore where the sea floor is shallower (Area A in Figure 6-37). The channel will lead to a barge harbour excavated into Hope Point using land-based earthmoving equipment. Approximately 284,500 m^3 will be removed by excavator from the inshore area which is primarily limestone (Figure 6-37) (AAM Hatch 2004).

All excavated and dredged material will be used onshore as part of the project civil works, either as rock armour or in bund, pad and pavement construction.

The dredge channel will disturb approximately 8.9 ha of inshore hard habitat (above the 2 m depth contour) and 7.5 ha of soft habitat. The area inshore of the 2 m depth contour mostly comprises limestone substrate which is either bare or supports attached algae and sponges.

Surveys by Oceanica (2006a) and work by Loneragan *et al.* (2003) in the Hope Point area have allowed the following conclusions to be drawn for the region:

1. The Hope Point area is relatively energetic, exposed to strong south westerly winds and wind waves. The inshore region consists of very shallow (exposed at low tide) hard limestone pavement and rubble, this substrate would be typical of all waters inland of the 0 m CD contour line. Attached algae are the primary form of vegetation.
2. Offshore from the pavement/rubble area, in waters from the 0 m CD contour to the 1 m CD depth contour in summer there is likely to be reasonably dense macro-algal beds (60–100% cover).
3. The waters 1 m to 2 m deep may comprise of sponges (up to 10% cover), algae and rock.
4. The waters from 2 m to 3 m deep tended to be dominated by soft sand/muddy seabed which supported small quantities of ephemeral seagrass (1–2% cover at the time of survey).
5. The seabed beyond 3 m deep tended to be muddy and unvegetated.
6. Shallow soft substrates which are needed to support seagrass, tend to be found in the more protected waters in the lee of Hope Point and Burnside Island.

There are no significant coral reef features in the channel alignment.

Dredging will take approximately four months to complete and will be undertaken between 30 March and 30 October. This corresponds to when the above ground biomass and growth rates (and therefore light requirements) of the seagrasses and algae in the region are minimal (Lanyon and Marsh 1995, Loneragan *et al.* 2003, Oceanica 2006a). This period of seagrass dormancy is also when turbidity is naturally high in the Exmouth Gulf (Section 1.3.4).

Pump stations

The construction of pump stations at Dean's Creek (Figure 6-24) and Naughton Creek (Figure 6-23) will result in the direct loss of approximately 200 m^2 of marine habitat, classified as tidal creek habitat (100 m^2 at each site). At Dean's Creek the benthic habitat that will be disturbed was found to be generally bare or support brown algae, and at Naughton Creek the benthic habitat was found to be bare and mostly comprised fine red mud with some areas of sand and shell (there was no benthic flora). The direct loss of habitat due to pump construction is considered insignificant.

The sediments in these areas were sampled for potential acid sulphate soils as there is likely to be excavation of the seabed and subsequent disposal of sediment onshore. Note, the volumes of soils to be disturbed that are potentially acid generating, is relatively small compared with the total volume of soil proposed to be earthworked in the entire project.

The Marine Management Plan and Construction Environmental Management Plan will address management measures to reduce impacts and monitoring during construction.

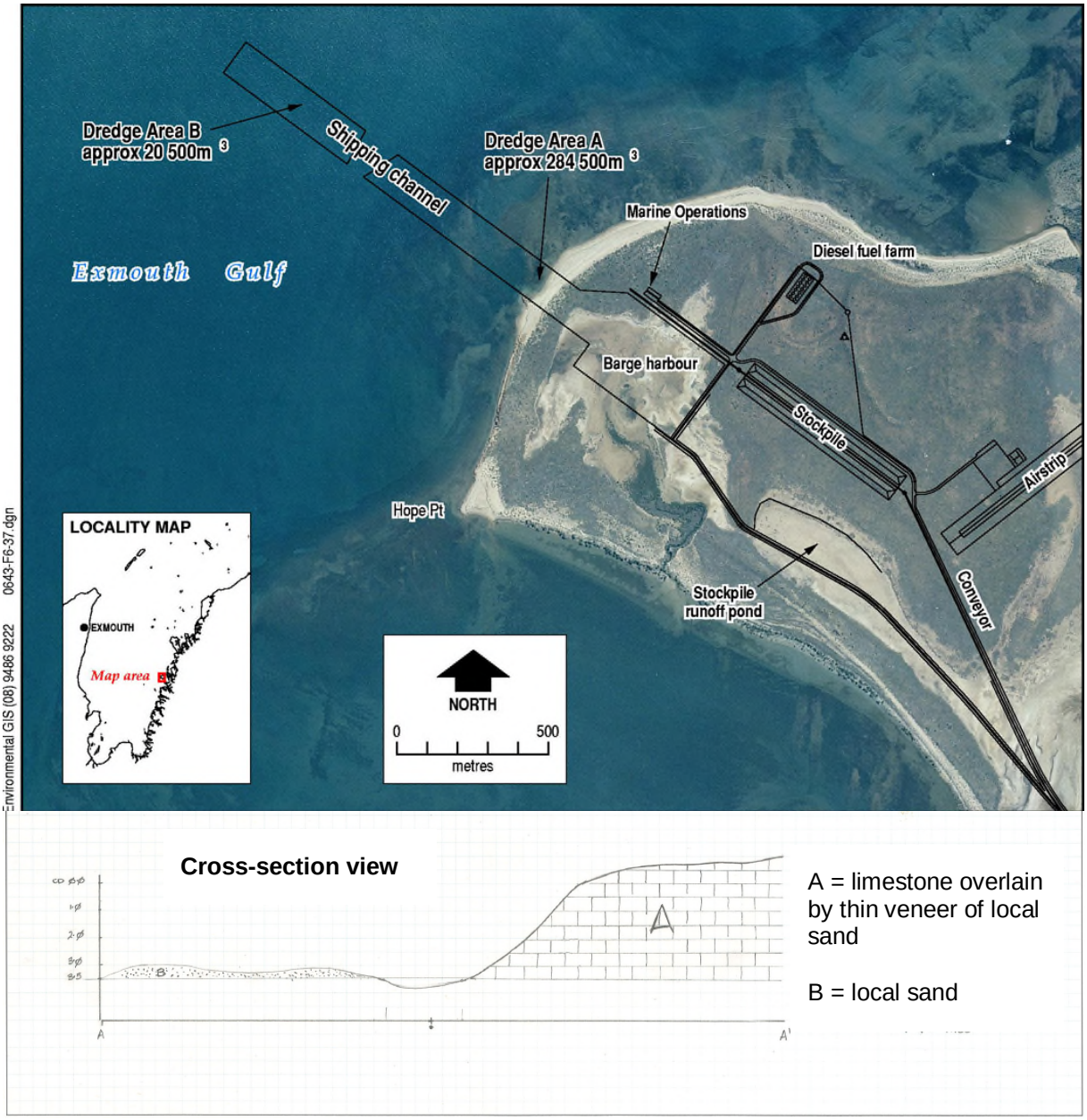


Figure 6-37 Hope Point dredging channel and barge harbour

2.6.9 Assessment and management of turbidity impacts on subtidal BPPH

Turbidity due to dredging

The region is naturally turbid and the flora and fauna found on the east coast is typical of that found in turbid environments elsewhere on the Pilbara coast (Hutchins *et al.* 1996). Natural turbidity concentrations recorded by Oceanica (2006a) during surveys are provided in Table 6-11. The turbidity on the east coast is largely due to the strong currents in the tidal creeks continuously suspending fine sediments and drawing these out to the nearshore area environment, where prevailing winds generate waves which serve to maintain the finer sediments in suspension.

Table 6-11 Suspended sediment concentrations recorded on the east coast of Exmouth Gulf

Site name	Location	TSS[1] concentration (mg/L)
HOPE1	Upper Hope Creek	21.5
HOPE2	Mid Hope Creek	4.8
SCOTT1	Upper Scott Creek	4.6
SCOTT2	Scott Creek mouth	5.4
T2S1-surface	Barge channel area	1.7
ANCHORAGE2	Mid Gulf	2.1
US1	Nearshore Urala Creek South	19.5
US2	creek mouth Urala Creek South	21.3
US3	mid-Urala Creek South	28.7
US4	Upper-Urala Creek South	32.4

Source: Oceanica 2006a

[1] TSS: total suspended soilds

Turbidity arising from dredging and barging operations has the potential to affect marine biota and habitats through reduced light levels and smothering.

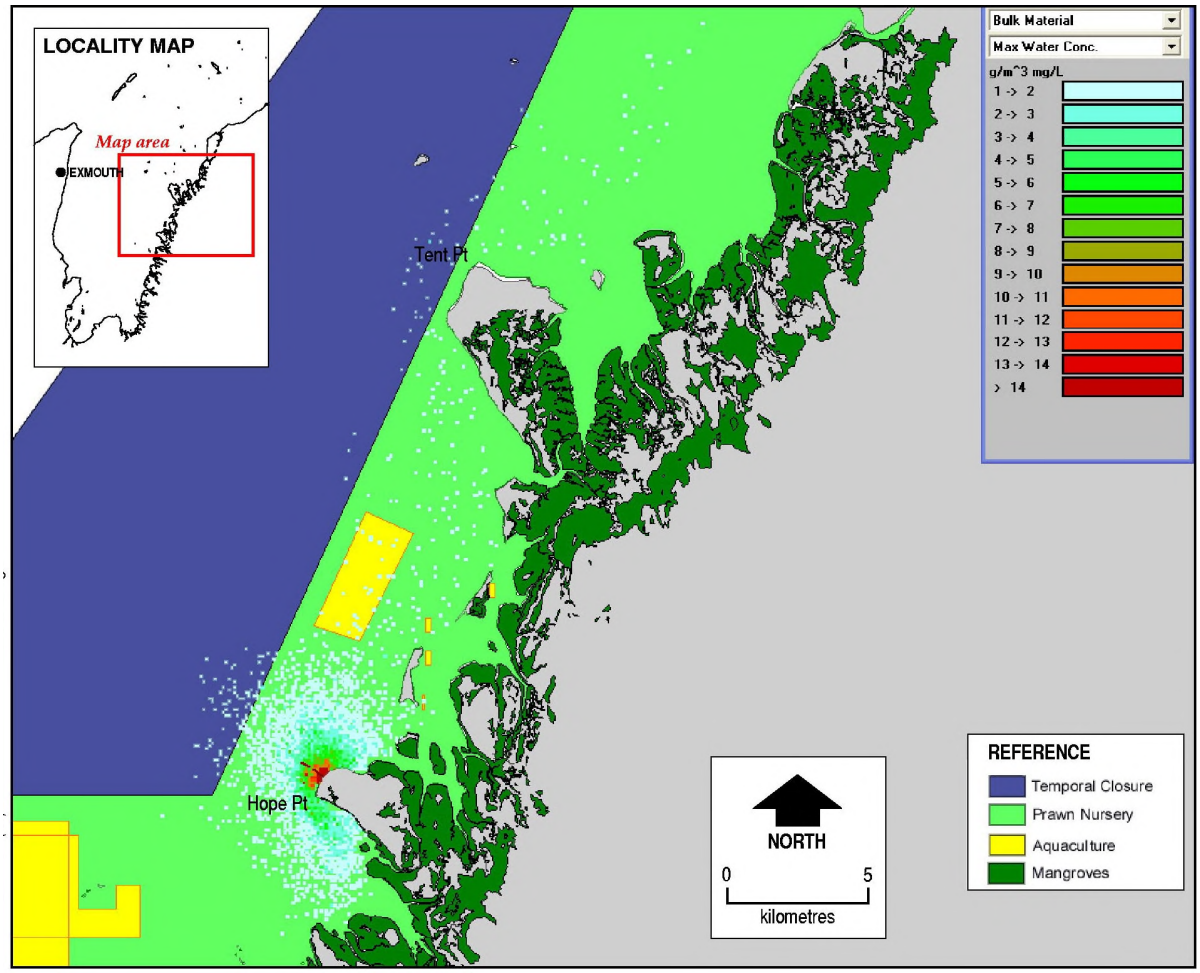
Turbidity modelling results and impact

The likely extent of suspended sediments and the associated level of deposition from the dredge plume was modelled for a worst case scenario being a period of prolonged south westerly and westerly winds such that onshore flow was maximum (APASA 2005). The winds will usually tend to alternate between south westerly and south easterly allowing for dispersion of the plume into deeper waters not containing vegetated habitat (Oceanica 2006a).

The winds tend to drive the plume north and north east, while the tidal exchange with Hope Creek will draw some suspended sediments into the mouth of the creek (Figure 6-38). The conservative modelling suggests that the adjacent aquaculture leases will not be affected by the dredging. An aquaculture lease, which is currently not being utilised for aquaculture production, is located north of the barge channel and is not anticipated to be affected by dredging (Figure 6-38 and Figure 6-39).

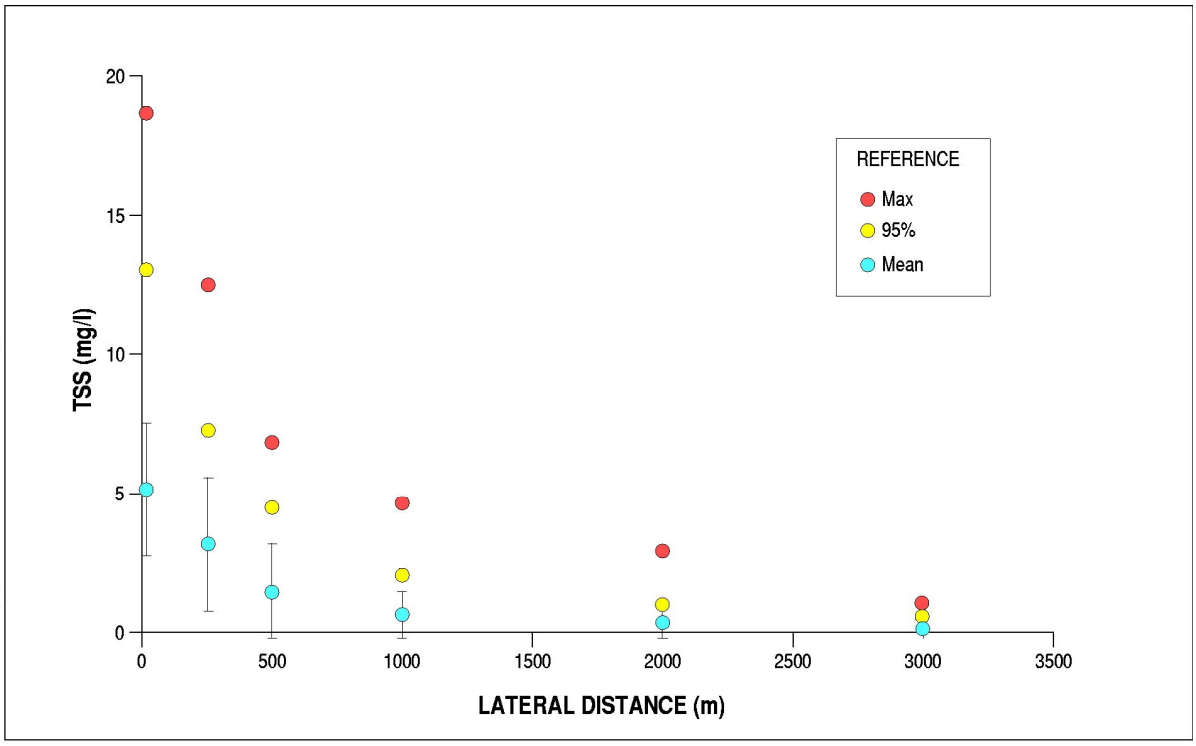
The predicted suspended sediment concentrations are generally similar to, or less than, the measured naturally occurring concentrations (Figure 6-38 and Table 6-11).

The levels of deposition are unlikely to cause any adverse impacts on adjacent habitats as they are low and also deposited in an environment subject to very regular wind waves caused by south west winds which will tend to constantly resuspend and rework sediments in the shallow areas (Figure 6-41).



Source: APASA 2005

Figure 6-38 Modelled maximum suspended sediment concentrations caused by excavation and dredging at Hope Point



Source: APASA 2005

Figure 6-39 Modelled deposition of sediment following excavation and dredging activity at Hope Point

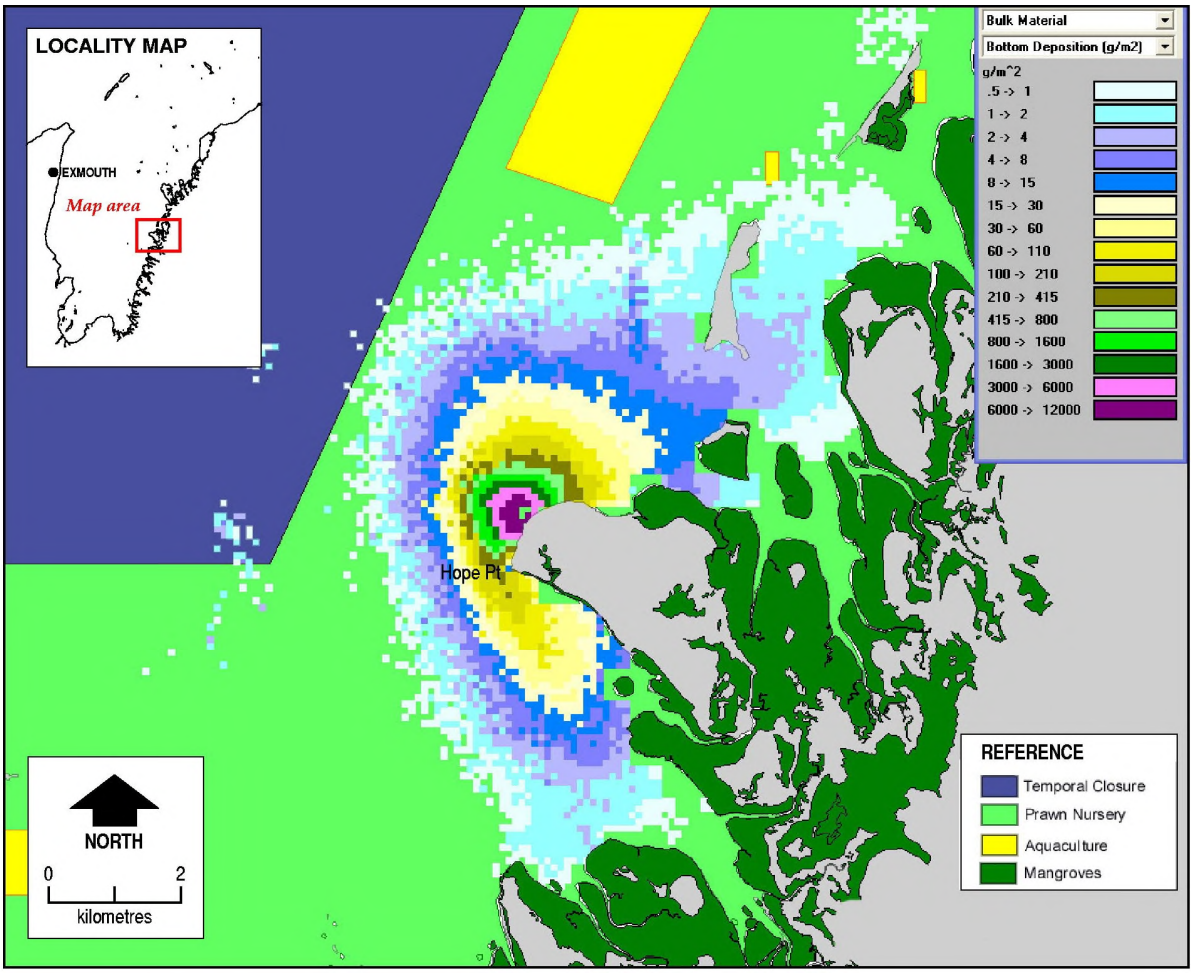
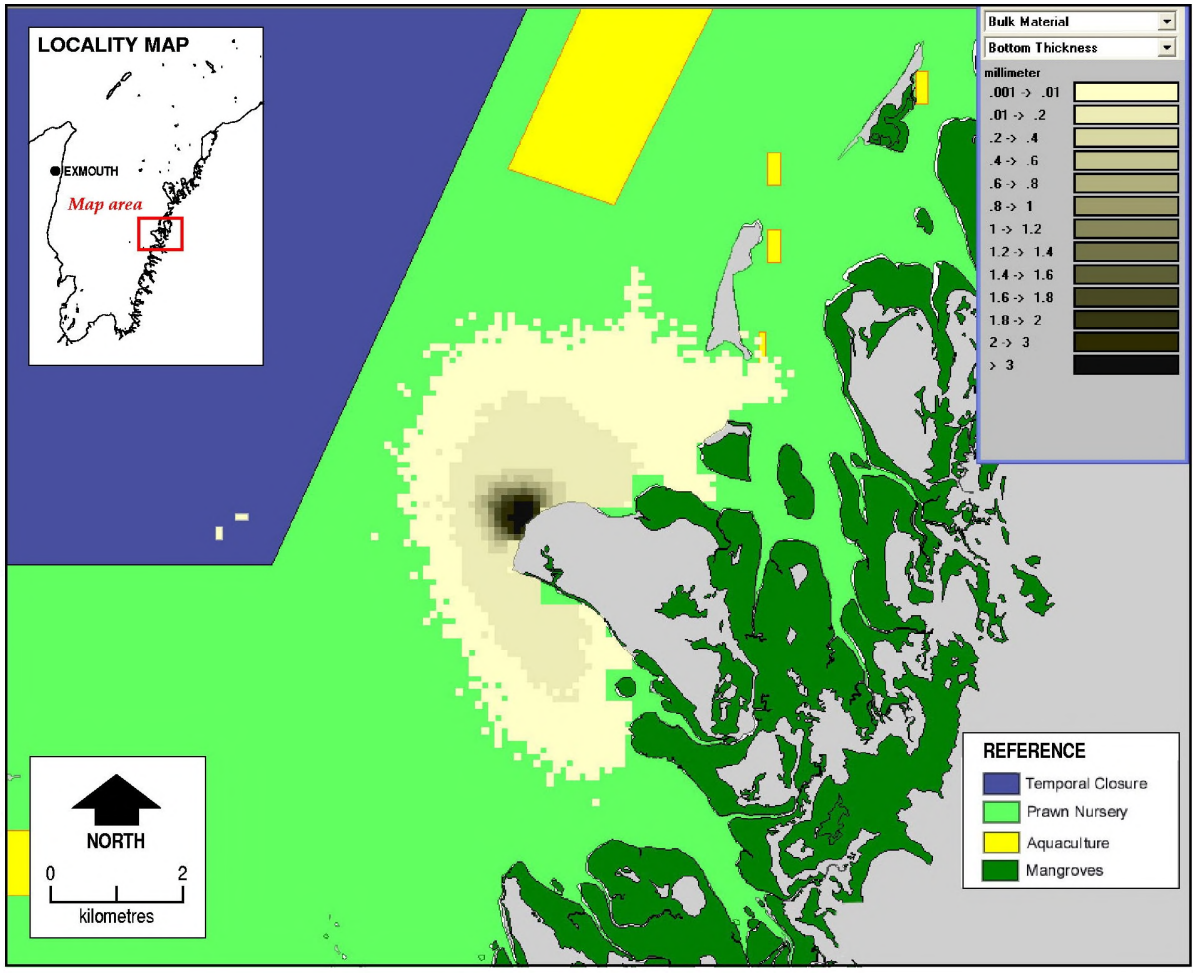


Figure 6-40 Suspended sediment concentrations vs. horizontal distance from dredge/excavator



Source: APASA 2005

Figure 6-41 Predicted thickness of deposition due to dredging and excavation activity at Hope Point

Summary of predicted dredging effects

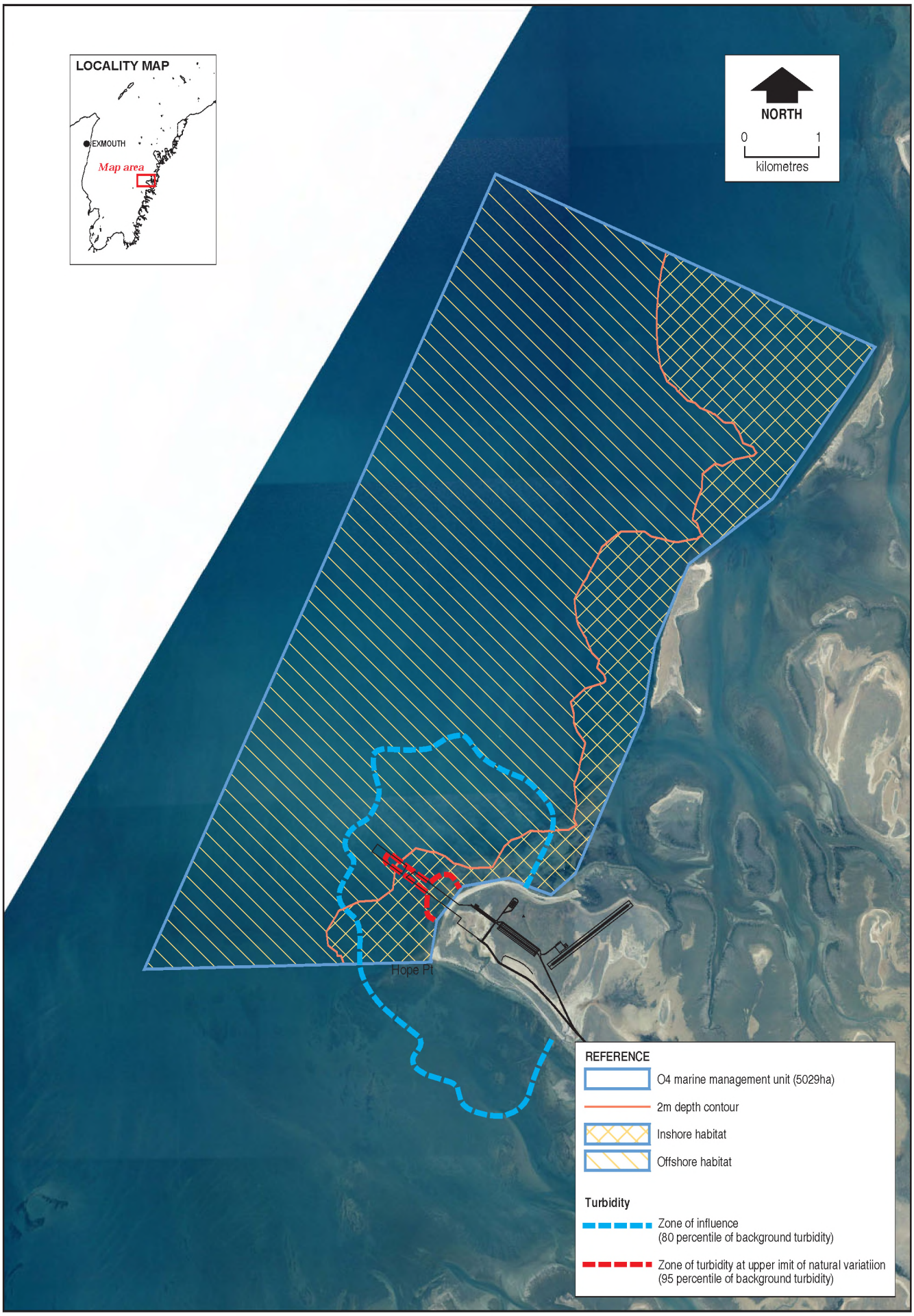
During the period of dredging the Exmouth Gulf will be naturally turbid and seagrass meadows will be dormant. The median nearshore suspended sediment concentration is 2.7 mg/L based on measurements made just north of Hope Point, where the dredging is required. The 'zone of influence' of the turbidity plume has been defined as the 80th percentile of median background turbidity levels (Figure 6-42). The zone of turbidity at the upper limit of natural variation or 95th percentile of background is highly confined (Figure 6-42). However, the only impact on benthic primary producers is expected to be caused directly by the dredging footprint (Figure 6-25).

The risk of any adverse impacts on benthic flora due to turbidity from a dredge program will be low as:

- a cutter suction dredge will be used for dredging 20,500 m^3 of material and all the dredged material will be pumped onshore (this method is generally accepted as producing the least turbidity)

- tides permitting, an excavator or similar will be used to break and excavate 284,500 m^3 of limestone material, with the material being transferred to an onshore holding area. The aim will be to maximise the production of large rock material for use in armouring the seawalls, which will also help ensure that the production of fines is reduced as far as practicable (i.e. there will not be any 'grinding' of limestone)
- the duration of the dredging program is relatively short (less than four months) and is expected to be a single event. Maintenance dredging is not anticipated
- dredging is occurring in a naturally turbid environment which has adapted to turbidity (Hutchins *et al.* 1996)
- the benthic flora is largely ephemeral and has a demonstrated capacity to recover (Loneragan *et al.* 2003)
- the region is not populated by significant coral stands (due to turbid waters)
- the dredging will be at the northern end of the extent of major seagrass occurrences. Dominant currents will carry any turbidity plume northwards, away from the key vegetated areas located south of Hope Point (APASA 2005b)
- dredging will occur between 30 March and 30 October to coincide with the period of seagrass dormancy and when light requirements of benthic habitat are naturally at a minimum.

Overall, there is a very low risk of any adverse impact on benthic habitats due to turbidity associated with the dredging and excavation works at Hope Point.



Fri 17 Nov 06

Environmental GIS (08) 9486 9222 0643-F6-41.dgn

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Oceanica, 2006
Date: 17 Nov 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-42 Zones of turbidity influence compared to background levels

Management of dredging

Turbidity from dredging will be managed by:

1. Dredging between 30 March and 30 October to coincide with the period of seagrass dormancy and when light requirements of benthic habitat are naturally at a minimum.
2. Conducting baseline turbidity measurements and suspended sediment concentrations, with sampling based on the predictions from the modelling and the location of sensitive habitat and aquaculture leases.
3. Ensuring that the type and size of dredge head used matches the performance and capacity of the suction pump.
4. Reassessing dredging if wind speed and wave height exceed the operational parameters of the dredge.
5. Preparing and implementing a Dredging Management Plan which addresses the following:
    - timing of dredging
    - collection of a set of baseline turbidity and suspended sediment data
    - appropriate criteria for protecting identified sensitive areas
    - sampling and analysis plan developed on the basis of National Ocean Disposal Guidelines for Dredge Material (Commonwealth of Australia 2002)
    - monitoring of turbidity and nominated sensitive areas during and following dredging
    - environmental management procedures relating to sediment mobilisation
    - reassessing dredging if wind speed and wave height exceed the operational parameters of the dredge.

Turbidity due to vessel movements

There will be about three bulk carriers loaded per week requiring about 19 barge trips per week for a 10 Mtpa project (Table 6-12). Barges will be towed by a tug and barging will only occur between Hope Point and the ship anchorage area (Figure 6-43).

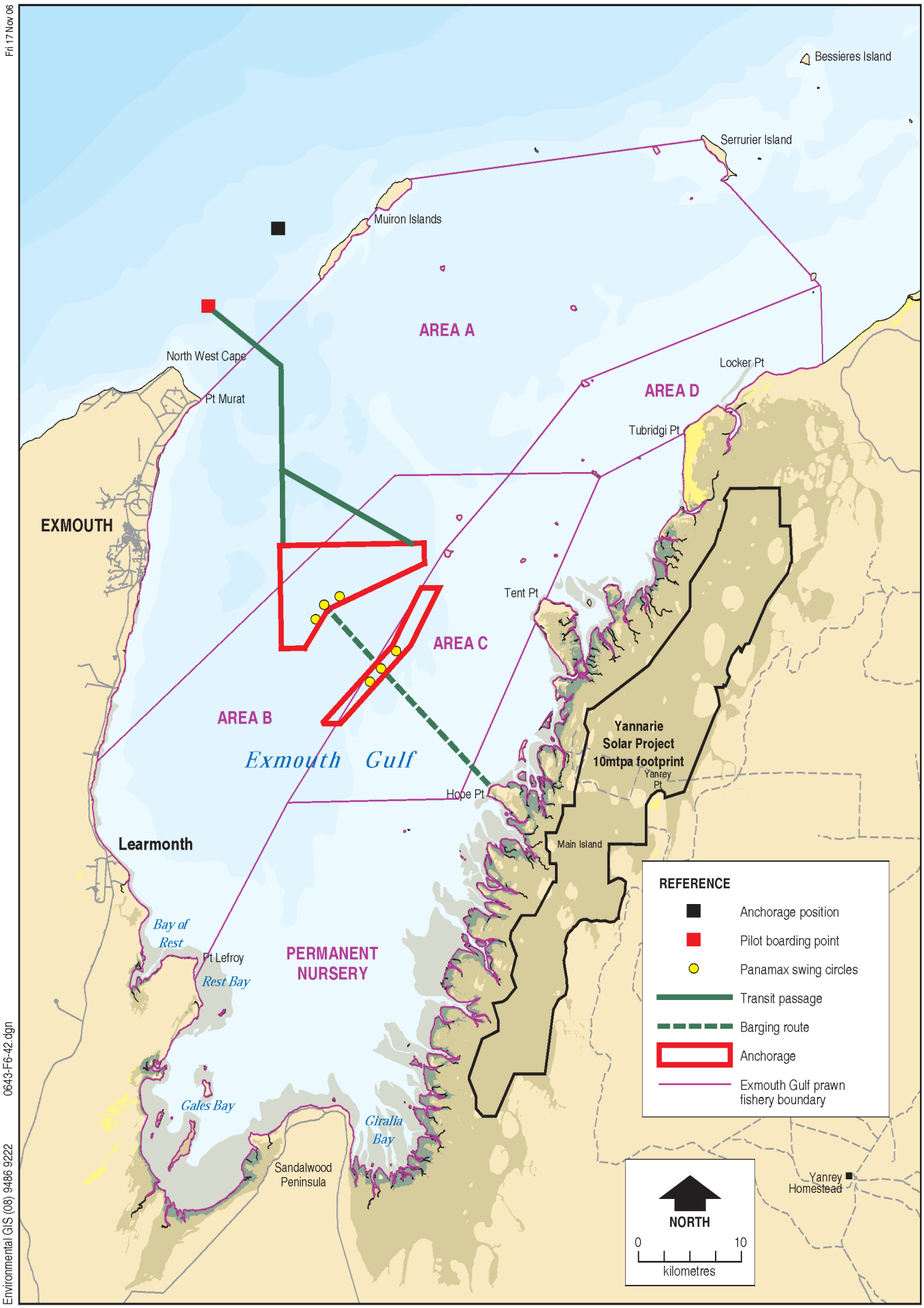
Table 6-12 Characteristics and movements of vessels associated with the Straits Solar Project

Vessel	Dimensions	Area of operation	Frequency (10 Mtpa)
Ship (bulk carrier)	Length 300 m Width 30 m Draft 12 m Max load 65,000 tonnes	Passage between Muiron Islands and Point Murat to central Gulf ship anchorage area.	3 ships per week or 150 ships per year. Up to 3 ships anchored in central Gulf at any one time.
Barge	Length 125 m Width 25 m Draft 4.5 m Max load 10,000 tonnes	Hope Point to central Gulf ship anchorage area.	1 barge every 10 hours while loading. Each ship needs 6–7 barge loads to fill. This means an average of 19 barge trips per week. Laden barges move at 3 knots. Empty barges move at 6 knots.
Tug	Length ~25 m Width ~10 m Draft ~3 m	Hope Point to central Gulf ship anchorage area.	As above. Each barge trip is accompanied by a tug.

Vessel	Dimensions	Area of operation	Frequency (10 Mtpa)
Dredge (small cutter suction dredge)	Length 40 m Width 15 m Draft 3 m	Hope Point to approx. 800 m offshore (~5 m depth contour).	1 dredge for approximately 4 months.
Research vessel	Length ~6 m Draft ~1 m	Entire east coast, specifically Hope Point, Dean's Creek and South Urala Creek.	1 boat at any one time for up to 1 month (both construction and operation phases).

The channel area in the region close to shore is in hard limestone and after an initial short period, barging movements are not anticipated to create a turbidity plume in the channel. The softer sediments at 4 m and deeper may be re-suspended by the passage of the tug and barge further offshore, however these areas are not vegetated and the size and duration of the plume will be limited. The Gulf is naturally turbid, especially the inshore areas, while the offshore areas will not be affected by the passage of the tug and barge due to the water depth. There is unlikely to be any need for management of turbidity arising from barging operations.

Ships of (nominally) Panamax size (300 m long and 12 m draft) will be piloted from outside the Gulf along a designated shipping route to one of the designated anchorage areas (Figure 6-43) and will be restricted to a maximum speed of 10 knots within the Gulf. The area traversed by the ships is subject to intensive prawn trawling activity (Oceanica 2005b) and is not considered to be sensitive to turbidity impacts.



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-43 Proposed ship transit passage and anchorage areas

Datum: MGA Zone 50
Source: Oceanica, 2005 and Dep't of Fisheries, 2006
Date: 17 Nov 2006

2.6.10 Assessment and management of salt spills

Salt loading and barging operations could result in the spillage of salt on habitat adjacent to the loading area. This issue was originally raised when it was proposed that loading may occur from a jetty up to 5 km long. A jetty is no longer proposed and barges will be used to transport salt to the waiting ships. While spills of salt may occur during barge loading and unloading, these spills will be negligible and will have no significant impact.

The risk of salt being lost to the marine environment through spillage during barge loading has been reduced by the construction of a barge harbour within Hope Point. The salt loading will all occur away from the natural marine environment and any spillage will be contained within the barge harbour. The barges are custom designed with high side boards that prevent any spillage when underway. The barges have a conveyor system installed such that they can unload themselves directly to the receiving ship.

The salt stockpile will be set well back from the Gulf (Figure 2-10) and there will be no direct runoff or spillage from the stockpile to the Gulf.

The barges will have multiple compartments and will be moved by tug at low speed when fully laden (3 knots). The likelihood of a significant salt spill associated with a barging incident is considered to be negligible.

The most likely potential causes of a salt spill could be attributed to a collision between a barge and a trawler, or transportation during adverse weather conditions. It is highly unlikely that either of these events will occur for the following reasons:

1. The transportation of salt between the harbour and receiving ships will be scheduled to avoid fishing trawlers.
2. Salt transportation/loading operation would not occur in adverse weather conditions.

Any spillage of salt would dissolve and be diluted with the surrounding seawater.

2.6.11 Assessment and management of oil spills on subtidal BPPH

A number of shipping and land-based activities will involve the storage, transport and handling of hydrocarbons and therefore have the potential to result in spillage to the marine environment unless appropriately managed. Accidental spills could occur from:

- leakage of diesel, lubricating oil, or contaminated bilge water from vessels
- leakage of diesel or lubricating oil from water transfer pumps
- runoff of hydrocarbon contaminated surface water from the development
- spillage of diesel fuel during refuelling activities
- leakage or rupture of fuel oil from export ships due to collision or grounding.

Table 6-13 provides a summary of shipping activities and the hydrocarbons that will be handled in each situation during construction and operational phases.

Table 6-13 Summary of shipping activity and hydrocarbons associated with the Straits Solar Project

Vessel	Area of operation	Oil handled	Frequency
Dredge (small cutter suction dredge)	Hope Point to approx. 800 m offshore (~5 m depth contour)	Marine diesel oil	1 dredge for approximately 4 months as a one-off event for lifetime of the project.
Barge mounted excavator (not self-propelled)	Hope Point to approx. 300 m offshore (2 m depth contour)	Marine diesel oil, hydraulic fluid	1 excavator for approx. 4 months.
Dredge support vessel	Exmouth fuelling jetty to Hope Point dredging site	Marine diesel oil	1 per week for 4 months as a one-off event for lifetime of the project.
Barging for delivery of construction plant and materials	Exmouth supply jetty to Hope Point	Marine diesel oil	Intermittent for 6 months.
Export ship	Entry and exit to Gulf between Muiron Islands and Pt Murat, with transit to central Gulf ship anchor station. No refuelling of the ship within Exmouth Gulf	Heavy fuel oil Lubricating oil Marine diesel oil	3 ships per week or 150 ships per year at full production. Up to 3 ships anchored in central Gulf at any one time.
Barge	Hope Point to central Gulf ship anchorage area	Not self-propelled Marine diesel oil	1 barge every 10 hours while loading. Each ship needs 6-7 barge loads to fill. This means an average of 19 barge trips per week. Laden barges move at 3 knots. Empty barges move at 6 knots.
Tug	Hope Point to central Gulf ship anchorage area	Marine diesel oil	As above. The tug propels the barge.
Fuel delivery	Take on fuel at Exmouth Fuel wharf, transit to Hope Point Barge Harbour and transfer fuel to storage tank	Marine diesel oil	1-2 refuelling operations per week with larger volumes per transfer.

Storage of all bulk fuels at the development site will be within bunded areas with sufficient capacity to accommodate both the volume of the tanks and rainwater associated with a heavy rainfall event. To prevent overflow of oily residues from the operation of machinery, all hard-stand areas will drain to sumps fitted with oil-water separators in accordance with Australian Standard *AS 1940-2004: The storage and handling of flammable and combustible liquids*.

The key environmental areas potentially at risk from an oil spill include:

- subtidal coral reefs surrounding various Islands within Exmouth Gulf
- intertidal rock shelfs fringing the islands and sections of the coastline
- mangrove forests, mudflats and saltmarsh habitats occupying the east coast
- sandy beaches along the west coast and islands
- seabirds and wading birds, including migratory species
- sea turtles, dugongs and whales, including potential interference with nesting and calving behaviour.

Although the risk of an oil spill occurring is low, the likelihood of occurrence is highest during refuelling operations of barges and tugs. Refuelling will take place within the barge harbour where precautionary measures (such as auto-shut off hose connectors) will be in place to localise and limit the spread of oil, in the event of a spill.

Spills are unlikely to escape containment measures within the harbour.

The most significant environmental impact that may potentially arise would be from a large oil spill originating from a shipping accident.

Appropriate response to any oil spill will take into account the sensitivities of the various habitats that could be exposed to oil, so that response actions are prioritised and clean-up efforts do not lead to greater long-term harm than would result from exposure to oil.

Management and prevention of oil spills

The proponent is committed to the preparation and implementation of a Marine Management Plan, which will:

- outline fuel handling procedures to prevent exposure to sensitive habitats located adjacent to fuel handling points and drainage from the development area
- outline environmental management controls which would be implemented in the event of a hydrocarbon or hazardous materials spill. These controls will address the following:
    - environmental sensitivity information and priority protection areas
    - oil spill movement/trajectory and fate information
    - response, cleanup and rehabilitation options and strategies
    - disposal strategies
    - tasks or actions that need to be carried out in the event of an oil spill
    - roles, responsibilities and authorities for ensuring the tasks are carried out
    - inventory lists of facilities, equipment and materials available for use in the event of a spill
    - resources and external emergency services
    - provision of spill clean-up kits to deal with spills on the dredger and a suitably sized oil spill boom for containment of oil spills on water.

An example of an oil spill contingency plan is provided in Appendix 10.

Risk of oil spill from ships will be reduced by measures such as compulsory pilotage, establishment of speed limits and using designated shipping routes and anchorage locations within the Gulf.

A risk assessment workshop was held in May 2006 and focussed on identifying all the potential sources of hydrocarbon spills and assessing their potential environmental impact. The Environmental Risk Assessment Workshop report (International Risk Consultants 2006) noted that no items were risk-ranked as ‘High’ or ‘Extreme’ because of the safeguards that are already in place to reduce both the consequence and likelihood of hydrocarbon spills.

2.6.12 Conformance with principles in EPA Guidance Statement No. 29

Principles

Guidance Statement No. 29 identifies that the EPA expects a hierarchy of principles to be followed in assessing proposals that could damage BPPH (EPA 2004a). The first three of these four principles need to be demonstrated prior to evaluating the loss of BPPH against the management unit framework specified in the final principle of the Guidance. These first three principles are addressed below.

1. All proponents should demonstrate consideration of options to avoid damage/loss of BPPH.

The mapping of mangroves and algal mats completed for the project was used as a design constraint for the layout of the saltfield infrastructure. This has resulted in the field itself being set back from the mangrove and algal mat zone. Several iterations of the field design were completed to arrive at the current proposal, in which:

- concentrator pond bund walls have been situated such that they will result in no direct clearing impacts to mangroves and algal mats
- crystalliser ponds have been redesigned so that there are no direct impacts on algal mats (including a customised design for the most north westerly crystalliser pond specifically to avoid an area of algal mat)
- location and design of the barge harbour to avoid direct impacts on the mangroves fringing Hope Point.

A Bitterns Resource Recovery Strategy will be implemented to avoid the need to discharge bitterns to the marine environment (Appendix 1).

2. Where avoidance of BPPH is not possible, then design should aim to minimise damage/loss of BPPH and proponents will be required to justify the need for damage/loss of BPPH.

The only locations where any loss of mangroves and algal mat will now occur are associated with the three locations where the project must cross from the saltfield to Exmouth Gulf in order to operate. These are the infrastructure crossing to the port and load out facility on Hope Point and the northern and southern pump stations; all of which are essential to the functioning of the saltfield. Consistent with Principle 2, the design of these facilities has aimed to avoid damage to BPPH through:

- siting of pump station intake locations and conveyance flumes to minimise mangrove clearing
- realignment of the conveyor and infrastructure corridor from the main field to Hope Point to minimise direct impacts on mangroves and algal mats
- selection of a minimal impact crossing location through the mangroves separating Hope Point from the salt flat area, with a narrow and defined band of mangroves.

3. Proponents will need to demonstrate 'best practicable' design, construction methods and environmental management aimed at minimising further damage/loss of BPPH through indirect impacts.

With the proposed design, there are limited areas where mangrove BPPH may be indirectly affected. The analysis of the hydrodynamic modelling indicates that there appears to be a low risk of any indirect impacts on mangroves due to changes to tidal wetting and drying regimes (the most probable

indirect impact mechanism). This is primarily due to the design, construction and environmental management methods being employed, including:

- design of the drainage treatment of the Hope Point crossing to ensure that it is tidally transmissive and does not affect tidal flushing of upstream mangroves
- the development of a site-specific hydrodynamic model to provide data for the culverting of this crossing to be properly designed to ensure this tidal exchange is unimpeded
- a mangrove monitoring programme focussing on these areas to identify any potential impacts and provide feedback to project environmental management (e.g. for the management of any siltation that might affect tidal exchange through the Hope Point crossing over time)
- alternative sources to Naughton Creek (northern) pump station will be assessed to select an environmentally more benign location.

Experience with other solar salt projects in WA (e.g. Onslow Salt) suggests that changes in the salinity regime could potentially see the expansion of mangrove and algal mat cover.

Assessment of losses of BPPH within proposed management units

Intertidal BPPH (mangroves and algal mats)

The loss of mangroves and algal mats are not anticipated through processes such as salt spills, turbidity generated by dredging and changes in sedimentation other than clearing for construction. Assessment of consistency of the proposal's impact on mangroves and algal therefore focuses on clearing.

The proposed BPPH management units for the intertidal zone are shown in Figure 6-18 and Table 6-14, with the management units designated from south to north as BPPH areas M1 through M4. The loss of BPPH in the proposed four management units varies between 0-0.11% and 0-0.55% for mangroves and algal mats respectively and the cumulative loss of BPPH in the four management varies between 0-18.1 ha or 0-0.3% and total loss is 36.2 ha or 0.2% of the current area (Table 6-14).

Table 6-14 Current areas and losses of intertidal BPPH in proposed management units along the east coast of Exmouth Gulf

Draft BPPH management unit	Size (km^2)	Current area (ha)		Losses within units (ha) and (% loss)		Cumulative loss (ha) and (% loss)
		Mangroves	Algal mats	Mangroves	Algal mats	BPPH
M1 – Tent Island to Tubridgi Point	120	3218	2639	3.6 (0.11)	14.5 (0.55)	18.1 (0.3)
M2 – Hope Point to Tent Island	81	1697	1147	1.0 (0.06)	3.6 (0.31)	4.6 (0.16)
M3 – Giralia Bay to Hope Point	160	3987	3377	0.8 (0.04)	12.7 (0.38)	13.5 (0.18)
M4 – Giralia Bay	47	1763	633	0	0	0
Total		10665	7796	5.4 (0.05)	30.8 (0.4)	36.2 (0.2)
Total (mangrove + algal mats)		18,461		36.2 (0.2)		

Source: Biota 2005d

EPA Guidance Statement No. 29 defines six categories of management unit marine ecosystem protection (categories A to F) and sets out cumulative loss thresholds for each category (EPA 2004a). The proposed BPPH management units in this project area have not previously been formally assigned a marine ecosystem category. The key attributes of these units that are relevant to the area:

- was recommended a marine reserve by the Wilson report (MPRSWG 1994)
- has been identified as a Category 1 area for mangrove protection (*Mangrove areas of very high conservation value (designated "regionally significant")* by Guidance Statement No. 1 (EPA 2001).

Given these attributes, the management units could be interpreted as being either:

- Category A ('Extremely special areas)' with a cumulative loss threshold of 0%; or
- Category B ('High protection areas other than above (Category A); cumulative loss threshold of 1%.

The Guidance identifies six bullet point areas of application for a site to qualify as Category A. The first five of these relate to marine parks, Rottnest Island and other classifications that clearly do not apply to the project area. The final Category A bullet point lists: *'Other areas identified through a statutory process or by the EPA as having extremely high conservation or ecological significance or otherwise being extremely special'* (EPA 2004a). Category B areas include Wilson report recommendation areas (such as the eastern part of the study area) and other areas identified by the EPA as having high conservation significance (EPA 2004a).

The only formal EPA process that has considered the area in this respect is the regional mangrove conservation assessment completed for Guidance Statement No. 1. Guidance No. 1 states that the mangroves of the project area have '*very high conservation value'*, while Guidance No. 29 refers to areas identified by EPA as having *'extremely high'* (Category A) or *'high'* conservation value. This difference between the terminologies used in the two statements leaves the precise designation of the mangroves of the study area somewhat unclear.

However, considering that Category B specifically identifies Wilson report areas as its area of application, this would appear to be the relevant Category to be applied to the project area management units.

Guidance Statement No. 29 also identifies the requirement to make an estimate of the cumulative loss of mangrove BPPH that has occurred historically in the management unit. While considerable mangrove loss has occurred due to cyclone events in recent years, there have been no identifiable losses of mangrove BPPH attributable to human activity. The loss of BPPH presented by this proposal is then in effect the first impact, with no historical loss to be considered in the cumulative total loss in the management units.

In those management units where a direct loss of BPPH occurs, the total cumulative loss of mangroves and algal mats is significantly less than the Category B threshold of 1%.

Offsetting any losses to some degree is the likelihood that some mangrove colonisation is likely to occur in new habitats created at pump stations and by bund walls (Paling *et al.* 2003).

Subtidal BPPH (seagrass, algal beds, sponges and corals

Six marine management units (O1 to O6) for subtidal areas have been proposed for offshore BPPH within the project area (Figure 6-18).

The proposed dredged channel is located within the O4 unit, which has an area of 50 km^2 (5029 ha). Within the O4 management unit, the following calculations were performed to assess the project in terms of the EPA's objectives:

- all loss/damage to BPPH caused by human activities since European habitation of Western Australia
- current area of BPPH
- loss/damage of BPPH likely to result from the proposal.

The area offshore of the east coast of Exmouth Gulf is undisturbed by human activity such as dredging or land reclamation works and there have been no recorded losses of BPPH due to anthropogenic pressures within the O4 management unit. The documented ability of the tropical seagrasses of the Gulf to re-establish following disturbance (Loneragan *et al.* 2003) means that any losses or impacts due to human activities more than 5–10 years past (e.g. such as may have occurred prior to the area being declared a Fish Nursery Area) would no longer exist (Oceanica 2006a).

The area of seabed in the O4 management unit less 2 m CD deep is 1175 ha (23% of the management unit area), while the area of seabed in the O4 management unit greater than 2 m deep is 3854 ha (77% of the management unit area). The total area of the dredge channel is 16.4 ha, which is 0.3% of the total area of the O4 management unit. Based on mapping by Oceanica (2006a) the channel will directly impact 0.8% of the mixed inshore habitat and 0.2% of the offshore habitat, but there will be no impact on ecosystem function.

2.7 MONITORING AND ASSESSMENT OF PERFORMANCE

The Marine Management Plan and Dredging Management Plan will describe the monitoring to be undertaken to ensure potential affects on the BPPH are appropriately managed. For example, the Marine Management Plan outlines a range of baseline surveys that will be undertaken to establish environmental conditions prior to development. These surveys include transects of mangroves and algal mats, surveys of creeks to determine sediment and nutrient flows and monitoring the health of benthic primary producers.

2.8 PROPONENT COMMITMENTS

Several commitments have been made under other key environmental factors which are relevant to benthic primary producer habitat including:

- Marine Management Plan (Section 1.6)
- Exmouth Gulf Research Project.

The proponent will undertake additional benthic habitat surveys in consultation with DEC to obtain more detailed information on the benthic primary producer habitat.

2.9 ENVIRONMENTAL OUTCOME

Intertidal BPPH

The area of mangroves and algal mats directly affected has been reduced as far as practicable through project infrastructure design.

No indirect losses of mangroves or algal mats are expected. Localised hydrodynamic changes may result in small-scale changes to wetting and drying regimes, however these are not expected to have any indirect impact on mangroves or algal mats. There are no expected impacts to mangrove communities from the very low levels of saline seepage expected, due to the extent of setback from the field walls to the mangrove zone along most of the field. As with seepage effects, the infrastructure of the field is generally set well back from the mangrove zone so no impacts on mangroves are expected from changes to small-scale surface hydrology. Mangrove colonisation of some parts of the project area are expected based on observations at other Western Australian saltfields.

Discharge of runoff water from stockpiles, drainage water from the plant site, fuel storage and other effluents will be managed to reduce the risk of contamination and keep impacts to insignificant levels.

Seawater pumping at Naughton Creek may result in enhanced sedimentation which could affect mangrove and algal mats if sedimentation was significant. Alternative locations will be investigated to select a site which will be environmentally more benign. In any case, bathymetric surveys will be undertaken to monitor changes in creek morphology and in the event that pumping is found to be causing siltation potentially causing loss to mangroves and algal mats, the pumping operation will be reviewed.

The project will result in the permanent loss of approximately 5.4 ha of the 11,154 ha (0.05%) of mangroves and 31 ha of the 8054 ha (0.38%) of active algal mats occurring in the study area in order to accommodate key project infrastructure. This loss, expressed as a percentage of proposed management units for the east coast of the Gulf, is below the 1% criterion in the EPA Guidance Statement 29 for Category B areas for each BPPH type and is likely to be less than the natural variation in coverage.

The experience with other saltfields in Western Australia is that algal mats tend to colonise areas within project areas offsetting, to some degree, the loss through clearing.

Subtidal BPPH

The construction of the dredge channel at Hope Point will result in the clearing of approximately 8.9 ha of inland hard habitat and 7.5 ha of soft habitat. The construction of the pump stations at Dean's Creek and Naughton Creek will result in the direct loss of approximately 200 m^2 of marine habitat (e.g. seagrass and algae). This loss expressed as a percentage of the proposed marine management unit off the east coast of the Gulf is below the 1% BPPH criterion in the EPA Guidance Statement No. 29 for Category B areas and is likely to be less than the natural variation in coverage.

There is a low risk of any direct loss of benthic habitats due to turbidity associated with dredging and excavation works at Hope Point.

The proposed seawater pumping at Dean's Creek will not significantly affect the current or tidal flux and will therefore not affect sediment dynamics in the creek, and there will be no loss of habitat due to pumping. Seawater pumping at Naughton Creek will however lead to changes in current velocities,

and this may result in enhanced sedimentation. There is unlikely to be vegetated benthic habitat within Naughton Creek due to the combination of existing high velocities and turbid waters.

The barge harbour and channel at Hope Point will not affect sediment transport beyond the immediate vicinity of Hope Point and there will not be any significant impacts on benthic habitat due to modified sediment transport processes.

3 MARINE FAUNA

Exmouth Gulf is an important habitat for whales and dugongs, and supports a valuable prawn fishery. The whales and dugongs, along with sharks and reptiles (turtles, sea snakes) found in the region are protected or listed under the EPBC Act.

Marine fauna addressed in this section does not include wader birds, as these are addressed under the terrestrial fauna environmental factor (Chapter 5, Section 5).

3.1 EPA OBJECTIVE

- *To maintain the abundance, species diversity and geographic distribution of marine fauna.*
- *To ensure that any impacts on locally significant marine communities are avoided, minimised and/or mitigated.*
- *To protect EPBC Act 1999 listed threatened or migratory species.*
- *To protect Specially Protected (Threatened) Fauna consistent with the provisions of the Wildlife Conservation Act 1950.*

3.2 LEGISLATIVE POLICY AND CONTEXT

3.2.1 Statutory framework

Several pieces of State and Commonwealth legislation are relevant to the consideration of the environmental impact on marine fauna including:

- EPBC Act - with regard to listed migratory and threatened species
- *Wildlife Conservation Act 1950–1979* - provides for the protection of all species of native fauna (including marine fauna)
- *Conservation and Land Management Act 1982* - in respect of the recommended marine reserve
- *Fish Resources Management Act 1994* - in respect of the exploitation of recreational and commercial fish stocks.

3.2.2 Policy framework

Australia's Ocean Policy 1998

This policy sets in place the framework for integrated and ecosystem-based planning and management for Australia's marine jurisdictions, and includes support for the development of a single national ballast water management system, and for the early withdrawal of the use of toxic organotin anti-fouling paints (Commonwealth of Australia 1998).

International agreements

Australia is party to the Japan-Australian (JAMBA) and China-Australia (CAMBA) Migratory Bird Agreements. Most birds listed in these agreements are associated with saline wetlands or coastal shorelines (refer to Chapter 5, Section 5).

3.3 DESCRIPTION OF MARINE FAUNA

3.3.1 Protected marine fauna

A number of marine species that may potentially occur within Exmouth Gulf region are listed under State and Federal legislation (Table 6-15).

Table 6-15 Marine species listed under State legislation and marine species listed as Matters of National Significance under Commonwealth legislation (accessed July 2005) for Exmouth Gulf region (excluding birds)

Species	Federal level	State level	Distribution	Likely presence
Blue Whale *Balaenoptera musculus*	Endangered Migratory species	Schedule 1	Distributed throughout oceans worldwide, undertaking extensive migrations between warm water (low latitude) breeding and cold water (high latitude) feeding. Recorded from all Australia states. Migration paths widespread, and exact breeding grounds unknown (Bannister *et al.* 1996).	Possible, not expected on a regular basis.
Southern Right Whale *Eubalaena australis*	Endangered Migratory species	Schedule 1	This species is found off the southern Australian coast during winter and spring (Burnell and McCulloch 2001) with sightings as far north as Shark Bay and Exmouth Gulf.	Possible, previous visits recorded, not expected on a regular basis.
Loggerhead Turtle *Caretta caretta*	Endangered Migratory species	Schedule 1	This species inhabits coastal subtropical and tropical waters with a temperature range of 16–20°C worldwide, and is found in bays, coral reefs and estuaries. In WA, loggerhead turtles breed in Shark Bay, along the Ningaloo coast and adjacent beaches and in the Muiron Islands off North West Cape, with a few turtles nesting in the Dampier Archipelago (Oceanica 2006b).	There is a likelihood of occurrence of the Loggerhead Turtle within the Gulf.
Fin Whale *Balaenoptera physalis*	Vulnerable	Schedule 1	Distributed throughout oceans worldwide, undertaking extensive migrations between warm water breeding grounds and cold water feeding grounds. Recorded from all states except New South Wales and Northern Territory. Migration paths oceanic (Bannister *et al.* 1996).	Possible, not expected on a regular basis.
Humpback Whale *Megaptera novaeangliae*	Vulnerable Migratory species	Schedule 1	Distributed worldwide, coastal off Australia in winter and spring, recorded from all states except the Northern Territory. Migrate annually between warm water breeding grounds and cold water feeding grounds (Antarctica) (Bannister *et al.* 1996).	Humpback Whales visit Exmouth Gulf annually from early August until late November.
Sei Whale *Balaenoptera borealis*	Vulnerable	Schedule 1	Distributed throughout oceans worldwide, undertaking long migrations between warm water breeding grounds and colder water breeding grounds (Bannister *et al.* 1996).	Possible, not expected on a regular basis.

Species	Federal level	State level	Distribution	Likely presence
Flatback Turtle *Natator depressus*	Vulnerable Migratory species	Schedule 1	This species is found only in the tropical waters of northern Australia and Papua New Guinea and Irian Jaya. In Western Australia it occurs in waters of the Kimberley region, the North Western shelf and Pilbara coastal waters (Oceanica 2006b).	No breeding sites for this species are known from the eastern side of the Gulf and there is little suitable nesting habitat on this mangrove-dominated coastline.
Green Turtle *Chelonia mydas*	Vulnerable Migratory species	Schedule 1	This species has a worldwide distribution in tropical and subtropical seas with temperatures above 20°C. In WA, they nest on beaches from the Ningaloo coast northwards. There are significant rookeries on Barrow Island, in the Montebello Islands, the Dampier Archipelago and the Lacepede Islands, and small rookeries on many smaller Pilbara islands, as well as in the Kimberley (Oceanica 2006b).	There is a likelihood of occurrence of the Green Turtle within the Gulf.
Hawksbill Turtle *Eretmochelys imbricata*	Vulnerable Migratory species	Schedule 1	Hawksbill turtles forage near coral reefs in the warm tropical waters of the central Atlantic and Indo-Pacific regions. They rarely stray into temperate seas. In WA, they nest from the Ningaloo coast northwards, including the Lowendal Islands, the Dampier Archipelago and some other small Pilbara islands (Oceanica 2006b).	It is likely that this species occurs within the project area.
Leatherback Turtle *Dermochelys coriacea*	Vulnerable Migratory species	Schedule 1	These turtles have the widest distribution of any turtle, but do not nest in WA. The closest rookeries are in Papua New Guinea, Indonesia and Malaysia. The turtles are regularly found in our coastal waters as far south as Cape Naturaliste, and occasionally stray into the Southern Ocean as far as Esperance (Oceanica 2006b).	Possible occurrence, however do not nest in the area
Great White Shark *Carcharodon carcharias*	Vulnerable Migratory species	Schedule 1	Widely distributed throughout temperate and sub-temperate regions in the northern and southern hemispheres (Environment Australia 2002a). In Australia its range extends from southern Queensland around the southern coastline and to North West Cape in Western Australia (Bruce 1995).	Possible occurrence during aggregation of calving Humpback Whales in the Gulf
Grey Nurse Shark *Carcharias taurus*	Vulnerable	Schedule 1	Broadly distributed throughout inshore areas in sub-tropical to cool temperate waters. In Australia are known to occur in southern Queensland, New South Wales and Western Australia. In WA recorded as far north as the North West Cape (Environment Australia 2002b).	Possible occurrence
Whale Shark *Rhincodon typus*	Vulnerable Migratory species	-	Whale Sharks occur in both tropical and temperate waters. In Western Australia, Whale Sharks aggregate close to the Ningaloo Reef front during late March to early May (Oceanica 2006b).	Whale Sharks have been sighted within the northern end of Exmouth Gulf, however, this is not a key site of interest as the aggregation is focussed on the food available at the Ningaloo reef edge.
Antarctic Minke Whale *Balaenoptera bonaerensis*	Migratory species	-	'Extensive migrations between cold water feeding grounds and warmer water breeding grounds, but less predictable than most other rorquals and possibly not migrating as far into warm waters as other balaenopterids' (Bannister *et al*. 1996)	Possible but unlikely
Bryde's Whale *Balaenoptera edeni*	Migratory species	-	Restricted to tropical and temperate waters from the equator to approximately 40°S. Recorded from all Australian States except the Northern Territory (Bannister *et al.* 1996).	Possible, previous visits recorded, not expected on a regular basis

Species	Federal level	State level	Distribution	Likely presence
Dugong *Dugong dugon*	Migratory species	Schedule 4	The Dugong's range spans the tropical and subtropical coastal and island waters of at least 37 countries and territories. Within Western Australian waters Dugongs are known to occur from Shark Bay to the North Kimberley coast (Oceanica 2006b).	Dugongs occur in the project area. Their activity is thought to be focussed on the southeast coast of the Gulf, associated with the shallow seagrass habitat in this area.
Killer Whale *Orcinus orca*	Migratory species	-	Distributed from polar regions to the equator in all oceans. Recorded from all Australian states except the Northern Territory, with concentrations around Tasmania. Not known to be migratory but seasonal movements may be made, possibly related to food supply (Bannister *et al.* 1996).	Likely presence, particularly during November
Sperm Whale *Physeter macrocephalus*	Migratory species	-	Distributed worldwide. Generally occur in deep water off the continental shelf. Recorded from all Australian states. Concentrations known to occur off the coast of Albany (Bannister *et al.* 1996).	Possible, not expected on a regular basis
Indo-Pacific Humpback Dolphin *Sousa chinensis*	Migratory species	-	Occurs in southern China through the Indo-Malay Archipelago to northern Australia. Occurs in coastal, estuarine and occasionally riverine habitats. In Australia the species extends to 25°S south on the west coast and 34°S on the east coast (Bannister *et al.* 1996).	Likely occurrence
Spotted Bottlenose Dolphin (Arafura/Timor Sea populations) *Tursiops aduncus*	Migratory species	-	Occurs around the top of Australia, from Port Macquarie in New South Wales, to the Northern Territory and south to Perth in Western Australia. Occurs further offshore but often in water of < 10 m depth and may range to about 10 km offshore in oceanic waters (Bannister *et al*. 1996)	Likely occurrence
New Zealand Fur Seal *Arctocephalus forsteri*	-	Schedule 4	Breeds on the coast of the Australian mainland and its nearshore islands. Hauloff Rock is one island of Western Australia that supports breeding colonies of the fur seal (Shaughnessy 1999)	Possible occurrence
Australian Sea Lion *Neophoca cinere*	-	Schedule 4	Found only in Australia between The Pages Islands in South Australia and Houtman Abrolhos off the Western Australian coast. The species mostly inhabits islands but also a few mainland sites. There is no evidence of migration or seasonal movements, apart from some movement of adult and subadult males on the west coast of Western Australia (MarineBio 2006).	Possible occurrence

3.3.2 Sea turtles

The four species of marine turtle known to occur in the region and their main nesting periods are as follows:

- Hawksbill Turtle *(Eretmochelys imbricate)*: July to March
- Flatback Turtle *(Natator depressus)*: September to March
- Green Turtle *(Chelonia mydas)*: September to March
- Loggerhead Turtle *(Caretta caretta)*: September to March (Oceanica 2006a).

The Green Turtle is the most common to the Ningaloo region (Preen *et al.* 1997). Of the four species, only the Green Turtle eats seagrasses regularly and on a large scale (Lanyon *et al.* 1989).

Turtles are most vulnerable during the nesting period when they congregate in shallow water near the breeding beaches and come ashore to lay eggs, and subsequently when the hatchlings make their way across the beaches to the water.

Investigations

Numerous turtles were observed by Oceanica in the shallow (approximately 1 m depth) waters along the eastern coast during field surveys (Oceanica 2006a) (Appendix 7). In addition, results from the fauna aerial survey program undertaken by the Centre for Whale Research in October 2004 to July 2005 demonstrated the importance of the east coast nearshore algae and seagrass habitat to turtles (Figure 6-44).

An inspection of the entire beach at the end of Hope Point was completed by Oceanica in late December 2005, when turtle nesting activity was occurring in the region. There was no evidence of the beach being used for nesting.

Aerial strip transects were flown over Exmouth Gulf during the winters of 1989 and 1994 (Preen *et al.* 1997). This study showed that the distribution of turtles was similar, with fewer turtles sighted in the deeper waters of central and western Exmouth Gulf in 1989. The majority of animals sighted on both surveys could confidently be identified as Green Turtles. Of the 262 turtles sighted in 1989 and the 115 animals in 1994, densities were concentrated north to south along the eastern region of the Gulf. The results from 1994 show turtles utilising areas closer to the mangrove coastline. These areas are known nursery areas for mostly juvenile Green Turtles due to the shallower protected waters (R. Prince, 2005, pers. comm.). Nesting opportunities for sea turtles are not present throughout the project area. The closest potential nesting opportunities are at the sandy beach at Tubridgi Point, although there is no available data for this area.

Description - Flatback Turtle (Natator depressus)

Vulnerable (EPBC Act), *Schedule 1 (Wildlife Conservation Act)*

Distribution

This species is found only in the tropical waters of northern Australia and Papua New Guinea and Irian Jaya (Spring 1982, Zangerl *et al.* 1988) and is one of only two species of sea turtle without a global distribution. Adults are known to inhabit soft bottom habitat over the continental shelf of Northern Australia (Spring 1982, Zangerl *et al.* 1988) although the extent of their range is not fully known (Zangerl *et al.* 1988). In Western Australia it occurs in waters of the Kimberley region, the North Western shelf and Pilbara coastal waters.

Foraging ecology

There is limited knowledge of the diet of this species, or foraging habits and habitats, however juveniles are known to eat crinoids gastropod hydroids, jellyfish, molluscs, soft corals, squid and siphonophores (Zangerl *et al.* 1988). Larger juvenile and adult turtles may occupy similar habitat and forage primarily on benthic organisms.

Breeding

Peak nesting occurs in the summer months on Barrow Island and the Pilbara region (Prince 1994). Nesting sites are known from Barrow Island (Prince 1994), Rosemary Island and Cowrie Beach

(Mundabullangana Station Coast) (R. Prince, 2002, pers. comm.). The periodicity of reproductive migrations is recorded to be between one and five years with a mean of 2.7 (Limpus *et al.* 1984).

Nesting habitat comprises sandy beaches in the tropics and subtropics, with sand temperatures between 25°C and 3°C at nest depth (Limpus 1995). Females will lay a mean of 2.8 clutches per season with an inter-nesting interval of 15 days. Egg clutches are laid at a depth of 55 cm (Limpus 1971) and contain approximately 50 eggs, with an average size of 5.2 cm in diameter and 78 g in weight. The sex ratio of the hatchlings is determined by the temperature of the sand, with males produced below 29°C and females produced above this temperature (Limpus 1995).

No breeding sites for this species are known from the eastern side of the Gulf and there is little suitable nesting habitat on this mangrove-dominated coastline.

Likelihood of occurrence

Three adult tagged turtles have been recorded caught in trawler nets from the top half of Exmouth Gulf (R. Prince, 2005, pers. comm.). Available records indicate that flatback turtles feed in turbid, shallow inshore waters north of latitude 25°S in depths from less than 10 m to depths of over 40 m (Robins 1995). There is a likelihood of occurrence towards the top end of Exmouth Gulf.

Description - Green Turtle (Chelonia mydas)

Vulnerable (EPBC Act), *Schedule 1 (Wildlife Conservation Act)*

Distribution

This species has a worldwide distribution in tropical and subtropical seas with temperatures above 20°C. In WA, they nest on beaches from the Ningaloo coast northwards. There are significant rookeries on Barrow Island, in the Montebello Islands, the Dampier Archipelago and the Lacepede Islands, and small rookeries on many smaller Pilbara islands, as well as in the Kimberley.

Ecology

Adults are large (up to 205 kg) and herbivorous, feeding on seaweeds and seagrasses, while immature Green Turtles are carnivorous, feeding on jellyfish, small molluscs, crustaceans and sponges. In some areas adults are recorded as feeding only on algae, while in others they feed solely on seagrasses. Adult females breed only once every six years or so, although the nesting interval varies considerable from year to year, with very little breeding occurring in some years and a lot in others. Females lay about 115 eggs per clutch and about five clutches per season. Hatchling sex ratios vary, depending on incubation temperature: warmer northern beaches produce predominantly females and southern beaches produce mainly males.

Likelihood of occurrence

There were no obvious nesting beaches in the project area, however a number of Green Turtles were observed near many of the offshore islands. The mangrove creeks and vegetated shallows of the east coast of the Exmouth Gulf and along the majority of the nearshore mangrove habitats are an important nursery for this species. Turtle-tagging work that occurred from December 1990 through to May 1998 revealed that 88.4% of turtles recorded from Sandalwood Peninsula base camp were Green Turtles and the majority of these were juveniles (B. Prince, 2005, pers comm.).

There is a likelihood of occurrence of the Green Turtle within the Gulf.

Description - Hawksbill Turtle (Eretmochelys imbricate)

Vulnerable (EPBC Act), *Schedule 1 (Wildlife Conservation Act)*

Distribution

Hawksbill turtles forage near coral reefs in the warm tropical waters of the central Atlantic and Indo-Pacific regions. They rarely stray into temperate seas. In WA, they nest from the Ningaloo coast northwards, including the Lowendal Islands, the Dampier Archipelago and some other small Pilbara islands (Burbridge 2004). Western Australia possesses the only remaining large population in the entire Indian Ocean (Burbridge 2004).

Ecology

Hawksbill turtles feed on sponges, seagrasses, algae, sea squirts, soft corals and molluscs. Females migrate long distances between feeding and breeding grounds. They lay about 130 eggs per clutch, and hatchling sex ratios depend on incubation temperature (Burbridge 2004).

Likelihood of occurrence

This species has been recorded from Sandalwood Peninsula base camp during turtle-tagging work that occurred between 1990 and 1998 (B. Prince, 2005, pers. comm.). This species comprised 2.4% of the total number of turtles tagged during that period. Even numbers of both adults and juveniles were recorded (B. Prince, 2005, pers. comm.). It is likely that this species occurs within the project area.

Description - Leatherback Turtle (Dermochelys coriacea)

Vulnerable (EPBC Act), *Schedule 1 (Wildlife Conservation Act)*

Distribution

These turtles have the widest distribution of any turtle, but do not nest in WA. The closest rookeries are in Papua New Guinea, Indonesia and Malaysia. The turtles are regularly found in our coastal waters as far south as Cape Naturaliste, and occasionally stray into the Southern Ocean as far as Esperance (Burbridge 2004).

Ecology

Leatherback Turtles feed mainly on jellyfish.

Likelihood of occurrence

There are no records of Leatherback Turtles nesting in Western Australia. Furthermore the area is not known as a foraging ground or a nursery.

It is unlikely that this species occurs in the project area.

Description - Loggerhead Turtle (Caretta caretta)

Endangered (EPBC Act), *Schedule 1 (Wildlife Conservation Act)*

Distribution

This species inhabits coastal subtropical and tropical waters with a temperature range of 16–20°C worldwide, and is found in bays, coral reefs and estuaries. In WA, Loggerhead turtles breed in Shark Bay (Dirk Hartog and Dorre Island), along the Ningaloo coast and adjacent beaches and in the Muiron Islands off North West Cape, with a few turtles nesting in the Dampier Archipelago.

Ecology

Loggerhead turtles eat shellfish, crabs, sea urchins and jellyfish. The WA population migrates from feeding grounds in northern WA, the Northern Territory and probably Indonesia to breeding areas further south. Mating occurs from October to early December followed by nesting from late October to early March. Females lay up to six clutches per nesting season, with about 125 eggs in each clutch. Hatchlings emerge from late December to early April. Breeding and nesting occurs every two to five years. The sex of the hatchling is determined by incubation temperature, with warmer beaches producing predominantly female hatchlings.

Likelihood of occurrence

There is a likelihood of occurrence of the Loggerhead Turtle within the Gulf. There were no obvious nesting beaches within the project area; therefore the likelihood of nesting adults in the area is low. In turtle-tagging work that occurred between December 1990 and May 1998, Loggerheads comprised 9.2% of the total numbers caught (R. Prince, 2005, pers. comm.). The majority of these were juveniles. The mangroves and Exmouth Gulf are an important nursery for the hatchlings, and an important foraging ground for juveniles.

3.3.3 Whales

Investigations

The Centre for Whale Research (WA) prepared a review of existing information on the Humpback Whale population in Exmouth Gulf (Centre for Whale Research 2004) and undertook a program of aerial surveys (Centre for Whale Research 2005).

Description – Humpback Whale (Megaptera novaeangliae)

Vulnerable (EPBC Act)*, Schedule 1 (Wildlife Conservation Act)*

Exmouth Gulf was first described by Chittleborough (1953) as a possible "nursery" for Humpback Whales based on aerial surveys over the area in 1951 and 1952. These flights were a regular part of an exploratory process designed to maximise returns for the commercial whaling industry. A whaling station operated at Norwegian Bay near Point Cloates from 1912–1916 and then from 1922–1928, and finally from 1949–1955. By 1963, when a moratorium on humpback whaling was passed, there was thought to be less than 800 whales left in the Group IV (WA) population (Chittleborough 1965).

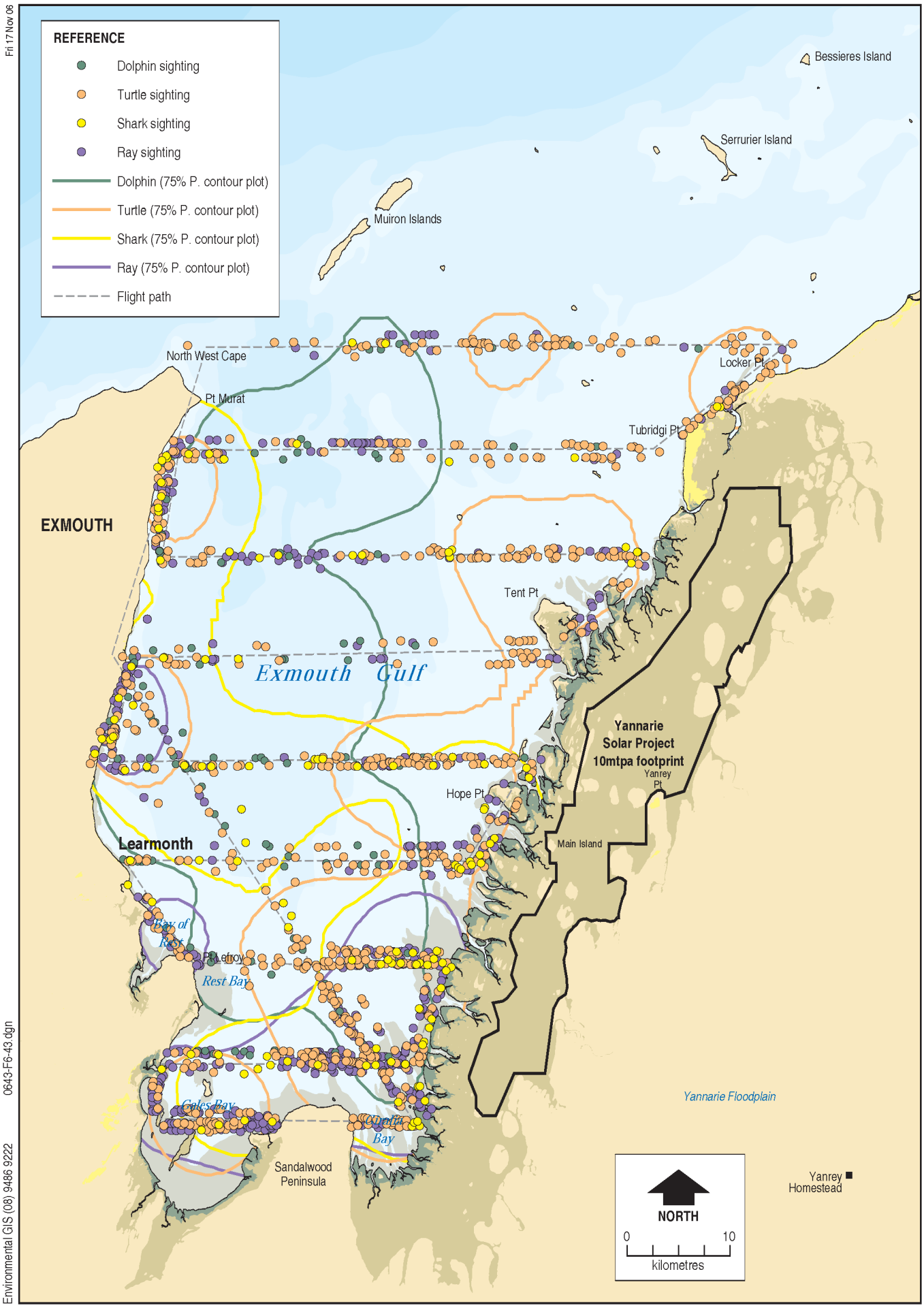
Following the cessation of whaling, the Group IV population has been estimated to be recovering at an annual rate of between 7 and 12%, such that numbers may be approaching 12,000 to 15,000 (Bannister and Hedley 2001). Extrapolating this recovery rate forward to 2010, the population could reach 20,000–30,000 individuals and would represent densities of whales double that of present levels. The number of resting cow/calf pairs likely to be using Exmouth Gulf each year is presently estimated at

1000–1500 cow/calf pairs. This could potentially double by 2010 to nearly 3000 cow/calf pairs (Centre for Whale Research 2004a).

Humpback Whales visit Exmouth Gulf annually from early August until late November. Whales are predominantly found in water depths greater than 7 m with the greatest number of whales being sighted in the deepest (approximately 20 m) portions of the Gulf. It is likely that water temperature plays a role in determining when whales, particularly cow/calf pairs trying to minimise metabolic expenditures, enter Exmouth Gulf. Cow/calf numbers inside the Gulf peak during the first two weeks of October, at a similar time that the sea surface temperature inside the Gulf becomes equal to that found offshore at the same latitude.

The migration of Humpback Whales both north and south past Exmouth Gulf follows predictable but complicated patterns each season. The migration patterns can be grouped into three categories:

1. **Northern migration** of whales off the North West Cape occurs from June to early August, and is lead by sub-adults and mature females that have terminated lactating, followed by mature males and females and then later pregnant females (carrying near-term foetuses) (Figure 6-45). Whales rarely enter Exmouth Gulf during this time, perhaps due to the 3°C or more temperature drop from the open ocean to the shallow Gulf. The northern migratory path is consistent for all age and sex classes off North West Cape and tends to centre on the 250 m depth contour.
2. **A transition phase** between the northern and southern migration occurs from early August to early September. Whale numbers peak during this time, and sightings of whales inside the northern, warmer part of the Gulf increase during early September and by mid to late September, the main southbound migratory peak passes west of North West Cape with some animals entering the Gulf (Figure 6-46). The migratory path spreads to include a much wider depth range than is observed during the northern or southern migration.
3. **Southern migration** occurs from mid September to December. Migration patterns follow a similar pattern to the northern migration, with the addition of cows with newly born calves at the tail end of the migration. It is this cow/calf portion of the migration that appears to congregate in greatest numbers inside Exmouth Gulf (Figure 6-47). Whale numbers peak inside the Gulf during the first two weeks of October, coinciding with the arrival of southbound cow/calf pods from the Kimberly. Cow/calf pods can rest and nurse inside the Gulf for periods of between one and two weeks before continuing their southern migration. This makes the Gulf a critical resting area for this portion of the population. Adult males can remain in Exmouth Gulf, or the immediate area, for periods up to 25 days and perhaps longer. Males enter Exmouth Gulf to find or attract females to mate with. They use a variety of competitive techniques including fighting and singing to attract females.

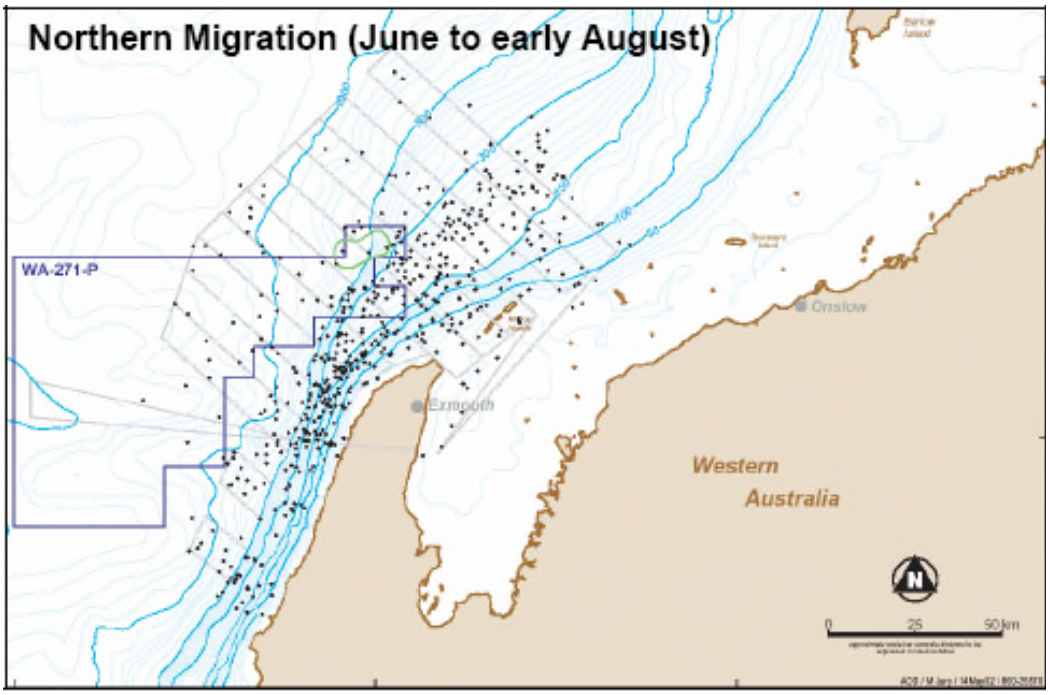


Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Centre for Whale Research WA, 2006
Date: 17 Nov 2006

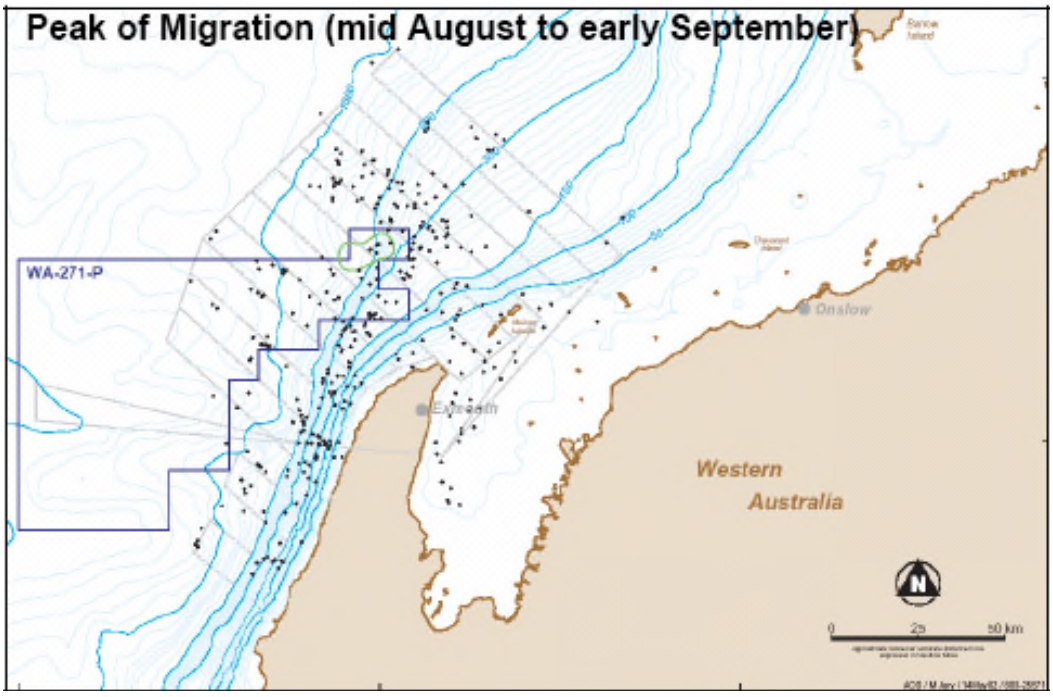
YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-44 Distribution of dolphins, turtles, sharks and rays in Exmouth Gulf based on aerial surveys from October 2004 to July 2005



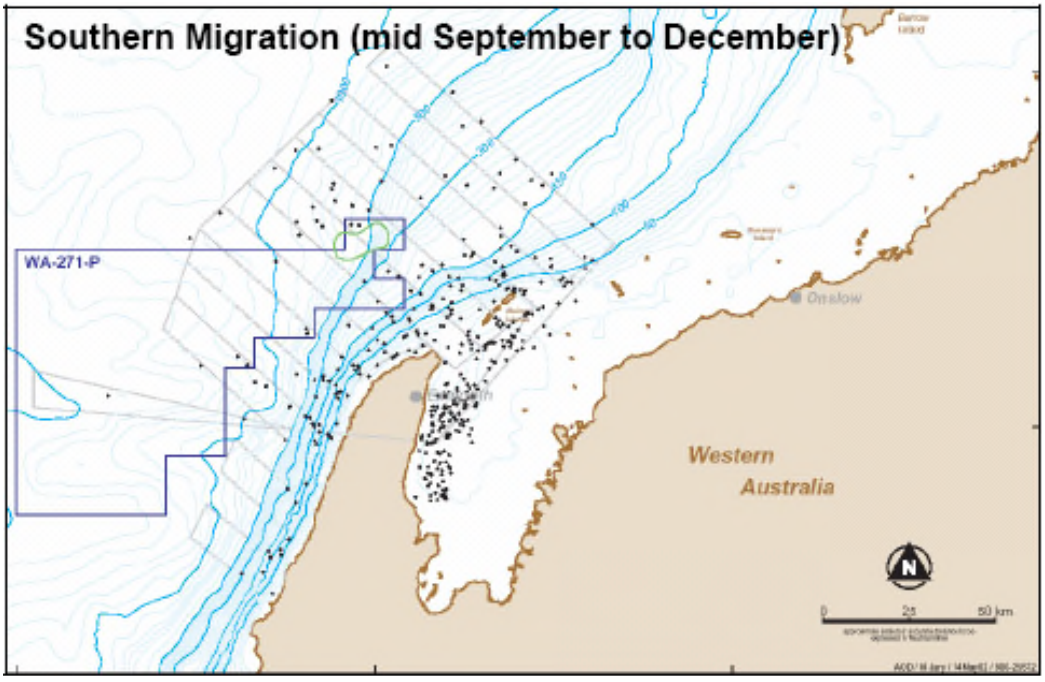
Source: Centre for Whale Research 2004

Figure 6-45 Aerial survey sightings of Humpback Whales during the northern migratory period (June to early August) in 2000 and 2001



Source: Centre for Whale Research 2004

Figure 6-46 Aerial survey sightings of Humpback Whales during the transition phase (mid-August to early September) in 2000 and 2001



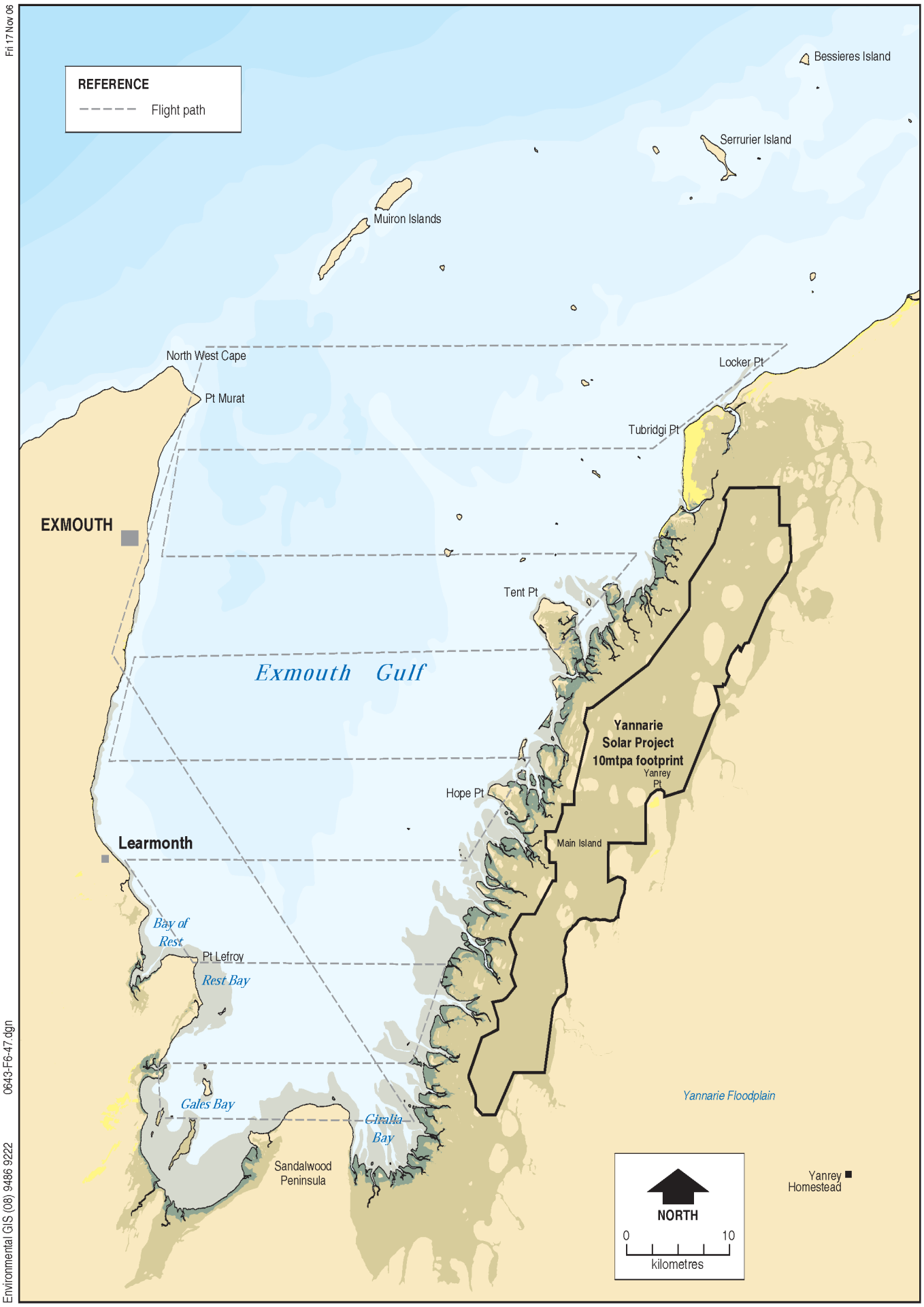
Source: Centre for Whale Research 2004

Figure 6-47 Aerial survey sightings of Humpback Whales during the southern migratory period (mid-September to December) in 2000 and 2001

Surveys

Initially, four aerial surveys targeting Humpback Whales were flown on randomly selected days (weather dependent) during each of four consecutive 10 day blocks between October 1 and November 10 in 2004 with the flight path shown in Figure 6-48 (Oceanica 2006a). This aerial survey program was subsequently expanded to be undertaken on a monthly basis through to October 2005 to provide more information on the reappearance of the whales in 2005. The survey was also expanded to include other marine megafauna such as turtles and dugongs.

Boat surveys of whales in Exmouth Gulf were undertaken by the Centre for Whale Research in 1996, 1997 and 1998 (Jenner and Jenner 2005). The results from boat surveys from previous years are shown in Figure 6-49 (Oceanica 2006a). The combined results of boat and aerial surveys are shown in Figure 6-50 (Oceanica 2006a). The sets of data are similar and demonstrate unequivocally that the preferred Humpback Whale resting area in the Gulf is within the deeper waters (15–20 m) of the western Gulf. There was no observable difference between the preferred habitat of cow/calf pods and that of pods without calve.

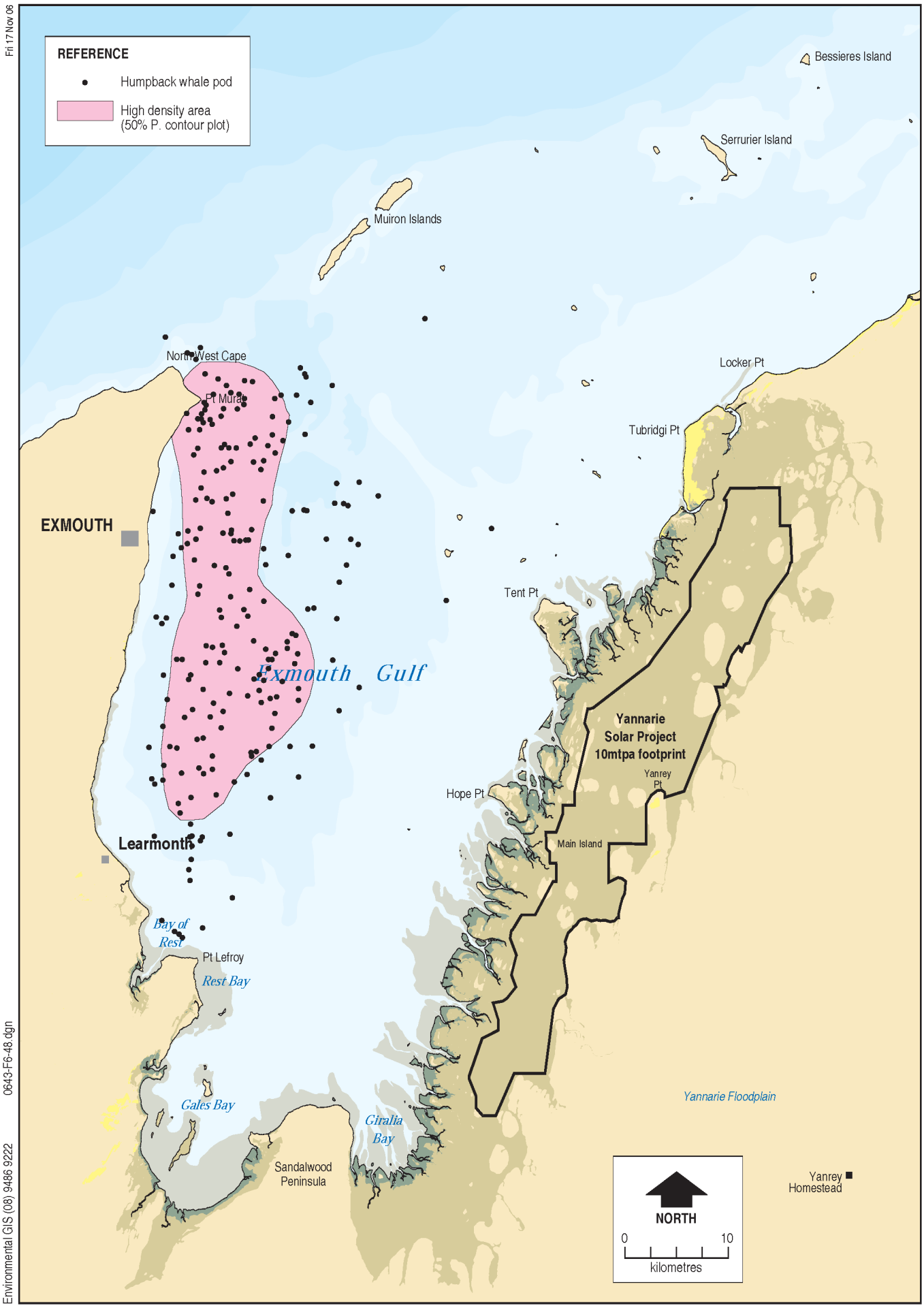


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-48 Flight plan for megafauna surveys of Exmouth Gulf

Datum: MGA Zone 50
Source: Centre for Whale Research WA, 2006
Date: 17 Nov 2006

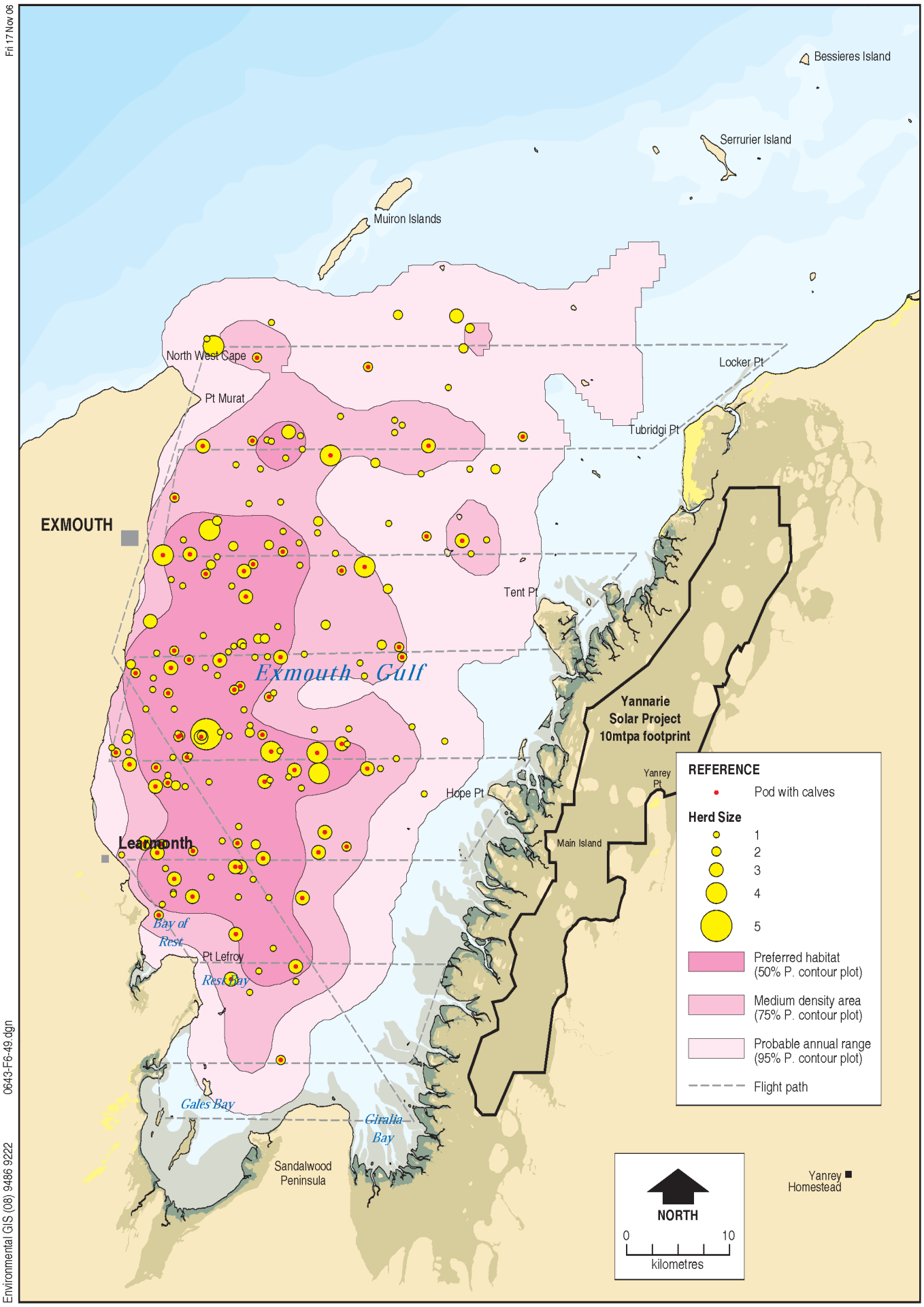


Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Centre for Whale Research WA, 2006
Date: 17 Nov 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-49 Preferred Humpback Whale resting area as measured by boat surveys from 1996 - 97 (Oct) and 1998 (8 Aug - 4 Oct)



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Centre for Whale Research WA, 2006
Date: 17 Nov 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-50 Location of all pods of whales sighted during all flights to July 2005

3.3.4 Dugongs

Schedule 4 (Wildlife Conservation Act)

Dugongs are listed as marine and migratory species under the *EPBC Act 1999* and are listed under the WA *Wildlife Conservation Act 1950* as Schedule 4 (fauna that is in need of special protection) (Table 6-15).

Investigations

Oceanwise (2005) reviewed the existing information on dugongs in the Gulf. The review presented the results of aerial surveys, and examined the threats posed by the saltfield proposal and their potential management. Aerial surveys for dugongs were conducted as part of the aerial whale surveys undertaken by the Centre for Whale Research (2005).

Description

The dugong's range spans the tropical and subtropical coastal and island waters of at least 37 countries and territories (Marsh *et al.* 2002, as cited in Oceanwise 2005). The presence of dugongs is dependent upon the distribution of the tropical and subtropical seagrasses on which they primarily feed (Edmonds *et al.* 1997, as cited in Oceanwise 2005). Within Western Australian waters, dugongs are known to occur from Shark Bay to the North Kimberley coast (Marsh *et al.* 2002, as cited in Oceanwise 2005).

Shoreline aerial surveys of the north west coast of Western Australia in February 1977 and July 1978 provided the first evidence of a substantial dugong population in Exmouth Gulf (Prince *et al.* 1981, as cited in Oceanwise 2005). Three regional-scale aerial surveys of the winter dugong populations of Shark Bay, Ningaloo Reef and Exmouth Gulf have occurred at five-year intervals since 1989. Quantitative surveys of the Exmouth Gulf resulted in a minimum dugong population estimate of 1062 (±s.e 321) in 1989, 1006 (±s.e. 494) in 1994 and 174 (±s.e. 82) in 1999. Dugong densities were estimated to be 1.142 /km^2 in 1989, 1.114 /km^2 in 1994, and 0.055 /km^2 in 1999. The 1989 survey did not incorporate the southern section of Ningaloo Reef therefore the 1989 dugong population estimate is not directly comparable to the latter years. In April 2000, the first quantitative survey for dugongs of the Pilbara coastal waters (<20 m isobath between Exmouth Gulf and the De Grey River mouth) recorded 2046 (±s.e 376) dugongs (Prince *et al.* 2001, as cited in Oceanwise 2005). However, only two individual dugongs were observed within the Exmouth Gulf section of this survey; too few to obtain a reliable population estimate (Prince *et al.* 2001, as cited in Oceanwise 2005).

The occurrence of Cyclone Vance prior to the 1999 and 2000 surveys affected the dugong populations in the Gulf, which are thought to be recovering (Gales *et al.* 2004, as cited in Oceanwise 2005).

Four aerial surveys of Exmouth Gulf dedicated to large marine fauna were conducted between 7 October and 2 November 2004. These provided some current data on the spatial distribution of dugongs in Exmouth Gulf at the time of the survey (Table 6-16) rather than a minimum population estimate necessary to determine the spatial and temporal changes in dugong distribution and abundance (as per previous surveys). Of the dugong herds sighted during these surveys, 76% were in the shallow (<6 m) south eastern portion of the Gulf (Figure 6-51), and 24% contained cow/calf pairs. The 50% point contour range plot is considered to be a 'home range' or most preferred/high density area, while a 95% point contour plot indicates the total range over which all of the dugong sightings occurred (Figure 6-51). The 75% point contour plot allow for movements between seasons that may

not have been observed and the spacing between survey transects (10 km) which was not concentrated enough for dugong sighting.

The number of herds sighted and the number of herds containing calves remained relatively constant across the four survey flights as shown in Table 6-16.

Dugong activity is thought to be focussed on the east coast of the Gulf, associated with the shallow seagrass habitat in this area; however there is a lack of understanding of the fine-scale movements and the importance of various habitats for resting, breeding and feeding (Oceanica 2006a).

Table 6-16 Results of Exmouth Gulf aerial dugong surveys

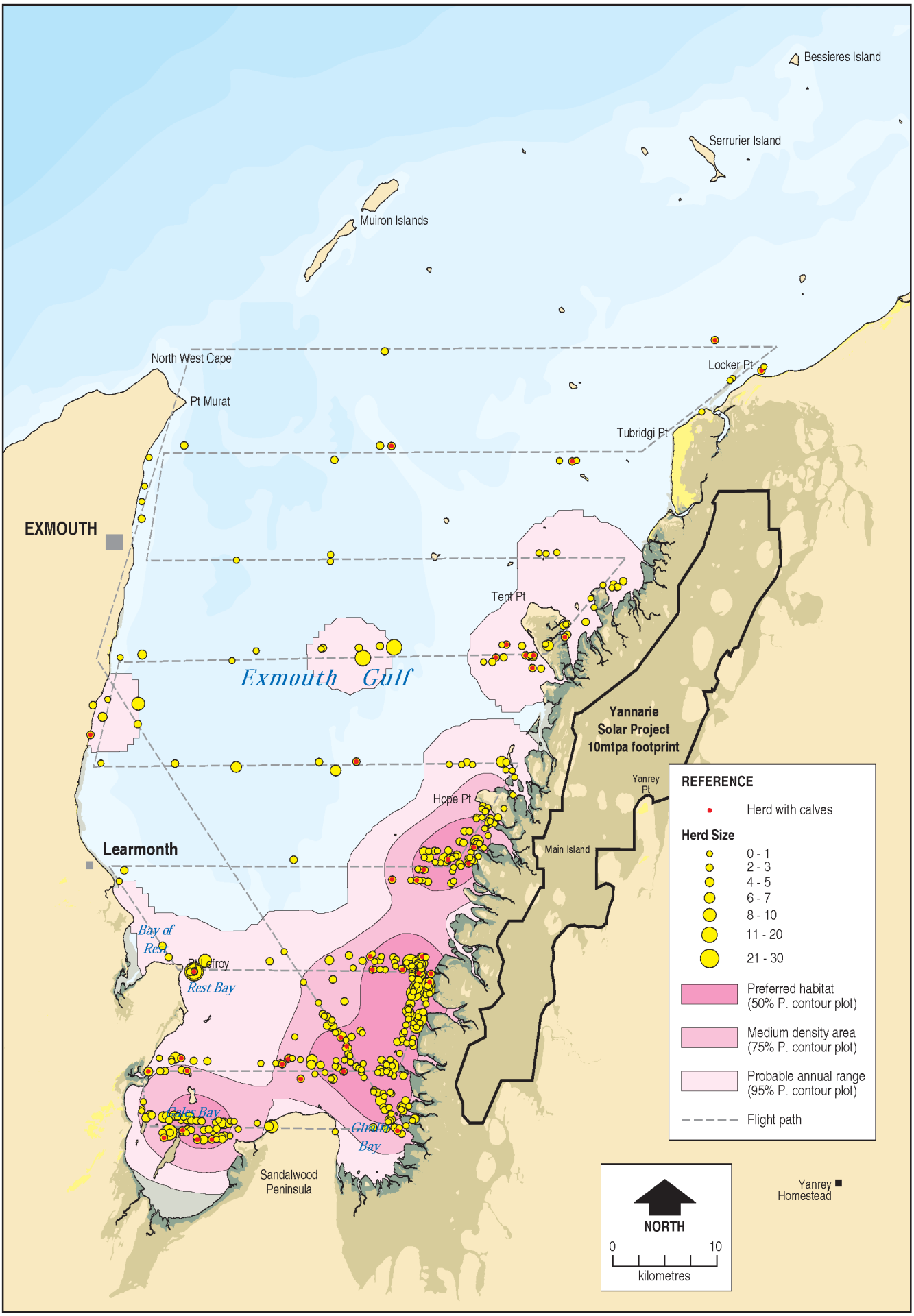
Block	Flight date	No. herds	No. dugongs	No. herds with calves	No. calves
1	7-Oct-2004	37	73	11	11
2	14-Oct-2004	53	114	9	9
3	26-Oct-2004	37	89	9	9
4	2-Nov-2004	41	165	12	12
5	18-Feb-2004	18	27	2	2
6	7-Mar-2005	29	52	6	6
7	3-Apr-2005	28	44	2	2
8	26-Apr-2005	27	64	5	5
9	22-May-2005	51	163	7	7
10	12-Jun-2005	16	32	1	1
11	12-Jul-2005	39	148	4	4
12	7-Aug-2005	27	53	1	1

Source: Centre for Whale Research 2005, as cited in Oceanwise 2005

3.3.5 Sharks and rays

Whale sharks

The Whale Shark *(Rhincodon typus)* feeds on plankton, small fish and squid and occurs in both tropical and temperate waters. Whale Sharks aggregate close to the Ningaloo Reef front during late March to early May following the mass spawning of coral when there is an abundance of food in the form of planktonic larvae and schools of small fish in the waters adjacent to the reefs. Whale Sharks have been sighted within the northern end of Exmouth Gulf, however, this is not a key site of interest as the aggregation is focussed on the food available at the Ningaloo reef edge (Oceanica 2006a).



Fri 17 Nov 06

0643-F6-50.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Centre for Whale Research WA, 2006
Date: 17 Nov 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-51 Location of all pods of dugongs sighted during all flights to April 2005

Other sharks and rays

Large sharks, such as the Oceanic White-tip Shark (*Carcharhinus longimanus*), Tiger Shark (*Galeocerdo cuvier*), Blue Shark (*Prionace glauca*) and Grey Reef Shark (*Carcharhinus amblyrhynchos*) predominantly occur in deep water outside the Gulf however, they are occasionally found in the Gulf. The aggregation of calving Humpback Whales may also attract Great White Sharks (*Carcharodon carcharias*). The Gulf is also an important area for Manta Rays (*Manta birostris*), with large schools observed in autumn and winter (Oceanica 2006a).

Numerous other species of rays and small sharks, such as the Blacktip Reef Shark (*Carcharhinus melanopterus*), Wobbegongs (*Orectolobus ornatus, Orectolobus wardi* and *Euchrossorhinus dasypogon*) and juveniles of the larger shark species may occur in the Gulf and along the shallower waters of the east coast.

The location of sharks spotted during the aerial surveys is shown in Figure 6-44.

3.3.6 Sea snakes

Sea snakes are common to the Gulf (Oceanica 2006a). Sea snakes are occasionally caught by trawlers and returned alive to the sea (Department of Fisheries 2002). The Shark Bay Sea Snake (*Aipysurus pooleorum*) and the Olive Sea Snake, (*Aipysurus laevis*) are commonly reported (Department of Fisheries 2002, LeProvost Dames and Moore 2000).

3.3.7 Fish

The region contains a diverse range of fish of tropical Indo-West Pacific affinity.

LeProvost Dames and Moore (2000) reported that for offshore waters, the key pelagic[8] species include:

- trevally (Family: *Carangidae*)
- tuna (Bigeye *Thunnus obesus*, Yellowfin *T. albacares*, Albacore *T. alalunga*, and Bluefin *T. maccoyii*)
- mackerel (Family: *Scombridae*)
- marlin (Striped Marlin *Tetrapturus audax*)
- sailfish (Broadbill Swordfish *Xiphius gladius*) (Family: *Istiophoridae*).

Commonly encountered species include:

- Spanish Mackerel (*Scomberus commerson*)
- Golden Trevally (*Gnathanodon speciocus*)
- Yellowfin tuna (*Thunnus albacares*).

[8] Pelagic species are those living in open water or seas.

Large demersal species also occur, including:

- snappers and seaperches (Family: *Lutjanidae*)
- emperors (Family: *Lethrinidae*)
- lizardfish (Family: *Sinodontidae*)
- goatfish (Family: *Mullidae*).

The Department of Fisheries undertake regular research trawls in the Gulf and as part of this they have identified trawl by-catch species. They found 305 species in the Gulf, including (Department of Fisheries 2005):

- Catsharks
- Wobbegongs
- Sharks
- Stingrays
- Rays
- Eels
- Herrings
- Sardines
- Anchovies
- Lizardfish
- Catfish
- Frogfish
- Anglerfish
- Flying Fish
- Garfish
- Longtom
- Hardyhead
- Pineapplefish
- Veilfin
- Pipefish
- Seahorses
- Scorpionfish
- Velvetfish
- Flathead
- Searobin
- Rockcod
- Dottyback
- Threadfin
- Trumpeter
- Bigeye
- Cardinalfish
- Whiting
- Cobia
- Suckerfish
- Trevally
- Ponyfish
- Seaperch
- Threadfin Bream
- Monocle Bream
- Pink Snapper.

The Gulf also contains important recreational target species such as:

- Coral Trout (*Plectropomus* spp.)
- Blue Bone or Baldchin Groper (*Chocrodon rubescens*)
- North-west Snapper (*Lethrinus nebulosus*)
- Yellow-tailed Emperor (*Lethrinus mahsena*)
- Red Emperor (*Lutjanus sebae*)
- various species of cod (*Epinephelus* spp.).

In addition, the mangrove creek systems support Mangrove Jack (*Lutjanus Argentimaculatus*), Brownstripe Snapper (*Lutjanus vitta*), Estuary Rockcod (*Epinephelus coioides*), Black-spotted Rockcod (*Epinephelus malabaricus)* and Barramundi (*Lates calcarifer*) (Travers 2006). Barramundi spawn in the creeks between September and March.

Travers (2006) has recently completed a review of the fish and crustacea of the Gulf and their lifecycles and distribution, on behalf of Straits.

3.3.8 Prawns

There are a number of prawn species in Exmouth Gulf, some of which are targeted by the Exmouth Gulf Prawn managed fishery. The fishery primarily targets Western King Prawns (*Penaeus latisulcatus*) and Brown Tiger Prawns (*Penaeus esculentus*), with lesser, but still commercially

significant, catches of Endeavour Prawns (*Metapenaeus endeavouri*) and occasionally Banana Prawns (*Penaeus merguiensis*).

Western King Prawn

This species spawns numerous times throughout the year, producing approximately 100,000 to 700,000 eggs per spawning per female prawn. After hatching of the eggs, larvae drift to a suitable nursery area (i.e. shallow sand/mud flats) where they settle and continue to grow into juveniles (Figure 6-52).

Juvenile Western King Prawns spend around three to six months in the nursery area. Recruitment from the nursery to the trawl fishing grounds occurs in the summer and autumn of each year.

Mature prawns are found over silt or sandy substrates.

Brown Tiger Prawn

Spawning takes place from August through to March with 50,000 to 400,000 eggs released per prawn per spawning. The number of eggs released reaches a peak during autumn and again in spring with lower levels of spawning activity occurring throughout the year.

Planktonic larvae drift to a suitable nursery area containing structured habitats such as algae or seagrasses where they settle and grow into juveniles (Figure 6-52).

The juvenile phase occurs in the vegetated shallow waters along the eastern shoreline of the Gulf (nursery grounds). Tiger prawns become mature at 6 to 7 months of age. The juveniles are vulnerable to predation by fish species including barramundi, threadfin salmon, cod and small sharks.

The young adult prawns migrate offshore entering the trawl fishing grounds in the summer and autumn of each year.

Endeavour Prawn

This prawn is believed to spawn year-round in the Exmouth Gulf, with spawning peaks occurring in March and September.

Juvenile endeavour prawns are most commonly associated with seagrass beds. They spend a short period of time in nursery areas and migration to adult habitats occurs at a small size (Figure 6-52). Recruitment occurs mainly in the summer months.

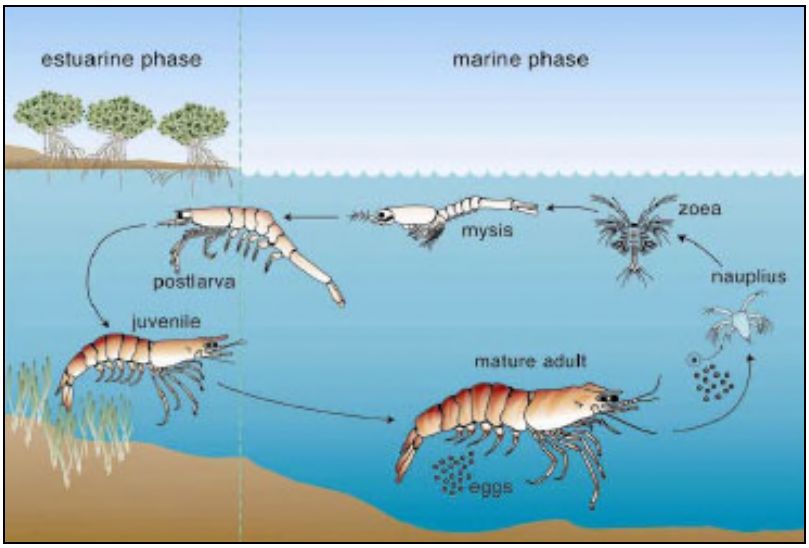
Mature endeavour prawns are generally found in coastal waters down to approximately 50 m and are commonly caught in muddy or sand/mud substrates. They are generally found inshore of the main fishing grounds for the tiger and king prawns.

Banana Prawn

This prawn becomes sexually mature at 7 to 8 months of age and spawns continually until it dies. Spawning is strongly related to rainfall events elsewhere in Australia but the population in Exmouth Gulf has not shown such a relationship.

The post-larval stage settle in mangrove creek nursery areas and spend 2 to 4 months there before starting to move offshore; this movement can take up to 2 months to complete (Figure 6-52). The maximum life span for banana prawns is 12 to 18 months.

Banana prawns typically aggregate and in some instances may be so dense as to produce surface 'boils'. This aggregating behaviour makes them highly vulnerable to exploitation.



Source: CSIRO 2005

Figure 6-52 Northern Prawn Fishery life cycle

Exmouth Gulf Prawn managed fishery

The Exmouth Gulf Prawn managed fishery is one of Western Australia's three most valuable managed fisheries, and has an annual value to fishers of approximately $12 million (Oceanica 2006a). The by-catch associated with prawn trawling is significant, with 2-5 times the total annual weight of the prawn catch being non-target species which are thrown overboard, largely dead. All nets are fitted with Turtle Exclusion Devices and most are fitted with Fish Escapement Devices. These have been demonstrated to significantly reduce the amount of by-catch and the incidence of turtles and larger animals being caught is understood to have dropped to close to zero.

The Department of Fisheries (WA) have a sophisticated Vessel Monitoring System (VMS), which polls the locations of trawlers and ensures that they are operating within the designated areas. The trawlers generally target the deeper waters in the centre and north of the Gulf. The Department of the Environment and Heritage has declared that the fishery is managed in an ecologically sustainable manner under the provisions of the *Environment Protection and Biodiversity Conservation Act 1999*.

The Exmouth Gulf Prawn managed fishery is discussed in detail in Chapter 7, Section 1.

3.3.9 Benthic macrofauna

Benthic macrofauna are animals that are large enough to be seen with the naked eye that live on the bottom of a water body (e.g. ocean floors, creek beds). The extensive intertidal sand and mudflats and mangrove-lined creek areas were poorly studied, with little information on the abundance and diversity of benthic macrofauna assemblages (Hutchins *et al.* 1996).

Investigations

Oceanica (2006b) (Appendix 7) sampled benthic macrofauna from 30 sites in 11 locations on the eastern margin of Exmouth Gulf between September 2004 and May 2005 (Figure 6-53). Sample sites were located in the channels, tidal creeks and sand and mudflats between South Creek and Urala Creek. Different locations and sites were sampled on the various sampling occasions, to include areas within the different options considered for the seawater intakes and potential bitterns discharges (Oceanica 2006b).

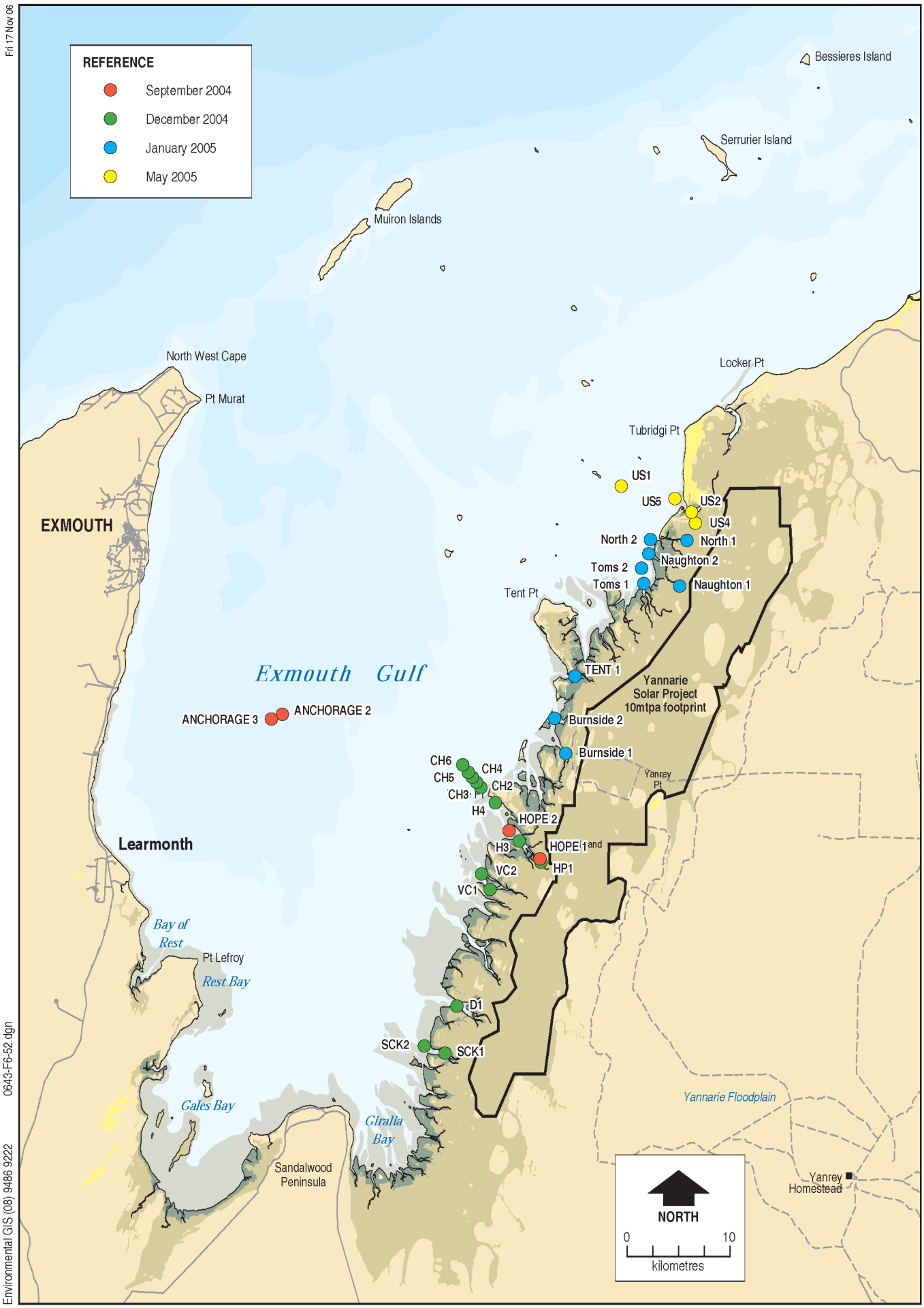
A total of 44 macrofauna taxonomic groups were recorded during sampling (Oceanica 2006b). These groups primarily consisted of Polychaetes, Crustaceans, Molluscs and Echinoderms (Oceanica 2006b). Statistical analysis of data indicated that there were differences in the benthic macrofauna assemblages in terms of taxonomic group composition and abundance between sampling sites. While there was variability in the benthic macrofauna assemblages recorded at different locations and sites, there was a general trend for lower numbers of taxonomic groups and individuals to be recorded at the upper creek sites compared to those sites located in the creek entrances. Polychaetes were generally the most abundant taxonomic group at the upper creek sites. The lowest numbers of both taxonomic groups and individuals were generally recorded at the deeper anchorage sites (Oceanica 2006b).

Differences in benthic macrofauna assemblages between sampling sites and shores areas are likely to be primarily linked to variation in natural environmental conditions such as depth, salinity, sediment grain-size, sediment organic matter content, near-bottom oxygen concentration, trophic status and habitat structure (Oceanica 2006b).

3.4 IMPACT ASSESSMENT AND MITIGATION

3.4.1 Pre-existing impacts on marine fauna

The pre-existing impacts on marine fauna in the Exmouth Gulf are primarily associated with prawn trawling, and commercial and recreational fishing. In addition to these impacts, there are also occasional oil exploration activities, pearl shell collection and boat traffic associated with tourism and commercial activities (primarily whale watching and pearl farm support).



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-53 Benthic macrofauna sampling locations

Datum: MGA Zone 50
Source: Oceanica, 2006
Date: 17 Nov 2006

3.4.2 Environmental aspects and potential impacts

Activities or aspects of the proposal that may potentially affect marine fauna include:

- **site preparation** (in particular dredging at Hope Point) leading to the physical removal or modification of habitat and potentially interrupting water flows
- **dredging** which gives rise to increased turbidity potentially leading to smothering of habitat
- **seawater pumping** leading to entrapment and entrainment of marine fauna
- **salt barge and ship movements** in the Gulf may potentially result in:
    - noise emissions and vibration which may disturb marine fauna
    - collisions or avoidance by marine megafauna
    - loss of anti-foulants from hulls potentially leading to contamination of marine waters and sediments
    - introduction non-indigenous marine species (NIMS) with potential to affect native species and local aquaculture
- **light spill** primarily associated with barge harbour infrastructure may potentially disturb some fauna species.

3.4.3 Assessment and management of habitat loss and modification

The shallow vegetated habitat of the east coast of the Gulf is of primary importance to the Gulf ecosystem, especially for fish and prawns (for which it functions as nursery habitat) and Dugongs and turtles (for which it provides the primary grazing area) (Oceanica 2006a).

The proposal has been designed to avoid as far as practicable impacts on this habitat either directly (e.g. removal through dredging) or indirectly (interfering with related ecosystem processes).

Direct loss of habitat

The greatest direct loss of benthic habitat associated with the development will be caused by dredging a 1.3 km long barge channel into Hope Point. The calculation of the area of habitat lost and the significance in relation to the EPA's Benthic Primary Producer Habitat Protection Policy is discussed in detail in Chapter 6, Section 2.

The total area that is likely to support benthic vegetation (seagrass and or algae) on the east coast is greater than 35,600 ha (or 356 km^2). The area lost to the channel will be 16.4 ha, of which the majority will be less than 2 m deep. This is less than 0.05% of the total area and less than 1% of the relevant proposed marine management unit (Chapter 6, Section 2). The impact of such a change in habitat on marine fauna is likely to be negligible.

The benthic habitat in the creeks is primarily bare sand, with banks and shallows supporting algae and seagrass (Oceanica 2006a). The area of the footprint of each pump station will be of the order of 375 m^2, which is also a negligible area in the context of the total available habitat. Based on previous experience with Onslow Salt, the disturbance associated with construction and operation of the pump stations will be minimal beyond the constructed footprint (Figure 6-54).

Source: Straits Salt Pty Ltd

Figure 6-54 Example of a pump station

Potential interference with tidal and water flows

The project has been designed so that it does not interfere with the tidal and water flows between the algal mats and the Gulf and consequently there is no impact on the east coast nutrient transport processes which are essential in maintaining the Gulf ecosystem (Oceanica 2006a, Biota 2005d). There will be no nutrient related loss or change in habitat arising from implementation of the proposal.

The indirect loss or impact on habitat arising from turbidity is discussed in Section 3.4.4. The primary cause of turbidity will be dredging. Given that dredging will occur during winter months and that the seagrasses and algae in the region have distinct seasonal growth patterns and documented high recovery rates (Loneragan *et al.* 2003) means that there is negligible risk of an adverse impact on marine fauna arising from turbidity impacts on benthic habitat.

In summary, loss of habitat associated with the development will be very small and is very unlikely to result in any significant adverse impact on marine fauna.

The marine habitats in the vicinity of the proposal will be monitored as part of a Marine Management Plan.

3.4.4 Assessment and management of dredging

Dredging may give rise to increased turbidity which may affect the productivity of benthic habitat used by fauna for grazing or shelter.

The potential impact turbidity arising from dredging on marine benthic habitat has been addressed in Chapter 6, Section 2. The impact of turbidity on BPPH is not considered to be regionally significant.

A Dredging Management Plan will be implemented to minimise the impacts of dredging on benthic primary producer habitat and marine fauna.

There is potential for localised smothering of benthic macrofauna in the vicinity of the dredging, however these impacts will be localised. Further sampling of benthic macrofauna assemblages will be undertaken to enable investigation of the relationships between benthic macrofauna assemblages and environmental conditions, such as turbidity.

3.4.5 Assessment and management of seawater pumping

This section appraises the impacts associated with seawater pumping on tidal creek faunal communities at both the local and regional scale. The impacts of seawater pumping on benthic and intertidal habitats are discussed in Chapter 6, Section 2.

The saltfield will have two seawater intake pump stations. Dean's Creek serves the southern portion of the field and the other, Naughton Creek, serves the northern portion of the field (Figure 2-6 and Figure 2-5 respectively).

The Dean's Creek station will comprise four pumps and the Naughton Creek station six pumps, which will be located on a platform above the level of the highest astronomical tide. The pumps will draw water from a 'well' area designed to reduce the amount of sediment entrained and to reduce the velocity of the water at the entrance to the pump station. Both pump stations will have a footprint of the order of 25 m by 15 m, with the longer edge open to the creek. Figure 2-7 depicts a pump station typically used within the salt industry.

The pump stations will operate on average 14 hours per day and will be synchronised with the semi-diurnal tidal cycle such that pumping coincides to periods when the depth of water in the creeks is greater than -1.4 m CD (or -0.6 m AHD).

Maximum seawater intake will occur once the field reaches full production because of the need to continually 'top-up' the ponds to replace evaporative losses (approximately 3,000 mm/yr). Peak annual pumping is also strongly seasonal and coincident with peak evaporative losses which occur between November and January.

The above assumptions have been used to appraise the likely impacts of seawater pumping, however, under operating conditions actual pump runtimes can be expected to vary slightly and will be dictated by a combination of evaporation, rainfall and salt production. Expected seasonal variability in seawater intake has been calculated and is presented in Table 6-17 and Table 6-18 for both the southern and northern pump intakes.

Table 6-17 Summary of pumping for southern seawater intake at full production of 10 Mtpa (Dean's Creek)

Month	Seawater Intake ($10^6 m^3$/month)	Rate of Pumping (m^3/s)	Pumped volume per flood/ebb (m^3)	% of Spring tidal prism	% of Neap tidal prism	Average % tidal prism
Jan	27.3	18.6	234,928	2.8%	11.0%	7.0%
Feb	17.0	11.7	146,912	1.8%	6.9%	4.3%
Mar	15.4	10.5	132,461	1.6%	6.2%	3.9%
Apr	14.7	10.1	126,686	1.5%	6.0%	3.8%
May	4.9	3.3	42,149	0.5%	2.0%	1.2%
Jun	1.9	1.3	16,504	0.2%	0.8%	0.5%
Jul	6.6	4.5	57,159	0.7%	2.7%	1.7%
Aug	10.6	7.2	91,013	1.1%	4.3%	2.7%
Sep	17.2	11.8	148,519	1.8%	7.0%	4.4%
Oct	24.8	16.9	213,363	2.6%	10.0%	6.3%
Nov	28.9	19.7	248,834	3.0%	11.7%	7.4%
Dec	32.1	22.0	276,710	3.4%	13.0%	8.2%
Total	**201.4**	**11.5**	**144,603**	**1.8%**	**6.8%**	**4.3%**

Notes:

(1) Based upon 14 hours per day (favourable tidal conditions)

(2) Based upon two tides per day

(3) Assumes pumping split evenly over flood and ebb phases

(4) A month is based upon a 29 day lunar month

Table 6-18 Summary of pumping for northern seawater intake at fill production of 10 Mtpa (Naughton Creek)

Month	Seawater Intake $10^6 m^3$/month	Rate of Pumping m^3/s	Pumped volume per flood/ebb m^3	% of Spring tidal prism	% of Neap tidal prism	Average % tidal prism
Jan	41.1	28.1	354,555	9.3%	47.0%	28.2%
Feb	25.7	17.6	221,720	5.8%	29.4%	17.6%
Mar	23.2	15.9	199,911	5.3%	26.5%	15.9%
Apr	22.2	15.2	191,195	5.0%	25.4%	15.2%
May	7.4	5.0	63,613	1.7%	8.4%	5.0%
Jun	2.9	2.0	24,909	0.7%	3.3%	2.0%
Jul	10.0	6.8	86,284	2.3%	11.4%	6.9%
Aug	15.9	10.9	137,357	3.6%	18.2%	10.9%
Sep	26.0	17.8	224,145	5.9%	29.7%	17.8%
Oct	37.4	25.6	322,009	8.5%	42.7%	25.6%
Nov	43.6	29.8	375,541	9.9%	49.8%	29.8%
Dec	48.4	33.1	417,611	11.0%	55.4%	33.2%
Total	**303.8**	**17.3**	**218,237**	**5.8%**	**28.9%**	**17.3%**

Notes:

(1) Based upon 14 hours per day (favourable tidal conditions)

(2) Based upon two tides per day

(3) Assumes pumping split evenly over flood and ebb phases

(4) A month is based upon a 29 day lunar month

As might be expected, the projected pumping (Table 6-17 and Table 6-18) will result in a change in the net flows within the creeks (as Gulf waters flow into the creek to replace the water pumped out) and this was especially the case in Naughton Creek.

The key potential adverse effects on fauna caused by seawater pumping are considered to be entrapment and entrainment.

Entrapment

Entrapment refers to injury and death caused by trapping marine life against intake screens due to the velocity of the intake water. The rate and degree of entrapment is a function of the large fauna present, water velocity, intake design and intake location.

The intake chambers will be open to the creek so that seawater can flow directly to the pumps via a bar screen. The primary objective of the screens is to prevent floating debris entering the pump intake, however they also act to prevent larger fauna entering the pump area.

The Dean's Creek (southern) pump station will be designed with a maximum expected velocity at the entrance to the pump station of 0.63 m/s. The Naughton Creek (northern) pump station will be designed with a maximum expected velocity at the entrance to the pump station of 0.95 m/s.

WorleyParsons (2005a) modelled the tidal creeks and found that pre-development peak tidal currents in Dean's Creek were 1.4 m/s on the ebb tide and 1.2 m/s on the flood tide. Similarly, pre-development peak tidal currents in Naughton Creek were 1.6 m/s, being slightly larger on the ebb tide than on the flood tide.

The intake velocities of both pump stations are predicted to be substantially lower than the maximum pre-development tidal velocities within these creek systems.

Dugongs, rays and turtles are the key fauna of concern in relation to entrapment. The greatest numbers of dugongs are found in the vicinity of Dean's Creek as shown in Figure 6-44 and Figure 6-51 (Oceanwise 2005, Oceanica 2006a, Centre for Whale Research 2004b). There are also sightings of dugongs at Naughton Creek; however there is less foraging habitat in this area. Dugongs are most frequently observed in the southern creeks and it has been assumed that the Dean's Creek area will be visited by dugongs all year round.

The average swimming speed of the dugong is about 10 km/hr (2.8 m/s) compared to the maximum expected velocity at the entrances of the pump stations of 0.63 m/s and 0.95 m/s. The maximum swimming speed of a dugong is reported to be about 5.6 m/s (Huffman 2006), which suggests that a dugong would be quite capable of swimming away from an intake screen should it find itself in the vicinity of the intake screen at pump startup. The other large marine fauna commonly found in the Gulf are all capable of swimming faster than the dugong and could also be reasonably expected to swim away from the intake screens without becoming entrapped.

Entrainment

Entrainment refers to the removal of relatively small marine organisms from the creek, such as small and juvenile fish, juvenile prawns, larvae and fish eggs. These organisms are naturally transported by currents and as the tidal creeks are likely to be used as nursery and spawning grounds for many species, there will be a proportion of the population in water entering the creeks that will be pulled into the first concentrator pond. In most existing saltfield operations, these organisms are lost to the

external ecosystem and become part of the first concentrator pond ecosystem (Molony and Parry 2002).

Given the role that creeks play as nursery and spawning habitat, entrainment is considered potentially the most significant environmental impact on fauna posed by pumping.

The fauna in the creeks will exhibit a variety of behaviours depending on season, time of day, presence/absence of other biota and time of tide, which will dictate their vertical position in the water column and distribution within the creek. Taking a conservative approach, it has been assumed that the amount of biota entrained from the creeks will be proportional to the volume of seawater pumped from the creeks.

For the purposes of appraising the effect of seawater pumping upon the pre-existing tidal flux and recruitment of small biota, the most commonly used measure of tidal effect—the 'tidal prism'—has been used. The tidal prism is the volume of water that flows into an area between low and high tide or in other words the volume exchanged on either a rising, or falling tide, but not the sum of both. The tidal prism is approximately half the tidal cycle or six hours in the Gulf as the tides are semi-diurnal (twice a day).

Assuming an average favourable tidal 'window' for pumping of 14 hours per day and apportionment of this equally between the rising and falling tides, the pumps will be operating for 3.5 hours during each rise or fall of the tide (for 2 tides per day). Operational conditions will require that the pumping rates vary to suit the tidal conditions, however average conditions have been assumed in determining the impact of pumping.

The proposed daily pumping volumes were compared with the volume of the tidal prism (Table 6-19) to appraise the likely significance of entrainment on recruitment of small biota within the tidal creek systems.

Table 6-19 Summary of local and regional impacts of seawater pumping on entrainment at full production of 10 mtpa (expressed as percentage of tidal prism)

Month	Local impacts of seawater pumping		Predicted regional impacts of seawater pumping	
	Naughton Creek average % tidal prism	Dean's Creek average % tidal prism	Tubridgi Pt to Tent Pt[1]	Giralia Bay to Hope Pt[2]
Jan	28.2%	7.0%	2.8%	0.9%
Feb	17.6%	4.3%	1.8%	0.5%
Mar	15.9%	3.9%	1.6%	0.5%
Apr	15.2%	3.8%	1.5%	0.5%
May	5.0%	1.2%	0.5%	0.2%
Jun	2.0%	0.5%	0.2%	0.1%
Jul	6.9%	1.7%	0.7%	0.2%
Aug	10.9%	2.7%	1.1%	0.3%
Sep	17.8%	4.4%	1.8%	0.6%

Month	Local impacts of seawater pumping		Predicted regional impacts of seawater pumping	
	Naughton Creek average % tidal prism	Dean's Creek average % tidal prism	Tubridgi Pt to Tent Pt[1]	Giralia Bay to Hope Pt[2]
Oct	25.6%	6.3%	2.6%	0.8%
Nov	29.8%	7.4%	3.0%	0.9%
Dec	33.2%	8.2%	3.3%	1.0%
Total	**17.3%**	**4.3%**	**1.7%**	**0.5%**

Notes:

(1) Assumes 10 tidal creek systems within Tubridgi Pt to Tent Pt management unit

(2) Assumes 8 tidal creek systems within Giralia Bay to Hope Pt management unit

The pumped volume at Dean's Creek station will range between 0.2% and 13% of the tidal prism over all tide conditions over a 29 day tide cycle, with an average of 4.3% over the 29 day cycle. That is to say, the pumped volume is likely to bring in, on average, nearly 4% more seawater from the Gulf in the Creek during pumping, with the draw occurring during the higher portions of the tide (Parsons Brinkerhoff modelling results).

Similarly for Naughton Creek, the pumped volume is likely to range between 0.7% and 55% of the tidal prism over all tide conditions, with an average of 17.3% over the 29 day cycle (Parsons Brinkerhoff modelling results).

Local Significance

It is assumed that seawater pumping will entrain a certain proportion of organisms, however with limited information on lifecycles and pumping regimes, this proportion can not be estimated at this time.

Regional significance

Tent Island, Hope Point and Giralia Bay form the junctures of distinct local marine management units (Figure 6-18). These units have been proposed to evaluate the impact on benthic habitat (Chapter 6, Section 2) and have been applied here to provide an indication of the likely regional impacts on marine macrofauna.

Dean's Creek is located within the geomorphic region bounded by Giralia Bay and Hope Point. This region contains 8–11 additional tidal creeks (the number varies depending upon how a creek system is defined, as some systems join together and others are relatively small). Using the same approach as outlined above and assuming that Dean's Creek is one of 8 similar size tidal creeks, then on average 0.5% of all small biota in the tidal prism in creeks between Giralia Bay and Hope Point could be entrained (Table 6-19).

Similarly, Naughton Creek is within the geomorphic region bounded by Tubridgi Point and Tent Point, which contains 10 major tidal creeks. Each creek has similar characteristics to Naughton Creek in that they are fringed with mangroves and algal mats and comprise of sandy sediments and turbid waters. The overall tidal creek system is relatively consistent (Oceanica 2006) and if it is assumed that each creek supports a similar amount of small biota in the water column, then on average 1.7% of all small biota in the tidal prism in creeks between Tubridgi Point and Tent Point could be entrained (Table 6-19).

Ecological significance

The Brown Tiger and Western King prawns are the primary commercial target species in the Gulf (Oceanica 2006a), with additional commercially significant catches of Endeavour Prawns and occasionally Banana Prawns (Oceanica 2006a). Brown Tiger Prawns and Western King Prawns spawn in the deep waters of the Gulf and then the larvae drift to the shallow areas on the east coast where the juveniles then grow out and repeat the cycle. As such, these species do not rely directly on the mangrove creek habitat and they are unlikely to be entrained in large numbers. However, Banana Prawns tend to live within mangrove creeks and spawn continuously, with peaks in spring and autumn. Of the species of prawns present, there is most likely to be entrainment of Banana Prawns.

The impact of pumping on prawn recruitment and species losses are unlikely to be measurable outside of Dean's Creek and Naughton Creek and there is a low risk of impact on the commercial fishery.

All of WA's solar salt operations have biota resident in the salt ponds which has originated from the adjacent marine environment. In current pond designs, the biota is generally unable to leave the ponds and so creates a unique ecosystem within the ponds. Molony and Parry (2002) prepared a report on the species and biomass of fish and *Artemia* in Dampier Salt's Port Hedland facility about fish deaths within the ponds and the potential economic resource that these fish presented.

The species assemblages of the marine biota inhabiting the east coast of the Gulf have been found to be most similar to that found in the Pilbara and Kimberley (Hutchins *et al.* 1996). Therefore, the fauna found in the Port Hedland concentrator ponds is likely to be similar to the fauna that will be found in the project's ponds and the findings of the study by Molony and Parry (2002) are relevant to understanding the potential impacts of the proposal.

Fish resources within the Port Hedland concentrator ponds were found to exceed 60 tonnes throughout the year and exceeded 100 tonnes in May 2000. Although the number of species found was lower than that typically recorded in other tropical estuaries, a large number of recreational and/or commercial species were present, sometimes in large numbers (Table 6-20).

It is expected that a number of fish species will inhabit the concentrator ponds of the Yannarie Solar project and become part of the pond ecosystem (Table 6-20). This ecosystem is also expected to provide habitat for migratory waders and other shorebirds which have been observed congregating at the concentrator ponds of other Western Australian saltfields (Dampier Salt Limited 2006).

As well as providing habitat for migratory birds, there are also further opportunities to benefit from the pond ecosystem through recreational fishing and bird watching ventures.

The significance of creek biota as part of the food chain hasn't been completely 'lost' by transfer to the pond ecosystems. This biota is still part of the food chain, both inside and outside the ponds. In addition, this ecosystem will still be available for other human values such as recreational fishing and birdwatching.

Table 6-20 Fish species captured in Dampier Salt's Port Hedland concentrator ponds

Scientific name	Common name	Total numbers
Allanetta mugiloides	Spotted hardyhead	11,579
Apogon ruppellii	Gobblyguts	6660
Ilisha striatula	Banded Ilisha	3634

Scientific name	Common name	Total numbers
Stolephorus spp.	Anchovy	2172
Gerres oyena	Common silver biddy	1605
Arramphus sclerolepis	Snub-nosed garfish	889
Amnitaba caudovittatus	Yellowtail trumpeter	725
Elops hawaiiensis	Giant herring	340
Sillago vittata	Western school whiting	266
Acanthropagrus latus	Western yellowfin bream	147
Chanos chanos	Milkfish	147
Valamugil buchanani	Blue tail mullet	130
Sillago analis	Golden-lined whiting	128
Leiognathus equulus	Common ponyfish	112
Scomberoides commersonnianus	Queenfish	110
Leiognathus bindus	Orangefin ponyfish	83
Ambassis vachellii	Telkara perchlet	33
Arius thalassinus	Giant salmon catfish	28
Platycephalus indicus	Bartail flathead	28
Bathygobius fuscus	Common goby	24
Dexillichthys muelleri	Tufted sole	24
Selenotoca multifasciata	Striped butterfish	16
Epinephelus coioides	Orange spotted grouper	8
Gnathanodon speciosus	Golden trevally	7
Pelates quadrilineatus	Trumpeter	7
Scomberomorous semifasciatus	Broad-barred spanish mackerel	5
Caranx ignobilis	Giant trevally	4
Pomadasys kaakan	Spotted javelinfish	4
Sillago sihama	Northern whiting	4
Anodontostoma chacunda	Gizzard shad	3
Polydactylus plebius	Northern threadfin	3
Syphraena jello	Giant seapike	3
Cymbacephalus nematophthalmus	Fringe-eyed flathead	2
Epinephelus malabaricus	Malabar groper	2
Lates calcarifer	Barramundi	2
Lutjanus argentimaculatus	Mangrove jack	2
Terapon puta	Three-lined grunter	2
Tylosurus crocodilus	Crocodilian longtom	2
Acanthopagrus palmaris	Black bream	1
Platycephalus endrachtensis	Bartail flathead	1
Scatophagus argus	Spotted scat	1
Siganus lineatus	Golden-lined spinefoot	1

Source: Molony and Parry 2002

Management

Entrapment

When the pump stations are being commissioned the screens will be intensively monitored for the first 14 days. If there are incidences of recurring entrapment or mortality, the pumps will either be shut down to allow improvements to the screening or the pumping rate reduced until entrapment no-longer occurs. The results of the initial screen monitoring survey together with any proposed management response, will be submitted to the DEC as far as practicable after this initial monitoring is completed.

Entrainment

Before the commencement of construction, the available methods for management of entrained fish will be evaluated in consultation with the Department of Fisheries and a report will be prepared detailing on how any proposed migration measures have been incorporated into the project detailed design. The techniques examined may include:

- internal bunding
- targeted removal
- screening the connections between ponds
- exploitation of the fish resources within the concentrator pond
- controlled management use of the ponds by recreational fishermen.

A program of monitoring on creek fauna will be prepared and implemented including the following key elements:

- before commencement of operations, baseline surveys of biota in four creeks on the east coast of the Gulf (Naughton Creek, Dean's Creek and two others selected as controls), with the aim of establishing baseline information on the species present and the stages of their life cycle that occur in the creeks
- ongoing monitoring of these creek systems to evaluate impacts on fauna arising from pumping
- recording the fauna within the ponds
- assessment of the effectiveness of management measures employed
- collaboration with the Department of Fisheries and DEC in all of the above, designing the sampling programs, refining management methods and interpreting the results
- annual reporting of the results of the program to the Department of Fisheries and DEC.

Exmouth Gulf Research Project

The proponent will support the development and implementation of Exmouth Gulf Research project to enhance the knowledge of the Gulf. Key components of this program will be as follows:

- a research project (PhD) to investigate the linkages between terrestrial and coastal habitats to improve the management strategies necessary for sustaining the productivity of the coastal zone. The investigation will provide a clear understanding of the relationship between the supratidal salt flats, algal mats, mangroves and secondary consumers such as crabs, fish and prawns

- a 2 year program ($50,000 per year) for a proposed dugong survey of Exmouth Gulf. This project will be developed in consultation with the DEC and investigate the link between dugong survey results and habitat use
- a research project (PhD) to investigate the linkages between benthic habitat and the dugong survey results arising from the Straits funded dugong survey of Exmouth Gulf
- a community turtle monitoring program (up to $20,000 per year) for the eastern part of Exmouth Gulf. The community turtle monitoring program will be developed and finalised in consultation with the Stakeholder Liaison Group
- a community seagrass monitoring program (up to $15,000 per year) for the eastern part of Exmouth Gulf. This program will be developed in consultation with the Stakeholder Liaison Group
- a whale interaction research program (Section 3.4.7).

3.4.6 Assessment and management of the effects of noise and vibration from barge and ship movements

The passage of shipping, barges and tugs creates the potential for disturbance of whales, dugongs and other marine fauna from noise and vibration.

Exmouth Gulf is well known as a resting area for southerly migrating Humpback Whales (Figure 6-50) and contains significant dugong, sea turtle and shark populations (Jenner 2004a, Oceanica 2006a). Background information on the whale, dugong, turtle and shark distributions is provided in Section 3.3.

Whales are the primary fauna of concern with regard to noise, collision and avoidance, as the largest and most regular vessel movements will occur through the waters frequented by whales. From September to October the deeper waters of the Gulf are used by a substantial population of humpbacks and calves (Centre for Whale Research 2004).

Initially around one ship per week is expected to pass around North West Cape and enter the Gulf, and this will increase to three ships per week when production reaches 10 Mtpa.

Noise modelling

Curtin University conducted a noise modelling study which examined the impacts of shipping, barges and tugs on the acoustic environment of the Gulf and commented on the impacts on whales and potential management measures (McCauley and Maggi 2005). The following summary is based on McCauley and Maggi (2005).

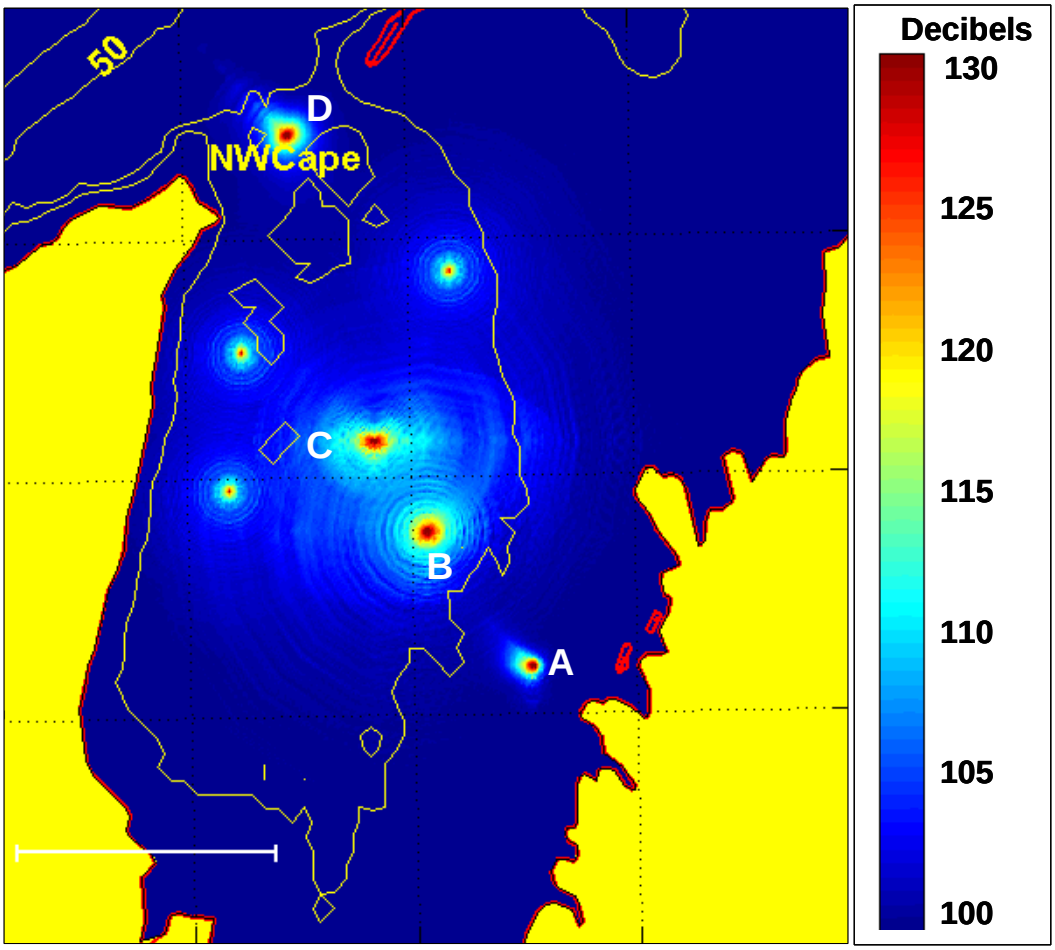
The noise field of proposed Yannarie marine operations can be broken into three categories:

- tugs towing barges traversing from Hope Point along the eastern Gulf side to the ship loading area in the centre of Exmouth Gulf
- loading operations in the centre of Exmouth Gulf involving anchored ships and tugs towing barges or manoeuvring barges alongside ships
- ships steaming through the main Gulf entrance between North West Cape and the Muiron Islands towards the designated loading area (Figure 6-43).

Noise transmission loss modelling was carried out at four representative sites within Exmouth Gulf. Representative water column sound speed profiles and a seafloor of a thin veneer of sand over limestone were used in transmission loss modelling. Seven scenarios of noise fields were modelled using eight sources representing noise from:

- extreme, moderate and light tug manoeuvring
- ship steaming
- ship anchored
- tug steaming
- tug anchored or idle
- steel trawlers towing nets on the bottom.

Noise field modelling resulted in 2D or 3D spatial grids of received levels for different scenarios of source combinations and background sea noise levels. Figure 6-55 provides an example of the noise modelling output and also shows the four representative sites.



Source: McCauley and Maggi 2005

Scenario: Tug underway at sites A and B, ship anchored for loading with dumb barge being manoeuvred nearby, ship steaming out at site C and three trawlers working, two along the western Gulf edge and one in the central northern Gulf, for background sea noise levels of 100 dB re 1µPa (bottom). The scale bar (lower left) is 20 km.

Figure 6-55 Example of acoustic modelling output

Tugs operating in shallow water near Hope Point will have the least noise impact, with high noise levels expected within a few hundred metres of the tugs and a maximum ensonification range of 4 km under calm sea conditions. Along the Hope Point to loading area track, tug noise is estimated to be audible for 13.6–20.5% of the time and high (>120 dB re 1µPa) for 2.1–3.1% of the time.

Ships passing around North West Cape may ensonify the entire channel between North West Cape and the Muiron Islands, although high noise levels can only be expected within approximately a 1 km radius of the ship. Individual ship noise may vary considerably between ships hence the calculated ranges may be more or less depending on the noise characteristics of the ship.

The loading area in the Gulf centre may produce the highest noise levels, potentially dominated by tug manoeuvring noise associated with bringing barges alongside ships. In severe cases with low background sea noise conditions (i.e. calm seastate), tug manoeuvring noise may be detectable up to 10 km from the ship/tug, and considered high (>120 dB re 1µPa) within 2.8 km and with whales expected to show avoidance at around 1 km. This is for extreme manoeuvring noise only, for less extreme operations and/or higher background sea noise levels these ranges will decrease to expected typical ranges of <5 km for ensonification radius, 700-1000 m for high noise levels and 400 m for whale avoidance. It should be noted that berthing effort will be lowest in calm conditions and therefore there is a low risk of extreme noise in combination with calm seastate. Based on the 10 Mtpa Yannarie export schedule, manoeuvring noise is estimated to occur at 5–28% (typically 12%) of the time during shipping operations.

The Yannarie marine operations will raise ambient sea noise levels in a large proportion of Exmouth Gulf, concentrated persistently near the loading area operations. Areas of detection of Yannarie and trawling operations were calculated based on reliable detection of vessel noise by an animal requiring vessel levels 3 dB above prevailing background sea noise conditions.

For calm sea conditions (background noise of 95 dB re 1µPa) the total detection area of ship noise associated with Yannarie operations ranged from 48–978 km^2, for respectively:

1. a ship steaming only; or
2. two tugs steaming along the Hope Point to loading area track, plus a ship anchored at the loading site, plus a tug manoeuvring heavily alongside the ship.

A typical scenario of tugs working along the Hope Point to loading area track and a ship being loaded with an idle tug alongside gave a total detection area of 526 km^2. This typical Yannarie operations scenario when combined with three operational trawlers increased the total detection area to 970 km^2, or approximately the same as the worst case Yannarie operations. This detection area was critically dependant on ambient sea noise levels, decreasing by approximately 50 km^2 for each dB increase in ambient sea noise level.

Potential impacts

The noise emissions that will be produced by the proposed Yannarie operations has some favourable features as they will be produced by stable platforms which either do not move (loading ships), which only move slowly (tugs and ships) or whose movements are independent of any nearby whales (i.e. no deliberate approaches). Also the noise is predicted to be reasonably constant in nature (i.e. there would normally be few sharp changes in noise level with time, only experienced during anchoring or barge manoeuvring operations).

Under normal operations, nearby marine megafauna are likely to be aware of the operations from perhaps 5–10 km from the loading area and may approach it to approximately 400–1000 m before exhibiting avoidance behaviour. Given the continual and constant nature of the noise, it is probable that animals will quickly habituate and the noise will not produce any startle or alarm type of responses.

While it would be expected that most whales will maintain some avoidance range from the loading operations, it may be possible that the loading operation noise will attract some whales through curiosity. For individual whales this would be a temporary effect, confined to a small component of the whale population for a short time only.

The total noise field associated with the loading area will be significant for masking in that it will persistently raise ambient noise above natural levels for ranges of approximately 5 to 10 km (calculated for normal marine operations under typical conditions to noisiest operations under quietest sea noise conditions). For receivers in the loading noise ensonified area, this noise will potentially reduce the detection range of humpback song in low sea noise states.

The environmental impacts of the noise field produced by the Yannarie operations are summarised as:

1. None of the sources will be capable of causing physiological harm to marine animals.
2. For invertebrates and some fishes, there may be temporary attraction to individual sources.
3. There may be potential short-term attraction of some whale species to sources out of curiosity, although animals are likely to habituate to the sources.
4. There may be persistent avoidance of vessel operations at the loading area in the Gulf centre, typically around 400 m from loading operations (continual) this increasing to around 1 km for periods of manoeuvring noise.
5. There may be avoidance of tug movements along the channel from Hope Point to the loading area with range at which this occurs varying along the route, increasing as the tug moves into deep water or the tide rises and very limited near to Hope Point due to poor sound transmission in shallow water.
6. The wide region of ensonification by Yannarie operations provides a wide detection area for the vessels, with this wide region comprised of mostly low level vessel noise, with animals transiting the area only being exposed to high levels near to specific vessels.
7. There is potential for masking of humpback signals within the Gulf, particularly near the loading area, with this most pertinent for singers or receivers close to the loading operations or noise source.

Management

Mitigation measures that will be applied (and addressed in the Marine Management Plan) to reduce underwater noise during the peak whale cow/calf activity in the Gulf (nominally 4 weeks between 20 September and 17 October). The start of the peak whale period may vary naturally by 2-3 weeks each year and will be subject to consultation with the Centre for Whale Research. Mitigation measures for vessels operating within the Gulf will include:

1. Restricting the speed of all vessels operating in the Exmouth Gulf as low as practicable and always less than 10 knots.

2. Requiring all tug Masters, as far as practicable, to:
    - keep manoeuvring operations as gentle as possible
    - avoid driving their vessels main propellers beyond cavitation inception
    - reduce the use of bow thrusters
    - maintain a watch for sleeping or resting cow/calf paris and maintain a 100 m approach limit.
3. Developing and implementing maintenance procedures and maintenance performance standards for all vessels directly associated with Yannarie operations (service vessels, tugs and barges) to ensure clean hulls and propellers, undamaged propellers, good mechanical condition of gearboxes and engines.

3.4.7 Assessment and management of marine vessel avoidance

Initially about one Panamax ship per week is expected to pass around North West Cape and enter the Gulf, and this will increase to three ships per week when production reaches 10 Mtpa. Approximately 6 to 7 barge return movements will be required to fill one 65,000 tonne Panamax ship resulting in 6 to 7 barge movements per week from Hope Point to the loading facility, and this will increase to approximately 19 barge movements per week when production reaches 10 Mtpa.

Dugongs are the fauna of primary concern with regard to vessel movements as they are relatively large and slow moving compared to the other fauna in the Gulf. They also do not hear vessels until they are very close and as such are susceptible to strikes from fast moving vessels (Preen 2001). Dugongs are most often found in the shallow vegetated areas of the Gulf (Figure 6-51).

One of the modifications made to the project is to transport the operational workforce between the saltfield and Exmouth by air rather than fast ferry to reduce the risk of collisions associated with the project.

Although there will be vessels involved in marine operations for the Yannarie Solar Project (Table 6-12) none of the large vessels will be required to move particularly fast (maximum speeds of less than 10 knots), while small environmental survey vessels would be manoeuvrable enough to avoid collisions.

For the larger vessels, the underwater noise combined with the slower speeds means that any collision risk with whales will be low (McCauley and Maggi 2005) as megafauna move to avoid the vessels.

Management

Speed limits and designated routes will be applied for reducing the risk of accidental strikes on dugongs (Oceanwise 2005). Preen (2001) prepared recommendations for vessel traffic management in the Hinchinbrook Dugong protected area. This work defined management areas on the basis of the known key habitats of the dugong (seagrass banks). Preen (2001) proposed a speed limit of 20 knots in the main Hinchinbrook channel area, which dugongs were known to traverse but not aggregate or feed, and then a 10 knot speed limit in areas where aggregation is likely, such as shallow seagrass beds. Similar controls will be imposed on vessels associated with the Straits Salt project.

The 2004/2005 aerial survey data indicate the year-round presence of dugongs in Exmouth Gulf (Oceanwise 2005, Figure 6-51).

A cautious approach will be taken assuming that dugongs will be present in the Gulf at all times, with the population focussed on, but not limited to, the vegetated shallow waters of the south eastern Gulf between Hope Point and Giralia Bay (Oceanwise 2005, Oceanica 2006a).

Management controls (to be addressed in Marine Management Plan) include:

- reduce as far as practicable shipping movements in the Gulf during the 4 week period of peak whale cow/calf activity (notionally between 20 September and 17 October). The commencement of the 4 week peak period of cow/calf activity will be subject to consultation with the CWR
- restrict the speed of all vessels operating in Exmouth Gulf as low as practicable and always less than 10 knots. The only exception will be if the vessel is required to attend an emergency situation (e.g. medical evacuation)
- establish and use designated routes and anchorage areas for salt transport ships and barge movements
- maintain a watch for sleeping or resting cow/calf paris and maintain a 100 m approach limit
- every bulk carrier in the Gulf will be under the control of a Straits engaged pilot who will board the vessel prior to it entering the Gulf
- during the peak whale cow/calf period of activity, Straits will avoid completely the medium density area (75% P Contour plot) identified by the CWR following an interpretation of the results from the aerial surveys commissioned for the project
- during the peak whale cow/calf period of activity, Straits will apply a buffer of 1.5 km along the medium density area contour and all ship loading activities (salt barges, tugs and bulk carriers) will be kept outside of this buffered zone
- Straits will monitor the presence of humpback whales along designated shipping and barge routes and anchorages during the peak whale cow/calf period of activity and inform ship and barge Masters of the presence of Humpback Whales in this vicinity of designated routes and anchorages
- prepare and implement avoidance procedures for whale strikes in the Gulf, in consultation with the CWR
- Straits will implement an initial 5 year whale interaction research program in consultation with the CWR. The Whale interaction research program will include, but not be limited to:
    - baseline monitoring of cow/calf distribution and movements prior to first export schedule. Monitoring to include satellite tagging
    - monitoring (including satellite tagging) of cow/calf distribution and movements in the Gulf for the first two years of export operations
    - development of criteria to assess and evaluate risk displacement of whales from the Exmouth Gulf
    - review of all whale monitoring data after each period of cow/calf activity in consultation with CWR. Results of the review of monitoring data to inform any necessary changes to the Marine Management Plan
    - population growth rate assessment with calculation of population maximum size and prediction of population 'tail-off'
    - determine importance and significance of mud-rolling areas within the Gulf to the population
    - whale monitoring data and assessment of displacement risk to inform the proposed major environmental review of the proposal prior to the commencement of Stages 3 and 4.

3.4.8 Assessment and management of water contamination due to loss of anti-foulants from vessels

All vessels associated with the project, the trawling industry and charter operations in Exmouth are likely to have some form of anti-fouling hull coating. Anti-fouling systems are a coating, paint, surface treatment, surface or device that is used on a ship to control or prevent attachment of unwanted organisms. Anti-fouling has the positive benefits of reducing fuel consumption of vessels by substantially reducing the build up of marine growth on the hull and also protecting the environment by reducing the amount of biota potentially transferred from one location to another. These compounds slowly 'leach' into the sea water, killing barnacles and other marine life that have attached to the vessel.

The international definition of anti-fouling coatings includes the following four generic types:

1. Soluble matrix: an acidic film that slowly dissolves when immersed in sea water. As this type of product is relatively inexpensive and requires little surface preparation it can be used on all vessel types, but it has a short lifetime. It is particularly suitable for small coastal vessels. The primary biocidal agent[9] is usually copper oxide.
2. Insoluble matrix/contact leaching/long life: the film-forming component of this type of product is insoluble and does not polish or erode when immersed. When immersed in water, the biocide dissolves from the paint film and is released, leaving an insoluble, leached layer behind. The primary biocidal agent is usually copper oxide.
3. Tributyltin oxide (TBT)-free self-polishing: the film-forming component of this type of product contains polymers selected from hydrolysable, soluble and insoluble resins. No part of this product contains organotin compounds. These products slowly polish and ablate the paint surface, releasing the biocide at a consistent rate. The durability is directly proportional to the coating thickness, and extended periods of service can be achieved. Anti-fouling performance continues until the paint polishes or erodes away.
4. TBT self-polishing copolymer: TBT is the main biocide in these products and is bound to a film-forming acrylic copolymer. Copper oxide and other secondary biocides may also be added. When immersed, the biocides are released as a result of TBT copolymer hydrolysis in seawater. This process also results in polishing and smoothing of the paint surface. Highly predictable anti-fouling performance is achieved with these products, and periods of service can extend for up to five years.

The International Maritime Organisation (IMO) 2001 Convention was passed and parties are required to prohibit and/or restrict the use of harmful anti-fouling systems (in this case, TBT based compounds) on ships flying their flag, as well as ships not entitled to fly their flag but which operate under their authority and all ships that enter a port, shipyard or offshore terminal of a Party to the Convention.

Annex I attached to the Convention states that by an effective date of 1 January 2003, all ships shall not apply or re-apply organotin compounds which act as biocides in anti-fouling systems. Given that this date has already passed, the IMO has been urging States to ratify the convention as soon as possible in order to achieve entry into force conditions. In November 2001, the IMO Assembly adopted Resolution A.928(22) on early and effective application of the international convention on the control of harmful anti-fouling systems on ships.

[9] Biocidal agents or biocides are chemicals that are used to kill biological organisms.

During such time before the entry into force of the convention, port States cannot apply any requirements of the convention to foreign ships calling into their ports. However, flag States may apply the requirements of the convention to their national fleet, depending on their national legal system and decisions of that country, but they may not expect the International Certificates to be recognised as effective until the date of entry into force.

The Australian and New Zealand Environment and Conservation Council (ANZECC) has also developed guidelines for the use and maintenance of anti-fouling coatings, also specifically targeting TBT based compounds (ANZECC 2000). The key outcome of these guidelines was that, in Australia, TBT has been banned on all vessels less than 25 m long and vessels operating in inland waterways. Copper oxide based anti-foulants are usually now used in place of TBT in Australia.

Investigations

Anti-fouling compounds such as TBT are known to accumulate in sediments. The remote nature of the project area meant that the chances of there being any human influence on sediment quality on the east coast of the Gulf were negligible (Oceanica 2006a).

Sediment surveys were undertaken to characterise the quality of sediments in the region of the development in more detail. Sediment samples were collected from the east coast of the Gulf, including Hope Point and no evidence of TBT or copper contamination was found at Hope Point (Oceanica 2006).

Management

The barges, tugs and service vessels owned by the proponent will generally be berthed in the Hope Point barge harbour. The following management measures will be implemented to prevent impacts associated with anti-foulants:

- prior to commissioning, vessels owned by the proponent will be anti-fouled with an environmentally-friendly commercially available anti-foulant
- no vessels owned by Straits will use TBT based paints
- potential contractors will be advised of the sensitivities of the local environment and that a clear preference will be given to engage contractors that use current best practise anti-fouling systems
- a sediment quality monitoring program will be implemented that will include baseline and ongoing monitoring of anti-foulants in the marine environment (Chapter 6, Section 1).

3.4.9 Assessment and management of potential introduction of non-indigenous marine species by marine vessels

The main vector for a primary introduction of NIMS in Exmouth Gulf through the proposed Yannarie Solar project is the bulk carrier vessels. Bulk carrier vessels may transport NIMS primarily through ballast water and hull fouling. It is estimated that approximately 150 bulk carriers per annum will visit the saltfield when it is producing at 10 Mtpa.

Oceanica (2005d) prepared a report outlining the risks posed by the Yannarie Solar Project in terms of the introduction of NIMS and management of these risks, and is summarised below.

Ballast water management

Ballast water is the water taken up by a ship at the port of origin to maintain trim and stability while sailing less than fully laden. A ship will discharge some or all of this water before being loaded because the product being loaded replaces the ballast.

The Australian Quarantine and Inspection Service (AQIS) is the lead agency for the management of ballast water taken up overseas. Part of the AQIS' charter is to ensure that foreign ballast water has been managed in accordance with the requirements before permitting its discharge inside Australia's territorial sea (12 nautical mile limit generally applies). Any ballast water that has been exchanged at sea by an approved method is deemed to be acceptable for discharge in Australian ports/waters. Ballast water reporting and verification systems also form an integral part of Australian requirements.

Australia's ballast water management requirements have legislative backing and are enforced under the *Quarantine Act 1908*. The Australian ballast water management requirements are consistent with IMO Guidelines for minimising the translocation of harmful aquatic species in ships' ballast water.

AQIS deems all salt water from ports (or coastal waters) outside Australia's territorial sea to present a 'high-risk' of introducing exotic marine pests into Australia. The discharge of high-risk ballast water from ships is prohibited anywhere inside Australia's territorial seas (12 nautical mile limit generally applies).

Ballast water of the following types is deemed by AQIS to be 'low-risk':

- fresh water from any source
- ballast water that has been assessed as 'low-risk' for discharge (at specified ports/locations on specified dates) by Australia's Ballast Water Decision Support System (BWDSS)
- ballast water that has been exchanged at an approved location (mid-ocean) by an approved method
- ballast water taken up in mid-ocean
- ballast water taken up inside Australia's territorial seas.

International shipping is required to forward a completed Quarantine Pre-Arrival Report form (QPAR) to AQIS 24 hrs prior to entering Australian waters. In this document they are required to confirm what measures have been taken to exchange ballast water while at sea and whether they have completed a risk assessment using Australia's BWDSS. AQIS board every vessel that arrives in Australian waters and check that the information provided in the QPAR is correct. This inspection includes a review of paperwork and can also include sounding of ballast tanks and other physical inspections.

Hull fouling

Managing the introduction of NIMS via biofouling on vessels (mainly on hulls) is in its early stages in Australia, despite hull fouling posing a risk greater than that associated with ballast water in many locations (Oceanica 2005d).

Western Australia, like most States and Territories is yet to implement formal management strategies for preventing NIMS from being introduced via biofouling. However, in July 2002 the Department of Fisheries developed a formal emergency/incident response plan should any NIMS be introduced. In

addition, access to National funding is available through the Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE). The WA State Government also encourages monitoring, by the community, for the presence/absence of NIMS in high risk areas of WA. Early detection of a pest is considered crucial to the success of any eradication attempt that aims to contain and then remove it before it spreads and becomes established. Eradication is not considered possible once a species has become well established and there are few published examples of the successful eradication of introduced NIMS, suggesting that to be effective, the eradication management option requires a rapid response following the detection of NIMS.

Rapid response to invasions is dependent on detecting NIMS before they become well established, such as through settlement/recruitment monitoring programs. Methods for community-based monitoring of marine pests, by divers and snorkellers, have also been documented (CALM 2003) and such approaches are the only form of monitoring currently in place for the Ningaloo Marine Park (CALM 2005).

NIMS status of Exmouth Gulf

The ability of NIMS to establish and survive is fundamentally a function of the receiving environment. The waters of the Gulf are tropical and therefore will be most at risk with introductions from tropical ports. In addition, the waters of the Gulf are turbid and muddy and very different to waters immediately outside the Gulf and at Ningaloo Reef, this is reflected in the difference between the species that are found inside and outside the Gulf (Hutchins *et al.* 1996). Therefore, the differences between the Gulf and the waters outside of the Gulf will be reflected in the ability of NIMS introduced to Gulf to survive conditions outside the Gulf.

The following is known with respect to potential vectors for NIMS introduction to Exmouth Gulf:

1. The Gulf has been visited by significant numbers of international vessels for over a century, with the nineteenth and twentieth centuries characterised by periods of whaling activity, pearling and oil exploration.
2. The Gulf has also been subject to approximately 30 years of continuous prawn trawling, with regular movements of trawlers between the Gulf and Fremantle and other ports and harbours in Western Australia.
3. The Gulf is subject to continuous international yacht visits and charter boat movements.
4. The seas offshore of Ningaloo Reef and the Muiron Islands are a busy international shipping route with approximately 1200 ships passing per annum.
5. The northern end of the Gulf is popular for recreational boating and work by Wyatt *et al.* (2005) has shown that recreational boating appears to have been a significant vector in facilitating NIMS introductions to Shark Bay.

Oceanica (2005d) concluded that:

1. There is no information on the presence or absence of NIMS in the Gulf or in Ningaloo Marine Park.
2. It is likely that NIMS have already established in the Gulf given the past and current vessel movements.
3. The removal/modification of benthic habitat by trawling may have further enhanced opportunities for introduced species to establish with the removal of competing native organisms.

4. There is no program planned or in place to monitor or measure NIMS in Exmouth Marina, the Gulf or in Ningaloo Marine Park.
5. The tropical environment at Exmouth means that the risk of introduction is considered to be greatest from tropical ports (e.g. traffic from the north).
6. The waters of the Gulf are significantly different to those at the Muiron Islands (and Ningaloo) and many species which have an affinity with the Gulf will not have the same survival success elsewhere in the region.

Potential impacts

Figure 6-56 shows a conceptual model for how NIMS could be introduced to Exmouth Gulf and outlines the following process of potential introduction.

Introduction by proponent vessels:

- if a NIMS was carried on a salt ship (vector A), it could dislodge at the anchoring area within the Gulf (node B)
- the pest could also be translocated via the barges and tugs that travel between the bulk carrier and the Hope Point harbour (route C) or via currents in the Gulf (vector D)
- the pest could become established at the marine facilities at Hope Point (node H).

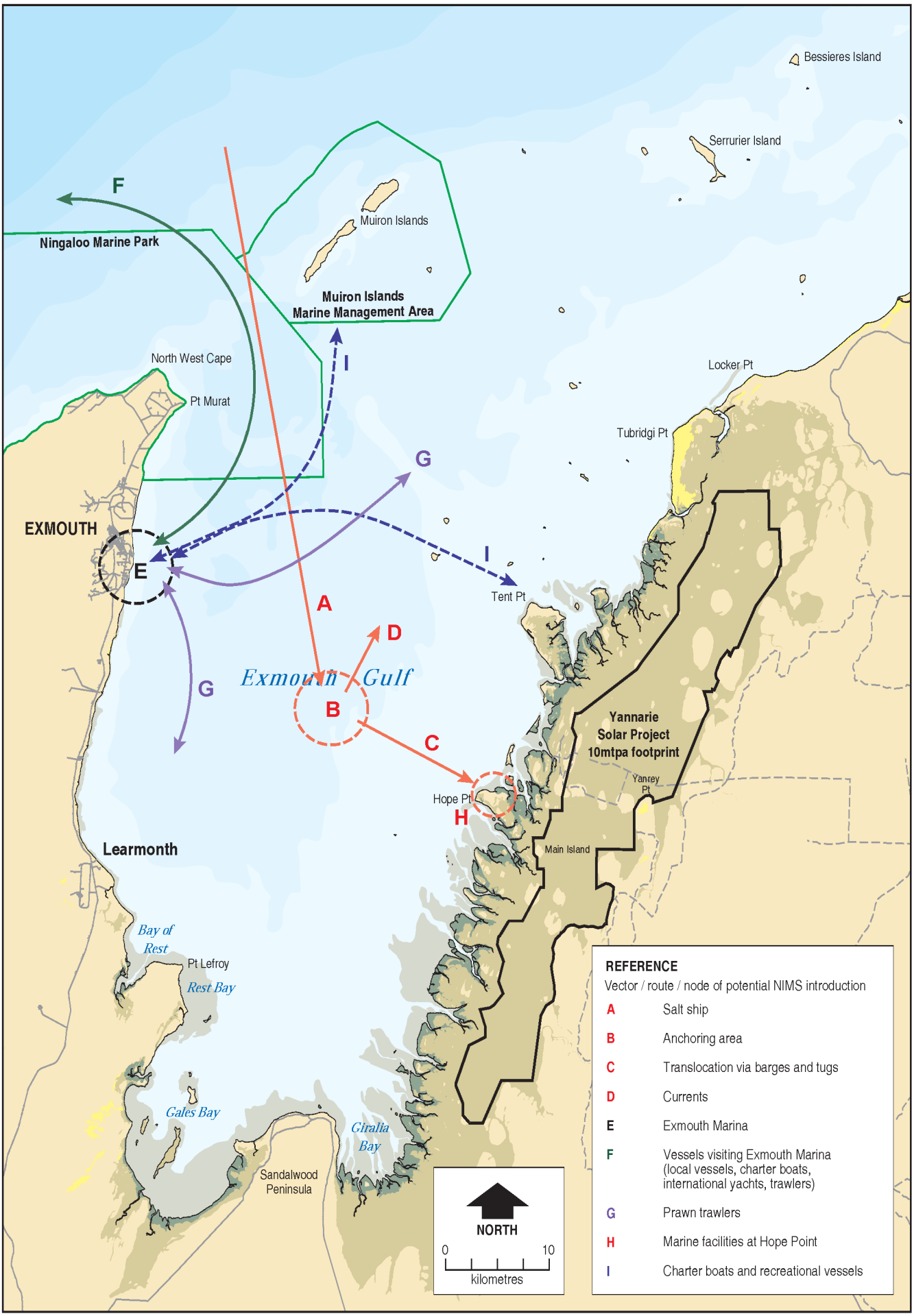
Introduction by other vessels:

- the non-project vectors in the Gulf are centred on the node that is the Exmouth marina (E)
- the marina is visited by local vessels, charter boats, international yachts and trawlers (F)
- prawn trawlers stationed at the marina then move throughout the Gulf on approximately 185 nights each year (G)
- in addition, charter boats and recreational vessels move from the marina throughout the Gulf, almost exclusively visiting the northern parts of the Gulf (I).

The main vector for introduction of NIMS to Exmouth Gulf through the Yannarie Solar Project will be the bulk carrier vessels that will be transporting the salt to south east Asian, Chinese and Indian markets. It is estimated that approximately 150 bulk carriers will visit the saltfield each year when it is producing at 10 Mtpa.

Potential environmental impacts associated with NIMS establishment in the Gulf include:

- displacement of native species by NIMS rapid growth
- depletion of stocks of native species due to consumption by NIMS
- depletion of commercially valuable species due to consumption by NIMS
- reduction in the perception and marketability of aquaculture or commercially valuable species being harvested from a ‘pristine’ environment
- translocation of the established NIMS to other regions visited by bulk carriers.



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Parsons Brinckerhoff, 2006
Date: 17 Nov 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 6-56 Potential mechanisms for introduction and translocation of non-indigenous marine species in Exmouth Gulf

Management

The draft State of the Environment Report for Western Australia (EPA 2006) states:

"Monitoring and preventative strategies to deal with introduced marine pests are generally effective for boats originating from international ports (especially ballast water exchange protocols). However, the major source of future introduced marine pests in Western Australia is likely to be other Australian ports. Better monitoring and reporting protocols are needed at ports, including baseline and regular follow-up surveys."

"Attention to interstate shipping and recreational vessels has begun but needs further development."

The EPA recommendation was:

6.7 Establish baseline survey data to understand the species that are normally found in an ecosystem and distinguish native from non-native species.

In line with this recommendation, Straits will conduct a baseline survey for the presence of NIMS at key locations in Exmouth Gulf, designed and implemented prior to commencement of the Yannarie Solar Project.

The Marine Management Plan will identify management controls for vessels entering Exmouth Gulf originating from foreign ports, and for vessels within Exmouth Gulf.

Management controls for vessels entering Exmouth Gulf, originating from foreign ports include:

- compliance of ships with AQIS requirements/procedures for ballast water exchange
- reduce the time any ship is anchored in the Gulf, as far as practicable. Ships unable to load immediately will anchor outside the Gulf
- monitoring the performance of export ships and captains via the use of 'Ship Right', an international shipping accreditation program
- an ongoing NIMS monitoring program will be designed and implemented for Hope Point and anchoring areas
- findings of all monitoring programs will be reported to AQIS, Department of Fisheries WA, EPA and DEC
- in the event that potential marine pests are found, the Marine Biosecurity Unit of the WA Department of Fisheries will be contacted immediately.

Management controls for proponent vessels within Exmouth Gulf:

- reduce mooring time near ships of support vessels and other marine craft, as far as practicable
- barges and tugs will be regularly inspected for NIMS and cleaned/anti-fouled in accordance with ANZECC (2000) Guidelines
- monitoring of NIMS as indicated above
- monitoring the performance of export ships and captains via the use of 'Ship Right', an international shipping accreditation program.

The risk of introductions through ballast water will be managed and enforced by the AQIS requirements for exchanging high-risk ballast outside of the 12 nautical mile limit of Australia's territorial sea (Oceanica 2005d). Carriers enroute to the Gulf will be required to exchange ballast water at sea outside the 12 nautical mile limit in accordance with AQIS procedures and after this action the ballast water will be considered 'low risk' in the Gulf. However, there are certain circumstances when ships will not be able to exchange ballast water while at sea. In such circumstances, AQIS approval will be obtained prior to ballast water being discharged in Australian waters.

Monitoring program

Given the number of vectors emanating from the Exmouth Marina, a baseline survey will be conducted to establish the status of NIMS in the marina, at the proposed anchorage sites and at Hope Point. This survey and all subsequent work would be in accordance with guidelines developed by the Centre for Research on Introduced Marine Pests (CRIMP) (Hewitt and Martin 1996, 2001). On commencement of operations, an ongoing monitoring program will be implemented at the anchoring area and in Hope Point harbour. Support vessels and other hard structures will be regularly inspected and if necessary, cleaned and anti-fouled to reduce risk for further translocation.

The Straits monitoring effort will be focussed on the ship anchorage areas and Hope Point barge harbour. A number of species will be targeted and identification guides developed based on the analysis of 'next pests' (Hayes *et al.* 2004).

In the event of a detected incursion, an immediate notification of the WA Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE) representative would trigger the WA State Emergency Response Plan. This plan would be implemented by State Agencies and other stakeholders including Straits Resources with national assistance from CCIMPE.

3.4.10 Assessment and management of light spill

Inappropriately specified lighting at the Hope Point facilities and the Dean's Creek and Naughton Creek pump stations has the potential to disorientate turtles. The primary impact of artificial light onshore is to attract hatchlings or nesting marine turtles which mistake the artificial light for moonlight. Disorientation caused by artificial lighting can result in increased predation.

While the mangroves and shallow vegetated habitat offshore are important nursery habitat for juveniles, nesting opportunities for sea turtles do not appear to be present throughout the project area (Oceanica 2006a). The closest potential nesting opportunities are at the sandy beach at Tubridgi Point, although there are no available data for this area (Oceanica 2006a).

Management of light impacts

The lighting system for the project will be designed on the assumption that the area is a turtle nesting area, even though there is no evidence of nesting sites at either pumping station sites or at Hope Point. Elements of the lighting design include:

- lighting near the coast will be avoided where possible
- reduce visibility of lighting from the shore as far as practicable, through shielding, positioning, directional lighting and use of timing switches

- use non-attracting lights, such as low-pressure sodium bulbs, in all coastal lighting (other than to meet regulatory requirements—marine and aircraft navigation lighting).

3.5 MONITORING AND ASSESSMENT OF PERFORMANCE

A comprehensive and integrated environmental monitoring program will be implemented to establish baseline information and monitor the impacts of the proposal on the following elements of the marine environment:

- BPPH (e.g. expansion or decline of communities around infrastructure)
- mangroves and algal mats (e.g. expansion or decline of communities around infrastructure)
- marine fauna (e.g. megafauna, fish, juveniles)
- water quality in the coastal tidal creeks and offshore areas.

The effectiveness of the management measures will be determined and reported annually to the DEC.

3.6 PROPONENT COMMITMENTS

Marine fauna issues will be addressed by the following management commitments:

- Prepare and implement a Marine Management Plan which addresses the following issues:
  - monitoring program
  - baseline surveys of turbidity, suspended sediment and nutrient concentrations, shoreline and creek morphology/bathymetry, benthic primary producer habitat, marine fauna and NIMS
  - ship and barge movements
  - prevention and management of oil spills
  - marine megafauna protection from vessel movements
  - marine fauna protection from seawater pumping
  - anti-foulant contamination
  - prevention of the introduction of NIMS
  - underwater noise emissions
  - light spill
- Prepare and Implement a Dredging Management Plan which will address:
  - timing of dredging
  - baseline turbidity and BPPH surveys
  - criteria for protecting identified sensitive areas
  - sampling and analysis plan developed on the basis of National Ocean Disposal Guidelines for Dredge Material (Commonwealth of Australia 2002)
  - environmental management measures to control impacts

- Develop and implement an Exmouth Gulf Research Project, which will address:
  - links between terrestrial and coastal habitats
  - relationship between benthic macrofauna assemblages and environmental conditions
  - dugong survey of Exmouth Gulf
  - links between benthic habitat and the dugong
  - community turtle monitoring program for the eastern part of Exmouth Gulf
  - community seagrass monitoring program
  - whale interaction research program.

3.7 ENVIRONMENTAL OUTCOME

Overall, the environmental impact on marine fauna in the Gulf or the east coast of the Gulf is anticipated to be insignificant. Commitments for the preparation and implementation of a Marine Management Plan to apply controls to the operations and monitor its affects, and the proposed Exmouth Gulf Research Project to provide more information on the characteristics of the Exmouth Gulf ecosystem will mitigate potential impacts of the project as far as practicable.

Habitat loss and modification

The area of direct habitat loss from dredging will not have a measurable detrimental effect on marine fauna of the Gulf.

Indirect impacts on marine fauna from dredging such as turbidity are expected to be negligible due to management controls to be applied to dredging, onshore dredge spoil disposal and the timing of dredging during the winter months when seagrass and algae are likely to be dormant.

Light spill

The lighting system for the project will be designed on the assumption that the area is a turtle nesting area, even though there is no evidence of nesting sites at either pumping station sites or at Hope Point. Appropriate controls will be applied to lighting consistent with the project being near a turtle nesting area.

Underwater noise and vibration from marine vessel operations

Noise is produced by stable platforms which either do not move (loading ships), which only move slowly (tugs and ships) or whose movements are independent of any nearby whales (i.e. no deliberate approaches). The noise is also predicted to be reasonably constant in nature.

It is probable that, under normal operations, nearby marine megafauna will be aware of the operations from perhaps 5–10 km from the loading area and may approach it to approximately 400–1000 m before exhibiting avoidance behaviour. Given the continual and constant nature of the noise, it is probable that animals will quickly habituate and the noise will not produce any startle or alarm type of responses.

Vessel avoidance

The potential for vessel avoidance has been reduced with the workforce transportation proposed to be by air rather than ferry. Implementation of the Marine Management Plan will also further reduce any risk of vessel avoidance. Underwater noise and low vessel speed will facilitate a response from megafauna to avoid the vessels.

Contamination associated with anti-foulants on marine vessels

No vessels owned by Straits will use TBT based paints. In addition, potential contractors will be informed of the sensitivities of the local environment and that a clear preference will be given to engage contractors that use current best practice anti-fouling systems.

A sediment quality monitoring program will be implemented that will include baseline and ongoing monitoring for the effects of anti-foulants. Initial surveys (Oceanica 2006a) found no existing evidence of TBT or copper contamination at Hope Point.

Introduction of non-indigenous marine species by marine vessels

Non-indigenous marine organisms will be strictly managed according to Australian Quarantine requirements and in line with a very strict set of management actions. The ongoing NIMS monitoring program will be the first of its kind for the Exmouth Gulf and provide a significant new level of environmental defence for the region. Consequently, there are not likely to be any significant impacts from NIMS as a result of Straits operations.

Seawater pumping – entrapment and entrainment

The intake velocities of both pump stations are predicted to be substantially lower than the maximum pre-development tidal velocities within the creek systems and also lower than the average swimming speed of dugongs. It is expected that a dugong would be quite capable of swimming away from an intake screen should it find itself in the vicinity of the intake screen at pump startup. The other large marine fauna commonly found in the Gulf are all capable of swimming faster than the dugong and could also be reasonably expected to swim away from the intake screens.

Removal of small marine organisms through seawater intake represents a low risk to the viability of the biota within the tidal creeks or regionally.

The recruitment of fauna to the concentrator ponds provides an opportunity to offset any loss albeit insignificant to commercial fisheries in the Gulf.

Chapter 7

Social surrounds

- Commercial fishing and aquaculture
- Recreation and ecotourism
- Cultural heritage and conservation values

Chapter 7 Social surrounds

1 COMMERCIAL FISHING AND AQUACULTURE

EPA Objectives

The EPA objectives relevant to this assessment include:

- *To avoid or minimise impacts on commercial and recreational fishing*
- *To avoid or minimise impacts on commercial aquaculture operations*
- *To not impact adversely on the Exmouth Gulf fishery.*

1.1 LEGISLATIVE AND POLICY CONTEXT

Legislation

Fish Resources Management Act 1994

This Act provides the legislative framework for the management of the Exmouth Gulf Prawn (EGP) Managed Fishery. The EGP Management Plan 1989 is the current management plan for the fishery, and is a formal statutory document that dictates the management measures for the fishery. The EGP Management Advisory Committee directs the management of the fishery by providing advice with the aim of achieving the maximum economic return from the prawn resource, maintaining sustainability of the fishery and ensuring cost effective management. Management of the EGP fishery is based on 'input controls' using a combination of management restrictions, including limited entry, boat size, engine power and gear controls, and seasonally varied spatial and temporal closures.

EPBC Act 1999

This Act enables management of the fishery in an ecologically sustainable manner. DEH has recently declared that the pearl oyster fishery is being managed in an ecologically sustainable manner under the provisions of the EPBC Act.

Pearling Act 1990

This Act provides the legislative mechanism to control the harvest from the pearl oyster fishery. There is an annual review of the performance of the major aspects of the Pearl Oyster Fishery through the completion of the 'State of the Fisheries' report. This is updated and published each year following review by the Office of the Auditor General (OAG).

The Pearling Industry Advisory Committee (PIAC) has been established under the *Pearling Act 1990* to provide the Minister for the Environment (WA) with independent advice on the management of the industry.

1.2 DESCRIPTION OF COMMERCIAL FISHING AND AQUACULTURE

1.2.1 Commercial fishing

Exmouth Gulf Beach Seine Fishery

The Exmouth Gulf Beach Seine Fishery is a small fishery that has operated in southern Exmouth Gulf since 1988 (Oceanica 2005b). There were only two licensed fishers using beach seines and gill nets as of the year 2000. The fishery produces a mixed catch of mullet, Perth herring, shark, whiting and yellowfin bream. Of these, the main species caught are Perth herring, western sand whiting and shark. Catch and values for fisheries with fewer than five operators are not reported for reasons of confidentiality (Department of Fisheries 2004). The estimated maximum catch for human consumption handled in one netting operation is around 0.5 tonnes of fish.

Exmouth Gulf Prawn Managed Fishery

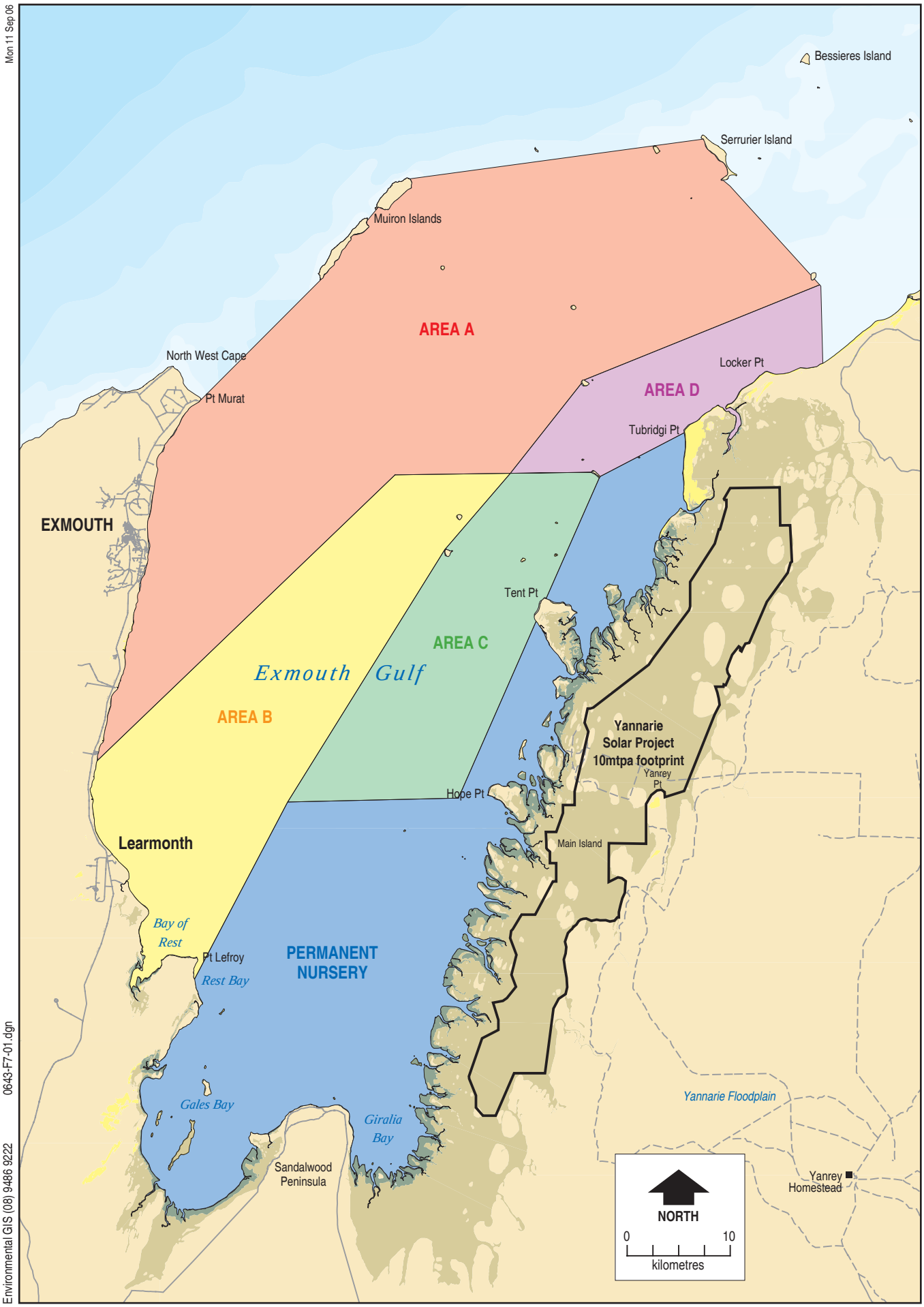
The Exmouth Gulf Prawn Managed Fishery is one of Western Australia's three most valuable managed fisheries (Shaw 2000). It is the second largest prawn fishery in Western Australia after the Shark Bay Prawn Fishery, and has an annual value to fishers of approximately $12 million (Oceanica 2005b). The Fishery is divided up into four distinct fishing areas, areas A, B, C and D and a permanently closed nursery area (Figure 7-1) (Oceanica 2005b). The Exmouth Gulf prawn fishery employs approximately 120 people directly (fishing, processing and administration) with some 20 other jobs as support activities (engineering, equipment supplies etc.) (Department of Fisheries 2003).

The fishery targets Western King Prawns (*Penaeus latisulcatus*) and Brown Tiger Prawns (*Penaeus esculentus*), with lesser (but still commercially significant) catches of endeavour prawns (*Metapenaeus endeavouri*) and occasionally banana prawns (*Penaeus merguiensis*). A detailed review of fishing and aquaculture in the Gulf is reported in Oceanica (2005b).

The prawn season opens in early April and closes in mid to late November and the number of prawn trawlers is presently limited to 13. Prawn trawling is capped by the Department of Fisheries at no more than 200 nights per year, where the trawlers use quad gear with 10 mm ground chains and the power of the vessels and the total length of the head ropes of nets are limited. The trawl areas are opened and closed throughout the season to protect juvenile and spawning stocks. There is permanent closure of the eastern shore to protect prawn nursery habitat.

Tropical Cyclone Vance caused widespread destruction of prawn nursery habitat and disturbance of the seabed. Prawn catches were below average for the following two years. Although rainfall is positively correlated with Banana Prawn catches elsewhere, there is no such correlation evident in catch records for Exmouth Gulf (Oceanica 2005b).

The prawn trawling grounds within the Exmouth Gulf have been trawled for over four decades. Evidence from other studies (Rester 2000, Beaumont & Hadley 2004, Thrush & Dayton 2002, Kaiser et al. 2002) indicate that the use of ground chains would have essentially cleared any pre-existing marine habitat (e.g. sponges and corals) from the trawl grounds, which now largely comprise of muddy sediments. The Department of Fisheries have a sophisticated Vessel Monitoring System (VMS), which logs the locations of trawlers and ensures that they are operating within the designated areas. The trawlers generally target the deeper waters in the centre and north of the Gulf (Figure 7-1).



Mon 11 Sep 06

0643-F7-01.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Dep't of Fisheries, 2006
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-1 Boundaries of the Exmouth Gulf prawn fishery

The Department of the Environment and Heritage has declared that the fishery is managed in an ecologically sustainable manner under the provisions of the Environment Protection and Biodiversity Conservation Act (Department of Environment and Heritage 2002).

Other commercial fisheries

There are some relatively small commercial fishing activities which may occur in the eastern side of the Gulf occasionally, including:

- Blue Swimmer Crab Fishery
- Tropical Rock Lobster Fishery
- Marine Aquarium Managed Fishery.

1.2.2 Aquaculture

The potential for aquaculture in the Exmouth Gulf is considerable as land and suitable water resources (e.g. hypersaline, marine, brackish and artesian water) are readily available. In addition, the region supports many fish and shellfish species that have commercial value and are considered suitable for further development (Department of Fisheries 2004). There are currently 21 aquaculture licenses and 8 pearl farm lease sites in the Gulf. The main aquaculture species are silver lipped pearl oysters (*Pinctada maxima*), black lipped pearl oysters (*Pinctada margaritifera*) and black tiger prawns (*Penaeus monodon*).

Two of the biggest concerns in the Exmouth Gulf arising from aquaculture are the importation of disease and genetic "pollution" (e.g. a mixing of hatchery and wild stock). In Western Australia, there are stringent controls in place concerning the translocation of stocks and the release of hatchery stock into the marine environment (governed by the Department of Fisheres). Disease testing requirements for hatchery stock are aimed at removing the risk of introducing disease from this source (Department of Fisheries 2004).

Pearling

The pearling operation in the Exmouth Gulf involves both the capture of wild pearl oysters by diving and the cultivation of pearl oysters on pearl farms. South sea pearls are grown in the silver lipped pearl oyster (*Pinctada maxima*) which occurs naturally in the Gulf and in all tropical waters of Western Australia (Oceanica 2005b).

Wild pearl oysters are stored in holding sites after they are collected. In the past, wild pearl oysters were transported from these sites to farms where seeding was performed (Brown 2004). However, most West Australian pearl companies now significantly reduce mortality rates that used to occur as a consequence of this transfer by seeding wild pearl oysters at the fishing grounds (from June to September) using vessels that are equipped with clean operating facilities (Brown 2004).

The implanted pearl oysters are returned to net panels on bottom longlines at holding sites adjacent to the operating sites following seeding. The oysters remain for up to three months at this location, during which time they are inspected and turned regularly by divers to ensure that an even envelope of nacre secreting cells (the pearl sac) forms around the seed nucleus. The net panels are then retrieved (during October and November) and the implanted pearl oysters are transported by boat to pearl farms

in protected coastal bays and inlets (Brown 2004). The pearls are harvested in the cooler winter months, after about two years of cultivation (Brown 2004).

There has been a move away from the capture of wild pearl oysters in recent years and hatchery production of *Pinctada maxima* is now of critical importance to the pearl industry, where recruitment of oysters in the wild is irregular and unable to be relied on for commercial operations.

1.3 IMPACT ASSESSMENT AND MITIGATION

1.3.1 Environmental aspects and potential impacts

Key activities or aspects of the proposal that may potentially affect commercial fisheries and aquaculture operations include:

- **dredging** resulting in direct habitat loss and modification through increased turbidity of the water column associated with sediment plumes
- **seawater pumping** resulting in the entrainment of small marine fauna and juveniles
- **barge and ship movements** in the Gulf potentially leading to:
    - the introduction of non-indigenous marine species
    - navigation risks and interference with trawling operations
    - contamination from anti-foulants
    - oil spills
- **project infrastructure** leading to the interference with nutrient flows to the Gulf.

1.3.2 Assessment and management

Dredging related habitat loss and modification

The shallow vegetated habitat of the east coast of the Gulf is of primary importance to the Gulf ecosystem, especially for fish and prawns as it functions as nursery habitat (Oceanica 2006a, Figure 7-1). The Yannarie Solar Salt Project has been designed as far as practicable, to avoid impacts on this habitat either directly (e.g. removal through dredging) or indirectly (e.g. interfering with related ecosystem processes).

The primary direct loss of benthic habitat associated with the proposed development is the dredging of a 1.3 km long channel into Hope Point. Estimations of habitat loss and the significance in relation to the EPA's Guidance Statement No. 29 on benthic primary producer habitat (BPPH) is addressed in detail in Chapter 6, Section 2. The total area of habitat that is likely to support benthic vegetation (seagrass and or algae) on the east coast is greater than 35,600 ha (or 356 km^2). The area lost from the construction of the channel is 16.4 ha, which is less than 0.05% of the total area of the Gulf and less than 1% of the relevant 50 km^2 management unit. The impact to the fishery from a reduction in habitat on this scale is considered negligible.

The indirect loss or impact arising from dredging is addressed in Chapter 6, Section 2. Dredging will occur only during winter months to minimise impact, as seagrasses and algae in the Exmouth Gulf region have distinct seasonal growth patterns and documented high recovery rates (Loneragan *et al.*

2003). On-shore dredge spoil disposal will be utilised, which will significantly reduce the impact on marine fauna and habitat arising from turbidity.

There will be minor losses of habitat at Dean's Creek and Naughton Creek where the seawater intake pumps are proposed to be constructed (Chapter 6, Section 2). The benthic habitat in the creeks primarily consists of bare sand, with the banks and shallows supporting algae and seagrass (Oceanica 2006a). The area of the footprint of each pump station will be of the order approximately 0.04 ha. Based on similar experience with Onslow Salt, the disturbance associated with construction and operation of the pump stations will be minimal beyond the constructed footprint.

Seawater pumping

The seawater intake pumps will take large volumes of water (Chapter 2, Section 3.7.2) out of two creeks and deliver it into the concentrator ponds. Chapter 6, Section 3 provides discussion on the effects of seawater pumping on the creek systems and potential impacts to fauna are not expected to arise as the tiger prawn and the endeavour prawn rely on the extensive seagrass and algal habitat located offshore from the tidal creeks for their nursery grounds, rather than the tidal creek systems themselves (Oceanica 2005b). The banana prawn however, uses creeks during its life cycle.

It is assumed that pumping will entrain a certain proportion of organisms, however with limited information on lifecycles and pumping regimes, this proportion can not be estimated at this time.

Entrapment against the pump intake screens could potentially impact marine fauna. The intake velocities of both pump stations are predicted to be substantially lower than the maximum pre-development tidal velocities within the creek systems and much less than the maximum swimming speed of dugongs. Most marine fauna found in the Gulf are all capable of swimming faster than the dugong, hence the risk of entrapment is not considered significant. Chapter 6, Section 3 provides additional information in relation to impacts on fauna from seawater pumping.

Barge and ship movements

Potential introduction of non-indigenous marine species (NIMS)

The risk of introducing marine species through ballast water will be controlled by AQIS requirements for exchanging high-risk ballast outside of the 12 nautical mile limit of Australia's territorial sea (Oceanica 2005b) and 'Ship Right'. It is estimated that approximately 150 bulk carriers will visit the Gulf each year to export salt, when production is at the 10 Mtpa maximum. Carriers enroute to the Gulf will be required to exchange ballast water outside the 12 nautical mile limit in accordance with AQIS procedures, where the risk of introduction of NIMS is considered as 'low risk'. However, there are certain circumstances when ships will not be able to exchange ballast water while at sea. In such circumstances, AQIS approval will be required to be obtained prior to ballast water being discharged in Australian waters.

A baseline survey of NIMS, and all subsequent work, would use the guidelines developed by the Centre for Research on Introduced Marine Pests (CRIMP) (Hewitt & Martin 1996 and 2001). On commencement of operations an ongoing monitoring program will be implemented at the anchoring area and in Hope Point harbour. Support vessels and other hard structures will be regularly inspected and if necessary, cleaned and anti-fouled to reduce risk for further translocation.

Navigation risks and interference with trawling operations

The deeper waters of the Exmouth Gulf (10-15 m deep) comprising Area B and Area C in Figure 7-1 are some of the most intensely trawled waters in the Gulf. The Department of Fisheries provided vessel monitoring system (VMS) data for the fishery for 2003/04 (Oceanica 2005b). The VMS output gives the location of trawlers 'polled' at certain points in time (rather than tracks). An example is provided in Figure 7-2, where it was apparent that the central region of the Gulf was most intensively trawled, with trawl paths generally running parallel to the long axis of the Gulf, following the depth contours.

The Department of Fisheries manage the location and duration of trawling effort via a system of closures throughout the season (Oceanica 2005b). Research trawls and information from trawler skippers is used to guide the program of closures. The timing for closures is communicated by the Department of Fisheries to vessel owners, skippers and managers at least 24 hours prior to a closure being implemented (E. Sporer, Department of Fisheries, 2005, pers. comm.). The information obtained from this system has been used to identify anchorage locations, with the objective being to minimise disturbance to existing commercial fishing operators.

The Yannarie Solar Project will barge salt to ships (nominally Panamax size) anchored in the Gulf (refer Chapter 2, Section 3). Laden Panamax ships require 15 m water depth and for a 10 Mtpa project, up to three ships will be anchored in the Gulf at any one time. The swept area of a Panamax ship on a swing anchoring is shown as the yellow circles on the east edge of the deep anchorage in Figure 6-43 (the diameter of a ship swing circle is approximately three times the ship length, in this case the ships will be approximately 300 m long so each swing circle will have a radius of about 1 km). Ship anchorage will be within the primary trawling grounds (Area B; Figure 7-1).

Straits will, wherever practicable, load ships in the shallower anchorage shown along the boundary of trawl areas B and C. After a certain tonnage is loaded and if a deeper draft is required, the ships will be moved out to the deeper anchorage for completion of loading.

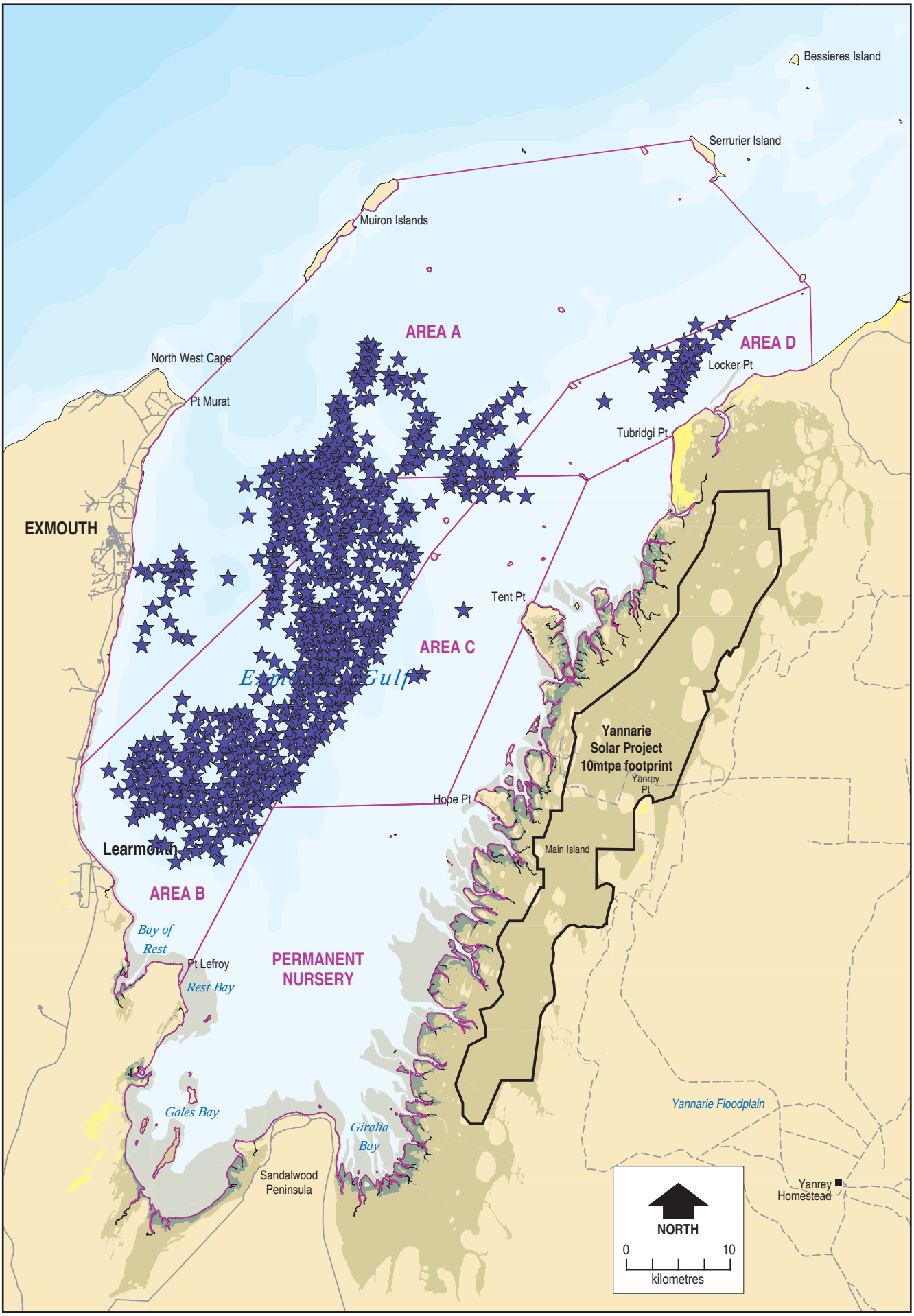
The red polygons in Figure 6-43 (Oceanica 2005b) are simply to depict likely zones for anchoring and there will not be any restrictions placed on trawling in these areas. The only restrictions will be due to the physical presence of the ships and their anchors; the yellow circles represent the maximum level of restriction on trawl grounds in the Gulf. The intention is to work with existing trawlers with an aim to avoid, wherever practicable, any possible dual use of an area at the same time.

If three Panamax ships are anchored in the Gulf (at 10 Mtpa production) then at most 236 ha of Area B will be temporarily inaccessible to trawling. Area B has an area of 69,887 ha so the area affected will be about 0.3% of the total area. Most of the time there will be one ship present, which would equate to 0.1% of the trawl ground being inaccessible.

There will be no permanent mooring gear installed and so the area will be able to be trawled entirely whenever there are no ships anchored.

During the trawling season, the coordinates of the anchoring locations and swing areas will be communicated to the trawler skippers and Department of Fisheries on completion of each anchoring procedure and ships will be well lit.

There is negligible risk that the anchoring of shipping in the Gulf will result in reduced catches or increased trawling costs as it is well established that the prawns move through the Gulf (i.e. the anchoring of ships will not 'protect' prawns from harvesting).



Mon 11 Sep 06

0643-F7-02.dgn

Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-2 Example of VMS data for four trawlers (June 2004)

Datum: MGA Zone 50
Source: Oceanica, 2005
Date: 11 Sep 2006

Anti-foulants

The barges, tugs and service vessels owned by Straits will be berthed in the Hope Point barge harbour. Before commissioning, these vessels will be anti-fouled with an environmentally-friendly commercially available anti-foulant. No vessels owned by Straits will use TBT-based paints. In addition, Straits will inform potential contractors of the sensitivities of the local environment and outline that a clear preference will be given to engage contractors that use current best practise anti-fouling systems during establishment of its shipping contracts.

Straits will design and implement a sediment quality monitoring program that will include baseline and ongoing monitoring for the effects of anti-foulants. Initial surveys (Oceanica 2006a) found no existing evidence of TBT or copper contamination at Hope Point.

Fuel/oil spills

A number of shipping and land-based activities will involve the storage, transport and handling of hydrocarbons and therefore have the potential to result in spillage to the marine environment unless appropriately managed.

Storage of all bulk fuels at the development site (Chapter 2, Section 3) will be within bunded areas with sufficient capacity to accommodate both the volume of the tanks and rain-water associated with a heavy rainfall event. To prevent overflow of oily residues from the operation of machinery, all hard-stand areas will drain to sumps fitted with oil-water separators in accordance with Australian Standard *AS 1940-2004: The storage and handling of flammable and combustible liquids* (Chapter 6, Section 1).

The risk of an oil spill occurring is low but the likelihood of occurrence is highest during refuelling operations of barges and tugs. Refuelling will take place within the barge harbour where precautionary measures (such as auto-shut off connections) will be in place to localise and limit the spread of oil, in the unlikely event of a spill.

It is recognised that the most significant environmental impact would be from a large oil spill originating from a shipping accident. However, management measures such as compulsory pilotage, establishment of speed limits and using established shipping routes and anchorage locations within the Gulf all reduce the likelihood of an incident such that the risk is small.

The proposed Marine Management Plan (see Proponent Commitments in Chapter 6, Section 1) will address measures to prevent and respond to a spill.

Potential changes to nutrient flows

The east coast intertidal ecosystem (algal mats and mangroves) is a key source of nutrients to the Exmouth Gulf. These nutrient flows are almost entirely related to the tidal action which drives the wetting and drying of the east coast ecosystem. The project has been specifically designed to reduce impact to the tidal (and hence nutrient) flows (Chapter 6, Section 1) by ensuring that the seawalls will be constructed landward of the easternmost extent of the algal mats (approximately the high water mark).

1.4 MONITORING AND ASSESSMENT OF PERFORMANCE

An Integrated Environmental Monitoring and Reporting Plan will be prepared and implemented to monitor the direct and indirect impacts on commercial fishing and aquaculture activities in the Exmouth Gulf. Monitoring will include:

- benthic primary producer habitat (e.g. expansion or decline of communities around infrastructure)
- marine fauna (e.g. megafauna, fish, juveniles)
- surface water quality in the coastal tidal creeks (e.g. impacts of seawater pumping stations, changes to tidal circulation etc.).

1.5 PROPONENTS COMMITMENTS

Refer to commitments for marine fauna environmental factor which include:

- preparation and implementation of Marine Management Plan which addresses measures to manage impacts on marine macrofauna from vessel movements, introduction of NIMS, anti-foulants, oil spills and seawater pumping
- preparation and implementation of a Dredging Management Plan to manage impacts on marine macrofauna from dredging.

Additional commitment to addressing commercial fishing and aquaculture

1. A feasibility study will be implemented to investigate aquaculture opportunities that can co-exist with the project.

1.6 ENVIRONMENTAL OUTCOMES

The proposed Yannarie Solar Salt project has been developed to prevent impacts on commercial fishing and aquaculture operations. The Exmouth Gulf Aquaculture Plan (Department of Fisheries 2004) recognises the benefits that the establishment of solar salt production facilities would have with regard to providing potential aquaculture facilities (e.g. saltfields are highly suitable for the production of *Artemia* (or brine shrimp)) (Oceanica 2005b). Straits Resources have committed to fund a feasibility study to investigate aquaculture opportunities which do not compromise the primary function of the Yannarie Solar project.

Dredging and seawater intake from pumping stations will be required within the Gulf, which could impact habitat both directly and indirectly. Dredging is expected to impact less than 1% of the total Gulf area, whilst the footprint of the pumping stations should not exceed 0.04 ha.

Barge and ship movements could potentially impact commercial fisheries and aquaculture through the introduction of non-indigenous marine species, interference with trawlers, inappropriate anti-fouling techniques or fuel/oil spills. The risks associated with these activities can be managed through the implementation of AQIS requirements and Ship Right, communication with the Department of Fisheries and commercial fishery operators, and development and implementation of procedures in regards to fuel/oil spills.

2 RECREATION AND ECOTOURISM

2.1 EPA OBJECTIVE

The EPA objectives relevant to this assessment include:

- *To avoid or minimise impacts on recreational fishing and tourism.*

2.2 LEGISLATIVE POLICY AND CONTEXT

2.2.1 Relevant guidance

Fish Resources Management Act 1994

This Act is used to manage the commercial and recreational exploitation of all fishes in State Waters and demersal fisheries on the continental shelf to the 200 m isobath.

2.3 DESCRIPTION OF RECREATION AND ECOTOURISM

2.3.1 Recreational use

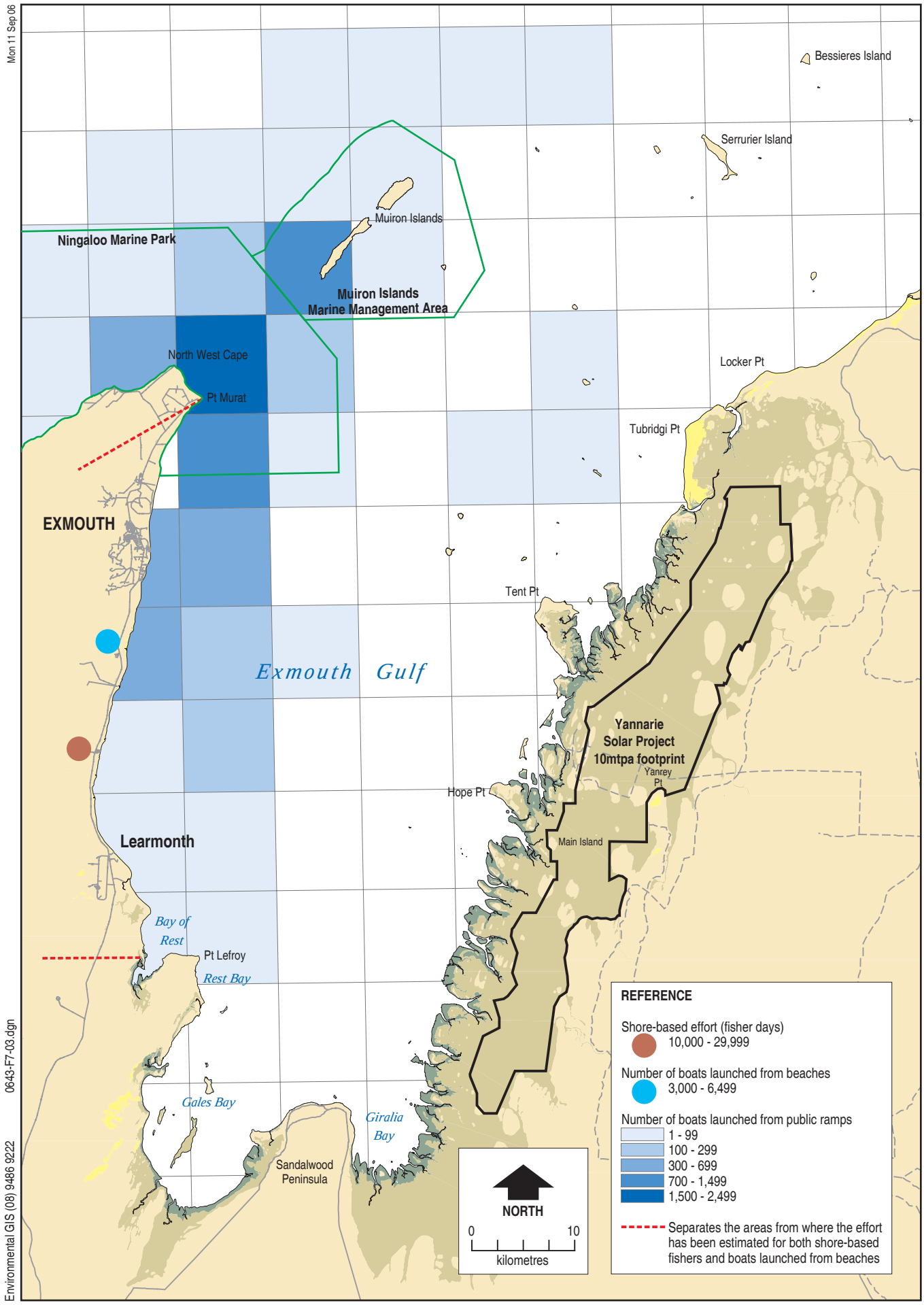
Recreational fishing activity in the Gascoyne area has increased significantly since the early 1980s. The estimate of recreational fishing participation in the region is 5% of the State's fishers or 30,000 fishers a year (Baharthah and Sumner 2003). Fishing activity tends to peak between April and August each year. Most fishers stay an average of less than two weeks and intend to fish every day (Sumner *et al*. 2002).

A 12-month survey of recreational fishing in the Gascoyne area was conducted between 1998 and 1999 by Sumner *et al*. (2002). The spatial distribution of recreational fishing effort in the Exmouth Gulf was recorded and the findings are shown in Figure 7-3. Recreational fishing data from the Exmouth region are presented in Figure 7-4 (Department of Fisheries 2004).

Sumner *et al*. (2002) estimated that the total annual recreational fishing effort for the Gascoyne region was 243,000 fisher-days from April 1998 to March 1999. The total recreational catch of all finfish species was estimated at 350 tonnes. This was one third of the commercial catch of 1,082 tonnes at the time.

These figures do not include the catch from charter boats and therefore understate the total recreational catch for the Bioregion (Sumner *et al*. 2002). Charter activity is significant, with 72 fishing tour licences and 12 "ecotour" licences valid for the Gascoyne region in 2003 (Department of Fisheries 2003).

Locals at Exmouth enjoy fishing and visiting the east coast of the Gulf when conditions are suitable for small boats. However, the frequent strong winds, the distance across the Gulf (approximately 40 km) and the proximity to other attractions such as Ningaloo Reef and the Muiron Islands means that recreational boating is not a significant source of vessel movement across the Exmouth Gulf to the east coast (Oceanica 2005b).



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Sumner et al., 2002
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-3 Distribution of recreational fishing in Exmouth Gulf (Apr 1998 to Mar 1999)

Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: Dep't of Fisheries, 2004
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-4 Current recreational fishing activity in the Exmouth Gulf region

2.3.2 Ecotourism

A number of charter boats operate out of Exmouth, the number varying with season. There would currently be fewer than 20 operators and licenses are tightly controlled by the Department of Planning and Infrastructure (Oceanica 2005b).

The charters are generally focussed on the Ningaloo Marine Park or the Muiron Islands. However, during the months of peak Humpback Whale aggregation, operators run whale-watching tours in the deep area of the Gulf. Self-charter boats are also available for hire and these are occasionally used by fishers to access the east coast of the Gulf (Oceanica 2005b).

2.3.3 Landscape and aesthetics

The proposed project area is largely confined to the supratidal salt flats which lie between the tidal mangrove zone of the Gulf shoreline and the eastern edge of the flats where they abut the terrestrial systems. The saltfield will change the appearance of the project area as there is currently no infrastructure present within the area other than the old Talandji Salt Evaporator, some pastoral fences and tracks.

2.4 IMPACT ASSESSMENT AND MITIGATION

2.4.1 Environmental aspects and potential impacts

The activities or aspects of the proposal that may potentially affect recreational use and ecotourism operations include:

- **vessel avoidance** of marine megafauna could harm these organisms and is addressed in Chapter 6, Section 3
- **dredging** resulting in direct habitat loss and modification through increased turbidity of the water column associated with sediment plumes and is addressed in Chapter 6, Section 1 and 2
- **construction of saltfield infrastructure** affecting the visual amenity of the area
- **operation of the saltfield** could potentially reduce recreational access to tidal creeks, increase visitation to the east coast of the Gulf and increase recreational fishing pressures from on site staff and contractors
- **indirect impacts** from seawater pumping on marine fauna (including species of recreational interest), introduction of non-indigenous marine species, changes to nutrient flows, navigational risks and hydrocarbon spills are addressed in Chapter 6, Section 3.

2.4.2 Assessment and management

Vessel avoidance

Marine operations associated with the project involve the risk of vessel avoidance or displacement of marine megafauna. Management measures will be addressed in the Marine Management Plan and include a maximum speed of 10 knots for all vessels when there are Humpback Whales in the Gulf as well as a maximum speed of 10 knots in the designated fish nursery at all times. Fixed routes for vessel movements will be established.

Construction of saltfield infrastructure

The nature of the proposed infrastructure for the Salt project is such that the majority of the infrastructure will be under 5 m in height above ground level (AGL). The exceptions to this are the salt stockpile (25 m), stacker (25 m) and barge loader (10 m).

The Yannarie Solar Project has a footprint of approximately 410 km^2. The majority of the saltfield consists of earthen embankments covered with limestone material to reduce erosion. The height of the seawalls will be typically 5 m AHD, which will not be visible from the water (approximately 5 km from the east coastline) predominantly due to screening by mangroves.

The majority of the project infrastructure will be located behind the mangroves between 4 and 5 km inland from the coastline. The potential visual impact of the project has been significantly reduced through the location of the salt production behind the mangroves on the salt flats.

Visual amenity in the area could be affected by:

- lighting
- salt stockpile
- seawalls and internal embankments
- pumping stations
- infrastructure associated with the transport of salt (conveyor, stacker, trucks, barges and ships).

All tourism ventures are located on the western side of the Gulf and North West Cape and will not be affected by changes to the visual landscape by the project.

The only impact of the project on Whale watching tours Exmouth Gulf would be the site of ships anchored in the Gulf. The visual presence of ships will not reduce the value of the whale watching business as similar ventures operate from Fremantle where considerable numbers of large ships are anchored in Gage Roads.

Operation of the saltfield

There will be no reduced access to the tidal creeks currently available for recreational activities.

For visitors to the east coast of the Gulf, Straits will ensure adequate markers are deployed to delineate and notify the public that recreation, fishing and aquaculture are precluded within the barge harbour. Straits will liaise with the Exmouth Sea Search and Rescue group and the Exmouth police to establish protocols for emergency events involving recreational users of the east coast.

Construction staff and contractors will not have recreational access to the east coast or be allowed to fish or recreate on the coast while on site. Operations staff will be based in Exmouth and will only be on site for the hours that they are working. Operations staff will also not be allowed to fish or recreate on the east coast while on site for Straits Salt business.

Opportunities to enhance tourism and recreation

Straits will collaborate with any new viable independent Exmouth business venture seeking to provide managed access to the project site for recreational fishing and site tours. This is a unique opportunity within Western Australian saltfields.

2.5 MONITORING AND ASSESSMENT OF PERFORMANCE

The Marine Management Plan will address monitoring of the impacts of the proposal including elements of the environment that are relevant to recreational and ecotourism values such as:

- marine fauna (e.g. megafauna, fish, juveniles)
- surface water quality in the coastal tidal creeks (e.g. impacts of seawater pumping stations, changes to tidal circulation etc).

2.6 PROPONENTS COMMITMENTS

Refer to commitments for marine fauna environmental factor and commercial fishing and aquaculture factor which include:

- preparation and implementation of a Marine Management Plan which addresses measures to manages impacts on marine macrofauna from vessel movements, introduction of NIMS, anti-foulants, oil spills and seawater pumping
- preparation and implementation of a Dredging Management Plan which addresses measures to manage effects on marine macrofauna from dredging.

An additional commitment relevant to recreation and ecotourism is:

1. Straits will collaborate with any new viable independent Exmouth business venture seeking to provide managed access to the project site for recreational fishing and site tours.

2.7 ENVIRONMENTAL OUTCOMES

Marine operations associated with the project could increase the risk of vessel avoidance to fauna and this will be managed through development and implementation of the Marine Management Plan and Dredging Management Plan. Construction of the saltfield will affect the appearance of the visual appearance of the supratidal salt flat but given the isolation of the project, its location well behind the mangrove fringe and relatively low profile no significant impact on visual amenity is anticipated.

Operation of the saltfield could increase access to the area and result in increased fishing undertaken in the vicinity. Straits will ensure adequate communication with the community and relevant authorities to ensure increased access is appropriately controlled. Straits will seek to incorporate means and management of public access to the first stage concentrator ponds in the vicinity of the pump stations to facilitate controlled recreational fishing.

3 CULTURAL HERITAGE AND CONSERVATION VALUES

3.1 EPA OBJECTIVES

The EPA objectives relevant to this assessment include:

- *To avoid or minimise impacts on Aboriginal and non-Indigenous cultural heritage sites*
- *To ensure that the proposal complies with the requirements of the* Aboriginal Heritage Act 1972
- *To ensure that the proposal complies with the requirements of the* Heritage of Western Australia Act 1990
- *To maintain the integrity, ecological functions and environmental values associated with Exmouth Gulf, the intertidal zone and adjacent hinterland.*

3.2 LEGISLATIVE AND POLICY CONTEXT

3.2.1 Aboriginal heritage

Aboriginal Heritage Act 1972

The Minister for Indigenous Affairs is responsible for the administration of the *Aboriginal Heritage Act 1972*. The Act provides for the protection of Aboriginal cultural materials and places of significance.

EPA Guidance Statement No. 41

EPA Guidance Statement No. 41, "*Assessment of Aboriginal Heritage*", provides guidance on the process for the assessment of Aboriginal heritage as an environmental factor. This guidance statement also details those actions that may be pertinent to the factor of Aboriginal heritage, including undertaking surveys and consulting local Aboriginal people (EPA 2004b).

Native title

Native title, or indigenous land rights, is a concept in the law of Australia that recognises the continued ownership of land by local Australian Aborigines or Torres Strait Islanders. The colonisation of Australia was conducted under the false assumption that the land was unoccupied (*terra nullius*) and could therefore be claimed for the Crown and distributed to colonists by the Government. The legal concept of Native Title as it applies in Australia was recognised by the judicial system in 1992, and the Keating government later enacted the *Native Title Act 1993* (Commonwealth) to clarify the legal position of landholders and the processes that must be followed for Native Title to be claimed, protected and recognised through the courts.

3.2.2 European heritage

Heritage of Western Australia Act 1990

The Heritage Council of WA operates under the *Heritage of Western Australia Act 1990* (Heritage Act). The Heritage Council of WA maintains the State Register, which provides official recognition of a place's cultural heritage significance to WA. Protection is achieved through the requirement under the Heritage Act that all development proposals regarding a registered place be referred to the Heritage Council for advice.

Commonwealth

The Australian Heritage Council is the principal adviser to the Australian Government on Australian heritage matters. The Council assesses nominations for the National Heritage List and the Commonwealth Heritage List and compiles the Register of the National Estate.

The Australian Heritage Database is maintained by the Council and contains a listing of natural, historic and Indigenous places listed in the World Heritage List, National Heritage List, Commonwealth Heritage List and the Register of the National Estate.

Environmental Protection and Biodiversity Conservation Act 1999

The EPBC Act has relevance to:

- World Heritage properties
- Ramsar wetlands of international importance
- listed threatened species and communities
- migratory species protected under international agreements; and
- the Commonwealth marine environment.

3.3 DESCRIPTION OF CULTURAL HERITAGE AND CONSERVATION VALUES

3.3.1 Background

The North West Cape is rich in Aboriginal history and there is evidence of Aboriginal occupation dating back 25,000 years, continuously until at least 400 years ago. Aboriginal people from the Jinigudira tribe camped in the coastal dunes, in rock shelters of the Cape Range, and in the foothills. The Jinigudira were reported to have died out as a result of disease at about the time of European settlement (Turner, cited in Morse and Wright 1989).

The Gnulli people now hold custodianship of the land for the original Jinigudira tribe and have also been present on the Cape participating in pastoral activities for a number of years. They have a registered native title claim over a significant area of the Gascoyne. The Gnulli group are recognised by the Aboriginal Community as the custodians of Aboriginal culture for the Exmouth Region and Ningaloo area (WAPC 2004).

The traditional land owners of the Onslow area are the Thalanyji, Nhuwala and Burama people, who came from the Cane and Ashburton River area, however the Onslow area is also inhabited by Aboriginal people from the inland Pilbara region who were moved to camps in the coastal areas of Onslow when the pastoral award was introduced in 1968.

In addition to the Thalanyi, Nhuwala and Burama people, the main tribal groups in town are the Punjima (Bunjima) and Innawonga (from the Wittenoom and Tom Price area); the Yindjibarndi people (one of the larger language groups, from the Millstream area); the Ngarluma people (from Roebourne and Whim Creek areas) and the Martuthinira group (traditionally from the coast around the mouth of the Fortescue River and south to Robe River). According the WA Planning Commission, Aboriginal people are now moving back to their traditional homeland areas, which has lead to the decrease in population in the Onslow area (WAPC 2003).

3.3.2 Aboriginal heritage

According to the National Native Title Tribunal Register, there are 2 claims covering the area around the proposed development site. These are the Thalanyji Claimant Application (WC99/45) and the Gnulli Application (WC97/28) (National Native Tribunal Register 2004).

Previously identified sites

A search was made of the Department of Indigenous Affairs (DIA) Register of Aboriginal Sites within an area measuring 150 km (north east/south west) by 60 km (north west/south east) incorporating the project area. A total of 131 archaeological sites were identified, of which only four are located within the Project area (Table 7-1). Most of these sites have been recorded as the result of Aboriginal heritage surveys undertaken prior to various pipeline constructions, mining and exploration activities and associated infrastructure development. No Indigenous academic archaeological research has been conducted in the Onslow region (Archae-Aus 2005).

Table 7-1 Previously recorded archaeological sites within the project area

Site Id	Site no.	Easting*	Northing*	Site type	Site name	Exploration licence
7057	P05888	273638	7589705	Artefact Scatter, Midden	Urala Midden 1	E 0801394
7177		273938	7560055	Artefact Scatter	Wadawan 1	E 0801421
11062	P01108	245638	7552655	Structure	Kurt Island	E 0801397
11063	P01109	245638	7555655	Structure	Terminal Island	E 0801397

*Source: Archae-Aus 2005 Notes: * = Datum: GDA 94; Zone 50K; Grid Reference Accuracy: ±1000m*

Heritage surveys completed

A number of Aboriginal heritage surveys have been commissioned by Straits, which has resulted in the identification and recording of additional sites. The survey methodology used a combination of four wheel drive vehicles and a helicopter, which allowed large areas to be accessed efficiently, while still allowing more detailed site investigations (Archae-Aus 2005).

The survey area chosen for the first round of detailed archaeological surveys was approximately from Hope Point to the northern boundary of the saltfield (Figure 7-5). The project area was broken into two sections at the request of the Aboriginal groups – Thalanyji and Gnulli. The entire project area was considered too large to be covered adequately during a single survey, due to the time commitments required from the Aboriginal consultants (Archae-Aus 2005).

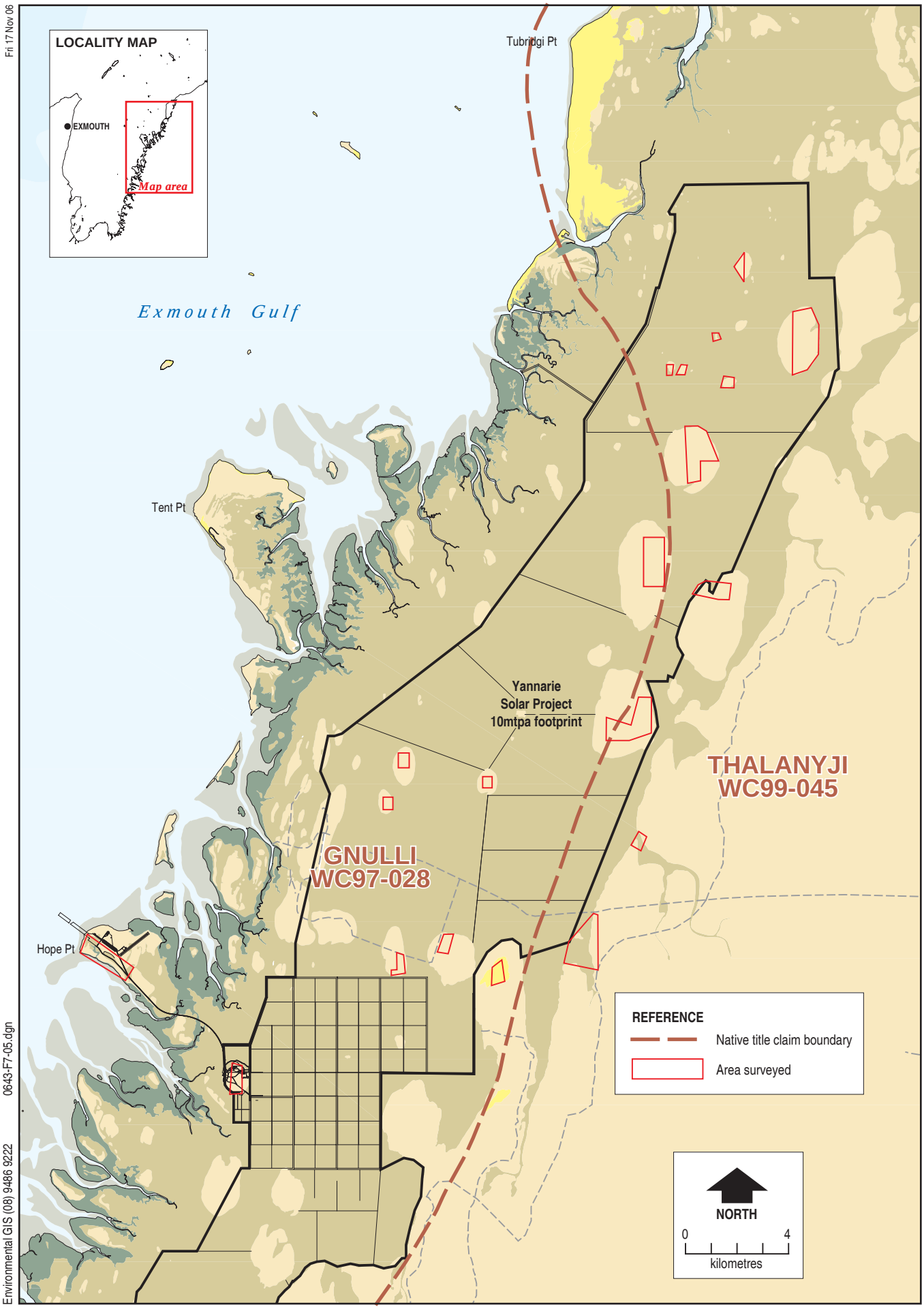
Given that the Thalanyji and Gnulli Native Title Claim Areas are adjacent to one another, there was some potential for an archaeological site to overlap the native title boundary. To overcome this issue,

joint surveys were conducted between 27 and 28 May 2005. Results of the surveys are outlined in Table 7-2 (Archae-Aus 2005).

Table 7-2 Aboriginal heritage surveys completed

Date of Survey	Aboriginal Group	Type of Survey	Results of Survey/comments
3–4 Aug 04	Thalanyji	Site avoidance survey	Clearance given for drill holes and test pit installation
7 Sep 04	Gnulli	Site avoidance survey	Clearance given for drill holes and test pit installation
6–8 Sep 04	Thalanyji	Ethnographic	The Thalanyji survey was of the northern project area, concurrent to that area surveyed during the archaeological investigations. Three sites were identified outside of the project area
23–26 May 05	Thalanyji	Archaeological	A total of 18 new Aboriginal archaeological sites were located within or immediately outside the Thalanyji Native Title Claim Area (Figure 7-6). No burials were identified in the coastal dunes however there is a chance, owing to the nature of the environment, that unidentified subsurface sites may occur within the coastal dune system. Additionally, 39 isolated artefacts were located within the survey area. Ten of these are located in proximity to the Thalanyji and Gnulli Native Title Claim Boundary.
27–28 May 05	Thalanyji and Gnulli	Archaeological	There were 18 archaeological sites identified that were adjacent to the Thalanyji and Gnulli Native Title Claim Boundary.
29–31 May 05	Gnulli	Archaeological	A total of 11 new Aboriginal archaeological sites were located within or immediately outside the Gnulli Native Title Claim Area (Figure 7-7). Additionally, 26 isolated artefacts (Figure 7-8) were located within the survey area. Ten of these are located in proximity to the Thalanyji and Gnulli Native Title Claim Boundary.
1 Jun 05	Gnulli	Ethnographic	The Gnulli survey was of the entire project area, incorporating both the northern and southern fields. No sites identified

Source: Archae-Aus 2005



Fri 17 Nov 06

0643-F7-05.dgn

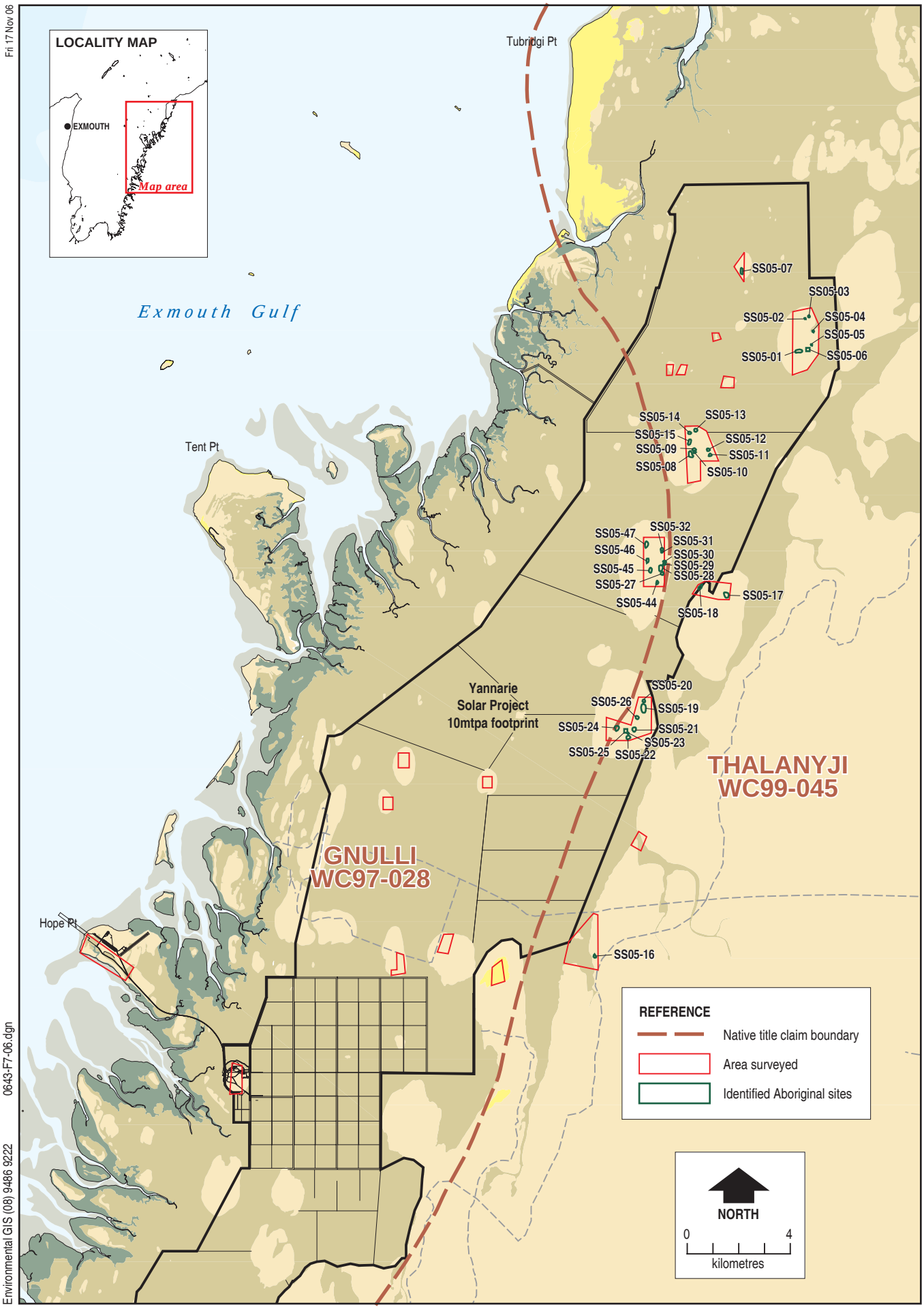
Environmental GIS (08) 9486 9222

Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-5 Archaeological survey area

Datum: MGA Zone 50
Source: Archae-Aus, 2005
Date: 11 Sep 2006

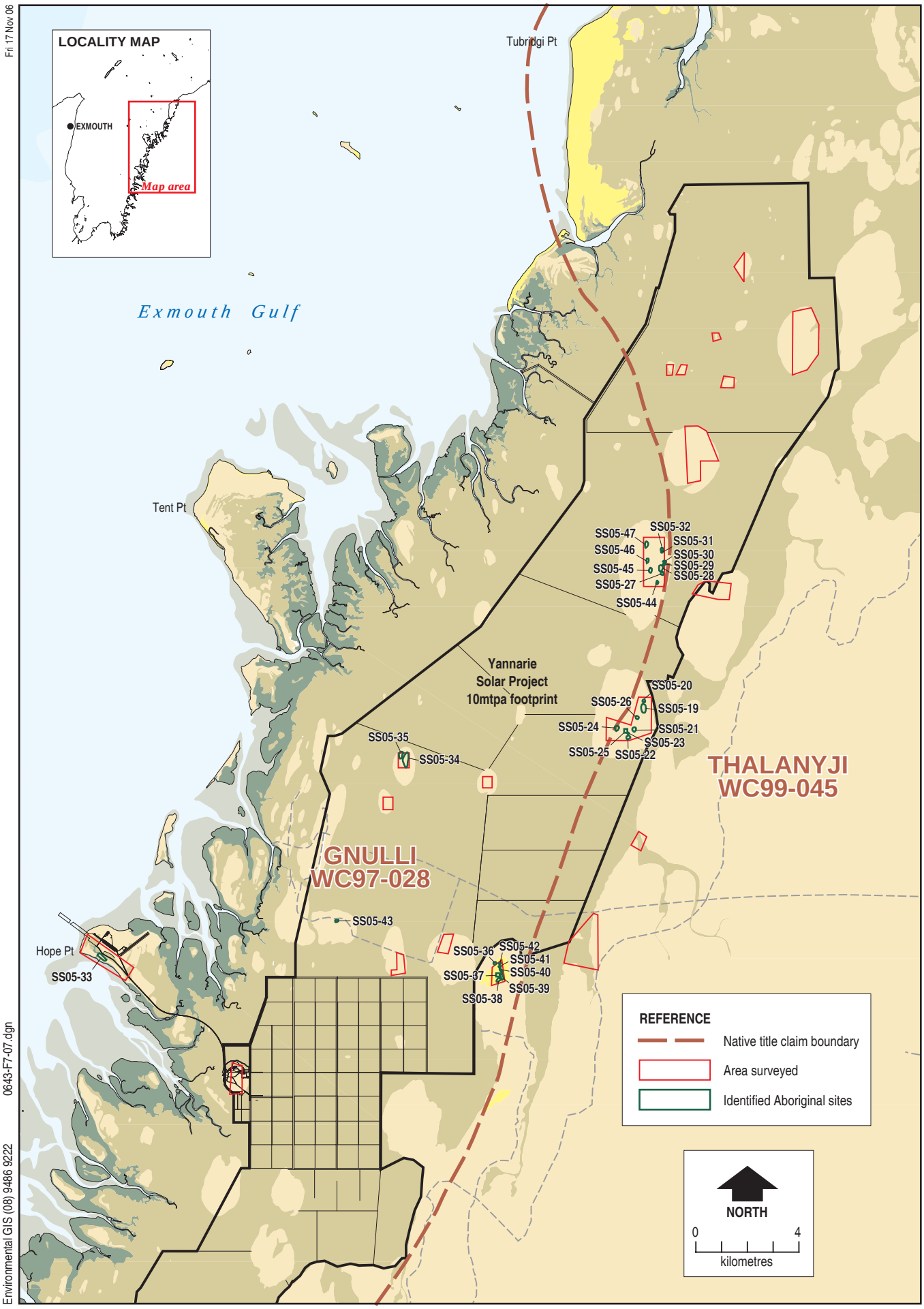


Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-6 Aboriginal archaeological sites within the Thalanyji native title claim area

Datum: MGA Zone 50
Source: Archae-Aus, 2005
Date: 11 Sep 2006



Yannarie Solar
a Straits initiative

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-7 Aboriginal archaeological sites within the Gnulli native title claim area

Datum: MGA Zone 50
Source: Archae-Aus, 2005
Date: 11 Sep 2006

Figure 7-8 Artefacts collected from one site, prior to being recorded

3.3.3 European heritage

There are no known significant European Heritage sites within the project area. Although there are a number of shipwreck sites within the region, none have been identified in locations that are likely to be affected by the project (Oceanica 2006a).

3.3.4 Conservation values

The east coast of the Exmouth Gulf has been identified as having a range of high conservation values, including extensive mangrove and algal mat systems, fish and prawn nursery areas and important habitat for threatened marine fauna.

Interim Marine and Coastal Regionalisation for Australia

The Interim Marine and Coastal Regionalisation for Australia (IMCRA) was established by the IMCRA Technical Group (IMCRA 1998). This regionalisation extended the existing marine reserve system, contributing to the ultimate goal of developing a National Representative System of Marine Protected Areas.

The North West Cape area is the overlap point of tropical and southern temperate biogeographic regions. At the broadest scale, IMCRA (1998) identified two main pelagic provinces—the Northern (tropical) and Southern (temperate)—with a zone of overlap (referred to as a biotone) on both the western and eastern coasts. The Northern Pelagic Province (1,390,000 km^2 area) extends from just south of North West Cape in the west, encircling the tropical north and down the eastern coast of Australia to Dunk Island. Exmouth Gulf is located at the western-most extent of the Northern Pelagic Province.

Marine Reserves Report

The Marine Parks and Reserves Working Group (MPRWG) (CALM 1994) published a recommendation that 70 sites around Western Australia be considered for marine reservations. The working group did not consider mining or commercial fishing at the time as these issues were considered to be more appropriate at a future phase prior to implementation. The MPRWG report states:

"The areas proposed in this report as worthy of consideration for reservation have been identified on the grounds of conservation, scientific and public recreation values. It is acknowledged that further consideration of management issues, especially those relating to boundaries and impacts on existing users, will be necessary before any reserve is declared. The boundaries shown in the maps of this report, where they occur, are provisional only, and may be modified during the necessary further public consultation phases."

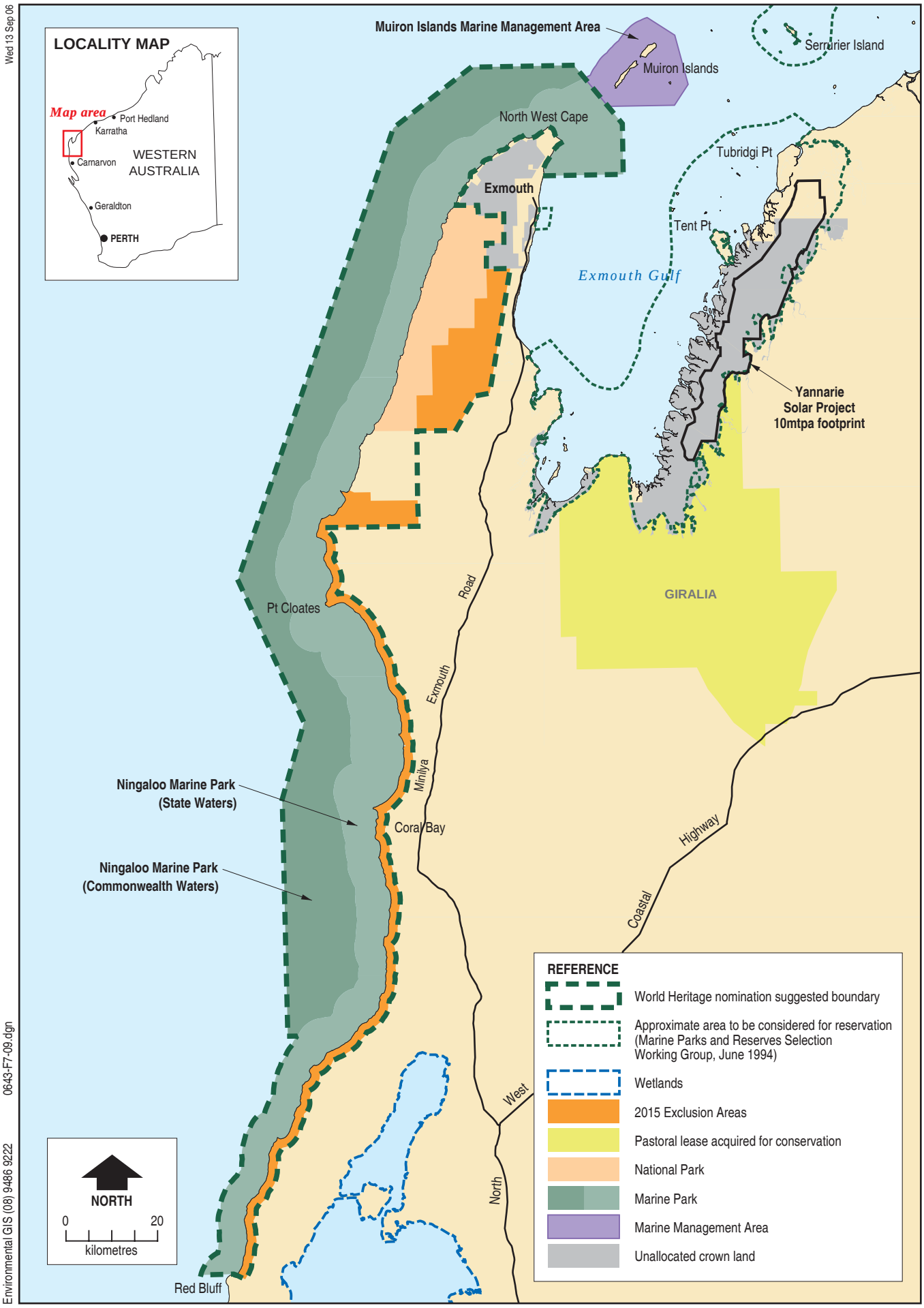
Figure 7-9 shows that proposed nominal marine reserve boundary for Exmouth Gulf.

Directory of Important Wetlands in Australia

The east coast of Exmouth Gulf is a Commonwealth "Directory Wetland", specifically "Exmouth Gulf East—WA007" (Environment Australia 2001). This listing is on the basis of the mangrove coast and intertidal area and is described as "An outstanding example of tidal wetland systems of low coast of north west Australia, with well developed tidal creeks, extensive mangrove swamps and broad saline coastal flats".

World Heritage Area Nomination

A nomination for World Heritage listing for Cape Range and Exmouth Gulf is currently in the process of being advanced by the State Government. A number of boundary options were originally considered by the State Government which included the Exmouth Gulf and the eastern coast and hinterland. A proposed boundary for World Heritage Area nomination has now been endorsed for community consultation. This area excludes the waters of Exmouth Gulf and the Yannarie Solar Project Area on the eastern shore of the Gulf (Figure 7-9).



Yannarie Solar
a Straits initiative

Datum: MGA Zone 50
Source: World Heritage Consultation Commission, 2005
Date: 11 Sep 2006

YANNARIE SOLAR PROJECT ERMP/EIS

Figure 7-9 Existing and nominal marine reserve boundaries in the Exmouth Gulf region

World Heritage values

In addition to the World Heritage Area nomination, there were two other values outlined in the Scoping Document, namely the captured delta of the Yanrey River and freshwater springs. Advice from CALM in December 2005 on the proposed world heritage values of the project area included the following references to the captured delta of the Yanrey River and the freshwater springs:

"The captured delta of the Yanrey River was identified as a possible World Heritage value under criterion vii, illustrating a typical Pilbara-type drainage system overwhelmed by a Pleistocene dunefield. However, a decision was made not to include this feature as additional evidence of the geoevolutionary history of the western margin of the Australian continental plate, because of a lack of supporting information."

As this was the only information available on the captured delta of the Yanrey River, no further assessment of this issue has been undertaken.

The 2005 advice from CALM on the freshwater springs continues on from the reference to the captured delta of the Yanrey River:

"Limited work on this potential value did draw attention to the existence of freshwater springs at the seaward end of this feature which will probably have biodiversity significance and therefore be a distinctive biodiversity feature under criterion x."

Further clarification on the location of the freshwater springs was sought from CALM and it was subsequently explained that the existence of the freshwater springs was theoretical, proposed as evidence of the existence of a paleodrainage system under the saltflat. The possible paleodrainage system was considered to be a geological remnant of a 'drowned' section of the Yanrey River (A. Hopkins, 2006, pers. comm.).

Straits will undertake observations over the project area following significant rainfall events in order to detect and investigate any freshwater springs. The biodiversity values of any freshwater springs discovered in the project area will be documented and managed in consultation with the DEC.

Protection of tropical arid zone mangroves along the Pilbara coastline (EPA Guidance Statement No. 1, May 2001).

EPA Guidance Statement No. 1 classified the mangroves of eastern Exmouth Gulf as a Guideline 1 area: 'Regionally significant mangroves - Outside designated industrial areas and associated port areas' (EPA 2001). The Guidance Statement identified a continuous management area from Sandalwood Peninsula (Giralia Bay) in the south to Tubridgi Point in the north, an extent corresponding to the spatial scope of the current assessment.

This area was described as 'Area 2: Giralia Bay to Yanrey Flats, Exmouth East Shore' and the regionally significant mangrove areas were classified as being of 'Very High' conservation significance (EPA 2001). The Guidance Statement identified that for Guideline 1 areas, the EPA expects that 'No development should take place that would adversely affect the mangrove habitat, the ecological function of these areas and the maintenance of ecological processes which sustain the mangrove habitats' (EPA 2001). The classification of various mangrove areas along the Pilbara coast in GS No. 1 was underpinned by the regional scale conservation significance assessment completed by Semeniuk (1999).

The mangrove systems of the Yannarie Solar Project area are therefore considered to be regionally significant and to have very high conservation value.

3.4 IMPACT ASSESSMENT AND MITIGATION

3.4.1 Environmental aspects and potential impacts

The activities or aspects of the proposal that may potentially affect cultural heritage and conservation values include:

1. Aboriginal heritage:

- **ground disturbance** impacts on Aboriginal heritage and cultural values

2. Conservation values:

- **dredging** resulting in direct habitat loss and modification by sediment plumes (Chapter 6, Sections 1 and 2)
- **construction of saltfield infrastructure** affecting the visual amenity of the area
- **barge and ship movements** in the Gulf potentially leading to:
    - vessel avoidance of marine megafauna
    - the introduction of non-indigenous marine species
    - contamination from anti-foulants (Chapter 6, Section 3).

3.4.2 Assessment and management – Aboriginal heritage

Ground disturbance

The study area is subject to two registered Native Title claims and has a number of identified Aboriginal archaeological sites and isolated artefacts.

Aboriginal archaeological sites identified during the combined surveys have been recorded. Where possible, disturbance to identified sites will be avoided, however should it be necessary to disturb a site, the relevant claimant group will be consulted and approval will be obtained from the Department of Indigenous Affairs prior to any disturbance occurring. This may require further detailed archaeological recording at identified sites.

To assist with this process, an Aboriginal Site Management Plan (ASMP) will be prepared and implemented that outlines the processes and procedures for managing Aboriginal heritage sites identified during this survey, as well as inadvertent discovery of additional sites during site based works.

3.4.3 Assessment and management – Conservation values

The potential impacts on conservation values from dredging and barge or ship movements have been addressed in previous chapters of this document and therefore are not considered further. The potential visual impact of the project has been significantly reduced through the location of the salt production infrastructure behind mangroves on the salt flats. The majority of the project infrastructure will be located behind the mangroves, between 4 and 5 km inland from the coast. Here the project is

mostly low lying and except for the top of the salt stockpile, and associated infrastructure, will not be visible from the ocean. There will also be some infrastructure visible on Hope Point from the nearshore waters.

3.5 MONITORING AND ASSESSMENT OF PERFORMANCE

As outlined in previous chapters, monitoring of the marine environment will be conducted to ensure appropriate management of the environment, thus protecting the conservation values of the area. Such monitoring includes water quality, water quantity and flora and fauna monitoring (Volume 2).

Monitoring of Aboriginal sites can be undertaken and any new sites identified by additional surveys will be placed on a register of sites.

The monitoring program for Aboriginal sites will be addressed in detail in the Aboriginal Sites Management Plan.

3.6 PROPONENTS COMMITMENTS

Refer also to commitments for environmental factors of marine and commercial fishing and recreation which require the:

- preparation and implementation of a Marine Management Plan which addresses measures to manage impacts on marine macrofauna from vessel movements, introduction of NIMS, anti-foulants, oil spills and seawater pumping
- preparation and implementation of a Dredging Management Plan that will address measures to manage affects on marine macrofauna from dredging.

1. An Aboriginal Sites Management Plan (ASMP) will be prepared, implemented and reviewed in consultation with the relevant authorities. The Plan will include;
    - developing and implementing heritage and culture awareness programs for employees and contractors
    - prior to any disturbance of identified Archaeological sites, traditional owners will be consulted and consent under Section 18 of the *Aboriginal Heritage Act 1972* will be obtained.

3.7 ENVIRONMENTAL OUTCOME

The implementation of the project will avoid disturbance to Aboriginal sites but where this is not possible approval will be obtained from the Minister for Indigenous Affairs. There are no identified European heritage sites affected by the project.

The conservation values of Exmouth Gulf and the adjoining area will not be significantly affected by the project because:

- there will be no discharge of bitterns
- the design of the project results in only a small loss of mangrove (which will be offset) and other benthic primary producer habitat leading to minimal impact on ecological processes
- there will not be a significant impact on marine fauna.

The Yannarie Solar project will meet the EPA objectives for avoiding or minimising impacts on Aboriginal sites and conservation values. The project will also meet the EPA objective to maintain the integrity, ecological functions and environmental values associated with Exmouth Gulf, the intertidal zone and adjacent hinterland.

Aboriginal archaeological sites identified during the combined surveys have been recorded. Implementation of the Aboriginal Sites Management Plan will ensure the EPA objectives are met.

4 REFERENCES

AAM Hatch 2004, Straits Resources Hope Point. Proposed Salt Processing Plant, Exmouth Gulf WA. Hydrographic and Geophysical Surveys. Report to Straits Resources Pty Ltd.

Actis, 2005 *Bitterns Ecotoxicology Study*. Report prepared for Straits Salt Pty Ltd, August 2005.

Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) & Australia and New Zealand Environment and Conservation Council (ANZECC) 1996, *National Principles for the Provision of Water for Ecosystems*, Commonwealth of Australia.

Archae-Aus 2005, *A report of an Aboriginal Archaeological Heritage Assessment of the Straits Resources proposed Yannarie Salt project northern field Boundary, Giralia Gulf, Western Australia.*

Asia Pacific Applied Science Associates (APASA) 2005a, *Yannarie Salt Project Phase 1 Progress Report Regional-scale hydrodynamic modelling of Exmouth Gulf*, report to Straits Salt Pty Ltd, April 2005.

Asia Pacific Applied Science Associates (APASA) 2005b, *Yannarie Salt Project Phase 2 Regional-scale circulation of Exmouth Gulf*, report to Straits Salt Pty Ltd, October 2005.

Asia Pacific Applied Science Associates (APASA) 2006, *Quantification of mixing zones for proposed discharge of salt bitterns*, report to Straits Salt Pty Ltd. January 2006.

Australia and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, *Australian and New Zealand guidelines for fresh and marine water quality*.

Australia and New Zealand Environment and Conservation Council (ANZECC) and Agriculture and Resource Management Council of Australia and New Zealand (ARMCANZ) 2000, Water Provisons.

Australia and New Zealand Environment and Conservation Council (ANZECC) 1998, *Towards Sustainability: Achieving Cleaner Production in Australia*.

Australian and New Zealand Environment and Conservation Council (ANZECC 2000), *Code of Practice for anti-fouling and in-water hull cleaning and maintenance*.

Australian Bureau of Statistics 2001, Census data, www.abs.gov.au/websitedbs/d3310114.nsf/Home/Home?OpenDocument.

Australian Greenhouse Office (AGO) 2004, *AGO Factors and Methods Workbook*, Australian Greenhouse Office, Department of Environment and Heritage.

Australian Greenhouse Office (AGO) 2004, *National Greenhouse Gas Inventory*, Australian Greenhouse Office, Department of Environment and Heritage.

Ayukai T and Miller D 1998, 'Phytoplankton biomass, production and grazing mortality in Exmouth gulf, a shallow embayment on arid, tropical coast of Western Australia', *Journal of Experimental Marine Biology and Ecology*, vol. 225, pp. 239-251.

Baharthah T & Sumner N R 2002, *Community survey 2003*, Department of Fisheries, Western Australia.

Bamford M and Biota Environmental Sciences (Biota) 2005, *Gorgon Gas Development on Barrow Island, Migratory Wader Assessment*, unpublished report prepared for Gorgon Gas Australia, Perth.

Bannister J L and Hedley S L 2001, Southern Hemisphere Group IV humpback whales: their status from recent aerial survey, *Memoirs of the Queensland Museum* vol. 7, no. 2, pp. 587-598, Brisbane.

Bannister J L, Kemper C M and Warneke R M 1996, *The Action Plan for Australian Cetaceans*, Australian Nature Conservation Society, September 1996.

Baseggio G 1974, 'The Composition of Sea Water and Its Concentrates', in A M Coogan (Ed.) *Fourth Symposium on Salt. Northern Ohio Geological Society, Cleveland, Ohio*, pp. 351-358.

Beard J S 1975, *Vegetation survey of Western Australia, 1:100,000 Vegetation series, Mapsheet 5 – Pilbara*, University of Western Australia Press, Perth.

Beaumont N & Hadley D 2004, *Managing the effects of trawl fishing on the benthic environment: a management manual*, an output of the COST-IMPACT Project: Costing the impact f dimersal fishing on marine ecosystem processes and biodiversity.

Biota Environmental Sciences (Biota) 2006a, *Fauna Habitats and Fauna Assemablage of the Mesa A Transport Corridor and Warramboo*, report prepared for Robe River Iron Associates, January 2006.

Biota Environmental Sciences Pty Ltd (Biota) 2006b, *Perth – Bunbury Highway (Peel Deviation Section) Targeted Threatened Fauna Survey*, Prepared by R E & C Johnstone and T Kirby of Biota Environmental Sciences Pty Ltd for Main Roads Western Australia, April 2006.

Biota Environmental Sciences (Biota) 2005a, *Yannarie Salt Project: Flora and vegetation assessment – Baseline Botanical Survey*, unpublished report prepared for Straits Salt Pty Ltd.

Biota Environmental Sciences (Biota) 2005b, *Straits Salt Project: Fauna and fauna assemblages survey*, unpublished report prepared for Straits Salt Pty Ltd.

Biota Environmental Sciences (Biota) 2005c, Onslow Solar Saltfield Annual Environmental Report 2003-2004, unpublished report prepared for Onslow salt Pty Ltd.

Biota Environmental Sciences (Biota) 2005d, *Yannarie Salt Project: Mangrove and Coastal Ecosystem Study–Baseline Ecological Assessment*, unpublished report to Straits Salt Pty Ltd, October 2005.

Biota Environmental Sciences (Biota) 2004, Mesa A and Bungaroo Creek Subterranean Fauna Survey, unpublished report prepared for Robe River Iron Associates.

Biota Environmental Sciences (Biota) 2003, *Onslow Solar Saltfield Annual Environmental Report 2002-2003*, unpublished report prepared for Onslow Salt Pty Ltd.

Biota Environmental Sciences (Biota) 2002a, Exmouth Limestone Troglobitic Fauna Sampling Stage III, unpublished report prepared for Exmouth Limestone Pty Ltd, Perth.

Biota Environmental Sciences (Biota) 2002b, Onslow Solar Saltfield Annual Environmental Report 2001-2002, unpublished report prepared for Onslow Salt Pty Ltd.

Brown G 2004, *The Australian Pearling Industry and its Pearls*, [Online], The Gemmological Association of Australia, Available from: <http://www.gem.org.au/gallery/pearl.htm> [18 January 2005].

Bruce B D 1995, 'The Protection of White Shark – A Research Perspective', *Southern Fisheries*, vol. 3, no. 2, pp. 11-15.

Brunskill G J, Orpin A R, Zagorskis I, Woolfe K J and Ellison J 2001, 'Geochemistry and particle size of surface sediments of Exmouth Gulf, Northwest Shelf, Australia', *Continental Shelf Research*, vol. 21, pp. 157–201.

Bruun P 1962, 'Sea-level rise as a cause of shore erosion', *Journal of the Waterways and Harbours Division*, ASCE, 80 (WWI): 117-130.

Burbridge A A 2004, *Threatened Animals of Western Australia*, Department of Conservation and Land Management, Perth.

Bureau of Meterorology 2004a, *Averages for Learmonth Aiport*, Available at http://www.bom.gov.au/climate/averages/tables/cw_005007.shtml.

Cahoon D R & Lynch J C 1997, 'Vertical accretion and shallow subsidence in a mangrove forest of southwestern Florida, USA', *Mangroves and Salt Marshes*, 1: 173-186.

Cardno Lawson Treloar 2005, Storm tide and wave climate investigation, Exmouth Gulf Solar Salt Project.

Centre for Water Research 2004, University of Western Australia, 2004

Centre for Whale Research 2005, *Final Report: Distribution and abundance of humpback whales and other mega-fauna in Exmouth Gulf, Western Australia during 2004/2005*, report prepared for Straits Salt Pty Ltd, 18 November 2005.

Centre for Whale Research 2004a, *Current State of Knowledge: Humpback Whale* (Megaptera novaeangliae) *Survey Report for Exmouth Gulf 1995-2004*, report to Straits Salt Pty Ltd, November 2004.

Centre for Whale Research 2004b, *Final distribution and abundance of Humpback whales and other megafauna in Exmouth Gulf, Western Australia, during 2004/2005*.

Chittleborough R G 1965, 'Dynamics of two populations of the Humpback Wahle, Megaptera novaeangliae (Borowski)', *Australian Journal of Marine and Freshwater Research*, 4.

Chittleborough R G 1953, 'Aerial observations on the humpback whale, *Megaptera nodosa* (Bonnaterre), with notes on other species', *Australian Journal of Marine and Freshwater Research*, vol. 4.

Churchill S K 1998, *Australian Bats*, New Holland Publishers (Australia) Pty Ltd, Sydney, NSW.

Clarke P J 1995, 'The population dynamics of the mangrove shrub *Aegiceras corniculatum* (myrsinaceae): Fecundity, dispersal, establishment and population structure', Proc. *Linn. Soc. N. S. W*., 115: 35-44.

Clarke P J and Allaway W G 1993, 'The regeneration niche of the grey mangrove (*Avicennia marina*): effects of salinity, light and sediment factors on establishment, growth and survival in the field', *Oceanica*, 93: 548-556.

Clarke P J and Eliot I G 1983, 'Mean sea-level variations and beach width fluctuation at Scarborough, Western Australia', *Marine Geology*, 51: 251-267.

Clarke P J and Eliot I G 1987, 'Groundwater-level changes in a coastal dune, sea-level fluctuation and shoreline movement on a sandy beach', *Marine Geology*, 77: 319-326.

Clark S A and Richardson B J 2002, 'Spatial analysis of genetic variation as a rapid assessment tool in conservation management of narrow-range endemics', *Invertebrate Systematics*, 16:583-587.

Cogger H G, Cameron E E, Sadlier R A and Eggler P 1993, *The Action Plan for Australian Reptiles*, Endangered Species Unit, Australian Nature Conservation Agency, Project 124, December 1993.

Commonwealth of Australia 2002, *National Ocean Disposal Guidelines for Dredge Material*, Canberra.

Commonwealth of Australia 1998, *Australia's Oceans Policy*, Environment Australia, Canberra.

Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2005, *CSIRO Research in the Northern Prawn Fishery*, [Online], CSIRO, Available from: http://www.marine.csiro.au/media/05releases/24jun05-bgmod.html [7 August 2006].

Commonwealth Scientific and Industrial Research Organisation (CSIRO) 2004, *Desktop Investigation of the Economic Potential of Bitterns from Exmouth Gulf (WA)*, DMR-2563, CSIRO Minerals Minerals, November 2004.

Cox R J and Horton P R 1999, *Implications of Climate Change on Coastal Management*, COPEDEC V, p. 568-579.

Dampier Salt Limited 2006, *Port Hedland Efficiency Project*.

D.C. Blandford & Associates Pty. Ltd. and Oceanica Consulting Pty Ltd, 2005 *Physical Environment of the Yannarie Salt Project area*. Report produced for Straits Salt Pty Ltd, Report No. 391/3, August 2005.

Department of Conservation and Land Management (CALM) 2005, Management Plan for the Ningaloo Marine Park and Muiron Islands Marine Management Area 2005 – 2015, Management Plan Number 52.

Department of Conservation and Land Management (CALM) 2004a, http://www.calm.wa.gov.au/news/news.cgi?item=1101947178, accessed 14/2/2005.

Department of Conservation and Land Management (CALM) 2003, Marine Community Monitoring Manual Part II (A) Methods (Biological) Chapter 9 Introduced Marine Pests, http://www.calm.wa.gov.au/national_parks/marine/mcmp/manual_contents.html.

Department of Conservation and Land Management (CALM) 2002, *A Biodiversity Audit of Western Australia's 53 Biogeographical Subregions in 2002*, Department of Conservation and Land Management, Perth.

Department of Conservation and Land Management (CALM) 1994, *A representative marine reserve system for Western Australia*, report of the Marine Parks and Reserves Selection Working Group.

Department of Defence 2002, *Australian National Tide Tables 2002*, Australian Hydrographic Publication 11.

Department of Environment (DoE) 2006, *Pilbara Coastal Water Quality Consultation Outcomes: Environmental Values and Environmental Quality Objectives, MR1*, Department of Environment, Western Australia.

Department of Environment (DoE) 2004, *Identification and Investigation of Acid Sulphate Soils – Acid Sulphate Soil Guideline Series*, Department of Environment, Perth, Western Australia.

Department of Environment and Conservation (DEC) 2006, *General explanatory notes on the Waste Avoidance and Recovery Bill*.

Department of Environment and Heritage 2004, *About Ramsar Wetlands*, http://www.deh.gov.au/water/wetlands/ramsar/about.html.

Department of Environment and Heritage 2002, *Assessment of the Exmouth Gulf Prawn Fishery: Part 2*, Department of Environment and Heritage.

Department of Environmental Protection 1996

Department of Fisheries 2005, *Exmouth Gulf fish species*, list of fish species reported by the Department of Fisheries, July 2005.

Department of Fisheries 2004, *Draft Aquaculture Plan for Exmouth Gulf*, Fisheries Management Paper No. 172, Department of Fisheries, Western Australia.

Department of Fisheries 2003, *State of the Fisheries Report 2002/2003*, Department of Fisheries, Western Australia.

Department of Fisheries 2002, *Application to Environment Australia on the Exmouth Gulf Prawn Fishery*, Department of Fisheries, April 2002.

Department of Local Government and Regional Development

Department of Planning and Infrastructure 2003

Department of the Environment, Sport and Territories 1996, *National Strategy for the Conservation of Australia's Biological Diveristy*, endorsed by the Council of Australian Government (COAG).

Dickman C R and Braithwaite R W 1992, Postmating mortality of males in the dasyurid marsupials, Dasyurus and Parantechinus, *Journal of Mammalogy*, vol. 73, pp. 143-147.

Duncan A, Baker G B and Montgomery N (Eds) 1999, *The Action Plan for Australian Bats*, with assistance from the Editorial Panel Biodiveristy Group Environment Australia.

Ecologically Sustainable Development Steering Committee 1992, *National Strategy for Ecologically Sustainable Development*, endorsed by the Council of Australian Government.

Edmonds J S, Shibata Y, Prince R I T, Preen A R and Morita M 1997, Elemental composition of a tusk of a dugong, *Dugong dugon*, from Exmouth, Western Australia, *Marine Biology*, vol. 129, pp. 203-214.

Environment Australia 2000, *IBRA 5.1 Update*, http://www.deh.gov.au/parks/nrs/ibra/version5-1/summary-report/index.html.

Environment Australia 2001, *Directory of Important Wetlands in Australia* (3rd ed.), Environment Australia, Canberra.

Environment Australia 2001, *National objectives and targets for biodiversity conservation 2001-2005*, http://www.deh.gov.au/biodiversity/publications/objectives/forword.html.

Environment Australia 2002a, *White Shark (Carcharodon carcharias) Recovery Plan 2002*, Marine Conservation Branch, Environment Australia, Canberra.

Environment Australia 2002b, *Assessment of the Exmouth Gulf Prawn Fishery: assessment of the ecological sustainability of management arrangements*, Environment Australia – Marine and Water Division.

Environmental Protection Authority (EPA) 2006a, *Draft State of the Environment Report, Western Australia*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2006b, *Position Statement No. 9: Environmental Offsets*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2006c, *Guidance Statement No. 6: Rehabilitation of terrestrial ecosystems*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2005a, *Revised Environmental Quality Reference Document for Cockburn Sound*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2005b, *Position Statement No. 8: Environmental Protection in Natural Resource Management*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2004a, *Guidance Statement No. 29: Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment*. EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2004c, *Guidance Statement No. 56: Terrestrial fauna surveys for environmental impact assessment in Western Australia*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2004d, *Position Statement No. 4: Environmental protection of wetlands*, EPA, Perth, Western Australia.

Environmental protection Authority (EPA) 2004e, *Guidance Statement No. 41: Assessment of Aboriginal Heritage*, EPA, Perth, Western Australia.

Environmental protection Authority (EPA) 2004f, *Position Statement No. 5: Environmental Protection and Ecological Sustainability of the Rangelands in Western Australia*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2003, *Guidance Statement No. 54: Consideration of Subterranean Fauna in Groundwater and Caves during Environmental Impact Assessment in Western Australia*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2003, *Guidance Statement No. 51: Terrestrial Flora and Vegetation Surveys for Environmental Impact Assessment in Western Australia*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2002a, *Guidance Statement No. 12: Guidance Statement for Minimising Greenhouse Gas Emissions*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2002b, *Position Statement No. 3: Terrestrial Biological Surveys as an Element of Biodiversity Protection*, EPA, Perth, Western Australia.

Environment Protection Authority (EPA) 2001, *Guidance Statement No. 1: Tropical Arid Zone Mangroves*, EPA, Perth, Western Australia.

Environmental Protection Authority (EPA) 2000, *EPA Position Statement No. 2, Environmental Protection of Native Vegetation in Western Australia*, EPA, Perth, Western Australia.

Finlayson B L and McMahon T A 1988, 'Australia v. the World: a comparative analysis of streamflow characteristics', In: Warner R F (Ed.) *Fluvial geomorphology of Australia*, Academic Press, pp. 17-40.

Flannery T 1990, The Bilby *Macrotis lagotis*, in: *Australia's Vanishing Mammals: Endangered and Extinct Native Species*, WWF Press.

Gales N, McCauley R D, Lanyon J and Holley D 2004, Change in abundance of dugongs in Shark Bay, Ningaloo and Exmouth Gulf, Western Australia: evidence for large-scale migration, *Wildlife Research*, vol. 31, pp. 283-290.

Garnett S T and Crowley G M 2000, *The action plan for Australian birds 2000*, Environment Australia, Canberra.

Gordon D M. 1988, 'Disturbance to mangroves in tropical-arid Western Australia: hypersalinity and restricted tidal exchanged as factors leading to mortality', *Journal of Arid Environments*, vol. 15, pp. 117-145.

Government of Western Australia 2000, *State Water Quality Management Strategy: Objectives, principles, strategies and implementation framework*, Government of Western Australia.

Government of Western Australia 2000b, *Bush Forever Volume 2: Directory of Bush Forever Sites*, Department of Environmental Protection.

Government of Western Australia 2003, *Hope for the future: The Western Australian State Sustainability Strategy*, Department of the Premier and Cabinet, Perth.

Harvey M S 2002, 'Short-range endemism among Australian fauna: some examples from non-marine environments', *Invertebrate Systematics*, vol. 16, pp. 555-570.

Harvey M S 1988, 'A new troglobitic schizomid from Cape Range, Western Australia (Chelicerata: Schizomida)', Records of the Western Australian Museum, vol. 14, no. 1, pp. 15-20.

Hayes K, Sliwa C, Migus S, McEnnulty F and Dunstan P 2004, *National priority pests: Part II Ranking of Australian marine pests*, an independent report undertaken for the Department of Environment and Heritage, CSIRO Marine Research, Hobart, Tasmania.

Hewitt C L and Martin R B 1996, *Port surveys for introduced marine species - background considerations and sampling protocols*, Centre for Research on Introduced Marine Pests, CSIRO Marine Research, Technical Report No. 4, Hobart, Australia, 1-40 pp.

Hewitt C L and Martin R B 2001, *Revised protocols for baseline port surveys for introduced marine species: survey design, sampling protocols and specimen handling*, Centre for Research on Introduced Marine Pests, CSIRO Marine Research, Technical Report No. 22, Hobart, Australia, 52 pp.

Higgins P J 1999, *Handbook of Australian, New Zealand and Antarctic Birds, Volume 4: Parrots to Dollarbird*, Oxford Univeristy Preass, Melbourne.

Huffman B 2006, An ultimate ungulate fact sheet *Dugong dugon*, [Online], Available: http://www.ultimateungulate.com/Sirenia/Dugong_dugon.html.

Humphreys W F 2001, 'The subterranean fauna of Barrow Island (Northwestern Australia)', Memoires de Biospeologie (International Journal of Subterranean Biology), vol. 28.

Humphreys W F 2000, 'Background and glossary', in Wilkens H, Culver D C and Humphreys W F (eds) *Subterranean Ecosystems, Ecosystems of the World 30*, Elsevier: Amsterdam.

Humphreys W F 1999, 'Relict stygofaunas living in sea salt, karst and calcrete habitats in arid northwestern Australia contain many ancient lineages', in: *The other 99%. The conservation and biodiversity of invertebrates*, W Ponder and D Lunney (eds.), Transactions of the Royal Zoological Society of New South Wales, Mosman, pp.219-227.

Humphreys W F 1993, 'Cave Fauna in Semi-Arid Tropical Western Australia: A diverse relict wet-forest litter fauna', Memoires de Biospeologie (International Journal of Subterranean Biology), pp. 105-110.

Humphreys W F and Shear W A 1993, 'Troglobitic Millipedes (Diplopoda, Paradoxosomatidae) from semi-arid Cape Range, Western Australia: systematics and biology', *Invertebrate Taxonomy* vol. 7, pp. 173-195.

Hutchins J B, Slacksmith S M, Bryce C W, Morrison S M and Hewitt M A 1996, *Marine Biological Survey of the Muiron Islands and the Eastern Shore of Exmouth Gulf, Western Australia*, WA Museum Report for the Ocean Rescue 2000 Program (Project Number G012/94), February 1996.

Interim Marine and Coastal Regionalisation for Australia Technical Group 1998, *The Interim Marine and Coastal Regionalisation for Australia – An ecosystem-based classification for marine and coastal environments*, Version 3.3, Environment Australia and Commonwealth Department of Environment, Canberra.

International Maritime Organisation 2002, International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78), [Online], Available at: http://www.imo.org/Conventions/contents.asp?doc_id=678&topic_id=258#2, [8 August 2006].

International Risk Consultants 2006, *Yannarie Salt Project Environmental Risk Assessment Workshop*.

Jenner K C S, Jenner M-N M and McCabe 2001, 'Geographical and temporal movements of humpback whales in Western Australian waters', *APPEA Journal* 2001, pp. 749-765.

Jennings J N and J A Mabbutt 1986, 'Physiographic outlines and regions', in: Australia: *A Geography, Volume One, The Natural Environment* (DN Jeans Ed).

Kaiser M J, Collie J S, Hall S J, Jennings S and Poiner R 2002, 'Modification of marine habitats by trawling activities: prognosis and solutions', *Fish and Fisheries*, 3: 114-135.

Lanyon J M, Limpus C J and Marsh H 1989, 'Dugongs and turtles: grazers in the seagrass system in Biology of Seagrasses: A Treatise on the Biology of seagrasses with special reference to the Australian Region', *Aquatic Plant Studies*, vol. 2.

Lanyon J M and Marsh H 1995, 'Temporal changes in the abundance of some tropical intertidal seagrasses in North Queensland', *Aquatic Botany*, vol. 49, pp. 217-237.

LeProvost Dames and Moore 2000, Ningaloo Marine Park (Commonwealth Waters) Literature Review, LeProvost Dames & Moore, Perth.

Limpus C 1995, Global overview of the status of marine turtles: a 1995 viewpoint, in: Bjorndal K A (ed.), *Biology and Conservation of Sea Turtles*, revised edition, Smithsonian Institution Press, Washington.

Limpus C J 1971, 'The flatback turtle, Chelonia depressa garman in southeast Queensland, Australia', *Herpetologica*, vol. 27, pp. 431-446.

Limpus C J, Fleay A and Baker V 1984, 'Further observations on breeding of *Dermochelys coriacea* in Australia', *Australian Wildlife Research*, vol. 11, pp. 567-571.

Loneragan N R, Kenyon R A, Crocos P J, Ward R D, Lehnert S, Haywood M D E, Arnold S, Barbard R, Burford M, Caputi N, Kangas M, Manson F, McCulloch R, Penn J W, Sellers M, Grewe P, Ye

Y, Harch B, Barvington M, and Toscas P 2003, *Developing techniques for enhancing prawn fisheries, with a focus on brown tiger prawns* (*Penaeus esculentus*) *in Exmouth Gulf*, Final Report on FRDC Project 1999/222, CSIRO, Cleveland, pp.287.

Marine Bio 2006, [On-line], *Neophoca cinerea Australian Sea Lion*, Avavilable From: http://www.marinebio.com/species.asp?id=267, Accessed 10 August 2006.

Marine Parks and Reserves Selection Working Group 1994, *A Representative Marine Reserve System for Western Australia*, Department of Conservation and Land Management, Perth.

Marmonier P, Vervier P, Gibert J and Dole-Olivier M J 1993, 'Biodiversity in groundwaters', *TREE*, vol. 8, no. 11, pp. 392-395.

Marsh H, Penrose H, Eros C and Hugues J 2002, *The Dugong (Dugong dugon) Status Reports and Action Plans for Countries and Territories*, UNEP Early Warning and Assessment Report Series 1, Nairobi, Kenya.

Massel S R, Brinkman R M, Mason L and Bode L 1997, 'Water circulation and waves in Exmouth Gulf', in Love P K (ed.), *Proceedings of the Australian Physical Oceanography Conference (10–12 February 1997)*, Macquarie University, Sydney, p.48.

Maxwell S, Burbidge A A & Morris K 1996, *The 1996 Action Plan for Australian Marsupials and Monotremes*.

McCauley R D and Maggi A 2005, *Yannarie Salt Project: Modelled Underwater Noise In Exmouth Gulf From Proposed Yannarie Marine Activities*, report to Straits Salt Pty Ltd by Centre for Marine Science and Technology (CMST), Curtin University, September 2005.

McCook L J, Klumpp D W and McKinnon A D 1995, 'Seagrass communities in Exmouth Gulf, Western Australia: a preliminary survey', *Journal of the Royal Society of Western Australia*, vol. 78, pp. 81-87.

McKinnon D and Ayukai T 1996, 'Copepod egg production and food resources in Exmouth Gulf, Western Australia', *Marine and Freshwater Research*, vol. 47, pp. 595–603.

Meekan M J, Carleton J H, McKinnon A D, Flynn K and Furnas M 2003, 'What determines the growth of the tropical reef fish larvae in the plankton: food or temperature?', *Mar Ecol Prog Serv*, vol. 256, pp. 193-204.

Molony B W and Parry G 2002, 'Preliminary assessment and seasonal fluctuations in the fish biota inhabiting the concentrator ponds of Dampier Salt, Port Hedland, with options for the potential application of results', *Fisheries Research Report No. 133*, Department of Fisheries, Western Australia, p. 54.

Morse K and Wright G 1989, *An archaeological and ethnographic surveyof the proposed Coral Coast development area, Point Maud, Western Australia*, report prepared for Coral Coast Marina Development Pty Ltd.

M. P. Rogers and Associates 2005, *Yannarie Salt Project: Environmental edge effects of pond bunds*.

National Native Title Tribunal Register 2004, [On-line], Available from http://www.nntt.gov.au/registers/

Nott J and G Hubbert 2003, Comparisons between topographically surveyed debris lines and modelled inundation levels from severe Tropical Cyclones Vance and Chris, and their geographic impact on the sand coast, *Australian Meteorological Magazine*.

Oakwood M 2000, Reproduction and demography of the northern quoll, *Dasyurus hallucatus*, in the lowland savanna of northern Australia, *Australian Journal of Zoology*, vol. 48, pp. 519-539.

Oakwood M 1997, *The ecology of the northern quoll Dasyurus hallucatus*, PhD Thesis, Australian National University.

Oceanica Consulting Pty Ltd 2006a, *Yannarie Salt Project: Marine and coastal environment of eastern Exmouth Gulf, Report No. 391/3, Volume I: Report and Volume II: Appendices*, report prepared by Oceanica Consulting Pty Ltd. for Straits Salt Pty Ltd, February 2006.

Oceanica Consulting Pty Ltd 2006b, *Eastern Exmouth Gulf Benthic Macrofauna Assemblages Data Report*, report prepared by Oceanica Consulting Pty Ltd. for Straits Salt Pty Ltd, February 2006.

Oceanica Consulting Pty Ltd 2005a, *Yannarie Salt Project – Benthic Habitat Mapping: Image Analysis*, report prepared by Oceanica Consulting Pty Ltd. for Straits Salt Pty Ltd, May 2005

Oceanica Consulting Pty Ltd 2005b, *Yannarie Salt Project – Exmouth Gulf Fisheries and Aquaculture: Potential Impacts and Management*, report prepared by Oceanica Consulting Pty Ltd. for Straits Salt Pty Ltd, August 2005.

Oceanica Consulting Pty Ltd 2005d, *Yannarie Salt Project, Non-indigenous Marine Species: Assessment of the risk of introduction and potential management measures*, report prepared for Straits Salt Pty Ltd, October 2005.

Oceanwise Environmental Scientists (Oceanwise) 2005, *The Dugong (Dugong dugon) of Exmouth Gulf, Western Australia*, report prepared for Straits Salt Pty Ltd, December 2005.

Paling E I and Kobryn H 2005, *Assessing the extent of mangrove change caused by Cyclone Vance in the eastern Exmouth Gulf*, Marine and Freshwater Research Laboratory Environmental Science.

Paling E I, Kobryn H and Humphreys G 2005, *Assessing the extent of mangrove change caused by Cyclone Vance in the eastern Exmouth Gulf*, unpublished report prepared for Straits Salt Pty Ltd.

Paling E I and McComb A J 1994, 'Cyanobacterial Mats: A Possible Nitrogen Source for Arid-Coast Mangroves', *International Journal of Ecology and Environmental Sciences*, vol. 20, pp. 47-54.

Paling E I, McComb A J and Pate J S 1989, 'Nitrogen Fixation (Acetylene Reduction) in Nonheterocystous Cyanobacterial Mats from the Dampier Archipelago, Western Australia', *Australian Journal of Marine and Freshwater Research*, vol, 40, pp. 147-153.

Paling E I, Humphries G & McCardle 2003, 'The effect of a harbour development on mangroves in northwestern Australia', *Wetlands Ecology and Management*, 11:5, p. 281-290.

Parsons Brinkerhoff 2006a, *Groundwater supply options – Yannarie Salt Project*, report to Straits Salt Pty Ltd.

Parsons Brinkerhoff 2006b, *Surface Hydrology for the Yannarie Salt Project*, unpublished report prepared for Straits Salt Pty Ltd.

Parsons Brinkerhoff 2005a, *Surface hydrology for Yannarie Salt Project – Supporting information for application for a clearing permit*.

Parsons Brinckerhoff 2005b, *Superficial Aquifer Hydrogeology of the Yannarie River Delta*, report prepared for Straits Salt Pty Ltd, July 2005.

Parsons Brinkerhoff 2005c, *Exmouth Straits Solar Salt Project – Construction Materials*, report prepared for Straits Salt Pty Ltd.

Parsons Brinckerhoff 2005h, *Straits Ecotoxicity Project, Direct Toxicity Assessment of Bitterns Using Resident Species*, report prepared for Straits Salt Pty Ltd, September 2005.

Parsons Brinkerhoff 2005n, Acid sulphate soil management plan (Construction), EMP prepared for Straits Salt Pty Ltd, September 2005.

Payne A L, Mitchell A A and Holman W F 1988, 'An inventory and condition survey of rangelands in the Ashburton River catchment', *Western Australian Department of Agriculture Technical Bulletin*, No. 62, 1988.

Ponder W F & Colgan D J 2002, 'What makes a narrow-range taxon? Insights from Australian freshwater snails', *Invertebrate Systematics*, vol. 16, pp. 571-582.

Preen A R 2001, *Dugongs, boats, dolphins and turtles in the Townsville-Cardwell Regiona and recommendations for a Boat Traffic Management Plan for the Hinchbrook Dugong Protection Area*, Research Publication No. 67, Great Barrier Reef Marine Park Authority, Townsville.

Preen A R, Marsh H, Lawler I R, Prince R I T and Shepherd R 1997, 'Distribution and Abundance of Dugongs, Turtles, Dolphins and Other Megafauna in Shark Bay, Ningaloo Reef and Exmouth Gulf, Western Australia', *Wildlife Research*, vol. 24, no. 2, pp. 185-208.

Prince R I T 1994, Update: Sea turtles in Western Australia, *Marine Turtle Newsletter*, no. 64, pp18-19.

Prince R I T, Anderson P K and Blackman D 1981, Status and distribution of dugongs in Western Australia, In: Marsh H (ed), *The Dugong: Proceedings of a Seminar/Workshop held at James Cook University*, Australia, 8-13 May 1979, pp. 67-87, James Cook University Press, Townsville.

Prince R I T, Lawler I R and Marsh H D 2001, *The distribution and abundance of dugongs and other megavertebrates in Western Australian coastal waters extending seaward to the 20 metre isobath between North West Cape and the De Grey River mouth, Western Australia*, Report for Environment Australia, April 2000.

Q & A Communications 2005, *Straits Salt Project: Social Impact Assessment*, report to Straits Salt Pty Ltd, April 2005.

Rester J K 2000, *Annotated bibliography of fishing impacts on habitat*, Gulf States Marine Fisheries Commission, No. 73.

Robertson A I 1991, 'Plant-animal interactions and the structure and function of tropical mangrove systems', *Aust. J. Ecol.*, vol. 16, pp. 433-443.

Robertson A I & Alongi D M 1995, 'Mangrove systems in Australia: structure function and status', *Great Barrier Reef Marine Park Authority State of the Marine Environment Report for Australia*, Department of the Environment, Sports and Territories, Canberra.

Robertson A I & Duke N C 1987, 'Mangroves as nursery sites: comparisons of the abundance and species composition of fish and crustaceans in mangroves and other nearshore habitats in tropical Aistralia', *Marine Biology*, 96: 193-205.

Robins J B 1995, 'Estimated catch and mortality of sea turtles from the East Coast Otter Trawl Fishery of Queensland, Australia', *Biological Conservation*, vol. 74, pp. 157-167.

RPS Bowman Bishaw Gorham Pty Ltd 2004, The Marine and Intertidal Environments of Exmouth Gulf, with Reference to Human Usage, report prepared for Straits Resources Ltd.

Semeniuk V 1983, 'Mangrove distribution in Northwestern Australia in relationship to regional and local freshwater seepage', *Vegetation*, vol. 53, pp. 11-31.

Semeniuk V 1993a, 'The Pilbara Coast: A riverine coastal plain in a tropical arid setting, northwestern Australia', *Sedimentary Geology*, vol. 83, pp. 235–256.

Semeniuk V C 1999, *Selection of Mangrove Stands for Conservation in the Pilbara Region of Western Australia*, unpublished report for the Environmental Protection Authority, Perth.

Semeniuk V, Kenneally J F and Wilson P G 1978, *Mangroves of Western Australia*, Handbook No. 12, Western Australian Naturalists Club, Perth.

Shaughnessy P D 1999, *The action plan for Australian seals*, CSIRO Wildlife and Ecology.

Shaw J 2000, *Fisheries Environmental Management Review: Gascoyne Region*, Fisheries Environmental Management Review No. 1, Fisheries WA, Western Australia.

Spring C S 1982, 'Tag recovery supports satellite tracking of green turtle', *Marine Turtle Newsletter*, no. 82, p.8.

SSJV 2006

Solar Salt Joint Venture (SSJV) 2005, *Straits Salt Project – Exmouth Yannarie Salt elements of levee design and construction methodology*, Report No. SS – 006, report produced for Straits Salt.

Stal L J, Grossberger S and Krumbein W E 1984, 'Nitrogen fixation associated with the cyanobacterial mat of a marine laminated microbial ecosystem', *Marine Biology*, vol. 82, pp. 217-224.

Start A N and McKenzie N L 1992, *Conservation Values of Islands in Exmouth Gulf: A Preliminary Report*, unpublished internal report, Department of Conservation and Land Management, Perth, Western Australia.

Stive M J F, Nicholls R J & de Vriend H J 1991, 'Sea-level rise and shore nourishment: a discussion', *Coastal Engineering*, 16: 147-163.

Strategen 2006, Mesa A/Warramboo Iron Ore Project Public Environmental Review, report prepared for Robe River Mining Company Pty Ltd, July 2006.

Storr G M & Hanlon T M S 1980, 'Herpetofauna of the Exmouth region, Western Australia', *Records of the Western Australian Museum*, vol. 8, no. 3, pp. 423-439.

Storr G M & Harold G 1985, 'Herpetofauna of the Onslow region, Western Australia', *Records of the Western Australian Museum*, vol. 12, no. 3, pp. 277-291.

Strayer D L 1994, 'Limits to biological distributions in groundwater', in *Groundwater Ecology*, eds J Gilbert, D L Danielopol & J A Stanford, Academic Press, San Diego, pp. 287-310.

Sumner N R, Williamson P C & Malseed B E 2002, *A 12-month survey of recreational fishing in the Gascoyne Bioregion of Western Australia during 1998-99*, Fisheries Research Report No. 139, Department of Fisheries, Western Australia.

Thackway R and Cresswell I 1995, *An Interim Biogeographic Regionalisation for Australia: a framework for setting priorities in the National Reserves System Cooperative Program*, Version 4, Australian Nature Conservation Agency, Canberra.

Thom B G 1982, 'Mangrove Ecology—A Geomorphological Perspective', in Clough B F 1982 (Ed.) *Mangrove Ecosystems in Australia: Structure, Function and Management, Proceedings of the Australian National Mangrove Workshop*, Australian institute of Marine Science, Canberra.

Thrush S F & Dayton P K 2002, 'Disturbance to marine benthic habitats by trawling and dredging: implications for marine biodiversity', *Annual Review of Ecology and Systematics*, 33: 449-473.

Travers M 2006, Review of life cycles of the major fish and crustacean species that are abundant in Exmouth Gulf, draft report prepared for Oceanica Consulting Pty Ltd, August 2006.

United Nations Environment Programme (UNEP) 1994, *Government strategies and policies for cleaner productions*, United Nations Environment Programme, Paris, France.

UNESCO World Heritage Centre 2005, *Operational Guidelines for the Implementation of the World Heritage Convention*, Intergovernmental Committee for the Protection of the World Cultural and Natural Heritage, February 2005.

Water and Rivers Commission (WRC) 2000, *Statewide Policy No. 5: Environmental Water Provisions Policy for Western Australia*, Water and Rivers Commission.

Wells F E 1983, 'An analysis of marine invertebrate distributions in a mangrove swamp in northwestern Australia', *Bulletin of Marine Science*, vol. 33, pp. 736–744.

Watts C H S and Humphreys W F 1999, 'Three new genera and five species of Dytiscidae (Coleoptera) from underground waters in Australia', *Records of the South Australian Museum*, vol. 32, pp. 121-142.

Western Australian Mercantile Services 2005, *Salt export from Hope Point, Exmouth Gulf, Western Australia – Marine transit and anchorage options study*, report prepared for Parsons Brinkerhoff, April 2005.

Western Australian Museum 2006, Subterranean Fauna Database search, Department of Terrestrial Invertebrates, Western Australian Museum.

Western Australian Museum 2005, FaunaBase vouchered specimens search results, http://www.museum.wa.gov.au/faunabase.html.

Western Australian Planning Commission (WAPC) 2004, *Carnarvon-Ningaloo Coast: Planning for Sustainable Tourism and Land Use*, Western Australian Planning Commission, May 2004.

Western Australian Planning Commission (WAPC) 2003a, *Onslow Structure Plan*, Western Australian Planning Commission, September 2003.

Western Australian Planning Commission (WAPC) 2003b, *Planning Bulletin No. 64: Acid Sulfate Soils*, WAPC, Western Australia.

Western Australian Sustainability Industry Group (WASIG) 2001, *Western Australian Cleaner Production Statement*.

Western Sydney Regional Organisation of Councils (WSROC) 2000, *State of Environment Report*, http://www.wsroc.com.au/report/report/chapt9/intro9.htm.

Wolanski E, Mazda Y & Ridd P 1992, 'Mangrove hydrodynamics', in Robertson A I & Alongi D M (eds.), *Tropical mangrove ecosystems; coastal and estuarine studies*, Number 41, American Geophysical Society, Washington D C, p. 329.

Woo L M and Pattiaratchi C B 2003, *Summer surface circulation on the Gascoyne Continental Shelf*, Oceans 2003 Conference, IEEE OES and the Marine Technology Society, September 26 2003, San Diego, California, 2003.

Woolley 1992

WorleyParsons 2005a, *Model Results to Aid in the Selection of Pump Location in Dean's Creek*, report to Straits Salt Pty Ltd, April 2005.

WorleyParsons 2005b, *Straits Resources Limited: Yannarie Salt Project Hydrodynamic Modelling Mangrove Inundation Analysis—Southern Region*, report to Straits Salt Pty Ltd, October 2005.

WorleyParsons 2005c, *Straits Resources Limited: Yannarie Salt Project Hydrodynamic Modelling Mangrove Inundation Analysis—Northern Region*, report to Straits Salt Pty Ltd, October 2005.

Wyatt A S J, Hewitt C L, Walker D I and Ward T J 2005, 'Marine introductions in the Shark Bay World Heritage Property, Western Australia: a preliminary assessment', *Diversity and Distributions*, vol. 11, pp. 33–44.

Zangerl R, L P Hendrickson and Hendrickson J R 1988, 'A redistribution of the Australian flatback sea turtle *Natator depressus*', *Bishop Museum Bulletins in Zoology* 1. VII, p. 69.

5 SHORT TITLES AND ACRONYMS

Table 7-3 sets out the short titles and acronyms used in this report.

Table 7-3 Short titles and acronyms

Short title or acronym	Long title
ABS	Australian Bureau of Statistics
AIMS	Australian Institute of Marine Science
ANC	Acid neutralising capacity
ANZECC	Australian and New Zealand Environment and Conservation Council
APASA	Asia Pacific Applied Science Associates
ARI	Annual recurrence interval
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
AQIS	Australian Quarantine and Inspection Service
BPP	Benthic primary producer
BPPH	Benthic primary producer habitat
BRL	Below reporting limits
BWDSS	Ballast Water Decision Support System
CALM	Department of Conservation and Land Management
CAMBA	China-Australia Migratory Bird Agreement
CCG	Cape Conservation Group
CCIMPE	Consultative Committee on Introduced Marine Pest Emergencies
CCWA	Conservation Council of Western Australia
CD	Chart datum
cm	Centimetre
CO_2	Carbon dioxide
DEC	Department of Environment and Conservation (WA)
DEH	Department of Environment and Heritage (Commonwealth)
dB	Decibels
DoE	Department of Environment (WA)
DoF	Department of Fisheries (WA)
DRF	Declared Rare Flora
EIS	Environmental Impact Statement
EPA	Environmental Protection Authority (WA)
EP Act	*Environmental Protection Act 1986* (WA)
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)
EGP	Exmouth Gulf Prawn
EQC	Environmental quality criteria
EQG	Environmental quality guideline
EQMF	Environmental Quality Management Framework
EQO	Environmental quality objective
ERMP	Environmental Review and Management Program
ESD	Ecologically sustainable development
EV	Environmental values

Short title or acronym	Long title
GDP	Gross domestic product
GHG	Greenhouse gas
g/ml	Grams per millilitre
ha	Hectare
HAT	Highest Astronomical Tide
IMO	International Maritime Organisation
JAMBA	Japan-Australia Migratory Bird Agreement
kL	Kilolitre
kVA	Kilovolt amperes
LAT	Lowest Astronomical Tide
LEP	Level of ecological protection
MARPOL	International Convention for the Prevention of Pollution from Ships
mg/kg	Milligrams per kilogram
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low water Springs
ML/yr	Megalitres per year
MSL	Mean sea level
Mtpa	Million tonnes per annum
m^3/year	Metres cubed per year
mm/day	Millimetres per day
m/s	Metres per second
MW	Megawatt
NGO	Non-government organisation
NIMS	Non-Indigenous marine species
NOEC	No-effects concentration
OAG	Office of the Auditor General
PIAC	Pearling Industry Advisory Committee
ppt	Parts per thousand
QPAR	Quarantine Pre-Arrival Report
RO	Reverse osmosis
SLG	Stakeholder liaison group
TAA	Total actual acidity
TBT	Organotin tributylin
tCO_2/kL	Tonnes of carbon dioxide per kilolitre
TEC	Threatened ecological community
TKN	Total kjeldahl nitrogen
TP	Total phosphorus
VMS	Vessel monitoring system
WAPC	Western Australian Planning Commission
WWF Australia	World Wildlife Fund Australia
µS/cm	Micro Siemens per centimetre