Department of Environment and Conservation

Your ref: 314/04
Our ref: 2005F001662V01
Enquiries: Raquel Carter
Phone: (08) 9334 0124
Fax: (08) 9334 0140
Email: Raquel.Carter@dec.wa.gov.au

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The Chairman
Environmental Protection Authority
PO Box K822
PERTH WA 6842

Attention: Dr Sue Osborne

STRAITS SALT PTY LTD YANNARIE SOLAR SALT ERMP: (ASSESSMENT NO. 1521)

I refer to Mr Tacey's letter of 1 December 2006 requesting comment on the proposal referred to in this Environmental Review and Management Programme (ERMP). The Department of Environment and Conservation (DEC) provides the following advice and comments on the basis of its *Conservation and Land Management Act 1984* (CALM Act) and *Wildlife Conservation Act 1950* responsibilities for your consideration in assessing this proposal.

The Summary of Recommendations and our Conclusion is provided as Attachment 1. The full detailed comments are provided in Attachment 2, with Attachment 3 detailing the references used and Attachment 4 a discussion on the conservation significance of Exmouth Gulf.

Please note that considerable categories of information are either incomplete or absent in the ERMP as provided, including coverage of:

- flora and vegetation;
- subtidal benthic communities;
- subterranean fauna; and,
- hydrogeological/geotechnical issues.

While we understand that the proponent is preparing supplementary reports based on additional investigations into the above areas, the lack of full and proper coverage of these issues in the ERMP is of significant concern. Impacts on significant biodiversity values cannot be assessed without the necessary additional information from the proponent. It would clearly be easier to undertake necessary assessments if the ERMP as presented for review was complete. The EPA should consider what message accepting a clearly incomplete ERMP for public consultation is providing to the community and the proponent. In addition to the above deficiencies, the ERMP is, in our view, inadequately detailed in many areas, to the extent that the environmental impact of the proposal cannot be properly assessed.

This proposal involves a major disturbance to a marine and coastal area of very high national and international conservation significance. It may also pose considerable ecological risks to important coastal and marine ecosystem values in the Exmouth Gulf and nearby Cape Range sub-bioregion. As outlined above, information critical to determining the nature and extent of impacts on ecological systems and processes and biota is either unavailable or inadequately discussed or presented within the ERMP.

In summary, based on the information available and the responsibilities of this Department under the CALM Act and the Wildlife Conservation Act, the proponents have not adequately demonstrated that the proposal can be implemented with acceptable impacts on biodiversity values. The proposal also would preclude future opportunities to conserve an outstanding area of a largely intact coastal ecosystem type with significant potential as an area for economically important nature based tourism. Based on our consideration of biodiversity conservation values and threats, the proposal should not receive environmental approval.

Advice on detailed management aspects of the implementation of the proposal has not been provided in this submission on the basis that the proposal is not, in the Department's view, environmentally acceptable. Should the proposal, or a variation thereof, be recommended for approval by the Environmental Protection Authority, the Department would seek an opportunity to provide further advice on conservation management issues within an appropriate timeframe.

Keiran McNamara
DIRECTOR GENERAL

12 March 2007

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ATTACHMENT 1

DEC KEY RECOMMENDATIONS AND CONCLUSION

The key recommendations provided below represent a subset of the recommendations made in Attachment 2 of this submission. The full set of recommendations are considered important and should be addressed by the proponent and considered by the EPA.

1. The EPA should consider that the proponent, through the ERMP, has failed to adequately take into account and address environmental impact issues associated with:
   - the very large scale of the proposal and its inherent potential for disruption of natural coastal processes by the proposed development;
   - the high natural environmental variability occurring in this area of the coastline; and
   - the potential for significant changes to the coastal and marine systems of Exmouth Gulf, which are considered to be of very high conservation and ecological significance.

3. Given the very large footprint of the proposal and extensive area of coastal algal mats and regionally significant mangals at risk from large scale changes, further detailed investigation into the impacts of the proposed diversion of surface water flow is required. Peer reviews by independent coastal ecologists with expertise in mangals and algal mats should be undertaken to aid in verifying the risks of large scale changes to coastal processes though significant modification of surface and subsurface water flows from the hinterland to the intertidal zone (also see recommendations in Section 2.2 of this submission).

4. Further investigations are required into the scale, size and potential irreversibility of the direct and indirect impacts associated with the construction of ponds and other infrastructure on approximately 40,000ha of supratidal flats, which appear likely to form an integral component of the Exmouth Gulf ecosystem. The proponent should investigate, and report on, the degree to which the adjacent primary producer habitats and the wider Exmouth Gulf and adjacent areas are at risk from the potentially large scale alteration of ecosystem function.

5. The project's primary footprint of approximately 41,000 is likely to be very significantly increased if a comprehensive risk based ecological footprint analysis of the proposal was undertaken. The EPA should require such an analysis.

6. The proponent and the EPA should consider the high levels of uncertainty and coastal zone risks associated with climate change, sea level rise and storm events and note that the proposal poses indirect long-term and irreversible impacts to the integrity of the Exmouth Gulf ecosystem.

7. A quantitative relationship between tidal water levels and the salt flat topography should be established by the proponent as a basis for a more thorough assessment of likely site inundation by tides, sea level variation in response to the passage of weather systems at weekly to decadal scales, relative rise in sea level associated with climate change and subsidence of the land surface, storm surge due to extreme events, wave conditions, and tsunami. The relationship of cross-shore inundation to groundwater and biota also warrants closer investigation as a basis for investigation of risks to biodiversity arising from construction and operation of the salt ponds.

9. The proponent and EPA should consider the limitations of the Bruun Rule (1954) and the associated setback analysis in evaluating the impacts of the proposal. The project should be designed to incorporate worst case scenario sea level rise projections based on contemporary sea level rise predictions and methods of predicting local change and the use of the Bruun Rule in this instance should be peer reviewed by appropriate experts or abandoned. On the basis that the eastern side of Exmouth Gulf is low lying and prone to sea level rise and potentially increased frequency of severe storm events, the project can be considered to present a high risk to the integrity of Exmouth Gulf ecosystems, requiring the best currently available water level analysis and predictions, taking into account contemporary climate change modelling predictions with a suitable safety margin.

10. The proponent should be required to undertake further impact analysis of storm surge and cyclone events incorporating the following:

    10.1 Modelling to indicate the consequences of a one in 100-year (or greater if appropriate) storm event during a spring high tide event incorporating worst case scenario sea level rise projections;

    10.2 Discussion of the ecological consequences should a significant failure in seawall and levee structures occur at a large scale along the proposed site (including bitterns management area); and

    10.3 Further investigation and independent advice indicating the likely ecological consequences as a result of storm surge deflection from seawalls incorporating the prolonged inundation of mangals and algal mats and energy deflection impacts. These studies should detail the potential impacts resulting from the construction of sea wall/bund in an area of high natural variability using broad scale temporal (decadal) hydrodynamic and hydrological studies.

11. Geophysical testing or geotechnical drilling should be undertaken by the proponent, to a depth at which natural capillary or forced vertical leakage could be expected to occur, in order to verify the extent and depth and uniformity of the horizontal clay layer beneath the supratidal saltflats. The results of these investigations should be assessed independently with reference to the Halpern-Glick (1966) investigation data and the hydraulic permeability measurements of Parsons Brinckerhoff (2005) mapped spatially to depict the uniformity of the clay layer using agreed geoscientific means.

12. Further hydrogeological work should be undertaken by the proponent (possibly including seismic surveys) to determine the depth and extent of limestone features in the area of proposed ponds and associated infrastructure. The locations of limestone outcrops and subcrops identified on the mainland remnants within the supratidal areas should be mapped and correlated with results of other work to develop a clear understanding of the hydrogeology of the project area including natural water movement (of various qualities and nutrient loads) at different times of the natural water cycle. It is important to recognise that any karstic limestone pillars could provide vertical horizontal conduits for hypersaline or contaminated water to enter the natural system through the base of ponds.

13. The presence of groundwater flows/seepage to the near shore environment and the dependence of coastal benthic primary producer habitat thereon should be investigated further in order to provide a high degree of certainty that mangals and other benthic communities will not be indirectly adversely affected through potential changes to the groundwater hydrology of the supratidal flats.

14. The necessary studies (as highlighted in Section 2.2 of Attachment 2 of this submission) should be undertaken to ascertain the importance of surface water flows to Exmouth Gulf east in terms of groundwater recharge, salinity regime and nutrient delivery at long temporal scales. This should include surveys immediately after severe storm events to determine water and nutrient contributions to the Exmouth Gulf.

17. There is a need for a high level of certainty in the relationships between groundwater and coastal ecosystem processes. This should be ascertained prior to the final assessment and decision on this proposal. This should include a clear understanding of long-term groundwater dependency of algal mats, mangroves and nutrient supply to the Exmouth Gulf.

20. Further studies, similar to those undertaken in the Arabian Gulf (published in Barth and Boer, 2002) should be undertaken to gain an understanding of the role of the salt flats of Exmouth Gulf in the overall maintenance of ecological function. There is minimal available information on the role of the salt flats in the Exmouth Gulf ecosystem and therefore further studies that investigate the productivity of the flats and potential ecological linkages between the supratidal flats, algal mats and mangroves with the entire Gulf ecosystem should be undertaken.

21. There is a need for further sampling to clarify whether there is significant storage of heavy metals in the deep soil profile of the supratidal flats. An assessment of the potential for release of heavy metals to occur should be undertaken and if appropriate, the risk of bioaccumulation should be investigated as part of the impact assessment of this proposal.

22. The contribution of the supratidal salt flats to nutrient flows, productivity and ecological function of the Exmouth Gulf should be analysed further to investigate the possibility that the supratidal flats are important sources of nutrients for the Gulf. As described in Section 3 of this submission, other saltflat systems have been known to support algae productivity within the sub-surface areas of the flats. Brunskill *et al.* (2001) state that the salt flat is partly covered with a mat of blue-green algae and these organisms fix atmospheric nitrogen and provide this nutrient element to supratidal waters. The proponent should describe the extent of any cyanobacterial mats above and below the surface and this should be depicted on maps.

24. The EPA's consideration of this proposal should take into account that, should the proposal be approved, one of the largest and most extensive, intact examples of Western Australian arid zone coastal salt flat ecosystems will be severely modified with the potential for portions of the adjacent primary producer habitats to also be significantly modified, thereby foregoing long-term opportunities for formal protection of outstanding and essentially unmodified examples of these ecosystem types in the formal conservation reserve system for Western Australia.

25. The EPA should apply the policy referred to in Guidance Statement No. 1 and not support industrial development on the eastern side of Exmouth Gulf, recognising the potential adverse impacts of the proposal on these regionally significant arid zone mangrove communities. These impacts potentially include alteration of groundwater hydrology, large scale modifications to surface water flows, erosion and sedimentation of tidal creeks and alteration of coastal processes.

26. The proponent and the EPA should recognise that the information presented in the ERMP does not provide the level of certainty required to demonstrate that the integrity and ecosystem functional values of mangrove ecosystems will be maintained over the long term (decadal scales).

30. The consequences (in addition to the probability) of the failure of the levee walls for the bitterns management area, crystalliser ponds and concentrator ponds should be discussed and the possible impacts on algal mats and other systems evaluated by the proponent. Justification should be provided for the proposed design of these walls to withstand a one in 25-year storm event, rather than more severe (1:100 year or greater return interval) events such as severe cyclones.

31. The proponent should undertake detailed mapping of algal mat distribution within the project area to provide a better understanding of the productivity of the algal mats system and its contribution to nutrient inputs to the Gulf systems.

34. Potential impacts to seagrass and macro-algal beds that could result from release of hypersaline and toxic substances resulting from pond wall failure should be identified and assessed by the proponent through modelling or other predictive approaches and considered in the impact assessment of the project.

38. The EPA should recognise that any potential loss in the benthic primary producer habitats of the Exmouth Gulf could reduce the habitat availability for reef species during juvenile and breeding stages of their life cycles. It is important to note the high likelihood that marine fish fauna that inhabit reef communities of the Ningaloo Reef and the Muiron Islands require the mangrove and/or seagrass habitats of Exmouth Gulf for one or more life cycle stages (e.g. snapper, bream and mackerel).

39. Broad scale temporal and spatial habitat mapping of Exmouth Gulf should be undertaken by the proponent to assist in determining impacts to Exmouth Gulf marine ecosystems.

40. Fine scale temporal habitat mapping of the zone of influence of the proposal should be undertaken by the proponent to predict the likely direct project impacts on benthic primary producer habitats.

41. Possible impacts from discharge of bitterns should be taken into account by the EPA as a potential disposal option under consideration by the proponent, on the basis that statements within the ERMP indicate significant technical and economic uncertainty with respect to the feasibility of bitterns recovery and there appears to be a reasonable likelihood that discharge will be required under scenarios A, B or C as referred to in Appendix 1 of the ERMP.

43. Prior to completion of the assessment of this proposal, the proponent should provide a comprehensive impact evaluation of 'worst case scenario' options for bitterns management including options involving discharge of bitterns into the natural environment and provide sufficient information to the EPA on the financial costs and environmental impacts of these methods to provide confidence that they would not make the project either economically unviable or environmentally unacceptable. Ecotoxicity testing and an ecological risk assessment of disposal options should be undertaken by the proponent and presented to the EPA so that the likely biological and ecological consequences of possible bitterns disposal to the environment can be assessed.

44. The EPA should seek independent expert advice on the feasibility of the proposed bitterns resource recovery strategy and possible disposal strategies prior to completing its assessment.

47. The proponent should provide the EPA and decision making authorities with a detailed scientific discussion on the ecological consequences of worst case scenarios including impoundment failure, bitterns seepage and overtopping.

48. The proponent should model the potential changes in the salinity regime in the area of Naughton's Creek and Dean's Creek (and any other proposed sites for intake pumps) and discuss the potential impacts on prawn recruitment and other ecological and biodiversity values potentially affected. This information should be provided to the EPA and decision making authorities (e.g. Department of Fisheries and DEC) as part of the assessment of this proposal.

49. The proponent should identify any secondary impacts from the dredging that may impact on water quality, benthic habitat and biota (including the release of Monosulphide Black Oozes MBOs - see Section 6.2, Attachment 2 of this submission) and define and discuss the local and regional significance of the habitat impacted by the dredging.

50. The proponent should identify dredging techniques to address the potential for MBO accumulation. Clear mitigation measures to reduce the risk of disturbing MBOs need to be identified. This information should be provided prior to a decision on this proposal.

51. The proponent should undertake a risk assessment of oil spills including impact analysis and dispersion modelling to identify the worst case impacts to the Exmouth Gulf, Ningaloo Marine Park and the Muiron Islands and their ecosystem and biodiversity values. This assessment should include specific details on the potential impacts to conservation significant species.

53. The ERMP is largely deficient in information on the management of acid sulphate soils, the extent of acid sulphate soils and the consequences of acid sulphate soil impacts on the ecology of Exmouth Gulf. The following additional information is required in order to continue with the assessment:

- A map that identifies where potential acid sulphate souls exist overlaid with proposed areas of disturbance.
- Quantitative and adequately justified estimates of the volumes of acid forming material that could potentially be affected during construction, dewatering and operational activities of this proposal.
- Acid sulphate soil management commitments consistent with national standards.
- The volume of lime required for management of these areas and the sources of lime that will be utilised.

54. The proponent should undertake a scientific analysis of the risks and consequences associated with the disturbance and exposure of acid forming materials including potential impacts on benthic habitats, water quality and marine and coastal fauna and should provide the results of this analysis to the EPA and decision making authorities during the assessment of this proposal.

56. The breeding and calving season for the dugong population of Exmouth Gulf should be determined prior to the completion of this assessment, along with any possible heightened impacts to the species in this period. This should include the use of Exmouth Gulf as dugong habitat for feeding, lekking, travel, shelter from weather, thermal refuges, calving, protection from predators and refuge in the event of habitat change.

58. Targeted dugong surveys should be conducted in both winter and summer seasons to provide a baseline dataset on dugong prior to the completion of assessment of this proposal.

61. The proponent and the EPA should consider to what extent the potential for loss of benthic primary producer habitats, in particular mangroves, macroalgae and seagrass and other zoobenthos communities through the proposed project could have a significant long-term implications for marine turtle populations given that extensive marine habitat degradation has already occurred throughout the Pilbara region.

62. The EPA should take into account that the eastern Exmouth Gulf area affected by the proposal is a nationally important wetland and is ranked as being of international significance for at least five species of migratory waders. The modification or destruction of internationally important habitat for migratory waders could have ramifications for future assessments of our commitments to the JAMBA and CAMBA migratory bird agreements.

63. The proponent should provide more detailed maps of the distribution and relative abundance of each species of migratory bird in relation to foraging activity.

69. The EPA should note that the risk of non-indigenous marine species being introduced and establishing in Exmouth Gulf will be increased by the significant rise in shipping traffic that is associated with this proposal. The possible impact to the marine environment of Exmouth Gulf from the introduction and establishment of non-indigenous marine species is significant.

71. In the event that significant subterranean fauna is detected during the proponent's preliminary sampling program, further studies will be required to determine the distribution, abundance and species richness of subterranean fauna within areas that could be potentially affected by the proposal. Should conservation significant subterranean fauna occur, the impacts on subterranean fauna cannot be ascertained in the absence of an adequate understanding of the hydrogeology of the site and therefore a satisfactory assessment of the risks to subterranean fauna will be difficult until the required information on hydrogeology referred to earlier in this submission is available.

76. The proponent should provide information on the level of impacts expected to vegetation communities of high reservation priority, provide information indicating whether remaining vegetation in the local area and region will adequately represent communities that will be impacted, and outline mitigation measures that will be implemented to mitigate impacts to these communities.

77. The proponent should undertake necessary fauna surveys in consultation with DEC to determine the presence/absence of conservation significant terrestrial fauna in or adjacent to the study area prior to the completion of assessment of the ERMP.

78. The proponent should provide further information on the full range of potential impacts, direct and indirect, on terrestrial fauna as a result of the development, focusing on impacts including, but not limited to habitat fragmentation, changes in hydrology and light emissions. Adequate management strategies should be developed in consultation with and to the satisfaction of DEC.

79. The EPA should take into account in its assessment of this proposal, the highly significant 'wilderness' values of Exmouth Gulf, and acknowledge that the project area is one of the last remaining areas on the mainland Pilbara coast without significant industrial development.

81. The significant contribution that nature-based tourism in the Ningaloo area provides for the State should be recognised in consideration of the costs and benefits of this proposal and the potential for ecologically sustainable nature-based tourism in Exmouth Gulf focused on wilderness tours, sustainable recreational fishing and wildlife interactions should be taken into account. These opportunities are likely to be foregone through the large-scale industrialization of Exmouth Gulf.

82. The EPA should give consideration to recommending that the Government undertake an economic and social analysis of the value that Exmouth Gulf and its productive habitats, commercial fishery, wilderness, geoheritage and intrinsic natural values provide to the State in comparison to the social and economic gains proposed through the construction of the proposed Straits Solar Salt mine. This would enable a cost-benefit analysis of the environmental, social and economic aspects of this proposed development.

83. There should be a requirement for a decommissioning strategy associated with this proposal, should it proceed, to protect the State in terms of restoration and management costs.

Conclusion

DEC is of the view that this proposal is environmentally unacceptable due to the significant risks associated with the design, size, scale and location of the proposal and the inability of the proponent to demonstrate that the large scale impacts can be mitigated. Without the additional information outlined in the recommendations throughout this submission, there is insufficient basis for the Department to be satisfied that the risks to the ecologically significant ecosystems of the Exmouth Gulf can be successfully mitigated. These potential impacts include large-scale changes to coastal processes, loss of critical habitats for significant fauna, decline in water quality from hypersaline and toxic leachate and potential major impacts on the project area resulting from projected sea level rise and major cyclonic and storm surge events.

The site of the proposal is within a complex coastal area with uncertain hydrogeology and valued coastal ecosystems of high conservation significance. Given that the information in the ERMP is not sufficient to understand the hydrogeology of the area, the importance and role of the supratidal flats, the groundwater and surface water dependence of native vegetation, mangals, seagrass and algal mats, it is extremely difficult to undertake an informed and technically sound impact prediction analysis of the long-term consequences for Exmouth Gulf ecosystems. The cumulative effects of the project's operations and potential changes in natural hydrology are not sufficiently well discussed or documented by the proponent for the Department to be satisfied that major adverse ecological impacts will not occur. Unless the proponent undertakes the identified studies to confirm assertions the proponent has made that the project poses a low level of environmental risk from altered hydrology, it is DEC's view that the EPA will not have enough information to make an informed assessment.

There are a number of conservation significant species that occur on the eastern side of Exmouth Gulf. Given there is a high degree of uncertainty relating to the potential impacts on the water quality and benthic habitats of the Gulf, the proposal does not provide an adequate level of confidence that impacts to marine fauna are acceptable.

The ERMP provides no evaluation of the ecological value and interconnectivity between the marine waters, inshore coastal habitats, the supratidal 'sabkha' salt flat system and the hinterland area. It is not clear from the ERMP that the risks associated with major change to the 'sabkha' system will be acceptable or manageable. Further ecological studies into the role that the supratidal flats play in maintaining Exmouth Gulf's ecosystem health should be available to enable an evaluation of the potential long-term impacts. Furthermore, there is no recognition of the ecological linkages between the eastern Exmouth Gulf (incorporating the supratidal flats) and the coral reef communities of Ningaloo and the Muiron Islands.

Finally proceeding with the proposal would represent a foregone opportunity to conserve an outstanding area of a largely intact coastal ecosystem type with significant potential as an area for economically important nature based tourism and fisheries protection. The costs associated with the loss of these values need to be compared with the level of economic and social benefits and potential liabilities associated with the project.

On the basis of available information indicating that the ecological and conservation values of the Exmouth Gulf ecosystem are very high at the regional, national and international scales, and in recognition that the ERMP does not provide an adequate assessment of the environmental risks and management requirements, this proposal represents a high risk of permanent loss of significant environmental values and is therefore not supported.

Department of Environment and Conservation
March 2007

Detailed Evaluation of the Yannarie Solar Proposal

DEC has reviewed the ERMP for the Yannarie Salt Project as it relates to the Department's responsibilities under the *Wildlife Conservation Act 1950* and *Conservation and Land Management Act 1984*.

Based on the importance of the area for conservation, a review of the ERMP, literature reviews, visits to the area by staff and specialist scientific advice, DEC is of the view that the proposal represents a very significant risk to the unique and highly important ecological and conservation values of the eastern Exmouth Gulf and should not proceed. The Department's position can be summarised under the following key concerns for the EPA's consideration.

Scale of Proposed Development

A 10 million tonnes per annum (mtpa) salt production facility is proposed for the eastern side of Exmouth Gulf with an operating life of 60 years. A key element of the proposal involves construction of evaporation ponds over an area of at least 41,000 ha of the existing Yannarie Delta system in order to evaporate and concentrate large scale quantities of hypersaline water (brine) along more than 66 km of coastline (refer Figure 2 below and Table 2-11, page 2-25 of the ERMP).

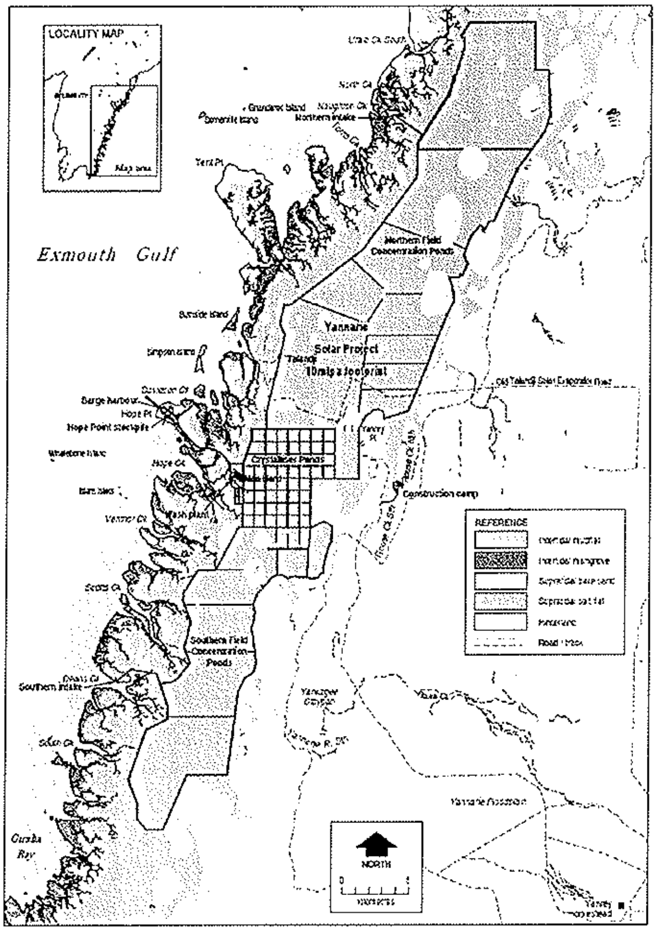

Figure 2: Primary footprint of the proposal in relation the Exmouth Gulf supratidal flats. (Source: Figure 2-2 page 2-24 of the ERMP.)

The very large scale of the proposal, encompassing extensive areas of evaporation ponds and other infrastructure will impact on the majority of the Exmouth Gulf supratidal flats, which are regarded as an essential and integral component of the marine and coastal ecosystems of the Gulf. This will result in a major direct loss of the habitat and ecological function values of the supratidal flats, large scale changes to surface water flows, and the disruption of ecological linkages to the Exmouth Gulf. As a result there is a significant likelihood of long-term adverse ecological consequences for primary producing communities in the eastern Gulf, including algal mats, regionally significant mangroves and productive seagrass beds supporting an important prawn fishery and conservation significant macrofauna species (discussed in detail in Sections 1, 2, 3 and 4 of this submission). There may also be significant impacts on fauna that utilise the supratidal flats during or following episodic disturbances such as cyclones.

High level of uncertainty

The ERMP contains many uncertainties in regard to the risk of long-term impacts to the Exmouth Gulf marine and terrestrial ecosystems. A significant amount of data required to make an informed decision on the proposal is not available. Partly as a result of the remoteness of the location, there is limited understanding of the ecosystem processes that operate in the Gulf, and how these relate to the known biodiversity values of the area. Given these uncertainties, much of the ERMP seems to be based on assumptions that are not adequately supported with confirmed data.

In particular there are major uncertainties in relation to the hydrogeology of the supratidal flats and wetland areas of the eastern side of Exmouth Gulf and the potential impacts of the proposal on these areas. For example, Figure 4-8 (page 4-14) and section 2.3.4 'Supratidal salt flat' (pages 5-18 – 5-19) of the ERMP depicts the hydrogeological model presented by the proponent indicating that a continuous and impermeable clay layer exists below the supra-tidal flats. However, there is no discussion on the extent and nature of limestone features throughout the supratidal flats, which are known to occur there. Furthermore, section 3.4.2 'Diversion or redirection of Yannarie River flows' (pages 5-39 – 5-48) neglects to discuss the long-term ecological consequences related to the large scale diversion of surface water flows from the hinterland through the Yannarie North and South Rouse Channels. Uncertainties relate to a range of issues, including the effect of large-scale hydrological changes resulting from the location of ponds and other obstructions, and the unidentified and unknown risk of hypersaline and toxic brine leaching through the base of evaporative and other ponds into the groundwater system over time and affecting the adjacent algal mat, mangrove and tidal creek communities. The implications of these risks in relation to a project of this scale are that there is significant potential for large-scale adverse changes to ecosystem productivity and function (discussed in detail in Sections 2, 3 and 4 of this submission).

There is also currently a high degree of uncertainty in relation to the importance of periodic surface water flows from the hinterland across the supratidal flat, extensive algal mats and mangroves for the nutrient limited waters of Exmouth Gulf. This uncertainty has implications for the effect of the project on the future productivity and ecological function of the Exmouth Gulf ecosystem and dependent marine fauna.

DEC is of the view that the significant biodiversity conservation values of the Exmouth Gulf ecosystems and the scale of the proposal require a high level of certainty in prediction and evaluation of potential impacts. This is notwithstanding DEC's view that the values of the area warrant protection within a conservation reserve.

Location of the proposal in an area of extreme natural variability

There are considerable uncertainties about the potential for long-term changes to the Gulf as a result of climatic factors such as sea level change, and changes in the frequency and intensity of cyclonic and storm events.

The proposal area may potentially be subject to large scale changes to coastal processes as a result of predicted climate change, sea level rise, frequency of cyclone events and significant storm surges crossing the coastline. This places considerable importance on the ability of the proponent to:

1. maintain the integrity of more than 60 km of seawall and permanent salt pond structures over the long-term; and
2. make reliable predictions on the potential for the presence (or failure) of these structures to affect coastal processes and ecosystem stability.

The consequences of altering coastal processes in areas of high natural variability include large scale erosion, loss of primary producer habitats and long-term loss of ecosystem integrity and function (discussed in detail in Sections 1 and 4 of this submission).

Potential irreversibility and manageability of impacts over the long-term

The potential for reversibility and manageability of the potential impacts of this proposal over the long term have not been adequately addressed in the ERMP.

The proposal involves the construction and operation of salt fields and associated infrastructure over an indeterminate period with little or no discussion of plans for management of residual impacts or restorative measures in the event that serious impacts occur or the project is discontinued.

Given the importance of the ecological and conservation values of the eastern Exmouth Gulf, there must be full confidence that the proponent would have the resources and ability to reverse residual impacts with ecological consequences. The scale of the project in this case is such that it is questionable whether the proponent will be able to restore ecosystems potentially impacted and in this sense at least, the potential impacts of the project may be irreversible.

Potential for impacts on important areas through ecological linkages

There is a potential for significant negative impacts from the proposal for marine species that utilise Exmouth Gulf during critical life cycle stages and also for ecosystems in the eastern Exmouth Gulf.

While the full scope and extent of ecological linkages between the eastern Exmouth Gulf ecosystem and the proposed Ningaloo World Heritage Area, Ningaloo Marine Park and Muiron Islands Marine Management Area are yet to be published, there is evidence available to DEC that a number of marine fauna species inhabiting these areas utilise the ecological resources of the Gulf system as nursery and foraging areas during specific life stages (discussed in detail in Section 4.6 of this submission).

PROPOSAL IMPACT ASSESSMENT

This section provides advice and comment on the impact assessment, design and location of the proposal, based on a review of the information provided in the ERMP and associated documents, discussions with the proponent, information derived from site visits and readily available literature. Each topic area includes discussion of the issue and includes recommendations for consideration by the EPA and the proponent.

1. Coastal processes

1.1 Scale of the proposal

Straits Salt Pty Ltd proposes a 10 mtpa salt mine on the eastern side of Exmouth Gulf. This area is ecologically significant and relatively undisturbed by anthropogenic activities. The proposal has an estimated life of 60 years and will directly affect an area greater than 41,624 ha (416.24 km2) which excludes known marine infrastructure requirements and also the area of hinterland to the east of the supratidal flats subject to potential inundation as a result of the proposal. The proposal involves a very large ecological footprint extending for a length of over 60 km along the coast and up to 13 km wide (Straits Salt Pty Ltd 2007).

Exmouth Gulf is considered to have highly significant biodiversity values and has been identified as a candidate area for marine reservation by the Marine Parks and Reserves Selection Working Group (Wilson et al. 1994). Based on a combination of the size and scale of the proposal, the high natural biodiversity values of the Pilbara coast and the known significant values of Exmouth Gulf, this proposal presents significant risks for both short and long-term negative impacts with potentially high ecological consequences. The scale and location of the proposal abutting the algal mats and mangals, encompassing almost the entire area of supratidal flats presents an extreme risk to a very important area of largely ecologically intact marine and coastal ecosystem. Figure 3 provides one perspective of the significant size and scale of the proposal.

Recommendation:

1. The EPA should consider that the proponent, through the ERMP, has failed to adequately take into account and address environmental impact issues associated with:
    - the very large scale of the proposal and its inherent potential for disruption of natural coastal processes by the proposed development;
    - the high natural environmental variability occurring in this area of the coastline; and
    - the potential for significant changes to the coastal and marine systems of Exmouth Gulf, which are considered to be of very high conservation and ecological significance.

1.2 Large scale changes to surface water flows: Potential implications for coastal processes

There is considerable uncertainty in relation to the importance of surface water flows from the hinterland area to the supratidal flat and mangals. According to the ERMP (page 5-44), the large-scale modification of surface water flows will have negligible impacts on the mangals and will not change the sediment and nutrient transmission pathways of the eastern side of Exmouth Gulf. However, since inundation of the supra and intertidal mudflats is caused by both terrestrial and marine flooding, it appears unlikely that surface water flows are insignificant for two main reasons.

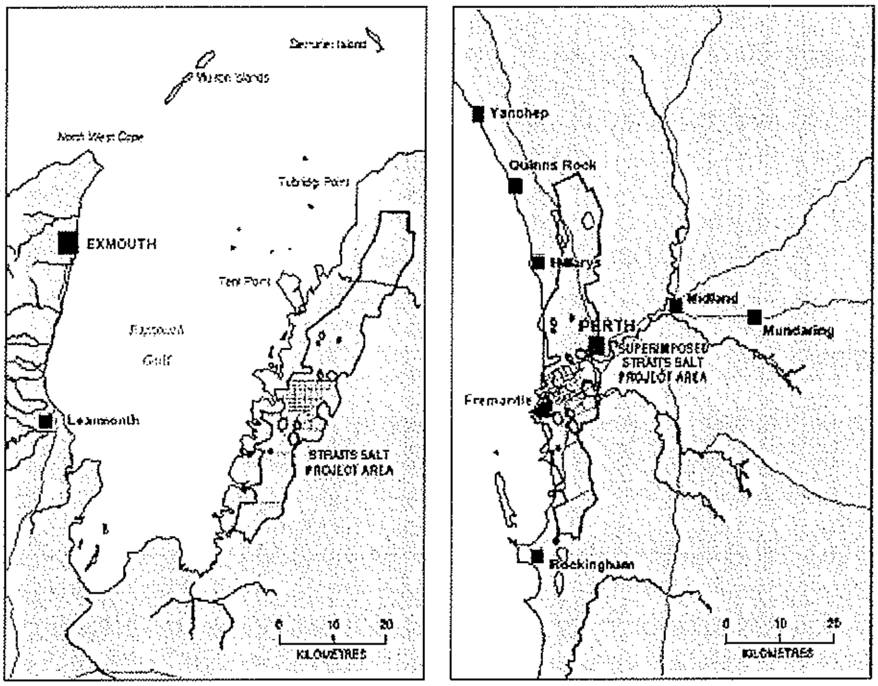

Figure 3Outline of Yannarie Solar Salt proposal salt pond footprint superimposed over: a) Exmouth Gulf and b) Perth Metropolitan Area (Source: Conservation Council Western Australia).

Firstly, surface water flows to an estimated 66 km of coastline will be disrupted and/or prevented and these flows will be redirected around the bunds containing salt ponds with little resultant flow seaward across the supratidal and intertidal mudflats to the mangroves. It is considered likely that these flows contain ecologically important fresh water and nutrient supplies to the Gulf and contribute to groundwater recharge.

Secondly, the potential effects of the proposed seaward bunds/levees on the depth and intensity of flooding of mangroves and tidal mats during ocean surge events appear likely to accelerate ebb discharges in the tidal creeks and enhance erosion.

In relation to surface flows from the terrestrial catchment, satellite imagery (Figure 4) taken shortly after Cyclone Bobby in 1995 illustrates that the whole region along the eastern side of Exmouth Gulf may form a major delta system during and after major storms and other rainfall events. Specifically the appearance of turbid water 'plumes' entering the Gulf via major creek systems in the photograph serves to highlight the potentially important function of the supratidal flats in the export of surface water from the hinterland areas to the Gulf during these extreme, but likely to recur, events.

The proponent's conclusion within the ERMP that surface water flow events do not significantly affect the algal mats, groundwater, mangroves and overall productivity of the Gulf (section 3.4.2 'Diversion or redirection of Yannarie River flows' page 5-40 – 5-48 of the ERMP) is considered to be of questionable validity. In particular, there is a high level of uncertainty surrounding the actual importance of surface water flows for groundwater recharge, the quality of groundwater below the supratidal flats and the ecological value of freshwater flows direct to benthic habitats during and immediately following storm events, as well as during wet seasons.

The ERMP proposes (pages 5-39 – 5-40 and Figures 5-14 and 5-15) that surface water be diverted around the salt field through the construction of a diversion weir in the hinterland

and levee walls to mitigate breaches during major surface water flows. This is a large diversion of surface water and as a result there is significant potential for significant long-term alteration of tidal creek systems and changes to coastal processes. It is likely to be difficult to quantify the ecological consequences of such changes given the complexity of the system and dynamic nature of coastal processes. The ability of the proponent to successfully engineer and manage water flows around levee walls has not been demonstrated and the impact of the proposed ponds on the sediments of the tidal flats is currently unclear. Section 2.2 of this submission discusses surface water flow modification in more detail.

Recommendations:

2. The EPA should find that the proponent has failed to demonstrate the acceptability of the project given the uncertainty of the consequences associated with large scale changes to surface and subsurface water flow to Exmouth Gulf and the natural functioning of coastal processes that appear likely to result from the proposal. Notably, these changes include the diversion of surface water flows from behind the supratidal flats, around the levee walls and directly into the creek systems immediately north and south of the project. The consequences of the removal of surface water flow from the supratidal flats and the majority of the eastern coastline and benthic habitats combined with the potential for intensified flows to the north and south of the proposal present high risks and uncertain consequences for ecosystem integrity.

3. Given the very large footprint of the proposal and extensive area of coastal algal mats and regionally significant mangals at risk from large scale changes, further detailed investigation into the impacts of the proposed diversion of surface water flow is required. Peer reviews by independent coastal ecologists with expertise in mangals and algal mats should be undertaken to aid in verifying the risks of large scale changes to coastal processes though significant modification of surface and subsurface water flows from the hinterland to the intertidal zone (also see recommendations in Section 2.2 of this submission).

1.3 Large scale modification to the function of supratidal flats

The ERMP indicates that the 'ecological footprint' of the area is 'minimised' (to 41,000ha Table 2-11, page 2-25) by moving the salt field behind the inter-tidal zone to a location on *"unvegetated and non-primary productive salt flats"* (Table 2-3, row 14, page 2-10).

Firstly, it should be noted that an ecological footprint analysis should incorporate the wider effects and impacts of the proposal and should not be minimised to incorporate only the primary footprint. Secondly, given that almost the entire area of supratidal flats on the eastern side of Exmouth Gulf will be modified through large scale salt field development, further consideration of the importance of the supratidal flats as an integral component of the marine and coastal ecosystem should be explored. Without verification of the importance of the supratidal flats to the physical and ecological processes occurring within the marine/coastal ecosystems of the Gulf, the potential consequences of ponding almost the entire area of supratidal flats are uncertain. Studies in other parts of the world have shown that marine arid zone salt flats do have ecological values (Section 3 of this submission). There is a likelihood that the supratidal flats contribute significantly to ecosystem function through moderating inputs of fresh water to marine and groundwater systems, nutrient cycling, heavy metal sinks, and transport of nutrients during storm events.

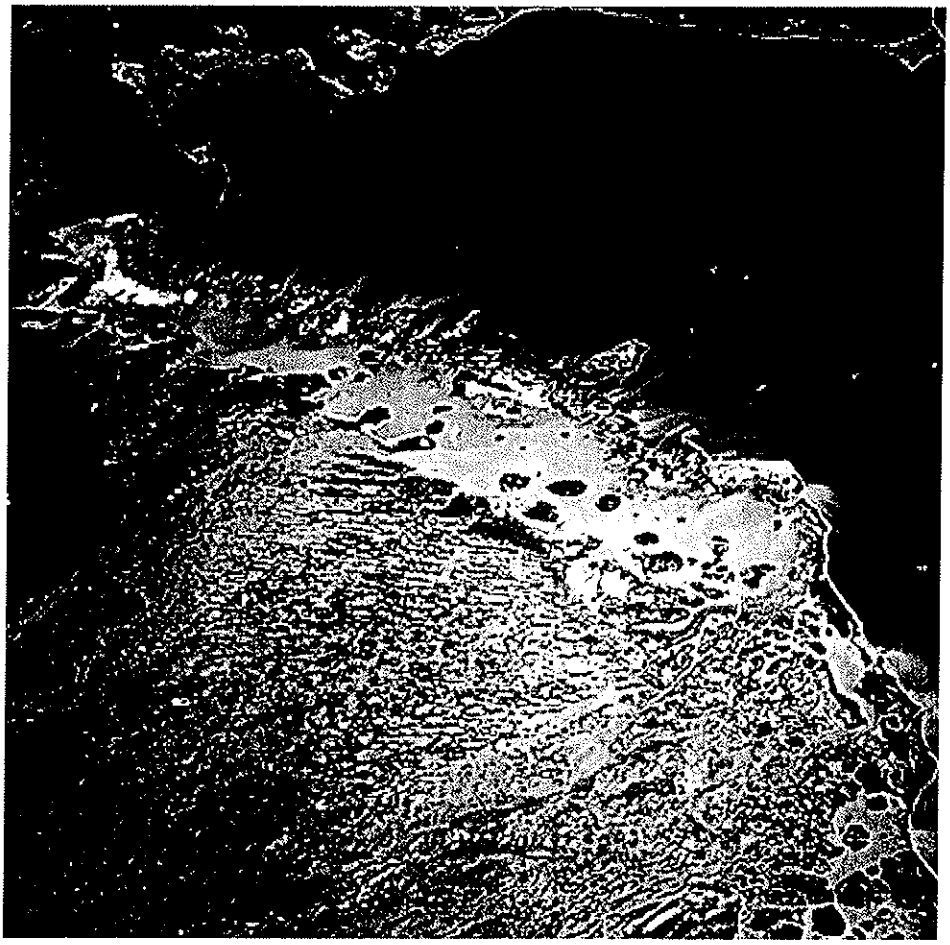

Figure 4: Surface water flow from Cyclone Bobby (approximately 300 mm of rain) 1995 illustrating surface water flow from hinterland, across supratidal flats and into Exmouth Gulf. This image was taken March 3, 1995.Source: NASA 2006.

On this basis the use of the ecological footprint analysis to evaluate the total impact footprint of the project within the ERMP is considered possibly invalid because the supratidal flats should, unless clearly demonstrated to the contrary, be considered to be an integral component of the ecological footprint. The current footprint area (depicted on Figure 2-2, page 2-24 and Table 2-11, row 4 'Site disturbance', page 2-25 of the ERMP) estimate does not incorporate areas at risk from the potential long-term indirect impacts of this proposal, which include mangrove and other habitats over a much broader area of Exmouth Gulf.

Recommendations:

4. Further investigations are required into the scale, size and potential irreversibility of the direct and indirect impacts associated with the construction of ponds and other infrastructure on approximately 40,000ha of supratidal flats, which appear likely to form an integral component of the Exmouth Gulf ecosystem. The proponent should investigate, and report on, the degree to which the adjacent primary producer habitats and the wider Exmouth Gulf and adjacent areas are at risk from the potentially large scale alteration of ecosystem function.

5. The project's primary footprint of approximately 41,000 is likely to be very significantly increased if a comprehensive risk based ecological footprint analysis of the proposal was undertaken. The EPA should require such an analysis.

1.4 Effect of evaporation ponds and sea walls on coastal processes and salt flats

Tidal Inundation

The supratidal salt flats are subject to inundation by sea level changes resulting from tides, sea level variations in response to the passage of weather systems at weekly to decadal scales, relative rises in sea level associated with climate change and subsidence of the land surface, storm surge due to extreme events, wave conditions, and, rarely, tsunami. These processes function in combination and as noted earlier, interact with flooding from terrestrial sources. The result is that different parts (zones) of the mudflats, from the high debris lines on the remnant hillocks along their eastern margin seawards to the margin of the subtidal terrace skirting the mangals, are subject to different periods of inundation and salinities. For this reason, it is important that the characteristic zonation of inundation which is related to the frequency, duration and elevation of sea level change across the supratidal flats is identified. It is this pattern of processes that the construction of the salt ponds will substantially and perhaps irreversibly disrupt. The identification of periods in which the flats are exposed to inundation and related processes is important in assessing impacts to coastal processes and ecological function and is inadequately considered in the ERMP.

Tides are given some attention in the ERMP document (pages 4-9, 6-5 and 6-118), with semidiurnal tidal ranges at Exmouth and Hope Point being quoted. However, lower-frequency tidal activity associated with annual, interannual and longer period oscillations in water level are not discussed, although they could be expected to have effects on coastal processes over the functional 'life' of the project. For example, it is important to note that sea level fluctuates in response to meteorological conditions of four to six year cycles associated with El Nino and Southern Oscillation events. This means that there are super elevated sea level occurrences that have not been discussed or obviously accounted for in the ERMP.

A more detailed understanding of the precise relationship between tidal water levels and local salt flat topography should be established, since it is fundamental to the assessment of inundation frequencies affecting coastal processes in the area and impacts of the proposed development on these. This could potentially be achieved by surveying levels within the project area across the salt flats from the eastern dunes to the deep-water sea bed off the sub-tidal flats skirting mangals to an established datum (such as the nearest standard port). It is recommended that the establishment of this survey be undertaken in consultation with coastal zone experts, in consultation with DEC.

Climate change and sea level rise

Climate change in any region may be considered in two contexts:

1. as the natural variability of climate in a region over a specified period, usually related to the time for which historic records are available; and
2. in terms of forecast future change, such as the predictions made under various Greenhouse related scenarios.

Analysis of the historic climate information for a particular area is fundamental to risk assessment and establishes a context for extreme events, especially through identification of phases of extreme storm activity likely to have cumulative and long-lasting effects on the environment. In semi-arid areas such as Exmouth Gulf in particular, the pattern of extreme rainfall events is considered to be closely linked to the major nutrient cycles across the landscape. Interruption of these could have potentially serious consequences for ecological functioning across the local landscape. Consideration of extreme events on the basis of a single storm, i.e. Cyclone Vance, regardless of its severity, is likely to be misleading in risk assessment. Forecasting change in climate is fraught with problems related to the development of suitable numerical models and it is only recently that detailed models describing regional change in Western Australia have been developed for the Pilbara oil and gas region.

National and global models consistently point to substantial change in climate and sea level in the foreseeable future and the ramifications of this for the project require careful consideration and incorporation in any plans for development (IPCC, 2001).

A report by the Intergovernmental Panel on Climate Change (IPCC, 2001) providing a summary of climate change issues for policy makers estimates that global mean sea level is to rise by 0.09 metres to 0.88 metres between 1990 and 2100. The proponent has used the average of 0.38 metres to design and manage the potential for sea level rise. However, a paper published in *Science* on 14 December 2006 (Rahmstorf, 2006) presents a semi-empirical relation which connects global sea level rise to global mean sea surface temperature. When applied to future warming scenarios of the IPCC, this relationship results in a predicted sea level rise of 0.5-1.4 metres above 1990 levels by 2100. The paper warns that the potential for greater increases needs to be taken into account when planning coastal defences and given the uncertainties inherent in climate change prediction and the potential consequences of designing coastal structures based on an underestimation of sea level rise, it is considered important that worst case scenarios are factored into sea level rise projections in the planning of high risk developments in the coastal zone.

The proponent has used the "Bruun Rule" (Bruun 1954) to estimate the effect of sea level rise on the shoreline of Exmouth Gulf (refer to ERMP section 2.2.4, page 4-10). Using this method, the estimated sea level tidal boundary is 38 metres landward of the current high water mark. As a result of this analysis, the sea walls are to be set 40 metres from the current high water mark. The use of the Bruun Rule in this manner and the subsequent placement of levee walls and sea walls raises concerns for a number of reasons.

Firstly, the use of the Bruun Rule is considered inappropriate. The Bruun Rule is a simple two-dimensional model of shoreline response to sea level rise which provided an advanced understanding of the potential impacts on coastal systems at the time of its first publication in 1954. It has now been superseded by numerous subsequent findings and is considered by some authors as invalid (Cooper and Pilkey, 2004). According to Cooper and Pilkey, the Bruun Rule has no power for predicting shoreline behaviour under rising sea level and should be abandoned because it ignores various important geological and oceanographic principles and cannot predict shoreline retreat due to sea level rise accurately. These authors have also recommended that setback zone coastal engineering models based upon the Bruun Rule should be re-evaluated. Perhaps most importantly for the Yannarie Floodplain, Bruun (1983) subsequently pointed out the limitations of the model and stated that it should not be applied to muddy or rocky coast. As the proponent has based setbacks on Bruun Rule analysis, it is recommended that a more appropriate alternative analysis that takes a more conservative approach, taking into account modern predictions of possible sea level rise, should be undertaken.

Although there are others that may be more effective, the conceptual model reported by Kirby (2000) provides an example of an alternative approach and identifies some of the difficulties in applying the Bruun Rule to muddy coast. Without the assurance that the best available approach to modelling of shore responses to sea level rise has been used, the proposal cannot be regarded as properly incorporating provision for sea level rise impacts on the existing shoreline, coastal processes and distribution of mangrove and other ecosystems, which could potentially have large ecological consequences given the proposed 60 year life of the project.

Furthermore as a result of non-recognition of the limitations of sea level rise predictions, the potential consequences of sea level rise have not been discussed in the ERMP. The proposal to have all other non-marine infrastructure set back to a minimum of 40m from the inland edge of the algal mat and therefore be possibly detrimentally impacted by further sea level change or higher than predicted storm surge is a concern (refer to ERMP section 3.8.2, page 2-34). For example, the consequences of worst case scenario sea level rise projections combined with the potential increased frequency of severe storm events and associated storm surge, and the implications these scenarios have on Exmouth Gulf ecosystems, have not been evaluated and presented in the ERMP (refer to ERMP section 3.8.1, page 2-34).

Large scale salt pond depression of salt flat

A further change in relative sea level that requires consideration for this proposal is related to the potential compaction of floodplain and salt flat sediments by an overlying water body. Although depth limited, the projected size of constructed salt ponds will place a very substantial load on the floodplain and salt flat surface. This load may be sufficient to cause depression of the seaward margin of the floodplain and a corresponding increase in sea level relative to the position of the land surface (Ian Elliot, pers. comm, 2007). The potential for such change in the case of this proposal is unknown and has not been considered in the ERMP document (e.g. page 5-23 'Seepage from salt ponds'. However, it could have major consequences for coastal processes and the evolution of the local tidal creeks. The interaction between sea level and the development of floodplains and associated mudflats is such that small changes in sea level may result in large changes to tidal creek and floodplain morphology (Kirby 2000; Winn *et al.* 2006) with likely adverse local and regional ecological consequences.

Storm events, astronomical high tides and prevailing winds

According to the ERMP (Table 6-1, page 6-5), water levels in the Exmouth Gulf (Hope Point) are 3.17 metres at High Astronomical Tide and 1.74 metres at Mean Sea Level. How these values relate to different parts of the floodplain and salt flat topography is unclear. The ERMP does not provide modelling and analysis of water levels during 'worst case scenario' storm conditions involving the potential impacts of a one in 100-year storm event or greater combined with highest astronomical tidal conditions (refer to ERMP 'Water levels in Exmouth' Gulf page 6-5).

Water levels are influenced by astronomical tides, barometric tides, wind, storm surge, and long-term sea level rise. Storm surge is an important process in and around Exmouth Gulf (BOM, 2007) and a significant threat to coastal infrastructure. The magnitude and duration of storm surge in any given coastal area is a complex function of cyclone intensity, duration and path, extent of maximum winds, bathymetry and coastline shape. The actual water level is a combination of storm surge and tidal variation. The worst case scenario would involve a severe cyclone generating strong onshore winds and a large storm surge pass at the same time as high tide and combined seasonal or longer period high water levels along the coast. Under these circumstances water level will be well above the highest astronomical tide (BOM, 2007).

In considering the potential for extreme variation in local conditions for this proposal it is important to be aware of the severity of known storm events recorded in Exmouth Gulf in recent times. The ERMP (section 2.2.3, page 4-10) states that "severe cyclones occur approximately every 25 years" however, this quote has not been substantiated. According to the Bureau of Meteorology (BOM, 2007) it is estimated that a cyclone causing wind gusts in excess of 90 km/hr in the vicinity of Exmouth occurs about once every two to three years. Since 1982 there have been three cyclones causing gale force winds including Cyclone

Vance and 14 cyclones have been recorded in the previous 20 years (BOM, 2007). Cyclone Bobby tracked along the Pilbara coast in 1995 delivering approximately 300-400 mm of rainfall to Onslow. Surface water flooding of the supratidal flats following Cyclone Bobby is shown in Figure 4. Cyclone Vance caused widespread devastation to mangals and seagrass on the eastern side of Exmouth Gulf with storm surges reaching the salt flat areas of the supratidal flats. Although Cyclone Vance did not occur at high tide, it changed the appearance of the Gulf through destruction of mangals and some of the smaller inland dunes as well as of benthic primary producer habitats including seagrass and macroalgae. According to the ERMP ('Sandsheet', page 5-8), dunefields along the eastern margin of the saltflats were significantly affected during Cyclone Vance, which completely removed the lower dunes, some of which were 6-7 metres in height. At Onslow the storm surge was estimated to be 4 metres, three large barges were stranded on the end of Beadon Creek and the lower parts of the town were inundated by seawater (BOM, 2006).

Application of modelling and engineering methods using worst case scenario storm surge and tidal height projections is recommended to demonstrate that the proposed solar salt field mitigation measures to address potential breaching of seawalls and levee walls during major storm surges and cyclone events are adequate. This is particularly important for minimising the risk of discharge of bitterns and hypersaline water from the storage ponds into the marine/coastal environment. At present, levee walls and seawalls have been designed to mitigate against one in 25 and one in 50-year storm events respectively. This recommended modelling needs to be coupled with a description and quantitative modelling and analysis of the ecological consequences should storm surge and tidal mitigation measures be unsuccessful. This crucial information is absent in the ERMP.

Finally, the erosional effects of storm surge deflected from seawalls has not been considered in the ERMP. There are significant risks from these effects given the probability of a number of severe storm surge events generated through cyclonic activity, low pressure systems, sea level rise and high tides during the life of the project. The potential consequences of this form of disturbance, which has a capacity to enhance ebb tidal flows in the tidal creeks crossing the mangal and algal mat communities, should have been investigated for the ERMP. It is recommended that an independent review of the risks and consequences of surge reflection from sea wall structures be undertaken by independent engineers or coastal geomorphologists given the risks of disturbance and erosion of the algal mat and mangal communities (also see Section 4.2.3 of this submission).

Without a high degree of certainty that the seawall structures will not result in adverse ecological consequences during storm events, impact evaluation is difficult. Environmental risks and ecological consequences arising from the project will remain uncertain without more detailed evaluation.

Tsunami

Nott (2004) investigated the likely occurrence of tsunamis in Western Australia. North West Cape formed a focus of this study, and the deposition of boulders and wooden structures made by humans at 3 metres AHD resulting from 4-6 metre waves was discussed. Nott concluded that a storm surge created from a cyclone more powerful than the most powerful recorded cyclones to cross the Australian coast (Cyclone Tracey and Cyclone Vance) or a relatively small tsunami was responsible for the deposition of the boulders and historical artefacts at this height AHD on North West Cape.

It is important that the proponent acknowledges that there is evidence to suggest that storm events more powerful than Cyclone Vance and/or a small tsunami may have crossed this coastline in the past and that impact assessment and mitigation must consider the potential consequences (as well as the risks) of such extreme and unusual events in future.

Recommendations:

6. The proponent and the EPA should consider the high levels of uncertainty and coastal zone risks associated with climate change, sea level rise and storm events and note that the proposal poses indirect long-term and irreversible impacts to the integrity of the Exmouth Gulf ecosystem.

7. A quantitative relationship between tidal water levels and the salt flat topography should be established by the proponent as a basis for a more thorough assessment of likely site inundation by tides, sea level variation in response to the passage of weather systems at weekly to decadal scales, relative rise in sea level associated with climate change and subsidence of the land surface, storm surge due to extreme events, wave conditions, and tsunami. The relationship of cross-shore inundation to groundwater and biota also warrants closer investigation as a basis for investigation of risks to biodiversity arising from construction and operation of the salt ponds.

8. The proponent should be required to investigate the potential for the project to impact on the compaction of sediments comprising the salt flats, thus generating a relative rise in sea level over and above that forecast to occur in response to global climate change. The potential for this change is unknown and has not been considered in the ERMP document. However, the close interaction between sea level and the development of floodplains and associated mudflats is such that small changes in sea level may result in large changes to tidal creek and floodplain morphology (Winn *et al.* 2006). This matter requires geotechnical assessment to determine potential for occurrence and related evaluation of ecological consequences.

9. The proponent and EPA should consider the limitations of the Bruun Rule (1954) and the associated setback analysis in evaluating the impacts of the proposal. The project should be designed to incorporate worst case scenario sea level rise projections based on contemporary sea level rise predictions and methods of predicting local change and the use of the Bruun Rule in this instance should be peer reviewed by appropriate experts or abandoned. On the basis that the eastern side of Exmouth Gulf is low lying and prone to sea level rise and potentially increased frequency of severe storm events, the project can be considered to present a high risk to the integrity of Exmouth Gulf ecosystems, requiring the best currently available water level analysis and predictions, taking into account contemporary climate change modelling predictions with a suitable safety margin.

10. The proponent should be required to undertake further impact analysis of storm surge and cyclone events incorporating the following:

    10.1 Modelling to indicate the consequences of a one in 100-year (or greater if appropriate) storm event during a spring high tide event incorporating worst case scenario sea level rise projections;

    10.2 Discussion of the ecological consequences should a significant failure in seawall and levee structures occur at a large scale along the proposed site (including bitterns management area); and

    10.3 Further investigation and independent advice indicating the likely ecological consequences as a result of storm surge deflection from seawalls incorporating the prolonged inundation of mangals and algal mats and energy deflection impacts. These studies should detail the potential impacts resulting from the construction of sea wall/bund in an area of high natural variability using broad scale temporal (decadal) hydrodynamic and hydrological studies.

2. Surface Water and Groundwater

2.1 Uncertain hydrogeology and need for further investigations

The information provided in the ERMP (section 2.2.5, page 4-12; section 2.3.4 page 5-18; section 2.4.3 page 5-24; section 2.6.6 page 6-67) in relation to hydrogeology describes a semi impermeable clay layer underlying a shallow hypersaline superficial aquifer which would prevent major seepage from salt evaporation and concentration ponds into groundwater, but does not indicate whether this situation is uniform throughout the project area or whether further layers containing aquifers or transmissive materials occur at depth.

It is the view of DEC that the ERMP does not include an adequately detailed assessment of the hydrogeology of the area, based on comprehensive and adequate sampling and modelling. It is therefore impossible to undertake an informed evaluation of possible consequences for ecological systems of changes to the hydrogeology of Exmouth Gulf's coastal systems that may result from the project. The following points highlight apparent inconsistencies and information gaps in the ERMP in relation to hydrogeology:

- The natural groundwater system may be influenced by the supratidal hydrology. According to the proponent there is a continuous, uniform clay layer across the supratidal flat which prevents deep groundwater evaporation and seepage from salt ponds ('Seepage from salt ponds' and 'Saline groundwater intrusion' pages 5-23 - 5-24). The proponent's view is that that there is little or no vertical movement through the uniform, continuous and impervious clay layer (refer to ERMP Figure 4-8, page 4-14). The assumed uniformity and continuity of this clay layer does not however appear to be supported by geotechnical investigations undertaken by Halpern-Glick and Lewis (1966), which describes a coral-limestone basement outcropping irregularly. Karstic features in the limestone may also occur, and these would produce significant variations in both the clay thickness and also possibly in the vertical permeability of the Quaternary materials overlying any deeper groundwater system. These important existing data were not referred to in Parsons Brinkerhoff (2005) and do not appear to have been available during the hydrological investigations undertaken by this consultant for the purposes of their report, or for interpretation in the ERMP. Further geophysical geotechnical and groundwater hydrology investigations are required to confirm the proponent's assumption of uniformity in the underlying clay layer and to better characterise the groundwater hydrology of the project area.
- There is limited discussion in the ERMP (e.g. section 2.3.4 pages 5-18 – 5-19 and section 2.5, pages 4-21) on limestone features that may occur below the supratidal flat and the associated hydrological regime, presumably due to the limited geotechnical investigations below the superficial profile (section 2.3.1 page 5-16). Without this information, it is difficult to determine the extent of impact and the consequences of alteration of the hydrogeology of the supratidal flats. For example, limestone areas provide potential pathways for the movement of water and the presence of karstic limestone pillars could provide a transmissive 'conduit' for hypersaline and toxic waters to enter the natural water system under pressure. Furthermore, there is also potential for karstic springs in tidal creeks and offshore to support localised shallow marine communities. Karst springs at sea level have been known in Northern Australia to support specific mangrove species. The absence from the ERMP of definitive information on the presence of karstic system within the proposal area makes it difficult to assess the potential for impacts on these systems.
- The interconnectivity/relationships between surface water and groundwater have not been ascertained in the ERMP (refer to Chapters 2 and 3). There is currently a high degree of uncertainty with regard to the fate of surface water entering the area from the

Yannarie River/hinterland in relation to groundwater recharge processes. Additionally, the quality of groundwater below the clay layer underlying the supratidal flats and the relationship between groundwater and coastal primary producer habitats is unclear as investigations have been limited to surface and shallow aquifer sampling.

Recommendations:

11. Geophysical testing or geotechnical drilling should be undertaken by the proponent to at least a depth at which natural capillary or forced vertical leakage could be expected to occur, in order to verify the extent and depth and uniformity of the horizontal clay layer beneath the supratidal saltflats. The results of these investigations should be assessed independently with reference to the Halpern-Glick (1966) investigation data and the hydraulic permeability measurements of Parsons Brinckerhoff (2005) mapped spatially to depict the uniformity of the clay layer using agreed geoscientific means.

12. Further hydrogeological work should be undertaken by the proponent (possibly including seismic surveys) to determine the depth and extent of limestone features in the area of proposed ponds and associated infrastructure. The locations of limestone outcrops and subcrops identified on the mainland remnants within the supratidal areas should be mapped and correlated with results of other work to develop a clear understanding of the hydrogeology of the project area including natural water movement (of various qualities and nutrient loads) at different times of the natural water cycle. It is important to recognise that any karstic limestone pillars could provide vertical horizontal conduits for hypersaline or contaminated water to enter the natural system through the base of ponds.

13. The presence of groundwater flows/seepage to the nearshore environment and the dependence of coastal benthic primary producer habitat thereon should be investigated further in order to provide a high degree of certainty that mangals and other benthic communities will not be indirectly adversely affected through potential changes to the groundwater hydrology of the supratidal flats.

2.2 Uncertain impacts associated with changes to the surface water flow

Significant changes to surface water flows are proposed through the construction of the salt field and the subsequent flow diversions. According to the ERMP (section 3.3.2, page 5-28), surface water flows are represented by a complex interrelationship between water course, floodplain and intricate dune ridges. Yannarie River, Chinty Creek and Rouse Creek provide the major surface water flows to the eastern side of Exmouth Gulf.

Figure 5-14 on page 5-41 of the ERMP depicts natural surface water flows showing the major flows onto the supratidal flats. Flows from Yannarie North, Yannarie South, Rouse North and Rouse South can amount to a flow rate of $780m^3/s$, $1010\ m^3/s$, $460m^3/s$ and $490m^3/s$ respectively during a one in 100-year storm event (refer to ERMP, Table 5-3, page 5-35. These flows result in a water level above the supratidal flats of between 1.8 and 2.2 metres (Table 5-3 ERMP). The proposed diversion of surface water flow will occur at the Yannarie North channel and is designed to prevent pond levee wall breaches which are to be built to a one in 25-year storm event. A diversion weir and choke point (levee) (refer to ERMP Figure 5-16, page 5-43) will be constructed in the hinterland approximately 18 km from the crystalliser ponds/supratidal flats to divert the flows away from the crystalliser ponds and into the North Rouse and South Rouse channels.

In an effort to determine the natural surface water flow regime from the discharge channels of the hinterland onto the supratidal flats, the proponent commissioned Parsons Brinkerhoff to undertake a study to model and predict flows emanating from surface water catchments to the east of the proposal area. In part this analysis utilised flow from 1999 and 2004 storm events comparative spectrum analysis to validate modelled predictions and provide supplementary information on likely flows for parts of the study area with limited historic flow and other data (Parsons Brinkerhoff, 2006). It is noted that the report on this study advises that "comparative spectrum analysis has an inherent degree of error" (ERMP Appendix 8, page 23) which can be substantial depending on the site conditions and the quality of the image and that further modelling is recommended to ascertain a greater level of accuracy for flood protection work (Parsons and Brinkerhoff, 2006).

All hydrological modelling and predictive approaches contain a degree of inherent uncertainty (and hence potential for predictive error) based on the variability of natural systems and assumptions made (for example in relation to surface water leakage via groundwater recharge). These uncertainties are likely to increase for extreme events and in cases where limited actual data are available to test the model. Given the potential for error in the surface water modelling study used in the ERMP (ERMP Appendix 8 page 23) and the planned large scale diversion of surface water flows from the hinterland to the supratidal flat, the following potential issues have been highlighted:

- The impacts resulting from a possible failure of the proposed weir, significant alteration of surface flows and modification of potential nutrient transport pathways have not been discussed. There is a high degree of uncertainty in relation to the role and importance of the surface water flows across the supratidal flats to the intertidal zone/marine environment and the role these flows may play in the environment of these areas such as delivery of nutrients to the nutrient-limited Gulf.
- Detail on the design of surface water flow diversion appears to be absent from the ERMP. Information on the weir diversion and choke point is presented in section 3.3.5 of the ERMP, however patterns of movement of surface water past the choke point are unclear, particularly once the northern and southern ponds have been built to full capacity (refer to ERMP Figure 5-14, page 5-41).
- The ERMP (section 3.4.2, page 5-40, paragraph 7) indicates that impacts from the increased flow and velocities in North and South Rouse channels are unlikely to result in adverse impacts to these systems, however justification for this conclusion is absent from the ERMP. The potential for erosion through the north and southern diversions, effects on mangrove communities, algal mats and habitat values is an issue that presents mitigation complexities and requires further assessment.
- The construction of the weir will result in the flooding of at least 151 ha of hinterland vegetation during storm events. The significance of this vegetation and potential impacts of inundation cannot be assessed as flora and vegetation information in this area of hinterland is not provided in the ERMP document (page 5-43 'Impoundment and inundation'. The period of inundation may exceed 2-4 weeks under high humidity conditions which indicates that there is significant potential for loss and permanent change to vegetation communities.
- The ERMP dismisses the potential for surface water flows to act as a nutrient vector from the supratidal flat to the Gulf (page 5-44, paragraph 4). Targeted studies that provide a high degree of certainty that surface water flows across the supratidal flats do not provide important water or nutrient pathways from the hinterland across the supratidal flats and algal mats should be undertaken. This work should ideally occur immediately following the next major storm event.
- Surface water quality sampling, including nutrient concentrations and sediment quality has not been undertaken (refer to ERMP section 3.1.1 'Investigations' page 5-30 and Appendix 8 Parsons and Brinkerhoff (2006)). Without a baseline surface water quality dataset, it is difficult to assess impacts of directed surface water flows on marine water

quality or the impact of redirecting surface water flow from its current pathway across the supratidal flats.

- At present, there is some uncertainty surrounding the role of surface water flow for groundwater recharge. It is therefore difficult to assess environmental impacts and ecological consequences of surface water diversion without a clear understanding of this potential hydrologic function.
- The ERMP states that groundwater, soil salinity and tidal inundation strongly influence the distribution of mangrove communities (refer to ERMP page 4-14, paragraph 1). The changes to surface water and potential impacts on mangroves have not been discussed in section 3.4.2 'Diversion or redirection of Yannarie River flows' (pages 5-39 – 5-50). The ERMP states that the groundwater and surface water flows from the hinterland have negligible influence on the maintenance of salinity gradients in the intertidal zone (section 2.4, page 4-18), however, this statement has not been verified through a scientifically based explanation and evidence of how the system is currently functioning.
- According to section 2.4.2 (page 4-21) of the ERMP tidal creeks facilitate the inundation and draining of mangrove and algal communities and convey nutrients to offshore areas of the eastern side of the Gulf. The potential for surface water flows related to major storm or rainfall events to play an important role in the flushing of these creek systems has not been discussed and an explanation of the consequences of the loss of these flows is absent.

Based on the above mentioned uncertainties and information gaps related to significantly modified surface water flows, it is difficult to ascertain the long-term ecological consequences of surface water flow diversion that appears to be an integral component of the proposal. As there is a likelihood that surface water flows play a role in delivering nutrients to the Gulf either from the hinterland or through the flushing of the supratidal flats and algal mats and may be important in their own right to maintaining the existing salinity regime within the coastal interzone, the removal of these flows could have major long-term impacts on primary benthic producer habitats in the Gulf which support conservation significant fauna and a significant prawn fishery.

Mitigation and management measures to address these issues are largely unclear as the management of surface water is currently dependent on a future Surface and Groundwater Management Plan, success of the proposed weir/diversion point system and the questionable prediction that surface water flow does not play a role in the Exmouth Gulf east ecosystem.

Recommendations:

14. The necessary studies (as highlighted above) should be undertaken to ascertain the importance of surface water flows to Exmouth Gulf east in terms of groundwater recharge, salinity regime and nutrient delivery at long temporal scales. This should include surveys immediately after severe storm events to determine water and nutrient contributions to the Exmouth Gulf.

15. The proponent and the EPA should recognise the uncertainties and lack of data in relation to the potential effects of large scale alterations to surface water flows within the proposal area and the indirect long-term impacts that could result in these changes.

2.3 Potential for changes to groundwater hydrology and dependent ecosystems

The interconnectivity of groundwater between the mainland remnants, the nearby primary producer habitats and the aquifers below the supratidal flats, has not been modelled. Information gaps include groundwater quality and groundwater formation, particularly within limestone features. In addition, the groundwater hydrological links are unclear and the potential for groundwater to be an important contributor to the maintenance of algal mat and mangals has not been explored in detail. Therefore the management measures and impact analysis have been developed without the necessary information to make informed risk and impact evaluations.

In addition, there will be some dewatering required at Hope Point for the construction of the barge harbour and establishment of limestone quarries. The ERMP states that "Full geotechnical surveys of these sites have not yet been possible due to site access constraints" (page 5-22, paragraph 1). Given the lack of survey, there are no data available to predict or model the potential drawdown cone of influence as a result of dewatering, and therefore determine impacts to groundwater-dependent ecosystems in this area.

Based on the uncertainty in relation to groundwater hydrogeology, the following potential risks to the long-term integrity and function of the Exmouth Gulf ecosystem have been identified:

- long-term changes to mangals and algal mats through potential large scale modification of the groundwater system of eastern Exmouth Gulf;
- additional seepage of hypersaline groundwater into algal mats, tidal creeks and mangroves as a result of construction of ponds over the supratidal flats and infiltration of saline water through the proposed ponding process;
- modifications of subterranean fauna habitat (see Section 9 of this submission); and
- release of heavy metals from within layers of the sabkha system.

Recommendations:

16. The proponent should determine areas/communities within proximity to the boat harbour that are potentially sensitive to groundwater drawdown prior to a final assessment and decision on this proposal.

17. There is a need for a high level of certainty in the relationships between groundwater and coastal ecosystem processes. This should be ascertained prior to the final assessment and decision on this proposal. This should include a clear understanding of long-term groundwater dependency of algal mats, mangroves and nutrient supply to the Exmouth Gulf.

18. The long-term consequences of changes to groundwater systems that may result from salt field construction should be investigated and the results of these investigations should be provided to decision making authorities prior to the completion of the EPA's assessment. This should include the potential risks and consequences of heavy metal release into the marine and tidal environments of Exmouth Gulf.

3. Impacts on conservation of salt flat (sabkha) ecosystems

3.1 Possible underestimated value of the supratidal flats

An area of sabkha can be described as a flat and barren area usually consisting of sand or finer unconsolidated substrate showing superficial evaporite accumulations. Coastal sabkha are periodically flooded by sea water and the groundwater is of marine origin as well as most sediments. Their surface is an equilibrium of deflation and Aeolian sedimentation controlled by shallow local groundwater level which is the lower limit of deflation (Barth & Boer, 2002).

Based on the above definition, further information in Barth & Boer (2002) and expert advice, the supratidal flats, or salt flats of the eastern side of the Exmouth Gulf, within the study area could be considered as typical of a 'sabkha' ecosystem (Steve Appleyard, pers. comm, 2007). The ERMP (section 1.4.2 'Landform modification' page 5-11) states that the solar field will occupy approx 410 km^2 at full production which accounts for 32% of the salt flat land form within the Ashburton Land System (1270 km^2 in total). Given that much of the 'sabkha' salt flat systems within the Pilbara are likely to be impacted by other industrial developments such as salt fields, the proponent should provide an estimate of the project's primary footprint as a percentage of the remaining salt flat systems along the Pilbara coast.

The ERMP also states that the ecological significance of this landform to the mangrove and algal mat communities is negligible (page 5-11, 'Landform modification'). According to Table 5-8, 161.32 ha will be cleared for the solar salt development. Table 5-8 does not recognise the 411 km^2 of salt flat that will be disturbed as a result of the development. The ERMP (e.g. section 1.3.4 page 5-6 and section 2.5 page 4-21) does not provide any detailed discussion on the direct and indirect impacts of the development on the values of the salt flats system, and instead presumes that these areas have no values, with no supporting argument.

DEC is of the view that the ecological importance of salt flats has been substantially underestimated for this proposal. The proponent appears to be adopting a widespread but ill informed belief that the 'sabkha' areas impacted by this proposal are wastelands. Many sabkha have undergone development based on this belief, however the ecological significance of sabkha systems is far from being properly defined. For example, there is very little known about primary productivity (e.g. cyanobacterial mats, diatoms), birds and benthic organisms possibly relying on sabkha ecosystems (Barth & Boer, 2002). Lieth and Menzel (2002) recommend the designation of suitable sabkha as research reserves.

Studies of the Middle Eastern sabkha have confirmed the associations between these areas and coastal habitats such as seagrass and macroalgal beds (John, 2002 and Philips, 2002) and indicated that long-term ecological impacts can result from the modification of such sensitive and complex ecosystems (Barth and Boer, 2002). Studies in Abu Dhabi undertaken by Round (2002) indicated that sabkha can be colonised by microscopic algae that feature prominently at the base of the food chain. These diatom dominated communities are largely unstudied and their contribution to carbon fixation is unknown but is likely to be significant for extensive areas. Belnap (2002) discusses the important ecological role that soil crust on the surface of sabkha may have and that the disturbance of soil crusts often leads to reduced nutrient input and increased soil erosion.

The removal of the supratidal salt flat system and replacement with enclosed salt ponds for a prolonged period may have long-term irreversible impacts for the sabkha ecosystem of the Eastern Exmouth Gulf and the ecological interactions with coastal systems such as through movement of nutrients and groundwater.

3.2 Potential for release of heavy metals accumulated in sabkha

Microbial mats in sabkha sediments are known to accumulate large amounts of heavy metals (Taher *et al.* 1994) and many of the world's important base metal deposits such as the Kupferschiefer in Germany and Poland, and the Copper Belt in Zambia were formed in sabkha environments at various times in geological history (Brown, 1977). However, as microbial mats in sabkha are very sensitive to disturbance, there is a risk that large amounts of metals currently trapped by microbial mats could be released and discharged to the nearshore environment of the proposed salt works and impact on the algal mat communities.

Metal release to the marine environment from coastal disturbance has already been recorded in a similar setting in Shark Bay where cadmium concentrations in excess of 10 mg/kg were measured in several species of molluscs despite the absence of any obvious point sources of contamination in the area (McConchie and Lawrance, 1991). Subsequent investigations (McConchie and Lawrance, 1991) indicated that cadmium was being transported on iron oxide coatings on soil particles eroded from the coast. When the soil particles settled onto the seafloor, altered chemical conditions and filter feeding by molluscs stripped the cadmium from this material and transferred it to soft tissue in these organisms.

While the ecological consequences of high cadmium levels in biota in Shark Bay have not been fully investigated, cadmium is of significant environmental concern because of the ability of this metal to be biomagnified in local food webs and affect the health of organisms at higher trophic level in a given ecosystem. Bird populations appear to be particularly sensitive to cadmium toxicity. For example, Larison *et al.* (2000) found that about half of the entire adult population of one bird species (white tailed ptarmigan) in a mining district in Colorado USA suffered from bone and kidney damage due to cadmium poisoning from the release of cadmium into local soils and sediments.

It is important that the potential for large scale release of heavy metals from the supratidal flats of Exmouth Gulf through hydrological modifications and any adverse implications for the adjacent and nearby habitats of the Exmouth Gulf (in particular, filter-feeding organisms and fauna that prey on these communities) are properly investigated and evaluated. The release of heavy metals in sabkha could result in irreversible long-term impacts that may impact on the productivity and conservation values of the Exmouth Gulf ecosystem.

3.3 Conservation and reservation of sabkha ecosystems

Arid and semi arid zones account for more than one-third of the earth's land area. Until recent times these lands had relatively low levels of human pressure. Through development pressures and climate change, the productive potential of the arid zones have been weakened and desertification and irreversible soil degradation have resulted (Clusener-Godt, 2002). The United Nations Educational, Scientific and Cultural Organisation (UNESCO) has recognised the importance of sabkha ecosystems and has included the preservation of arid and semi-arid regions in the Man and the Biosphere Programme. UNESCO has recognised the potential important interaction of sabkha with adjacent marine or terrestrial ecosystems such as active sand dunes, mangroves, seagrass and other coastal systems (Clusener-Godt, 2002). Importantly, the Marine Parks and Reserves Selection Working Group Report (Wilson et al. 1994) has specifically recognised the importance of the eastern Exmouth Gulf salt flats by identifying the importance of including this area in the recommended Exmouth Gulf candidate marine conservation reserve.

It should be noted that the eastern side of Exmouth Gulf represents one of the largest and last intact examples of sabkha in Western Australia and the development of the project would severely compromise its conservation values. The WA Biodiversity Audit also identifies "Bare Areas mudflats" vegetation association description as being an ecosystem of high priority for reservation, with none of this ecosystem within the Carnarvon Bioregion currently included in the conservation reserve system (page 74, WA Biodiversity Audit). The ERMP recognises that the proposed Solar Salt project covers the largest expanse of mud flats in the Cape Range sub-bioregion (section 4.3.2 page 5-54).

Recommendations:

19. Further investigations are required as part of impact assessment to enable the EPA to evaluate the ecological importance of the Exmouth Gulf salt flat system and the ecological relationship between the sabkha and adjacent algal mat and mangrove communities. These studies may include, but are not limited to the following:
    - Seasonal and tidal variations in water table and interdependencies between the salt flats and mangroves, algal mats and island vegetation;
    - Monitoring of soil salinity fluctuations to gain a baseline understanding of the seasonal soil salinity across the sabkha ecosystem; and
    - Microbial activity within the sabkha and the contribution of nutrients to the Exmouth Gulf.

20. Further studies, similar to those undertaken in the Arabian Gulf (published in Barth and Boer, 2002) should be undertaken to gain an understanding of the role of the salt flats of Exmouth Gulf in the overall maintenance of ecological function. There is minimal available information on the role of the salt flats in the Exmouth Gulf ecosystem and therefore further studies that investigate the productivity of the flats and potential ecological linkages between the supratidal flats, algal mats and mangroves with the entire Gulf ecosystem should be undertaken.

21. There is a need for further sampling to clarify whether there is significant storage of heavy metals in the deep soil profile of the supratidal flats. An assessment of the potential for release of heavy metals to occur should be undertaken and if appropriate, the risk of bioaccumulation should be investigated as part of the impact assessment of this proposal.

22. The contribution of the supratidal salt flats to nutrients, productivity and ecological function of the Exmouth Gulf should be analysed further to investigate the possibility that the supratidal flats are important sources of nutrients for the Gulf. As described in Section 3 of this submission, other salt flat systems have been known to support algae productivity within the sub-surface areas of the flats. Brunskill *et al.* (2001) state that the salt flat is partly covered with a mat of blue-green algae and these organisms fix atmospheric nitrogen and provide this nutrient element to supratidal waters. The proponent should describe the extent of any cyanobacterial mats above and below the surface and this should be depicted on maps.

23. The EPA should take into account the extent of existing anthropogenic impacts on salt flat ecosystems and the lack of representation of these areas in the formal conservation reserve system and note that the development of the current proposal on the Yannarie Salt Flats will forego opportunities to formally reserve a highly intact example of a sabkha ecosystem. Occurrences of these systems in other areas of the world are considered ecologically significant by UNESCO.

4. Disturbance to benthic primary producing habitats

4.1 "Wilson Report" recommendation and marine conservation reserve

Key benthic primary producer habitats that occur within the Exmouth Gulf ecosystem include mangroves, algal mats, seagrass, algal beds and coral communities. The Marine Parks and Reserves Selection Working Group (MPRSWG) Report (Wilson et al. 1994) has identified the eastern side of Exmouth Gulf as an area of high ecological value and an important nursery supporting the Exmouth Gulf prawn fishery. The Report also recommends this area as a candidate marine conservation reserve (Figure 5). Exmouth Gulf provides the following critical habitats and biodiversity values:

- Six species of mangroves and algal mats occur in the area which provide primary productivity and support nutrient flows and other ecological functions to the eastern Exmouth Gulf.
- The area contains regionally significant mudflats and sand flats with associated epibenthic and burrowing faunal communities containing a number of species endemic to the Pilbara and Kimberley regions. In particular the mud/sand flats and mangrove areas around Hope Point are important habitat which is regarded as internationally important for five migratory species (Straits Salt Pty Ltd, 2006).
- Several low limestone islands in the area fronting the mangals provide nesting sites for seabirds.
- Extensive seagrass beds provide habitat for marine turtles and a dugong population of around 1000. Exmouth Gulf provides important linkage between the Pilbara and Shark Bay systems in supporting the dugong populations of the Western Australian coast, and is of further significance in providing developmental and foraging habitat for marine turtles (R. Prince pers. comm).
- The eastern banks of the Gulf produce significant quantities of seagrass detritus and the supply of this material to the remainder of the Gulf may be an important supply of nutrients to the ecosystem (McCook et al. 1995).

The MPRSWG has recommended the reservation of "*the distinctive eastern mangal and adjacent coastal water of the gulf to enhance protection.*" and has also indicated that "*Reservation of the supratidal flat between the mangroves and the hinterland would be essential to ensure adequate management of the mangal and coastal habitats of the marine reserve*".

Recommendation:

24. The EPA's consideration of this proposal should take into account that, should the proposal be approved, one of the largest and most extensive, intact examples of Western Australian arid zone coastal salt flat ecosystems will be severely modified with the potential for portions of the adjacent primary producer habitats to also be significantly modified, thereby foregoing long-term opportunities for formal protection of outstanding and essentially unmodified examples of these ecosystem types in the formal conservation reserve system for Western Australia.

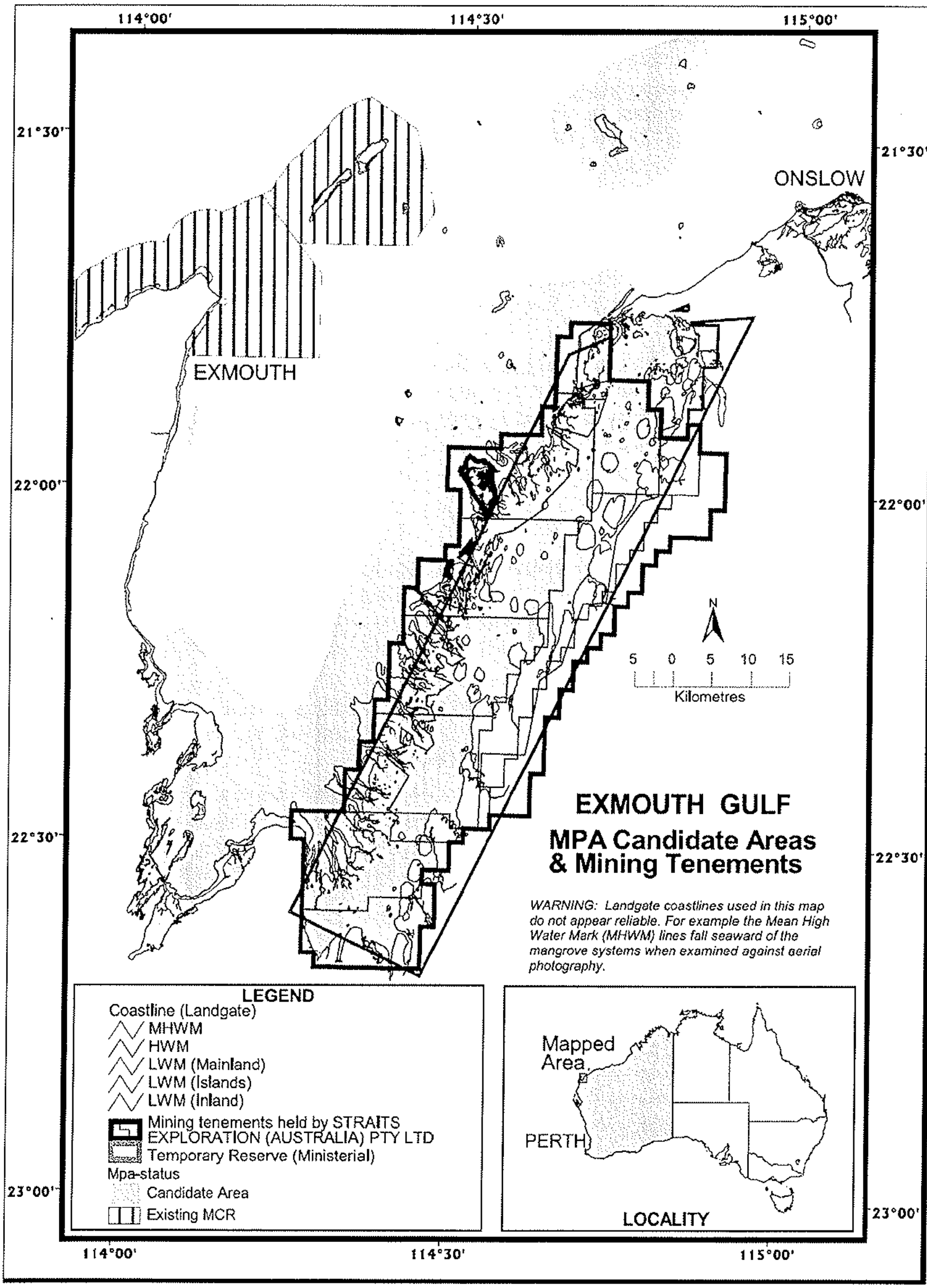

Figure 5: Map indicating the recommended boundary for reservation of Exmouth Gulf overlaid with Straits Salt Pty Ltd tenements.

4.2 Mangroves

4.2.1 EPA Guidance Statement 1

As referred to in EPA Guidance Statement 1 (EPA 2001), Semeniuk (1997) has assessed the regional significance of the tropical arid zone mangrove systems of the Pilbara Coast including Exmouth Gulf and concluded that the eastern Exmouth Gulf mangroves communities are regionally significant.

EPA Guidance Statement no 1 (EPA 2001) indicates that the mangroves of Exmouth Gulf fall within 'Area 2' which falls within guideline category incorporating as areas that "*contain regionally significant mangroves that occur outside of areas that have been designated for industrial areas, associated ports or related development*". The EPA's stated operational objective for areas that fall within this category is 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*". The Guidance statement also states that "*Proponents should be aware that where developments are proposed in these areas, the EPA will adopt a presumption against finding the proposal environmentally unacceptable*".

Figure 6 depicts the areas of Exmouth Gulf to which Guideline 1 of Guidance Statement No. 1 applies.

Recommendation:

25. The EPA should apply the policy referred to in Guidance Statement No. 1 and not support industrial development on the eastern side of Exmouth Gulf, recognising the potential adverse impacts of the proposal on these regionally significant arid zone mangrove communities. These impacts potentially include alteration of groundwater hydrology, large scale modifications to surface water flows, erosion and sedimentation of tidal creeks and alteration of coastal processes.

4.2.2 Mangrove dependence on groundwater and surface water flows

A central factor controlling mangrove occurrence is the combination of tidal elevation and daily seawater inundation which affect the groundwater salinity in mangrove sediments. Semeniuk (1983) has shown that groundwater salinity in the upper tidal range can be reduced by seepage from perched aquifers occurring as superficial lenses on mainland remnants. According to the ERMP (page 6-30 paragraph 3) large stands of mangroves occur in the upper tidal range on the edge of the supratidal mainland remnants.

Of significant concern are the claims within the ERMP (e.g. 'Landform modification' page 5-11, and section 2.3.4 pages 5-18, 5-19), that hinterland flood events and natural groundwater seepage through aquifers below the supratidal flats and the effects of these flows on the system appear to be negligible, without the results of adequate studies to provide supporting evidence. This is of particular relevance in terms of flow events that may occur at the decadal time scale.

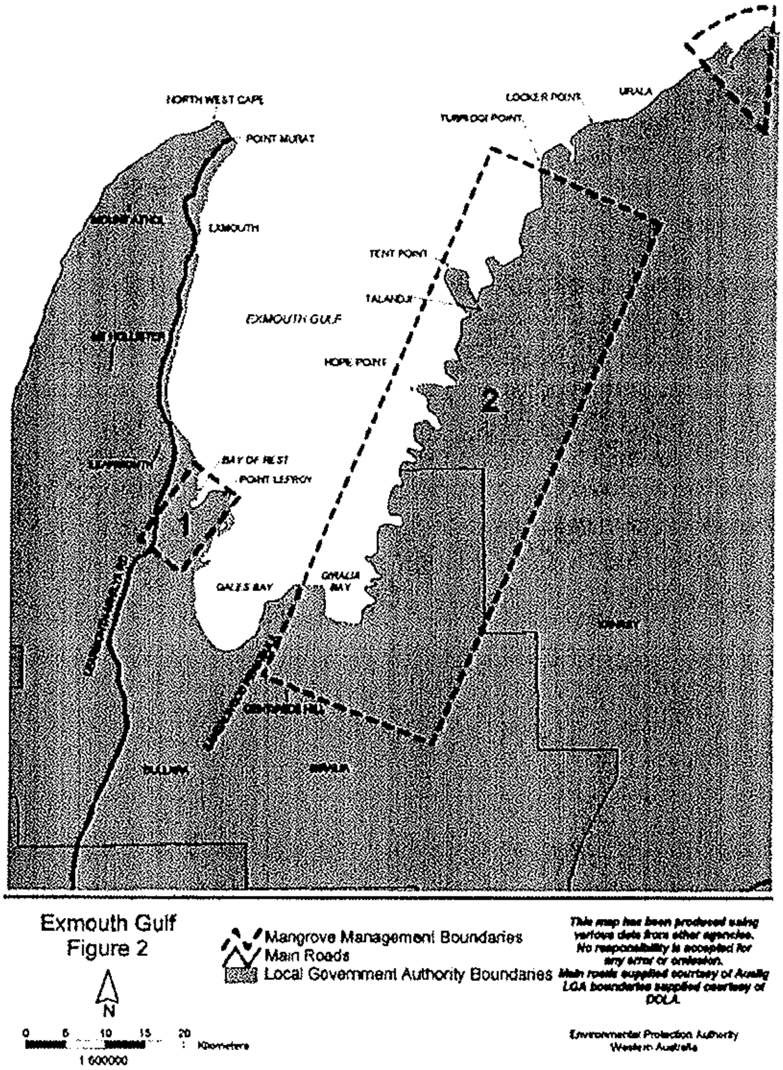

Figure 6: Area of Exmouth Gulf Affected By Guideline 1 within Guidance Statement No 1.

The ERMP (section 3.3.5, Table 3-5, page 5-35) indicates that hydrological modelling and review of historical rainfall data has shown that only one in 20-year and one in 100-year events generate significant rainfall enough to cause outlets from Yannarie River and Rouse Creek to flow onto supratidal flats. The claim that "most rainfall events do not flow onto supratidal flats and are insignificant" does not take into account the potentially high importance to the hydrological and ecological system of infrequent, but potentially ecologically very important, major flooding events. A more important consideration in relation to the significance of these events is the extent to which these contribute to flushing of the tidal creek systems and recharge of groundwater systems below the supratidal flats and mainland remnants, and the significance of these in the nutrient cycle and coastal hydrodynamic processes of the Gulf.

4.2.3 Potential effects of the pond sea walls

The construction of the pond sea walls within the tidal inundation zone is considered to pose a high risk of altering the hydrodynamics of the intertidal mangrove and algal mat ecosystem. As discussed in section 1, Exmouth Gulf is an area prone to intense weather and tidal perturbations including severe cyclones and the potential impacts of the location for construction of the sea walls and levees require careful scrutiny. The following potential impacts of the construction of the sea walls, levees and salt ponds within the tidal and supratidal zone require specific consideration:

- Deflection of energy from storm surges resulting in erosion of substrate which supports benthic primary producer habitat; and
- Restriction of mangrove retreat capability through the removal of habitat necessary for retention in order to allow for adaptation/migration in response to potential changes in sea level.

Deflection of energy and alterations to hydrodynamics and erosional processes

The potential impacts of constructing permanent structures within the tidal zone must be explored and the deflection of wave and other energy from storm surge and low pressure systems combined with highest astronomical tides must be discussed. There is potential for the deflection of wave energy combined with longer inundation periods resulting from cyclones, storm and tidal surge to result in subsequent loss of mangrove and algal mat communities. Given the likelihood that these communities play a vital role in sustaining the productivity of Exmouth Gulf and possibly ecological linkages with Ningaloo Reef and the Muiron Islands, the construction of these large sea wall structures poses risks which must be assessed and addressed as part of the assessment of this proposal.

The need for this assessment is reinforced by the observation of Brunskill *et al.* (2001) that there is little evidence of coastal trapping of sediment and oceanic elements in Exmouth Gulf and some regions of intertidal mangrove and salt flat are being eroded into the Gulf and adjacent shelf, such that the mangrove zone may be diminishing in area. The potential impacts on mangroves and algal mats from the construction of a sea wall and levee walls in an area potentially prone to such erosion have not been adequately discussed in the ERMP (i.e. Chapter 6 - 2.6 'Impact Assessment and Mitigation', pages 6-42 - 6-91).

Effect on ecological changes and migration of mangrove communities

Finally, there is a likelihood that the project will create a barrier preventing mangroves from retreating/migrating landward in response to sea level rise or other changes in coastal processes. This potential adverse impact has not been discussed adequately in the ERMP (i.e. Chapter 6 - 2.6 'Impact Assessment and Mitigation', page 6-42 - 6-91).

Recommendations:

26. The proponent and the EPA should recognise that the information presented in the ERMP does not provide the level of certainty required to demonstrate that the integrity and ecosystem functional values of mangrove ecosystems will be maintained over the long term (decadal scales).

27. The proponent and the EPA should recognise that the changes to surface water flow, groundwater integrity, sedimentation rates and erosion caused by the scale and location of the proposed pond sea walls have the potential to adversely affect the

distribution of regionally significant arid zone mangrove communities and ecosystem processes that underpin the values of these communities.

4.3 Algal mats

DEC understands that the algal mats of Exmouth Gulf cover approximately 8000 ha and date back to the pre-Cambrian. These cyanobacterial mats are based on ecosystems dating back approximately 3.5 billion years and fix atmospheric nitrogen into bio-available nutrients. The ERMP (section 2.4.3 page 6-32 – 6-33) recognises the importance of the algal mats as a key source of nitrogen in the nitrogen-limited Exmouth Gulf (Straits Salt, 2006).

Table 6-3 of the ERMP (page 6-11) indicates that supratidal salt flats and algal mats contain the highest concentrations of nitrogen, phosphorus and sulphur. The algal mat provides in the order of 550 tonnes of nitrogen per year to the mangrove and nearshore ecosystems of the eastern Gulf (page 6-33, paragraph 1).

The ERMP (page 5-44 'Sediment and nutrient pathways') indicates that surface water flows are negligible in providing nutrients to the Gulf, however Paling and McComb (1994) indicate that the export of biologically available nitrogen to the Exmouth Gulf can occur through tidal movements and incident rainfall.

DEC notes that Straits Salt Pty Ltd is contributing to a PhD study currently being undertaken which is focused on the food web ecology of the supratidal, algal mat and mangrove areas of Exmouth Gulf. This research will investigate the role of transient nekton in supporting estuarine food webs in tropical-arid north-western Australia. In these systems, the hypersaline supratidal salt flats and associated cyanobacterial mat formations that occur landward of the mangroves are the dominant landscape feature, yet intermittently available to estuarine consumers on high spring tides. Tidal movements of nekton from this habitat to adjacent habitats may represent a significant functional link by subsidising nutrients and energy to adjacent coastal fisheries via a 'trophic relay', a series of predator-prey interactions (Kneib, 1997). Specifically, this research aims to determine:

1) the relative importance of mangroves vs. cyanobacterial mats in supporting nekton in an arid zone estuary;
2) whether trophic connectivity via nekton is dependent on the spatial arrangement of the estuarine habitat mosaic; and
3) whether tidal movements of the giant shovelnose ray (*Rhinobatos typus)* are likely to represent an important biotic vector of energy transfer across the arid zone habitat mosaic.

The preliminary results of this study are worthy of consideration by the EPA during the assessment of this project as the functional links and energy transfers via nekton between habitats on the eastern and southern shores of Exmouth Gulf may be significant.

The ERMP lacks balanced and scientifically substantiated discussion of whether the surface water flows entering the system periodically via the supratidal flats play a role in regulating the salinities to optimal levels for algal mats (page 6-36 'Factors controlling algal mat distribution'). Information on the likely optimal salinity regime (in water quality and temporal terms) for the support of algal mat growth should be provided in addition to a discussion on the dependence of the algal mats on groundwater seepage.

Recommendations:

28. The proponent should quantify the significance of surface flows including flows resulting from a greater than two year annual return interval as a potential pathway for transfer of nutrients from the primary producer algal mats and Exmouth Gulf.

29. The proponent should provide sufficient information on the hydrogeology of the site to enable decision makers to make an assessment of the likely impacts to algal mat communities resulting from groundwater seepage from salt ponds and changes in surface and groundwater flows resulting from the proposal. Modification of the water and nutrient flows to Exmouth Gulf has the potential to result in long-term impacts to the system that are irreversible given the age of algal mats and their potential importance as a nutrient source.

30. The consequences (in addition to the probability) of the failure of the levee walls for the bitterns management area, crystalliser ponds and concentrator ponds should be discussed and the possible impacts on algal mats and other systems evaluated by the proponent. Justification should be provided for the proposed design of these walls to withstand a one in 25-year storm event, rather than more severe (1:100 year or greater return interval) events such as severe cyclones.

31. The proponent should undertake detailed mapping of algal mat distribution within the project area to provide a better understanding of the productivity of the algal mats system and its contribution to nutrient inputs to the Gulf systems.

32. The potential for negative impacts on algal mat communities to have long-term ecological consequences for the Exmouth Gulf ecosystem through reductions in the amount of bio-available nutrients entering the Gulf should be taken into account in the assessment of the proposal.

4.4 Seagrass/algae beds

Algal beds

Within an area of rocky pavement between north of Hope Point and a shallow ledge that extends in a north-westerly direction from Hope Point is a significant area of algal bed growth with almost 100% cover which forms an important nursery and nutrient source. It appears that the area around Hope Point will be disturbed through the construction of the barge harbour and dredging of the barge channel. The extent of algal beds is unclear as benthic primary producer habitat maps are not available. It is likely that the algal beds, mangroves and seagrass meadows together, provide important habitats for the recruitment of fish fauna, although it is noted that McCook et al. (1995) suggest that the extensive algal beds within the Gulf are probably the major primary producers in this ecosystem. While the directly impacted area is not large relative to the scale of the Gulf, the lack of accurate benthic habitat mapping means that the significance of this area for primary production cannot be determined.

Seagrass

The shallow areas of the eastern side of Exmouth Gulf, particularly around Islam inlet south of Hope Point, are important in supporting high biomass seagrass (*Halodule uninervis*). High biomass seagrass are likely to support better survival and growth rates of juvenile prawns (Loneragan, Exmouth Gulf Scientific Forum 2006). The extent of the seven species of seagrass and the high biomass areas within the vicinity of Hope Point and the proposed barge harbour and channel is unclear due to the absence of adequate benthic habitat maps.

The eastern side of the Gulf south of Tubridgi Point contains extensive shallow waters that support seagrass species and algae. There have been observations of a significant increase in seagrass biomass from October to December, with biomass decreases in seasonal cycles between August and September.

McCook *et al.* (1995) provide the only significant study focused on seagrasses in Exmouth Gulf and described strong linkages between seagrass, algae and prawns. A marked loss in prawn catch was noted following Cyclone Vance with a fast recovery in seagrass showing a parallel recovery in prawn returns. It is possible that this rapid recovery could be attributable to the nutrients provided from the south-eastern side of the Gulf. The ERMP (section 2.6 pages 6-42 – 6-49 and section 3.4 pages 6-115 – 6-141 has not considered the consequences of impoundment failure and consequential release of potentially hypersaline and toxic brine, particularly as it relates to impacts on the algal mats and the ability of seagrass to recover following cyclone events and marine fauna. It is important then to consider that if the proposal is approved, there are significant risks to ecological and economic values of the Exmouth Gulf through potential loss of seagrass habitats.

Recommendations:

33. The proponent should undertake benthic habitat mapping to identify the distribution and biomass of the seasonal seagrass beds in the area. This will provide the necessary baseline for assessing potential changes to benthic habitats. Benthic habitat maps should indicate the most important nursery areas for fish, prawns and other marine fauna and the percentage coverage for each species of seagrass. This will assist in identifying critical habitats for marine fauna, including dugong (also refer to section 4.7).

34. Potential impacts to seagrass and macroalgal beds that could result from release of hypersaline and toxic substances resulting from pond wall failure should be identified and assessed by the proponent through modelling or other predictive approaches and considered in the impact assessment of the project.

35. The proponent and the EPA should recognise the risks to seagrass beds associated with this proposal resulting from potential large-scale changes in nutrient pathways, water quality and coastal sedimentation rates and the potential consequences for the ecological integrity (including habitat for conservation significant fauna such as marine turtles and dugong) and productive capacity of the Gulf marine systems (also refer to section 4.7).

4.5 Filter feeders/coral

Filter-feeding communities (sponges, tunicates and cnidarians) particularly in the north of Exmouth Gulf are well developed (CALM, 2005 Ningaloo Marine Park Management Plan). Soft sediment communities occur in the more protected environments of Exmouth Gulf. Soft sediment communities are important because of the high diversity of in-fauna and epifauna (particularly invertebrates) found in this habitat. The distribution of other filter-feeding communities is unknown (but they are likely to occur in some of the deeper, high current areas between the offshore islands).

The ERMP (page 6-40) states that sponges were observed in waters up to 3 metres deep with up to over 30% cover and are considered an important element of Exmouth Gulf ecosystem especially in areas with stronger currents. Although diverse filter feeders occur in the deeper waters of the Gulf, the distribution of filter-feeding communities is yet to be ascertained. As benthic habitat mapping has not been completed, the distribution and extent of filter-feeding communities in the eastern Exmouth Gulf is largely unknown. Sponge communities may also provide foraging habitat for hawksbill turtles (R Prince, pers. comm).

There is little information available on coral in the ERMP (page 6-40). The transect surveys that were undertaken were limited to Hope Point. A coral community has been recorded in the Bay of Rest in waters that are relatively turbid for coral reef development (Appendix 7 of the ERMP). These conditions have favoured turbid water resistant corals, particularly members of the genera *Alveopora* and this is currently the only such community known in the region.

A small area dominated by bryozoans also occurs in tidal channels on the north-eastern side of Tent Point. Bryozoans form terrace reefs approximately 0.5 metres high. The possible distributions of similar communities within the region are presently unknown (this type of formation in turbid waters is quite unusual and at present is only known at this site within the region) (Appendix 7 ERMP).

Potential impacts to corals include sedimentation from dredging activities and changes to sediment loads due to surface water diversion, resulting in increased turbidity. Figure 6-38 (page 6-74) in the ERMP shows the maximum suspended sediment concentrations caused through excavation and dredging at Hope Point, indicating that sediment loads will reach the waters surrounding Tent Island Nature Reserve. The possible impacts of this on corals has not been discussed in the ERMP (section 2.6 pages 6-42 – 6-49)and it is difficult to determine the level and significance of impacts in absence of an adequate benthic habitat map.

Recommendations:

36. The proponent should provide information on the potential impacts of sedimentation/turbidity on coral and filter-feeding communities resulting from dredging and changes to sedimentation processes associated with major surface water diversion and the effects of this during storm events.

37. For impact assessment to be undertaken and risks to benthic communities to be determined, adequate habitat mapping is required to provide a baseline dataset for benthic primary producer habitats in the waters of Exmouth Gulf east and those areas directly affected by the proposal (also refer to Section 4.7 of this submission).

4.6 Linkages with Ningaloo Reef and Muiron Islands

Of very high importance is the likely ecological interconnectivity between benthic primary producer habitats in Exmouth Gulf (primarily mangroves, macroalgae and seagrass) and the Ningaloo Marine Park (proposed World Heritage Area) and the Muiron Islands Marine Management Area. These marine protected areas supported extensive coral reef systems and tropical fish fauna and also provide habitat for other species of conservation significance. Although the ecological linkages between Exmouth Gulf and Ningaloo Reef are relatively understudied at present, the likelihood of ecological relationships between the mangrove and seagrass communities of the Gulf and Ningaloo Reef coral and other communities is considered high. Mangroves, seagrass and coral reefs are linked together by the water masses that move in and out with the tide and by the fauna that move between these habitats. Given the mangrove areas of the eastern side of Exmouth Gulf provide the most extensive mangrove system in the vicinity of the Ningaloo Reef and the Muiron Islands, it is likely that these mangroves provide nursery habitat for both commercially valued and non-commercial marine fauna species.

Studies in other parts of the world have substantiated the interconnectedness between coral reef, seagrass and mangrove communities.

Recommendation:

38. The EPA should recognise that any potential loss in the benthic primary producer habitats of the Exmouth Gulf could reduce the habitat availability for reef species during juvenile and breeding stages of their life cycles. It is important to note the high likelihood that marine fish fauna that inhabit reef communities of the Ningaloo Reef and the Muiron Islands require the mangrove and/or seagrass habitats of Exmouth Gulf for one or more life cycle stages (e.g. snapper, bream and mackerel).

4.7 Benthic primary producer habitat mapping

Estimations of benthic habitats from work undertaken in the ERMP are not adequate as there is no benthic habitat mapping of the area of influence available in the ERMP document (section 2.5, pages 6-37 – 6-42). Adequate benthic habitat mapping must be provided in order to determine the magnitude of potential impacts on benthic primary producer habitats. To determine the long-term impacts to the ecosystem of Exmouth Gulf, broad scale temporal and spatial habitat mapping is required to determine the distribution and abundance of seagrass, macro algae and other important benthic primary producer habitats within the Gulf. Secondly, fine scale habitat mapping for the zone of influence of the project, including intake pumps, the barge harbour and barge channel, is strongly recommended as standard impact assessment practice for determining the degree of impact and the effectiveness of management.

Recommendations:

39. Broad scale temporal and spatial habitat mapping of Exmouth Gulf should be undertaken by the proponent to assist in determining impacts to Exmouth Gulf marine ecosystems.

40. Fine scale temporal habitat mapping of the zone of influence of the proposal should be undertaken by the proponent to determine the likely direct project impacts on benthic primary producer habitats.

5. Marine water and sediment quality

5.1 Bitterns discharge

Although the proponent is not seeking approval for the discharge of bitterns as part of the proposal, the ERMP includes a "Bitterns Resource Recovery Strategy" as Appendix 1. This Strategy broadly outlines the technical and economic opportunities for Straits Salt Pty Ltd through the processing of salt bitterns to produce magnesium oxide, magnesium hydroxide, hydrochloric acid and fertilisers. The strategy indicates that economic viability of further processing will depend on a range of factors including product integration and market opportunities. Appendix 1 states that bitterns resource will be collected, concentrated and managed as an integral part of the salt production business for the Yannarie Solar Project and that site specific research work will be required to confirm the technical and market options for the recovery of potassium salts from bitterns resource recovery. The material leaving the crystallizer ponds contains up to 25% of the $NaCl_2$ in the brine pumped into the crystallizer ponds. According to Appendix 1 the recovery of magnesium is the ultimate target which would result in full resource recovery. However the feasibility of this has not been calculated (Straits Salt, 2006). The proponent has provided three scenarios on a range of