# Gorgon Gas Development Revised and Expanded Proposal

## Public Environmental Review : Appendices

EPBC Referral 2008/4178

Assessment No. 1727

September 2008

Operated by Chevron Australia
in joint venture with

ExxonMobil

Gorgon Project

## Disclaimer

This Public Environmental Review (PER) has been prepared by Chevron Australia Pty Ltd on behalf of the Gorgon Joint Venturers. In preparing the PER, Chevron Australia has relied on information provided by specialist consultants, government agencies and other third parties who are identified in the PER. Chevron Australia has not verified the accuracy or completeness of the findings, conclusions and observations of these consultants, government agencies and other third parties, except where expressly acknowledged in the PER.



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Title: Public Environmental Review for the Gorgon Gas Development Revised and Expanded Proposal

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# APPENDIX A

## Exisiting Government Environmental Approvals For The Gorgon Gas Development

# Western Australian Ministerial Implementation Statement No. 748 (Statement No. 748) for the Approved Development.

Please note that Schedule 5 (Coordinates that define the High Impact Zone, Moderate Impact Zone and Zone of Influence) of Statement No. 748 has not been included in this PER due to the size of this Schedule. Electronic copies of this schedule can be made available to reviewers upon request. Please see Chevron Australia contact details at the beginning of this PER.

Minister for the Environment; Climate Change; Peel

Statement No.

000748

# STATEMENT THAT A PROPOSAL MAY BE IMPLEMENTED (PURSUANT TO THE PROVISIONS OF THE ENVIRONMENTAL PROTECTION ACT 1986)

GORGON GAS DEVELOPMENT:
BARROW ISLAND NATURE RESERVE

**Proposal:** The construction of facilities for the development of the Greater Gorgon Gas Fields on the North-West Shelf, and the processing and export of the gas at a liquefied natural gas plant to be constructed on Barrow Island, as more generally described in the Draft Environmental Impact Statement/ Environmental Review and Management Programme for the Proposed Gorgon Development and the Final Environmental Impact Statement/ Response to Submissions on the Environmental Review and Management Programme.

The Proposal is further documented in Schedule 1 of this statement.

**Proponent:** Chevron Australia Pty Ltd

**Proponent Address:** Level 24 QV1 Building, 250 St Georges Tce, Perth, WA, 6000

## PART 1: Preamble

### Context

The implementation of this Proposal is subject to the conditions set out in part 2 of this Statement and are part of the Western Australian Government announced three point environmental protection plan, being:

- An additional $60 million commitment by the Gorgon Joint Venturers to a series of new initiatives to conserve the Flatback turtle population and protect other endangered species, more particularly described in the following section entitled "Additional Gorgon Joint Venture Undertakings";
- A Government commitment to expand land and marine parks and reserves in the Pilbara and lower west Kimberley, to protect turtles and improve the management of the existing Montebello/Barrow Islands conservation reserves; and
- These environmental conditions.

In addition, the Barrow Island Act 2003 (BI Act) and its Schedule 1 (Gorgon Gas Processing and Infrastructure Agreement) also address issues for the Proposal that relate to environmental management on the island.

As well as approvals through Part IV of the *Environmental Protection Act 1986* (the EP Act), the Proponent will also need certain other approvals, notably, from the Commonwealth Government.

These matters will be discussed below to provide the context of the environmental conditions.

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### The conservation significance of Barrow Island and surrounding marine waters

The conditions contained in this Statement are set in recognition of the following environmental constraints:

- Barrow Island is a Class 'A' Nature Reserve of significant conservation value;
- The Island's flora and fauna have exceptional biodiversity largely because the Island has been quarantined from invasive species;
- The surrounding marine waters are of significant conservation value, with some designated for a Marine Park and other areas categorised as Marine Management Area; and
- The marine water contains some significant benthic communities, including corals, and provide habitat for some listed species such as some marine turtle species.

### Additional Gorgon Joint Venture Undertakings

*1. North West Shelf Flatback Turtle Conservation Program*

The Gorgon Joint Venture partners have agreed to fund a 30-year North West Shelf Flatback Turtle Conservation Program to increase protection of the population in areas away from Barrow Island, at a cost of $32.5 million.

Consistent with that agreement, it is proposed that the program be administered by an executive committee comprising an independent chair nominated by the State government and one representative each from the State and Commonwealth Governments and the Gorgon Joint Venture. The program will include activities to:

- Survey, monitor and research turtle populations;
- Mitigate the loss by reducing interference to key feeding and breeding locations; and
- Establish information programs to support protection.

*2. North West Shelf Flatback Turtle Intervention Program*

If the abovementioned executive committee agrees monitoring clearly demonstrates that the Proposal is having a significant impact on the Flatback turtle population, the Gorgon Joint Venture partners will be required to take or fund further actions to improve recruitment to the turtle population, including the establishment of hatcheries. Additional funds will be capped at $5 million.

*3. Threatened Species Translocation and Reintroduction Program*

The Gorgon Joint Venture partners have agreed to fund a 12-year Threatened Species Translocation and Reintroduction Program for selected species from Barrow Island to other Pilbara islands at a cost of $10 million.

The program will include the initial translocation actions, plus ongoing island management. The State will manage the program and be responsible for the translocation and reintroduction outcomes.

*4. Eradication of non-indigenous species*

The Gorgon Joint Venture partners have responsibilities for the eradication of non-indigenous species that establish on Barrow Island following commencement of the Gorgon Project.

In addition to stringent quarantine management conditions outlined in the attached conditions, the Gorgon Joint Venture partners have agreed to also provide a financial guarantee of $10 million to cover Government costs for eradication of non-indigenous species established on Barrow Island, other than through natural causes, and following commencement of the Gorgon Project.

*5. Dredging*

The proposed dredging is one of the largest single dredging operations carried out in Western Australian (WA) waters.

The Gorgon Joint Venture partners have agreed to fund the Government's costs for auditing and surveillance of marine activities during dredging and marine construction, and ongoing auditing of the marine environment response and recovery ($2.5million over two years). This is in addition to the amount payable by the GJV under clause 12 of the *Gorgon Gas Processing and Infrastructure Agreement* (see below).

## Barrow Island Act (2003) and Schedule 1 (Gorgon Gas Processing and Infrastructure Agreement)

*Overview*

There are certain matters covered by the Barrow Island (BI Act) and its Schedule 1 which are relevant to environmental management of the Island but not duplicated in these conditions and are described here. The key environmental matters are:

- Establishment of the Barrow Island Coordination Council to coordinate certain matters for industry users of the Island (Clause 13 of Schedule 1);
- Approval to inject $CO_2$ on the Island (Section 13);
- Land tenure for gas processing project purposes (as defined in the BI Act) to be granted over no more than 300 ha in total of uncleared land (section 9, BI Act);
- A quarantine management plan (Clause 7 (1)(f) of Schedule 1);
- Closure plan (Clause 7(1)(p) of Schedule 1);
- The Gorgon Joint Venture partners to fund a Net Conservation Benefit Fund up to $40 million (Clause 11 of Schedule 1); and
- The Gorgon Joint Venture partners to fund a permanent Department of Environment and Conservation (DEC) management presence on the Island for the purpose of managing the Gorgon Project's presence in relation to island and marine conservation (Clause 12 of Schedule 1).

Some of these are described in more detail below.

*Barrow Island Coordination Council (BICC)*

Consistent with Schedule 1, the GJV partners are required to make arrangements with the Barrow Island Joint Venture (holder of petroleum lease 1H on the island) to form and operate a BICC to:

- Provide a single point of contact and interaction for DEC on Barrow Island;
- Liaise with DEC on the management of Barrow Island; and
- Any other matters the BICC Participants agree to coordinate under the BICC (see fire management).

*Quarantine*

Clause 13(e)(iii) & (iv) of Schedule 1 of the BI Act, requires the BICC is to:

- Establish, monitor and review from time to time procedures to apply to quarantine of all people and materials brought to Barrow Island for the purposes of the operations of BICC Participants; and

- Plan and coordinate BICC's role in emergency response to and undertaking where necessary, remediation of any suspected or actual breach of quarantine in the operations of any of the BICC Participants, and hazardous spills to the Barrow Island environment.

*Fire Management*

It is intended that Island wide fire management also be a matter considered by the BICC. Both the Gorgon Joint Venture participants and the DEC intend to use the BICC to coordinate fire management on Barrow Island outside the Terrestrial Disturbance Footprint (Clause 13 (e) (vii) of Schedule 1). Matters to be considered are:

- Detection and reporting of fires off the project site;
- Management of fires off the project site started either by natural causes, DEC initiated fires or fires initiated from the Proposal; and
- Monitoring of the impact or effect of fire on indigenous taxa in affected areas for fires attributable to the Proposal.

NOTE: The management of fires off the project site, including proposals for DEC initiated fires, has implications for both conservation management and the other users of the island. The DEC, as the lead agency, would consider and evaluate these matters in consultation with the Conservation Commission, DOCEP, DoIR and BICC Participants.

*Net Conservation Benefits*

Under Clause 11 of Schedule 1 of the BI Act, the Gorgon Joint Venture partners have agreed to pay $40 million (indexed) in instalments to fund Net Conservation Benefits. Net Conservation Benefits are defined as demonstrable and sustainable additions to, or improvements in, biodiversity conservation values of Western Australia targeting, where possible, the biodiversity conservation values affected or occurring in similar bio-regions to Barrow Island.

*DEC Funding*

Under Clause 12 of Schedule 1 of the BI Act, the Gorgon Joint Venture partners have agreed to provide services and facilities for a permanent DEC management presence on Barrow Island (including accommodation, transport, etc): comprising three DEC officers during major construction phases; and two officers at other times.

The Gorgon Joint Venture partners will also pay certain DEC costs (i.e. salaries and on-costs) capped at $1 million a year during the major construction phases, and $750,000 at other times (indexed).

The purpose of DEC's permanent presence on Barrow Island is to:

- provide a full-time independent quarantine audit on Barrow Island and the mainland; and
- ensure all onsite and offsite areas are appropriately monitored, researched and managed in relation to direct and indirect impacts and to ensure the ecological knowledge base is being properly developed.

**Commonwealth Government Approval and common condition**

The Gorgon Proposal is being examined by the Commonwealth Government under the provisions of the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act). Should the Commonwealth Government consider approval of the Proposal, any conditions of approval imposed by the WA Government will be taken into consideration in the formulation of EPBC Act Conditions. The EPBC Act assessment and approval process for the Proposal centres on specific matters of national environmental significance, namely Listed threatened species and communities; Listed migratory species; and the (Commonwealth) Marine environment. To protect these matters it may be necessary for the Commonwealth Government to impose its own conditions. These will be compatible with WA conditions and as far as possible the planning, monitoring and reporting requirements likely to be placed on the Proponent by both governments are expected to be able to be met using single, integrated, document sets.

## Other approvals and submission of plans, programs etc

The Proponent will also need other approvals from both the Commonwealth Government and State Government, where conditions are also likely to be set requiring the preparation of certain plans, programs etc. It is the intention that where another approval process requires a plan, program etc. that addresses the same issue as a condition in this Statement, that the same plan, program etc could cover both approval processes.

## Other agency access Barrow Island

Representatives from other agencies may require access to Barrow Island from time to time, and this will need to be carried out in consultation the BICC and BICC Participants.

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## PART 2: Conditions

The Proposal may be implemented. The implementation of the Proposal is subject to the following Conditions and Schedules.

### 1. Proposal Implementation

1. The Proponent shall implement the Proposal as documented and described in Schedule 1 of this statement subject to the conditions and schedules of this statement.

### 2. Proponent Nomination and Contact Details

1. The Proponent for the time being nominated by the Minister for the Environment under sections 38(6) or 38(7) of the *Environmental Protection Act 1986* is responsible for the implementation of the Proposal.

2. The Proponent shall notify the Chief Executive Officer of the DEC (CEO) of any change of the name and address of the Proponent for the serving of a notice or other correspondence within 30 days of such change.

### 3. Time Limit of Authorisation

1. The authorisation to implement the Proposal provided for in this statement shall lapse and be void within five years after the date of this statement if the Proposal to which this statement relates is not substantially commenced.

2. The Proponent shall provide the CEO with written evidence which demonstrates that the Proposal has substantially commenced on or before the expiration of five years from the date of this statement.

### 4. Compliance Reporting

1. The Proponent shall submit annually an audit compliance report, for the previous twelve-month period. The date of the first compliance report shall be 12 months from the date of formal authority issued to the decision-making authorities under section 45(7) of the Act.

2. The audit compliance report shall:
    i. Be endorsed by the Proponent's Managing Director or a person, approved in writing by the Department of Environment and Conservation, delegated to sign on the Proponent's Managing Director's behalf;
    ii. Include a statement as to whether the Proponent has complied with the Conditions, procedures, commitments and actions within the management plans, reports, systems, and programs referred to in the Conditions;

iii. Identify all non-compliances and describe the related corrective and preventative actions taken;
iv. Review the effectiveness of all corrective and preventative actions taken;
v. Provide verifiable evidence of compliance with the Conditions;
vi. Describe the state of implementation of the Proposal; and
vii. Be prepared in accordance with an audit program and in a format acceptable to the Department of Environment and Conservation.

## 5. Environmental Performance Reporting

1. The Proponent shall submit annually to the Minister an Environmental Performance Report covering the topics listed in Condition 5.2, and the specific details shown in Schedule 3, covering the previous 12 month period as determined by the Minister. The date of the first Environmental Performance Report (the Report) shall be 15 months from the date of formal authority issued to the decision-making authorities under section 45(7) of the Act, with each subsequent report 12 months from the date of the previous report.

2. The Report shall cover the following topics:
   i. Terrestrial and subterranean environment baseline state;
   ii. Terrestrial and marine quarantine;
   iii. Marine turtles;
   iv. Short range endemics and subterranean fauna;
   v. Fire management;
   vi. Carbon Dioxide Injection System;
   vii. Coastal stability; and
   viii. Terrestrial rehabilitation.

3. Every five years from the date of the first annual Environmental Performance Report the Proponent shall submit to the Minister an Environmental Performance Report covering the previous five year period, comprising:
   i. The topics listed in Condition 5.2;
   ii. Specific details shown in Schedule 3;
   iii. A five year overview of environmental performance; and
   iv. Proposed environmental management improvements.

## 6. Terrestrial and Subterranean Baseline State and Environmental Impact Report

1. Prior to commencement of construction of terrestrial facilities on Barrow Island, as defined in Condition 6.3, the Proponent shall submit to the Minister a Terrestrial and Subterranean Baseline State and Environmental Impact Report (the Report) that meets the purposes set out in Condition 6.4, as determined by the Minister. The report shall cover the following ecological elements:
   i. flora;
   ii. vegetation;

iii. fauna (including subterranean fauna and short range endemics);
iv. habitat;
v. ecological communities;
vi. groundwater;
vii. surface water landforms; and
viii. other significant landforms.

2. The Proponent shall consult with DEC in the preparation of the Report required by Condition 6.1, including the methodology to be used to survey, collect and collate the baseline data and information for all ecological elements identified in Condition 6.1.

3. The terrestrial facilities referred to in Condition 6.1 are:

   i. Gas Treatment Plant;
   ii. Carbon Dioxide Injection System;
   iii. Associated Terrestrial Infrastructure;
   iv. Areas impacted for seismic data acquisition; and
   v. Onshore Feed-gas Pipeline System and terrestrial component of the Shore Crossing

   As defined in Schedule 1.

4. The purposes of the Report are to:

   i. Define and map the pre-development baseline state for the ecological elements within the areas that are expected to, or may be at risk of Material or Serious Environmental Harm due to any works associated with the terrestrial facilities listed in Condition 6.3;
   ii. Define and map the ecological elements within the Terrestrial Disturbance Footprint; and
   iii. Define and map the ecological elements which are at risk of Material or Serious Environmental Harm due to construction or operation of the terrestrial facilities listed in Condition 6.3.
   iv. Define and map the ecological elements of reference sites to be used as part of Condition 8, which are not at risk of Material or Serious Environmental Harm due to construction or operation of the terrestrial facilities listed in Condition 6.3.

5. The Report shall include:

   i. A review of the results of the existing qualitative ecological risk assessments of the likelihood and consequence of Proposal impacts on the ecological elements identified in Condition 6.1;
   ii. Details of the methodology that was used to survey, collect and collate the baseline data and information for all ecological elements identified in Condition 6.1;
   iii. A description and map of the ecological elements within the Terrestrial Disturbance Footprint;
   iv. A description and map of the ecological elements which are at risk of Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint

due to construction and operation of the terrestrial facilities listed in Condition 6.3;

v. A review of the results to include existing areas of disturbance, including clearing, existing non-indigenous species (including weeds) and disturbed landscapes;

vi. Spatially accurate (e.g. rectified and geographically referenced) maps showing the baseline data and information for the ecological elements identified in Condition 6.1;

vii. Discussion of the data on the baseline biological, physical and chemical variables including any significant relationships, for the ecological elements identified in Condition 6.1;

viii. Significant ecological elements to be protected in areas of risk - e.g. Declared Rare Flora (DRF), threatened ecological communities, Threatened Species under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), habitats of rare fauna;

ix. An analysis of, and procedures to address reasonable data and information gaps associated with the baseline data for the areas identified in iv. above for the ecological elements identified in Condition 6.1 and associated relationships; and

x. A description and map of the ecological elements of reference sites in locations which are not at risk of Material or Serious Environmental harm due to construction and operation of the terrestrial facilities listed in Condition 6.3.

6. The Proponent shall not cause or allow Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint.

## 7. Terrestrial and Subterranean Environment Protection Plan

1. Prior to commencement of construction of any of the terrestrial facilities identified in Condition 6.3, the Proponent shall submit a Terrestrial and Subterranean Environment Protection Plan (the Plan) that meets the objectives identified in Condition 7.4 and the requirements of Condition 7.5 as determined by the Minister, unless otherwise allowed in Condition 7.2.

2. In the event that any portions of the Plan related to specific elements or sub-elements (Schedule 1) is not submitted as required by Condition 7.1, the Proponent shall submit the portions of the Plan relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the Plan shall meet the objectives identified in Condition 7.4 and the requirements of Condition 7.5 as determined by the Minister.

3. The Proponent shall consult with DEC in the preparation of the Plan.

4. The objectives of the Plan are:

   i. To reduce the adverse impacts from the construction and operation of the Terrestrial Disturbance Footprint as far as practicable; and

ii. To ensure that construction and operation of the terrestrial facilities does not cause Material or Serious Environmental Harm outside and below the Terrestrial Disturbance Footprint.

5. The Plan shall include the following:

   i. Management measures to reduce the adverse impacts from the construction and operation on the Terrestrial Disturbance Footprint as far as practicable; and

   ii. Management measures to ensure that construction and operation of the terrestrial facilities does not cause Material or Serious Environmental Harm outside and below the Terrestrial Disturbance Footprint.

6. The measures required by 7.5.i. and ii. shall address but not be limited to:

   i. Vegetation Clearing Audit Procedures to determine the extent of clearing and rehabilitation on an annual basis;

   ii. Procedures in relation to and protocols for capturing, relocating, handling, housing and caring for significant fauna found within the Terrestrial Disturbance Footprint that are not required by DEC for translocation to other islands;

   iii. Procedures to avoid secondary impacts to fauna as a consequence of risks such as animals being trapped in construction trenches or subject to vehicle strike;

   iv. Measures including detailed drainage and containment designs for all works and infrastructure that control stormwater run-off outside the Terrestrial Disturbance Footprint with the aim of ensuring that runoff is consistent with the pre-development runoff regime as far as practicable, and any recharge does not cause pollution; and

   v. Measurable limits which specify the performance standards to be met when undertaking actions controlled by the Plan.

7. The Proponent shall report any Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint to DEC within 48 hours of their detection.

8. The Proponent shall implement the Plan.

## 8. Terrestrial and Subterranean Environment Monitoring Program

1. Prior to commencement of construction of the terrestrial facilities listed in Condition 6.3 the Proponent shall prepare and submit a Terrestrial and Subterranean Environment Monitoring Program (the Program) to the Minister that meets the aim set out in Condition 8.3 and the requirements of Condition 8.4 as determined by the Minister, unless otherwise allowed in Condition 8.2.

2. In the event that any portion of the Program related to specific elements or sub-elements (Schedule 1) is not submitted as required by Condition 8.1, the Proponent shall submit the portion of the Program relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-

element. All portions of the Plan shall meet the objectives identified in Condition 8.3 and the requirements of Condition 8.4 as determined by the Minister

3. The objective of this Program is to establish a statistically valid ecological monitoring program to detect any Material or Serious Environmental Harm to the ecological elements outside the Terrestrial Disturbance Footprint.

4. The Program shall include:
   i. Indicators, parameters and /or criteria to be used in measuring changes on the ecological elements identified in Condition 6.1 that are at risk of Material or Serious Environmental Harm as identified in Condition 6.3.
   ii. Protocols for on-going reporting of adverse changes to the ecological elements identified in Condition 6.1;
   iii. Protocols for identifying additional areas not originally identified that are at risk of sustaining Material or Serious Environmental Harm from the proposal, and for adding monitoring sites to include these additional locations if required;
   iv. Establishing an ecological monitoring program with the ability to detect at a statistical power of 0.8 or greater, or an alternative statistical power as determined by the Minister, any environmental harm to the ecological elements listed in Condition 6.1;
   v. Location of monitoring sites in areas that are at risk of Material or Serious Environmental Harm due to construction and operation of terrestrial facilities listed in Condition 6.3; and
   vi. Location of reference sites (see Condition 6.4iv.).

5. The Proponent shall implement the Program.

## 9. Establishing a Quarantine Expert Panel

1. Prior to commencement of construction of the terrestrial facilities listed in Condition 6.3, the Proponent shall establish and provide reasonable funding to resource a Quarantine Expert Panel (QEP) to carry out the roles set out in Condition 9.2 with membership as described in Condition 9.3.

2. The role of the QEP is to provide advice to the Proponent and the Minister on Proposal related terrestrial and marine quarantine matters including:
   i. Development and implementation of the Terrestrial and Marine Quarantine Management System (QMS) as required by Condition 10;
   ii. Preventing the introduction of Non-indigenous Terrestrial Species and Marine Pests to Barrow Island through all Proposal attributable introduction pathways;
   iii. Detecting the presence of introduced species and detecting environmental change caused by the presence of introduced species;
   iv. Control and eradication measures in the event that an introduced species is detected;
   v. Improvements to effectiveness of the QMS;
   vi. Biological baselines and surveys conducted for quarantine management;

vii. Source of Non-indigenous Terrestrial Species and Marine Pests;
viii. Auditing the effectiveness of the QMS;
ix. Review and recommend quarantine studies; and
x. Any other Proposal-related quarantine matters as requested by the Proponent or the Minister.

3. The membership of the QEP shall be established as follows:
   i. Proponent shall appoint its representative(s);
   ii. Proponent shall nominate candidates for the Independent Chair to be appointed by the Minister (NOTE: the Minister may seek advice from other sources, including DEC, on nominees for Independent Chair);
   iii. Proponent shall, in consultation with the Independent Chair, invite DEC, Western Australian Department of Agriculture and Food (DAF) and Western Australian Department of Fisheries (DoF) to nominate suitably qualified subject matter expert(s) to participate in the QEP; and
   iv. Proponent shall, in consultation with the Independent Chair, nominate independent expert(s) as required to fulfil the roles set out in Condition 9.2, to be appointed by the Minister (NOTE: the Minister may seek advice from other sources, including DEC, on nominees for independent expert(s)).

4. The Proponent shall develop the Terms of Reference for the QEP consistent with the roles as set out in Condition 9.2 in consultation with the Minister and the Independent Chair.

**10. Terrestrial and Marine Quarantine Management System**

1. Prior to commencement of construction of any terrestrial facilities listed in Condition 6.3 and the marine facilities listed in Condition 14.3, the Proponent shall submit the Quarantine Management System (QMS) to the Minister, taking into account the advice of the Quarantine Expert Panel (QEP) that meets the aim and objectives set out in Condition 10.3 and the requirements of Condition 10.4, as determined by the Minister, unless otherwise allowed in Condition 10.2.

2. In the event that any portions of the QMS related to specific elements or sub-elements (Schedule 1) of the Proposal are not submitted as required by Condition 10.1, the Proponent shall submit the QMS portions relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element, taking into account the advice of the QEP that meets the aim and objectives set out in Condition 10.3 and the requirements of Condition 10.4, as determined by the Minister.

3. The overall aim of the QMS is that the Proponent shall not introduce or proliferate Non-indigenous Terrestrial Species and Marine Pests to or within Barrow Island or the water surrounding Barrow Island, as a consequence of the Proposal. The specific objectives of the QMS are:
   i. To prevent the introduction of Non-indigenous Terrestrial Species and Marine Pests;

ii. To detect Non-indigenous Terrestrial Species (including weed introduction and/or proliferation ) and Marine Pests;

iii. To control and, unless otherwise determined by the Minister, eradicate detected Non-indigenous Terrestrial Species (including weeds) and Marine Pests; and

iv. Mitigate adverse impacts of any control and eradication actions taken against detected Non-indigenous Terrestrial Species (including weeds) and Marine Pests.

4. The QMS shall address the following topics. These topics are specified in more detail in Schedule 4:

   i. Risk Assessment, Supply Chain Management, Vessel Management and Inspection;

   ii. Detection, Control and Eradication Program;

   iii. Mitigation (of introductions or weed proliferations and any Control and Eradication) Program;

   iv. Reporting and Recording;

   v. Integrating with whole of Island Quarantine Management;

   vi. Reviewing and further studies; and

   vii. Measurable limits which specify the performance standards to be achieved by the QMS within the Terrestrial and Marine Quarantine Controlled Access Zones and Terrestrial and Marine Quarantine Limited Access Management Zones.

5. The Proponent shall implement the QMS required by Condition 10.1.

6. The Proponent shall review and update the QMS required by Condition 10-1 annually during the construction phase of the Proposal and then at least every five years thereafter unless varied by the Minister.

## 11. Short Range Endemics and Subterranean Fauna Monitoring Plan

1. Prior to commencement of construction of the Gas Treatment Plant, the Proponent shall prepare and submit to the Minister, a Short Range Endemics and Subterranean Fauna Monitoring Plan (the Plan) for the further survey and identification of those short range endemics and subterranean fauna species which have previously only been located on the Gas Treatment Plant site. The Plan shall address the following:

   i. survey methods;

   ii. survey sites;

   iii. frequency of surveys; and

   iv. indicators for cessation of surveys,

   as determined by the Minister.

2. The Proponent shall implement the Plan.

**12. Fire Management Plan**

1. Prior to commencement of construction of any terrestrial facilities identified in Condition 6.3 the Proponent shall prepare and submit a Fire Management Plan (the Plan) that meets the aim and objectives set out in Condition 12.4 and the requirements of Condition 12.5, as determined by the Minister, unless otherwise allowed in Condition 12.2, consistent with the requirements of the *Occupational Safety and Health Act 1984* (WA).

2. In the event that any portions of the Plan related to specific elements or sub-elements (Schedule 1) of the Proposal are not submitted as required by Condition 12.1, the Proponent shall submit the portion of the Plan relevant to that element or sub-element to the Minister prior to the planned commencement of construction of that element or sub-element. All portions of the Plan shall meet the objectives identified in Condition 12.4 and the requirements of Condition 12.5 as determined by the Minister.

3. The Proponent shall consult with DEC, Conservation Commission, the BICC Participants, DOCEP and DoIR in the preparation of the Plan.

4. The specific objectives of the Plan are to ensure that:
   i. The Proposal does not cause Material or Serious Environmental Harm outside the Terrestrial Disturbance Footprint due to fire; and
   ii. Fire risk reduction measures are built into the design of the facilities to protect the Proponent's assets from the impact from fire on Barrow Island.

5. The Plan shall include the following:
   i. A fire risk assessment of all project infrastructure and measures to protect infrastructure and the surroundings from fires on Barrow Island; and
   ii. On-going management of infrastructure for fire prevention, suppression and management including incident control systems so that fires do not escape from the Terrestrial Disturbance Footprint.

6. The Proponent shall implement the Plan.

7. The Proponent shall review the Plan at least every five years unless otherwise determined by the Minister.

8. In the event that a fire attributable to the Proposal occurs outside the Terrestrial Disturbance Footprint and the Conservation Commission requires that site to be rehabilitated, the Proponent shall develop and implement rehabilitation measures in consultation with DEC, BICC and the Conservation Commission.

## 13. Groundwater Abstraction Management Plan

1. Prior to the commencement of construction of facilities to abstract groundwater for water supply purposes, the Proponent shall submit a Groundwater Abstraction Management Plan (the Plan) to the Minister that meets the aim set in Condition 13.3 and the requirements of Condition 13.4 as determined by the Minister.

2. In preparing this Plan the Proponent shall consult with DoW and DEC.

3. The aim of the Plan is to ensure that groundwater abstraction does not cause Material or Serious Environmental Harm to the target aquifer, surface vegetation or subterranean fauna habitats of Barrow Island.

4. The Plan shall include:
   i. Practicable environmental triggers for contingency plans to avoid Material or Serious Environmental Harm to the target aquifer, surface vegetation or subterranean fauna habitats of Barrow Island (this may include separate triggers for within and outside the Terrestrial Disturbance Footprint);
   ii. Actions (including an immediate reduction in or cessation of the rate of bore water abstraction) which will be taken to avoid Material or Serious Environmental Harm to the target aquifer, surface vegetation or subterranean fauna habitats of Barrow Island; and
   iii. Reporting procedures.

5. The proponent shall implement the Plan.

## 14. Coastal and Marine Baseline State and Environmental Impact Report

1. To establish the methodology to be used in the Report required by Condition 14.2, the Proponent shall submit to the Minister a Scope of Works reporting the methodologies to be used in the preparation of the Report that covers the following:
   i. Survey methods for each of the ecological elements;
   ii. Location and establishment of survey sites;
   iii. Timing and frequency of surveys;
   iv. Habitat classification schemes;
   v. Mapping methodologies;
   vi. Treatment of survey data; and
   vii. Method for hydrodynamics data acquisition and reporting.

2. Prior to commencement of construction of marine facilities on Barrow Island, as defined in Condition 14.3, the Proponent shall submit a Coastal and Marine Baseline State and Environmental Impact Report (the Report) that meets the purposes set out in Condition 14.5, as determined by the Minister, unless otherwise allowed in Condition 14.4. The report shall cover the following ecological elements:
   i. Hard and soft corals;

ii. Macro algae;
iii. Non-coral benthic macro-invertebrates;
iv. Seagrass;
v. Mangroves;
vi. Demersal fish; and
vii. Surficial sediment characteristics

As well, water quality (turbidity and light) and deposited surficial sediment characteristics will be required where the construction of marine facilities will adversely affect the environment.

3. The facilities to which this condition apply are:
   i. Marine Off-loading Facility (MOF),
   ii. LNG Jetty,
   iii. Dredge Spoil Disposal Ground,
   iv. Offshore Feed-gas Pipeline System and marine component of the shore crossing, and
   v. Domestic Gas Pipeline.

4. In the event that any portions of the Report related to specific elements or sub-elements (Schedule 1) of the Proposal are not submitted as required by Condition 14.1, the Proponent shall submit the portion of the Report relevant to that element or sub-element to the Minister prior to the commencement of construction of that element or sub-element. All portions of the Plan shall meet the purposes identified in Condition 14.6 and the requirements of Condition 14.7 and 14.8 as determined by the Minister.

5. In preparing this Report the Proponent shall consult with CDEEP (If established at that time – see Condition 19), DEC, DPI, DoF and DEW.

6. The purposes of this Report are to:
   i. Define and map the ecological elements within the Marine Disturbance Footprint;
   ii. Define and map the ecological elements which are at risk of Material or Serious Environmental Harm due to construction or operation of the marine facilities listed in Condition 14.3;
   iii. Define and map the ecological elements of reference sites which are not at risk of Material or Serious Environmental Harm due to construction or operation of the marine facilities listed in Condition 14.3, including water quality (turbidity and light); and
   iv. Define the existing water quality (turbidity and light) and surficial sediment characteristics where dredging and dredge spoil disposal may affect the environment.

7. The geographic extent of the Report shall be:
   i. The facilities and locations listed in Condition 14.3
   ii. Dredge Management Areas (Figures 1 and 2) including the Zone of High Impact, the Zone of Moderate Impact and areas in the Zone of Influence

including those that contain significant benthic communities including coral assemblages; and

iii. Benthic habitats within 200m of the facilities listed in Condition 14.3 in State Waters.

NOTE: whilst the presence of coral determines the location of these additional sites, the other benthic habitats need to be reported on.

8. The Report shall:

   i. Contain spatially accurate (e.g. rectified and geographically referenced) maps showing the locations and spatial extent of the marine coastal facilities in Condition 14.3;
   ii. Present the results of the surveys described in Condition 14.1;
   iii. Record the existing dominant and sub-dominant hard and soft coral species and the dominant species of macro algae non-coral benthic macro-invertebrates, seagrass and mangroves, and demersal fish assemblages that characterise these communities;
   iv. Record the population structure, as size class frequency distributions, and other population statistics of recruitment, survival and growth, of dominant hard coral species and selected other key indicator species that characterises these communities;
   v. Contain a description and map of the ecological elements within the Marine Disturbance Footprint;
   vi. Contain a description and map of the ecological elements which are at risk of Material or Serious Environmental Harm due to construction and operation of the marine facilities listed in Condition 14.3;
   vii. Present data in an appropriate Geographic Information System (GIS) format;
   viii. Establish background water quality (turbidity and light) where dredging and dredge spoil disposal may affect the environment;
   ix. Report on the distribution and characteristics of surficial sediments where dredging and dredge spoil disposal may affect the environment; and
   x. Report on the natural rates and spatial patterns of sediment deposition, and the physical characteristics of the deposited sediment where dredging and dredge spoil disposal may affect the environment.

9. To meet the requirements of Condition 14.8, the Proponent shall collect water quality data and data on natural rates, and spatial patterns of sediment deposition for at least one full annual cycle prior to the construction of the marine facilities listed in 14.3.

NOTE: data on metocean conditions may also be useful.

## 15. Establishing a Marine Turtle Expert Panel

1. Prior to commencement of any construction associated with the terrestrial facilities listed in Condition 6.3 to be located on the east coast of Barrow Island, the Proponent shall establish and provide reasonable funding to resource a Marine Turtle Expert Panel (MTEP) for the roles set out in Condition 15.2 with membership as described in Condition 15.3.

2. The role of the MTEP is to provide advice to the Proponent and the Minister on marine turtle monitoring and management including;

   i. Development and implementation of the Long-Term Marine Turtle Management Plan as required by Condition 16.1;
   ii. Proposal-specific turtle studies as required by Condition 16.4;
   iii. Monitoring program design and methodology as required by Condition 16.4;
   iv. Additional management measures as required by Condition 16.4; and
   v. Any other marine turtle management matters requested by the Proponent or the Minister.

3. The membership of the MTEP shall be established as follows:

   i. Proponent shall appoint its representative(s);
   ii. Proponent shall nominate candidates for the Independent Chair to be appointed by the Minister (NOTE: the Minister may seek advice from other sources, including DEC, on nominees for Independent Chair);
   iii. Proponent shall, in consultation with the Independent Chair, invite DEC, DoF and DEW to nominate suitably qualified subject matter expert(s) to participate in the MTEP; and
   iv. Proponent shall, in consultation the with Independent Chair, nominate independent expert(s) as required to fulfil the roles set out in Condition 15.2, to be appointed by the Minister (NOTE: the Minister may seek advice from other sources, including DEC, on nominees for independent expert(s)).

4. The Proponent shall develop the Terms of Reference for the Panel consistent with the roles as set out in Condition 15.2 in consultation with the Minister and the Independent Chair.

**16. Long-term Marine Turtle Management Plan**

1. Prior to commencement of construction of any facility identified in Conditions 6.3 and 14.3 to be located on the east coast of Barrow Island, the Proponent shall prepare and submit a Long-term Marine Turtle Management Plan (the Plan) that meets the objectives set out in Condition 16.3 and the requirements of Condition 16.4, as determined by the Minister.

2. The Proponent shall consult with MTEP, DEC and DEW in the preparation and future updating of the Plan.

3. The specific objectives of the Plan are to:

   i. Address the long-term management of the marine turtle species that utilise the beaches on the east coast of Barrow Island adjacent to the east coast facilities identified in Conditions 6.3 and surrounding waters on the east coast of Barrow Island adjacent to the east coast facilities identified in Conditions 6.3 and 14.3
   ii. Establish baseline information on the population of turtles that utilise the beaches on the east coast of Barrow Island adjacent to the east coast facilities identified in Conditions 6.3 and 14.3;

iii. Establish a monitoring program to measure and detect changes to the flatback turtle population in accordance with Condition 16.4ii.; and
iv. Specify design features, management measures and operating controls to avoid adverse impacts to the marine turtle population.

4. The Plan shall address the following:
   i. Report the baseline information on the population of turtles that utilise the beaches on the east coast of Barrow Island adjacent to the east coast facilities identified in Conditions 6.3 and 14.3;
   ii. Define the monitoring program to measure and detect changes to the flatback turtle population. Monitoring methods shall have the ability to detect at a statistical power of 0.8 or greater, or an alternative statistical power as determined by the Minister, on advice of the MTEP, changes or impacts on parameters related to population viability;
   iii. Identify the significant Proposal-related stressors with the potential to cause adverse impact on the population viability of the flatback turtles;
   iv. Specify design features, management measures and operating controls that aim to avoid adverse impacts to the marine turtle population;
   v. Define the scope of studies aimed at understanding the ecology of flatback turtles that utilise the beaches on the east coast of Barrow Island adjacent to the facilities identified in Conditions 6.3 and 14.2 to be located on the east coast of Barrow Island, and aimed at improving the management of impacts; and
   vi. Identify measurable limits which specify the performance standards of the extent of change which adversely affect the viability of flatback turtle populations. These limits may be used to trigger the need for additional management measures or could trigger the Gorgon Joint Venturers' undertaking to take or fund further actions to improve recruitment to the turtle population (described in the Preamble to these Conditions).

5. The Proponent shall review and update, as required, the Plan at least every five years, unless otherwise determined by the Minister.

6. The Proponent shall implement the Plan.

7. The Proponent shall report any detected mortality of any marine species listed as specially protected under the provisions of section 14(ba) of the *Wildlife Conservation Act 1950* to DEC within 48 hours of observation.

**17. Marine Facilities Construction Environmental Management Plan**

1. Prior to the commencement of construction of the marine facilities listed in Condition 17.2, the Proponent shall prepare and submit to the Minister a Marine Facilities Construction Environmental Management Plan (the Plan) that meets the objectives set out in Condition 17.4 and requirements set out in Conditions 17.5 and 17.6, as determined by the Minister.

2. The marine facilities relevant to this condition are:

i. Marine Off-loading Facility (MOF); and
ii. LNG jetty.

3. The Proponent shall consult with the DEC, DoF, DPI and DEW in the preparation of the Plan.

4. The objectives of the Plan are:
   i. To reduce the impacts from the construction of the marine facilities (excepting from the generation of turbidity and sedimentation from dredging) as far as practicable; and
   ii. To ensure that construction of the marine facilities does not cause Material or Serious Environmental Harm outside the Marine Disturbance Footprint (excepting from the generation of turbidity and sedimentation from dredging).

5. The Plan shall include the following:
   i. Management measures to reduce the impacts from the construction of the facilities as far as practicable; and
   ii. Management measures to ensure that construction of the facilities does not cause Material or Serious Environmental Harm outside the Marine Disturbance Footprint.

The measures required by Conditions 17.5.i. and 17.5.ii. shall address but not be limited to:

   iii. Generation and dispersion of turbidity caused by construction activities other than dredging;
   iv. Monitoring and managing the quality of any decant water released from the MOF bunded area;
   v. Preventing turtle harm or fatalities;
   vi. Noise and percussion;
   vii. Direct disturbance of habitat; and
   viii. The avoidance of blasting as far as practicable and management measures to be applied if blasting is required.

6. Turbidity and sedimentation generated and permanent coral loss caused by the construction of the facilities shall be subject to the requirements of Conditions 18 and 21.

**18. The Limits of Environmental Impacts (Marine)**

1. The permanent loss of coral assemblages within the high and moderate zones of impact shall not exceed 22 ha for the marine works associated with construction and dredging and dredge spoil disposal activities for the facilities listed in Condition 17.2.

   NOTE: This performance criterion shall be met if the net coral mortality within the high and moderate zones of impact determined at the time of the first Coastal Marine Post Development Survey Report required by Condition 24 does not exceed 22 ha, with no net loss of coral outside those zones.

2. The Proponent shall manage its dredging and spoil disposal activities related to the facilities listed in Condition 17.2 to ensure the Limits of Acceptable Change to Corals defined in Table 1 are not exceeded. The three zones referred to in Table 1 are shown in Figures 1 and 2 and defined in Schedule 5.

**Table 1. Limits of Environmental Impacts to Corals for Zones of High Impact, Moderate Impact and Influence**

| Zone | Limits of Acceptable Change |
|---|---|
| High Impact | No limit |
| Moderate Impact | 30% Average Net Mortality of Porites |
| Influence | No detectable net mortality of coral |

3. If the net coral mortality exceeds 22 ha after the third Post-Dredging Marine Habitat Survey the Proponent shall, in consultation with CDEEP and DEC, prepare and submit a Report to the Minister that

   i. predicts the rate of natural recovery and

   ii. whether that rate of recovery is sufficient to ensure predicted permanent loss of coral assemblages will be reduced to less than 22 ha.

   If the predicted rate of natural recovery is not sufficient to ensure predicted permanent loss of coral assemblages will be reduced to less than 22 ha, the Proponent shall include in that Report an Action Plan with the aim of addressing compliance with Condition 18.1, as determined by the Minister.

4. The Proponent shall implement any Action Plan included in the Report required by Condition 18.3.

## 19. Establishing a Construction Dredging Environmental Expert Panel

1. Prior to commencement of any construction dredging or spoil disposal activities associated with the facilities listed in Condition 17.2, the Proponent shall establish and provide reasonable funding to resource a Construction Dredging Environmental Expert Panel (CDEEP) for the roles set out in Condition 19.2 and membership as described in Condition 19.3.

2. The role of the CDEEP is to provide advice to the Proponent and the Minister on construction dredging and spoil disposal management and monitoring including:

   i. Development and implementation of the Dredge and Spoil Disposal Management and Monitoring Plan as required by Condition 20;

   ii. Interpretation of results of monitoring data acquired during dredging as required by Condition 20.4 iii;

   iii. Proponent's proposed water quality criteria representing the relationship between water quality and coral health as required by Conditions 20.4 iii., 21.1 and 21.3;

   iv. Impact Management Plans required by Condition 21.7 v.;

v. Coastal and Marine Post-development survey reports required by Condition 24; and
vi. Any other aspects of construction dredging and spoil disposal management and monitoring requested by the Proponent or the Minister.

3. The membership of the CDEEP shall be established as follows:
   i. Proponent shall appoint its representative(s);
   ii. Proponent shall nominate candidates for the Independent Chair to be appointed by the Minister (NOTE: the Minister may seek advice from other sources, including DEC, on nominees for Independent Chair);
   iii. Proponent shall, in consultation with the Independent Chair, invite DEC, DoF, DPI and DEW to nominate suitably qualified subject matter expert(s) to participate in the CDEEP; and
   iv. Proponent shall, in consultation with the Independent Chair, nominate independent expert(s) as required to fulfil the roles set out in Condition 19.2, to be appointed by the Minister (NOTE: the Minister may seek advice from other sources, including DEC, on nominees for independent expert(s)).

4. The Proponent shall develop the Terms of Reference for the CDEEP consistent with the roles as set out in Condition 19.2 in consultation with the Minister and the Independent Chair.

## 20. Dredge and Spoil Disposal Management and Monitoring Plan

1. Prior to commencement of any dredging or spoil disposal activities associated with the facilities listed in Condition 17.2, the Proponent shall prepare and submit a Dredge and Spoil Disposal Management and Monitoring Plan (the Plan) to the Minister that meets the aim set out in Conditions 20.3 and the requirements of Condition 20.4, as determined by the Minister.

2. In preparing this Plan the Proponent shall consult with CDEEP, MTEP, DEC, DoF, DPI, and DEW.

3. The aim of the Plan is to ensure that the Limits of Environmental Impacts specified in Condition 18.2 Table 1 are not exceeded due to the impacts of the dredging or spoil disposal activities associated with the facilities listed in Condition 17.2.

4. The Plan shall include (but not necessarily be limited to):
   i. Scale maps showing
      a. The ecological elements as required for Condition 14.6 as relevant to the facilities listed in Condition 17.2;
      b. The facilities listed in Condition 17.2;
      c. Zones of High Impact, Moderate Impact and Influence as shown in Figures 1 and 2 of this Statement;
      d. The locations and geographical coordinates of each Monitoring Site and Reference Site for both water quality and coral health monitoring programs; and

e. Site designs within each Monitoring and Reference Site.

ii. The Plan shall include the following management elements:

a. Describe the types of dredge(s) and their modes of operation;

b. Predict the most probable and worse-case timing and duration of dredging and spoil disposal activities and contingencies for unforseen delays;

c. Specify the management actions and contingency measures through a tiered management framework to be implemented in the event of exceedance of the triggers specified in Condition 21;

d. Describe practicable additional management measures to be implemented during flatback turtle aggregation and nesting periods intended to prevent harm or fatalities;

e. Set out reporting protocols between the Proponent and the CDEEP;

f. Set out procedures to provide to the CDEEP a schedule of works and the 24 hour contact details of an on-site liaison officer, to be updated on a weekly basis during the dredging period; and

g. Set out the procedures to enable the CDEEP to have timely access to environmental monitoring and relevant operational data comprising contact details of personnel undertaking monitoring, telemetry and on-line access to water quality and coral health data and dredge logs.

iii. The Plan shall include the following water quality and sediment deposition monitoring program elements:

a. Specify monitoring frequency and the location of each monitoring and reference site;

b. Detail the use of in-situ deployable water quality and sediment deposition monitoring instruments, including those with the capability of real-time telemetry access to data;

c. Set out Operating Procedures and Quality Assurance/Quality Control (QA/QC) protocols for environmental condition monitoring methods, site and field instrument maintenance, and data capture, analyses and interpretation;

d. Have sufficient monitoring sites and replication to be able to at a to detect at a statistical power of 0.8 or greater, or an alternative statistical power as determined by the Minister, on advice of the CDEEP detect impacts of any dredging or spoil disposal activities;

e. Details of how the monitoring program will be used to establish predictive links between water quality, sediment deposition and coral health to enable timely management of dredging and spoil disposal activities associated with the facilities listed in Condition 17.2; and

f. Details of how the monitoring program will be able to show qualitatively the extent of the turbidity plume from the dredging and spoil disposal or re-use activities (NOTE: remote sensing is an option).

iv. The Plan shall include the following coral condition monitoring elements:

a. Specify monitoring frequency for monitoring and reference sites that does not exceed 2 weeks;

b. Set out Operating Procedures and QA/QC protocols for coral health monitoring methods, monitoring site maintenance, and data capture, analysis and interpretation;

c. Have sufficient monitoring sites and replication to be able to detect, to detect at a statistical power of 0.8 or greater, or an alternative statistical power as determined by the Minister, on advice of the CDEEP. limits of environmental impacts on coral as established in Condition 18.2 of any dredging or spoil disposal activities on coral health or to an alternative statistical power as determined by the Minister on advice of the CDEEP;
d. Set out protocols and procedures for sampling of corals to determine if they are gravid; and
e. Identify and predict significant autumn and spring mass coral spawning periods that could occur during the dredging program.

5. Dredging and dredge spoil disposal activities associated with works for the facilities listed in Condition 17.2 are to cease five days prior to the predicted commencement of mass coral spawning predicted by Condition 20.4.iv.e, or as soon as coral spawning is detected if prior to that predicted time, and to remain suspended for 7 days from commencement of mass spawning.

6. The Proponent shall implement the Plan.

**21. Management Triggers**

1. The Proponent shall, based on the results of monitoring programs undertaken prior to commencement of any dredging and dredge spoil disposal activities, establish initial water quality criteria that represent the link between water quality and coral health on advice of the CDEEP, and as determined by the Minister.

2. The Proponent shall commence coral monitoring once these initial water quality criteria are exceeded and continue monitoring for as long as these criteria are exceeded or the modified criteria are exceeded as set out in Condition 21.3.

3. The Proponent may continue investigating the link between water quality and coral health during dredging and dredge spoil disposal activities associated with works for the facilities listed in Condition 17.2 and report the findings to the CDEEP. The Proponent may recommend modified water quality criteria that better represent the link between water quality and coral health.

   NOTE: The Minister may set modified water quality criteria that better represent the link between water quality and coral health in response to the Proponent's recommendations on advice of the independent experts on the CDEEP.

4. The coral health management triggers in Table 2 below are to apply to the dredging and dredge spoil disposal activities associated with works for the facilities listed in Condition 17.2, which will require the Proponent to adopt the actions specified in Conditions 21.6, 21.7, 21.8. 21.9 and 21.10.

5. Table 2: Management triggers for dredging and dredge spoil disposal activities associated with works for the facilities listed in Condition 17.2.

| Zone | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| High Impact | n/a | n/a | n/a |
| Moderate Impact | 15% Average Net Mortality *Porites*; *50%* Mortality *Porites at any site* | 25% Average Net Mortality *Porites* | 30% Average Net Mortality *Porites* |
| Influence | Detectable adverse change in the health of coral | 10% coral bleaching at any site | Detectable net mortality of coral |

6. The Proponent shall complete analysis of coral monitoring data from each site within 72 hours of the sampling being carried out at all monitoring sites.

7. If any Level 1 Management Trigger Criterion in Condition 21.5 Table 2 is exceeded, within 72 hours of detection of the exceedance, the Proponent shall notify the CDEEP of the exceedance and provide an Impact Management Plan to the CDEEP and Minister, describing what measures it is taking, or intends to take, to keep impacts within approved limits specified in Condition 18.2: Table 1.

8. If any Level 2 Management Trigger Criterion in Condition 21.5 Table 2 is exceeded the Proponent shall:
    i. Immediately advise the CDEEP and report to the Minister, and suspend dredging and dredge spoil disposal activities within 48 hours unless otherwise authorised by the Minister;
    ii. Identify the dredge spoil activities and metocean conditions which caused the exceedance;
    iii. Identify locations of the dredging and dredge spoil disposal activities where existing impacts are low and those activities could recommence;
    iv. Confirm coral health monitoring results with the CDEEP and report to the Minister the status of coral health parameters against the "limits of environmental impacts" set in Condition 18; and
    v. Prepare an Impact Management Plan, on advice of CDEEP and submit to the Minister describing what measures the Proponent is taking, or intends to take to keep impacts to below Limits of Acceptable Change, set in Condition 18.2 Table 1, and the marine water quality criteria that will be met to allow for the recommencement of dredging and spoil disposal activities to ensure that mortality and or impacts will not exceed the Limits of Acceptable Change, set in Condition 18.2 Table 1.

9. The Proponent shall only recommence dredging and dredge spoil disposal activities when water quality meets the criteria established in Condition 21.8v. and shall adopt the measures set in the Impact Management Plan prepared for Condition 21.8v.

10. If any Level 3 Management Trigger Criterion in Condition 21.5 Table 2 is exceeded the Proponent shall:
    i. Immediately suspend all dredge spoil disposal activities associated with works for the facilities listed in Condition 17.2; and
    ii. Report to the Minister and the CDEEP that the Proponent is in non-compliance with Condition 18.2 Table 1.

**22. Horizontal Directional Drilling Management and Monitoring Plan**

1. Prior to the commencement of construction of the Feed Gas Pipeline System Shoreline Crossing on the west coast of Barrow Island, the Proponent shall prepare and submit to the Minister a Horizontal Directional Drilling (HDD) Management and Monitoring Plan (the Plan) for the management of HDD activities associated with the construction of the shoreline crossing on the west coast of Barrow Island that meets the objectives set out in Condition 22.3 and the requirements set out in Condition 22.4, as determined by the Minister.

2. The Proponent shall consult with the DEC, DoF and DoIR in the preparation of the Plan.

3. The objectives of the Plan are to:
    i. Reduce the impacts of HDD activities on the Terrestrial and Marine Disturbance Footprints as far as practicable; and
    ii. Ensure that HDD activities do not cause Material or Serious Environmental Harm outside the Terrestrial and Marine Disturbance Footprints or coral loss limit in Condition 22.5.

4. The Plan shall include:
    i. Management measures to reduce the impacts from HDD activities as far as practicable; and
    ii. Management measures to ensure that HDD activities do not cause Material or Serious Environmental Harm outside the Terrestrial and Marine Disturbance Footprints or the coral loss limit in Condition 22.5 to be exceeded.

The measures required by 22.4.i. and 22.4.ii. shall address:

- iii. The generation and dispersion of turbidity associated with discharge of drill cuttings and fluids to the marine environment;
- iv. Noise and percussion;
- v. Direct disturbance of habitat;
- vi. Preventing harm to, or fatalities of turtles;
- vii. The use of low toxicity polymer drilling fluids unless otherwise authorised by the Minister;
- viii. Management and disposal of drill cuttings and fluids returned to the surface by circulation to prevent pollution; and
- ix. A marine monitoring program to detect changes to ecological elements outside the Marine Disturbance Footprint identified in Condition 14.

5. The net mortality of coral assemblages for the HDD activities associated with the construction of the shoreline crossing on the west coast of Barrow Island shall not exceed 1.2 ha.

6. The Proponent shall implement the Plan.

**23. Offshore Gas Pipeline Installation Management Plans**

1. Prior to commencement of installation of the Feed Gas Pipeline System and Domestic Gas Pipeline respectively, the Proponent shall submit to the Minister an Offshore Gas Pipeline Installation Management Plan (the Plan) that meets the objectives set out in Condition 23.3 and the requirements of Condition 23.4 as determined by the Minister.

2. In preparing the Plan the Proponent shall consult with DEC, DEW and DoIR.

3. The objectives of the Plan are to:

   i. Reduce the impacts of pipeline installation activities on the Terrestrial and Marine Disturbance Footprints as far as practicable; and

   ii. Ensure that pipeline installation activities do not cause Material or Serious Environmental Harm outside the Terrestrial and Marine Disturbance Footprints.

4. The Plan shall include:

   i. Management measures to reduce the impacts from pipeline installation activities as far as practicable; and

   ii. Management measures to ensure that pipeline installation activities do not cause Material or Serious Environmental Harm outside the Terrestrial and Marine Disturbance Footprints.

   The measures required by Conditions 23.4.i. and 23.4.ii. shall address:

   iii. The generation and dispersion of turbidity associated with pipeline installation activities;

   iv. Direct disturbance of habitat;

   v. Preventing harm to, or fatalities of turtles;

   vi. Program for pre and post pipeline installation seafloor survey of the Marine Disturbance Footprint and the areas at risk of Material or Serious Environmental Harm due to the construction of the pipeline in State waters;

   vii. Detail mooring pattern design, range and bearing from fairleads of individual anchor drops to show how the mooring pattern has been designed to limit impacts in significant benthic habitat areas within State waters;

   viii. Detail a typical mooring pattern design for other than significant benthic habitat areas within State waters;

   ix. Procedures to minimise as far as practicable the impacts resulting from anchoring, wire and chain sweep, and wash from thrusters and propellers, on benthic communities;

x. Details of proposed hydrotest water discharge and how this will be managed to avoid Material or Serious Environmental Harm to the marine environment; and

xi. A marine monitoring program to detect changes to ecological elements outside the Marine Disturbance Footprint for the Offshore Gas Pipelines identified in Condition 14.

5. The Proponent shall implement the Plan.

### 24. Post-Development Coastal and Marine State and Environmental Impact Report

1. Within three months following completion of dredging and spoil dumping operations associated with the marine facilities listed in Condition 17.2, the Proponent shall repeat the surveys of marine habitats consistent with Condition 14.2 to determine the initial impacts on marine ecological elements consistent with the scope of works required by Condition 14.1.

2. Within 3 months of completion of the surveys required by Condition 24.1, the Proponent, on advice of the CDEEP, shall report the results of the survey to the Minister including detected changes to marine ecological elements.

3. The Proponent shall repeat the post dredge survey annually for at least three years following completion of dredging, unless otherwise determined by the Minister and within 3 months of completion of each survey report the results to the Minister including detected changes to marine ecological elements, on advice of the CDEEP.

4. The report of the third and subsequent surveys shall contain a recommendation as to the need of continuing the surveys and reporting.

### 25. Coastal Stability Management and Monitoring Plan

1. Prior to the commencement of construction of the facilities listed in Condition 17.2, the Proponent shall submit a Coastal Stability Management and Monitoring Plan (the Plan) to the Minister that meets the objectives set in Condition 25.3 and the requirements of Condition 25.4 as determined by the Minister.

2. In preparing the Plan the Proponent shall consult with DPI, MTEP, and DEC.

3. The objectives of the Plan are to:

   i. Ensure that the facilities listed in Condition 17.2, do not cause significant adverse impacts to the beaches adjacent to those facilities; and

   ii. Establish a monitoring programme to detect adverse changes to the beach structure and beach sediments that have implications for marine turtles nesting on those beaches.

4. The Plan shall include:

i. Baseline state of the beaches adjacent to Town Point from Mean Low Water to beyond the permanent dune vegetation line;
ii. A monitoring program to detect changes to profiles of beaches and grain size adjacent to Town Point from Mean Low Water to beyond the permanent dune vegetation line and the extent of any erosion or accretion of sand; and
iii. Measurable limits which specify the performance standards with respect to the extent of change which could affect turtles nesting on those beaches.

5. The Proponent shall implement the Plan.

6. If monitoring shows that the beach profiles and grain size do change beyond the performance standards in Condition 25.4iii., the Proponent shall submit a report to the Minister describing:
   i. The nature and extent of any change and implications for turtle nesting;
   ii. The likely causes of that change; and
   iii. Proposed mitigation measures, including identifying appropriate sand sources and vegetation stock.

7. In preparing any report required as part of Condition 25.6 the Proponent shall consult with DPI, MTEP, and DEC.

**26. Reservoir Carbon Dioxide Injection System**

1. The Proponent shall design and construct Carbon Dioxide Injection System infrastructure in conjunction with the Gas Treatment Plant on Barrow Island that is capable of disposing by underground injection, 100% of the volume of reservoir carbon dioxide to be removed during routine gas processing operations on Barrow Island and that would be otherwise vented to the atmosphere.

2. The Proponent shall implement all practicable means to inject reservoir carbon dioxide removed during gas processing operations on Barrow Island and ensure that calculated on a 5 year rolling average, at least 80 percent of reservoir carbon dioxide removed during gas processing operations on Barrow Island and that would be otherwise vented to the atmosphere is injected.

3. The Proponent shall prepare and implement a monitoring program to satisfy the annual reporting requirements for the performance of the Carbon Dioxide Injection System (Condition 5.2 vi and Schedule 3.6).

**27. Greenhouse Gas Abatement Program**

1. Prior to the commencement of construction of the Gas Treatment Plant the Proponent shall prepare and submit to the Minister a Greenhouse Gas Abatement Program (the Program) that meets the objectives set in Condition 27.2 and the requirements set out in Condition 27.3, as determined by the Minister.

2. The objectives of the Program are to:

i. Ensure that the Gas Treatment Plant is designed and operated in a manner which achieves reductions in "greenhouse gas" emissions as far as practicable;
ii. Provide for ongoing "greenhouse gas" emissions reductions over time;
iii. Ensure that through the use of best practice, the total net "greenhouse gas" emissions and/or "greenhouse gas" emissions per unit of LNG produced from the project are minimised; and
iv. Manage "greenhouse gas" emissions in accordance with the Framework Convention on Climate Change 1992, and consistent with the National Greenhouse Strategy.

3. The Program shall address the following:
   i. Calculation of the "greenhouse gas" emissions associated with the Proposal, using methodologies endorsed by the Australian Greenhouse Office;
   ii. Specific measures, including but not limited to those that have been included in the Proposal, to reduce the total net greenhouse gas emissions and/or the greenhouse gas emissions per unit of LNG produced by the Proposal using a combination of "no regrets" and "beyond no regrets" measures;
   iii. The ongoing review and implementation where practicable of "greenhouse gas" offset strategies with such offsets to remain in place for the life of the Proposal;
   iv. Estimation of the "greenhouse gas" efficiency of the project (per unit of LNG and /or other agreed performance indicators) and comparison with the efficiencies of other LNG producing facilities producing a similar product, both within Australia and overseas;
   v. Implementation of thermal efficiency design and operating goals for permanent installations consistent with the Australian Greenhouse Office – Generator Efficiency Standards;
   vi. Actions for the monitoring, regular auditing and annual reporting of "greenhouse gas" emissions and emission reduction strategies;
   vii. A target set by the Proponent for the progressive reduction of total net "greenhouse gas" emissions and/or "greenhouse gas" emissions per unit of product and as a percentage of total emissions over time, and annual reporting of progress made in achieving this target. Consideration should be given to the use of renewable energy sources such as solar, wind or hydro power;
   viii. A program to achieve a reduction or abatement in "greenhouse gas" emissions, consistent with the target referred to in (vii) above;
   ix. Apply for entry, whether on a Proposal-specific basis, company wide arrangement or within an industrial grouping, into the Commonwealth Government's Greenhouse Challenge Plus program; and
   x. Reviewing and adopting a "Continuous Improvement Approach" so that advances in technology and potential operational improvements of plant performance are adopted.

4. The Proponent shall implement the Program.

**28. Best Practice Pollution Control Design**

1. The Proponent shall submit to the DEC as part of its Works Approval application for the Gas Treatment Plant a report that:
   i. Demonstrates that the proposed works adopt best practice pollution control measures to minimise emissions from the Gas Treatment Plant;
   ii. Sets out the base emission rates for major sources for the Gas Treatment Plant and the design emission targets; and
   iii. Addresses normal operations, shut down, start up, and equipment failure conditions.

**29. Air Quality Management Plan**

1. The Proponent shall submit to the DEC as part of its Works Approval application for the Gas Treatment Plant an Air Quality Management Plan (the Plan) that meets the objectives of Condition 29.2 and the requirements of Condition 29.3.

2. The Objectives of the Plan are to:
   i. Ensure air quality meets appropriate standards for human health in the workplace; and
   ii. Ensure air emissions from the Gas Treatment Plant operations do not pose a risk of Material or Serious Environmental Harm to the flora, vegetation communities, terrestrial fauna, and subterranean fauna of Barrow Island.

3. The Plan shall include:
   i. An ambient air monitoring program to ensure the objectives set in Condition 29.2. are met;
   ii. The program shall include a list of chemicals to be monitored, the location of air quality sampling points and the frequency of air quality monitoring;
   iii. Emission targets for these chemicals; and
   iv. A programme of annual reporting of air quality results and any air improvement plans where emission targets are not met.

**30. Solid and Liquid Waste Management Plan**

1. Prior to commencement of construction of the terrestrial facilities listed in Condition 6.3, the Proponent shall submit a Solid and Liquid Waste Management Plan (the Plan) to the Minister that meets the objectives of Condition 30.2 and the requirements of Condition 30.3 as determined by the Minister to cover all solid wastes, waste from the wastewater treatment plant and other liquid waste.

2. The objectives of the Plan are to:
   i. Ensure all Proposal-related solid and liquid wastes are either removed from Barrow Island or, if not, that all practicable means are used to ensure that

waste disposal does not cause Material or Serious Environmental Harm to Barrow Island and its surrounding waters;

ii. Ensure discharges from any waste water treatment plant, reverse osmosis plant, or other process water are disposed of via deep well injection, unless otherwise authorised by the Minister; and

iii. Ensure any deep well injection of Proposal-related liquid wastes is conducted in a manner that will not cause Material or Serious Environmental Harm to subterranean fauna and their habitats on Barrow Island.

3. The Plan shall include a description of the facilities to be provided and management measures to be implemented to ensure wastes are managed to meet the objectives set in Condition 30.2.

## 31. Aboriginal Cultural Heritage Management Plan

1. Prior to commencement of construction of terrestrial facilities listed in Condition 6.3 the Proponent shall submit an Aboriginal Cultural Heritage Management Plan (the Plan) that meets the requirements of Condition 31.3 as determined by the Minister.

2. In preparing the Plan, the Proponent shall consult with the Department of Indigenous Affairs and Indigenous stakeholders.

3. The Plan shall include:
   i. Surveys for potential cultural heritage sites within the Terrestrial Disturbance Footprint; and
   ii. The retrieval and relocation of any heritage material which lies within the Terrestrial Disturbance Footprint in consultation with the Indigenous stakeholders.

4. The Proponent shall implement the Plan.

## 32. Post-Construction Rehabilitation Plan

1. Prior to commencement of construction of terrestrial facilities listed in Condition 6.3, the Proponent shall submit to the Minister a Post-Construction Rehabilitation Plan (the Plan) to cover those areas that will be disturbed as part of construction and areas that are part of the Terrestrial Disturbance Footprint, but which are not required for the future construction and operation of the Proposal that meets the objectives set in Condition 32.4 and the requirements of Condition 32.5 as determined by the Minister, unless otherwise allowed in Condition 32.2.

2. In the event that any parts of the Plan related to specific elements or sub-elements (Schedule 1) of the Proposal are not submitted as required by Condition 32.1, the Proponent shall submit the portions of the Plan relevant to that element or sub-element to the Minister prior to the planned commencement of construction of that element or sub-element. All portions of the Plan shall meet the objectives identified

in Condition 32.4 and the requirements of Condition 32.5 as determined by the Minister.

3. In preparing the Plan the Proponent shall consult with DEC and DoIR.

4. The objectives of the Plan are to:
   i. Ensure that the rehabilitation of terrestrial areas following construction is properly planned in a manner which promotes self-sustaining ecosystems able to be managed as part of their surroundings consistent with the conservation objectives of a class 'A' Nature Reserve;
   ii. Design rehabilitation of native vegetation to ultimately develop into viable ecological systems which are comparable and compatible with surrounding native vegetation and its land uses, and restores as closely as practicable the pre-disturbance biodiversity and functional values;
   iii. Ensure planning, implementation, monitoring and reporting on rehabilitation is carried out in a manner consistent with industry best practice;
   iv. Ensure management of rehabilitation continues until affected areas are self sustaining; and
   v. Better inform any on-going rehabilitation and post-closure rehabilitation.

5. The Plan shall include:
   i. Identification of those sites that will be disturbed for construction but are not required for the future construction and operation of the Proposal;
   ii. Identify those areas that are part of the Terrestrial Disturbance Footprint not required for the future construction and operation of the Proposal that can be rehabilitated;
   iii. Objectives for rehabilitation, including site-specific variation;
   iv. Plans for topsoil management;
   v. Targets for completion criteria including nutrient cycling and self sustainability of ecosystems;
   vi. Targets for flora and fauna recruitment, including specific targets for:
      a. the return of recalcitrant species,
      b. the return of key fauna habitat,
      c. the translocation of viable specimens of long-lived species required for fauna habitat,
      d. the re-colonisation of invertebrate fauna, and
      e. the re-colonisation of mycorrhizal fungi;
   vii. Hydrological function;
   viii. Integration with island-wide management;
   ix. Monitoring, and adaptive management including climate change;
   x. Identification of knowledge gaps and on-going studies to address lack of knowledge;
   xi. Plant species composition including consideration of species vulnerability to and dependence on fire;
   xii. Rehabilitation following Proposal-attributable fires;
   xiii. Reporting protocols including peer review; and
   xiv. Completion criteria agreed with DEC.

6. The Proponent shall implement the Plan.

7. The Proponent shall revise as required and submit to the Minister a revised Post-Construction Rehabilitation Plan in response to the results of the monitoring program and results of any on-going studies. In revising the Plan the Proponent shall consult with DEC.

8. The Proponent shall also implement the Plan for other areas requiring rehabilitation prior to final project closure not identified in Condition 32.4.

**33. Project Site Rehabilitation Plan**

1. Within five years following commencement of Operations the Proponent shall submit a draft Project Site Rehabilitation Plan (the Plan) for review by the DEC. The draft plan shall be informed by the monitoring, results of any ongoing studies and experience obtained through the implementation of the Post-Construction Rehabilitation Plan required by Condition 32.1. The Plan shall meet the objectives set in Condition 33.3 and the requirements of Condition 33.4 as determined by the Minister.

2. In preparing the draft Plan the Proponent shall consult with DEC, DoIR and DEW.

3. The objectives of the Plan are to:
   i. Ensure that the rehabilitation of terrestrial areas following decommissioning is properly planned in a manner which promotes self-sustaining ecosystems able to be managed as part of their surroundings consistent with the conservation objectives of a class 'A' Nature Reserve;
   ii. Design rehabilitation of native vegetation to ultimately develop into sustainable ecological systems which are comparable and compatible with surrounding native vegetation and its land uses, and restores as closely as practicable the pre-disturbance biodiversity and functional values;
   iii. Ensure planning, implementation and reporting on rehabilitation is carried out in a manner consistent with industry best practice;
   iv. Ensure management of rehabilitation continues until affected areas are self sustaining; and

4. The Plan required by Condition 33.1 shall address the requirements as set out in the Post-Construction Rehabilitation Plan required for Condition 32.5 but for final rehabilitation purposes.

5. Within 12 months following receipt of formal advice from the DEC on the draft Plan, the Proponent shall prepare and submit the revised Plan, taking into account comments and recommendations (if any) received from DEC, to the Minister that meets the objectives set in Condition 33.3 and the requirements of Condition 33.4 as determined by the Minister.

6. The Proponent shall revise the Plan as required and submit the final Plan no less than five years prior to the anticipated date of decommissioning and closure,

informed by the results of any studies, monitoring and experience of the implementation of the Post-Construction Rehabilitation Plan required by Condition 32.1. In preparing the revised Plan the Proponent shall consult with DEC.

7. The Proponent shall implement the Plan upon project closure and decommissioning.

**34. Decommissioning and Closure Plan**

1. At least four years prior to the anticipated date of decommissioning and closure, or at a time otherwise agreed by the Minister, the Proponent shall prepare a Decommissioning and Closure Plan (the Plan) for terrestrial and marine infrastructure facilities, that meets the requirements of Condition 34.3 as determined by the Minister.

2. In preparing the Plan the Proponent shall consult with DEC, DoIR and DEW.

3. The Plan shall include:
   i. Removal or, if appropriate, retention of plant and infrastructure;
   ii. The rationale for the siting and design of plant and infrastructure to be retained as relevant to environmental protection;
   iii. Identification of contaminated areas, including provision of evidence of notification and proposed management measures to relevant statutory authorities; and
   iv. Relationship to and consistency with the Project Site Rehabilitation Plan.

4. The Proponent shall implement the Plan.

**35. Public availability of Plans, Programs etc.**

1. Management plans, reports, systems, and programs referred to in the following conditions shall be made publicly available as determined by the Minister: 5.1, 6.1, 7.1, 8.1, 10.1, 11.1, 12.1, 13.1, 14.1, 16.1, 17.1, 20.1, 22.1, 23.1, 24.1, 25.1, 27.1, 28.1, 29.1, 30.1, 31.1, 32.1, 33.1 and 34.1.

**36. Submission of Plans, Programs etc**

1. Where a Condition requires that a plan, report, system or program meet certain aims, objectives or purposes and certain requirements 'as determined by the Minister', the plan, report, system or program is not deemed to have met the Condition unless and until the Minister finds that the aims, objectives or purposes and certain requirements have been met.

2. In the event that following the approval of a document (plan, report, system or program referred to in Condition 36.1) the document is found by the Proponent to no longer meet the requirements set out in Condition 36.1 or the Proponent has identified elements of works not appropriately covered by the document or the

Proponent identifies measures to improve the document, an amendment or addendum to the approved document may be developed and submitted to the Minister.

3. All supplementary plans, reports, systems or programs submitted under Condition 36.2 are subject to Condition 36.1, and if agreed by the Minister, to constitute an approved amendment or addendum to the plan, report, system or program.

David Templeman MLA
MINISTER FOR THE ENVIRONMENT; CLIMATE CHANGE; PEEL

– 6 SEP 2007

## Schedule 1 - Summary of Key Proposal Characteristics

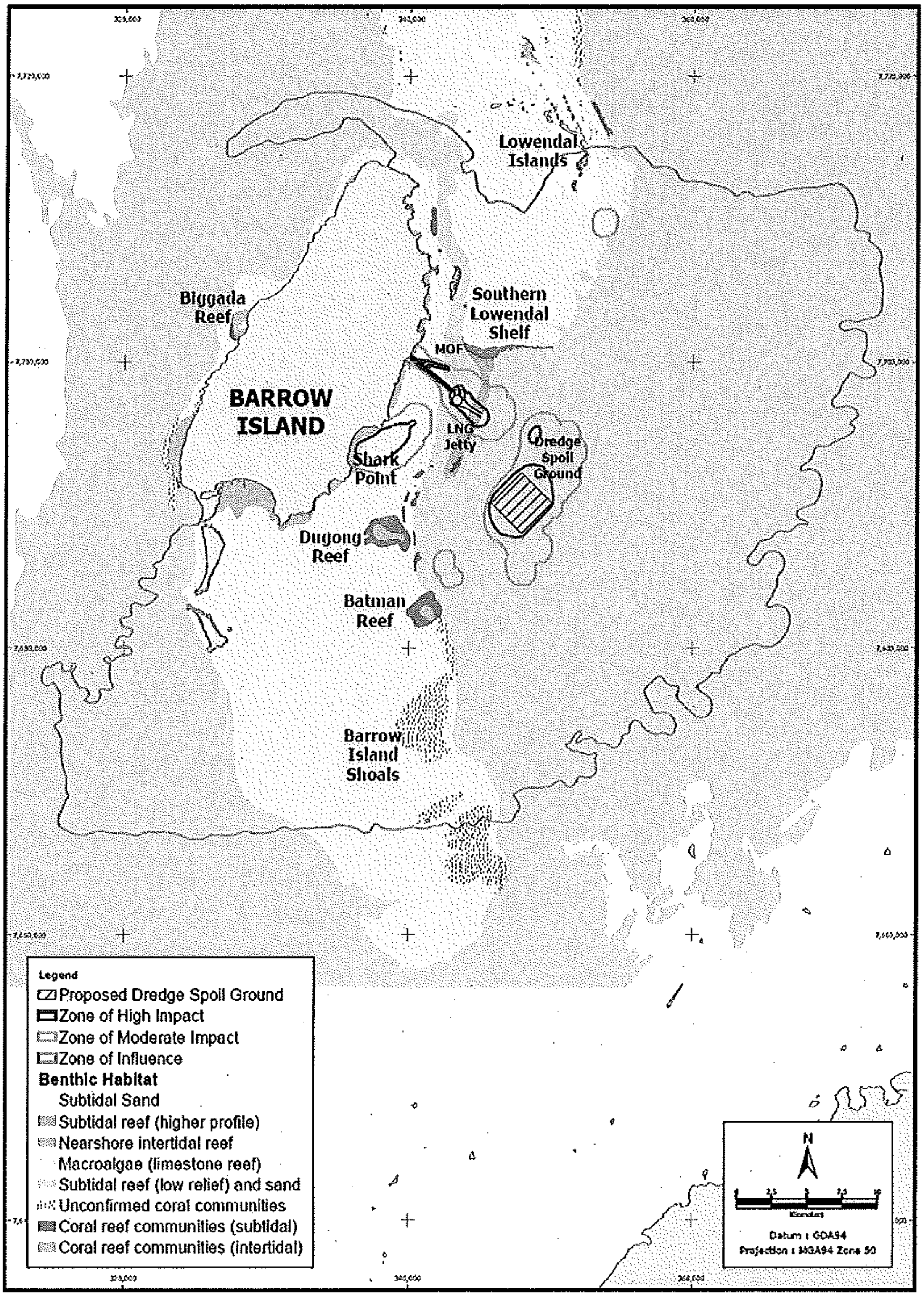
| Element | Description |
|---|---|
| **Terrestrial Facilities** | |
| **Gas Treatment Plant** | |
| • Location | Town Point |
| • Number of Liquefied Natural Gas (LNG) trains | 2 |
| • Size of LNG trains | 5 MTPA nominal |
| • LNG tank size | 2 x 165,000 $m^3$ (net) |
| • Gas Processing Drivers | 4 x 80 MW dry low NOx (DLN) gas |
| • Power Generation | 4 x 116 MW conventional gas turbines |
| • Flare design | Ground flare for main plant flare<br>Elevated flare in storage and loading area (rarely used) |
| • Domestic gas production rate | 300 TJ/day |
| • Condensate production rate | 2,000 $m^3$/day hydrocarbon condensate |
| • Condensate tank size | 2 x 60,000 $m^3$ |
| **Associated Terrestrial Infrastructure** | |
| **Barge Landing** | |
| • Materials offloading prior to MOF access | Upgrade existing WAPET landing |
| • Construction Village (inclusive of operations accommodation) | 2.6 km south of Gas Treatment Plant. Standalone pioneer camp eliminated |
| • Administration and Operations Complex | Near the Gas Treatment Plant outside the Plant boundary |
| • Utilities Area | Near the Gas Treatment Plant |
| • Utilities Corridors | Between Utilities Area, Construction Village and Gas Treatment Plant |
| • Road Upgrades | WAPET landing to Town Point. Town Point to the Airport (via Construction Village). Feed Gas Pipeline System route. |
| • Airport Modifications | Extension of existing runway to the south<br>No realignment<br>Vegetation clearing within current airport perimeter required |
| • Communications | Microwave communications tower and associated infrastructure to be installed on Barrow Island. Optic Fibre Cable no longer required. |
| **Onshore Feed Gas Pipeline System** | |
| • Length onshore (Barrow Island) | ~ 14 km |
| • Design onshore | Buried (~ 1000 mm cover) |
| • Construction easement (onshore) | ~ 42 ha |
| • Shore crossing | North White's Beach |
| **Onshore Domestic Gas Pipeline** | |
| • Route onshore (BWI) | Within Gas Treatment Plant footprint |

| Element | Description |
|---|---|
| • Length onshore (mainland) | 30 to 40 km |
| • Construction easement (mainland) | 90 to 120 ha |
| • Shoreline crossing (mainland) | To be determined by the Proponent |
| **Water Supply** | |
| • Source | Seawater intake will be required |
| • Location | Preferred intake location under MOF structure |
| • Volume | ~ 5,150 $m^3$/day raw water supply |
| **Carbon Dioxide ($CO_2$) Injection System** | |
| • $CO_2$ Compression Facilities | Located within Gas Treatment Plant boundary |
| • $CO_2$ Pipeline | Length approximately 5 km.<br>Easement approximately 6 ha. |
| • $CO_2$ Injection Wells | Approximately seven injection wells directionally drilled from two or three surface locations |
| • Observation Wells | Observation well (or wells) may be drilled from each cluster of injection wells |
| • Pressure Management Wells | Pressure relief well (or wells) may be required once injection performance is established |
| • Monitoring | Monitoring activities, including the acquisition of seismic data, will be undertaken as part of ongoing reservoir performance management. |
| **Greenhouse Gas Emissions Abatement** | |
| Abatement actions below are anticipated to yield a greenhouse gas emissions intensity of 0.35 tonnes $CO_2$e per tonne of LNG shipped. | |
| • "Beyond No Regrets Measures": | |
| - Underground injection of reservoir carbon dioxide | |
| - Improved LNG Technology | Adoption of a no routine venting or flaring policy.<br>Use of dry compressor and hydrocarbon pump seals.<br>Providing a cold recovery exchanger for the overhead gas from the Nitrogen Rejection Column to allow reuse of overhead gas in the high pressure (HP) fuel gas system. |
| • "No Regrets Measures": | |
| - Gas production via a sub-sea production system | |
| - Improved LNG Technology | LNG processing trains increased to the maximum capacity that is practicable. A-MDEA selected as the carbon dioxide removal medium.<br>Utilisation of waste heat, such that fired heaters are only required for plant start-up. |

| Element | Description |
|---|---|
| **Wastewater** | |
| • Wastewater Treatment Plant (WWTP) | Wastewater treatment plant installed during pre-construction (with sufficient capacity for construction workforce) will be modified as necessary to support operations workforce. |
| • Treated effluent disposal | Deep well injection of surplus treated effluent |
| • Reverse osmosis (RO) brine disposal | Deep well injection or ocean outfall (east coast Barrow Island) |
| • Contaminated wastewater disposal | Deep well injection of contaminated wastewater streams when practicable |
| • Process water disposal | Deep well injection of process water |
| **Marine Facilities** | |
| **Marine Offloading Facility (MOF)** | |
| • Causeway design | Solid |
| • Causeway length | ~ 800 m |
| • MOF design | Solid with offloading facilities including wharf, dock, mooring dolphins, ramp and tug pens to support a range of vessel sizes and loads. |
| • MOF length | ~ 520 m |
| • MOF access | Constructed channel ~ 1.6 km long x 120 m wide, dredged to 6.5 m relative to chart datum. |
| **LNG Jetty** | |
| • LNG jetty design | Open pile structure |
| • LNG jetty length | ~ 2.7 km |
| • LNG and Condensate load-out | Via dedicated lines installed to the LNG Berth (eastern end of LNG Jetty) |
| • Turning basin and access channel design | Turning basin 1 x 700 m circle (approximately), channel 300 m wide (approximately). Dual Berth facility. |
| • Turning basin and access channel depth | Dredged to 14 m relative to chart datum |
| **Dredging** | |
| • MOF volume | 1.1 million $m^3$ |
| • LNG Turning Basin and Shipping Channel volume | 6.5 million $m^3$ (dual berth). Design to be determined by the Proponent. Refer to section 2.1.4 (Part A, Final EIS/ERMP) |
| **Dredge Spoil Ground** | |
| • Location | Closest point is approximately 10 km from the east coast of Barrow Island |
| • Area | 900 ha |
| **Offshore Feed Gas Pipeline System** | |
| • Length in State waters | 5.6 km (3 nautical miles) |
| • Shore crossing | North White's Beach |
| **Offshore Domestic Gas Pipeline** | |
| • Length offshore | ~ 70 km |

| Element | Description |
|---|---|
| • Offshore route | Essentially direct line |
| **Applicable to the Entire Proposal** | |
| **Clearing** | |
| • All elements of the Proposal | Clearing of native vegetation for the purpose of implementing the Proposal. |

*Figure 1*




Chevron Australia Pty Ltd

**Figure 1 - Dredging and Spoil Disposal Zones of High Impact, Moderate Impact and Zone of Influence - Regional Perspective**

*Figure 2*

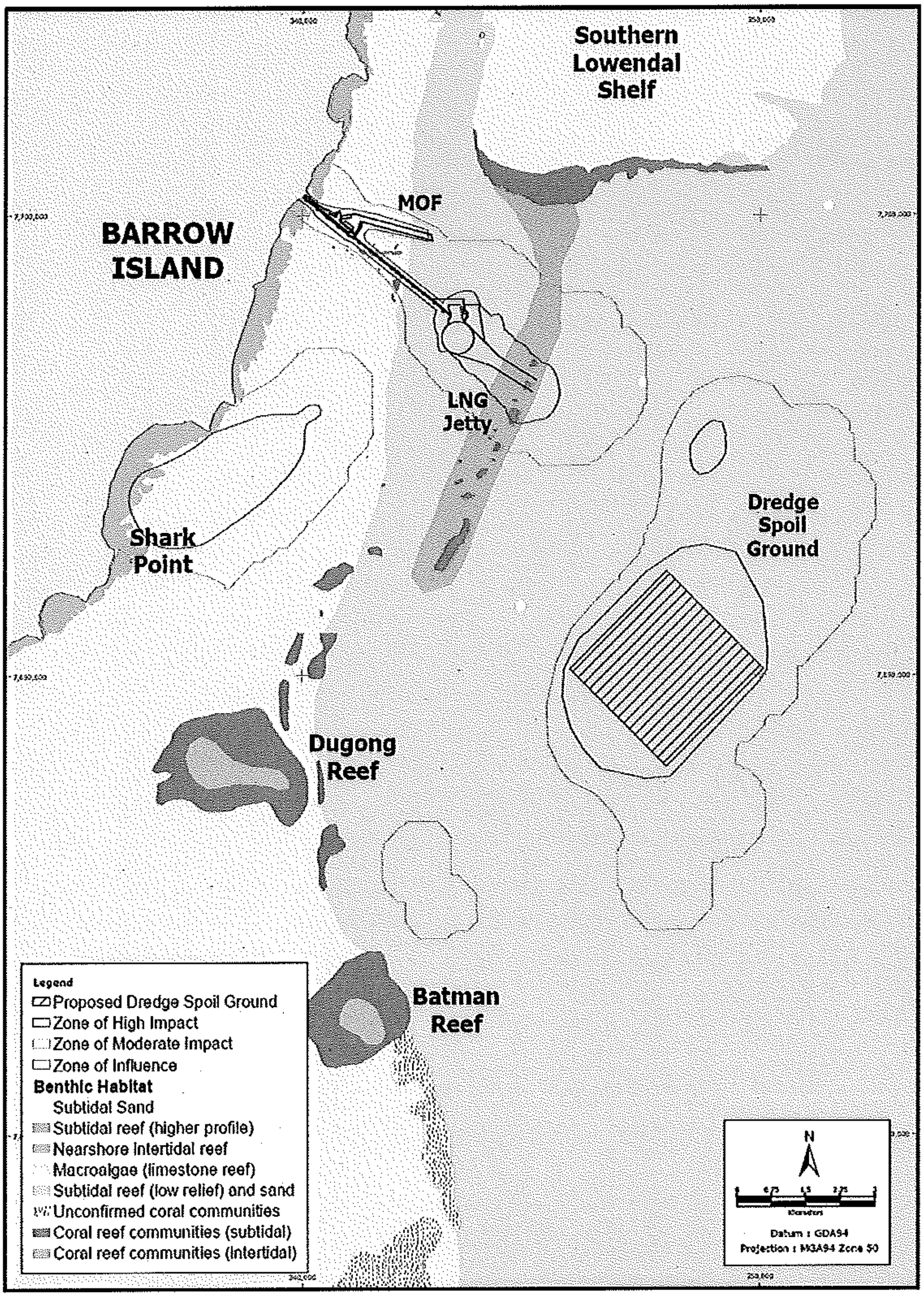



Figure 2 - Dredging and Spoil Disposal Zones of High Impact, Moderate Impact and Zone of Influence - Focus on Dredging and Spoil Disposal

NOTE: The coordinates of the lines on these figures that defines the three zones are set out in a document titled ""Gorgon Project - Zones of High Impact Moderate Impact and Zone of Influence" Document Number: G1-NT-REPX0000937 Revision 0. This document makes up Schedule 5 of these conditions.

## Schedule 2 – Terminology, definitions and acronyms

AQIS – Australian Quarantine Inspection Service

-"As far as practicable", "where practicable" and "practicable" all mean reasonably practicable having regard to, among other things, local conditions and circumstances (including costs) and to the current state of technical knowledge.

Average Net Detectable Mortality - Average Net Detectable Mortality of coral is the result of averaging the Net Detectable Mortality of all Monitoring Sites within the Zone, i.e. the mean of Net Detectable Mortality of any Zone.

Barrow Island Industry Participants – The Gorgon Joint Venture Participants, the Barrow Island Joint Venture Participants and any other future Industry Participant.

Best Practicable Measures - Has the meaning as defined in Western Australian Environmental Protection Authority Guidance Statement No 55 (2003)

BI or BWI – Barrow Island

BICC – Barrow Island Coordination Council as established under Schedule 1 of the Barrow Island Act 2003.

Carbon Dioxide ($CO_2$) Injection System – the mechanical components required to be constructed to enable the injection of reservoir carbon dioxide, including but not limited to compressors, pipelines and wells.

CDEEP – Construction Dredging Environmental Expert Panel

Coral Mortality definitions

*Direct loss* is defined as permanent removal of Benthic Primary Producer Habitat (BPPH) substrate and mortality of coral.

*Indirect loss* is defined as mortality of coral with no removal of BPPH substrate. BPPH may return at some future time, but this will be dependent upon the condition of substrate and successful recruitment.

*The Change in coral mortality* is determined by subtracting the baseline extent of Gross coral mortality from the extent of Gross coral mortality measured on a sampling occasion.

*Net detectable coral mortality at a monitoring location* is the result of subtracting the Change in coral mortality at the Reference Site from the Change in coral mortality at that Monitoring Site.

*Averaged Net detectable coral mortality* is the result of averaging the net mortality of all monitoring locations within the Zone i.e. the mean of net mortality of any Zone.

Gross coral mortality at a site is expressed as a percentage of total coral cover at the time of sampling at that monitoring location.

In determining the coral loss, measurement uncertainty is to be taken into consideration.

Construction – Construction includes any Proposal-related construction and commissioning activities within the Terrestrial and Marine Disturbance Footprints, excluding investigatory works such as, but not limited to, geotechnical, geophysical, biological and cultural heritage surveys, baseline monitoring surveys and technology trials.

Construction Period - The period from the date on which the Gorgon Joint Venturers first commence construction of the Proposal until the date on which the Gorgon Joint Venturers issue a notice of acceptance of work under the EPCM, or equivalent contract entered into in respect of the second LNG train of the Gas Treatment Plant.

DAF – Western Australian Department of Agriculture and Food

DEC – Western Australian Department of Conservation and the Environment

Deep wells (in the context of liquid waste disposal) – refer to injection wells completed in the Barrow Group (a well defined geological formation approximately 1,000 – 1,800m below the surface).

DEW – Commonwealth Department of Environment and Water Resources.

Disposal of carbon dioxide (CO2) underground – an activity conducted pursuant to Part 4 section 13 and Clauses 7, 8 and 9 of Schedule 1 of the Barrow Island Act 2003 (WA).

DOCEP – Western Australian Department of Consumer and Employment Protection

DoIR – Western Australian Department of Industry and Resources

DoF - Western Australian Department of Fisheries.

DoW – Western Australian Department of Water

Dominant coral species – species with the highest relative percentage cover. Percentage cover is expressed as the proportion of total coral cover.

DPI – Western Australian Department of Planning and Infrastructure.

DRF - Declared Rare Flora has the meaning given by the *Wildlife Conservation Act 1950* (WA)

Ecological Community – refers to all the interacting organisms living together in a specific habitat.

EIS/ERMP - the Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development dated September 2005 as amended or supplemented from time to time.

Endemic – Unique to an area; found nowhere else.

Environmental Harm - has the meaning given by Part 3A of the *Environmental Protection Act 1986 (WA)*

EP Act – *Environmental Protection Act 1986 (WA)*

EPCM - Engineering, Procurement and Construction Management

GIS – Geographic Information System

GJV – Gorgon Joint Venture

Greenhouse gas abatement 'Beyond No Regrets Measures' – are measures that involve additional costs to the Proposal which are unlikely to be recovered

Greenhouse gas abatement 'No Regrets Measures' – are measures that are cost-neutral and do not add additional cost to the Proposal.

HDD – Horizontal Directional Drilling

Introduced Terrestrial Species - non-indigenous terrestrial species (including weeds).

LNG – Liquefied natural gas

Marine Disturbance Footprint – the area of the seabed to be disturbed by construction or operations activities associated with the Marine Facilities listed in Condition 14.3 (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and dredge spoil disposal).

Marine Pests – Species other than the native species known or those likely to occur in the waters of the Indo-West Pacific region and the Pilbara Offshore (PIO) marine bioregion in Interim Marine and Coastal Regionalisation for Australia: An Ecosystem Based Classification for Marine and Coastal Environments (IMCRA, 1997), of which Barrow Island is a part, that do or may threaten biodiversity in the Pilbara Offshore (PIO) marine bioregion. As a minimum, the National Introduced Pest Information System Database (NIMPIS, Dept Environment and Water Resources, Commonwealth Government), National Priority Pests listed in the document National Priority Pests, Part II, Ranking of Australian Marine Pests (CSIRO Marine Research, 2005) will guide the interpretation of this definition. Additional species may be added on the advice of experts from the WA Department of Fisheries and the Quarantine Expert Panel.

Marine Quarantine Controlled Access Zone – The zone that extends from 500m offshore from the Barrow Island MHHW mark and encapsulates the entire coastline of Barrow Island. The zone also extends 500m from all marine facilities contiguous with Barrow Island.

Marine Quarantine Limited Access Management Zone – The zone that commences at the outer boundary approximately 2.5 km from the Barrow Island shoreline (MHHW Mark) up to the 500 metre mark from the shoreline.

Marine Turtles – Refers to flatback, green and hawksbill turtles nesting on Barrow Island.

Material Environmental Harm – means environmental harm that is neither trivial nor negligible.

MTEP – Marine Turtle Expert Panel

Minister – WA Minister for the Environment

Non-indigenous terrestrial species - Any species of plant, animal or micro-organism not native to Barrow Island. (Native - species that are native to (naturally occurring in) a region. (Reference: State of the Environment Advisory Council (1996). Australia: State of the Environment 1996)

Operations – for the respective LNG trains, this is the period from the date on which the Gorgon Joint Venturers issue a notice of acceptance of work under the Engineering, Procurement and Construction Management (EPCM) contract, or equivalent contract entered into in respect of that LNG train of the Gas Treatment Plant; until the date on which the Gorgon Joint Venturers commence decommissioning of that LNG train.

Porites – An important genus of long-lived, reef building corals.

QEP – Quarantine Expert Panel

QMS – Quarantine Management System

Reservoir Carbon Dioxide - a gas stream that consists overwhelmingly of carbon dioxide and coming from the acid gas removal units of the Gas Treatment Plant to be located on Barrow Island. The carbon dioxide will contain incidental associated substances derived from the natural gas and the process used to separate the carbon dioxide from that natural gas.

Serious Environmental Harm - means environmental harm that –

a. is irreversible, of a high impact or on a wide scale; or
b. is significant or in an area of high conservation value or special significance and is neither trivial nor negligible.

Short-Range Endemics - Taxonomic group of invertebrates that are unique to an area; found nowhere else and have naturally small distributions (i.e. $<10{,}000 km^2$)

Statistical Power - The probability of detecting a meaningful difference, or effect, if one were to occur.

Sub-dominant coral species – species, excluding Dominant coral species, which have greater than or equal to 5% cover. Percentage cover is expressed as the proportion of total coral cover.

Substantially Commenced - physical construction activities for, and progress of an important or essential element or elements of the Proposal scope.

Terrestrial Disturbance Footprint – the area to be disturbed by construction or operations activities associated with the terrestrial facilities listed in Condition 6.3.

Terrestrial Quarantine Controlled Access Zone – The zone encompassing the following points of entry to Barrow Island:

a. Quarantine Approved Premises ( marine offloading facility, warehouse, remedial facility, quarantine washdown bay and first stage laydown);
b. Airport; and
c. WAPET Landing

Terrestrial Quarantine Limited Access Management Zone – The Zone encompassing areas of the Terrestrial Disturbance Footprint which are used for intensive, long-term development activities on Barrow Island:

a. Gas Treatment Plant
b. Construction Village and Barrow Island Oil Joint Venture Camp
c. Administration and Operations Complex
d. Onshore Feed Gas Pipeline System and Carbon Dioxide Injection System corridors

Waters Surrounding Barrow Island - refers to the waters of the Barrow Island Marine Park and Barrow Island Marine Management Area (approximately 4,169 ha and 114,693 ha respectively) as well as the port of Barrow Island representing the Pilbara Offshore Marine Bioregion which is dominated by tropical species that are biologically connected to more northern areas by the Leeuwin Current and the Indonesian Throughflow resulting in a diverse marine biota is typical of the Indo-West Pacific flora and fauna.

## Schedule 3 – Details of Annual Environmental Performance Reporting

The annual Environmental Performance Report referred to in Condition 5.1 shall report on the following environmental aspects of the Proposal, relevant management and associated studies:

**1. Terrestrial and subterranean environment state**

i. Results of monitoring and any measurable impacts from Proposal including any changes from the baseline;
ii. Any mitigation measures applied and results of that mitigation; and
iii. Any changes to monitoring sites.

**2. Terrestrial and marine quarantine**

i. Results of the audits and monitoring programs;
ii. Detected introduction(s) of non-indigenous terrestrial flora or fauna and marine pest species, including procedure breaches and 'near misses' including special reference to weeds;
iii. Consequences of the introduction,
iv. Modification, if any, to the QMS because of
   a. Audits and monitoring
   b. detected introductions;
   c. 'best practice' improvements
v. Eradication actions if any taken; reasons for any action or non-action; changes to improve procedures and outcomes and progress;
vi. Mitigation actions; and
vii. Results of any QMS related studies, where conducted, to improve performance.

**3. Marine Turtles**

i. Results of flatback turtle monitoring carried out by the Proponent including any detected changes to the population;
ii. Reportable Incidents involving harm to marine turtles;
iii. Changes to the flatback turtle monitoring program;
iv. Conclusions about the status of flatback turtle populations on Barrow Island; and
v. Changes (if any) to the Long-Term Marine Turtle Management Plan required as part of Condition 16.1.

**4. Short range endemics and subterranean fauna**

i. Results of survey and studies to locate outside of the Gas Treatment Plant footprint those remaining short range endemics and subterranean fauna species previously found only within the Gas Treatment Plant footprint (as required in Condition 11.1).

**5. Fire Management**

i. incidence of fires caused by the Proposal, and fires that impact on the Proponent's facilities;

ii. Material or Serious Environmental Harm caused by fire directly attributable to the Proposal ; and

iii. changes to management plan including:

   a. management responses to address Material or Serious Environmental Harm caused by fire directly attributable to the Proposal; and

   b. improvement to fire management practices..

**6. Carbon dioxide Injection System**

i. Volume of reservoir carbon dioxide removed from the incoming natural gas stream and available for injection;

ii. Volume of reservoir carbon dioxide injected;

iii. Results of environmental monitoring and identified Material or Serious Environmental Harm, if any, resulting from the seepage of injected carbon dioxide to the surface or near surface environments including those which may support subterranean fauna;

iv. Reasons for shortfall between the volume of reservoir carbon dioxide extracted and injected;

v. In the event the amount of carbon dioxide injected falls significantly below the target levels set in Condition 26.2 the Proponent shall report on:

   a. measures that could be implemented that would ensure that target level set in Condition 26.2 is met or, if injection is not considered feasible for all or some of the gas, measures to otherwise offset

   b. which if any of these measures the Proponent intends to implement; and

vi. In the event that monitoring shows there is an elevated risk of Material or Serious Environmental Harm and/or risk to human health associated with the injection of reservoir carbon dioxide, the Proponent shall report to the Minister on the efficacy of continuing to geo-sequester and alternative offsets considered instead of continuing injection of reservoir carbon dioxide.

**7. Changes to the terrestrial and subterranean environment state**

i. Terrestrial and subterranean environment monitoring program including identification of impacts;

ii. Results of any mitigation actions;

iii. Any changes to the terrestrial and subterranean environment monitoring program; and

iv. Any changes to the Terrestrial Flora, Fauna and Subterranean Fauna Management Plan.

**8. Air quality**

i. Air quality results and any air improvement plans where emission targets are not met.

**9. Coastal Stability**

i. Results of beach and sediment monitoring; and
ii. Any mitigation measures applied in response to Proposal related impacts of beach profile.

**10. Terrestrial Rehabilitation**

i. Results of monitoring program;
ii. Results of any studies;
iii. Changes to management plan; and
iv. Areas where completion criteria have been achieved.

## Schedule 4 – Details of the Quarantine Management System

The Quarantine Management System required by Condition 10.1 shall include the following elements:

1. **Risk Assessment, Supply Chain Management and Vessel Management and Inspection:**

    i. A qualitative risk assessment of all Proposal-attributable introduction pathways for entry of terrestrial non-indigenous species to Barrow Island and entry of marine pests to the Waters Surrounding Barrow Island;

    ii. Procedures and barriers to be applied at each potential introduction pathway that is directly attributable to the Proposal to ensure that the risk of introducing species is consistent with the objectives of the QMS;

    iii. Procedures and specification for the preparation, packing and shipment of all material destined for Barrow Island related to this Proposal;

    iv. Procedures and checklists for the inspection of all material destined for Barrow Island related to this Proposal;

    v. Procedures for ensuring that any item related to this Proposal which is not approved by an authorised inspector is denied entry to Barrow Island unless remedial cleaning in the Quarantine Approved Premises have made such item/s quarantine compliant;

    vi. An accreditation program that all Proposal related quarantine inspectors must complete before engaging in quarantine management activities related to this Proposal, in consultation with DEC, DAF and DoF (and AQIS in the event of Direct Shipments to the Quarantine Approved Premises on BI from overseas ports; and

    vii. Procedures for when DEC officers require access to project site.

2. **Detection, Control, Eradication and Mitigation Program:**

    i. A detection program with the to detect at a statistical power of 0.8 or greater, or an alternative statistical power as determined by the Minister on advice of the QEP, detect the presence of non-indigenous species introduced to Barrow Island or proliferated within facility construction sites and marine pests in the waters surrounding the Proponent's marine infrastructure (as listed in Condition 14.3);

    ii. Emergency Response and Eradication Protocols (including, but not limited to species action plans) for all detected terrestrial non-indigenous species on Barrow Island and marine pests in the waters surrounding Barrow Island that contains and controls or eliminates any introduced or proliferated non-indigenous species unless alternatively determined by the Minister on the advice of the QEP;

    iii. Contingency management plans that can be immediately implemented to control and eradicate detected terrestrial non-indigenous species on Barrow Island and marine pests in the waters surrounding Barrow Island;

iv. Management plans that can be implemented to mitigate impact caused by detected terrestrial non-indigenous species on Barrow Island and marine pests in the waters surrounding Barrow Island, and mitigate impact caused in the management of detected terrestrial non-indigenous species on Barrow Island and marine pests in the waters surrounding Barrow Island;

**3. Reporting and Recording:**

i. Procedures that will be used to maintain electronic records, including a geographic information system (GIS), of breaches of Proposal QMS procedures; quarantine incidents which resulted in the introduction of terrestrial non-indigenous species to Barrow Island and marine pests to waters surrounding Barrow Island; and corrective actions taken to rectify those breaches, close out incidents, and address introductions that are verifiably attributable to the Proposal;

ii. Procedures to make information covered in Schedule 4 3.i accessible to DEC;

iii. Provision for reporting detected terrestrial non-indigenous species on Barrow Island and marine pests in the waters surrounding the Proponent's marine infrastructure on Barrow Island to DEC; and

iv. Provisions for ensuring that any information regarding quarantine management is available and provided to the DEC in a timely manner.

**4. Reviewing, audits and further studies:**

i. Protocols for regular audits of the Proponent's quarantine management measures in place under the QMS to determine their effectiveness and to determine if any corrective actions are required;

ii. The regular audits shall be conducted at six monthly intervals during the construction phase and at least biannually upon commissioning;

iii. The Proponent shall prepare and submit a report to DEC and the Conservation Commission detailing the results and outcomes of the audits referred to in 4i. and 4ii.; and

iv. The Proponent will undertake quarantine studies from time to time on advice of the QEP when audits and performance monitoring indicate the need to do so.

Western Australian Environmental Protection Authority approval under section 45C of the *Environmental Protection Act 1986* (WA) for changes to the Approved Development that will not result in a significant detrimental, environmental effect.

**Environmental Protection Authority**

The Atrium,
Level 8, 168 St Georges Terrace,
Perth, Western Australia 6000.
Telephone: (08) 6364 6500.
Facsimile: (08) 6467 5557.

Postal Address: Locked Bag 33,
Cloisters Square, Perth, Western Australia 6850.
Website: www.epa.wa.gov.au

Dr Julia Martin
Environmental Team Leader
Gorgon Project
GPO Box S1580
**PERTH WA 6845**

*Your Ref:* CVXPH-EPAPH-0000012
*Our Ref:* DEC DOC 48104
*Enquiries:* *Warren Tacey 64675170*
*Email:* *warren.tacey@dec.wa.gov.au*

Dear Dr Martin

**CHANGE TO – GORGON GAS DEVELOPMENT ON BARROW ISLAND NATURE RESERVE - STATEMENT 748**

Under section 45C of the *Environmental Protection Act 1986* I am able to approve a change or changes to a proposal without a revised proposal being submitted to the Environmental Protection Authority.

I consider that the changes described in the attachment will not result in a significant, detrimental, environmental effect in addition to, or different from, the effect of the original proposal.

Approval is therefore granted under section 45C of the *Environmental Protection Act 1986* for the changes to the proposal. You are reminded that this approval shall be implemented in accordance with the implementation conditions in Statement 748 and, also, that this approval does not replace any responsibilities you may have for seeking approvals from other government agencies to implement the change.

Yours sincerely

**Dr Paul Vogel**
CHAIRMAN

21 May 2008

Encl.

## Attachment 1 to Statement 748

## Change to Proposal

**Proposal:** The construction of facilities for the development of the Greater Gorgon Gas Fields on the North-West Shelf, and the processing and export of the liquefied natural gas plant to be constructed on Barrow Island, as more generally described in the Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development and the Final Environmental Impact Statement/Response to Submissions on the Environmental Review and Management Programme.

**Proponent:** Chevron Australia Pty Ltd

**Change:** Excavation of berthing pocket at Barge Landing facility;

Installation of additional communications facilities;

Relocation of the seawater intake; and

Modification of Seismic Monitoring Program.

**Components of original Proposal:**

| Component | Description |
|---|---|
| **Associated Terrestrial Infrastructure** | |
| **Barge Landing** | |
| • Materials offloading prior to MOF access | Upgrade existing WAPET landing |
| **Communications** | Microwave communications tower and associated infrastructure to be installed on Barrow Island.<br>Optic Fibre Cable no longer required. |
| **Water Supply** | |
| • Location | Preferred intake location under MOF structure |
| **Carbon Dioxide ($CO_2$) Injection System** | |
| • Monitoring | Monitoring activities, including the acquisition of seismic data, will be undertaken as part of ongoing reservoir performance management. |

**Components of changed Proposal:**

| Components | Description |
|---|---|
| **Associated Terrestrial Infrastructure** | |
| **Barge Landing** | |
| • Materials offloading prior to MOF access | Upgrade existing WAPET landing including excavation of berthing pocket at the existing land-backed wharf. |
| **Communications** | Microwave communications towers and associated infrastructure to be installed on Barrow Island.<br>Optic Fibre Cable (to mainland) no longer required. |
| **Water Supply** | |
| • Location | Seawater intake location adjacent to MOF structure |
| **Carbon Dioxide ($CO_2$) Injection System** | |
| • Monitoring | Monitoring activities, including the acquisition of seismic data using sub surface explosives (approximately 1300 shot-holes), will be undertaken as part of ongoing reservoir performance management. |

**Approved under delegation**
**from Minister for the Environment:**

EPA Chairman

**Approval Date:** 22.5.08

Commonwealth Minister for the Environment and Water Resources Approval for the Approved Development (EPBC Reference: 2003/1294).

Minister for the Environment and Water Resources

# APPROVAL

## Gorgon Gas Development (EPBC Reference: 2003/1294)

This decision is made under Section 133 of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

### Proposed action

| | |
|---|---|
| **Person to whom the approval is granted** | Chevron Australia Pty Ltd |
| **Proposed action** | To construct and operate facilities associated with the production and transport of gas from the Gorgon gas fields to Barrow Island, the construction and operation of a gas processing facility on the eastern side of Barrow Island, treatment and disposal of waste products including possible sequestration of carbon dioxide, the shipping of gas products from Barrow Island, and the construction and operation of infrastructure associated with processing and transport of gas including pipelines from Barrow Island to the mainland of Western Australia, and all associated activities comprising the Gorgon Development. |

### Approval decision

| | |
|---|---|
| **Relevant controlling provisions** | The approval has effect for:<br>• Listed threatened species and communities (sections 18 & 18A)<br>• Listed migratory species (sections 20 & 20A)<br>• Commonwealth marine areas (section 23 & 24A) |
| **Conditions of approval** | This approval is subject to the conditions specified below. |
| **Expiry date of approval** | This approval has effect until 1 January 2070. |

### Person authorised to make decision

| | |
|---|---|
| **Name and position** | MALCOLM BLIGH TURNBULL<br>Minister for the Environment and Water Resources |
| **Signature** | |
| **Date of decision** | 3.10.2007 |

**Conditions attached to the approval**

1) A terrestrial and marine quarantine management plan or system must be developed by the person taking the Action. The plan or system must take into account the advice of the Department of the Environment and Water Resources (DEW), the Department of the Environment and Conservation (DEC), the Department of Agriculture and Food (DAF) the Department of Fisheries (DoF) and the Quarantine Expert Panel (QEP).

   a) The aim of the quarantine management plan or system is to prevent the introduction of Non-indigenous Terrestrial Species or Marine Pests.

   b) The terrestrial and marine quarantine management plan or system must be provided to the Minister for approval prior to commencement of construction of any Terrestrial or Marine Facilities.

   c) This plan or system shall provide a description of proposed barriers, as well as monitoring, control, mitigation and eradication programs in the event that a Non-indigenous Terrestrial Species is detected.

   d) Once approved by the Minister, the plan or system must be implemented.

2) The person taking the Action will consult with DEW concerning the membership of the QEP.

3) Prior to commencement of construction of any Terrestrial Facilities, a baseline state and environmental monitoring program must be developed and approved by the Minister.

   a) The monitoring program shall:

      i) be developed in consultation with DEW and DEC;

      ii) determine those EPBC Act listed threatened fauna and flora species and their habitat at risk of Significant Impact;

      iii) identify reference sites outside of the Terrestrial Disturbance Footprint; and

      iv) establish statistically valid ecological monitoring to enable detection of Significant Impact to the terrestrial species and their habitat monitored under the program.

   b) The program will establish criteria for measuring impacts and protocols for ongoing reporting to DEW.

      i) Protocols shall include a requirement to report within 48 hours of detecting any Significant Impacts to species or habitat covered by the scope of the monitoring program.

   c) The approved monitoring program must be implemented.

4) If the monitoring program referred to in Condition 3 indicates that remedial action is required to minimise Significant Impacts then Practicable measures shall be developed to reduce or offset impacts.

   a) Such measures must:

      i) be developed within three months of the need for remedial action being identified;

      ii) be developed in consultation with DEW and DEC;

      iii) be provided to the Minister for approval; and

      iv) once approved, must be implemented.

5) Prior to commencement of construction of any Marine Facilities, a coastal and marine baseline state survey plan and a coastal and marine environmental monitoring program must be developed and approved by the Minister. The program must be developed in consultation with DEW.

   a) The aim of the survey plan is:

      i) to determine those EPBC Act listed threatened fauna species and listed migratory species, and their habitat, that are at risk of Significant Impact which will be monitored under the program; and

      ii) to identify monitoring reference sites independent of Action-attributable impacts.

   b) The monitoring program will:

      i) establish statistically valid ecological monitoring to detect Significant Impact;

      ii) establish criteria for measuring Significant Impacts; and

      iii) establish protocols for ongoing reporting to DEW, including a requirement to report within 48 hours of detecting any Significant Impacts to species or habitat covered by the scope of the monitoring program.

   c) The approved monitoring program must be implemented.

6) If the monitoring program referred to in Condition 5 indicates that remedial action is required to minimise Significant Impacts, then Practicable measures shall be developed to reduce or offset impacts. Such measures must:

      i) be developed within three months of the need for remedial action being identified;

      ii) be developed in consultation with DEW and CDEEP;

      iii) be provided to the Minister for approval; and

      iv) once approved, must be implemented

7) Prior to commencement of construction, a construction environment management plan or plans for the Terrestrial and Marine Facilities must be developed. The plan must take account of the advice of DEW and the relevant Western Australian government agencies particular to the relevant Action element, and be provided to the Minister for approval.

   a) The aim of the plan is to minimise risk of Significant Impacts to EPBC Act listed threatened species and ecological communities, listed migratory species and Commonwealth marine areas during construction of that specific Facility.

   b) The plan shall establish Practicable measures for;

      i) Management of EPBC Act listed fauna and flora in Terrestrial and Marine Disturbance Footprints;

      ii) Strict controls on the construction of onshore pipelay trenches and interaction of vehicles and staff with fauna;

      iii) Dredging and spoil disposal management and monitoring, including the provision for:

         (1) Use of management measures to minimise turtle injuries or fatalities in consultation with the Marine Turtle Expert Panel (MTEP) and the CDEEP;

(2) Modifying lighting on dredging equipment to minimise impacts on turtles or hatchlings;

iv) Fire control and management;

v) Solid and liquid waste management;

vi) Air quality management;

vii) Groundwater management;

viii) Coastal stability;

ix) Noise management;

x) Offshore Gas Pipeline installation management;

xi) Management measures to be applied if blasting is required;

c) Once approved by the Minister, the plan for the specific Facility must be implemented.

8) An operations environment management plan for any of the Terrestrial and Marine Facilities must be approved by the Minister prior to commencement of operations of the specific Facility.

a) The aim of the plan is to minimise risk of Significant Impacts to EPBC Act listed threatened species and ecological communities, and listed migratory fauna and their habitats, and the Commonwealth marine area during operation of the Terrestrial and Marine Facilities.

b) The plan shall establish Practicable measures for:

i) Protection of EPBC Act listed threatened species and ecological communities and listed migratory fauna in the Terrestrial and Marine Disturbance Footprints;

ii) Management of lights or glow, that may cause significant impact to nesting turtles or hatchlings;

iii) Air quality management;

iv) Solid and Liquid waste management;

v) Rehabilitation in relation to EPBC Act listed threatened terrestrial fauna and flora habitat;

vi) Groundwater management;

vii) Post-dredging and spoil disposal surveys to detect and report Significant Impacts to EPBC Act listed threatened marine species and migratory species, and to the identified marine habitat of the EPBC Act listed threatened marine fauna. These surveys are to be conducted annually for at least three years post-dredging and the results reported to DEW.

viii) Fire control; and

ix) Noise management.

c) Once approved by the Minister, the plan for the specific Facility must be implemented.

9) A Long-Term Marine Turtle Management Plan, including a turtle monitoring program, shall be prepared in consultation with MTEP prior to the commencement of construction of any one of the Terrestrial or Marine Facilities to be located on the east coast of Barrow Island.

   a) The aim of the plan is to minimise risk of Significant Impacts to the marine turtle population.

   b) The plan shall be updated and implemented throughout the life of the Action.

   c) DEW shall be consulted and may nominate a suitable marine turtle expert to participate in the MTEP.

   d) The plan shall:

      i) Establish baseline information on the populations of the marine turtle species that utilise the beaches adjacent to the Terrestrial and Marine Facilities on the east coast of Barrow Island;

      ii) Establish a monitoring program to measure and detect Significant Impact on the Flatback turtle (*Natator depressus*) population (such as adverse changes in the distribution of Flatback turtle nesting, hatchling survivorship, and orientation of adult and hatchling turtles within beaches adjacent to the Marine Facilities on the east coast of Barrow Island);

      iii) Establish a monitoring program to detect Significant Impacts to the beaches adjacent to the Marine Facilities on the east coast of Barrow Island;

      iv) Identify the significant Action-attributable stressors with the potential to cause Significant Impact on the population viability of marine turtle species that utilise the beaches adjacent to the Terrestrial and Marine Facilities on the east coast of Barrow Island;

      v) Define the scope of studies aimed at understanding the ecology of Flatback turtles (including foraging habitats) that utilise the beaches adjacent to the Terrestrial and Marine Facilities on the east coast of Barrow Island;

      vi) Specify design features, management measures and operating controls to minimise adverse impacts to the marine turtle populations that utilise the beaches adjacent to the Terrestrial and Marine Facilities on the east coast of Barrow Island;

      vii) Identify potential response and mitigation measures in the event that monitoring detects Action-attributable change in the abundance, species diversity, geographic distribution, behaviour patterns breeding success, predation levels or demographics that is likely to cause Significant Impact to the population viability of marine turtles species that frequent and rely on the beaches on the east coast of Barrow Island or its surrounding waters for recruitment.

   e) The Long-Term Marine Turtle Management Plan (including the turtle monitoring program) must be approved by the Minister prior to the commencement of construction of any one of the Terrestrial or Marine Facilities to be located on the east coast of Barrow Island.

   f) Once approved by the Minister, the Plan must be implemented.

10) A carbon dioxide injection monitoring program that is able to indicate unexpected carbon dioxide migration must be prepared and implemented.

   a) Within three months of the monitoring program showing a significant increase in the risk of carbon dioxide leakage into the environment inhabited by the Blind Gudgeon (*Milyeringa verita*), a survey focused on an assessment of the habitat of the Blind Gudgeon shall be carried out and a plan for Practicable actions proposed to avoid or mitigate the risk of Significant Impact to the environment inhabited by the Blind Gudgeon developed.

      i) This plan shall be provided to the Minister for approval. Once approved by the Minister, the plan must be implemented.

11) A decommissioning and closure plan (covering both Marine and Terrestrial Facilities) must be prepared for the Minister's approval at least one year prior to the anticipated date of decommissioning. Once approved by the Minister, the plan must be implemented.

12) An Environmental Performance Report shall be submitted annually to DEW. This report shall contain the results of and the state of implementation of the:

   a) terrestrial and marine quarantine management plan or system (Condition 1)

   b) Terrestrial Facilities baseline state and environmental monitoring program (Condition 3)

   c) Marine Facilities coastal and marine baseline state survey plan and coastal and marine environmental monitoring program (Condition 5);

   d) construction environment management plan/or plans for Terrestrial and Marine Facilities (Condition 7);

   e) operations environment management plan/or plans for Terrestrial and Marine Facilities (Condition 8);

   f) Long-term Marine Turtle Management Plan and turtle monitoring program (Condition 9);

   g) carbon dioxide injection monitoring program (Condition 10); and

   h) any remedial action or offset implementation as required (Conditions 4 and 6)

   The first Environment Performance Report shall be submitted at the same time as the first Environment Performance Report is submitted to the WA Government. It must be submitted within 15 months from the date of approval of the Action and each subsequent report 12 months from the date of the previous report.

13) If the person taking the Action wishes to carry out any activity otherwise than in accordance with a plan, program or system referred to in this Approval, the person taking the Action may submit for the Minister's approval a revised version of any such plan, program or system. If the Minister approves a revised plan, program or system so submitted, the person taking the Action must implement that plan, program or system instead of the plan, program or system as originally approved.

14) If the Minister believes that it is necessary or desirable for the better protection of the environment to do so, the Minister may request the person taking the Action to make specified revisions to a plan, program or system approved pursuant to the Conditions and to submit the revised plan, program or system for the Minister's approval. The person taking the Action must comply with any such request. If the Minister approves a revised plan, program or system pursuant to this condition, the person taking the Action must implement that plan, program or system instead of the plan, program or system as originally approved.

15) Within five years of the date of this approval, the person taking the Action must, to the satisfaction of DEW, provide evidence that the Action has been Substantially Commenced. If DEW is not satisfied that there has been substantial commencement of the Action, the Action must not thereafter be commenced without the prior approval of the Minister.

16) Where a plan, program or system is required by these conditions prior to construction or operation of any Terrestrial or Marine Facility, it will be sufficient for the person taking the Action to submit and have approved that component of the plan, program or system relevant to that Facility before commencing construction or operation of that Facility.

**Definitions**

CDEEP – Construction Dredging Environmental Expert Panel established in accordance with condition 19 of Ministerial Statement 748 issued under the *Environmental Protection Act 1986 (WA).*

Construction - any action related construction and commissioning activities within the Terrestrial and Marine Disturbance Footprints, excluding investigatory works such as but not limited to geotechnical, geophysical, biological and cultural heritage surveys, baseline monitoring surveys and technology trials.

DAF – Western Australian Department of Agriculture and Food

DEC – Western Australian Department of Conservation and the Environment

DEW – Commonwealth Department of the Environment and Water Resources.

DoF - Western Australian Department of Fisheries.

DPI – Western Australian Department of Planning and Infrastructure.

EPBC Act - The Environment Protection and Biodiversity Conservation Act 1999

LNG – Liquefied natural gas

Marine Disturbance Footprint – means the area of the seabed to be disturbed by construction or operations activities associated with the Marine Facilities (excepting that area of the seabed to be disturbed by the generation of turbidity and sedimentation from dredging and dredge spoil disposal) as determined in accordance with condition 14 of Ministerial Statement 748 issued under the *Environmental Protection Act 1986 (WA).*

Marine Facilities - means:

i. Marine Off-loading Facility (MOF);
ii. LNG Jetty;
iii. Dredge Spoil Disposal Ground;
iv. Offshore Feed-gas Pipeline System and marine component of the shore crossing; and
v. Domestic Gas Pipeline.

Marine Pests – Species other than the native species known or those likely to occur in the waters of the Indo-West Pacific region and the Pilbara Offshore (PIO) marine bioregion in Interim Marine and Coastal Regionalisation for Australia: An Ecosystem Based Classification for Marine and Coastal Environments (IMCRA, 1997), of which Barrow Island is a part, that do or may threaten biodiversity in the Pilbara Offshore (PIO) marine bioregion. As a minimum, the National Introduced Pest Information System Database (NIMPIS, Dept Environment and Water Resources, Commonwealth Government), National Priority Pests listed in the document National Priority Pests, Part II, Ranking of Australian Marine Pests (CSIRO Marine Research, 2005) will guide the interpretation of this definition. Additional species may be added on the advice of experts from the WA Department of Fisheries and the Quarantine Expert Panel.

MTEP – means the Marine Turtle Expert Panel established in accordance with condition 15 of Ministerial Statement 748 issued under the *Environmental Protection Act 1986 (WA).*

Minister – Commonwealth Minister for the Environment and Water Resources

Non-indigenous Terrestrial Species – any species of plant, animal or micro-organism not native to Barrow Island. (Native – species that are native to (naturally occurring in) a region) (Reference: State of the Environment Advisory Council (1996). Australia: State of the Environment 1996).

Offset - An action taken outside of a development site that compensates for the impacts of that development - including direct, indirect or consequential impacts.

Practicable – means reasonably practicable having regard to, among other things local conditions and circumstances (including costs) and to the current state of technical knowledge.

QEP – Quarantine Expert Panel established in accordance with condition 9 of Ministerial Statement 748 issued under the *Environmental Protection Act 1986 (WA).*

Significant Impact(s) – an impact that is important, notable or of consequence having regard to its context or intensity.

Substantially Commenced - physical construction activities for, and progress of, an important or essential element or elements of the Action.

Terrestrial Disturbance Footprint - means the area to be disturbed by construction or operations activities associated with the terrestrial facilities as determined in accordance with condition 6 of Ministerial Statement 748 issued under the *Environmental Protection Act 1986 (WA).*

Terrestrial Facilities – means:

i. Gas Treatment Plant;
ii. Carbon Dioxide Injection System;
iii. Associated Terrestrial Infrastructure;
iv. Areas impacted for seismic data acquisition; and
v. Onshore Feed-gas Pipeline System and terrestrial component of the Shore Crossing.

# APPENDIX B

## Summary Of The EPA's Key Findings, Chevron Australia's Management Obligations And The Ministerial Conditions Relevant To The Revised Proposal

| | Key EPA Assessment Findings (Bulletin 1221) | Proponent Management Obligations | Relevant Ministerial Conditions (Statement No. 748) - Performance Objectives and Targets [1] | Conditions Relevant to Revised Proposal |
|---|---|---|---|---|
| 1 | **Flatback Turtles**<br><br>The EPA concluded that the risk of significant environmental impacts to the Barrow Island Flatback turtle population is unacceptably high. [3]<br><br>Risks identified by the EPA included: Significance of Barrow Island for turtles; Light pollution; Alteration of beach profiles; Direct impacts from vessels; Pipelines; and Dredging. [3] | North West Shelf Flatback Turtle Conservation Program ($32.5 M/30 yrs) [1]<br><br>North West Shelf Flatback Turtle Intervention Program [1]<br><br>Enforced boat speed limits [2]<br><br>Pre-dredge trawling [2]<br><br>Avoid turtle nesting period during maintenance dredging [2]<br><br>Light Management [2]<br><br>Turtle watches/monitoring during dredging [2] | **15. Marine Turtle Expert Panel** - To develop and implement the Long Term Marine Turtle Management Plan; Proposal-specific turtle studies; Monitoring program design; Advice to the Proponent and the Minister. | **15. Marine Turtle Expert Panel** |
| | | | **16. Long Term Marine Turtle Management Plan**<br>To address the long-term management of the marine turtle species that utilise the beaches and surrounding waters on the east coast of Barrow Island adjacent to the east coast facilities;<br>Establish baseline information on the population of turtles that utilise the beaches on the east coast of Barrow Island adjacent to the east coast facilities;<br>Establish a monitoring program to measure and detect changes to the flatback turtle population;<br>Specify design features, management measures and operating controls to avoid adverse impacts to the marine turtle population. | **16. Long Term Marine Turtle Management Plan** |
| | | | **17. Marine Facilities Construction Environmental Management Plan** - To reduce the impacts from the construction of the marine facilities as far as practicable; To ensure that construction of the marine facilities does not cause Material or Serious Environmental Harm outside the Marine Disturbance Footprint (except from the generation of turbidity and sedimentation from dredging). | **17. Marine Facilities Construction Environmental Management Plan** |
| | | | **20. Dredge and Spoil Disposal Management and Monitoring Plan** - To ensure that the Limits of Environmental Impacts specified in Condition 18.2 Table 1 (below) are not exceeded due to the impacts of the dredging or spoil disposal activities associated with the facilities listed in Condition 17.2.<br><br>**Zone** — **Limits of Acceptable Change**<br>High Impact — No limit<br>Moderate Impact — 30% Average Net Mortality of Porites<br>Influence — No detectable net mortality of coral | **20. Dredge and Spoil Disposal Management and Monitoring Plan** |
| 2 | **Dredging**<br><br>A key issue raised by the EPA related to the level of confidence of the prediction of impacts; and a lack of understanding of the cause-effect pathways between turbidity generated by dredging and the impacts on marine habitats, biota and ecological processes. [3] | Government Auditing Costs ($2.5M/2yrs) [1]<br><br>Flexible, adaptive Dredging Strategy to allow movement of the dredge between the MOF and LNG channel as needed to mitigate turbidity at either location [2]<br><br>Commitment to not exceed 22 ha permanent loss of coral assemblages within High and Moderate Zones of Impact [1] | **17. Marine Facilities Construction Environmental Management Plan** - To reduce the impacts from the construction of the marine facilities as far as practicable; To ensure that construction of the marine facilities does not cause Material or Serious Environmental Harm outside the Marine Disturbance Footprint (except from the generation of turbidity and sedimentation from dredging). | **17. Marine Facilities Construction Environmental Management Plan** |
| | | | **19. Construction Dredging Environmental Expert Panel** - To develop and implement the Dredge and Spoil Disposal Management and Monitoring Plan; Interpretation of results of monitoring data acquired during dredging; Advice regarding the proponent's proposed water quality criteria representing the relationship between water quality and coral health. | **19. Construction Dredging Environmental Expert Panel** |
| | | | **20. Dredge and Spoil Disposal Management and Monitoring Plan** - To ensure that the Limits of Environmental Impacts specified in Condition 18.2 Table 1 are not exceeded due to the impacts of the dredging or spoil disposal activities associated with the facilities listed in Condition 17.2. | **20. Dredge and Spoil Disposal Management and Monitoring Plan** |
| | | | **21. Management Triggers** - To establish initial water quality criteria that represent the link between water quality and coral health; Commence coral monitoring once these criteria are exceeded; Three predetermined 'levels' (1, 2 and 3) of coral health management triggers apply to the dredging and dredge spoil disposal activities associated with works for the facilities listed in Condition 17.2 which will require the Proponent to adopt the actions specified in Conditions 21.6, 21.7, 21.8. 21.9 and 21.10.<br>The levels apply to three Zones of Impact (High, Moderate and Influence) and specify that:<br>- Within the High Impact Zone no management triggers apply (i.e 100% mortalities of *Porites* permitted);<br>- Within the Moderate Impact Zone, Level 1,2 and 3 triggers are 15% (or 50% Mortality of *Porites* at any site), 25% and 30% Average Net Mortality of *Porites* respectively;<br>- Within the Influence Zone, the respective triggers are: detectable adverse change in health of coral, 10% coral bleaching; and Detectable net mortality of coral.<br>Analysis of coral monitoring data from each site within 72 hours of sampling. | **21. Management Triggers** |
| 3 | **Introduced Non-Indigenous Organisms**<br><br>The EPA identified introduced invasive organisms as the most significant potential hazard the Project posed to the terrestrial flora, fauna and vegetation values of Barrow Island. [3] | Threatened Species Translocation and Reintroduction Program ($10M/12 yrs) [1]<br><br>Eradication of Non-Indigenous Species (QMS + $10M fund) [1] | **9. Quarantine Expert Panel -** To develop and implement the Terrestrial and marine Quarantine Management System (QMS); Prevent the introduction of Non-indigenous Terrestrial and Marine Pests to Barrow Island through all Proposal attributable introduction pathways;<br>Detect the presence of introduced species and detect environmental change caused by their presence;<br>Control and eradication measures if introduced species are detected; Improvements to and auditing the effectiveness of the QMS;<br>Biological baselines and surveys conducted for quarantine management;<br>Source of Non-indigenous terrestrial Species and Marine Pests;<br>Review and recommend quarantine studies;<br>Any other Proposal-related quarantine matters requested by the Proponent of the Minister. | **9. Quarantine Expert Panel** |
| | | | **10. Terrestrial and Marine Quarantine Management System** - To prevent the introduction of Non-indigenous Terrestrial Species and Marine Pests; To detect Non-indigenous Terrestrial Species (including weed introduction and/or proliferation ) and Marine Pests; To control and, unless otherwise determined by the Minister, eradicate detected Non-indigenous Terrestrial Species (including weeds) and Marine Pests; and Mitigate adverse impacts of any control and eradication actions taken against detected Non-indigenous Terrestrial Species (including weeds) and Marine Pests. | **10. Terrestrial and Marine Quarantine Management System** |

| | Key EPA Assessment Findings (Bulletin 1221) | Proponent Management Obligations | Relevant Ministerial Conditions (Statement No. 748) - Performance Objectives and Targets [1] | Conditions Relevant to Revised Proposal |
|---|---|---|---|---|
| 4 | **Subterranean Fauna and Short Range Endemics**<br><br>The EPA considered there to be an unacceptable risk of extinction of some species if certain species that were identified within the Gas Treatment Plant site are not found elsewhere.[3] | Additional surveys and studies commissioned to better understand the status and wider distribution of subterranean taxa both within and external to the Gas Treatment Plant footprint.<br><br>The additional surveys found that fewer subterranean taxa are restricted to the Gas Treatment Plant footprint than previously thought.<br><br>At the time of the Draft EIS/ ERMP, 8 subterranean taxa were found only within the Gas Treatment Plant footprint. Additional surveys found all but 2 of these 8 taxa elsewhere on Barrow Island. As a result of the surveys an additional taxa (Thysanura) was also added to the list, taking the current total of subterranean taxa thought to be restricted to the Gas Treatment Plant footprint to 3 taxa, namely Bathynellacea, Amphipoda and Thysanura. A further survey is currently underway, the findings of which will better our understanding of the status and distribution of these taxa. | **6. Terrestrial and Subterranean Baseline State and Environmental Impact Report** - To define and map the pre-development baseline state for the ecological elements within the areas that are expected to, or may be at risk of Material or Serious Environmental Harm due to any works associated with the terrestrial facilities listed in Condition 6.3;<br>Define and map the ecological elements within the Terrestrial Disturbance Footprint; Define and map the ecological elements which are at risk of Material or Serious Environmental Harm due to construction or operation of the terrestrial facilities listed in condition 6.3;<br>Define and map the ecological elements of reference sites to be used as part of Condition 8, which are not at risk of Material or Serious Environmental Harm due to construction or operation of the terrestrial facilities listed in condition 6.3 | **6. Terrestrial and Subterranean Baseline State and Environmental Impact Report** |
| | | | **7. Terrestrial and Subterranean Environment Protection Plan** - To reduce the adverse impacts from the construction and operation of the Terrestrial Disturbance Footprint as far as practicable; and to ensure that construction and operation of the terrestrial facilities does not cause Material or Serious Environmental Harm outside and below the Terrestrial Disturbance Footprint. | **7. Terrestrial and Subterranean Environment Protection Plan** |
| | | | **8. Terrestrial and Subterranean Environment Monitoring Program** - to establish a statistically valid ecological monitoring program to detect any Material or Serious Environmental Harm to the ecological elements outside the Terrestrial Disturbance Footprint. | **8. Terrestrial and Subterranean Environment Monitoring Program** |
| | | Commitment to collecting baseline data on water levels and composition. | **11. Short Range Endemics and Subterranean Fauna Monitoring Plan** - for further survey and identification of those short range endemics and subterranean fauna species which have previously only been located on the Gas Treatment Plant site. | **11. Short Range Endemics and Subterranean Fauna Monitoring Plan** |
| 5 | **Greenhouse Gases**<br><br>The EPA considered that the project would not be environmentally acceptable it if did not include a scheme to inject a high percentage of the reservoir $CO_2$ or otherwise mitigate an equivalent amount of $CO_2$.[3] | Commitment for at least 80% of reservoir $CO_2$ removed to be injected [1] | **26. Reservoir Carbon Dioxide Injection System** - Must be capable of disposing by underground injection, 100% of the volume of reservoir $CO_2$ to be removed during routine gas processing operations on Barrow Island and that would be otherwise vented to the atmosphere; to ensure that calculated on a 5 year rolling average, at least 80% of reservoir $CO_2$ removed during routine gas processing operations on Barrow Island and that would be otherwise vented to the atmosphere is injected. | **26. Reservoir Carbon Dioxide Injection System** |
| | | | **27. Greenhouse Gas Abatement Program** - Ensure that the Gas Treatment Plant is designed and operated in a manner which achieves reductions in “greenhouse gas” emissions as far as practicable; Provide for ongoing “greenhouse gas” emissions reductions over time; Ensure that through the use of best practice, the total net “greenhouse gas” emissions and/or “greenhouse gas” emissions per unit of LNG produced from the project are minimised; and manage “greenhouse gas” emissions in accordance with the Framework Convention on Climate Change 1992, and consistent with the National Greenhouse Strategy. | **27. Greenhouse Gas Abatement Program** |
| | | | **28. Best Practice Pollution Abatement Control Design** - Demonstrates that the proposed works adopt best practice pollution control measures to minimise emissions from the Gas Treatment Plant; Sets out the base emission rates for major sources for the Gas Treatment Plant and the design emission targets; and addresses normal operations, shut down, start-up and equipment failure conditions. | **28. Best Practice Pollution Abatement Control Design** |
| | | | **29. Air Quality Management Plan** - Ensure air quality meets appropriate standards for human health in the workplace; and ensure air emissions from the Gas Treatment Plant operations do not pose a risk of Material or Serious Environmental Harm to the flora, vegetation communities, terrestrial fauna, and subterranean fauna of Barrow Island. | **29. Air Quality Management Plan** |
| | **General** | Net Conservation Benefits ($40M [indexed] in installments- pursuant to Clause 11 of Schedule 1 of the Barrow Island Act 2003) [1]<br><br>DEC Funding ($750k - $1M/yr) to provide accommodation and transport facilities and cover certain costs for a permanent DEC management presence on Barrow Island [1] | | |

[1] *Gorgon Gas Development: Barrow Island Nature Reserve* , *Statement that a Proposal may be Implemented (Pursuant to the Provisions and the Environmental Protection Act 1986), Statement No. 748* , Office of the Appeals Convenor, 6 September 2007 page 2, 3 & 4

[2] *Gorgon Project - Appeal on EPA Bulletin 1221,* Chevron Australia Pty Ltd, 19 June 2006, Page 7, 16

[3] *Report to the Minister for the Environment - Gorgon Gas Development, Barrow Island - Appeals Against Report and Recommendations of the Environmental Protection Authority* , Appeals Committee, November 2006

# APPENDIX C

## Risk Assessment Tables

# Summary of Aspects and Associated Environmental Factors

As presented in the Environmental Scoping Document (Chevron Australia 2008d)

| Aspect | Associated environmental factors | Preliminary risk-based analysis conclusion |
|---|---|---|
| **Aspects and associated environmental factors requiring further data acquisition and assessment in the PER** | | |
| Atmospheric emissions (other than dust) | Air quality and greenhouse gas emissions | The Revised Proposal may result in additional impacts to these environmental factors from the Approved Gorgon Gas Development.<br>This aspect and associated environmental factors will be subject to further data acquisition and assessment in the PER. |
| | Flora and vegetation | |
| | Soils and landform | |
| | Terrestrial fauna | |
| $CO_2$ migration or release to the surface or near-surface environment | Terrestrial fauna | The Revised Proposal is not anticipated to result in any additional impacts to these environmental factors from the Approved Gorgon Gas Development (based on continuing research into $CO_2$ behaviour within the Dupuy Reservoir).<br>There is likely to be community/public interest in this component of the development, and so this aspect and associated environmental factors will be subject to further assessment in the PER utilising existing data/information |
| | Subterranean fauna | |
| | Flora and vegetation | |
| | Soils and landform | |
| Physical disturbance of seabed | Marine primary producers | The Revised Proposal may result in additional impacts to these environmental factors from the Approved Gorgon Gas Development.<br>These aspects and associated environmental factors will be subject to further data acquisition and assessment in the PER. |
| | Physical environment – seabed (subtidal and intertidal) and foreshore) | |
| | Marine water quality | |
| Physical presence of infrastructure | Marine primary producers | |
| | Marine fauna | |
| | Physical marine environment (including intertidal environment) | |
| | Beach environment | |
| Physical interaction | Marine fauna | |
| **Aspects and associated environmental factors not requiring further data acquisition but will be addressed or analysed in the PER** | | |
| Vegetation clearing | Flora and vegetation | The Revised Proposal may result in some additional impacts to these environmental factors from the Approved Gorgon Gas Development, but these impacts are not likely to be significant.<br>There is likely to be community/public interest in vegetation clearing, and so this aspect and associated environmental factors will be further assessed in the PER utilising existing data/information. |
| | Terrestrial fauna | |
| Site disturbance/ excavation | Terrestrial fauna | The Revised Proposal may result in some additional and/or different impacts to these environmental factors from the Approved Gorgon Gas Development.<br>This aspect and associated environmental factors will be subject to further assessment in the PER utilising existing data/information. |
| | Subterranean fauna | |
| Fire | Flora and vegetation | |
| | Terrestrial fauna | |
| Liquid and solid waste disposal | Terrestrial fauna | |
| Spills and leaks | Soils and landform | The Revised Proposal may result in some additional impacts to these environmental factors from the Approved Gorgon Gas Development.<br>This aspect and associated environmental factors will be subject to further assessment in the PER utilising existing data/information. |
| | Surface water | |
| | Groundwater | |
| | Flora and vegetation | |
| | Terrestrial fauna | |
| | Subterranean fauna | |
| | Marine primary producers | |
| | Marine fauna | |
| | Water and sediment quality | |
| Dust emissions | Flora and vegetation | |
| | Terrestrial fauna | |
| | Air quality | |
| Physical presence of infrastructure | Terrestrial fauna | The Revised Proposal may result in some additional and/or different impacts to these environmental factors from the Approved Gorgon Gas Development.<br>This aspect and associated environmental factors will be subject to further assessment in the PER utilising existing data/information. |
| Physical interaction | Terrestrial fauna | |

| Aspect | Associated environmental factors | Preliminary risk-based analysis conclusion |
|---|---|---|
| Creation of shade | Terrestrial fauna | The Revised Proposal may result in some additional impacts to these environmental factors from the Approved Gorgon Gas Development.<br>This aspect and associated environmental factors will be subject to further assessment in the PER utilising existing data/information. |
| Hot and/or cold emissions | Terrestrial fauna | |
| Noise and vibration emissions | Terrestrial fauna | |
| | Subterranean fauna | |
| | Marine fauna | |
| Light emissions | Terrestrial fauna | The Revised Proposal may result in additional impacts to these environmental factors from the Approved Gorgon Gas Development.<br>This aspect and associated environmental factors will be subject to further assessment in the PER utilising existing data/information. |
| | Marine fauna | |
| Introduction and/or spread of non-indigenous species (quarantine) | Terrestrial fauna | The Revised Proposal may result in some additional impacts to these environmental factors from the Approved Gorgon Gas Development, but these impacts are not likely to be significant.<br>There is likely to be community/public interest in these environmental factors so will be further assessed in the PER utilising existing data/information. |
| | Flora and vegetation | |
| | Marine primary producers | |
| | Marine fauna | |
| Physical disturbance of seabed | Marine fauna | The Revised Proposal may result in some additional and/or different impacts to these environmental factors from the Approved Gorgon Gas Development.<br>This aspect and associated environmental factors will be subject to further assessment in the PER utilising existing data/information. |
| Atmospheric emissions | Water and sediment quality | The Revised Proposal is not anticipated to result in any additional impacts to this environmental factor from the Approved Gorgon Gas Development.<br>Given community interest in this aspect of the Development, this aspect and associated environmental factor will be subject to further assessment in the PER utilising existing data/information. |
| $CO_2$ migration or release to the marine environment | Water and sediment quality | |
| | Marine primary producers | |
| **Aspects and associated environmental factors not requiring further assessment in the PER** | | |
| Vegetation clearing | Soils and landform | The Revised Proposal may result in some additional and/or different impacts to this environmental factor from the Approved Gorgon Gas Development, but these impacts are not likely to be significant.<br>These aspects will be addressed under the Management Plans and systems required by the Conditions of Approval in Statement No. 748 and by other Conditions required under Commonwealth approval (EPBC Reference: 2003:1294).<br>These aspects and associated environmental factors will not be further assessed in the PER. |
| | Subterranean fauna | |
| Site disturbance/ excavation | Soils and landform | |
| | Surface water | |
| Runoff | Surface water | |
| | Subterranean fauna | |
| Liquid and solid waste disposal | Soils and landform | |
| | Surface water | |
| | Groundwater | |
| | Subterranean fauna | |
| | Flora and vegetation | |
| Physical presence of infrastructure | Surface water | |
| | Groundwater | |
| | Subterranean fauna | |

**Preliminary Environmental Risk Assessment**
**Receptor = Terrestrial Fauna (Not including short range endemics (SREs))**

Those impacts with a Medium – High preliminary environmental risk level (and highlighted green in the following table) are addressed further in the PER.

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Direct displacement or loss of individuals | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term because there will be Fauna handling procedures and Vegetation Clearing and Audit Procedures in place. |
| | Increased resource competition in adjacent areas | 2 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP |
| | Habitat fragmentation | 2 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised (representing a very small percentage of Barrow Island) and because there will be Vegetation Clearing and Audit Procedures, and a Fire Management Plan, in place to manage unplanned fires and unplanned clearing. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Site disturbance/ excavation | Entrapment in pipeline trenches and other open holes/pit excavated | 1 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP<br>Focus on management to prevent fauna from becoming entrapped and/or for inspections of trenches/pits |
| Fire | Loss of habitat | 2 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP<br>Fire management will be the focus of discussion (e.g. fire prevention and response measures) |
| | Injury of death of fauna | 2 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP<br>Fire management will be the focus of discussion (e.g. fire prevention and response measures) |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Fire | Maintenance of unnatural fire regime to protect infrastructure with consequent loss of habitat diversity | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised because there will be Vegetation Clearing and Audit Procedures, and a Fire Management Plan, in place to manage unplanned fires and unplanned clearing. |
| Liquid and solid waste disposal | Change in habitat composition | 5 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term because there will be a Solid and Liquid Waste Management Plan in place, and Remediation and response protocols to reduce infiltration of fluids into substrate. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Spills and leaks (acute/chronic/cumulative) | Smothering of, or metabolic effects on habitat and/or fauna | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures in place for early response to spills/leaks leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |
| | Metabolic effects on sensitive habitat and/or fauna | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures are in place for early response to metabolic effect-causing spills/leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Atmospheric emissions | Physiological effects from inhalation of pollutants | 5 | 5 | L | While emissions will increase under the Revised Proposal, levels will be well below levels required to have an affect to fauna.<br><br>Consequences deemed to be localised as there will be an air quality monitoring program established. |
| | Physiological effects from ingestion of pollutant that has deposited on vegetation or in water | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established. |
| | Direct metabolic effect from unplanned emissions of $H_2S$ or BTEX | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established. |
| | Asphyxiation from $CO_2$ inhalation in burrows or low lying areas | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an ecological monitoring program established to detect changes in the population of significant fauna near the construction site. There will also |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | be a monitoring program to detect $CO_2$ release from surface soils, and $CO_2$ in the groundwater. |
| Dust emissions | Physiological affects on fauna | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an ecological monitoring program established to detect changes in the population of significant fauna near the construction site. A dust monitoring program will also be established. |
| | Effects on vegetated habitats and forage plants (i.e. making them unsuitable for consumption) | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an ecological monitoring program established to detect changes in the population of significant flora near the construction site. A dust monitoring program will also be established. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Presence of infrastructure | Entrapment of fauna in pipeline trenches and other excavated holes/pits etc. | NA | | | |
| | Change in fauna behaviour/movement | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as fauna are known to become habituated to construction activities on Barrow island (active boodie warrens occur near facilities) |
| Physical interaction | Direct behavioural disturbance | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an ecological monitoring program established to detect changes in the population of significant fauna near the construction site. All personnel will also be inducted to educate them on fauna interactions. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Injury or fatality (i.e. road kill) | 1 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP Vehicle movement management will be the focus of discussion (e.g. restricting speed limits, times etc.) |
| | Possible obstruction of fauna movements | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term, particularly as fauna will habituate to presence of infrastructure for movement patterns. |
| Light emissions | Attraction of insects to light will increase the availability of food for adaptable birds and bats | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given lighting strategies will be in place, studies in progress for shielding boil off gas (BOG) flares, and an ecological monitoring program established to detect changes in the population of significant fauna near the construction site. |
| | Attractant for non-indigenous species | 3 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | Consequences deemed to be localised and short-term given establishment of the quarantine management system (QMS), and an ecological and quarantine monitoring and surveillance program established to detect changes in the population of significant fauna near the construction site. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Light emissions | Change in movement/behaviour of seabirds | 1 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP and any new information generated via the light emission study<br>Light management will be focus of discussion (e.g. the lighting strategy that has been developed)<br>Will need to utilise information being prepared via the light emissions study |
| | Changes in community structures in areas affected by light spill | 3 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised given lighting strategies will be in place, studies in progress for shielding boil off gas (BOG) flares, and an ecological monitoring program established to detect changes in the population of significant fauna near the construction site. |
| Creation of shade | Congregation of fauna in areas of shade | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised given an ecological monitoring program established to detect changes in the population of |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | significant fauna near the construction site. |
| Creation of shade (cont) | Injury or fatality of sheltering fauna under machinery | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given past records of fauna injury near machinery on island is low (and acts at the individual scale of impact) |
| | Increase in range of shade dependent fauna | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised given certain areas will have fauna exclusion fences, and an ecological monitoring program will be established to detect changes in the population of significant fauna near the construction site. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Asphyxiation of fauna in low-lying areas (e.g. fauna burrows) | 4 | 2 | M | Will need to liaise with $CO_2$ Advisor regarding the risk associated with this aspect<br>Need to discuss the likelihood of this occurring with $CO_2$ Advisor.<br>$CO_2$ Advisor is undertaking an assessment of the risk associated with this aspect - this info will need to be utilised for the terrestrial fauna assessment |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Hot and/or cold emissions | Injury or death to avifauna flying through heat plume from flare or air coolers | 1 | 3 | H | Ospreys nesting on top of flares<br>Use existing data and assessment undertaken in EIS/ERMP |
| | Attraction of insects and reptiles to heat in cold weather | 2 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP |
| | Attraction of fauna to condensate under feed gas pipeline and/or cryogenic/cold equipment at gas treatment plant | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given certain areas will have fauna exclusion fences, and an ecological monitoring program will be established to detect changes in the population of significant fauna near the construction site. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Noise and vibration emissions | Physiological impacts to fauna due to air blast overpressure | 4 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given an ecological monitoring program will be established to detect changes in the population of significant fauna near the construction site. |
| | Behavioural changes | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised as fauna are known to become habituated to construction noise on Barrow island (active boodie warrens occur near facilities) |
| | Displacement of fauna in vicinity of blasting caprock | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Site excavation will be managed to maximise mechanical soil and rock removal and minimise the need for high intensity blasting.<br>Directional blasting will be used to reduce total blasting requirements and to minimise disturbance beyond footprint area. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Direct loss of habitat from collapse (e.g. bettong warren, termite mounds) | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development given that boodies within the construction area will be relocated/ translocated from the site, no new warrens are known from the additional clearing area and that vegetation clearing procedures will manage clearing outside the construction area. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Introduction or spreading of exotic taxa (quarantine) | Introduction and/or spread of non-indigenous species | 4 | 2 | M | Will be discussed in section 8 of the PER |
| | Loss of native species due to competition from introduced species | 4 | 2 | M | Will be discussed in section 8 of the PER |
| | Change in taxon dominance | 4 | 2 | M | Will be discussed in section 8 of the PER |

## Receptor = Terrestrial Fauna (SREs)

Those impacts with a medium – high preliminary environmental risk (and highlighted green in the following table) are addressed further in the PER.

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Direct displacement or loss of individuals | 1 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP |
| | Increased resource competition in adjacent areas | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised because there will be Vegetation Clearing and Audit Procedures, and a Fire Management Plan, in place to manage unplanned fires and unplanned clearing. |
| | Habitat fragmentation | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised because there will be Vegetation Clearing and Audit Procedures, and a Fire Management Plan, in place to manage unplanned fires and unplanned clearing. |
| Site disturbance/ excavation | Entrapment in pipeline trenches and other open holes/pit excavated | 1 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Fire | Loss of habitat | 2 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP<br>Fire management will be the focus of discussion |
| | Injury of death of fauna | 2 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP<br>Fire management will be the focus of discussion |
| | Maintenance of unnatural fire regime to protect infrastructure with consequent loss of habitat diversity | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised because there will be Vegetation Clearing and Audit Procedures, and a Fire Management Plan, in place to manage unplanned fires and unplanned clearing. |
| Liquid and solid waste disposal | Change in habitat composition | 5 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term because there will be a Solid and Liquid Waste Management Plan in place, and Remediation and response protocols to reduce infiltration of fluids into substrate. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Spills and leaks (acute/chronic/cumulative) | Smothering or metabolic effects on habitat and/or fauna | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures in place for early response to spills/leaks leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |
| | Metabolic effects on sensitive habitat and/or fauna | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures are in place for early response to metabolic effect-causing spills/leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Atmospheric emissions | Physiological effects from inhalation of pollutants | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established. |
| | Physiological effects from ingestion of pollutant that has deposited on vegetation or in water | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established. |
| | Direct metabolic effect from unplanned emissions of $H_2S$ or BTEX | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established. |
| | Asphyxiation from $CO_2$ inhalation in burrows or low lying areas | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established site. There will also be a monitoring program to detect $CO_2$ release from surface soils, and $dCO_2$ in the groundwater. |
| Dust emissions | Physiological affects on fauna | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program (including dust monitoring). |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Effects on vegetated habitats and forage plants (i.e. making them unsuitable for consumption) | 5 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program (including dust monitoring), and an ecological monitoring program for significant vegetation. |
| Presence of infrastructure | Entrapment of fauna in pipeline trenches and other excavated holes/pits etc. | | | | This impact is covered above so is not required here |
| | Change in fauna behaviour/movement | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as fauna are known to become habituated to construction activities on Barrow island (active boodie warrens occur near facilities). Impacts to SRE are expected to be les than larger terrestrial vertebrates. |
| Physical interaction | Direct behavioural disturbance | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as Impacts to SRE are expected to be les than larger terrestrial vertebrates. All personnel will also be inducted to educate them on fauna interactions. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Injury or fatality (i.e. road kill) | 1 | 4 | M | Use existing data and assessment in EIS/ERMP |
| | Possible obstruction of fauna movements | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term, particularly as SRE are expected to habituate to presence of infrastructure for movement patterns. |
| Light emissions | Attraction of insects to light will increase the availability of food for adaptable birds and bats | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given lighting strategies will be in place, studies in progress for shielding boil off gas (BOG) flares, and an ecological monitoring program established to detect changes in the population of significant fauna near the construction site. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Attractant for non-indigenous species | 3 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given establishment of the QMS, and an ecological and quarantine monitoring and surveillance program established to detect changes in the population of significant fauna near the construction site. |
| | Change in movement/ behaviour of seabirds | | | | |
| | Changes in community structures in areas affected by light spill | 3 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given lighting strategies will be in place, studies in progress for shielding boil off gas (BOG) flares, and an ecological monitoring program established to detect changes in the population of significant fauna near the construction site. |
| Creation of shade | Congregation of fauna in areas of shade | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given an ecological monitoring program established to detect changes in the population of significant terrestrial fauna near the construction site. SRE impacts anticipated to be less than larger terrestrial fauna. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Injury or fatality of sheltering fauna under machinery | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given all SRE on Barrow Island are unlikely to be affected by machinery at a population level. |
| | Increase in range of shade dependent fauna | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given all SRE on Barrow Island are unlikely to be affected by machinery at a population level. |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Asphyxiation of fauna in low-lying areas (e.g. fauna burrows) | 4 | 2 | M | Will need to liaise with $CO_2$ Advisor regarding the risk associated with this aspect<br>Need to discuss the likelihood of this occurring with $CO_2$ Advisor<br>$CO_2$ Advisor is undertaking an assessment of the risk associated with this aspect - this info will need to be utilised for the terrestrial fauna assessment |
| Hot and/or cold emissions | Injury or death to avifauna flying through heat plume from flare or air coolers | | | | |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Attraction of insects and reptiles to heat in cold weather | 2 | 4 | M | Use existing data and assessment in EIS/ERMP |
| | Attraction of fauna to condensate under feed gas pipeline and/or cryogenic/cold equipment at gas treatment plant | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given SRE on Barrow Island are unlikely to be affected by machinery at a population level. |
| Noise and vibration emissions | Physiological impacts to fauna due to air blast overpressure | 4 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as per larger terrestrial fauna. |
| | Behavioural changes | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences to SRE deemed to be localised and short-term as larger terrestrial fauna are known to become habituated to construction noise on Barrow island (active boodie warrens occur near facilities) |
| | Displacement of fauna in vicinity of blasting caprock | 1 | 5 | L | Site excavation will be managed to maximise mechanical soil and rock removal and minimise the need for high intensity blasting. Directional blasting will be used to reduce total blasting requirements and to minimise disturbance beyond footprint area. |
| | Direct loss of habitat from collapse (e.g. bettong warren, termite mounds) | 1 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development given that termite mounds will only be impacted within the construction area, and |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | that vegetation clearing procedures will manage clearing outside the construction area. |
| Introduction or spreading of exotic taxa (quarantine) | Introduction and/or spread of non-indigenous species | 4 | 2 | M | Will be discussed in section 8 of the PER |
| | Loss of native species due to competition from introduced species | 4 | 2 | M | Will be discussed in section 8 of the PER |
| | Change in taxon dominance | 4 | 2 | M | Will be discussed in section 8 of the PER |

## Receptor = Subterranean Fauna

Those impacts with a medium – high preliminary environmental risk (and highlighted green in the following table) are addressed further in the PER.

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Removal of organic input (energy) | 1 | 3 | H | Use existing data and assessment undertaken in the EIS/ERMP |
| Site disturbance/ excavation | Direct loss of troglofauna habitat within gas treatment plant footprint (e.g. from excavation, blasting and installation of piles) | 1 | 3 | H | Use existing data and assessment undertaken in the EIS/ERMP |
| Runoff | Sedimentation of aquifer leading to localised loss of stygofauna (Question: validity of this concern to be checked with subject matter expert) | 2 | 5 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures in place for surface water management |
| Liquid and solid waste disposal | Contamination of subterranean habitats | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures in place for early response to spills/leaks leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Nutrient loading of subterranean habitats | 3 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP |
| Spills and leaks (acute/chronic/cumulative) | Contamination of subterranean habitats | 4 | 4 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures are in place for early response to spills/leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |
| | Metabolic effects on subterranean habitat and/or stygofauna | 3 | 4 | M | Use existing data and assessment undertaken in the EIS/ERMP<br>Spill prevention and response will be focus of discussion |
| Presence of infrastructure | Reduced groundwater recharge under gas treatment plant affecting subterranean humidity and free water | 1 | 3 | H | Use existing data and assessment undertaken in the EIS/ERMP |
| Presence of infrastructure | Loss of stygofauna and troglofauna | 1 | 2 | H | Use existing data and assessment undertaken in the EIS/ERMP |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Acidification of groundwater with potential loss of stygofauna | 4 | 2 | M | Will need to liaise with $CO_2$ Advisor regarding the risk associated with this aspect<br>$CO_2$ Advisor is undertaking an assessment of the risk associated with this aspect - this info will need to be utilised for the terrestrial fauna assessment |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Asphyxiation of troglofauna from settlement of $CO_2$ above the water table | 4 | 2 | M | Will need to liaise with $CO_2$ Advisor regarding the risk associated with this aspect<br>$CO_2$ Advisor is undertaking an assessment of the risk associated with this aspect - this info will need to be utilised for the terrestrial fauna assessment |
| Noise and vibration emissions | Direct loss of habitat or rupture of subsurface karst lenses | 2 | 3 | M | Use existing data and assessment undertaken in the EIS/ERMP<br>A noise study is being undertaken however, results may not be available in time (but results will be utilised if available) |
| | Partial collapse of karst formations | 2 | 3 | M | Use existing data and assessment undertaken in the EIS/ERMP |

## Receptor = Flora and Vegetation

Those impacts with a medium – high preliminary environmental risk (and highlighted green in the following table) are addressed further in the PER.

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Loss and/or disturbance of flora species and communities | 1 | 3 | H | Use existing information and assessment undertaken for EIS/ERMP<br>Some of the new vegetation types to be disturbed may be restricted in distribution |
| | Removal of topsoil and seed bank | 1 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term because topsoil from major vegetation types will be stockpiled as a unit for later direct lay or storage. A Post-construction rehabilitation plan will assist with management of areas requiring future rehabilitation with topsoils. |
| | Reduced viability of topsoil for rehabilitation if fire is used | 4 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term because intent is to burn vegetation as a stockpile in situ. |
| | Change in vegetation community composition from changes to soil profile and drainage patterns | 1 | 4 | M | Use existing information and assessment undertaken for EIS/ERMP |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Fire | Loss of vegetation community | 2 | 4 | M | Use existing information and assessment undertaken for EIS/ERMP<br>Fire management will be focus of discussion (e.g. prevention and response) |
| | Alteration to vegetation community composition | 1 | 4 | M | Use existing information and assessment undertaken for EIS/ERMP<br>Fire management will be focus of discussion (e.g. prevention and response) |
| | Reduction of topsoil quality/ loss of seed bank | 2 | 4 | M | Use existing information and assessment undertaken for EIS/ERMP<br>Fire management will be focus of discussion (e.g. prevention and response) |
| Fire | Secondary effects of infrastructure damaged (e.g. may cause leakage of grey-water pipes | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term because there will be Vegetation Clearing and Audit Procedures, and a Fire Management Plan, in place to manage unplanned fires and unplanned clearing. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Spills and leaks (acute/chronic/cumulative) | Loss of vegetation | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures are in place for early response to metabolic effect-causing spills/leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |
| | Reduced plant growth | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures are in place for early response to metabolic effect-causing spills/leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |
| | Soil contamination affecting regrowth | 3 | 5 | L | Stressor has not changed in character from the Approved Development. Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given protocols and management measures are in place for early response to metabolic effect-causing |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | spills/leaks (Solid and Liquid Waste Management Plan), and remediation and response protocols to reduce infiltration of fluids into substrate. |
| Atmospheric emissions (other than dust) | Physiological effects of deposition of pollutants on vegetation | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established. |
| | Change in taxon dominance due to N enriched soil conditions and soil acidity | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established. |
| | Increased growth due to uptake of N or $CO_2$ | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an air quality monitoring program established, and significant vegetation will be monitored. |
| | Death or decreased growth due to pooling of excessive $CO_2$ following leak and accumulation in topographic lows | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term as there will be an ecological monitoring program established to detect changes in significant vegetation near the construction site. There will also be a |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | monitoring program to detect $CO_2$ release from surface soils, and $dCO_2$ in the groundwater. |
| Dust emissions | Reduced photosynthetic activity due to smothering of leaf surface | 1 | 4 | M | Use existing information and assessment undertaken for EIS/ERMP<br>Dust management will be focus of discussion |
| Dust emissions | Increase absorption of near-infrared radiation and elevated leaf temperatures | 1 | 4 | M | Use existing information and assessment undertaken for EIS/ERMP<br>Dust management will be focus of discussion |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Change in vegetation community composition | 4 | 3 | M | Will need to liaise with $CO_2$ Advisor regarding the risk associated with this aspect<br>$CO_2$ Advisor is undertaking an assessment of the risk associated with this aspect - this info will need to be utilised for the terrestrial flora and veg assessment |
| Introduction and/or spread of non-indigenous species (quarantine) | Loss of native species due to competition from introduced species | 4 | 2 | M | Will be discussed in section 8 of the PER |
| | | | | | |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Change in taxon dominance | 4 | 4 | L | Impact is not anticipated to change in magnitude from the Approved Development<br><br>Consequences deemed to be localised and short-term given establishment of the QMS, and an ecological and quarantine monitoring and surveillance program established to detect changes in the population of significant fauna near the construction site. |
| | Expansion of non-indigenous species into disturbed areas | 3 | 3 | M | Will be discussed in section 8 of the PER |
| | Introduction or spreading of exotic taxa | 4 | 2 | M | Will be discussed in section 8 of the PER |

## Receptor = Marine Fauna

Those impacts with a medium – high preliminary environmental risk (and highlighted green in the following table) are addressed further in the PER.

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| **CONSTRUCTION** | | | | | |
| Seabed disturbance | Loss and/or disturbance of marine fauna habitat | 1 | 4 | M | Loss and/or disturbance of habitat used by pipefish, flatback turtles and green turtles. No reduction in population viability.<br>If only assessing general fauna, consequence will be minor and risk is Low. Further assessment required. See Section 7.1.2.1 of PER. |
| | Direct loss of benthic faunal communities, including potential loss of pipefish (Receptor species) | 1 | 4 | M | Loss of benthic fauna and pipefish through rock dumping. Not likely to affect population viability. If only assessing general fauna consequence will be minor and risk is Low. Further assessment required. |
| | Loss of general benthic communities | 1 | 5 | L | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Decline in marine water quality (e.g. sedimentation, nutrient increases and/or oxygen depletion) | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Burial of infaunal communities by drilling solids | | | | Drilling piles for the jetty. If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Avoidance of development area by mobile megafauna | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | impact. |
| | Loss of fauna associated with coral communities | | | | If assessing incremental change to Revised Proposal I, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| Leaks and spills (acute/ chronic/ cumulative) | Metabolic effects on intertidal and shallow subtidal biota | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. During construction there is less jetty construction vessel traffic (approx 30%). Does not require re-assessment. |
| | Smothering of exposed intertidal biota or mobile fauna (e.g. turtle hatchlings and adults) that contact a surface slick of hydrocarbons | | | | |
| | Metabolic effects on sensitive habitats from oil contacting low energy shorelines and becoming entrained in sediments | | | | |
| | Metabolic effects on foraging seabirds in the intertidal zone that contact oil | | | | |
| | Metabolic effects on emergent turtle hatchlings traversing oiled sediments in the intertidal zone | | | | |
| | Physiological effects on listed marine fauna (turtles, dolphins, dugong, whales) surfacing in a surface slick or gas plume | | | | |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Physical presence of infrastructure | Disturbance or modification of habitats (e.g. change in sediment transport causing change of shape of turtle nesting beaches) | | | | Not reassessed for the construction period as there is a decrease in vessel traffic during this time so impacts from the presence of marine vessels will be less. |
| | Disturbance to marine fauna behavioural patterns (i.e. some obstruction of movement along east coast) | | | | |
| | Creation of 'artificial' habitat associated with subsea facilities | | | | |
| | Aggregation of fish and other fauna around jetty and causeway | | | | |
| | Change in wave direction due to refraction around causeway causing disorientation of hatchling turtles | | | | |
| | Development of infaunal community in sediments of dredged channels | | | | |
| Wastewater discharges | Metabolic effects of discharges to the marine fauna | | | | No change. Decrease in marine construction vessel spread. |
| Physical interaction | Behavioural changes in listed marine megafauna in response to structures and to avoid encounters with workforce (non-vessel beach access, turtles) | | | | No change. |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Vessel collision with listed marine fauna resulting in injury or death | | | | 30% reduction in construction vessels associated with shorter jetty will results in reduced risk of impact |
| | Injury or fatality of turtles or sea snakes hit by dredge cutter | | | | No change. |
| | Changes to distribution and abundance of fish species (increased recreational fishing pressure) | | | | No change. |
| | Reduced turtle nesting, by deterring the female turtles from emerging onto the beach (human presence) | | | | No change. |
| Light spill | Reduced turtle nesting, by deterring the female turtles from emerging onto the beach | 2 | 4 | M | Impact is likely to increase due to longer construction period. Risk is related to night time construction if it cannot be avoided. Danger if consistent work during turtle nesting (Nov to Feb).<br><br>Assessment required. See Section 7.1.2.2 of PER |
| | Hatchlings are attracted to artificial lights and will move towards these lights (inland) rather than the ocean leading to reduced survival rates | 2 | 5 | L | Likely to increase due to longer construction period. Risk is related to night time construction if it cannot be avoided. Danger if consistent work during turtle hatching period (Dec to April). Is not assessed further as risk is low. |
| | MOF Operational lights (during construction) attract hatchlings already at sea and expose them to increased predation in the light pool. (Note check | 2 | 5 | L | Likely to increase due to additional freight required for 3rd train (longer construction period). Risk is related to night time MOF operation. Is not assessed further as risk is low. |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | status with logistics requirement to operate MOF at night?) | | | | |
| Light spill | Increased availability of food (e.g. turtle hatchlings) favours adaptable species, such as silver gulls and may lead to a change in community composition | | | | No change for construction. |
| | Juvenile wedge-tailed shearwaters attracted to the lights of the gas processing facility may be injured through collision with infrastructure | | | | No change for construction. |
| | Bottlenose dolphins will use light spill over water to assist in hunting and are likely to congregate in lit areas at night | | | | No change for construction. |
| | Increased predation of fauna attracted to light spill | | | | No change for construction. |
| | Disturbances to turtle nesting, breeding and feeding activity | | | | No change for construction. |
| Noise and vibration emissions | Localised impact to listed marine fauna (dolphin, dugong, turtles, whales) due to noise and vibration | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Physiological impacts to marine fauna as a result of blasting and pile installation | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Noise and vibration emissions | Fatality of marine fauna as a result of blasting | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Behavioural effects to marine fauna as a result of underwater noise and vibration | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Disorientation of turtle hatchlings due to noise and vibration (resulting from night time operation of construction plant and equipment) | 3 | 5 | L | Likely to increase due to longer construction period. Risk is related to night time construction if it cannot be avoided. Danger if consistent work during turtle hatching (Dec to Apr). Is not assessed further as risk is low. |
| | Affect development of turtle eggs and movement induced mortality due to noise and vibration | 3 | 5 | L | Likely to increase due to longer construction period. Risk is related to night time construction if it cannot be avoided. Danger if consistent work during turtle nesting (Dec to Apr). Is not assessed further as risk is low. |
| Introduction and/or spread of non-indigenous species (quarantine) | Loss of native species due to competition from introduced species | | | | Will be discussed in section 8 of the PER |
| | Introduction of exotic taxa | | | | Will be discussed in section 8 of the PER |
| | Change in taxon dominance | | | | Will be discussed in section 8 of the PER |
| **OPERATION** | | | | | |
| Seabed disturbance | Loss and/or disturbance of marine fauna habitat | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| Seabed disturbance | Direct loss of benthic faunal communities, including potential loss of listed | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | pipefish | | | | impact. |
| | Decline in marine water quality (e.g. sedimentation, nutrient increases and/or oxygen depletion) | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Burial of infaunal communities by drilling solids | | | | NA |
| | Avoidance of development area by mobile megafauna | | | | If assessing incremental change to Revised Proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. |
| | Loss of fauna associated with coral communities | | | | NA |
| Leaks and spills | Metabolic effects on intertidal and shallow subtidal biota | 3 | 4 | M | Leaks and spills will impact on turtles near the spill. Impacts relate to diesel spills due to collision or grounding (tug boats, service vessels). Spill volume likely to be < 5 tonnes. Further assessment required. See Section 7). |
| | Smothering of exposed intertidal biota or mobile fauna (e.g. turtle hatchlings and adults) that contact a surface slick of hydrocarbons | | | | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel due to collision or grounding (60 tonnes). Turtles and hatchlings impacted over one season. Risk is considered Low |
| | Metabolic effects on sensitive habitats from oil contacting low energy shorelines and becoming entrained in sediments | | | | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel due to collision or grounding (60 tonnes). Turtles and hatchlings impacted over one season. Risk is considered Low |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Leaks and spills | Metabolic effects on foraging shorebirds in the intertidal zone that contact oil | | | | Ingestion or exposure to oil by migratory shore birds. Bunker fuel spill (60 tonnes) stranded on widespread area of beaches in easterly wind conditions. Risk is considered Low |
| | Metabolic effects on emergent turtle hatchlings traversing oiled sediments in the intertidal zone | | | | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel due to collision or grounding (60 tonnes). Turtles and hatchlings impacted over one season. Risk is considered Low |
| | Physiological effects on listed marine fauna (turtles, dolphins, dugong, whales) surfacing in a surface slick or gas plume | | | | Release of liquid hydrocarbons which results in a floating slick on the surface of the sea. Incidental contact of animals with surface slick lasting hours to days. Risk is considered Low |
| Physical presence of infrastructure | Disturbance to marine fauna behavioural patterns (i.e. some obstruction of movement along east coast) | 3 | 3 | M | Potential increased predation of juvenile turtles by sharks, due to barrier of the MOF in shallow water--requiring migrating turtles to swim around the MOF into deeper water. Further assessment required. See section 7.1.4.2 |
| | Disturbance or modification of habitats (e.g. change in sediment transport causing change of shape of turtle nesting beaches) | | | | If assessing incremental change to Revised Proposal, risk of impact is equal. Risk remains the same for cumulative impact. |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Creation of 'artificial' habitat associated with subsea facilities | | | | No change anticipated. Length of time of large workforce on Barrow Island may increase. Existing management measures will restrict access to sensitive beaches. |
| | Aggregation of fish and other fauna around marine infrastructure | | | | Potential increase in aggregation of fish around MOF structure. Potential decrease in aggregation of fish around shortened jetty. Anticipate minimal net change in aggregation behaviour in comparison to Approved Development. |
| Physical presence of infrastructure | Change in wave direction due to refraction/reflection around causeway causing disorientation of hatchling turtles (note rock armour design absorbs wave energy and minimises reflection) | | | | If assessing incremental change to Revised Proposal, risk of impact is equal. Risk remains the same for cumulative impact. |
| | Development of infaunal community in sediments of dredged channels | | | | If assessing incremental change to proposal, risk of impact is lower or equal. Risk remains the same for cumulative impact. |
| Physical interaction | Vessel collision with listed marine fauna resulting in injury or death | On hold pending further assessment | | | Assume approx. 50% increase in vessel movements. |
| | Behavioural changes in listed marine megafauna in response to structures and to avoid encounters with workforce (non-vessel beach access, turtles) | | | | No change anticipated. Length of time of large workforce on Barrow Island may increase. Existing management measures will restrict access to sensitive beaches. |
| | Injury or fatality of turtles or seasnakes hit by dredge cutter | | | | No change anticipated. |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | Changes to distribution and abundance of fish species (increased recreational fishing pressure) | | | | No change anticipated. Length of time of large workforce on Barrow Island may increase. Existing management measures will restrict access to sensitive beaches. |
| | Reduced turtle nesting, by deterring the female turtles from emerging onto the beach (human presence) | | | | No change anticipated. Length of time of large workforce on Barrow Island may increase. Existing management measures will restrict access to sensitive beaches. |
| Light spill | Offshore lights attract hatchlings already at sea and expose them to increased predation in the light pool (main light source is LNG and Condensate tankers which will berth at night) | 3 | 3 | M | Critical during hatching period (Dec to Apr). 50% increase in tanker movements (1 tanker per day). Further assessment required. (See Section 7.1.2.2) |
| | Increased availability of food (e.g. insects and small fish) favours adaptable species, such as silver gulls and may lead to a change in community composition | 2 | 3 | H | Impacts on bird species composition from increased silver gull population. 50% increase in tanker movements (1 tanker per day). Assessing incremental change results in only a minor increase in potential for consequences. Further assessment required. (See Section 7.1.2.2) |
| | Reduced turtle nesting, by deterring the female turtles from emerging onto the beach (light) | 2 | 5 | L | Additional Infrastructure (3rd train). No increase in flaring. Assessing incremental change results in only a minor increase in potential for consequences. Cumulative impact is negligible. Is not assessed further as risk is low. |
| | Hatchlings are attracted to onshore artificial lights and will move towards these lights (inland) rather than the ocean leading to reduced | | | | No way of measuring difference between impacts of 2 or 3 trains. Therefore risk can not be anticipated to change. |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | survival rates | | | | |
| | Juvenile wedge-tailed shearwaters attracted to the lights of the gas processing facility may be injured through collision with infrastructure | 2 | 5 | L | Additional Infrastructure (3rd train). No increase in flaring. Assessing incremental change results in only a minor increase in potential for consequences. Cumulative impact is negligible. Is not assessed further as risk is low. |
| | Bottlenose dolphins will use light spill over water to assist in hunting and are likely to congregate in lit areas at night | 2 | 5 | L | 50% increase in tanker movements (1 tanker per day). Assessing incremental change results in only a minor increase in potential for consequences. Cumulative impact is negligible. Is not assessed further as risk is low. |
| | Increased predation of fauna attracted to light spill | 2 | 5 | L | 50% increase in tanker movements (1 tanker per day). Assessing incremental change results in only a minor increase in potential for consequences. Cumulative impact is negligible. Is not assessed further as risk is low. |
| Noise and vibration emissions | Impact to listed marine fauna (dolphin, dugong, turtles, whales) due to noise and vibration | 1 | 5 | L | 50% increase in tanker movements (1 tanker per day) may result in additional underwater noise. Is not assessed further as risk is low. |
| | Physiological impacts to marine fauna as a result of blasting and pile installation | | | | NA |
| | Fatality of marine fauna as a result of blasting | | | | NA |
| | Behavioural effects to marine fauna as a result of underwater noise and vibration | | | | 50% increase in tanker movements (1 tanker per day) may result in additional underwater noise. Assessing incremental change results in only a minor increase in potential for consequences. Cumulative |

| Environmental Stressor | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | impact is negligible. |
| | Disorientation of turtle hatchlings due to noise and vibration | 3 | 5 | L | Potential increase in noise associated with operation of the 3rd train. Is not assessed further as risk is low. |
| | Effect on development of turtle eggs and movement induced mortality due to noise and vibration | 3 | 5 | L | Potential increase in noise associated with operation of the 3rd train. Is not assessed further as risk is low. |
| Introduction and/or spread of non-indigenous species (quarantine) | Loss of native species due to competition from introduced species | | | | Strict quarantine regulations developed to prevent marine quarantine breaches in EIS/ERMP<br>Will be discussed in section 8 of the PER |
| | Introduction of exotic taxa | | | | 50% increase in tanker movements (1 tanker per day) may result in additional risk of exotic introductions.<br>Will be discussed in section 8 of the PER |
| | Change in taxon dominance | | | | Will be discussed in section 8 of the PER |

## Receptor = Marine Physical Environment

Those impacts with a medium – high preliminary environmental risk (and highlighted green in the following table) are addressed further in the PER.

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in the PER |
|---|---|---|---|---|---|
| **CONSTRUCTION** | | | | | |
| Physical disturbance of the seabed | Change in seabed profile | 1 | 4 | M | Extension of the causeway from the original proposal will result in additional impacts to the seabed. Further assessment required see section 7.2.2.1. |
| | Damage to high profile reef structures | | | | No further assessment. Equal to or less than the disturbance described for the Approved development |
| | Change in seabed type (e.g. sand to rock) | 1 | 4 | M | Extension of the causeway from the original proposal will result in additional impacts to the seabed. Further assessment required see section 7.2.2.1. |
| | Smothering of seabed | 1 | 4 | M | Extension of the causeway from the original proposal will result in additional impacts to the seabed. Further assessment required see section 7.2.2.1 |
| | Foreshore soil compaction | | | | No further assessment. Clearing and earthworks on the foreshore are required but impacts are no greater than the Approved Development. |
| | Foreshore erosion | | | | No further assessment. Foreshore earthworks have the potential for causing erosion however this is no greater than the Approved Development. |
| | Changes to the foreshore profile | | | | No further assessment. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in the PER |
|---|---|---|---|---|---|
| | Sedimentation | 1 | 5 | L | Additional rock dumping for lengthened causeway may result in localised sediment release. This carries a low risk. No further assessment required. |
| Physical presence of infrastructure | Surge in water level due to entrapment by causeway | | | | No changes during construction period from Approved Development. No further assessment. |
| | Change in sediment structure | | | | No changes during construction period from Approved Development. No further assessment. |
| | Change in seabed profile | | | | No changes during construction period from Approved Development. No further assessment. |
| | Change in nearshore hydrodynamics and sediment transport patterns | | | | No changes during construction period from Approved Development. No further assessment. |
| | Smothering of intertidal zone | | | | No changes during construction period from Approved Development. No further assessment. |
| **OPERATION** | | | | | |
| Physical Disturbance of the seabed | Change in seabed profile | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |
| | Damage to high profile reef structures | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in the PER |
|---|---|---|---|---|---|
| | Change in seabed type (e.g. sand to rock) | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |
| | Smothering of seabed | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |
| | Foreshore soil compaction | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |
| | Foreshore erosion | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |
| | Changes to the foreshore profile | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |
| | Sedimentation | | | | No change from Approved Development. No change in planned maintenance dredging operations. No further assessment. |
| Physical presence of infrastructure | Surge in water level due to entrapment by causeway | 3 | 5 | L | No further assessment. Rock armour of causeway designed to reduce reflection and refraction. |
| | Change in sediment structure | 3 | 5 | L | No further assessment. |

| Aspect (Stressor) | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in the PER |
|---|---|---|---|---|---|
| | Change in seabed profile | 1 | 4 | M | The causeway will be longer resulting in additional modification of seabed. Further Assessment required see section 7.2.2.2. |
| | Change in nearshore hydrodynamics and sediment transport patterns | 1 | 5 | L | No further assessment. Nearshore modelling shows minor changes in current flow around the MOF and no change in sediment transport as a result of the causeway and MOF. |
| | Smothering of intertidal zone | | | | No further assessment. Modelling shows only a very minor increase in sedimentation on either side of causeway during cyclone events. |

**Receptor = Marine Water and Sediment Quality**

Those impacts with a medium – high preliminary environmental risk (and highlighted green in the following table) are addressed further in the PER

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| **CONSTRUCTION** | | | | | |
| Physical disturbance of the seabed | Change in local sediment quality | 1 | 5 | L | NO - Additional rock dumping for lengthened causeway poses negligible increase in risk. |
| | Change in water quality (nutrients, turbidity, oxygen depletion) | 1 | 4 | M | YES – Potential significant impacts limited to turbidity resulting from additional rock dumping and changes in the dredge footprint. Risk analysis relies on preliminary plume model results, which are yet to be published.<br><br>Widespread within dredge plume 'zone of influence', short-term change in water quality.<br><br>Large decrease in water quality within dredge plume "zone of high impact'. |
| Leaks and spills (acute/ chronic/ cumulative) | Contamination of marine sediments and water quality | | | | NO - Equal to or less than original proposal, based on a 30% reduction in the number of construction vessels to be used. |
| Wastewater discharge | Increases in turbidity | | | | NO - Equal to or less than original proposal, based on a 30% reduction in the number of construction vessels to be used. |
| | Pollution or contamination of marine sediments and water | | | | NO - Equal to or less than original proposal, based on a 30% reduction in the number of construction vessels to be used. |
| | Change in water quality due to deposition of pollutants on water surface | | | | NO - Equal to or less than original proposal. |

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Atmospheric emissions | Change in water quality due to deposition of pollutants on water surface | | | | Modelling indicates that emissions are within NEPM guidelines. |
| **OPERATION** | | | | | |
| Physical disturbance of the seabed | Change in local sediment quality | 2 | 5 | L | NO – No change from original proposal. Does not require re-assessment |
| | Change in water quality (nutrients, turbidity, oxygen depletion | 1 | 5 | L | YES – Although the 50% increase in shipping traffic will result in minor increase in disturbance to the seabed from tugboat propeller wash, diurnal tidal flushing will prevent sustained changes in water quality. |
| Leaks and spills (acute/ chronic/ cumulative) | Contamination of marine sediments and water quality | 4 | 4 | L | NO - The additional LNG train will increase shipping traffic, but existing mitigation measures are sufficient to ensure no increase in the risk of leaks and spills impacting sensitive receptors. |
| Wastewater discharge | Increases in turbidity | | | | NO – No change |
| | Pollution or contamination of marine sediments and water | 3 | 5 | L | NO – The 50% increase in shipping traffic will not alter risk of wastewater discharge or the leaching/flaking of antifouling (TBT) paints as existing mitigation measures will ensure no increase in risk of pollution. |
| Atmospheric emissions | Change in water quality due to deposition of pollutants on water surface | | | | Modelling indicates that emissions are within NEPM guidelines. |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Acidification of sediments and water | 5 | 3 | L | NO – A 50% increase in $CO_2$ production from 3rd LNG train will not increase the risk of a leak of geo-sequestered $CO_2$. |

Marine Benthic Primary Producers Preliminary Risk Assessment

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| **CONSTRUCTION** | | | | | |
| Physical disturbance of the seabed | Loss and/or disturbance to marine flora and coral communities within and adjacent to marine infrastructure | 1 | 5 | L | No. The net changes in marine infrastructure under the Revised Proposal, caused by increases in the causeway length but decreases in the jetty length, are expected to be no different to those proposed under the Approved Development design. The total area of impact to corals under the Revised Proposal remains the same .The coral communities (scattered corals on limestone pavement and *Porites* bombora) that will be disturbed are considered locally significant but are well represented throughout Barrow Island waters and in the broader region. |
| | Smothering/burial of marine flora/corals in dredge spoil | 1 | 5 | L | No. There is no change to the total amount of dredge spoil or the location of the dredge spoil ground under the Revised Proposal. |
| | Turbidity, light attenuation and reduced photosynthetic potential in dredge plume | 1 | 4 | M | If assessing incremental change to proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. Further assessment is required due to remodelling of impact zones. See section 7.3.2.1 |
| | Decreased water quality (nutrients and oxygen depletion) | 1 | 5 | L | If assessing incremental change to proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. Further assessment is required due to remodelling of impact zones. See section 7.3.2.1 |
| Leaks and spills (acute/ chronic/ | Smothering of mangrove pneumatophores | | | | No. If assessing incremental change to |

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| cumulative) | | | | | proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. During Construction there is less jetty construction vessel traffic (approx 30%). Does not require re-assessment |
| | Metabolic effects on shallow subtidal coral | | | | As above |
| | Metabolic effects on intertidal and shallow subtidal biota | | | | As above |
| | Contamination of intertidal reef or sediments | | | | As above |
| | Smothering of exposed intertidal biota from contact with slick of hydrocarbons | | | | As above |
| Physical presence of infrastructure | Enhanced growth of macroalgae and corals on causeway and jetty | | | | No. If assessing incremental change to proposal, risk of impact is equal to or lower. Risk remains the same for cumulative impact. Does not require re-assessment. |
| | Reduced growth due to shading from causeway, MOF and jetty | | | | As above |
| | Changes to distribution of macrophytes and corals due to changes in sediment distribution associated with causeway and pipelines | | | | As above |
| | Disturbance or modification of habitats | | | | As above |
| Wastewater discharge | Metabolic effects of contaminants in discharges | | | | No. If assessing incremental change to proposal, risk of impact is equal to or lower. |

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | | | | | Risk remains the same for cumulative impact. During Construction there is less jetty construction vessel traffic (approx 30%) resulting in reduced risk of waste release. Does not require re-assessment |
| | Eutrophication effects due to nutrients in sewage (vessels) | | | | As above |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Metabolic effects | | | | Not applicable during construction phase |
| Introduction and/or spread of non-indigenous species (quarantine) | Loss of native species due to competition from introduced species | | | | Will be discussed in section 8 of the PER |
| | Introduction of exotic taxa | | | | Will be discussed in section 8 of the PER |
| | Change in taxon dominance | | | | Will be discussed in section 8 of the PER |
| **OPERATION** | | | | | |
| Physical disturbance of the seabed | Loss and/or disturbance to marine flora and coral communities within and adjacent to marine infrastructure | | | | No change from original proposal. Does not require re-assessment |
| | Smothering/burial of marine flora/corals in dredge spoil | | | | No change from original proposal. Does not require re-assessment |
| | Turbidity, light attenuation and reduced photosynthetic potential in dredge plume | | | | No change from original proposal. Does not require re-assessment |
| | Decreased water quality (nutrients and oxygen depletion) | | | | No change from original proposal. Does not require re-assessment |

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| Leaks and spills (acute/ chronic/ cumulative) | Smothering of mangrove pneumatophores and impacts to associated biota | 4 | 3 | M | 50% Increase in shipping. Worst case is assumed to be a spill of bunker oil from a work boat in the vicinity of 60 tonnes. Impacts from condensate are likely to be less. Further assessment in the PER is required. See section 7.4.2.2 |
| | Metabolic effects on shallow subtidal coral | 4 | 5 | L | 50% increase in shipping (LNG carriers or condensate carriers). Worst case is assumed to be a major release of bunker fuel or condensate due to collision or grounding (60 tonnes). Impacts may be from hydrocarbons entrained in seawater (dissolution weathering of spill) |
| | Metabolic effects on intertidal and shallow subtidal biota | 4 | 5 | L | As above |
| | | | | | |
| | Smothering of exposed intertidal biota from contact with slick of hydrocarbons | 4 | 3 | M | 50% Increase in shipping. Worst case is assumed to be a spill of bunker oil from a work boat in the vicinity of 60 tonnes. Further assessment in the PER is required. See section 7.4.2.2 |
| Physical presence of infrastructure | Enhanced growth of macroalgae and corals on causeway and jetty | | | | The predicted impacts to BPPH from the physical presence of Revised infrastructure are equivalent to that of the Approved Development design. The increased length of the causeway is offset by the reduced length of the jetty in terms of BPPH impacts. The risk remains the same for the cumulative impact. |
| | Reduced growth due to | | | | As above |

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| | shading from causeway, MOF and jetty | | | | |
| | Changes to distribution of macrophytes and corals due to changes in sediment distribution associated with causeway and pipelines | | | | As above |
| | Disturbance or modification of habitats | | | | As above |
| Wastewater discharge | Metabolic effects of contaminants in discharges | | | | Sources of wastewater from the Revised Proposal include stormwater runoff from construction or hardstand areas, deck wash from construction or LNG vessels, ballast, bilge and grey water discharge.<br><br>During operation there will be no TBT contamination risks, no ballast discharges in nearshore waters, no additional grey water discharges associated with increased shipping traffic due to management protocols and international shipping regulations.<br><br>The cumulative impact on benthic primary producers from a 50% increase in shipping traffic is not likely to be greater than the Approved Development. |
| | Eutrophication effects due to nutrients in sewage (vessels) | | | | As above |
| Unplanned $CO_2$ migration or release to the surface or near surface | Metabolic effects | 5 | 3 | L | The Revised Proposal includes a 50% increase in $CO_2$ production from the third |

| Aspect | Impact | Likelihood | Consequence | Preliminary Assessment of Risk | Further Assessment in PER |
|---|---|---|---|---|---|
| environment | | | | | LNG train. This $CO_2$ will be reinjected through wells into an underground reservoir. The increased production carries with it an increased risk of unplanned $CO_2$ migration or release to the surface. |
| Introduction and/or spread of non-indigenous species (quarantine) | Loss of native species due to competition from introduced species | 4 | 5 | L | 50% increase in shipping is unlikely to result in BPPH introductions or impacts on BPP from exotics – Will be discussed in section 8 of the PER |
| | Introduction of exotic taxa | 4 | 5 | L | Will be discussed in section 8 of the PER |
| | Change in taxon dominance | 4 | 5 | L | Will be discussed in section 8 of the PER |

## Marine Risk Assessment Workshop Table - Revised Proposal

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment of Inherent Risk (no project-specific mitigations) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| **Receptor: Marine Physical Environment** | | | | | | | | | | | | |
| **Construction** | | | | | | | | | | | | |
| Physical disturbance of the seabed | Change in seabed profile | Extension of solid causeway under the Revised Proposal, turning flat reef into high profile rocky reef. Flat limestone shelf changed by turning basin for MOF (reduced access channel length). Local loss of well-represented landform habitats. | 1 | 4 | M | Marine Facilities Construction Environmental Management Plan<br><br>Dredge and Spoil Disposal Management and Monitoring Program<br><br>Areas for mooring of vessels adjacent to construction area and control of vessel operating locations to minimise disturbance and encroachment on coral communities. | Seabed and foreshore | 1 | 4 | M | 'Loss' is a permanent loss, but only on a local scale, leading to the choice of 'moderate' consequence. | Selection of alignment for MOF and loading jetty was made to avoid encroachment of dredging equipment and sediment on a significant and more extensive coral community to the north east.<br><br>Dredge spoil is removed to a dredge spoil ground to the south east, as described in the approved EIS/ERMP. No unconsolidated material is left in the construction area.<br><br>Clarify consequence table definitions to indicate 'and/or' in lists. |
| | Change in seabed type (e.g. sand to rock) | Dredging requirements have changed under the Revised Proposal.<br><br>Dredge channel changes from hard substrate to soft substrate (where sediment will accumulate). Local loss of well-represented landform habitats. | 1 | 4 | M | | Seabed and foreshore | 1 | 4 | M | | |
| | Smothering of seabed | Extension of the solid causeway under the Revised Proposal resulting in smothering by rock dumping. Local loss of well-represented landform habitats. | 1 | 4 | M | | Seabed and foreshore | 1 | 4 | M | | |
| **Operation** | | | | | | | | | | | | |
| Physical presence of infrastructure | Change in seabed profile | The Revised Proposal marine facilities are located in a slightly different area to that assessed for the Approved Development.<br><br>Causeway (raised rock profile) and maintenance of dredge channels. | 1 | 4 | M | | Seabed and foreshore | 1 | 4 | M | | Modelling report contains evidence of wave and current analysis used for design. |
| **Receptor: Marine Fauna** | | | | | | | | | | | | |
| **Construction** | | | | | | | | | | | | |
| Physical disturbance of the seabed | Loss of and/or disturbance to marine fauna habitat | Extension of causeway under the Revised Proposal, and layout of the dredged area. Loss of habitat for listed pipefish, flatback turtle (internesting and foraging). | 1 | 4 | M | Marine Facilities Construction Environmental Management Plan<br><br>Dredge and Spoil Disposal Management and Monitoring Program<br><br>Long-term Turtle Management Plan (comprehensive) | Listed marine fauna | 1 | 4 | M | Localised loss of pipefish habitat, and flatback habitat. No reduction in local population viability. | Some colonisation of causeway by pipefish may occur. |
| | | Dugongs are occasional visitors, no extensive seagrass meadows.<br><br>Not assessed. | | | | | | | | | | |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific mitigation) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| | Direct loss of benthic faunal communities, including potential loss of listed pipefish | Rock dumping to construct extend solid causeway under the Revised Proposal. Benthic faunal communities are well represented. Macro-algal communities are dominant in area of impact. Impact of pipefish in rock dumping zone. | 1 | 4 | M | | Listed marine fauna | 1 | 4 | M | Short-term impact, no reduction in local population viability.<br><br>Not considered unique or critical habitat for the area. | |
| | | Loss of general benthic communities which may be different to the benthic communities assessed for the Approved Development as the Revised Proposal marine facilities are in a slightly different location. | | | | | General marine fauna | 2 | 5 | L | | Loss of small additional area of seabed due to causeway construction will lead to loss of benthic community in affected area. Localised long-term loss without affecting ecosystem function. |
| | Decline in marine water quality (e.g. sedimentation, nutrient increases and/or oxygen depletion) | | | | | | General marine fauna | | | | No anticipated change in risk profile from approved development. | Dredge plume modelling is being revised, but no anticipated change in threats or risk to marine fauna.<br><br>Although no change in risk the PER will need to revise impact zones. Plume modelling did not include downtime. |
| Light spill | Reduced turtle nesting, by deterring the female turtles from emerging onto the beach (light) | Additional infrastructure will result in additional lighting requirements.<br><br>Reduced turtle nesting, by deterring the female turtles from emerging onto the beach (light), on either side of Town Point (one season). Construction activities occur only during daylight hours, dredges operate day and night, vessels berthing at MOF at night (change is 500m further offshore), flaring during commissioning, less onshore construction manpower (modular over stick-build). | 2 | 3 | H | Long-term Marine Turtle Management Plan (including monitoring of nesting activities) | Listed marine fauna | 2 | 4 | M | Turtles observed approaching beaches to nest both north and south of Town Point on the same night.<br><br>Small increase in flaring anticipated over approved project (commissioning occurs during night time hours)<br><br>Management of lighting on vessels to minimize impact to the extent practicable. | |
| Operation | | | | | | | | | | | | |
| Leaks and spills (acute/ chronic/ cumulative) | Metabolic effects to intertidal and shallow subtidal biota | Increased number and frequency of vessel movements (LNG carriers or condensate carriers) under the Revised Proposal. Major release of bunker fuel or condensate due to collision or grounding (60 tonnes). | 3 | 3 | M | Controlled Port of Barrow Island, marine operating procedures, navigational control (piloted vessels), double-hulled vessels (LNG, fuel/product carriers), oil spill contingency plan, on-island spill response capability, cyclone contingency plans<br><br>All LNG vessels to be vetted (no spot-market contracts).<br><br>No routine bunkering of vessels in the Port of Barrow Island during operations. | Listed marine fauna | 4 | 4 | L | Risk assessment based on release of bunker fuel (more severe consequences). | Fuel delivered to Barrow Island from vessels, via pump lines.<br><br>South westerlies during breeding season would tend to blow oil away from nesting beaches.<br><br>Consider criteria for dispersant use to prevent exposure to nesting turtles and hatchlings. |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific mitigation) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| | | | | | | | | | | | | |
| | | | | | | Contingency procedures for refueling of vessels if required (developed from construction phase procedures).<br><br>Supervised loading, shut off valves for loading operations, operational procedures.<br><br>Long-term Turtle Management Plan includes contingencies for hatchling rescue in the event of beach contamination (consider physical barriers to prevent nesting females from entering contaminated beach area). Seven main beaches on the east coast are the focus of the Management Plan. | | | | | | |
| | | Diesel spills due to collision or grounding (tug boats, service vessels - additional movements of these vessels under Revised Proposal). Spill volume less than 5 tonnes. | | | | | Listed marine fauna | 3 | 4 | M | | South westerlies during breeding season would tend to blow oil away from nesting beaches. |
| | | Condensate spills during loading of vessels (high rate of evaporation) - increased frequency of loading under Revised Proposal. Spill volume less than 200 litres. | | | | | Listed marine fauna | 2 | 5 | L | Respiratory hazard to turtles, short-term metabolic effects to fish/filter feeders. | Risk of spills associated with construction vessel reduced due to more land-based construction. Management of spill would minimise effects on listed fauna. |
| | Smothering of exposed intertidal biota or mobile fauna (e.g. turtle hatchlings and adults) that contact a surface slick of hydrocarbons | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel due to collision or grounding (60 tonnes). Turtles and hatchlings impacted over one season. | 3 | 3 | M | | Listed marine fauna | 4 | 4 | L | Weathering of stranded oil occurs over a period of months to years.<br><br>Exposure to nesting females swimming through contaminated intertidal zone (potential sub-lethal impacts). | Consider criteria for dispersant use to prevent exposure to nesting turtles and hatchlings. |
| | Metabolic effects to sensitive habitats from oil contacting low energy shorelines and becoming entrained in sediments (re-release of oil constituents). | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel due to collision or grounding (60 tonnes). Turtles and hatchlings impacted over one season. | 3 | 3 | M | | Listed marine fauna | 4 | 4 | L | | Consider criteria for dispersant use to prevent exposure to nesting turtles and hatchlings. |
| | Metabolic effects to foraging shorebirds in the intertidal zone that contact oil | Ingestion or exposure to oil by migratory shore birds. Bunker fuel spill (60 tonnes) stranded on widespread area of beaches in easterly wind conditions. | 3 | 4 | M | | Listed marine fauna | 4 | 4 | L | Short-term decrease in abundance. | Birds do not frequent the Town Point area as much as the more southern beaches on Barrow Island. Management of spill would minimise effects on shorebirds. |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific mitigation) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| | Metabolic effects to emergent turtle hatchlings traversing oiled sediments in the intertidal zone | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel due to collision or grounding (60 tonnes). Turtles and hatchlings impacted over one season. | 3 | 3 | M | | Listed marine fauna | 4 | 4 | L | | Consider criteria for dispersant use to prevent exposure to nesting turtles and hatchlings. |
| | Physiological effects on listed marine fauna (turtles, dolphins, dugong, whales) surfacing in a surface slick or gas plume | Release of liquid hydrocarbons which results in a floating slick on the surface of the sea. Incidental contact of animals with surface slick lasting hours to days. | 3 | 3 | M | | Listed marine fauna | 4 | 4 | L | Consequences to turtles and dolphins from respiration. | Leakage of $CO_2$ from disposal project has been assessed in a separate Failure Modes and Effects Workshop on 16 June 2008, to be considered in the PER. |
| Physical presence of infrastructure | Disturbance to marine fauna behavioural patterns (i.e. some obstruction of movement along east coast) | Under the Revised Proposal the solid causeway and MOF structure are extended further out to sea.<br><br>Potential increased predation of juvenile turtles by sharks, due to barrier of the MOF in shallow water--requiring migrating turtles to swim around the MOF in deeper water.<br><br>No evidence to make confident judgement of likelihood. | 3 | 3 | M | | Listed marine fauna | 3 | 3 | M | Precautionary principle used to select the high-side likelihood. High level of uncertainty.<br><br>Assumes single east coast population. | Adult female nesting Flatback turtles and juvenile Green turtles migrate up and down beaches in the vicinity of Town Point, at depths of about 1 metre (on same night). There is a concern that the MOF design may encourage predators (Tiger sharks swimming in the channel at the edge of the shallower limestone shelf) to hunt for turtles at the end of the MOF, at depths of 2-3 metres (at low tide), where migrating turtles swim around the MOF.<br><br>Vessel strikes are not considered a significant threat during operations when there are relatively few vessel movements.<br><br>Little is known about the behaviour of juvenile Flatback turtles. |
| | | Potential increased predation of nesting Flatback females by sharks, due to barrier of the MOF in shallow water--requiring migrating turtles to swim around the MOF in deeper water.<br><br>No evidence to make confident judgement of likelihood. | | | | | Listed marine fauna | | | | Risk analysis is pending additional desktop studies to reduce uncertainty in consequences and likelihood.<br><br>Assumes single east coast population. | Explanation of how risk increases from the approved project is needed, along with detailed consideration of bathymetry.<br><br>Under the previous design the water depths at the end of the MOF varied between 2-7 metres. Under the proposed version the water depth varies between 3-8 metres. The water depth should be considered in the predation threat. Distance from the end of the MOF to the channel decreases from 1300 metres to 500 metres. |
| Wastewater discharges | Metabolic effects of discharges to the marine fauna (leaching of antifoulant) | No credible scenario due to prohibited use of TBT, prohibitions on discharge from vessels in marine ports. | 2 | 4 | M | | | | | | | Risk eliminated as TBT prohibited from use. |
| Physical interaction | Vessel collision with listed marine fauna resulting in injury or death | Collision of tugs, service vessels, and trading vessels with turtles - more frequent movements of these vessels under the Revised Proposal. | 1 | 4 | M | Long-term Marine Turtle Management Plan | Listed marine fauna | X | X | M | Data is available to relate shipping traffic to turtle strikes.<br><br>Strike rates of tens of turtles in Townsville reported. | NOTE: Risk Analysis conducted by Pendoley Environmental used as Residual Risk Score (Likelihood and Consequence scores not supplied) |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific mitigation) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | **Remarks** | |
| Light spill | Offshore lights attract hatchlings already at sea and expose them to increased predation in the light pool (main light source is LNG and Condensate tankers which will berth at night) | Additional infrastructure under the Revised Proposal will result in additional lighting requirements.<br><br>Confusion of turtle hatchling behaviour when primary wave front cue for swimming direction competes with light source offshore, if leaving the beach in the vicinity of the MOF and loading jetty. If hatchlings swim offshore to the loading jetty lights, they may be attracted to the light and remain in the lit area. Currents will tend to sweep hatchlings away from loading jetty. | 1 | 3 | H | Lighting strategy | Listed marine fauna | 3 | 3 | M | | NOTE: Risk Analysis conducted by Pendoley Environmental used as Residual Risk Score (Likelihood and Consequence scores not supplied).<br><br>Pendoley Environmental Risk Analysis then combined with workshop assessment taking into account Lighting Strategy to agree on Residual Risk Score. |
| | Increased availability of food (e.g. insects and small fish) favours adaptable species, such as silver gulls and may lead to a change in community composition | Attraction of flying insects and fish to increased loading jetty lighting, resulting in observed increase in silver gull populations competing with other seabirds (some listed) for nesting space.<br><br>NOTE: High risk shown adjacent refers to Residual Risk. | 2 | 3 | H | | Listed marine fauna | 3 | 3 | M | Potential to reduce local population viability of seabirds (terns, etc)<br><br>NOTE: Medium risk shown adjacent refers to Treated Risk following additional monitoring - see Comments. | Nesting success goes through natural boom and bust cycles.<br><br>Consider monitoring of silver gull population.<br><br>If monitoring identifies a problem with increasing population, consider some form of intervention to control silver gull population (targeted poisons considered effective, trapping, culling). |
| | | Attraction of flying insects and fish to increased loading jetty lighting, resulting in an increase in silver gull populations, and subsequently become an increased threat to turtle hatchlings (primarily Hawksbills, but Green and Flatback turtles also predated). | | | | | Listed marine fauna | 3 | 4 | M | | Silver gull populations may increase from turtle hatchling predation, independently from foraging at the location of loading lights. |
| **Receptor: Marine Primary Producers** | | | | | | | | | | | | |
| **Construction** | | | | | | | | | | | | |
| Physical disturbance of the seabed | Turbidity, light attenuation and reduced photosynthetic potential in dredge plume | The Revised Proposal marine facilities will impact on different habitats to that assessed for the Approved Development.<br><br>Impacts to macroalgae and coral health, impacts measured by coral health criteria in the EIS/ERMP. | | | | Dredge Spoil and Disposal Management Plan<br><br>Marine Facilities Construction Environmental Management Plan | General benthic primary producer | 1 | 4 | M | Local, long-term physical disturbance to benthic primary producer community. | MOF orientation is different from the approved project, requiring revised modelling analysis. |
| | Decreased water quality (nutrients and oxygen depletion) | Release of nutrients from sediments as a result of cutter suction dredging of soft substrate, and impacting primary producers. Stimulates growth, and/or stimulate growth of epiphytes (opportunistic algae). | | | | | General benthic primary producer | 1 | 5 | L | | Sediments are likely to have very low nutrient concentrations and are likely to rapidly disperse if excavated. |
| **Operation** | | | | | | | | | | | | |
| Leaks and spills (acute/ chronic/ cumulative) | Leaks and spills (acute/ chronic/ cumulative) | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel or condensate due to collision or grounding (60 tonnes).<br><br>Impact to mangroves and associated fauna on the east coast of Barrow Island. | 3 | 4 | M | Oil spill contingency plan includes protection of mangroves and other sensitive resources. | Restricted and significant benthic primary producer communities | 4 | 3 | M | Change of status of mangroves on Barrow Island since publication of the EIS/ERMP. | Mangrove communities are identified with a list of priority ecological communities on Barrow Island by the Dept of Environment and Conservation (DEC). |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific mitigation) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| | Metabolic effects on shallow subtidal coral | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel or condensate due to collision or grounding (60 tonnes).<br><br>Hydrocarbons entrained in seawater (dissolution weathering of spill). | 3 | 4 | M | | General benthic primary producers | 4 | 5 | L | | Low entrainment of hydrocarbons into the water column and absence of intertidal corals indicate that the effect on coral would be minor. Change to tanker frequency not expected to increase likelihood above unlikely. |
| | Metabolic effects on intertidal and shallow subtidal biota | Same as previous. | 3 | 4 | M | | General benthic primary producers | 4 | 5 | L | | As above, subtidal BPPH unlikely to be affected. Intertidal BPP communities on east coast of Barrow Island not well developed and expected to recover after clean up, so short-term impact at local to widespread scale. |
| | Contamination of intertidal reef or sediments | Refer to marine biota. | 3 | 4 | M | | | | | | | |
| | Smothering of exposed intertidal biota from contact with slick of hydrocarbons | Increased number and frequency of vessel movements (LNG carriers or condensate carriers). Major release of bunker fuel or condensate due to collision or grounding (60 tonnes).Impact to mangroves and associated fauna on the east coast of Barrow Island. | 3 | 4 | M | | Restricted and significant benthic primary producer communities | 4 | 3 | M | Change of status of mangroves on Barrow Island since publication of the EIS/ERMP. | |
| **Receptor: Marine Water and Sediment** | | | | | | | | | | | | |
| **Construction** | | | | | | | | | | | | |
| Physical disturbance of the seabed | Change in water quality (nutrients, turbidity, oxygen depletion) | Dredging requirements are changed under the Revised Proposal.<br><br>Dredge plume introduces nutrients, turbidity, localised oxygen depletion, and increased light attenuation.<br><br>Change in water quality as an environmental value. | | | | Marine Facilities Construction Environmental Management Plan<br><br>Dredge and Spoil Disposal Management and Monitoring Program | Marine water quality | 1 | 4 | M | Risk analysis relies on preliminary model results, to be published.<br><br>Widespread, short-term change in water quality. Large reduction in water quality over a small area (zone of high impact). | Modelling to confirm changes in plume dispersion.<br><br>Refer to Pilbara water quality document.<br><br>Although no change in risk the PER will need to revise impact zones. |
| **Operation** | | | | | | | | | | | | |
| Physical disturbance of the seabed | Change in water quality (nutrients, turbidity, oxygen depletion) | Increase in vessel traffic under the Revised Proposal to change water quality as a result of prop wash. | 2 | 4 | M | | Marine water quality | 1 | 5 | L | Diurnal flushing prevents sustained changes to water quality. | Frequency and quantity of maintenance dredging does not change from EIS/ERMP assessment. |

## Terrestrial Risk Assessment Workshop Tables – Revised Proposal

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment of Inherent Risk (no project-specific mitigations) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| **Receptor: Terrestrial Fauna (not including short-range endemics)** | | | | | | | | | | | | |
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Increased resource competition in adjacent areas | Additional area of habitat to be cleared under the Revised Proposal above the initial land take required for the Approved Development.<br><br>Terrestrial fauna displaced from cleared areas move into adjacent areas. Results in moving to new locations, or potential loss of some fauna from competition. Listed species such as birds, mammals, reptiles (including amphibians), terrestrial invertebrates. Considering overall disturbance, relocating or flushing fauna into adjacent habitats. | 2 | 4 | M | Terrestrial and Subterranean Environment Protection Plan<br><br>Terrestrial and Subterranean Monitoring Program<br><br>Fauna handling procedures<br><br>Vegetation Clearing and Audit Procedures | Listed terrestrial fauna | 2 | 4 | M | Consequence judgment is not biased by any particular species.<br><br>Considered a local, short-term change. | No additional Boodie warrens are going to be disturbed by the additional land clearing.<br><br>All matters of National Environmental Significance (NES) are addressed in the PER (Section 13.0). |
| | Habitat loss in cleared area | Additional vegetation clearing - removing vegetation and other habitat components. Direct loss of habitat for fauna. | | | | | Listed terrestrial fauna | 1 | 4 | M | Small fraction of representative habitat lost through clearing. Long-term, localised loss of habitat impacting fauna.<br><br>One Boodie warren is removed (under the Approved Development) but no additional warrens disturbed as a result of the additional land disturbance associated with the Revised Proposal. Habitat for fairy wrens. | Management plans include protocols for limiting clearing to defined boundaries, only what is necessary for development.<br><br>Progressive rehabilitation post-construction.<br><br>Scenario not assessed during initial scoping risk assessment. However, external stakeholders deemed that the potential impact from this stressor should be considered. |
| Site disturbance/ excavation | Entrapment in pipeline trenches and other open holes/pit excavated | Feed gas pipeline excavation (14km total, 2km open at a time) results in potential for animals to fall into pit. Potential for heat stress, predation, burial.<br><br>Additional area of construction under the Revised Proposal - small infrastructure trenches on cleared construction site. | 1 | 4 | M | Terrestrial and Subterranean Environment Protection Plan, including fauna handling and management procedures for protection of wildlife exposed to trenches. Management protocols for the risk of flooding an open trench, and cyclone shut-down contingencies.<br><br>Terrestrial and Subterranean Monitoring Program | Listed terrestrial fauna | 1 | 4 | M | Pipeline alignment avoids sensitive habitats, considered a widespread, short-term change. | |
| Fire | Loss of habitat | Planned, controlled fire for windrowed vegetation as part of land clearing. | 2 | 4 | M | Fire Management Plan<br><br>Emergency Response Plan (protocols for response to accidental fires)<br><br>Wildlife handling and management protocols | Not further assessed | | | | | |
| | | Accidental fire as a result of source of ignition during maintenance activities, car exhaust, planned fire spreading (possibly more ignition sources under the Revised Proposal). | | | | | Listed terrestrial fauna | 2 | 5 | L | No general or restricted species are completely vulnerable to fire from association with a localised habitat that might be burned.<br>Likelihood selected on the basis of experience to date. | Fires caused by natural events or third parties will be subject to active response.<br><br>Scenario not assessed during initial scoping risk assessment. However, external stakeholders deemed that the potential impact from this stressor should be considered. |
| | | Large industrial fire that spreads to adjacent vegetation (more potential ignition sources under the Revised Proposal). | | | | | Listed terrestrial fauna | 4 | 3 | M | Impacts to flora as well.<br><br>Consequences contemplated to extend beyond immediate impact area: widespread. Allowed for fire spreading into the bush. | Scenario not assessed during initial scoping risk assessment. However, external stakeholders deemed that the potential impact from this stressor should be considered. |
| | Injury or death of fauna | Fauna directly exposed to fire. | 2 | 4 | M | | Listed terrestrial fauna | 2 | 5 | Low | Slow moving and juvenile mammals and reptiles. | Consequences deemed to be local and short-term as there will be a Fire Management Plan and Emergency Response Protocol in place |
| Physical interaction | Injury or fatality (i.e. road kill) | Extended construction time (under the Revised Proposal) and associated road traffic - road kill of mammals and reptiles. | 1 | 4 | M | Traffic control and safety for vehicles (speed limits, etc) | Listed terrestrial fauna | 1 | 4 | M | | |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| Light emissions | Change in movement/behaviour of seabirds | Flare during commissioning and operations, including elevated flares (incremental increase under Revised Proposal). Potential attraction of shore birds (e.g. shearwaters) to flare. | 1 | 4 | M | Lighting strategy | Listed terrestrial fauna | 3 | 4 | M | Low densities of shearwaters nest on Double Island, some distance from LNG site flares.<br>Local, long-term decrease in abundance. | Studies in progress for shielding boil off gas (BOG) flares.<br><br>Post-construction monitoring program. |
| | | Plant lighting during operations - additional infrastructure under Revised Proposal so additional lighting requirements.<br><br>Attraction of insects to lights, predation by silver gulls. Increase in silver gull population, competing with shore birds.<br><br>Refer to assessment for marine impacts and activities. | | | | | | | | | | |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Asphyxiation of fauna in low-lying areas (e.g. fauna burrows) | Increased Gas Treatment Plant throughput under Revised Proposal.<br><br>Unplanned $CO_2$ release to the surface or near-surface environment from unplanned migration of $CO_2$ from deep faults could lead to asphyxiation of fauna in low-lying areas (e.g. fauna burrows) | 4 | 2 | M | Selection of the Dupuy Formation for injection of reservoir $CO_2$.<br>Selection of injection location such that the $CO_2$ plume is not anticipated to approach faults.<br>Existing decommissioned wells will be worked over to ensure suitability for $CO_2$ injection service.<br>Plans to manage well penetrations to ensure they are fit for service.<br>A wellhead maintenance program and monitoring of annular pressures will be implemented.<br>$CO_2$ injection and monitoring wells will be designed for $CO_2$ service.<br>Future hydrocarbon wells will be designed for $CO_2$ service.<br>Development of a Pressure Management Strategy.<br>Carbon Dioxide Monitoring Program. | Listed terrestrial fauna | 3 | 5 | L | Calculate credible release volumes and assess potential for scenario to develop. Consider meteorological data and topographic features. Consider terrestrial fauna and troglofauna. | External stakeholders recognised that the impacts of unplanned migration or release of $CO_2$ to fauna associated with the Revised Development are not significantly different to the impacts of the Approved Development. The addition of a third LNG processing train will potentially increase the annual volume of reservoir $CO_2$ by 0.92 MTPA. This will require additional injection wells and an additional 3km of $CO_2$ pipeline however the method of $CO_2$ injection does not differ from the Approved Development.<br><br>Given the current measures to mitigate risks associated with unplanned $CO_2$ migration, it is considered highly unlikely that such a situation would eventuate over the life of the project.<br><br>It is considered that $CO_2$ injection association with the Revised Proposal does not represent significant additional or different environmental risk than the Approved Development. |
| Hot and/or cold emissions | Injury or death to avifauna flying through heat plume from flare or air coolers | Additional flares required under the Revised Proposal.<br><br>Avifauna exposed to heat stress. | 1 | 3 | H | | Listed terrestrial fauna | 1 | 5 | L | | Consequences deemed to be local and short-term as similar incidents have been reported on individuals only. Few incidents have been reported by industrial operations on adjacent islands. |
| | Attraction of insects and reptiles to heat in cold weather | Reptile attraction to ground flares (primarily heat, and/or insect food source) resulting in potential injury or mortality. | 2 | 4 | M | | General terrestrial fauna | 1 | 5 | L | Barricading of flare pit to exclude large mammals and reptiles may be an option | Consequences deemed to be local and short-term as similar incidents have been reported on individuals only. Few incidents have been reported by industrial operations on adjacent islands. |
| Introduction or spreading of exotic taxa (quarantine) | Introduction and/or spread of non-indigenous species | | 4 | 2 | M | Terrestrial and Marine Quarantine Management System (QMS) | | | | | | Quarantine risks are addressed as part of the Quarantine Management System (QMS) that has been developed for the Approved Development and equally applies to the Revised Proposal.<br><br>Acknowledge weed management with respect to additional earthworks. Refer to existing WA Oil Weed Management Plan. |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| | Loss of native species due to competition from introduced species | | 4 | 2 | M | | | | | | | |
| | Change in taxon dominance | | 4 | 2 | M | | | | | | | |
| Receptor: Terrestrial Fauna – Short-range Endemics | | | | | | | | | | | | |
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Direct displacement or loss of individuals | Additional area of habitat to be cleared under the Revised Proposal above the initial land take required for the Approved Development.<br><br>Fewer individuals inhabiting any particular vegetation unit, such that displacement or loss of individuals may affect local population size and genetic variation of species. | 1 | 4 | M | Short Range Endemics and Subterranean Fauna Monitoring Plan (originally intended in Ministerial Conditions to look for distribution of species that had not yet been discovered across the island-- subsequently discovered across Barrow Island).<br><br>Terrestrial and Subterranean Environment Protection Plan.<br><br>Ecological Monitoring Plan.<br><br>Vegetation clearing and auditing procedures. | Listed terrestrial fauna and terrestrial short-range endemics | 1 | 3 | H | | Threats and risks to SREs are believed to reflect the same scenarios described for non-SRE terrestrial fauna. SREs present on Barrow Island occur over a widely dispersed number of habitats across the Island.<br><br>Proposition made to consider risks to SREs using the same approach as described above for non-SREs.<br><br>Recommendation made to include terrestrial (not subterranean) SREs in the consequence table category of 'Listed terrestrial fauna', recognising their conservation significance as being more sensitive than general terrestrial fauna. |
| Site disturbance/ excavation | Entrapment in pipeline trenches and other open holes/pit excavated | Feed gas pipeline excavation (14km total, 2km open at a time) results in potential for animals to fall into pit. Potential for heat stress, predation, burial.<br><br>Additional area of construction under the Revised Proposal - small infrastructure trenches on cleared construction site. | 1 | 4 | M | Fauna handling procedures | Listed terrestrial fauna | 1 | 4 | M | Pipeline alignment avoids sensitive habitats, considered a widespread, short-term change. | As above. |
| Fire | Loss of habitat | Planned, controlled fire for windrowed vegetation as part of land clearing. | 2 | 4 | M | Fire Management Plan<br><br>Emergency Response Plan (protocols for response to accidental fires)<br><br>Wildlife handling and management protocols | Not further assessed | | | | | |
| | | Accidental fire as a result of source of ignition during maintenance activities, car exhaust, planned fire spreading (possibly more ignition sources under the Revised Proposal). | | | | | Listed terrestrial fauna | 2 | 5 | L | No general or restricted species are completely vulnerable to fire from association with a localised habitat that might be burned.<br>Likelihood selected on the basis of experience to date. | Fires caused by natural events or third parties will be subject to active response.<br><br>Scenario not assessed during initial scoping risk assessment. However, external stakeholders deemed that the potential impact from this stressor should be considered. |
| | | Large industrial fire that spreads to adjacent vegetation (more potential ignition sources under the Revised Proposal). | | | | | Listed terrestrial fauna | 4 | 3 | M | Impacts to flora as well.<br><br>Consequences contemplated to extend beyond immediate impact area: widespread. Allowed for fire spreading into the bush. | Scenario not assessed during initial scoping risk assessment. However, external stakeholders deemed that the potential impact from this stressor should be considered. |
| | Injury or death of fauna | Fauna directly exposed to fire. | 2 | 4 | M | | Listed terrestrial fauna | 2 | 5 | Low | Slow moving and juvenile mammals and reptiles. | Consequences deemed to be local and short-term as there will be a Fire Management Plan and Emergency Response Protocol in place |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| Physical interaction | Injury or fatality (i.e. road kill) | Extended construction time (under the Revised Proposal) and associated road traffic - road kill of mammals and reptiles. | 1 | 4 | M | Traffic control and safety for vehicles (speed limits, etc) | Listed terrestrial fauna | 1 | 4 | M | | As above. |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Asphyxiation of fauna in low-lying areas. | Increased Gas Treatment Plant throughput under Revised Proposal.<br><br>Unplanned $CO_2$ release to the surface or near-surface environment from unplanned migration of $CO_2$ from deep faults could lead to asphyxiation of fauna in low-lying areas. | 4 | 2 | M | Selection of the Dupuy Formation for injection of reservoir $CO_2$.<br>Selection of injection location such that the $CO_2$ plume is not anticipated to approach faults.<br>Existing decommissioned wells will be worked over to ensure suitability for $CO_2$ injection service.<br>Plans to manage well penetrations to ensure they are fit for service.<br>A wellhead maintenance program and monitoring of annular pressures will be implemented.<br>$CO_2$ injection and monitoring wells will be designed for $CO_2$ service.<br>Future hydrocarbon wells will be designed for $CO_2$ service.<br>Development of a Pressure Management Strategy.<br>Carbon Dioxide Monitoring Program. | Listed terrestrial fauna | 3 | 5 | L | Calculate credible release volumes and assess potential for scenario to develop. Consider meteorological data and topographic features. Consider terrestrial fauna and troglofauna. | External stakeholders recognised that the impacts of unplanned migration or release of $CO_2$ to fauna associated with the Revised Development are not significantly different to the impacts of the Approved Development. The addition of a third LNG processing train will potentially increase the annual volume of reservoir $CO_2$ by 0.92 MTPA. This will require additional injection wells and an additional 3km of $CO_2$ pipeline however the method of $CO_2$ injection does not differ from the Approved Development.<br><br>Given the current measures to mitigate risks associated with unplanned $CO_2$ migration, it is considered highly unlikely that such a situation would eventuate over the life of the project.<br><br>It is considered that $CO_2$ injection association with the Revised Proposal does not represent significant additional or different environmental risk than the Approved Development. |
| Hot and/or cold emissions | Injury or death to avifauna flying through heat plume from flare or air coolers | Additional flares required under the Revised Proposal.<br><br>Avifauna exposed to heat stress. | 1 | 3 | H | | Listed terrestrial fauna | 1 | 5 | L | | Consequences deemed to be local and short-term as similar incidents have been reported on individuals only. Few incidents have been reported by industrial operations on adjacent islands. |
| | Attraction of insects and reptiles to heat in cold weather | Reptile attraction to ground flares (primarily heat, and/or insect food source) resulting in potential injury or mortality. | 2 | 4 | M | | General terrestrial fauna | 1 | 5 | L | Barricading of flare pit to exclude large mammals and reptiles may be an option | Consequences deemed to be local and short-term as incidents are likely to act on individuals only. SRE skink is known to be widespread on Barrow Island so population-level effects unlikely to occur at this scale. |
| Introduction or spreading of exotic taxa (quarantine) | Introduction and/or spread of non-indigenous species | | 4 | 2 | M | Terrestrial and Marine Quarantine Management System (QMS) | | | | | | Quarantine risks are addressed as part of the Quarantine Management System (QMS) that has been developed for the Approved Development and equally applies to the Revised Proposal.<br><br>Acknowledge weed management with respect to additional earthworks. Refer to existing WA Oil Weed Management Plan. |
| | Loss of native species due to competition from introduced species | | 4 | 2 | M | | | | | | | |
| | Change in taxon dominance | | 4 | 2 | M | | | | | | | |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| Receptor: Subterranean Fauna | | | | | | | | | | | | |
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Removal of organic input (energy) | Additional area of vegetation to be cleared under the Revised Proposal above the initial land take required for the Approved Development.<br><br>Long-term change in nutrient supply to subterranean habitat of troglofauna (stygofauna is not likely to be as impacted). | 1 | 3 | H | Terrestrial and Subterranean Environment Protection Plan.<br>Vegetation clearing and auditing procedures.<br>Short Range Endemics and Subterranean Fauna Monitoring Plan.<br>Ecological Monitoring Plan. | Subterranean fauna | 1 | 3 | H | All troglofauna known only to the development site will be impacted, not found elsewhere (ongoing surveys to seek wider distribution in a highly porous environment). Nutrient supply may include a component of lateral sources.<br>From surveys to date, species distribution over wide areas is confirmed. The possibility that troglofauna and stygofauna are restricted to only the plant site is subject to ongoing surveys, which are intended to confirm a wider distribution. | |
| Site disturbance/ excavation | Direct loss of troglofauna habitat within gas treatment plant footprint (e.g. from excavation, blasting and installation of piles) | Additional area of land take under the Revised Proposal above the initial land take required for the Approved Development.<br><br>Earthworks (blasting, mechanical compaction, removal) physically destroy or remove troglofauna habitat during construction period. | 1 | 3 | H | Terrestrial and Subterranean Environment Protection Plan.<br>Vegetation clearing and auditing procedures.<br>Short Range Endemics and Subterranean Fauna Monitoring Plan.<br>Ecological Monitoring Plan. | Subterranean fauna | 1 | 3 | H | See above. | Consider depth to troglofauna habitats with respect to depth of disturbance for gas plant construction. |
| Liquid and solid waste disposal | Nutrient loading of subterranean habitats | Planned water disposal wells completed at depth of about 1000m. No credible exposure of subterranean fauna habitats to nutrient loading from water disposal wells.<br><br>Not assessed. | 3 | 4 | M | | | | | | | |
| Spills and leaks (acute/chronic/cumulative) | Metabolic effects on subterranean habitat and/or metabolic effects on stygofauna | Extended construction time under the Revised Proposal.<br><br>Accidental releases of hydrocarbon materials or chemicals during construction. Refueling of construction earthmoving equipment, drilling fluids used for borehole drilling.<br><br>Tens of litres spilt. | 3 | 4 | M | Spill kits on construction vehicles, contingency plans.<br><br>Maintenance and inspection program. Supervised refueling in designated areas.<br><br>Remediation and response protocols to reduce infiltration of fluids into substrate. | | 3 | 5 | L | Hydraulic fluid and fuel spills are most common types of spills during construction activities. Tens of litres. Use of predominantly new or as-new vehicles and equipment (quarantine requirement). | Any consequence from potential impact deemed to remain localised because certain management measures will be in place:<br>Spill kits on construction vehicles<br>Maintenance and inspection programs.<br>Supervised refuelling in designated areas.<br>Remediation and response protocols to reduce infiltration of fluids into substrate.<br>Risk of leaks deemed to be in order of tens of litres. |
| | | Additional hydrocarbons and chemicals required during operation under the Revised Proposal.<br><br>Accidental releases of hydrocarbon materials or chemicals during operation. Spillage or leaks from plant process equipment, leakage of equipment associated with injection wells (e.g. hydraulic fluids, workover fluids).<br><br>Tens of litres spilt. | | | | Maintenance and inspection program. Supervised refueling in designated areas.<br><br>Hard-stand and bunding of plant facilities, spill kits on site, response resources. | Subterranean fauna | 3 | 5 | L | | Any consequence from potential impact deemed to remain localised.<br><br>Risk of leaks deemed to be in order of tens of litres.<br><br>Any consequence from potential impact deemed to remain localised because certain management measures will be in place:<br>Maintenance and inspection programs.<br>Supervised refuelling in designated areas.<br>Remediation and response protocols to reduce infiltration of fluids into substrate.<br>Risk of leaks deemed to be in order of tens of litres.<br>Hard-stand and bunding of plant facilities,<br>Spill kits on site<br>Response resources. |
| Presence of infrastructure | Reduced groundwater recharge under gas treatment plant affecting subterranean humidity and free water | Additional infrastructure (and hence, terrestrial footprint) under the Revised Proposal.<br><br>Preventing aquifer recharge at plant site, potentially impacting humidity in restricted troglofauna habitat. | 1 | 3 | H | | Subterranean fauna | 1 | 3 | H | Investigate changes to groundwater occurrence and movement as a result of plant construction. | |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | Remarks | |
| Loss of stygofauna and troglofauna | Not assessed, given scenarios to be assessed above. | | | | | | | | | | | Loss of stygofauna and troglofauna |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Acidification of groundwater with potential loss of stygofauna | Increased Gas Treatment Plant throughput under Revised Proposal.<br><br>Unplanned $CO_2$ release to the surface or near-surface environment from unplanned migration of $CO_2$ from deep faults could lead to a localised anoxic environment for stygofauna in the superficial aquifer, or lead to the asphyxiation of troglofauna in subsurface areas. | 4 | 2 | M | Selection of the Dupuy Formation for injection of reservoir $CO_2$.<br>Selection of injection location such that the $CO_2$ plume is not anticipated to approach faults.<br>Existing decommissioned wells will be worked over to ensure suitability for $CO_2$ injection service.<br>Plans to manage well penetrations to ensure they are fit for service.<br>A wellhead maintenance program and monitoring of annular pressures will be implemented.<br>$CO_2$ injection and monitoring wells will be designed for $CO_2$ service.<br>Future hydrocarbon wells will be designed for $CO_2$ service.<br>Development of a Pressure Management Strategy.<br>Carbon Dioxide Monitoring Program. | Subterranean fauna | 3 | 5 | L | Likelihood of casing leak is considered very remote. Consider likelihood of leakage and preventive measures with subsurface engineering team. | NB: risk is based on release of $CO_2$ from fault conduits and not casing leaks as these were deemed by $CO_2$ specialists to represent a low residual risk.<br><br>External stakeholders recognised that the impacts of unplanned migration or release of $CO_2$ to fauna associated with the Revised Development are not significantly different to the impacts of the Approved Development. The addition of a third LNG processing train will potentially increase the annual volume of reservoir $CO_2$ by 0.92 MTPA. This will require additional injection wells and an additional 3km of $CO_2$ pipeline however the method of $CO_2$ injection does not differ from the Approved Development.<br><br>Given the current measures to mitigate risks associated with unplanned $CO_2$ migration, it is considered highly unlikely that such a situation would eventuate over the life of the project.<br><br>It is considered that $CO_2$ injection association with the Revised Proposal does not represent significant additional or different environmental risk than the Approved Development. |
| | Asphyxiation of troglofauna from settlement of CO2 above the water table | Unplanned $CO_2$ release to the surface or near-surface environment from unplanned migration of $CO_2$ from deep faults could lead to a localised anoxic environment for stygofauna in the superficial aquifer, or lead to the asphyxiation of troglofauna in subsurface areas. | 4 | 2 | M | | Subterranean fauna | 3 | 5 | L | Likelihood of casing leak is considered very remote. Consider likelihood of leakage and preventive measures with subsurface engineering team. | NB: risk is based on release of $CO_2$ from fault conduits and not casing leaks as these were deemed by $CO_2$ specialists to represent a low residual risk.<br><br>External stakeholders recognised that the impacts of unplanned migration or release of $CO_2$ to fauna associated with the Revised Development are not significantly different to the impacts of the Approved Development. The addition of a third LNG processing train will potentially increase the annual volume of reservoir $CO_2$ by 0.92 MTPA. This will require additional injection wells and an additional 3km of $CO_2$ pipeline however the method of $CO_2$ injection does not differ from the Approved Development.<br><br>Given the current measures to mitigate risks associated with unplanned $CO_2$ migration, it is considered highly unlikely that such a situation would eventuate over the life of the project.<br><br>It is considered that $CO_2$ injection association with the Revised Proposal does not represent significant additional or different environmental risk than the Approved Development. |
| Noise and vibration emissions | Direct loss of habitat or rupture of subsurface karst lenses | Assessed above in site disturbance aspect. | 2 | 3 | M | Dust suppression on construction site and roads<br><br>Dust monitoring | | | | | | |
| | Partial collapse of karst formations | Additional area of initial land disturbance and extended construction time under the Revised Proposal.<br><br>Damage to karst formations during construction activities caused by prolonged or acute vibrations. | 2 | 3 | M | | Subterranean fauna | 2 | 3 | H | Investigate conceptual model of subsurface geology with specialists to determine potential damage from routine construction activities.<br><br>Subterranean fauna and geotechnical specialists to be consulted. | |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | | |
| Receptor: Flora and Vegetation | | | | | | | | | | | | |
| Vegetation clearing<br><br>Clearing methodology may comprise use of mechanical techniques or fire or a combination of both | Loss and/or disturbance of flora species and communities | Additional area of vegetation to be cleared under the Revised Proposal above the initial land take required for the Approved Development.<br><br>Loss of restricted flora and restricted vegetation in cleared area. | 1 | 3 | H | Terrestrial and Subterranean Environment Protection Plan<br><br>Terrestrial and Subterranean Monitoring Program<br><br>Vegetation clearing procedures to limit vegetation loss<br><br>Vegetation surveys of available land clearing options<br><br>Surface Hydrology Procedure | Restricted flora and vegetation | 1 | 3 | H | Local, long-term reduction in viability and abundance. | One listed priority 3 species within the development plant footprint. Another 3 species which are not listed, but still considered sensitive due to limited distribution on Barrow Island or low regeneration rate (common on mainland). Also, some increase in clearing of restricted vegetation communities within the gas plant footprint.<br><br>Selection of CO2 well drill centre locations and pipeline alignment to avoid restricted flora and vegetation. |
| | | Loss of general flora and vegetation in cleared area, including two different vegetation associations from Approved Development. Less than five percent of each association's representation on the Island. | | | | | General flora and vegetation | 1 | 4 | M | | Scenario not assessed during initial scoping risk assessment. However, external stakeholders deemed that the potential impact from this stressor should be considered. |
| | Change in vegetation community composition from changes to soil profile and drainage patterns | Drainage altered due to physical presence of gas plant. Potential changes to composition due to opportunistic colonisation by species such as *Triodia angusta*. | 1 | 4 | M | As above | General flora and vegetation | 1 | 5 | L | Creation of a transition zone of vegetation is expected to occur over a short distance (metres) from the edge of disturbance.<br>Local changes. | Any consequence from potential impact deemed to remain localised as there will be a Surface Hydrology Procedure in place. Vegetation clearing audit procedures will assist to minimise clearing beyond allowed areas. |
| Fire | Loss of vegetation community | Additional ignition potential sources under Revised Proposal.<br><br>Accidental ignition of vegetation outside plant site and pipeline easement. Loss of restricted flora and vegetation associations. | 2 | 4 | M | Fire Management Plan | Restricted flora and vegetation | 2 | 3 | H | | Consider scale of fire under undesirable conditions (e.g. fuel load, wind) and ensure response capacity to limit the spread of fire is adequate. |
| | | Large industrial fire at plant site, which spreads beyond local vegetation.<br><br>Alteration of vegetation community composition during recovery.<br><br>Post-fire recovery causes recruitment changes to original composition during early stages of recovery. Change induced by a large burnt area. Competition of general vegetation with restricted vegetation that was impacted by fire. | | | | | Restricted flora and vegetation | 4 | 3 | M | Consequences contemplate recovery of species.<br>Populations are distributed across the island, and are not vulnerable to a fire in one location. | Consider protection of restricted vegetation communities in planning a fire response. Some reduction in the exposure of restricted vegetation would be expected.<br><br>Scenario not assessed during initial scoping risk assessment. However, external stakeholders deemed that the potential impact from this stressor should be considered. |
| | Alteration to vegetation community composition | See above. Cannot distinguish between large fire event scenario and this potential impact. | 1 | 4 | M | | | | | | | |
| | Reduction of topsoil quality/ loss of seed bank | Reduction of abundance and health of microbes and seed bank in topsoil, reducing recovery of vegetation. Expected to require a very hot accidental fire event. | 2 | 4 | M | | Restricted flora and vegetation | 3 | 3 | M | | Barrow Island Fire Management Plan (DEC) will become available to share information.<br><br>Consider research in post-fire recovery of vegetation and composition to assist with understanding of potential rehabilitation of fire-affected areas. |
| Dust emissions | Reduced photosynthetic activity due to smothering of leaf surface | Construction period extended under the Revised Proposal.<br><br>Dust generated during construction which disperses to vegetation in proximity of plant site. | 1 | 4 | M | Dust suppression on construction site and roads<br><br>Dust monitoring | General flora and vegetation | 1 | 5 | L | | Any consequence from potential impact deemed to remain localised. Road traffic procedure will manage vehicle speed on roads. Dust suppression will be conducted at sites where dust levels become unacceptably high. Dust monitoring will help to identify when dust levels become unacceptably high. |

| Aspect (stressor) | Impact | Scenario | Preliminary Assessment (no project-specific) | | | Project-specific Mitigation | Selected Consequence Table | Residual Risk (including project-specific mitigations) | | | | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Likelihood | Consequence | Risk Level | | | Likelihood | Consequence | Risk Level | | |
| | Increased absorption of near-infrared radiation and elevated leaf temperatures | Consequence of dust accumulation on leaves, filtering light. | 1 | 4 | M | | General flora and vegetation | 1 | 5 | L | | Any consequence from potential impact deemed to remain localised. Road traffic procedure will manage vehicle speed on roads. Dust suppression will be conducted at sites where dust levels become unacceptably high. Dust monitoring will help to identify when dust levels become unacceptably high. |
| Unplanned $CO_2$ migration or release to the surface or near surface environment | Change in vegetation community composition | Increased Gas Treatment Plant throughput under Revised Proposal.<br><br>Unplanned $CO_2$ release to the surface or near-surface environment from unplanned migration of $CO_2$ from deep faults could lead to a localised anoxic environment. | 4 | 3 | M | Selection of the Dupuy Formation for injection of reservoir $CO_2$.<br>Selection of injection location such that the $CO_2$ plume is not anticipated to approach faults.<br>Existing decommissioned wells will be worked over to ensure suitability for $CO_2$ injection service.<br>Plans to manage well penetrations to ensure they are fit for service.<br>A wellhead maintenance program and monitoring of annular pressures will be implemented.<br>$CO_2$ injection and monitoring wells will be designed for $CO_2$ service.<br>Future hydrocarbon wells will be designed for $CO_2$ service.<br>Development of a Pressure Management Strategy.<br>Carbon Dioxide Monitoring Program. | | 3 | 5 | L | | NB: risk is based on release of $CO_2$ from fault conduits and not casing leaks as these were deemed by $CO_2$ specialists to represent a low residual risk.<br><br>External stakeholders recognised that the impacts of unplanned migration or release of $CO_2$ to fauna associated with the Revised Development are not significantly different to the impacts of the Approved Development. The addition of a third LNG processing train will potentially increase the annual volume of reservoir $CO_2$ by 0.92 MTPA. This will require additional injection wells and an additional 3km of $CO_2$ pipeline however the method of $CO_2$ injection does not differ from the Approved Development.<br><br>Given the current measures to mitigate risks associated with unplanned $CO_2$ migration, it is considered highly unlikely that such a situation would eventuate over the life of the project.<br><br>It is considered that $CO_2$ injection association with the Revised Proposal does not represent significant additional or different environmental risk than the Approved Development. |
| Introduction and/or spread of non-indigenous species (quarantine) | Loss of native species due to competition from introduced species | | 4 | 2 | M | Terrestrial and Marine Quarantine Management System<br><br>Barrow Island Weed Management Plan (DEC) | | | | | | Refer to quarantine risk assessment process and QMS. |
| | Expansion of non-indigenous species into disturbed areas | Spreading weeds which already occur on Barrow Island due to project construction and operations (in additional areas under the Revised Proposal to that of the Approved Development). | 3 | 3 | M | | Restricted flora and vegetation | 1 | 5 | L | | Hygiene management protocols for personnel, material & equipment will be applied during construction on island to minimise transfer of weeds.<br><br>Mapping and monitoring of weeds on Barrow Island will inform management practices to prevent spread<br><br>Any consequence from potential impact therefore deemed to remain localised. |
| | Introduction of non-indigenous species | | 4 | 2 | M | | | | | | | Refer to quarantine risk assessment process and QMS. |

# APPENDIX D

## Light And Noise Emissions Risks And Management For The Revised Proposal

# CHEVRON AUSTRALIA PTY LTD

# LIGHT SPILL MODELLING STUDY

For The

# GORGON PROJECT
# BARROW ISLAND LNG PLANT

**Document No.: G1-TE-H-0000-REP1003**

| Revision: | A | 0 | | |
|---|---|---|---|---|
| Prepared by: | S Hart/A Bunyard | S Hart | | |
| Reviewed by: | G Davies | A Bunyard | | |
| KJV Approved by: | C Bradley | C Bradley | | |
| CVX Approved by: | | P Chen | | |
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Kellogg Joint Venture Gorgon
KBR JGC HATCH CLOUGH

Chevron

**SUMMARY OF DOCUMENT REVISIONS**

| Rev. No. | Date Revised | Section Revised | Revision Description |
|---|---|---|---|
| A | 19 Jun 08 | | Issued for Client Review |
| 0 | 6 Jul 08 | | Document title altered.<br>Revision of model outputs to include train 1.<br>Scenario Option B1, C1 and E included in study.<br>Limitations further defined.<br>Results updated.<br>Final client comments Included |
| | | | |
| | | | |

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# 1. GENERAL

## 1.1 Introduction

Chevron Australia Pty Ltd, as the operator of the Gorgon Project, proposes to develop the gas reserves of the greater Gorgon and Jansz areas via gas processing facilities located on Barrow Island (BWI).

The proposed development is based on the installation of subsea gathering systems and subsea pipelines delivering feed gas from the Gorgon and Jansz fields to BWI.

Up to 300 hectare (ha) will be cleared for infrastructure construction and upgrades on BWI, including the feed gas pipelines which will be buried as they transverse from the west coast of BWI to an onshore gas processing facility located on the central east coast of the island.

The gas processing facility at Town Point will consist of a Liquefied Natural Gas (LNG) plant, a domestic gas plant, hydrocarbon condensate handling facilities, and associated utilities. The LNG plant will comprise three LNG trains capable of producing a nominal capacity of 15 million tones per annum (MTPA), requiring approximately daily LNG shipments from the island, which will be loaded from a dedicated jetty. It is proposed to inject carbon dioxide, which occurs naturally in the reservoir, into deep formations below the island.

BWI, which is approximately 25 km long and 10 km wide and covers 23,567 ha, is Western Australia's second largest island. The island is located off the Pilbara coast 85 km north-north-east of the town of Onslow and 145 km from Karratha. It is the largest of a group of islands, including the Montebello and Lowendal Islands. BWI was declared an A Class Nature reserve in 1910 and has supported a production oilfield, operated by Chevron Australia, since 1967.

Light associated with Gas Treatment Plant operations and associated terrestrial and marine infrastructure (e.g. Materials offloading facility (MOF) and LNG Jetty) has the potential to adversely affect the behaviour of marine fauna, notably sea turtles and some seabirds (e.g. shearwaters and gulls). Critical environmental receptors that could be affected by light spill and light characteristics (light colour, intensity, etc) for the proposed Gorgon Gas Treatment Plant location included:

- Flatback turtles visiting the beaches both sides of Town Point to mate and rest in the near shore waters and lay eggs on the beaches. The five most important beaches for flatback turtles on BWI are Terminal Beach north of Townpoint and Bivalve, Inga, Yacht Club Beach North and Yacht Club Beach South on the southern side of Town Point; and
- The bridled tern and wedge tail shearwater colony on Double Island.

Chevron have requested KJVG to scope and commission a light modelling study for the light emissions associated with routine and non-routine operations of the proposed Gorgon Gas Treatment Plant on BWI. This report presents the methodology and finding of this study.

## 1.2 Purpose and Objectives

This report forms an input to the light impact assessment for the purposes of the Public Environmental Review process for the Revised Proposal Gas Treatment Plant as defined in Chevron's Gorgon Project, Revised Proposal Environmental Scoping Document, EPA Assessment 1727 (Ref. 1). This report will inform the desktop assessment of the significant light characteristics of the design for the Revised Proposal Gas Treatment Plant.

The objectives of the light modelling study are therefore as follows:

- Identify light modelling scenarios representative of routine and planned non-routine operations.
- Establish lighting levels for various parts of the plant as per project design guidance documents (Refs. 2 and 3).
- Presents light spill modelling results as isolux contours around the Revised Proposal Gas Treatment Plant; and
- Examine light intensity levels at the sensitive environmental locations specified by Chevron (see Table 2.2).

## 1.3 Acronyms and Definitions

| Acronym | Definition |
|---|---|
| BWI | Barrow Island |
| ha | hectare |
| KJVG | Kellogg Joint Venture Gorgon |
| LNG | Liquefied Natural Gas |
| Lux | A System International unit of illuminance and luminous emittance. It is used in photometry as a measure of the intensity of light. |
| FPSO | Floating storage, production and offloading (facility) |

# 2. MODELLING METHODOLOGY

## 2.1 Software and Limitations

KJVG engaged the services of a third party contractor, Chalmit Lighting, to provide light modelling expertise and predict light spill contours for the three LNG train Gas Treatment Plant.

Chalmit is a specialist supplier of lighting products for use in industrial and marine environments, providing lighting hardware and technical expertise to the industry. Chalmit is an active member of the Lighting Industry Federation and has been offering proprietary light modelling services to the industry for 15 years. Chalmit has been involved in the supply of lighting to offshore oil and gas platforms since the 1970's. In addition Chalmit provide approximately 85% of the North Sea oil industry's industrial lighting requirements. They have previously been involved in environmentally sensitive projects in the north west of Western Australia including LNG facilities, offshore oil and gas platforms as well as floating storage, production and offloading (FPSO) facilities.

Chalmit use an in-house light modelling software program– Chalmit version 4.04. This program has a limitation of 999 light sources and 12000 calculation points.

## 2.2 Modelling Scenarios

The following routine and non-routine operations scenarios were specified for modelling purposes:

**Table 2.1: Modelling Scenarios**

| Scenario | Description | Model Assumptions |
|---|---|---|
| Option A – Normal Operations | Normal operations for the three LNG trains. Lighting levels set for normal operations and movements of personnel within the plant. | Mean lighting levels of 20 lux for Trains 1, 2 and 3 and 5 lux for road lighting. |
| Option B – Train Maintenance | One train under maintenance whilst two other operating in normal mode. Task lighting provided for Train 3. | Mean lighting levels of 20 lux for Trains 1, 2 and 5 lux for road lighting. Train 3 (worst case scenario for light spill to the beach) illuminated to a mean lighting level of 50 lux. |
| Option C – LNG Tank Rooftop Maintenance | Normal operations for three LNG trains and maintenance works on LNG tanks rooftops. | Mean lighting levels of 20 lux for Trains 1, 2 and 3 and 5 lux for road lighting. LNG tanks rooftops illuminated to a local mean lighting level of 50 lux. |
| Option D – Maintenance Works in General Utilities Area | Normal operations for three LNG trains and maintenance works in the general utilities area. | Mean lighting levels of 20 lux for Trains 1, 2 and 3 and 5 lux for road lighting. General utilities area illuminated to a mean lighting level of 50 lux. |

| Scenario | Description | Model Assumptions |
|---|---|---|
| Option E – Administration Building | Administration area illuminated to normal operating levels. | Mean lighting levels of 20 lux for Administration Building. |

In addition, options A, B and C were modelled also for a vertical light spill above the plant. The results are presented as scenarios A1, B1 and C1 in the results section below.

Lighting sources were distributed in the required areas to produce the design lighting level within the plant areas. The required definition of the model output and size of the plot exceeded the models calculation grid computational capacity. As such results from individual model runs with a limited calculation grid were overlayed to develop a composite image of the predicted light contours.

## 2.3 Sensitive Environmental Receptor Locations

Table 2.2 below contains the coordinates of the five most important beaches for the flat back turtles on the east coast of BWI and the location of Double Island (Ref. 2). Of these Terminal and Bivalve beach are the closest to the Gas Treatment Plant and have been used to interpret the modelling results.

**Table 2.2**: Sensitive Environmental Location Coordinates

| Beach Name | Beach Length | Point | MGA Zone 50 | |
|---|---|---|---|---|
| | | | Easting | Northing |
| Yacht Club Beach South | 1231 | Start | 338395 | 7696414 |
| | | Mid | 338494 | 7697012 |
| | | End | 338703 | 7697589 |
| Yacht Club Beach North | 912 | Start | 338704 | 7697583 |
| | | Mid | 338831 | 7698020 |
| | | End | 338977 | 7698449 |
| Terminal Beach | 582 | Start | 340068 | 7700590 |
| | | Mid | 340261 | 7701056 |
| | | End | 340704 | 7701466 |
| Inga Beach | 1034 | Start | 339148 | 7698736 |
| | | Mid | 339236 | 7699072 |
| | | End | 339325 | 7699403 |
| Bivalve Beach | 779 | Start | 339866 | 7700363 |
| | | Mid | 339617 | 7700071 |
| | | End | 339509 | 7699714 |
| Double Island | NA | Mid | 343050 | 7705600 |

## 2.4 Modelling Assumptions and Inputs

Modelling assumptions and inputs included:

- The model was based on the Revised Proposal Gas Treatment Plant Plot Plan G1-TD-X-0000-GAD0100 (Ref.4). The MOF causeway, MOF and Jetty have not been included in the study. Flares have not been included in the study as the model cannot adequately represent flares. Areas west of the LNG Trains have less equipment per unit area and will not be as lit as the LNG Trains by comparison. These areas are also most distant from the sensitive environmental receptors specified in Table 2.2 and have therefore been excluded from the study.

- Mean to minimum lighting ratio 3:1 has been adopted as an input to the model. Thus if an average of 20 Lux is specified for an area the minimum light level allowed in the area is 6.66 Lux.

- Normal lighting in plant area has been assumed to be 20 Lux (mean) and road lighting 5 Lux (mean).

- No colour spectrum filtration of luminaries has been taken into account for the study. The lights modelled are high pressure sodium 50 Watt asymmetric reflector road lights, high pressure sodium 150 Watt floodlights and 2 x 36 Watt florescent lights.

- The lighting study has been completed modelling un-shielded luminaries.

- The administration area has been lit with asymmetric reflector luminaries and high pressure sodium 50 Watt asymmetric reflector road lights, as such no direct lighting contours will extend above the administration area.

## 2.5 Modelling Outputs

The model produces a two dimensional plot of isolux contours around the defined light sources on a single plane. To provide an estimation of light spill surrounding the plant lighting contours were projected onto a plane which is at plant grade; these are presented in Section 3 as plan projections of isolux contours.

To provide an estimation of light spill above the plant the plane has been rotated 90 degrees to provide a cross section of expected light spill above the plant, these are presented in Section 3 as elevation projections of isolux contours.

In addition, the modelling outputs do not take into account the barrier that a foredune is likely to provide between emission sources and receptors. As such the light levels as a result of direct lighting that will be experienced at the affected beach are likely to be significantly less than those predicted in the model as a result of the shielding effects of the dunes.

# 3. MODELLING RESULTS

Results of the modelling scenarios Option A, A1, B, B1, C, C1, D and E are shown in Figures 3.1 through to 3.8 respectively.

The light modelling results are summarised in Table 3.1 below:

**Table 3.1: Mean Illuminance Levels [lux] at Adjacent Beaches**

| Modelling Option | Bivalve Beach Mean Illuminance Levels [lux] | Terminal Beach Mean Illuminance Levels [lux] |
|---|---|---|
| Option A – Normal Operations | 0.04 – 0.08 | 0.03 |
| Option B – Train Maintenance | 0.04 – 0.08 | 0.04 |
| Option C – LNG Tank Rooftop Maintenance | 0.05 – 0.09 | 0.05 |
| Option D – Maintenance Works in General Utilities Area | 0.05 – 0.08 | 0.05 |
| Option E – Administration Area | approximately zero | approximately zero |

Typical natural illuminance levels (Ref. 5) are outlined in Table 3.2.

**Table 3.2: Typical Natural Illuminance Levels**

| Sky Condition | Approx. Levels of Illuminance – lux ($lm\ m^{-2}$) |
|---|---|
| Direct sunlight | $1\text{-}1.3 \times 10^{5}$ |
| Full daylight (Not direct sunlight) | $1\text{-}2 \times 10^{4}$ |
| Overcast day | $10^{3}$ |
| Very dark day | $10^{2}$ |
| Twilight | 10 |
| Deep twilight | 1 |
| Fullmoon | $10^{-1}$ |
| Quartermoon | $10^{-2}$ |
| Moonless, clear night sky | $10^{-3}$ |
| Moonless, overcast night sky | $10^{-4}$ |

In all modelled cases the light emitted by the LNG facility to the identified sensitive environmental receptors represents less light incidence than imposed by a full moon.

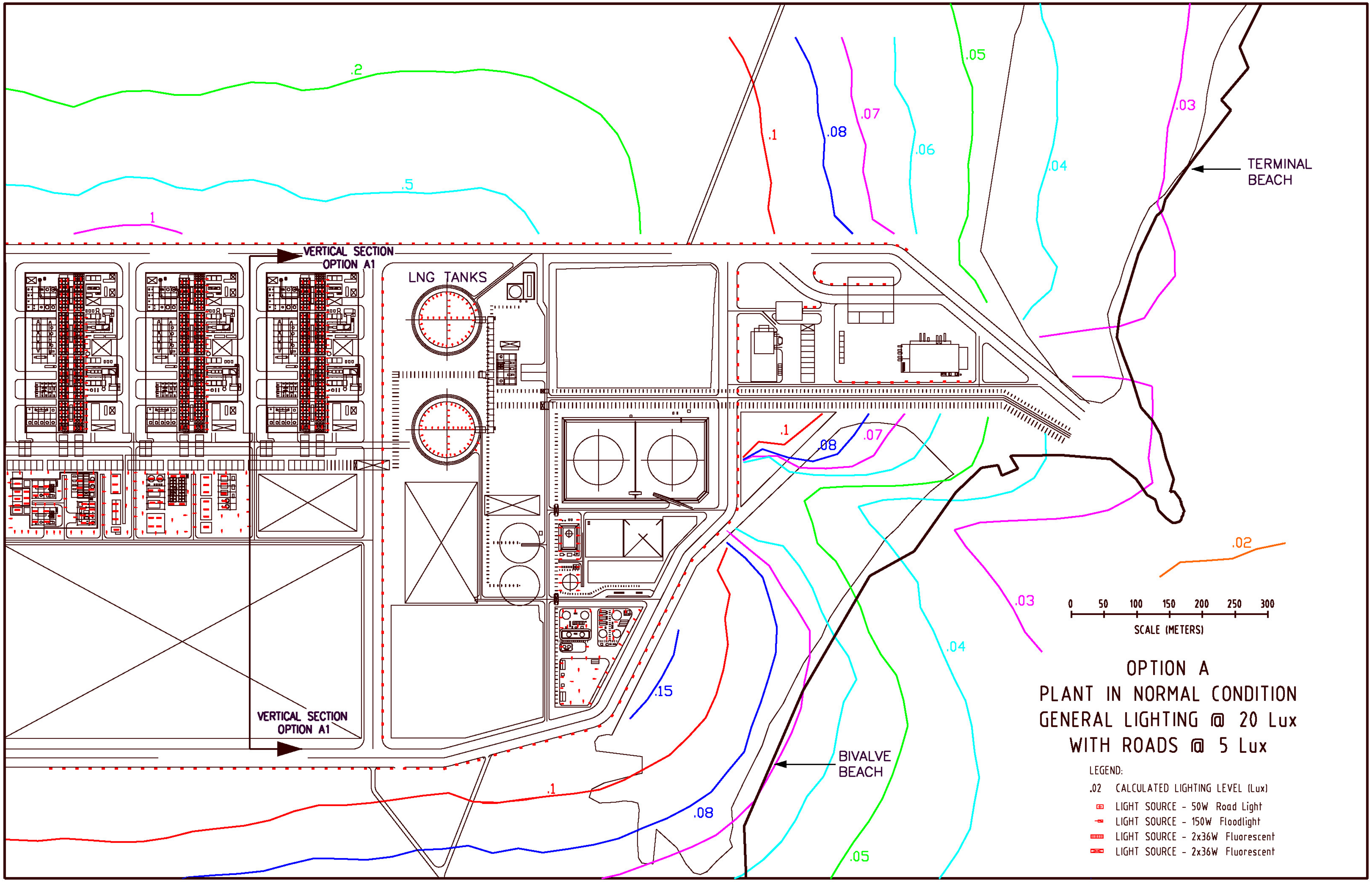



**Figure 3.1: Option A - Base Case Modelling Output**

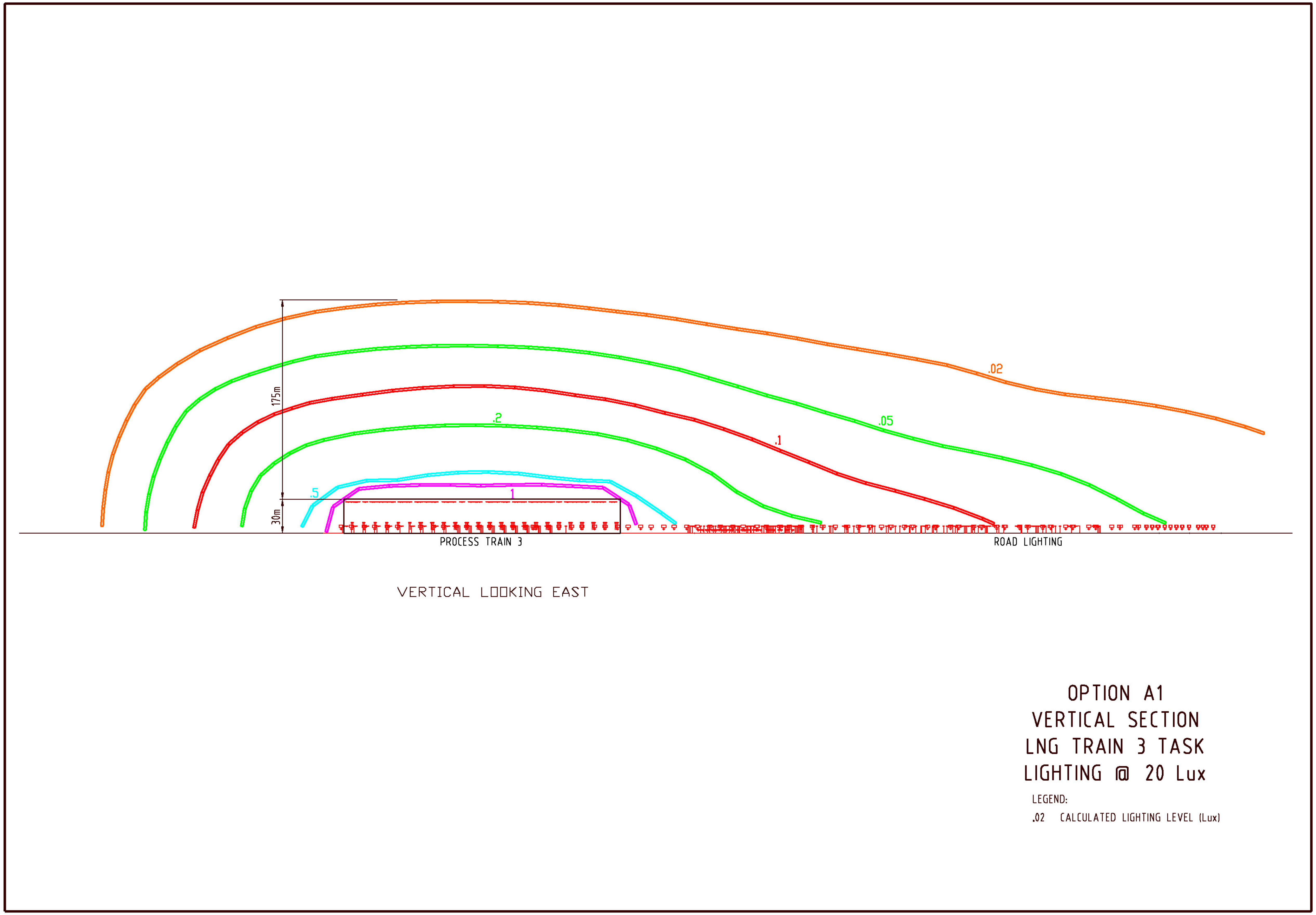



**Figure 3.2: Option A1 - Base Case Modelling Output**

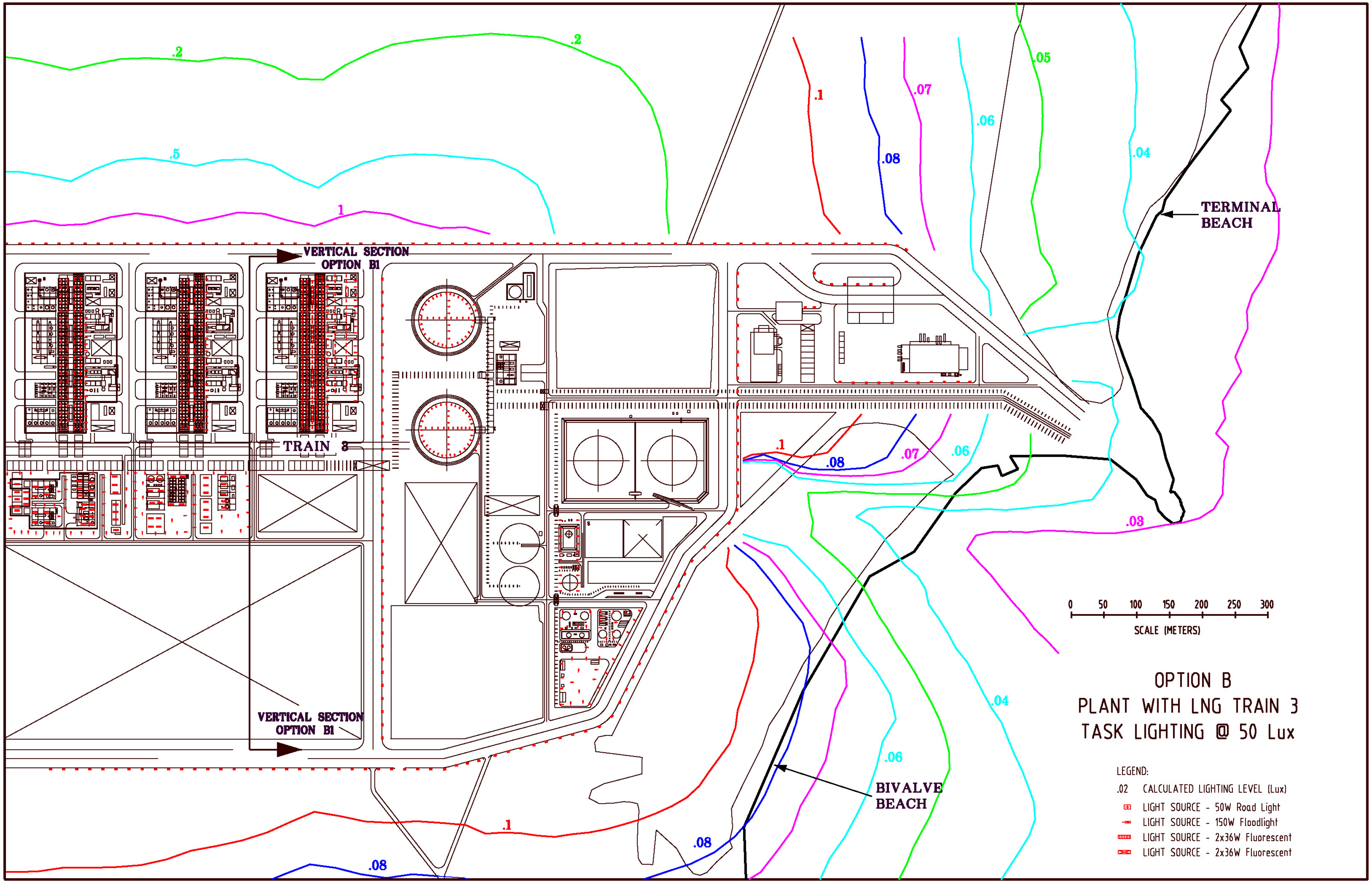



**Figure 3.3: Option B – Train 3 Task Lighting Case Modelling Output**

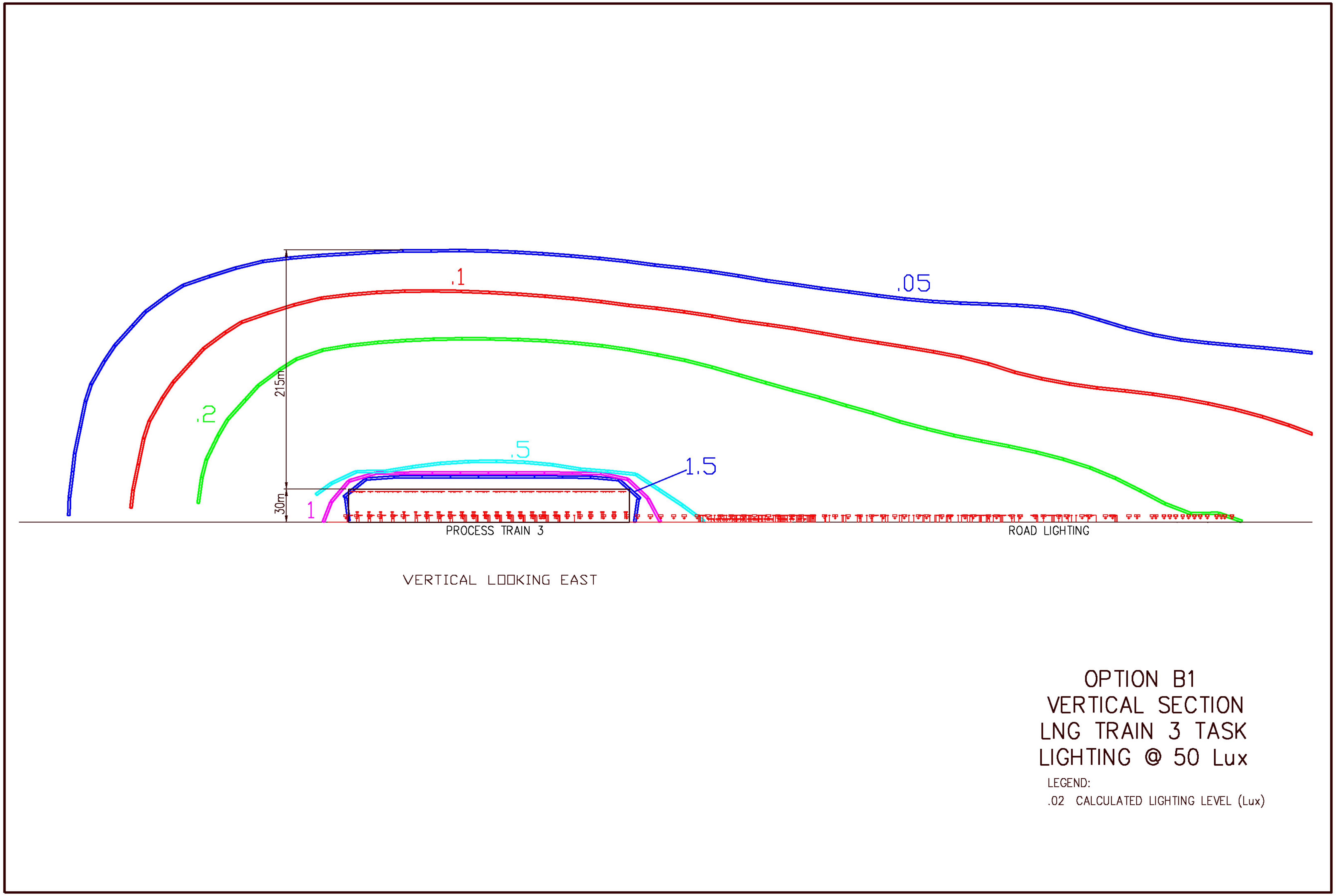
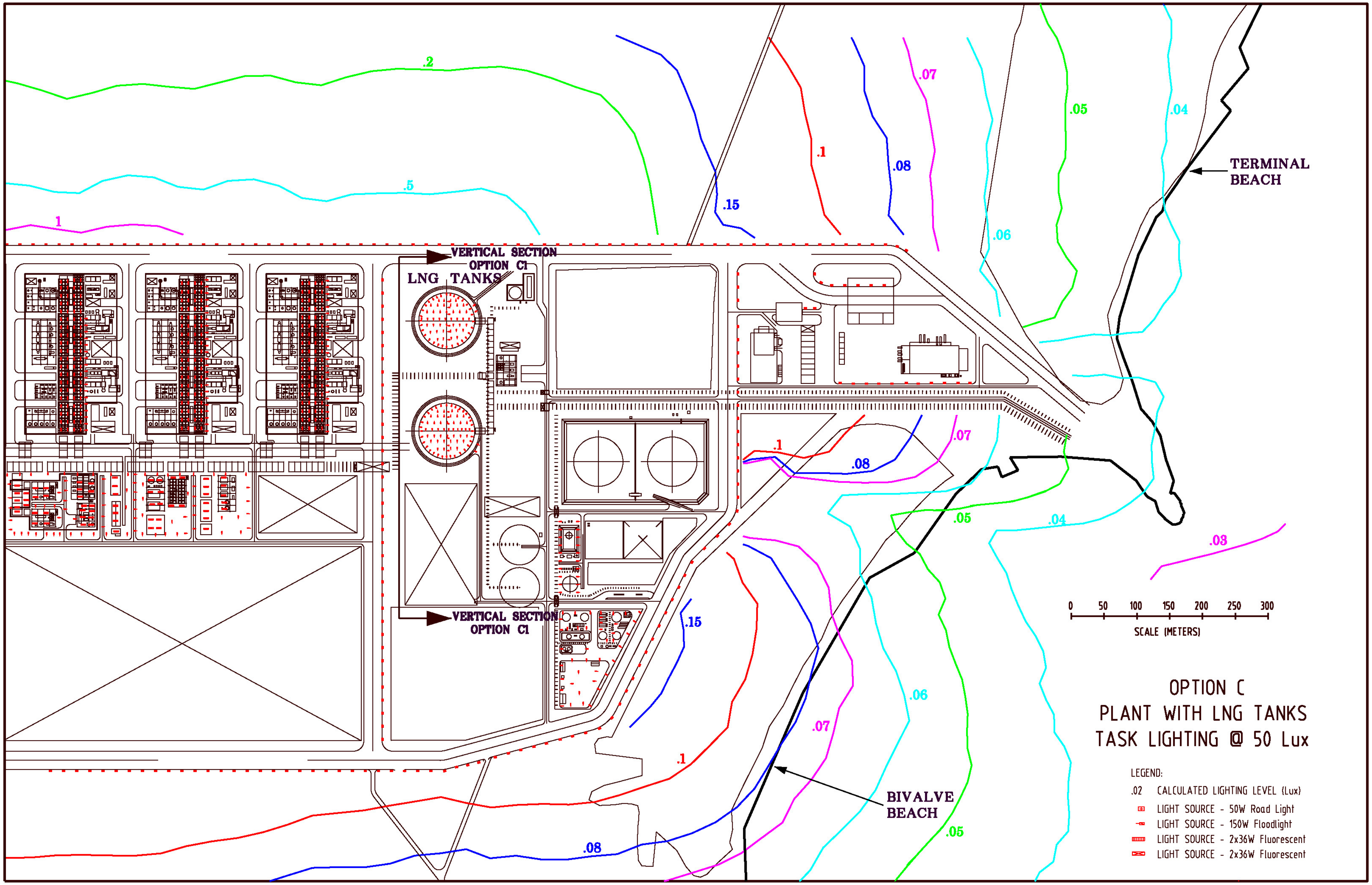



**Figure 3.4: Option B1 – Train 3 Task Lighting Vertical Section Modelling Output**

**Figure 3.5: Option C – LNG Tank**




**Task Lighting Case Modelling Output**

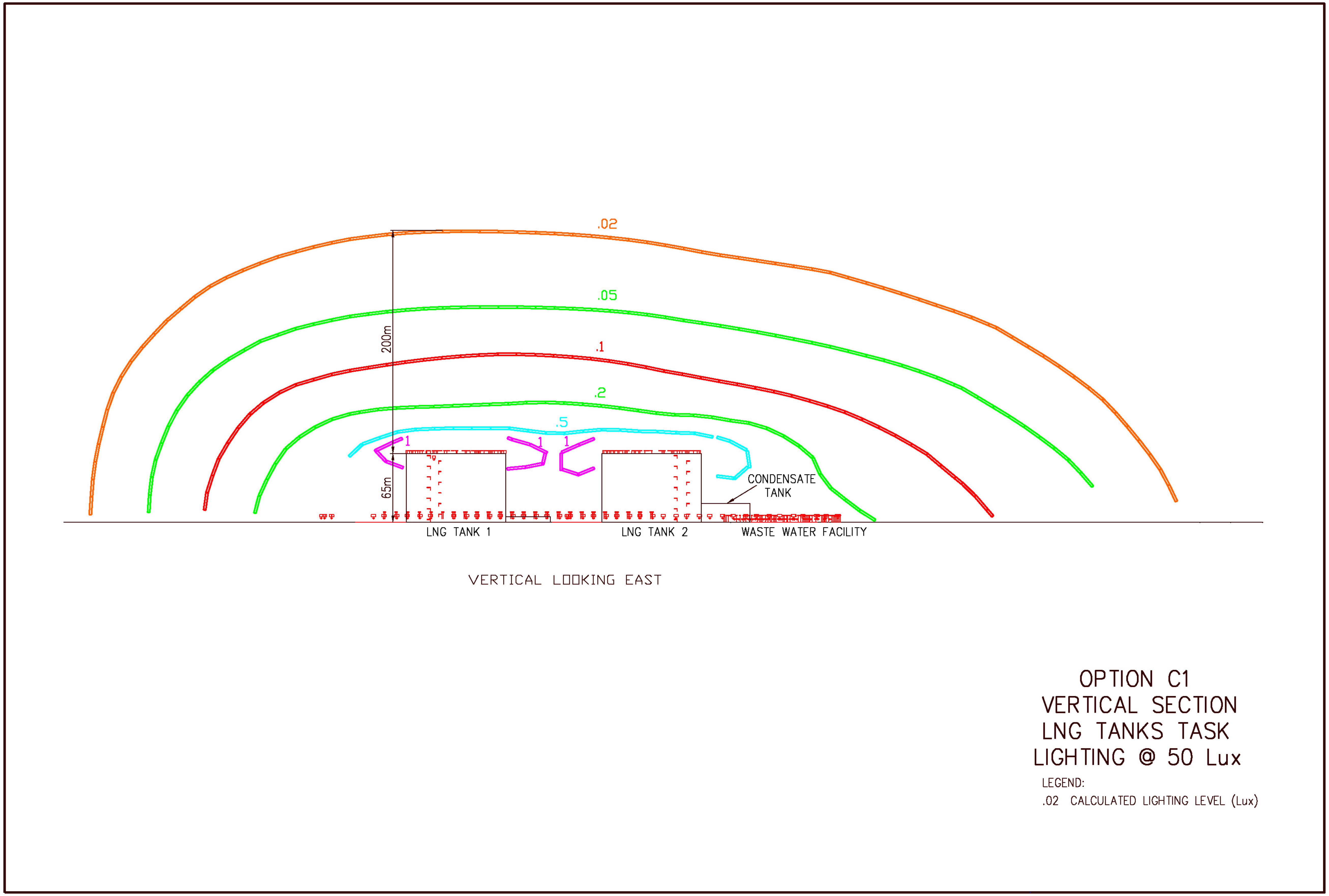



**Figure 3.6: Option C1 – LNG Tank Task Lighting Vertical Section Modelling Output**

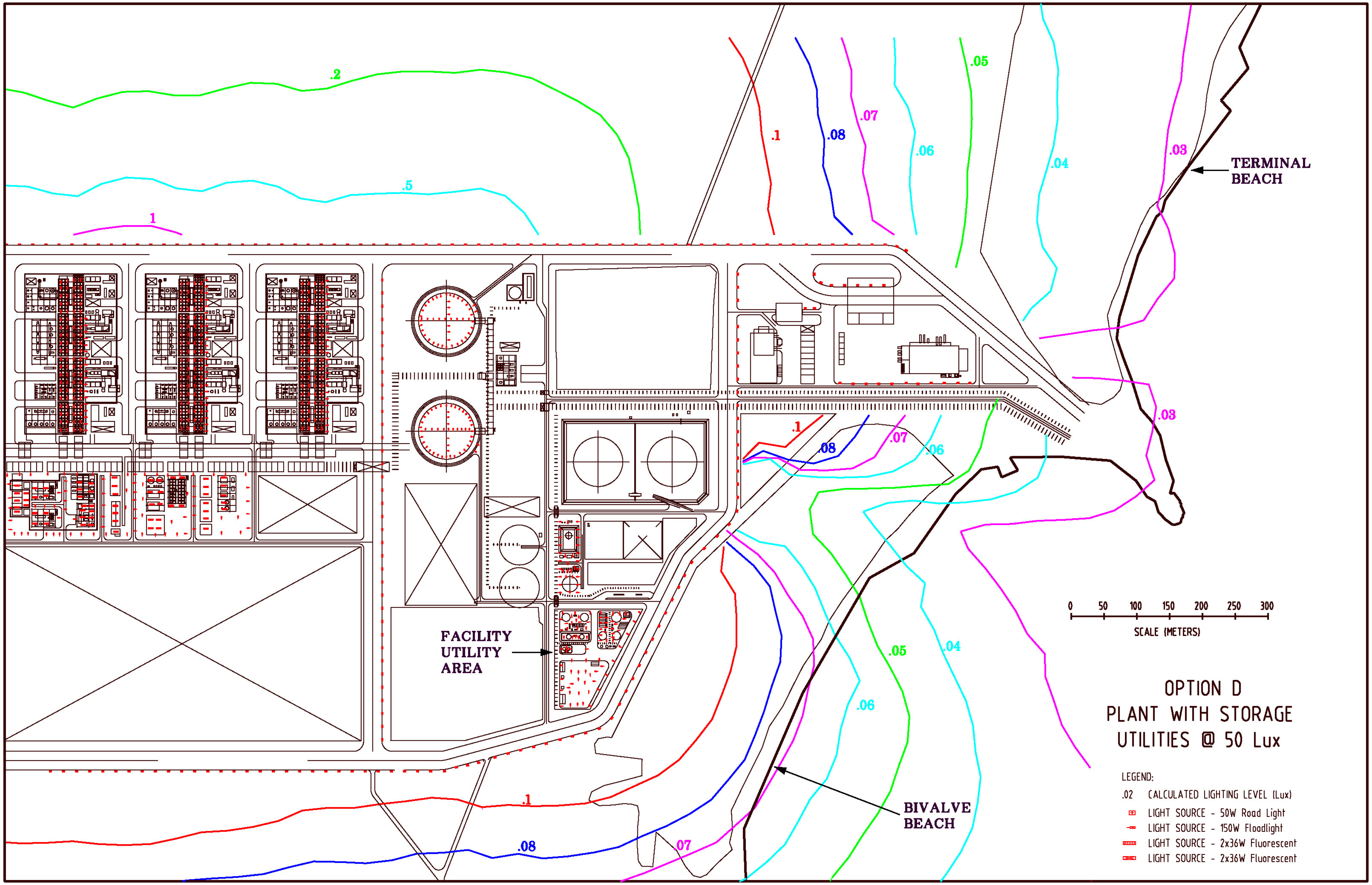



**Figure 3.7: Option D – Utilities Area Task Lighting Case Modelling Output**

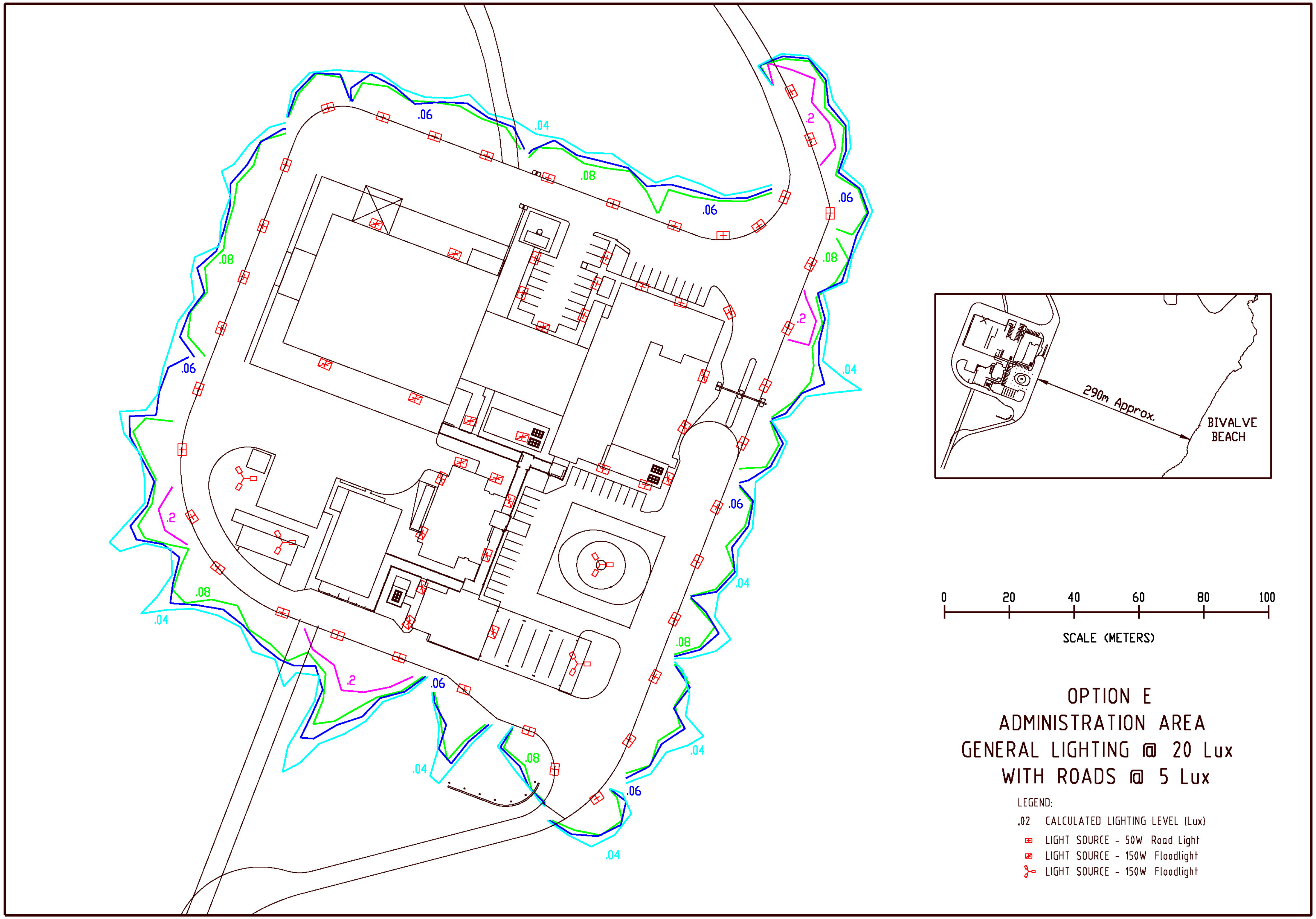



**Figure 3.8: Option E – Administration Area Lighting Case Modelling Output**

# 4. CONCLUSIONS

The light spill study modelling results indicate that normal lighting levels within the plant will result in mean illumination levels at the adjacent beaches commensurate with full to quarter moon lighting levels.

Maintenance operations for Train 3, LNG tanks and nearby utilities areas will increase lighting levels at Bivalve Beach by up to 25%, however the resultant illumination levels will still be within the range of moonlight illumination levels.

The administration area light modelling results indicate that direct illumination above the administration area will be zero and that illumination levels at the adjacent beaches as a result of the administration area lighting will be practically zero.

These modelling results have not taken into account the effects of shielding of individual lights and do not take into account any shielding effects provided by the elevation of the landscape including the elevated dune system and vegetation. It is therefore considered that these modelling results are conservative in the estimation of direct lighting impact resulting from the LNG facility.

# 5. REFERENCES

1. Chevron Australia Pty Ltd, Gorgon Project, Revised Proposal Environmental Scoping Document, EPA Assessment 1727, Doc No: G1-NT-REPX0001324;
2. Safety in Design: Incorporating Human Factors Doc No: ITC-HOC-0094W (CVX Doc No: SID-SU-5106)
3. Basis of Design for Lighting Doc No: G1-TE-E-0000-PDB0002
4. Revised Proposal Gas Treatment Plant Plot Plan, Doc No: G1-TD-X-0000-GAD0100, Rev. Q;
5. W.E.K. Middleton Vision Through The Atmosphere. University of Toronto Press, Toronto, Canada, 1952

*Attachment 1*

# CHALMIT LIGHT MODEL INPUT FILES

# OPTION A and A1 – PLANT IN NORMAL OPERATION
# NORTH AND SOUTH BEACH

## TARGET GRID SUMMARIES

Grid 1 is x-y plane at Z= 0.0 Meter faces x, y, z=1073,830,25
Limits: from x= 790.0 to x= 2790.0, from y= -200.0 to y= 1325.0
Average= 0.10 Minimum/Average=0.103
Maximum= 1.20 Minimum/Maximum=0.008
Minimum= 0.01 Number Points= 3496

## FLOODLIGHT/LUMINAIRE SUMMARY

A
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 62
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 230

B
PROTECTA Part No.502431 2X36 T8 EMERGENCY GRP.BODY Exe ATEX
Cat. Ref. PRGE/236/BI/EM Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 28 Number Locations= 28

C
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 95 Number Locations= 95
ASYMMETRICAL WIDE BEAM P.I. 24 DEG. ABOVE NADIR SAFE AREA
Cat. Ref. 844N/050/HS Lumens per lamp= 3500.0 LLF= 0.700
Mounting Height= 5m
Number Luminaires= 165
EVOLUTION-II 150W SON-T ASYMMETRIC WIDE BEAM p.I. 42 deg. Ex d ATEX 2
Cat. Ref. EV2D/150/MS Lumens per lamp= 15000.0 LLF= 0.700
Mounting Height= 6m
Number Luminaires= 282 Number Locations= 282

## Total Number Luminaires= 862

# OPTION B and B1 – TRAIN 3
# NORTH AND SOUTH BEACH

## TARGET GRID SUMMARIES

Grid 1 is x-y plane at Z= 0.0 Meter faces x, y, z=1073,830,25
Limits: from x= 790.0 to x= 2790.0, from y= -200.0 to y= 1325.0
Average= 0.12 Minimum/Average=0.084
Maximum= 1.62 Minimum/Maximum=0.006
Minimum= 0.01 Number Points= 3503

## FLOODLIGHT/LUMINAIRE SUMMARY

A
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 62
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 310

B
PROTECTA Part No.502431 2X36 T8 EMERGENCY GRP.BODY Exe ATEX
Cat. Ref. PRGE/236/BI/EM Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 28 Number Locations= 28

C
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 95 Number Locations= 95
ASYMMETRICAL WIDE BEAM P.I. 24 DEG. ABOVE NADIR SAFE AREA
Cat. Ref. 844N/050/HS Lumens per lamp= 3500.0 LLF= 0.700
Mounting Height= 5m
Number Luminaires= 165
EVOLUTION-II 150W SON-T ASYMMETRIC WIDE BEAM p.I. 42 deg. Ex d ATEX 2
Cat. Ref. EV2D/150/MS Lumens per lamp= 15000.0 LLF= 0.700
Mounting Height= 6m
Number Luminaires= 339 Number Locations= 339

## Total Number Luminaires= 999

# OPTION C and C1 – LNG TANKS
# NORTH AND SOUTH BEACH

## TARGET GRID SUMMARIES

Grid 1 is x-y plane at Z= 0.0 Meter faces x, y, z =1073,830,25
Limits: from x= 790.0 to x= 2790.0, from y= -200.0 to y= 1325.0
Average= 0.11 Minimum/Average=0.094
Maximum= 1.22 Minimum/Maximum=0.008
Minimum= 0.01 Number Points= 3498

## FLOODLIGHT/LUMINAIRE SUMMARY

A
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 62
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 230

B
PROTECTA Part No.502431 2X36 T8 EMERGENCY GRP.BODY Exe ATEX
Cat. Ref. PRGE/236/BI/EM Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 28 Number Locations= 28

C
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 163 Number Locations= 163
ASYMMETRICAL WIDE BEAM P.I. 24 DEG. ABOVE NADIR SAFE AREA
Cat. Ref. 844N/050/HS Lumens per lamp= 3500.0 LLF= 0.700
Mounting Height= 5m
Number Luminaires= 165
EVOLUTION-II 150W SON-T ASYMMETRIC WIDE BEAM p.I. 42 deg. Ex d ATEX 2
Cat. Ref. EV2D/150/MS Lumens per lamp= 15000.0 LLF= 0.700
Mounting Height= 6m
Number Luminaires= 282 Number Locations= 282

## Total Number Luminaires= 930

# OPTION D – UTILITIES
# NORTH AND SOUTH BEACH

## TARGET GRID SUMMARIES

Grid 1 is x-y plane at Z= 0.0 Meter faces x, y, z =1073,830,25
Limits: from x= 790.0 to x= 2790.0, from y= -200.0 to y= 1325.0
Average= 0.10 Minimum/Average=0.102
Maximum= 1.20 Minimum/Maximum=0.008
Minimum= 0.01 Number Points= 3504

## FLOODLIGHT/LUMINAIRE SUMMARY

A
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 62
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.5m
Number Luminaires= 230

B
PROTECTA Part No.502431 2X36 T8 EMERGENCY GRP.BODY Exe ATEX
Cat. Ref. PRGE/236/BI/EM Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 28 Number Locations= 28

C
PROTECTA Part No.500431 2X36 T8 GRP. BODY Exe ATEX
Cat. Ref. PRGE/236/BI Lumens per lamp= 3350.0 LLF= 0.700
Mounting Height= 2.3m
Distance from mounting location to photometric centre= 0.7m
Number Luminaires= 95 Number Locations= 95
ASYMMETRICAL WIDE BEAM P.I. 24 DEG. ABOVE NADIR SAFE AREA
Cat. Ref. 844N/050/HS Lumens per lamp= 3500.0 LLF= 0.700
Mounting Height= 5m
Number Luminaires= 165
EVOLUTION-II 150W SON-T ASYMMETRIC WIDE BEAM p.I. 42 deg. Ex d ATEX 2
Cat. Ref. EV2D/150/MS Lumens per lamp= 15000.0 LLF= 0.700
Mounting Height= 6m
Number Luminaires= 330 Number Locations= 330

## Total Number Luminaires= 910

# OPTION E – ADMINISTRATION AREA

## TARGET GRID SUMMARIES

Grid 1 is x-y plane at Z= 0.0 Meter faces x, y, z =440,90,5
Limits: from x= 281.0 to x= 591.0, from y= -84.0 to y= 221.0
Average= 0.07 Minimum/Average=0.000
Maximum= 5.14 Minimum/Maximum=0.000
Minimum= 0.00 Number Points= 2857

## FLOODLIGHT/LUMINAIRE SUMMARY

A
854 150W SON-T ASYMMETRIC WIDE BEAM P.I. 21 DEG. Ex n ATEX
Cat.Ref. 854N/150/HS Lumens per lamp= 15750.0 LLF= 0.700
Mounting Height= 6m
Number Luminaires= 12 Number Locations= 4

ASYMMETRICAL WIDE BEAM P.I. 24 DEG. ABOVE NADIR SAFE AREA
Cat.Ref. 844N/050/HS Lumens per lamp= 3500.0 LLF= 0.700
Mounting Height= 5m
Number Luminaires= 47

854 150W SON-T ASYMMETRIC WIDE BEAM P.I. 21 DEG. Ex n ATEX
Cat.Ref. 854N/150/HS Lumens per lamp= 15750.0 LLF= 0.800
Mounting Height= 6m
Number Luminaires= 19

## Total Number Luminaires= 78

# CHEVRON AUSTRALIA PTY LTD

# NOISE STUDY REPORT

**For The**

# GORGON PROJECT
# BARROW ISLAND LNG PLANT

Document No.: G1-TE-H-0000-REP1002

| **Revision:** | **0** | **0A** | **1** | |
|---|---|---|---|---|
| Prepared by: | Y. Davies | M. Smith | M. Smith | |
| Reviewed by: | J. Cowling | W. Seeto | W. Seeto | |
| KJV Approved by: | Dave Chapple | M. Hassett | M. Hassett | |
| CVX Approved by: | B. Frankie | | P. Chen | |
| Revision Date: | 31MAY06 | 04JUN08 | 04JUL08 | |
| Issue Purpose: | IFD | RCR | IFD | |

Kellogg Joint Venture Gorgon

KBR JGC HATCH CLOUGH

Chevron

## SUMMARY OF DOCUMENT REVISIONS

| Rev. No. | Date Revised | Section Revised | Revision Description |
|---|---|---|---|
| 0 | 31MAY06 | | For Design |
| 0A | 04JUN08 | | Revised for Client Review |
| 1 | 04JUL08 | | Revised for Client Review |
| | | | |

# TABLE OF CONTENTS

# 1. GENERAL

## 1.1 Introduction

This report documents the preliminary results and findings of the updated FEED Noise Study for the proposed 3-train Gorgon LNG project on Barrow Island, Western Australia. The basis and philosophies applied in this study are, in general, similar with those applied to the earlier 2-train study, but are updated for the current 3-train layout as depicted in the Plant Conceptual Plot Plan (G1-TD-X-0000-GA0107 Rev B). Some material from the 2-train basis work has not been updated as the conclusions are valid for both of the design bases. This material generally covers the development of the best practice ALARP noise control design, and has been attached for reference in Appendix 2.

The CVX-accepted Noise Control Basis developed for the earlier 2-train study forms the template for this 3-train study. It focuses on the assessment of predicted in-plant noise levels in terms of the compliance with the applicable worker's exposure limits from Commonwealth Government of Australia, State Government of Western Australia, and International Standards. In addition, the noise impact from the project on Barrow Island was also accessed. The Noise Control Design Basis was also evaluated in the context of the ALARP (As Low As Reasonably Practicable) Principle.

The noise study includes the prediction of operational sound pressure levels (noise contour maps) in the plant and in the sensitive areas outside the property line. Predictions are based on the best available equipment design, capacity and layout details at this point in the project Equipment noise level estimates were based on KJVG's field experience for similar design/capacity equipment.

The resulting Noise Control Design Basis documented in this report will set design parameters for the Detailed Engineering phase of the project that can be managed and enforced by CVX. This approach will yield the maximum benefit for the project in terms of providing a feasible design basis for the project that is in compliance with the applicable noise limits and follows ALARP Principle.

The noise study and this report follow the noise control design specifications detailed in project Noise Control Specification[1] and Health and Safety Basis of Design[2], which are in accordance with Occupational Safety and Health Act, 1984[3] and the Occupational Safety and Health Regulations, 1996[4], and Environmental Protection (Noise) Regulations, 1997[5].

The noise assessment has also been conducted in accordance with the requirements of the EPA Guidance Note No.8, Environmental Noise, May 2007, and with awareness of the discussion contained within the Gorgon Project EIS/ ERMP.

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[1] Project Document No. G1-TE-H-0000-SPC1001, "Noise Control Specification".
[2] Client Document No.G1-TE-H-0000-PDBX002: "Health and Safety Basis of Design", Jun. 27, 2008.
[3] West Australia Government, "Occupational Safety and Health Act, 1984.
[4] West Australia Government, "Occupational Safety and Health Regulations, 1996.
[5] West Australia Government, "Environmental Protection (Noise) Regulations, 1997

This report considers noise emissions from sources operating under normal plant operating conditions. Consequently, noise from flare operations is not included in this report. A separate flare noise study was performed for the project and reported in project document G1-TE-H-6200-REP1001[6].

## 1.2 Background

Barrow Island is located off the coast of Western Australia and is classified as a Class A Nature Reserve. There are no permanent residents on the Island. However, many protected fauna live on the Island or in the water surrounding the Island. Public access to the Island is restricted. Currently, there is only one industrial site on the Island operated by Chevron Australia PTY LTD. This site includes the production and export facilities and a camp for workers accommodation. The Chevron Australia Camp is located about 5.0 km south to the proposed Gorgon LNG site. The proposed Gorgon construction village, accommodation for construction workers during the construction phase of the LNG facilities, will be located approximately 3.6 km south from the LNG facilities site. These two sites, as shown in Fig.10, are designed to service the industry on the Island and are therefore classified as industrial premises according to Schedule 1, clauses 7 & 8, of the Environmental Protection (Noise) Regulations 1997.

## 1.3 Scope and Objectives

The scope and objectives of the noise study includes the following tasks:

1. Developing of a project noise model for the revised 3-train layout. This includes assigning noise levels for each piece of noisy equipment, locate the noise sources at the right locations on the plot plan, include the ground reflection and screening effects from in-plant buildings and tanks in the model.
2. Provide noise contour maps for in-plant areas and for specific receptors located nearby the plant.

The assumption is made that the Noise Control Design basis recommendations from the 2-train study (Appendix 2) still apply. The key noise control elements of this basis are installation of GT Enclosures [90dB(A) specification] and no enclosures proposed on compressors.

It should be noted that this report considers the noise emission from the proposed 3-train LNG facilities project only, and does not consider the effects of possible future plant expansion. It does not consider the impact from construction noise during the construction phase of the project. Neither does it consider the noise effects on the activities of the local fauna.

## 1.4 Definitions and Acronyms

**Table 1-1: Definitions & Acronyms**

| Acronym | Definition |
|---|---|
| ALARP | As Low As Reasonably Practicable |
| $L_W$ | Sound Power Level |
| $L_p$ | Sound Pressure Level |
| $L_{eq}$ Level | A-weighted Equivalent Continuous Sound Pressure Level over a measurement period |

[6] Project Document G1-TE-H-6200-REP1001, “Flare Noise Study”.

| Acronym | Definition |
|---|---|
| $L_{A10}$ Level | A-weighted Assigned Level which is not exceeded for more than 10% of the time. |
| dB(A) | Noise level measured in decibels with A-weighting system. |
| LNG | Liquefied Natural Gas |
| EEMUA | Engineering Equipment and Material Users Association |
| PNMS | Plant Noise Modeling System |
| ISO | International Standard Organization |
| MR | Mixed Refrigerant |

# 2. NOISE LIMITS

## 2.1 Project Noise Specification

Gorgon LNG Facilities project will be designed in accordance with Australian Government/Western Australian Government Regulations, and International Standards. Please refer to the project Noise Control Specification[1] for a list of relevant Australian national and international standards and regulations used in developing the project Noise Control Specification, general noise design requirements for the project, equipment noise data specification, etc.

## 2.2 In-plant Noise Requirement

The in-plant noise levels must be controlled to an acceptable level in the context of applicable employee noise exposure regulations[7]. In the project Noise Control Specification[1] the noise control philosophy and requirements for general noise design and control of the project are defined. The Australia National Exposure Standard for Noise is an equivalent sound level of 85 dB(A) averaged over an 8 hour work-shift, or 82 dB(A) averaged over an 12 hour work-shift. Noise exposure limits are intended to protect workers from hearing damage due to exposure to high noise levels. The regulations set a safe exposure limit of 85 dB(A)with a 3 dB doubling rule for exposure to higher noise levels (i.e. 88 dB(A) – 4 hours etc.). This approach obviously allows for some areas of a plant to exceed 85 dB(A), provided that plant personnel spend only short time periods (i.e. <8 hours) in these areas, with compensating time spent in lower noise areas of the plant. This allows the employees averaged noise exposure level to remain below the designated safe exposure limits.

It is not practical to design and construct the entire proposed Gorgon Facilities to comply with an in-plant noise limit of 82 dB(A), based simply on a 12 hour employee noise exposure to 82 dB(A). Experience has shown that a far more prudent approach is to use an 82 dB(A) in-plant noise limit as the primary noise control design goal and to designate, with Owner approval, areas of the plant, where this limit may not be feasible or practical, as a “Restricted Area”. In "Restricted Areas" employee noise exposure will be controlled by limiting access and the mandatory use of appropriate hearing protection.

## 2.3 ALARP Principle

The term ALARP stands for “As Low As Reasonably Practicable”. The similar term of “As Low As Practicable” is used in Australian National Occupational Health and Safety Standards 1991[8] & 2004[9] as a statutory requirement in Australia. The core part of ALARP Principle (the residual risk shall be ‘as low as reasonably practicable’) is the concept of “reasonably practicable”. This involves weighting of a risk against safety and operational, maintenance and economic considerations needed to control that risk. For the Gorgon LNG project this translates to every effort being made to reduce operational noise levels to an acceptable level that are as low as practicably feasible by practising good engineering design in the context of the overall needs of the project. This acceptable noise level should be a result of weighting between noise levels

[7] Australian Government National Occupational Health and Safety Commission, “National Standards for Occupational Noise”, NOHSC 1007 (2000), 2nd edition.
[8] Australian Government National Occupational Health and Safety Commission: “Control Guide Management of Noise at Work”, 1991
[9] Australian Government National Occupational Health and Safety Commission: “National Code of Practice for Noise management and Protection of Hearing at Work”, 3rd edition, NOHSC 2009, June, 2004

that can be tolerated, and plant operation and maintenance that can be performed safely together with the cost for implementing noise control options.

This report demonstrates that the ALARP Principle has been incorporated and exercised during the FEED Noise Study and in the final development and establishment of Noise Control Basis of Design for Gorgon LNG project.

During the initial FEED phase of a project the ALARP decisions relating to noise control tend to be focused on major noise control decisions relating to major equipment items or classes of equipment (e.g. acoustic insulation for piping). ALARP analysis for noise control must be a continuing effort throughout the project. During EPC when equipment details become better defined, decisions on specific noise abatement treatments for particular equipment items will need to be made following the ALARP Principle.

## 2.4 Property Line and Environmental Noise Limits

There are no known sensitive noise receptors on Barrow Island. Impacts of noise on native fauna populations are unknown, but project will be designed to meet human noise limits, defined in project Noise Control Specification[1], under the assumption that these limits will minimise the impact on local fauna. The project Noise Control Specification is in accordance with West Australian Occupational Safety and Health Act (1984)/ Australian Occupational Safety and Health Regulations (1996), and project HSE Noise Philosophy[2]. Thus, no environmental noise limits have been defined for the project.

The overall project property line is immediately adjacent to the process area (LNG train) battery limit. This is driven by project need to limit the land use on Barrow Island for the proposed LNG facilities (i.e. project “footprint” has to be minimised). It is impossible to meet a typical project property line limit, such as an $L_{A10}$ limit of 65 dB(A) as defined in Environmental Protection (Noise) Regulations[5] with a property line so close to process areas and major noise sources. Normally on a project of this type/size there would be a sizable buffer zone between the process areas and the property line. Thus, a property line noise limit is impractical.

The ALARP Principle is a more reasonable and cost effective guideline in minimizing the noise impact from the proposed LNG facilities on property line and the surrounding areas on Barrow Island. The project is endeavouring to minimise in-plant noise levels through application of the ALARP Principal. This will also result in the property line and environmental noise levels also being minimised.

# 3. BASELINE NOISE SURVEY

A baseline noise survey was conducted by SVT Acoustic Engineering Consultants during January 20 to February 10, 2004. The baseline survey data, shown in Table 3-1 below, were documented in "Noise Impact Assessment for the Gorgon Development Project", prepared for the draft EIS/ERMP report, submitted to Australia Government Agencies in 2005. See Fig.1 for the LNG Plant location and locations surveyed on Barrow Island.

Note that these levels were calculated from $L_{eq}$'s averaged at 15 minutes in the above specific time period from the two-week continuously recorded measurements.

**Table 3-1: Background Noise Levels**

| Location | $L_{90}$ Levels, dB(A) | | |
|---|---|---|---|
| | 0700-1900 hrs Mon. – Sat. | 1900-2200 hrs Mon. – Sat.<br>0900-2200 hrs on Sun. | 2200-0700 hrs Mon. - Sat.<br>2200- 0900 hrs on Sun. |
| Existing CVX Camp (3) | 50.0 | 50.0 | 49.5 |
| Proposed LNG Plant Site | 30.0 | 24.5 | 23.5 |
| T-Tree | 30.5 | 36.5 | 30.5 |
| Flacourt Bay | 40.2 | 42 | 41.5 |

# 4. NOISE MODELING AND EQUIPMENT NOISE LIMIT

## 4.1 Noise Modeling

KJVG has proprietary Plant Noise Modeling System (PNMS) software, which combines with commercial software (SoundPlan) for the development of the plant noise models and the prediction of in-plant and surrounding environmental sound pressure levels near the plant site. The PNMS software follows the prediction methodology defined in EEMUA[10] (the oil companies' European organization for environmental and health protection) and ISO 9613-2[11] and is used to assemble a matrix of Sound Power Level input data. The SoundPlan software then uses this PNMS data to calculate and graphically present both in plant and community noise levels nearby the plant. Both in-plant noise and community noise predictions are performed using the ISO 9613-2 prediction method.

Model assumptions/inputs are summarised below:

- Ground absorption – It was assumed that an acoustically "hard" ground is present for all areas over which sound is propagating (as identified in EPA Guidance Note No.8). The accuracy of this assumption for Barrow Island conditions shall be confirmed in future work;
- Air absorption – The model assumes air absorption based on ISO 9613-1 data;
- Barriers - LNG Storage Tanks (35m elevation) and Condensate Storage Tanks (15m elevation) were included in the model as barriers to sound propagation; and
- Plant site topography – Topographical information for the plant was included in the model and obtained from the "Proposed Terrace Levels" Plot Plan (Project Document No. G1-TD-C-6300-GRD1000 Rev C). In-plant sound pressure level predictions were based on a Model grid spacing of 1m resolution (for the units) and 10m resolution for the overall plant.
- Topography between LNG Plant and sensitive receptors – there are no major terrain undulations between the LNG Plant and sensitive receptor locations. Photos included in Appendix 1 Figure A-8 confirm that the terrain is relatively flat when viewing toward the south from the proposed plant location. Therefore, for modelling purposes it was assumed that the terrain contours are simply an interpolation between LNG Plant elevations and receiver elevations (16.5m).

The following meteorological conditions were also assumed:

- Temperature – 15°C (guidance taken from EPA Guidance Note No.8);
- Relative Humidity – 50% (guidance taken from EPA Guidance Note No.8);
- Atmospheric conditions – the ISO-9613 methodology implicitly assumes a sound propagation "worst case" atmospheric condition exists (temperature inversion); and
- Wind conditions – the ISO-9613 methodology implicitly assumes a sound propagation "worst case" wind condition exists, this being that the receiver experiences "moderate downwind conditions".

It should be noted that equipment specification and layout assumptions in the model are based on currently available information. In some situations, assumptions have not been revised since the 2-train study work, and consequently are assumed to remain valid. It is, however, expected

[10] Engineering Equipment Material Users Association (EEMUA), Publication No. 141 "Guide to the use of Noise Procedure Specification" (formerly OCMA Specification No. NWG 3, Rev 2).

[11] International Standard ISO 9613-2: Acoustics-Attenuation of Sound during Propagation Outdoors, part 2: General Prediction Method, 1996 (E).

that the model will require updating once revised data is made available (i.e. mechanical equipment lists, unit plot plans, etc).

## 4.2 Equipment Noise Data

Equipment noise limits for the project were based on a general requirement of 82 dB(A) @ 1 meter from equipment casings or surfaces, with the exception of air coolers, where the limit is 85 dB(A) @ 1 meter underneath of the fan. The relaxation of noise limit to 85 dB(A) for air coolers was decided early in the project to limit plot space for cooler platform. The reasoning behind this decision will be discussed later in this report.

The equipment noise levels in the model were estimated based on normally accepted noise levels of the installed standard noise control and KJVG's previous project field experiences, typical for facility of this design/capacity at normal operational conditions. The development of the project noise model drew heavily upon KJVG's previous project and field experience for similar design/capacity equipment in operational LNG plants.

Note that these noise levels are the levels for typical equipment without any additional noise control, other than those normally included in the package. For example, a compressor with gas turbine drive package, the estimated noise level for the compressor would be based on noise level without compressor enclosure and the gas turbines with a standard on-skid enclosure at 90 dB(A) @ 1 meter from the turbine surface.

The plant noise model for the project was developed based on the available equipment load, design, and layout data along with estimated noise data from field and previous project experience. The noise model included the following noise sources:

- Pumps and drivers
- Compressors and drivers
- Expanders
- Compressor suction/discharge/recycle piping and the connected piping
- Air coolers
- Generators and drivers
- Fired Heaters
- Fans and Blowers
- Downstream piping from noisy control valves

Table 4-1 shows the estimated sound power levels of major equipment and significant noise contributors from this project used in the noise model.

The model only considers noise sources that are deemed to be continuously operating during normal LNG Plant Operations. Infrequent or intermittently operating equipment (i.e. fresh / sea water fire pumps, diesel emergency power generators) and standby units are assumed not to contribute to plant noise.

It should be noted that the noise contributions from control valves and their downstream piping were not included in the noise model. They will be included when the project proceeds to detailed engineering phase and valve data becomes available.

While noise contribution from control valves may impact some localized in-plant noise contours, their effects on the overall plant noise maps are expected to be minimal. The majority of control valves for the project will be purchased in compliance with the defined 82 dBA @ 1 meter limit. Any noisy control valves, where the compliance with 82 dB(A) is an issue, will be considered for acoustic insulation during Detailed Engineering to ensure the control valves noise is adequately controlled and does not adversely affect overall plant noise levels.

The equipment noise levels assumed in the noise model are estimates based on KJVG's experience with similar type/capacity equipment. The review and verification of these estimates will be required as vendor noise data on the project becomes available (in accordance with normal procedures and the guidelines detailed in project Noise Control Specification[1]). This noise data review will typically take place as the project proceeds through Detailed Engineering, and more equipment-specific and accurate vendor data becomes available.

The noise model will be updated when major changes in plot layout occur or most of vendor noise data are available.

**Table 4-1: Summary of Normal Operational Sound Power Levels for Major Equipment**

| Equipment | Plant Area | Sound Power Level, dB(A) | Comments |
|---|---|---|---|
| Air Coolers | LNG Trains 1,2&3 | 95 /fan | Total sound power level of 119 dB(A) per train. Fan elevations = 20m |
| Air Coolers | $CO_2$ Re-injection Area | 95 /fan | Total sound power level TBA. Fan elevations = 7m |
| Air Coolers | AGRUs | 95 /fan | Total sound power level TBA. Fan elevations = 6m |
| Propane Compressor | LNG Trains 1,2&3 | 117 | Per Train - Including two propane compressors and HP MR compressor |
| Propane Compressor G/T driver | LNG Trains 1,2&3 | 117 | Per Train - Including G/T drive, intake/exhaust ducting, intake silencer |
| Propane/Mr G/T Exhaust Stack | LNG Trains 1,2&3 | 102 | Per Train. Stack height = 35m |
| Propane Help Motor | LNG Trains 1,2&3 | 109 | Per Train |
| MR Compressor Train | LNG Trains 1,2&3 | 112 | Per Train - Only includes LP MR Compressor |

| Equipment | Plant Area | Sound Power Level, dB(A) | Comments |
|---|---|---|---|
| MR Compressor G/T driver | LNG Trains 1,2&3 | 117 | Per Train - Including G/T drive, intake/exhaust ducting, intake silencer |
| MR Exhaust Stack | LNG Trains 1,2&3 | 102 | Per Train. Stack height = 35m |
| MR Help Motor | LNG Trains 1,2&3 | 109 | Per Train |
| End Flash Gas Compressor | LNG Trains 1,2&3 | 112 | Per Train |
| Motor and Gear for End Flash Gas Compressor | LNG Trains 1,2&3 | 113 | Per Train |
| Compressor suction/discharge piping | LNG Trains 1,2&3 | 119 | For all compressors/per LNG train |
| Stabilizer Overhead Compressor and Motor | Inlet | 106 | |
| Regeneration Gas Compressor & Motor | LNG Trains 1,2&3 | 102 | Per Train |
| LNG Expander | LNG Trains 1,2&3 | 106 | Per Train |
| MR Expander | LNG Trains 1,2&3 | 106 | Per Train |
| DOM Gas Export Compressor and driver | DOM Gas Compression and Export | 116 | |
| LP Fuel Gas Compressor & driver | Fuel Gas Area | 111 | |
| Instrument Air Compressor | Utilities | 112 | Per compressor |

| Equipment | Plant Area | Sound Power Level, dB(A) | Comments |
|---|---|---|---|
| MEG Flash Vapor Compressor | MEG Injection and Regeneration | 104 | |
| $CO_2$ re-injection Compressor | $CO_2$ Re-injection Area | 113 | Per compressor |
| Gas Turbine Generator | Generation Area | 116 | Per generator |
| LNG BOG Compressor | LNG BOG Area | 116 | |
| LNG BOG Recycle Compressor | LNG BOG Area | 116 | |
| Wellhead Injection Pump & driver | Inlet | 107 | |
| LNG Rundown Pump & Drive | LNG Train 1 & 2 | 105 | Per Train |
| Lean Amine Pump & Motor | AGRUs | 110 | Information based on Gorgon AGRU (2-train case) PWLs. To be updated for 3-train scenario during Detailed Design |
| Lean Amine Boost Pump & Motor | AGRUs | 105 | Information based on Gorgon AGRU (2-train case) PWLs. To be updated for 3-train scenario during Detailed Design |
| Condensate Loading Pump & Motor | LNG Storage & Loading | 107 | |
| Hot Oil Pump & Motor | Fuel Gas Area | 107 | For 3-train scenario, hot water replaces hot oil. Small increase in sound power may result |
| Hot Oil Recirculation Pump & Motor | Fuel Gas Area | 106 | For 3-train scenario, hot water replaces hot oil. Small increase in sound power may result |

| Equipment | Plant Area | Sound Power Level, dB(A) | Comments |
|---|---|---|---|
| Tempered Water Circulation Pump & Motor | Fuel Gas Area | 107 | |
| LNG BOG Compressor and Drive | BOG Area | 115.6 | |
| LNG BOG Recycle Compressor and Drive | BOG Area | 115.6 | |

## 4.3 Specification of Acoustic Insulation Class Systems

Acoustic insulation systems are usually classified as A, B, C, D systems. Refer to ISO standard 15665[12] Table 5 in Section 9.1 for descriptions of classes A, B and C systems. Below is a summary of brief descriptions of these classes.

**1)** Class A: minimum thickness of 50 mm (2") porous layer with max. stiffness of 2.0 x$10^6$ kg/$m^2$. The outer metal cladding (or mass loaded vinyl) shall have a minimum mass per unit area of 4.5 kg/$m^2$ (i.e., 0.6 mm steel plate).

**2)** Class B: minimum thickness of 100 mm (4") porous layer with max. stiffness of $10^6$ kg/$m^2$. The outer metal cladding (or mass loaded vinyl) shall have a minimum mass per unit area of 6.0 kg/$m^2$ (i.e., 0.8 mm steel plate).

**3)** Class C: minimum thickness of 100 mm (4") porous layer with max. stiffness of $10^6$ kg/$m^2$. The outer metal cladding (or mass loaded vinyl) shall have a minimum mass per unit area of 7.8.0 kg/$m^2$ (i.e., 0.8 mm steel plate) for pipe diameter < 300 mm (12") and 10.0 kg/ $m^2$.(i.e., 1.3 mm steel plate) for pipe diameter >=300 mm (12").

**4)** Class D (high temperature service): same with Class C, except there is an intermediate cladding of minimum mass per unit area of 6.0 kg/$m^2$ between the two 50 mm porous layers for pipe diameter >= 300 mm (12").

**5)** Class D (low temperature service): 25mm (1") closed-cell elastomeric foam, 25mm (1") open-cell elastomeric foam, 25mm (1") open-cell elastomeric foam, 4mm acoustic barrier jacket, 25mm (1") closed-cell elastomeric foam, 2mm flexible polymeric outer cladding.

[12] International Organization of Standardization (ISO) 15665: "Acoustics-Acoustic Insulation for pipes, valves and flanges", 1st edition, August 15, 2003

Note that there is no Class D insulation system in ISO 15665. However, Class D insulation system is widely used in the industry, especially for LNG plants.

In addition, a Class D system for low temperature service has been specifically developed for low temperature systems to minimise corrosion under insulation issues.

The actual acoustic insulation system used in the piping systems, sometimes, may be slightly different from the above descriptions. When an acoustic insulation system is combined with thermal insulation system, the acoustic performance may be increased due to thermal insulation materials. The details on material requirements for each of the above acoustic insulation systems, insulation code used in the project corresponding to each of the classes, and, finally, the insulation installation procedures and requirements are described in project documents [13 & 14].

# 5. RESULTS DISCUSSION

## 5.1 Discussion of In-plant Noise

Large rotating machinery sources such as Gas Turbine Generators and Drivers, and Compressors are predicted to dominate contributions to in-plant noise.

Based on the Noise Control Design Basis, outlined in Section 6, the predicted sound pressure levels have been determined, and are shown in the following figures included in Appendix 1:

Fig. A-2 - The predicted overall Gorgon LNG Facility sound pressure levels;

Fig. A-3 - The predicted in-plant sound pressure levels in LNG Train 1 area;

Fig. A-4 - The predicted in-plant sound pressure levels in the Power Generation area; and

Fig. A-5 - The predicted sound pressure levels at specific Noise Receptors.

These contour maps were calculated at an elevation of 1.5 m above grade (i.e. ear level height of Plant Operations Personnel).

Detailed noise contour maps for units such as Acid Gas Removal Units (AGRUs), CO2 Reinjection area, Boil-off Gas (BOG) Compression areas, and elevated compressor and air-cooler platform areas should be produced at Detailed Design Phase once the layout of the units is finalised and Unit Plot Plans are available.

## 5.2 Discussion of Plant Noise impact on community receptor locations

Low frequency noise sources with significant sound power output such as air coolers and compressor piping are expected to make the dominant contributions at sensitive community receptor locations.

[13] Project Document # G1-TE-L-0000-0011: “Specification for Installation for High Temperature Insulation”.
[14] Project Document # G1-TE-L-0000-0013: “Specification for Installation for Low Temperature Insulation”.

Predictions of noise at specific locations nearby to the LNG Facility are provided in Table 5-2 below. A comparison between the 2-train and 3-train study results is included. It should be noted that these predictions do not consider the ambient noise level conditions, and in some situations LNG Plant noise contribution maybe be negligible in comparison with background noise levels.

**Table 5-2: The Predicted Environmental Sound Pressure Levels**

| Location | The Predicted Sound Pressure Levels, dB(A) | |
|---|---|---|
| | 3-train study | 2-train study |
| LNG Plant Offices | 60.7 | 54.0 (approx) |
| Gorgon Construction Village | 46.8 | 38.0 |
| Existing Chevron Camp | 42.3 | 36.0 |

These revised predictions are somewhat higher (6-8dB) than those identified in the 2-train FEED Noise Study work, with the change in ground absorption assumptions (detailed further below) having the greatest impact.

The increase in predicted Sound Pressure Levels is due to several factors:

- increase in sound power level of the plant due to contributions of the additional LNG train, AGRU, and CO2 re-injection compressor;
- change of assumptions for the ground type over which sound is propagating. It is now assumed that an acoustically "hard" ground is present for all areas over which sound is propagating, which is in accordance with noise level prediction methodology outlined in Section 5.2.3 of the Guidance for the Assessment of Environmental Factors No.8 document.[15] Accuracy of this assumption for Barrow Island conditions shall be confirmed in future work; and
- small change in temperature and humidity assumptions to align with requirements outlined in Section 5.2.3 of the Guidance for the Assessment of Environmental Factors No.8 document.

It should also be noted that the ISO 9613-2 method utilised for modelling of sound propagation at remote receptor locations assumes a worst case meteorological scenario, where conditions are favourable for sound propagation. This scenario involves the receiver experiencing "…moderate downwind conditions…" under temperature inversion conditions which promotes refraction of sound towards the ground (conditions typically experienced during the evening). This assumption is also in accordance with noise level prediction methodology outlined in Section 5.2.3 of the Guidance for the Assessment of Environmental Factors No.8 document.

Due to the prevailing wind directions being SSW (October – March) and E (April – September), it is not expected that the worst case wind direction (i.e. Northerly) will be experienced on a regular basis.

[15] Environmental Protection Authority (EPA), Draft Publication No. 8 "Guidance for the Assessment of Environmental Factors – Environmental Noise", May 2007.

# 6. NOISE CONTROL DESIGN BASIS

The noise control design basis is aligned with the basis outlined in the 2-train FEED Noise Report, which was previously accepted by CVX. This philosophy is reiterated below:

- All compressor suction/discharge/recycle piping and connected piping are to be insulated with the Class D acoustic insulation system. The lines that require the acoustic insulation were marked on P&ID's and have submitted to the project. These lines now have the correct insulation code on current P&ID's.
- In-line silencers on compressor suction and discharge piping are **not** recommended.
- Acoustic enclosures at 90 dB(A) at 1 meter from the equipment surface for gas turbine drives for Mixed Refrigerant Compressors and Propane Compressors are recommended.
- No enclosures on compressors and expanders are recommended.
- Acoustic enclosures @ 90 dB(A) at 1 meter from equipment surface on gas turbine drives for generators are recommended.
- No enclosures on generators themselves are recommended.
- Enclosures on large pumps are not recommended in FEED stage. Review of large horse power pumps will take place when vendor noise data becomes available. Decision on whether the enclosure is needed will be made after the review with client's approval.
- Compressor gas turbine drive and generator gas turbine drive intake/exhaust ducting are to be acoustically insulated with Class D acoustic insulation. This acoustic insulation system class is generally regarded as representing the best available system with proven performance in the hydrocarbon process industry.
- Exhaust silencers required for gas turbine drives of generators.
- Vibration isolation pads, such as Fabreeka or equivalent, are recommended on compressor suction/discharge pipe supports to reduce the noise radiation from pipe supports.
- Low noise type air coolers not exceeding sound pressure level of 85 dB(A) per fan 1 meter below fan center are recommended.
- Acoustic insulation of Class D for intake ducting and discharge piping of air compressors
- Inlet silencers for the gas turbines of MR and Propane compressors;
- Exhaust silencers required for gas turbine drives of MR and Propane compressors;
- Inlet silencers for generator gas turbine drives are recommended;
- Noisy control valves, if any, and compressor recycle valves and their downstream piping are to be insulated with the same acoustic insulation system.
- Recommended "Restricted Areas" which is detailed in the Section 7.

- Personnel hearing protection is mandatory in the recommended “Restricted Areas” in the plant, where sound pressure levels exceed 85 dB(A), with client’s approval.

- Noisy control valves will be identified once the valve vendor noise data are available.

These noise control abatements, in conjunction with the recommended in-plant “Restricted Areas”, defined later in this report, form the “Best Practice” Noise Control Design Basis for the project.

## 7. RECOMMENDATION FOR "RESTRICTED AREAS"

The predicted in-plant noise levels with the recommended Noise Control Design Basis are consistent with KJVG experience and are typical for a facility of this size/capacity. In this context, the plant work areas with noise levels predicted to exceed 82 dB(A) are recommended for designation as "Restricted Areas". Where appropriate warning signs are erected and hearing protection is to be used.

The full extent of these "Restricted Areas" will be determined during EPC, as detailed design information (e.g. actual equipment noise data, piping routing, control valve noise data etc.) becomes available.

## 8. CONCLUSIONS AND RECOMMENDATIONS

This report has presented the findings and recommendations of the noise study for Gorgon LNG project. It has established the most feasible and practical Noise Control Design Basis for the project. The resulting Noise Control Design Basis will set design parameters for Detailed Engineering that can be managed and enforced by the facility owner.

The following recommendations are made based on the noise study work:

1) The recommended Noise Control Design Basis presents the most effective noise abatements for an LNG plant of this type/capacity.
2) The most effective acoustic insulation system, Class D insulation system, regarded as the best insulation system on the market for LNG plant and power plant applications, should be installed on all compressor suction/discharge/recycle and the connected piping as piping noise dominates.
3) Use of compressor enclosures on compressors can reduce the in-plant noise near the compressors but have less effect on the areas outside of the plant. Enclosures on compressors also present the access problem for equipment safety and maintenance.
4) Noise contribution from Air coolers can be significant. It is recommended to use low noise type of air coolers of sound pressure level of 85 dB(A) or less per fan.
5) The predicted in-plant noise levels are typical and consistent with KJVG's experiences for this type/capacity of an LNG plant.
6) The "Best Practice" Noise Control Design Basis, established in this report, is consistent with ALARP Principle.

# 9. NOISE CONTROL EXECUTION PLAN IN EPC PHASE

## 9.1 Noise Control Execution Plan

As specified in Project Noise Control Specification[1], during the EPC phase, the following tasks will take place:

1) When vendor indicates that the required equipment noise levels specified in equipment noise data sheet can not be met, project will involve noise specialist to discuss and decide what noise levels are acceptable and what control measures will be used with owner's approval.
2) The preliminary noise report will be updated from time to time as vendor noise data is received and evaluated or any changes in plot layout that affects the noise source location.
3) When all relevant items of equipment have ordered, a final noise report will be prepared. This report will include:
   a) List all equipment noise received as sound power levels.
   b) Indicate the final form of the noise control measures
   c) Estimate the noise levels in work areas and, where relevant, in neighbourhood areas or accommodation
   d) Indicate all areas of the plant which will be designated as "Restricted Areas" with approval by the Owner.

## 9.2 Acceptable Equipment Noise Levels

In generally, 82 dB(A) or less at 1 meter from equipment surface, defined in the project Noise Control Specification, will be the acceptable noise level, with the exception of air coolers, where 85 dB(A) /per fan is specified instead of 82 dB(A) in the equipment noise data sheet for the reasons discussed in these report.

However, when vendor indicates that his equipment will not meet 82 dB(A), specified in the equipment noise data sheet, the acceptable noise level, in this case, is determined in a case by case basis. Under such situations, the acceptable noise levels can be different depending on type/capacity of equipment. It is significant to point out that the final decision of the acceptable noise level for a particular piece of equipment or package will be determined by CVX. KJVG's responsibility is to present and provide all data and information to CVX in assisting client to determine the acceptable noise level for a particular piece of equipment. This decision, in KJVG's opinion, should be made based upon the considerations and weighting of the following, but not limited to, factors:

a) ALARP Principle;
b) Cost associated with additional noise control, other than standard, to reduce equipment noise level;
c) The actual noise reduction achieved by adopting the additional noise control abatement. Care must be taken in assessing the vendor claimed noise reduction due to additional noise control he proposes. For example, vendor may claim 10 dB(A) sound pressure level

reduction by using an enclosure on compressor. However the actual reduction in sound power level, which is the number used in all noise calculations, is definitely less than 10 dB(A) due to the increased noise radiation area by the use of enclosure, as the noise radiating area will be the total enclosure area instead of the total equipment surface area.

d) Equipment accessibility for maintenance and equipment operation issue and safety related issues due to additional noise control abatement;

e) Influence of the total plant sound power level from noise reduction in an equipment package by using additional noise control abatement;

f) Other factors, such power loss, fire hazard, etc.

# *Appendix 1*

# FIGURES

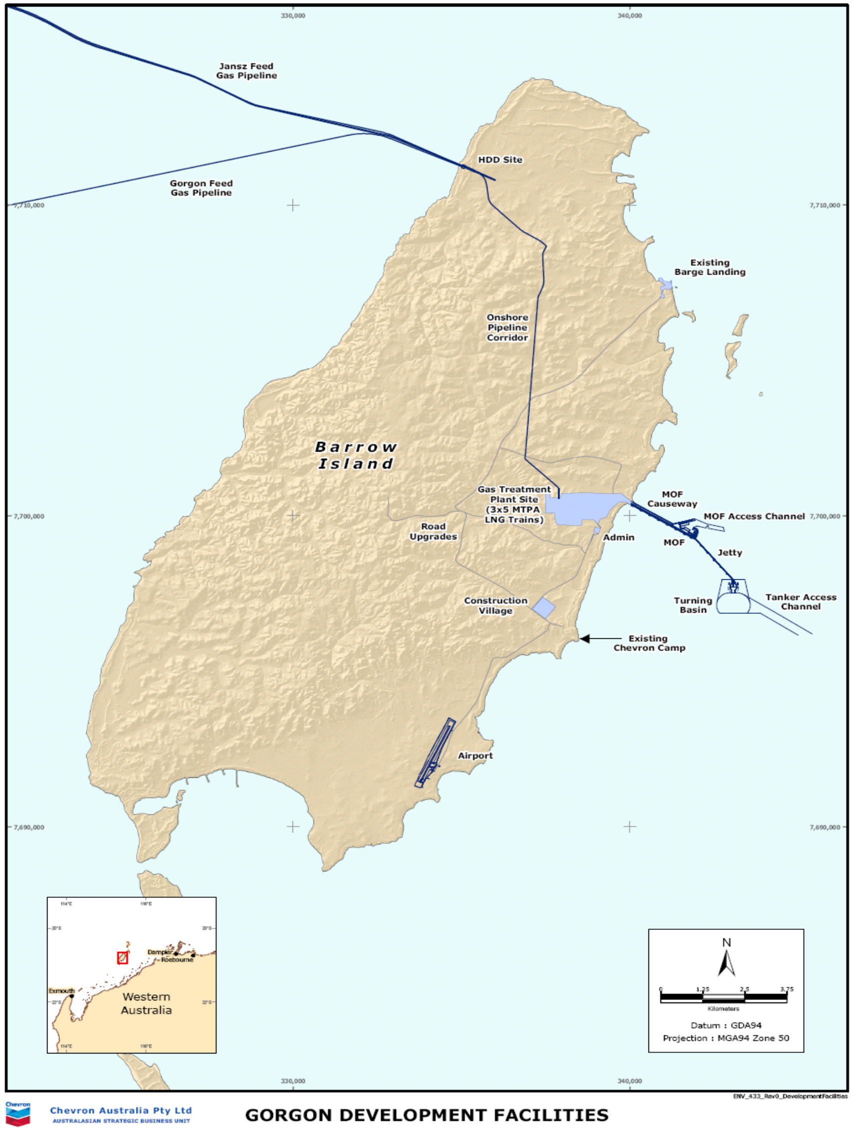



Figure A-1a: Barrow Island and proposed Gorgon LNG Plant Facilities

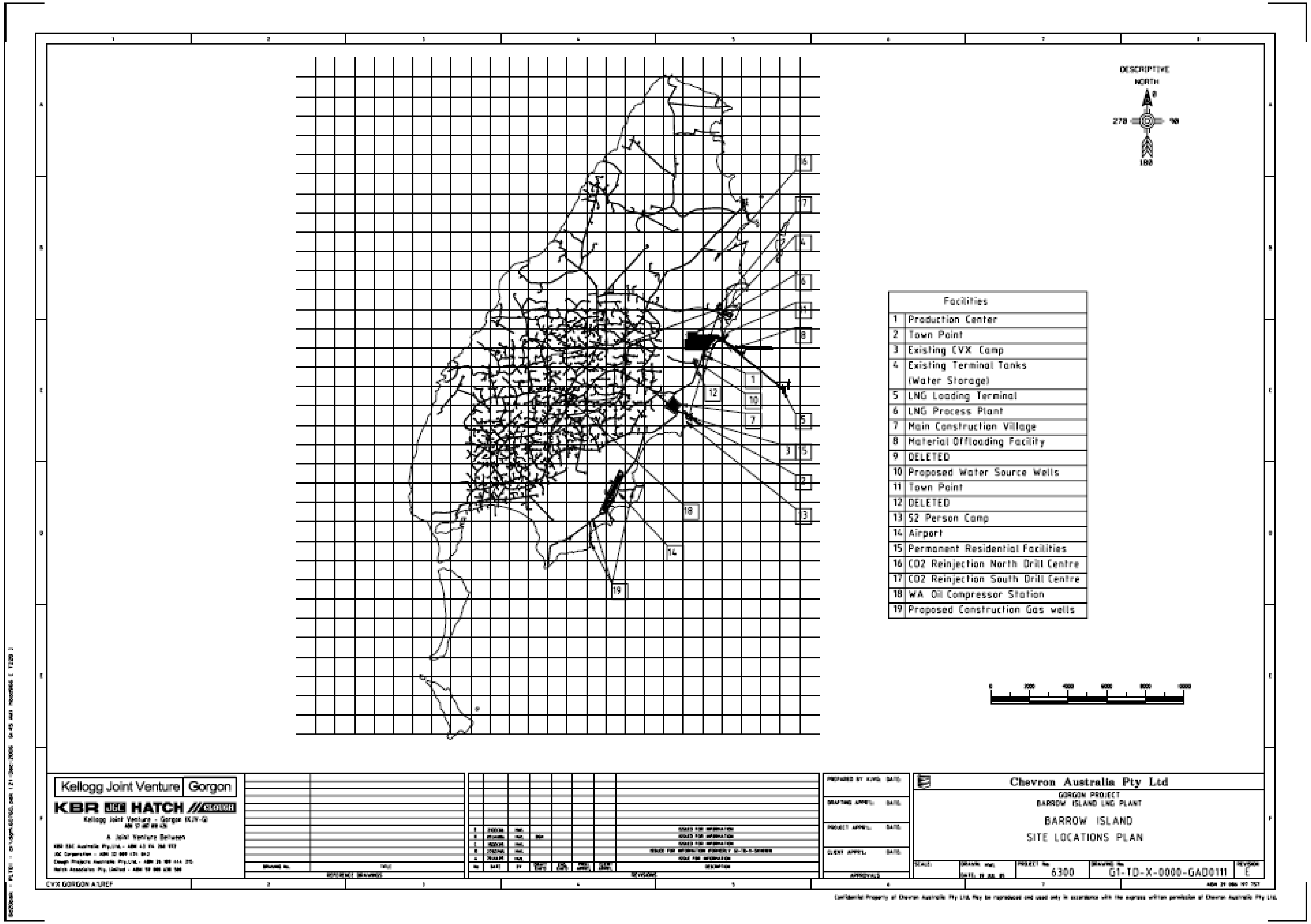



Figure A-1b: Barrow Island with existing and proposed Chevron Australia facilities

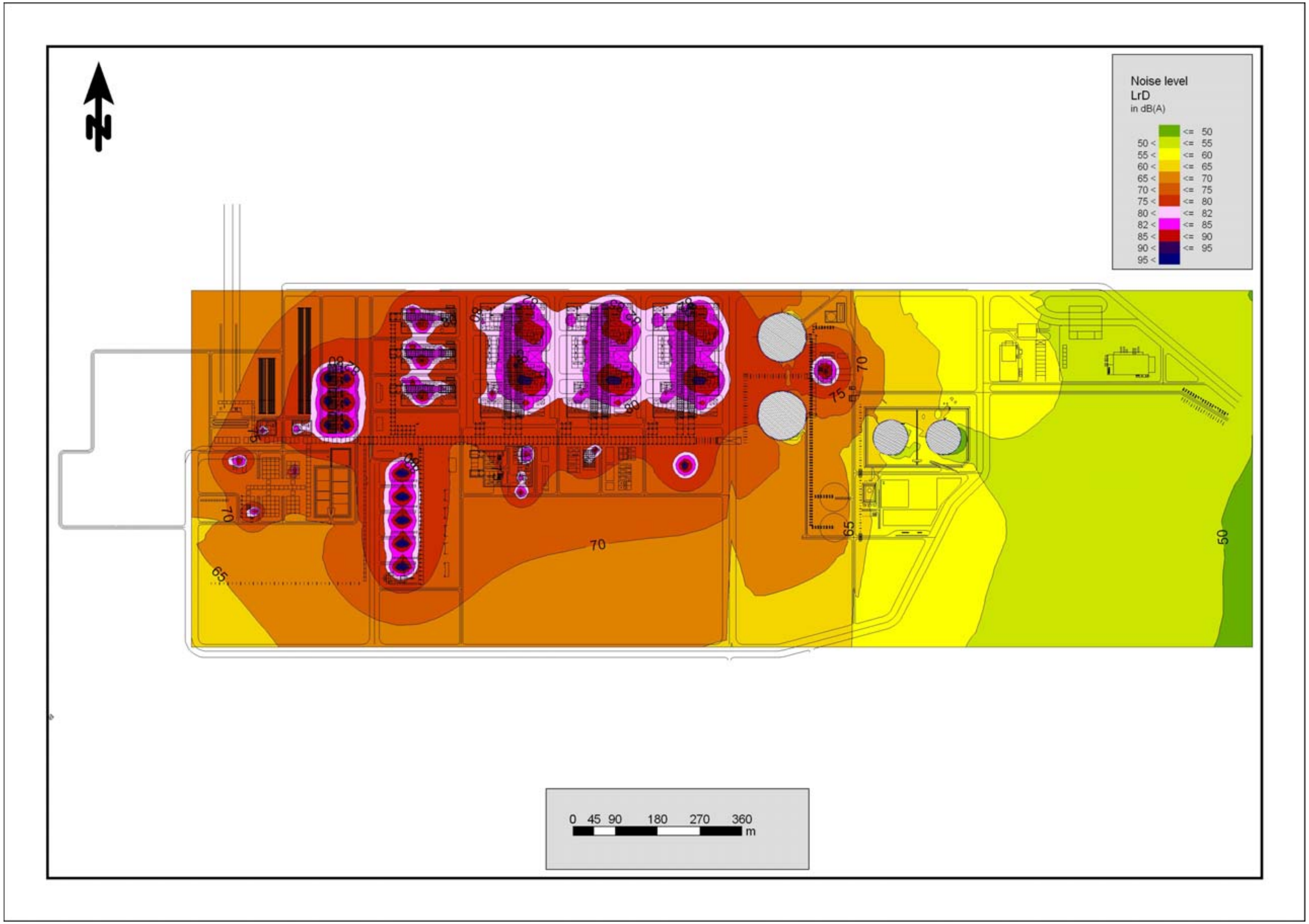
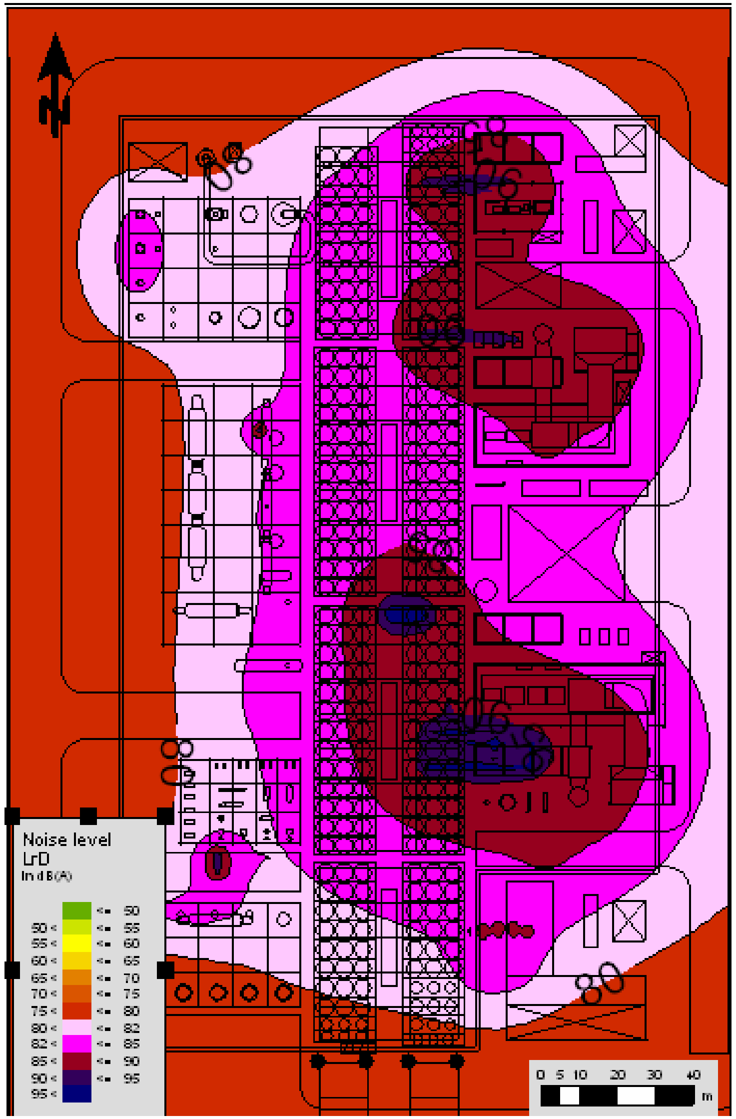
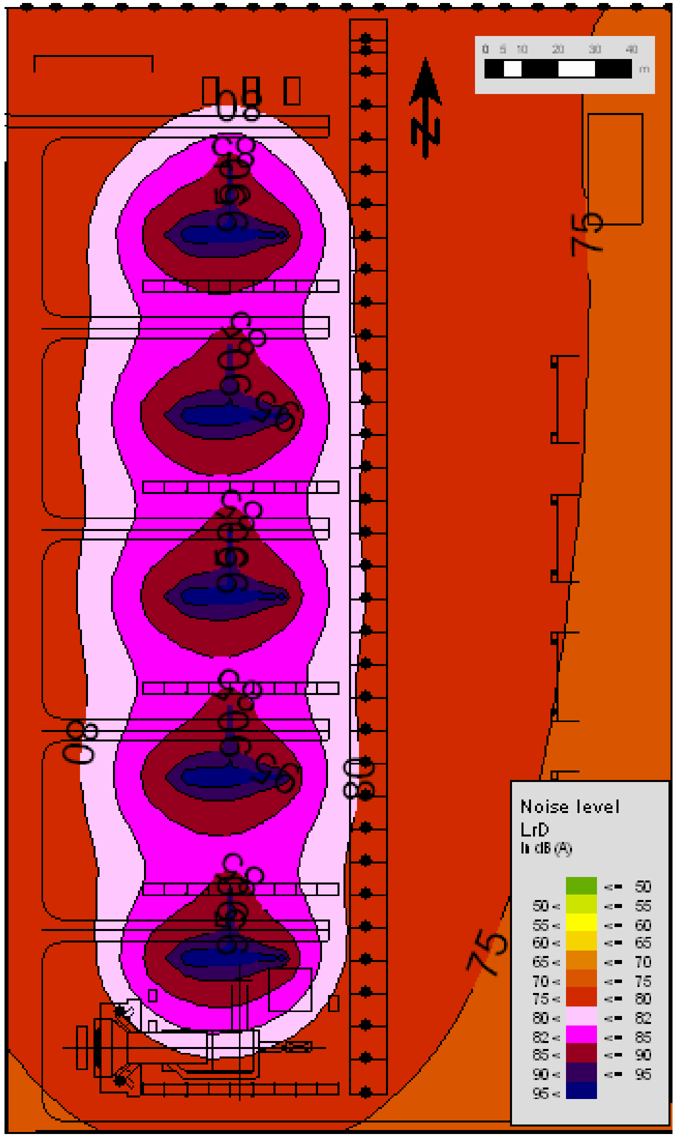


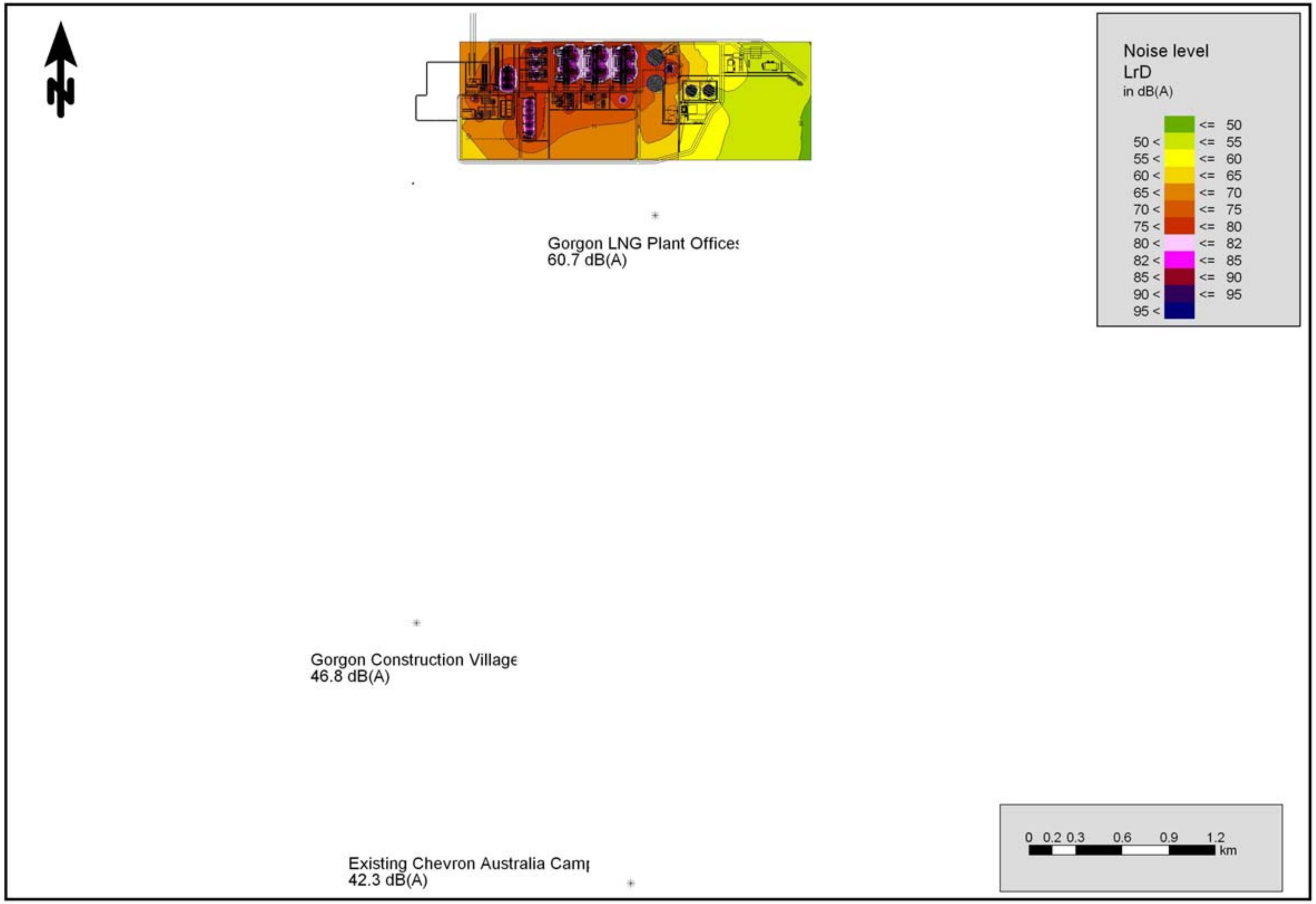

Figure A-2: Gorgon LNG Plant Predicted Sound Pressure Levels




Appendix A-3: LNG Train 1 Predicted Sound Pressure Levels




Appendix A-4: Gas Turbine Generators Area Predicted Sound Pressure Levels




Appendix A-5: Community Predicted Sound Pressure Levels

Appendix A-8: Terrain viewed from the proposed plant location toward the south

## *Appendix 2*

# 2-TRAIN FEED NOISE STUDY WORK

# 1. SCOPE AND OBJECTIVES OF 2-TRAIN STUDIES

Certain objectives of the noise study work were addressed for a 2-train basis and are equally valid for a three train basis. As such, this work is not updated for the new design basis, but is retained in the report as a record of the process of selecting the best configuration of noise control measures. The main objective was to establish, through discussions and agreement with CVX, the most feasible and practical ("Best Practice") Noise Control Design Basis for the project based on the case studies in the context of the applicable Australian Government and International Standard regulations and the ALARP Principle.

This objective was pursued by addressing a number of configurations of noise control measures 'cases', as defined in Section 3.

# 2. 2- TRAIN STUDIES NOISE LIMITS

## 2.1 ALARP Decisions

The ALARP decisions described in this Appendix are focused on major noise control decisions relating to major equipment items or classes of equipment (e.g. acoustic insulation for piping).

# 3. 2-TRAIN STUDIES NOISE MODELING

## 3.1 Noise Control Design Cases

The following noise control design cases, in increment of the degree of noise control abatements, were considered in developing the project noise model for this study:

**Case 1:** Equipment sound pressure levels were estimated based on KJVG's experience for similar type/capacity equipment with acoustic insulation Class D on compressor suction/discharge and recycle piping. Standard on-skid acoustic enclosures of 90 dB(A) @ 1 meter from equipment surface were assumed on all gas turbine drives and no enclosures on compressors were assumed.

**Case 2:** Same as Case 1 but add on-skid acoustic enclosures @ 90 dB(A) on all large compressors.

**Case 3:** Same as Case 2 but off-skid enclosures @ 85 dB(A) on all gas turbines and large compressors were assumed instead.

**Case 4**: Same as Case 3 but off-skid enclosures @ 82 dB(A) on all gas turbines and large compressors and large pumps were used.

Note that acoustic insulation system class D was used on compressor piping in all cases. Other acoustic class systems were not included in the cases study for this project. This is because KJVG's previous LNG project noise case study has shown that other insulation class systems do not provide adequate noise reduction for compressor piping in a world scale LNG plant. The Class D acoustic insulation system is generally regarded as representing the best available acoustic system with proven performance in the hydrocarbon process industry.

# 4. 2-TRAIN CASES RESULT DISCUSSION

## 4.1 Discussion of Noise Control Design Cases

Figs. 2-9 (Pages 37-45) show the overall predicted noise contour maps and LNG Train 1 area for each of the referenced design options considered. These noise maps were calculated at grade level (i.e. 1.5 m above grade).

Table A provides a comparison of the 85 dB(A) contour area size, i.e., the “Restricted Area” size, at grade for various noise control cases.

**Table A: >85 dB(A) Restricted Areas for Noise Control Cases in LNG Train Area**

| >85 dB(A) Restricted Area in percentage of the total Train Area | |
|---|---|
| Case 1: Enclosures at 90 dB(A) on G/T drives and no enclosures on compressors | 26% |
| Case 2: Enclosures at 90 dB(A) on G/T drives and on compressors (On-skid Enclosures) | 18% |
| Case 3: Enclosures at 85 dB(A) on G/T drives and on compressors and large pumps(Off-skid Enclosures) | 15% |
| Case 4: Enclosures at 82 dB(A) on G/T drives and on compressors on large pumps (Off-skid Enclosures) | 14% |

As can be seen from Figures 2-9 and Table A, the use of enclosures on compressors does not totally eliminate the areas where the sound pressure levels are above 85 dB(A). It merely reduces the 85 dB(A) contour area. More importantly, the use of enclosures on compressors only reduces the 85 dB(A) contour area near the compressors and has little impact on property line. Figures 2-5 shows that the 60 dB(A) contour line only moves closer to the plant by about 50 meters from no enclosure on compressor (Case 1) to 82 dB(A) enclosures on all compressors (Case 4).

The predicted sound pressure levels at Existing Chevron Australia Camp and Gorgon Construction Village are shown in Table B for various cases. It is shown from Table B that enclosures have hardly any effect on the predicted noise levels at these two locations. This is because, in an LNG plant, noise contributions from the main compressor suction/discharge piping and air coolers dominate over other noise sources.

**Table B: The Predicted Environmental Sound Pressure Levels**

| Location | The Predicted Sound Pressure Levels, dB(A) | | | |
|---|---|---|---|---|
| | Case 1 | Case 2 | Case 3 | Case 4 |
| Existing Chevron Camp | 36.0 | 35.9 | 35.4 | 35.2 |

| | The Predicted Sound Pressure Levels, dB(A) | | | |
|---|---|---|---|---|
| **Gorgon Construction Village** | **38.0** | **37.8** | **37.3** | **37.3** |

The dominating effect from piping noise can be seen in Fig. 11, where the 85 dB(A) contours at 14.0 meters above grade (i.e. pipe rack level) are significantly larger than those at grade (see Figs. 6 to 9).

Adding acoustic enclosures to the main compressors, while reducing but not eliminating the need for "Restricted Areas", does have a significant impact on costs.

KJVG experience from previous LNG project suggests that going from the Case 1 (no enclosures on compressors 90 dB(A) on-skid G/T enclosures) to Case 4 (82 dB(A) off-skid enclosures for compressor and G/T drives) will typically result in an increase of 20-25% in the capital cost of the compressor train. In addition, the off-skid enclosures bring access problems and safety issues for the maintenance and operation of compressor. Enclosing compressors of this size also brings significant issues associated with ventilation and purge gas flow for cooling and safety.

Based on the above observations and discussions with CVX with due consideration for ALARP Principle, the Case 1 with no compressor enclosures and 90 dBA @ 1 meter on-skid enclosures for the gas turbine drivers was selected as the most appropriate and applicable noise control design option for the gorgon project.

Analysis of the noise study predictions in the referenced noise contour maps lead to the following major noise issues and recommendations for the Gorgon project that were again fully discussed with the CVX Project Team:

- Piping noise tends to dominate over the contributions from equipment noise. Acoustic insulation on compressor piping therefore plays a pivotal role in controlling the overall sound pressure levels for both in-plant and surrounding areas outside of the property line. Therefore acoustically insulating the compressor suction/discharge piping with Class D acoustic insulation (currently best available piping acoustic insulation system in the industry) is critical for effective noise control in an LNG plant of this type/capacity.

- KJVG's previous LNG plant experience has shown that focusing on acoustic insulation and vibration isolation of pipe supports (e.g. trunions, pipe shoes etc.) also yields the good results in controlling and reducing noise radiated from compressor piping systems. This experience has enabled KJVG to develop a better overall acoustic insulation system design and performance for various piping components. The details of acoustic insulation for pipe supports and trunion supports are shown in the project Piping Insulation Specification. This helps to facilitate maximum performance from the Class D insulation system.

- Low noise air coolers at 85 dB(A) or less @ 1 meter below the fan center were used in the noise model and are recommended for this project for the following reasons:

  a) Total sound power per LNG Train is estimated around 127 dB(A) for Case 1. The total sound power level of all air coolers in an LNG Train is estimated at 119 dB(A) assuming 85 dB(A) 1 meter below the fan center per fan. Going to a lower noise design air cooler and reducing the air cooler sound power level to be lower than 119 dBA per train would only reduce total train sound power level by <1 dB(A) and would have an insignificant impact on the overall plant noise level.

b) Air coolers at 85 dB(A) 1meter below air cooler fan center have been used successfully on most recent world-scale LNG projects.

c) Low noise air coolers are available but they will require 15-20% larger plot space. Given the minimal impact on the overall train sound power level, coupled with the minimum plant footprint requirements for Barrow Island, the increase in plot area to accommodate the lower noise air coolers was not felt justified.

d) Cost increase for lower noise type air cooler.

- Acoustic enclosures on the main compressors will reduce in-plant 85 dB(A) contour areas but will not totally eliminate plant areas exceeding 85 dB(A). The compressor enclosures would have little impact on the sound pressure levels in the surrounding community/residential areas near the plant because noise contributions from the compressor piping dominate. Enclosures on compressors are therefore not recommended for the following reasons:

e) The use of enclosures on compressors presents access problems to equipment maintenance. One example is safety problem with opening and closing the enclosure door due to the amount of air flow required for temperature control inside the enclosures.

f) The use of enclosures on compressors presents safety issues, such as fire, to the equipment. Compressor area is a potential fire hazard area due to the leakage of gas from flange connections. Use of enclosure increases the fire risk.

g) While enclosures reduce noise levels from compressors by containing compressor noise inside the enclosures, they have larger noise radiating surfaces than that of the equipment itself. The actual noise reduction by the use of enclosures is reduced by the enclosure’s larger noise radiating surfaces.

- Enclosures on large pumps are not recommended at this stage of the project. KJVG’s experiences for LNG project shows that noise from large pumps normally does not present a problem if installed correctly and properly. However, acoustic blankets can be installed in the field to reduce the noise radiated from noisy large pumps, if necessary. The noise control needs of these pumps will be fully addressed following ALARP Principle during Detailed Engineering when specific equipment details are better defined.

- In-line silencers for the compressor suction and discharge lines are not recommended for this project for the following reasons:

a) In-line silencers will not replace acoustic insulation on compressor piping. Piping acoustic insulation will have to be used on compressor piping due to the following:

   i. In-silencers can not be installed close to the compressor nozzles because of layout restrictions and their influence on compressor’s performance if installed close to compressor nozzle.

   ii. This means that the piping between compressor nozzle and the in-silencer, at least 8-20 diameters, will still represent a significant sound power source and will need to be insulated anyway.

   iii. Lines connected into compressor discharge line before silencer and those connected into compressor suction piping after silencer will need to be acoustic insulated as silencers do not affect the noise on these lines.

b) In-line silencer’s performance is proportional to the pressure drop across the silencer. This additional pressure loss in the suction and discharge lines will impact compressor performance.

c) In-line silencers installed on suction piping leading to the compressors presents an unacceptable risk of silencer material breaking free and being sucked through the compressor with catastrophic consequences.

d) Vibration flanking transmission through the silencer casing is an issue that can reduce silencer performance and effectiveness.

e) KJVG’s previous LNG project experiences show that the use of in-line silencers do not effectively reduce compressor piping noise to the level achieved through the use of Class D acoustic insulation with improved pipe support noise control and vibration isolation.

f) Cost for in-line silencers.

Based on the results and discussions from the case studies above, the following noise control abatements are considered as the base case for Gorgon LNG Project:

1) The most prudent and cost effective approach for the project will be to install the best available acoustic insulation, Class D, on all compressor suction/discharge/recycle piping and turbine intake/exhaust ducting.
2) Use on-skid 90 dB(A) @ 1 meter acoustic enclosures for the gas turbine drives.
3) No acoustic enclosures for the main compressors for the reasons discussed above
4) No enclosures on power generators because operational noise levels for generators of this capacity do usually not exceeding 85 dB(A).
5) Use low noise air coolers at or less than sound pressure level of 85 dB(A) 1 meter below fan center per fan.

This represents the ”Best Practice” noise control design, consistent with other comparable world scale LNG facilities.

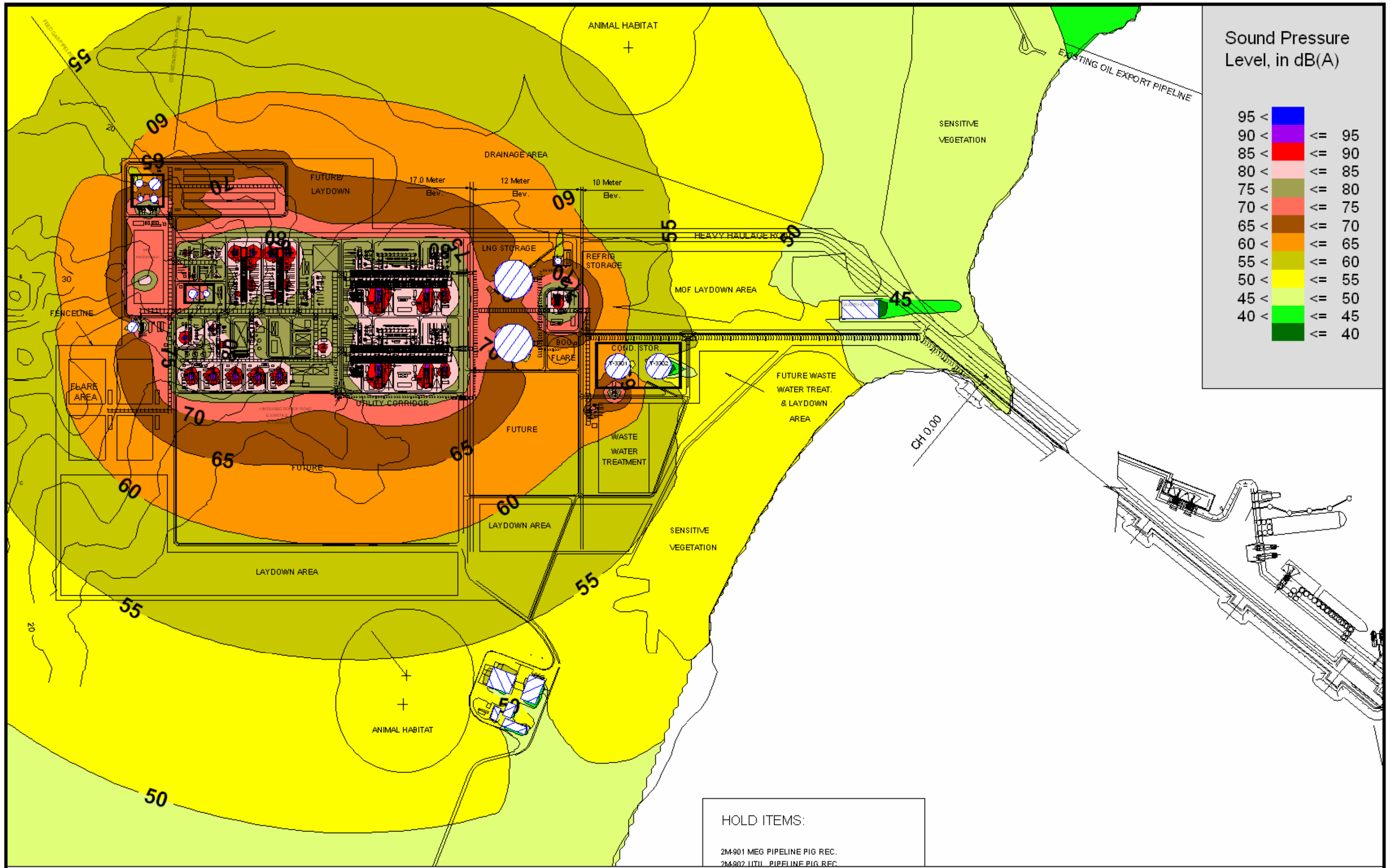



**Figure 2: The Predicted Overall Sound Pressure Levels (Class D Acoustic Insulation, No Enclosures )**

**Barrow Island, West Australia, Chevron Australia PTY LTD**

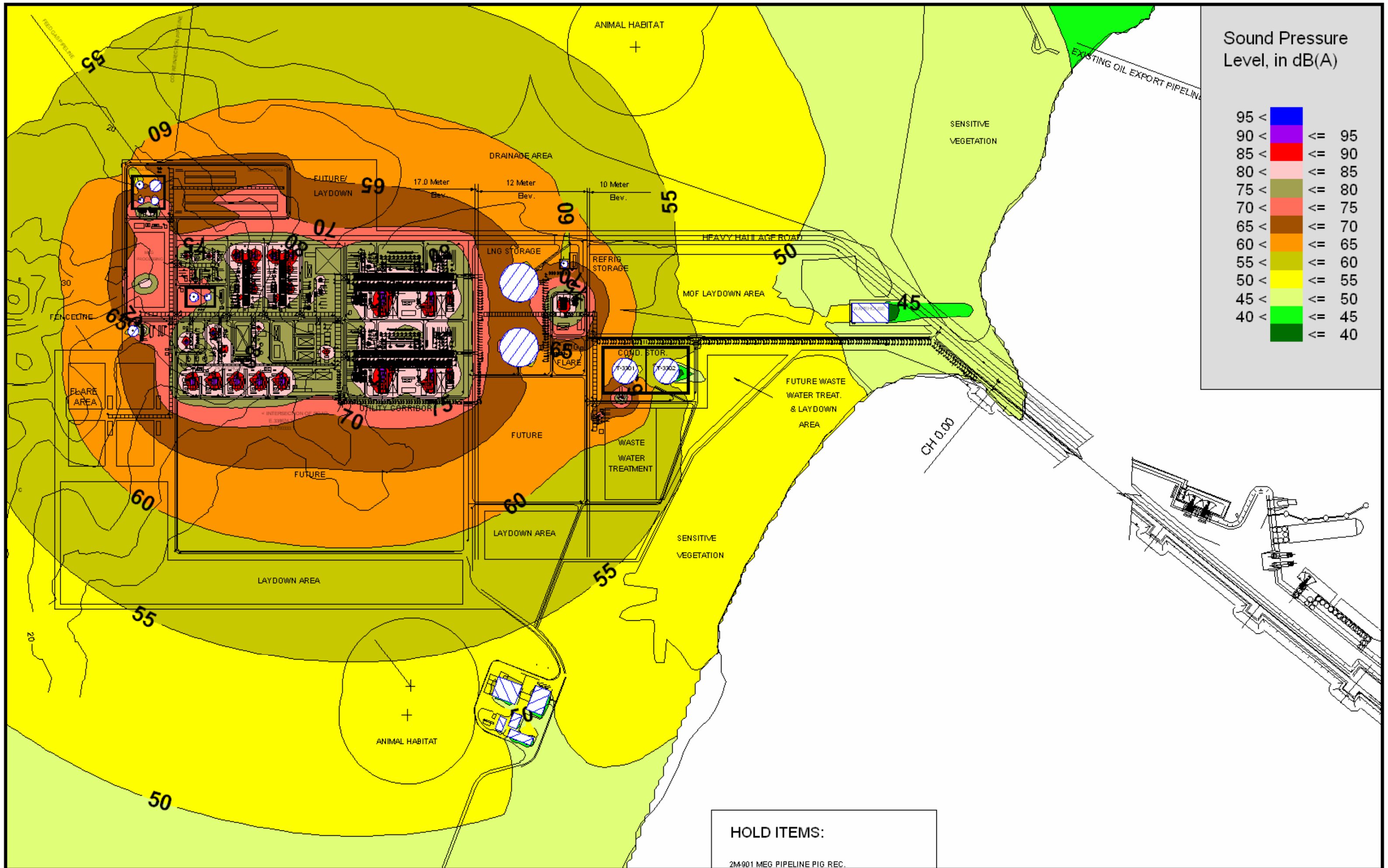


**Figure 3: The Predicted Overall Sound Pressure Levels (Class D Acoustic Insulation, Enclosures @ 90 dB(A))**

**Barrow Island, West Australia, Chevron Australia PTY LTD**

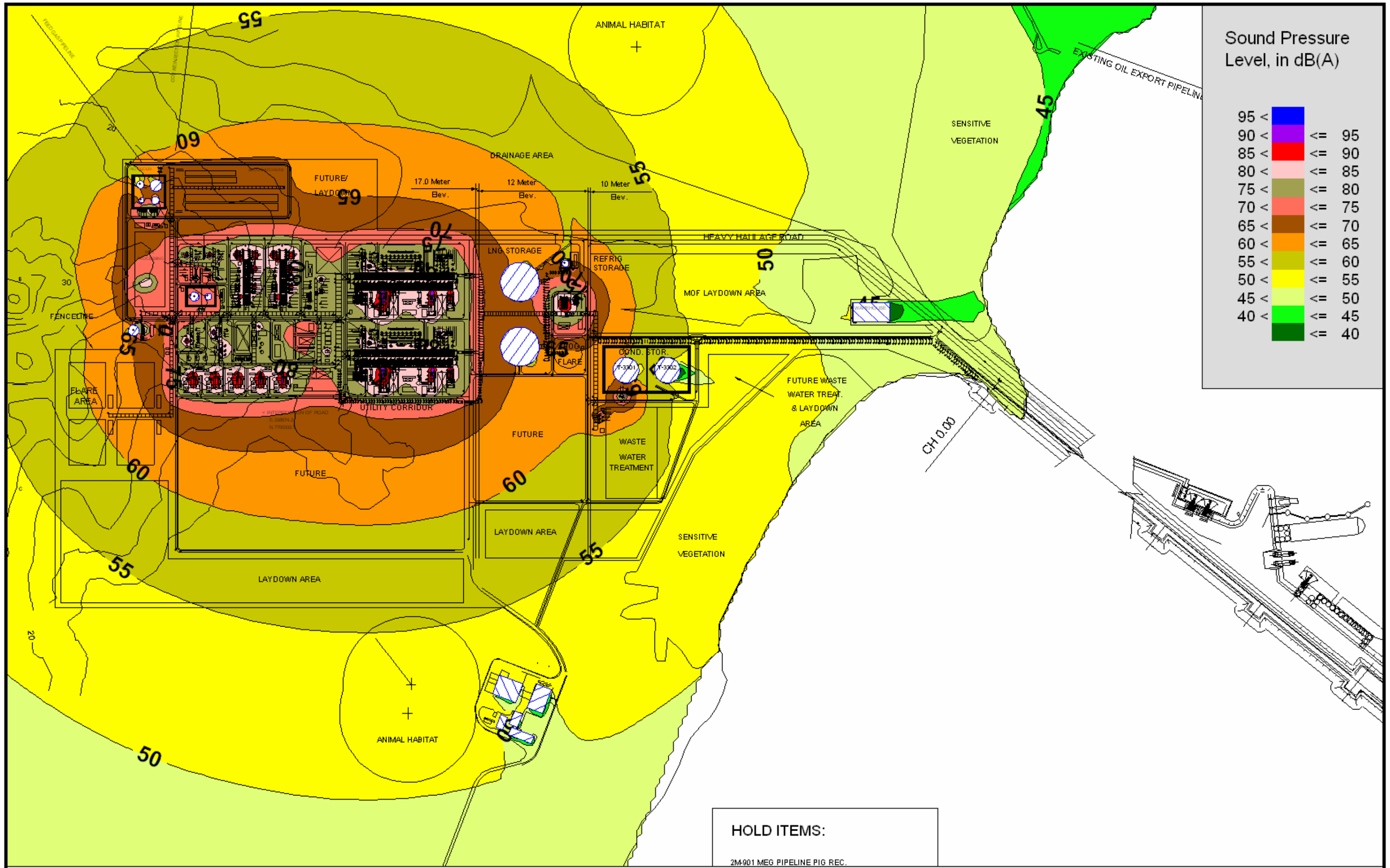



**Figure 4: The Predicted Overall Sound Pressure Levels (Class D Acoustic Insulation, Enclosures @ 85 dBA)**

**Barrow Island, West Australia, Chevron Australia PTY LTD**

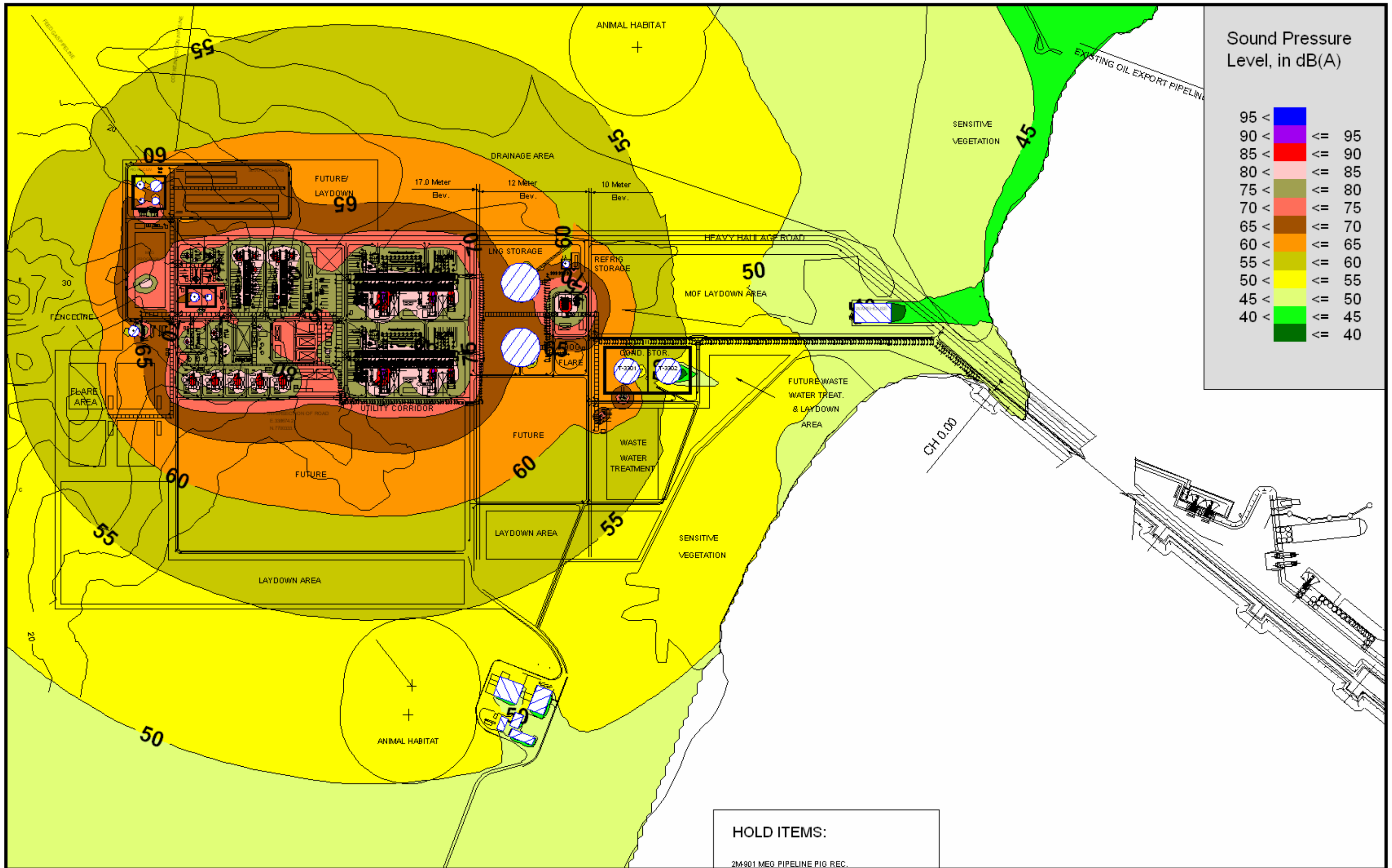



**Figure 5: The Predicted Overall Sound Pressure Levels (Class D Acoustic Insulation, Enclosures @ 82 dBA)**

**Barrow Island, West Australia, Chevron Australia PTY LTD**


**Figure 6: The Predicted Sound Pressure Levels in Train 1 Area (Class D Acoustic Insulation, No Enclosures)**

**Barrow Island, West Australia, Chevron Australia PTY LTD**


**Figure 7: The Predicted Sound Pressure Levels in Train 1 Area (Class D Acoustic Insulation, Enclosures @ 90 dBA)**

**Barrow Island, West Australia, Chevron Australia PTY LTD**

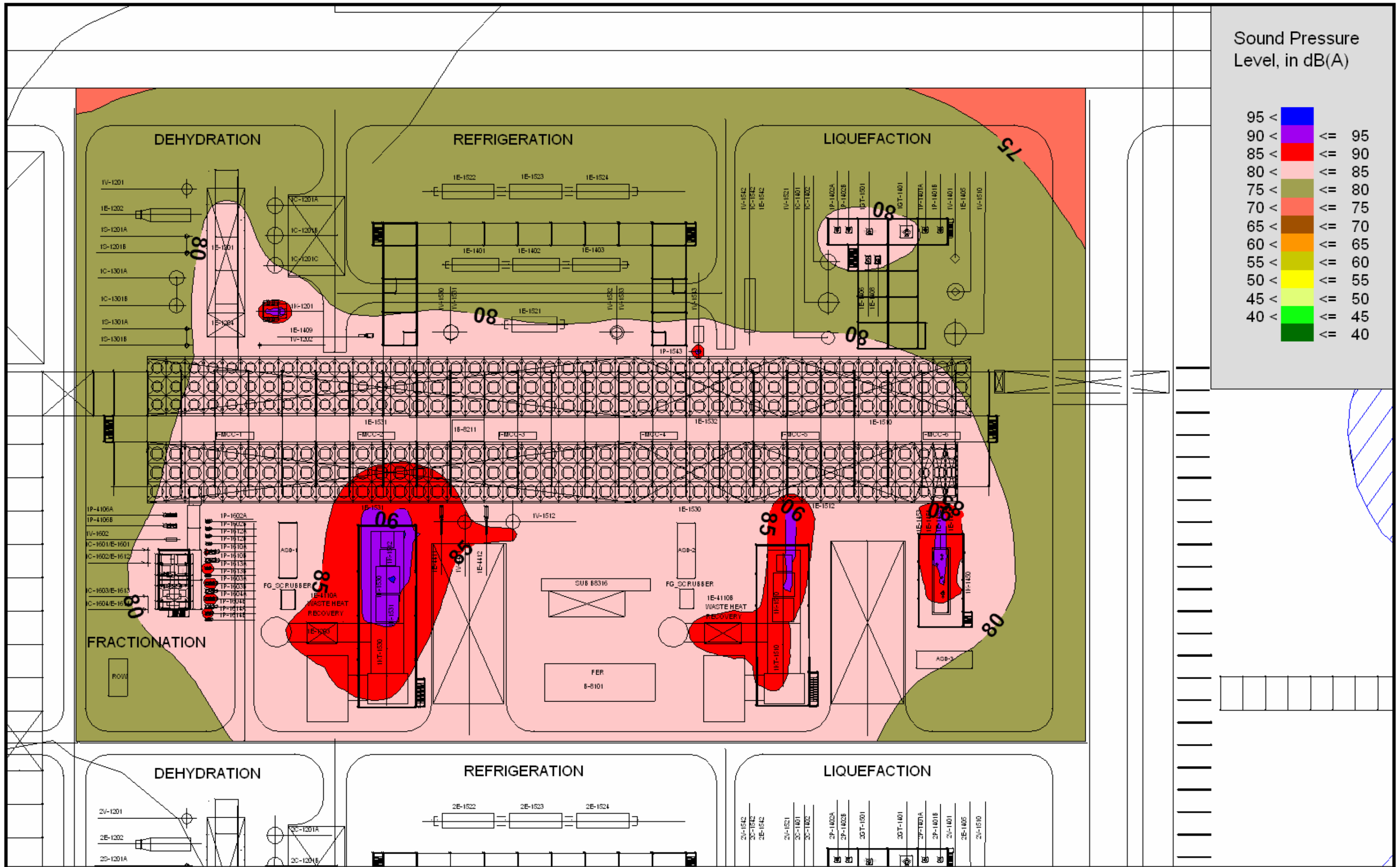



**Figure 8: The Predicted Sound Pressure Levels in Train 1 Area (Class D Acoustic Insulation, Enclosures @ 85 dBA)**

**Barrow Island, West Australia, Chevron Australia PTY LTD**

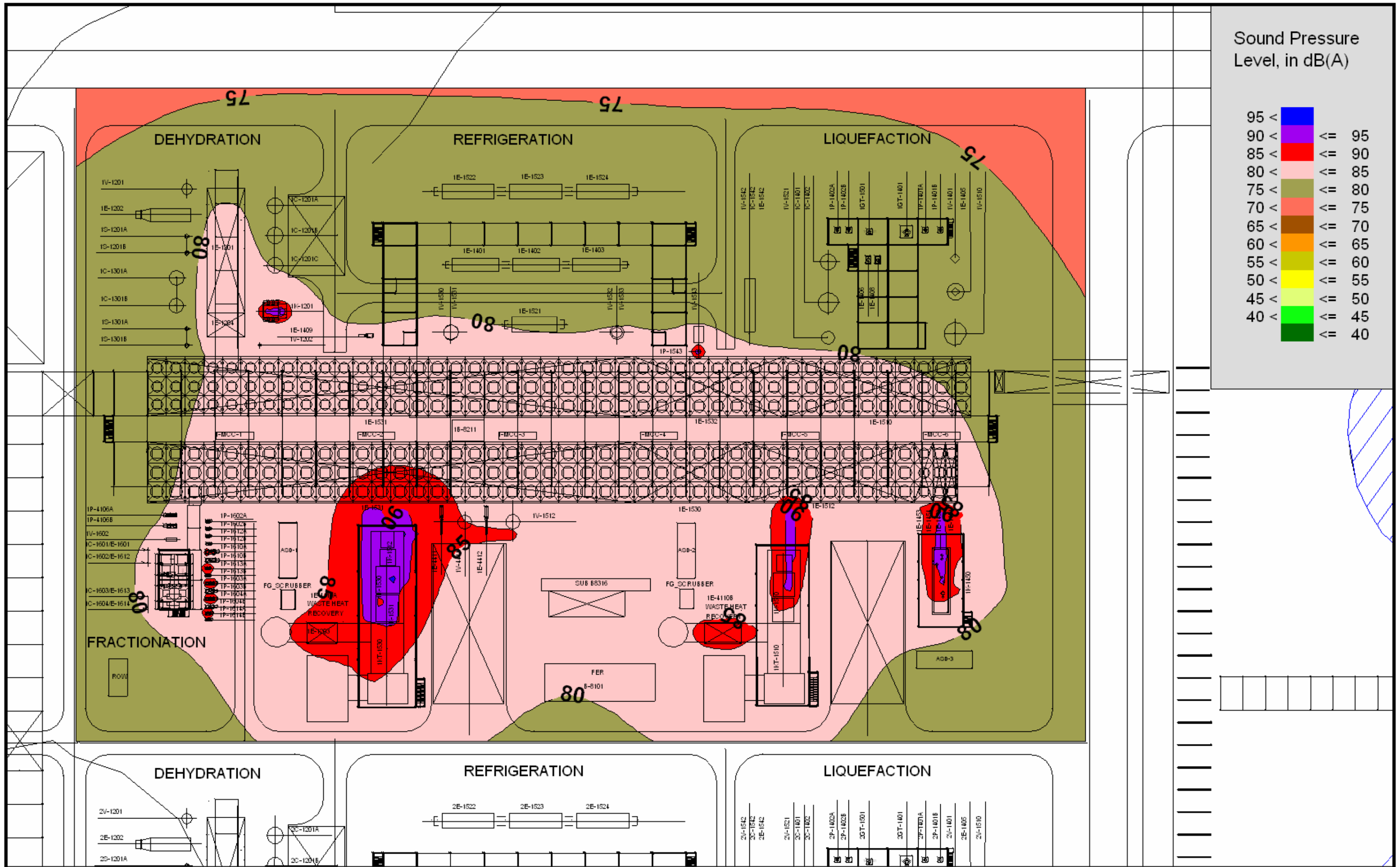



**Figure 9: The Predicted Sound Pressure Levels in Train 1 Area (Class D Acoustic Insulation, Enclosures @ 82 dBA)**

**Barrow Island, West Australia, Chevron Australia PTY LTD**

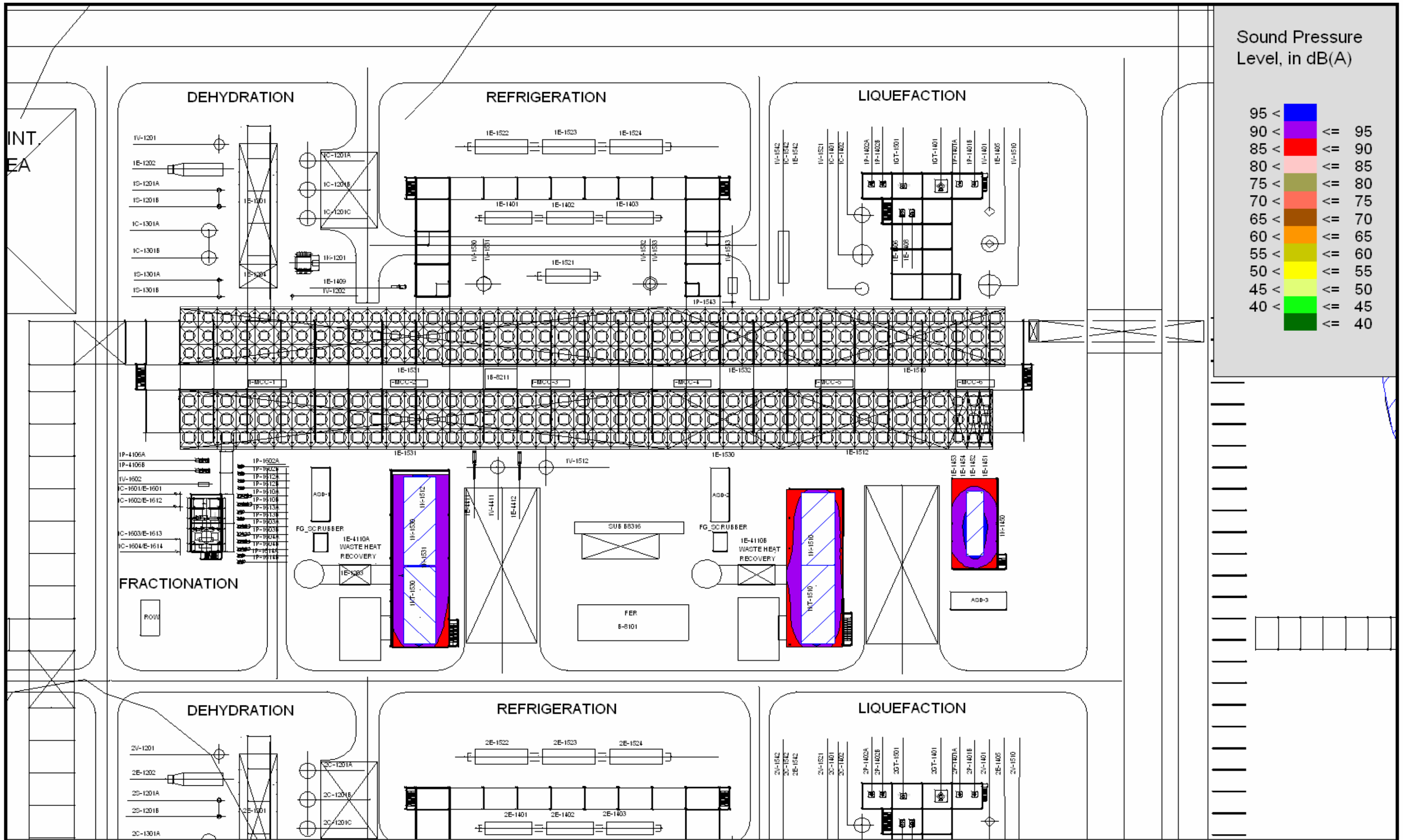



**Figure 11: The Predicted Sound Pressure Levels in Train 1 Comp Platforms (Class D Acoustic Insulation, No enclosures, 11.5 m Above Grade )**

**Barrow Island, West Australia, Chevron Australia PTY LTD**

# APPENDIX E

## Dredge Plume Modelling Report For The Revised Marine Infrastructure

**GEMS**

GLOBAL ENVIRONMENTAL MODELLING SYSTEMS

GLOBAL ENVIRONMENTAL MAPPING SYSTEMS

GLOBAL ENVIRONMENTAL MONITORING SYSTEMS

CHEVRON AUSTRALIA

# Gorgon Development

# Dredging Simulation Studies to Support the PER for the Revised Proposal

*July 2008*


| | |
|---|---|
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## About GEMS

Global Environmental Modelling Systems (GEMS), a wholly owned Australian company, has expertise in the development and application of high-resolution computer models to realistically predict atmospheric and oceanographic conditions for use in riverine, coastal and oceanic settings.

The GEMS team is made up of qualified and experienced physical oceanographers, meteorologists, numerical modellers and environmental scientists. GEMS is a leading developer of numerical models in Australia. It has developed a system of validated environmental models and rigorous analytical procedures that provide solutions to a variety of environmental, engineering and operational problems.

## Disclaimer

This report and the work undertaken for its preparation, is presented for the use of the client. Global Environmental Modelling Systems (GEMS) warrants that the study was carried out in accordance with accepted practice and available data, but that no other warranty is made as to the accuracy of the data or results contained in the report.

This GEMS report may not contain sufficient or appropriate information to meet the purpose of other potential users. GEMS, therefore, does not accept any responsibility for the use of the information in the report by other parties.

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## Table of Tables

# 1 INTRODUCTION

Global Environmental Modelling Systems (GEMS) carried out the original simulations of the hydrodynamics and the dredging of the Materials Offload Facility (MOF) and the LNG shipping access channel for the EIS/ERMP for the Gorgon Development at Barrow Island (GEMS 2005a and b; Chevron 2005). The plume modelling output was analysed to predict zones of impact due to sedimentation and turbidity, according to predefined coral health criteria. This modelling was subsequently revised during the public review period and released with the Final EIS and Response to Submissions on the ERMP (Chevron 2006).

Since the EIS/ERMP studies were undertaken, Chevron Australia (Chevron) has made some alterations to the dredge plan, mainly driven by the desire to avoid cutting through (or drilling and blasting) the hard rock at the original location of the MOF. Additional geotechnical data indicate that a lot of drilling and blasting would be necessary to break up the harder rock. This was considered environmentally unacceptable by Chevron and the facilities were redesigned to minimise the need for blasting.

The Revised Proposal is to locate the MOF further from the coast, resulting in a longer causeway and a shorter access channel to the MOF (see Figure 1.1). A further important change is that the MOF will be developed prior to the causeway joining it to the land thus allowing much better flushing during dredging in this area than the original method which involved building the causeway first.

The remaining components of the dredge plan are substantially the same as for the original studies except that the LNG access channel has been realigned slightly to avoid dredging through a shallow area of coral at the outer end of the channel.

Chevron commissioned GEMS to conduct further dredge plume modelling in support of the PER for the Revised Proposal. The additional modelling was requested to determine whether the changes to the Approved Development, in particular the dredging component of marine infrastructure construction, have changed the size and location of the effect zones (impact zones) substantially from those approved as part of the Approved Development.

This report describes the methods and outcomes of this new simulation.

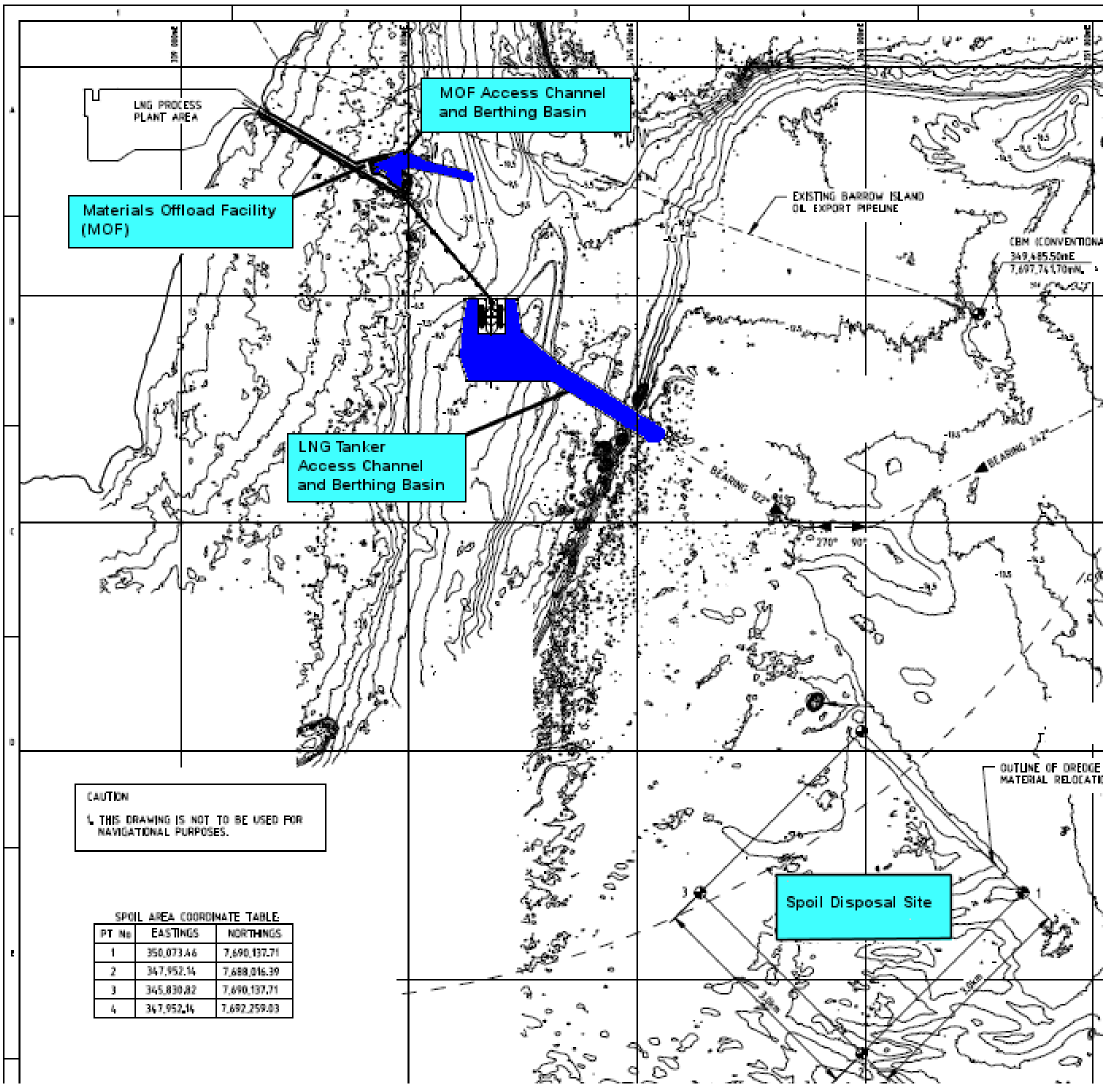


Figure 1.1: The dredging footprint for the LNG access channel and the relocated MOF.

## 2 APPROACH TO MODELLING

The current modelling study took the opportunity to include improvements/changes to the dredge modeling methodology which have become available since the release of the EIS/ERMP. The improvements/changes in methodology relevant to this study are explained in this report. In general however, the same assumptions were included to ensure consistency in approach and to increase the comparability of the outputs from the two modelling runs.

In broad detail, the dredge modelling took the following approach:

- Detailed dredge logs describing the best estimate of dredging the adjusted configuration were established by Baggermanns (the dredging advisors) in conjunction with GEMS (the dredge modellers).

- The major variations in this study were the adjusted dredge plan and associated footprint and the abandonment of the use of barges to dispose of material cut by the CSD in the LNG channel. Instead the CSD cuts/crushes the harder material in the channel and the TSHD comes along later to remove this material to the spoil ground.

- Due to the above change in dredging methodology, the assumptions regarding generation of fines, release of fines at the Cutter Suction Dredge (CSD) cutter head, overflow of fines from CSD barges and the Trailer Suction Hopper Dredge (TSHD) and release of fines at the spoil ground which were used during the original EIS/ERMP studies were adjusted. It was necessary to include the extra process of the CSD laying down material which is later picked up and transported to the spoil ground by the TSHD. The assumptions adopted for the release of fines were:

  a) 30% released at CSD cutter head

  b) 20% released during the process of leaving the cut and crushed material on the seabed

  c) 30% released during the pick-up and overflow by the TSHD

  d) 20% released during the dumping at the spoil ground

  These assumptions are somewhat conservative as they assume all the fine material is released, whereas in fact some of the fines will be trapped in the spoil ground.

- The same particle size distributions and settling rates reported in the studies for the EIS/ERMP were used in this study

- The new dredge plan has been simulated for the "base case" for the "normal" period of meteorology established in the original EIS/ERMP studies in order to provide a "sensitivity study" so that the expected environmental impacts of the new dredge plan can be compared with those submitted in the EIS/ERMP.

- The same impact criteria used in the original EIS/ERMP studies were used to analyse the results and produce impact boundaries which can be compared with the boundaries established for the EIS/ERMP.

# GEMS

These studies were undertaken using the output of three sophisticated numerical computer models to drive the GEMS 3D Dredge Simulation Model (DREDGE3D) to determine the fate of particles released into the water column during the dredging operations.   The three models providing input to DREDGE3D were:

- The Bureau of Meteorology (BoM) high resolution (10km) atmospheric model (MESOLAPS) hindcast fields for atmospheric pressure, wind speed and direction;
- The GEMS 3D Coastal Ocean Model (GCOM3D) to simulate the complex three-dimensional ocean currents surrounding Barrow Island; and
- The SWAN wave model run on four nested grids telescoping from the Indian Ocean down to the Northwest Shelf.

The basic tasks undertaken were:

- Run SWAN for the “typical” 13 month period driven by MESOLAPS winds (waves were not simulated in the original studies) to provide orbital velocities for re-suspension calculations;
- Work with the dredging advisors (Baggermanns) to enable them to develop new dredge logs for the simulations based on the altered dredge plan;
- Run the full dredge scenario for the MOF and the LNG access channel for the “typical” 13 month period.
- Analyse output from the simulation to derive impact zones, based on model output and the RPS coral health criteria established for the EIS/ERMP (Chevron 2005).

# 3 DREDGE PROGRAM SIMULATIONS

As described in the original studies, DREDGE3D is driven by a "dredge log" which sets out the detailed activities of the dredges as they execute the dredge plan. Of course the actual dredge log during the dredge program will be different but every effort is made to include all the realistic activities involved in the dredge plan to develop a "representative" dredge log for the simulations. It is over 2 years since the original studies and the detail included in the dredge logs has increased considerably, providing another source of difference with the original simulations.

The key assumptions/parameters used in the simulations and variations from the original studies are discussed below.

## 3.1 REVISED DREDGE PLAN

The major changes to the current dredge plan from the EIS/ERMP are:

- Location of the MOF further from the coast, resulting in a longer causeway and a shorter access channel to the MOF (see Figure 1.1);
- Development of the MOF prior to the causeway joining it to the land thus allowing much better flushing during construction.
- The dredging of the deeper parts of the LNG access channel with a Cutter Suction Dredge (CSD) and leaving the material on the seabed instead of using overflowing barges to take the material to the spoil ground. The material cut and crushed by the CSD is picked up later from the seabed by the TSHD.

## 3.2 DEVELOPMENT OF THE DREDGE LOGS

A further significant change in these studies is the greater detail included in the dredge logs. For the original PER studies GEMS developed the dredge logs based on information provided by Chevron and Baggermanns (the dredging advisors). For these studies the dredge logs were initially developed by Baggermanns and then adapted to the dredge model by GEMS. This approach allows for the dredging knowledge and experience of Baggermanns to be the driving force in development of the logs. This has introduced a much more detailed representation of dredging behaviour to the simulation process which now reflects a cut by cut approach to the dredge logs along defined paths rather than the original approach where a particular volume was dredged from a sector of the channel in a given time. Much of the information below has been extracted from detailed, commercial-in-confidence, drawings and spreadsheets provided by Baggermanns.

The assumptions/specifications from Baggermanns for the dredging of the MOF with a CSD loading hopper barges is given in Table 1. A sample of the first 18 hours of dredge log information provided by Baggermanns, based on these assumptions for the MOF dredging is shown in Table 2.

## 3.3 MODELLING ASSUMPTIONS

### 3.3.1 MOF

For the model simulation of the dredging for the Material Offload Facility (MOF) the following assumptions are included in the dredge log:

- The volume of cut and fill is estimated to be 1,000,000 $m^3$.
- The majority of the material to be dredged is crystalline limestone with a capping of calcarenite (supported by latest geotechnical data).
- The characteristics of the spoil are anticipated to be similar to that generated at Geraldton (i.e. a high proportion of fines/flour and coarse limestone rubble).
- The duration of the dredging/reclamation program is estimated to be 18 weeks plus 2 (or more) weeks weather downtime.
- The MOF will be dredged with a Jumbo CSD with a nominal cut width of 150 m and step height of 2 m. The step length varies according to the strength of the material but generally will be between 2 and 0.3 m.
- The cutting sequence is done as single layers or as multiple layers off a single anchor position.
- The dredging method assumes softer materials are removed in a single layer followed by the harder material.
- The number of moves per anchor position depends on the number of steps per spud position and assumes a 6 metre spud carriage travel length.
- A mean dredge work rate of 84 hours of dredging per week. (actual rate will vary depending on hardness of rock).
- Lost time is due to the dredge stopping and changing teeth every few hours in the softer rock and every 20-30 minutes in the harder rock and for maintenance or refuelling activities.
- The dredge will start at outer end of the access channel and gradually work towards the shore creating a 6.5m deep channel (LAT).
- Maintenance will occur as needed. However when dredging rock there will be shut downs each 7 to 14 days in harder material and longer in softer materials. Refuelling will be undertaken each four to six weeks for 2 days.
- It is assumed that 5% of total material cut will be below 100 microns and that the distribution of these particle sizes will be similar to Geraldton.

- It is assumed that 50% of these fines will be released at the cutter head and 50% from the tailwater discharge.
- The dredging simulations were commenced in September and lasted for approximately 13 months. In this time period it was assumed that two coral spawning periods took place, one in April and the other in September, just before completion of the dredging. A third coral spawning in the month of commencing dredging was not included as it was assumed that dredging would be planned to commence after completion of the coral spawning.

### 3.3.2 LNG ACCESS CHANNEL

For the simulation of the dredging of the LNG access channel and turning basin the following basic assumptions were made:

- The total volume to be dredged is estimated to be 6.6 million $m^3$.
- Roughly 40% of the total volume in the LNG Access Channel and turning basin is sediment which can initially be removed by TSHD.
- In general maintenance will be undertaken travelling to and from the spoil grounds but the TSHD will cease operations for two days every 4 to 6 weeks to refuel and undertake major maintenance.
- Overflow will operate for the last 60 minutes of dredging and will be released under the keel of the TSHD (-6 m depth).
- Overflow discharge rate will be approximately 8 $m^3$/sec (2 x 4 $m^3$ /sec dragheads).
- The sands are coarser than the “rock flour” and the particle size distribution used in this part of the simulation is based on laboratory analyses of field samples

The LNG Channel Dredging Method will be undertaken in 3 stages:

Stage 1: Remove Overburden of soft sandy sediments from Channel Alignment with a TSHD.

Stage 2: Cut and Crush Rock with a CSD and leave on bottom of Channel.

Stage 3: Remove Crushed Rock with a TSHD.

The TSHD in Stages (1) and (3) will:

- When dredging move at a speed of 1-2 knots across the seafloor zig zagging from one side of the channel to the other.
- The effective operational length for the TSHD loading is 1 to 2 kilometres at which point the vessel will normally turn.

- When travelling to and from the spoil ground the TSHD can reach speed of 13 knots. For this work the average speed achieved by the TSHD is taken as 10 knots. This allows for the acceleration and deceleration of the TSHD as it departs the dredging area and arrives at the spoil ground.
- When loading the TSHD progressively shaves thin layers off the surface of the seafloor generally penetrating 0.10 to 0.5 in situ density of the material.
- The TSHD dredging and disposal cycle period will be approximately 2.5 hrs (based on 90 minutes of dredging, 1 hour of travel to and from spoil ground including 10 minutes for dumping at the spoil ground).
- TSHDs are less weather dependent than CSDs and will be able to deliver about 134 hours production per week which equates to 53 loads per week on average.

In stage 2 of the works the CSD will:

- Operate over a 100 to 170 metres cut width and slowly advance the work faces.
- The CSD dredge behaviour and production rates are anticipated to be similar to the MOF dredging rates described above (effective production of 96 hours/week).
- The duration of CSD dredging is anticipated to be 48 weeks.

The distribution of fines released during the cutting, crushing and rehandling of the material removed by the CSD was assumed to be as follows:

- 30% at the CSD cutter head
- 20% release when deposited on sea bed
- 30% released when picked up and transported to spoil ground
- 20% released at spoil ground

Note this assumes a 100% release of fines and that none is bound up in the spoil ground, which is a conservative assumption.

## 3.4 SIMULATION OF THE “BASE” CASE UNDER ”NORMAL” METEOROLOGICAL CONDITIONS

For the “base” case DREDGE3D was used to simulate the behaviour of particles released into the water column by the dredges using the dredging program assumptions outlined in the previous section. The dredging was started on September 1, 2000 and finished on January 8, 2002 to cover the period of most average conditions. The X, Y and Z coordinates of all particles tracked by DREDGE3D were stored hourly throughout the study area.

Table 1: MOF - CSD LOADING HOPPER BARGE SPECIFICATIONS (supplied by Baggermanns)

| | | | | |
|---|---|---|---|---|
| Number of Barges | 3 | | Travel To Dump Time | 35.64 mins |
| Dump Distance | 11 km | | Dump & Turn Time | 10.00 mins |
| Return Distance | 11 km | | Return from Dump Time | 35.64 mins |
| Travel Speed (mean) | 10 knots | | Cycle Time | 81.27 mins |
| Volume Transported | 879,278 $m^3$ | | Loading Time | 27.09 mins |
| Barge Capacity | 3700 $m^3$ | | Total Cycle Time | 108.37 mins |
| Solids Filling Rate | 1097 $m^3$/hour | | | |

Table 2: MOF - CSD INITIAL 18 HOUR DREDGE LOG (supplied by Baggermanns)

| From | To | Description | Volume (m3) | Advance (m) | Barges | Accum. Volume (m3) | Overflow (mins) | Overflow Volume (m3) | Volume Overflow (m3) | Accum. overflow (m3) |
|---|---|---|---|---|---|---|---|---|---|---|
| 6:00 | | Move from anchor position to dredging area | | | | | | | | |
| 10:00 | | Position Barge alongside | | | | | | | | |
| | 10:30 | Commence Dredging | | | | | | | | |
| 10:30 | 10:57 | Load Barge 1 | 494 | 1.93 | 1 | 494 | 17 | 3.8 | 3,902 | 3,902 |
| 10:57 | 11:11 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 11:11 | 11:38 | Load Barge 2 | 494 | 1.93 | 2 | 988 | 17 | 3.8 | 3,876 | 7,778 |
| 11:38 | 11:52 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 11:52 | 12:19 | Load Barge 3 | 494 | 1.93 | 3 | 1,482 | 17 | 3.8 | 3,876 | 11,654 |
| 12:19 | 12:33 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 12:33 | 13:00 | Load Barge 1 | 494 | 1.93 | 4 | 1,976 | 17 | 3.8 | 3,876 | 15,530 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13:00 | 13:14 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 13:14 | 13:41 | Load Barge 2 | 494 | 1.93 | 5 | 2,470 | 17 | 3.8 | 3,876 | 19,406 |
| 13:41 | 13:55 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 13:55 | 14:22 | Load Barge 3 | 494 | 1.93 | 6 | 2,964 | 17 | 3.8 | 3,876 | 23,282 |
| 14:22 | 14:36 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 14:36 | 15:03 | Load Barge 1 | 494 | 1.93 | 7 | 3,458 | 17 | 3.8 | 3,876 | 27,158 |
| 15:03 | 15:17 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 15:17 | 15:44 | Load Barge 2 | 494 | 1.93 | 8 | 3,952 | 17 | 3.8 | 3,876 | 31,034 |
| 15:44 | 15:58 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 15:58 | 16:25 | Load Barge 3 | 494 | 1.93 | 9 | 4,446 | 17 | 3.8 | 3,876 | 34,910 |
| 16:25 | 16:39 | Change teeth, advance, mechanical etc | | | | | | | 0 | |
| 16:39 | 17:06 | Load Barge 1 | 494 | 1.93 | 10 | 4,940 | 17 | 3.8 | 3,876 | 38,786 |
| 17:06 | 17:20 | Change teeth, advance, mechanical etc | | | | | | | 0 | 0 |
| 17:20 | 17:47 | Load Barge 2 | 494 | 1.93 | 11 | 5,434 | 17 | 3.8 | 3,902 | 42,687 |
| 17:47 | 18:01 | Change teeth, advance, mechanical etc | | | | | | | 0 | 0 |
| 18:01 | 18:28 | Load Barge 3 | 494 | 1.93 | 12 | 5,928 | 17 | 3.8 | 3,876 | 46,563 |

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# 4 RESULTS

## 4.1 TURBIDITY AND SEDIMENTATION IMPACT ZONE ANALYSES

The impact criteria provided by RPS for the EIS/ERMP studies are reproduced in Table 3. These criteria were used to analyse the model output to produce effect zones showing regions affected by turbidity (TSS) or sedimentation that result in high impact, moderate impact or influence (but no impact) (see Figures 4.1 and 4.2). It should be noted that the "clover leaf" shape of the contours at the spoil ground are entirely a function of choosing 5 different locations (4 corners and one in the middle) within the spoil ground to release material. If more points had been chosen then a "squarer" result would have been obtained.

In addition to the impact zones, time series of turbidity and daily sedimentation were extracted from the modeling results at locations, shown in Figure 4.3, in the vicinity of the dredging of the MOF.

The time series of turbidity at these locations are shown in Figure 4.4 and the daily sedimentation rates are shown in Figure 4.5. These plots do not extend to the full 377 days of dredging as there is minimal impact at these locations during the dredging of the LNG channel.

Table 3: Cumulative Impact Zones defined for Dredging at Barrow Island

- Exposure for at least six hours during daylight hours was regarded as satisfying the criteria
- The minimum TSS level for the zone of influence (zone 3) was 2mg/litre
- The minimum sedimentation for the zone of influence (zone 3) was 1mg/$cm^2$

| **Zone 1: Zone of High Impact** | | | |
|---|---|---|---|
| Variable | Timeframe | Concentration | Time (cumulative days) |
| TSS | Short | ≥25 mg $l^{-1}$ | 5 in 15 |
| | Medium | ≥10 mg $l^{-1}$ | 20 in 60 |
| | Long | ≥5 mg $l^{-1}$ | 80 in 240 |
| Sedimentation | Daily | ≥100 mg $cm^{-2}$ $d^{-1}$ | 1 |
| | Short | ≥25 mg $cm^{-2}$ $d^{-1}$ | 5 in 15 |
| | Medium | ≥10 mg $cm^{-2}$ $d^{-1}$ | 20 in 60 |
| | Long | ≥5 mg $cm^{-2}$ $d^{-1}$ | 40 in 120 |
| **Zone 2: Zone of Moderate Impact** | | | |
| TSS | Short | ≥25 mg $l^{-1}$ | 2 in 6 |
| | Medium | ≥10 mg $l^{-1}$ | 7 in 21 |
| | Long | ≥5 mg $l^{-1}$ | 20 in 60 |
| Sedimentation | Daily | ≥50 mg $cm^{-2}$ $d^{-1}$ | 1 |
| | Short | ≥25 mg $cm^{-2}$ $d^{-1}$ | 2 in 6 |
| | Medium | ≥10 mg $cm^{-2}$ $d^{-1}$ | 7 in 21 |
| | Long | ≥5 mg $cm^{-2}$ $d^{-1}$ | 20 in 60 |
| **Zone 3: Zone of Visibility (Influence)** | | | |
| TSS | Any | ≥2 mg $l^{-1}$ | 1 |
| Sedimentation | Any | ≥1 mg $cm^{-2}$ $d^{-1}$ | 1 |

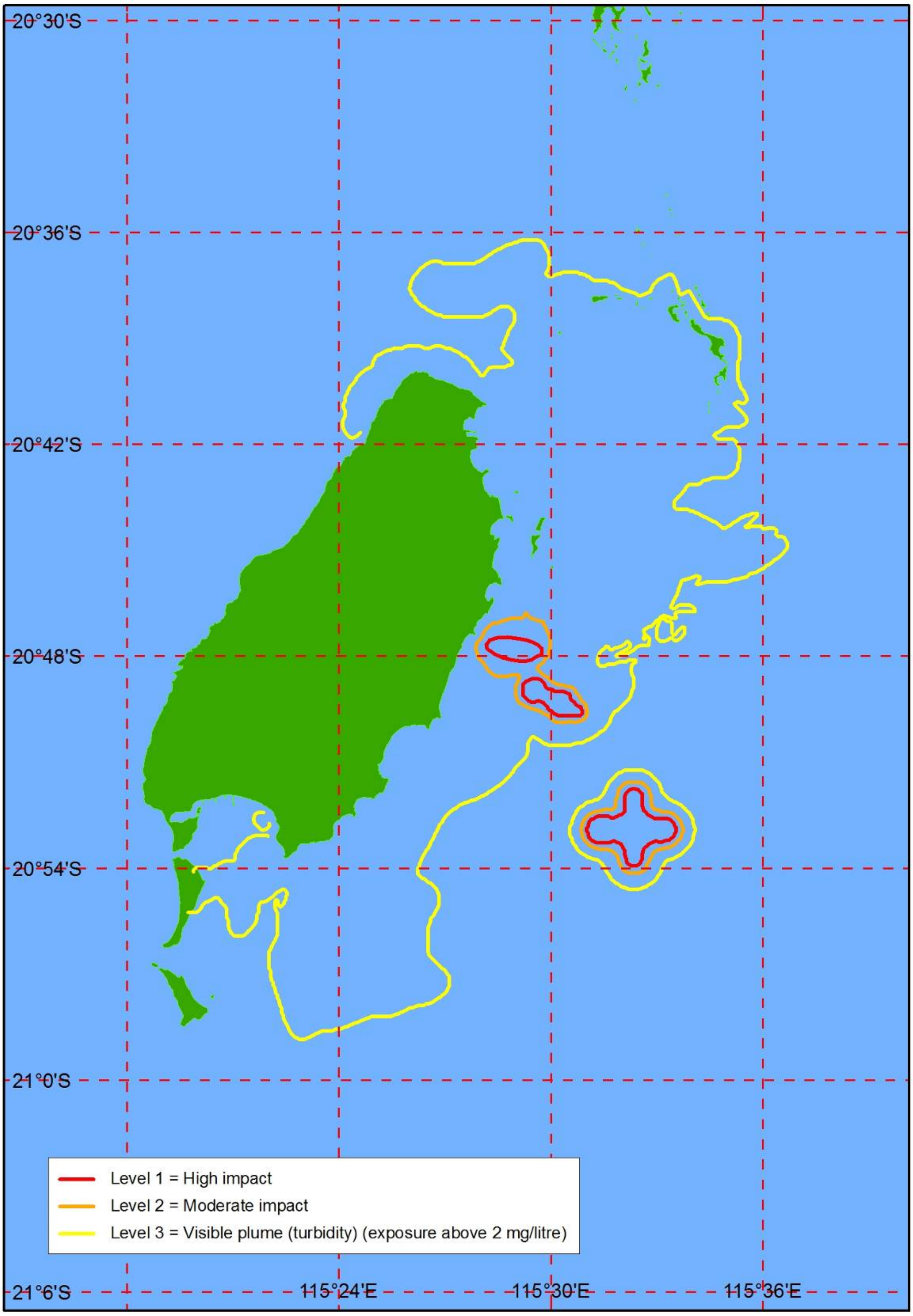



Figure 4.1 Impact zones derived from DREDGE3D predictions of turbidity for the "Base" case.

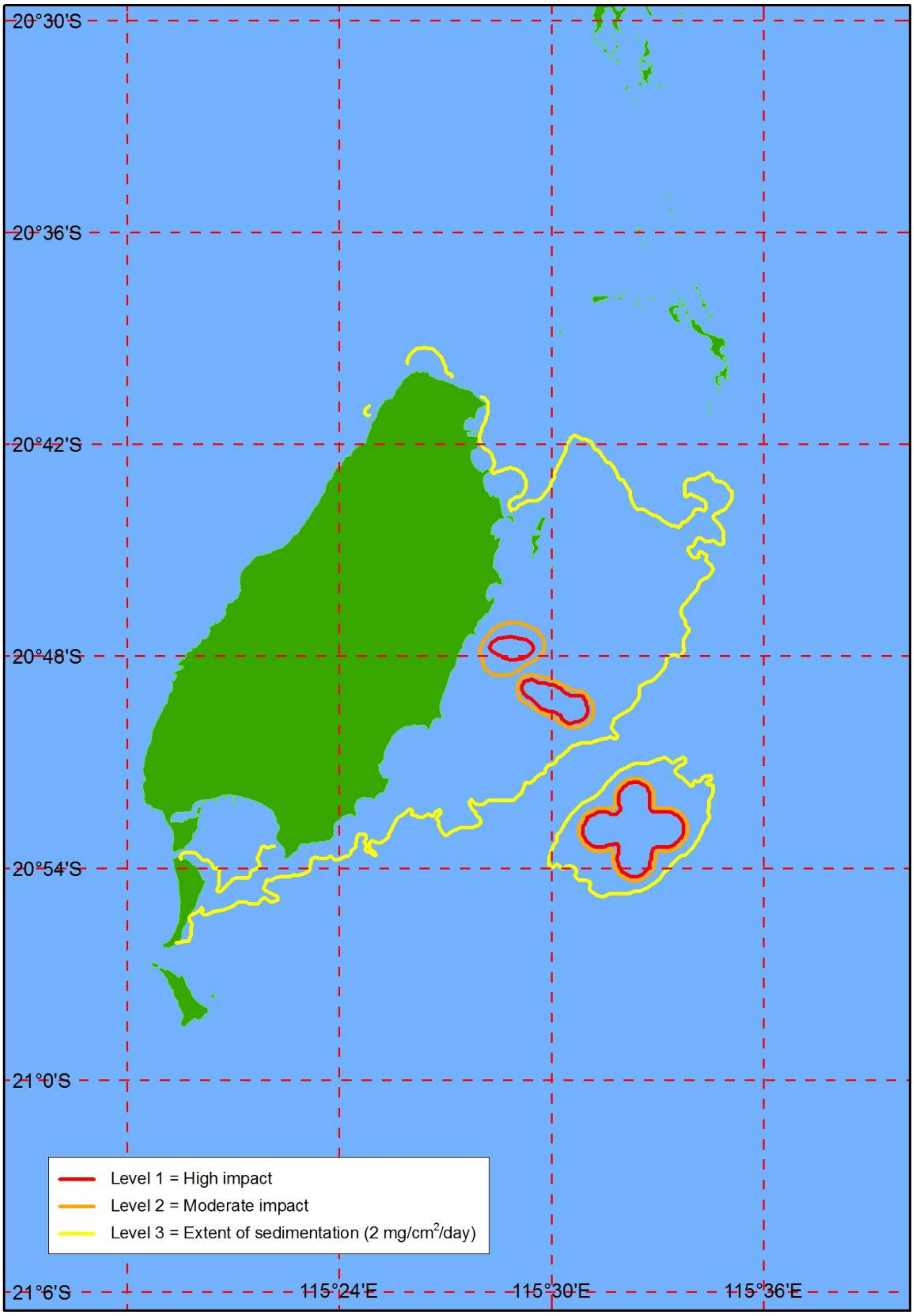



Figure 4.2: Impact zones derived from DREDGE3D predictions of sedimentation rates for the "Base" case.

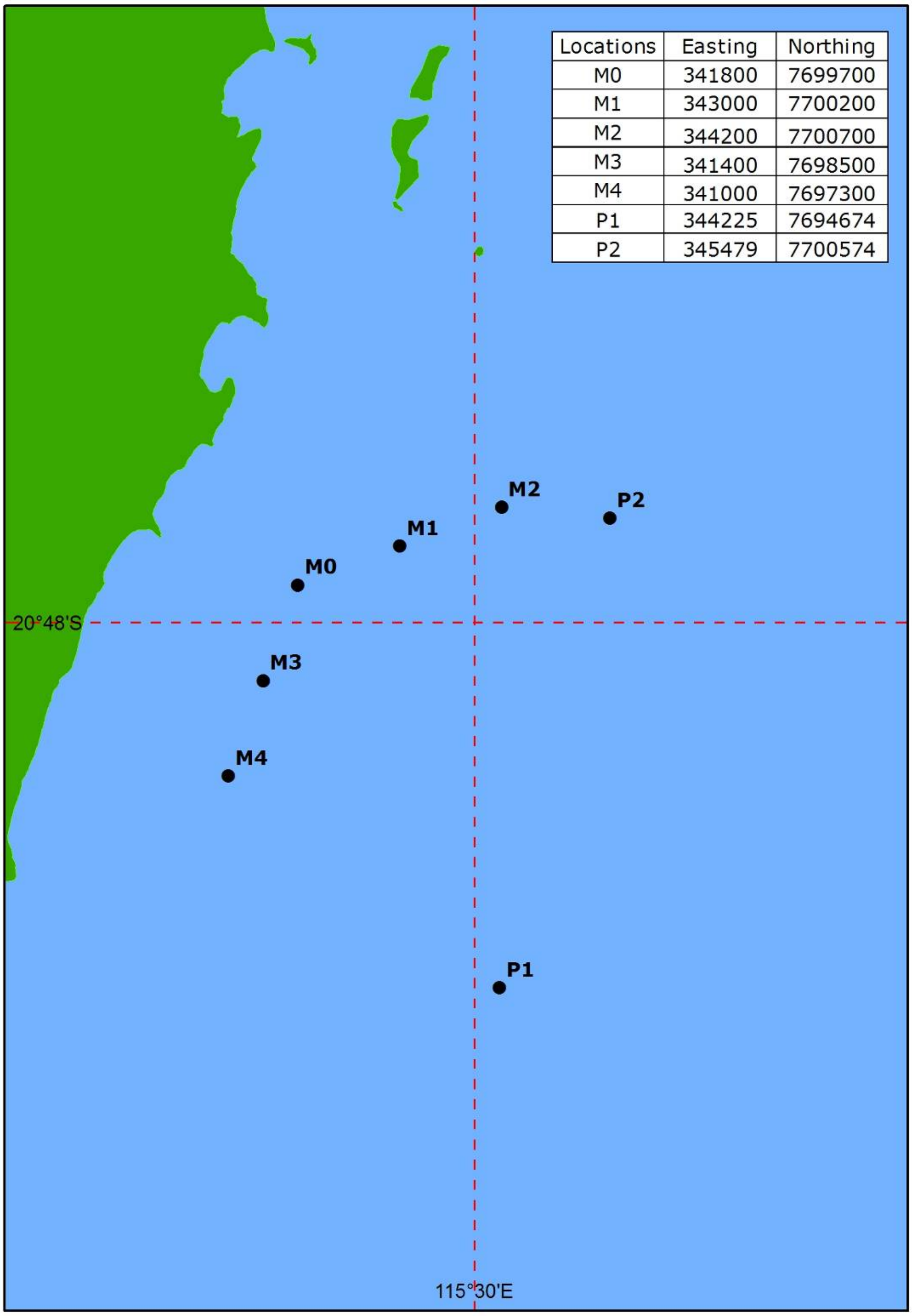



Figure 4.3: Locations within the vicinity of the MOF dredging where time series of turbidity and daily sedimentation were extracted.

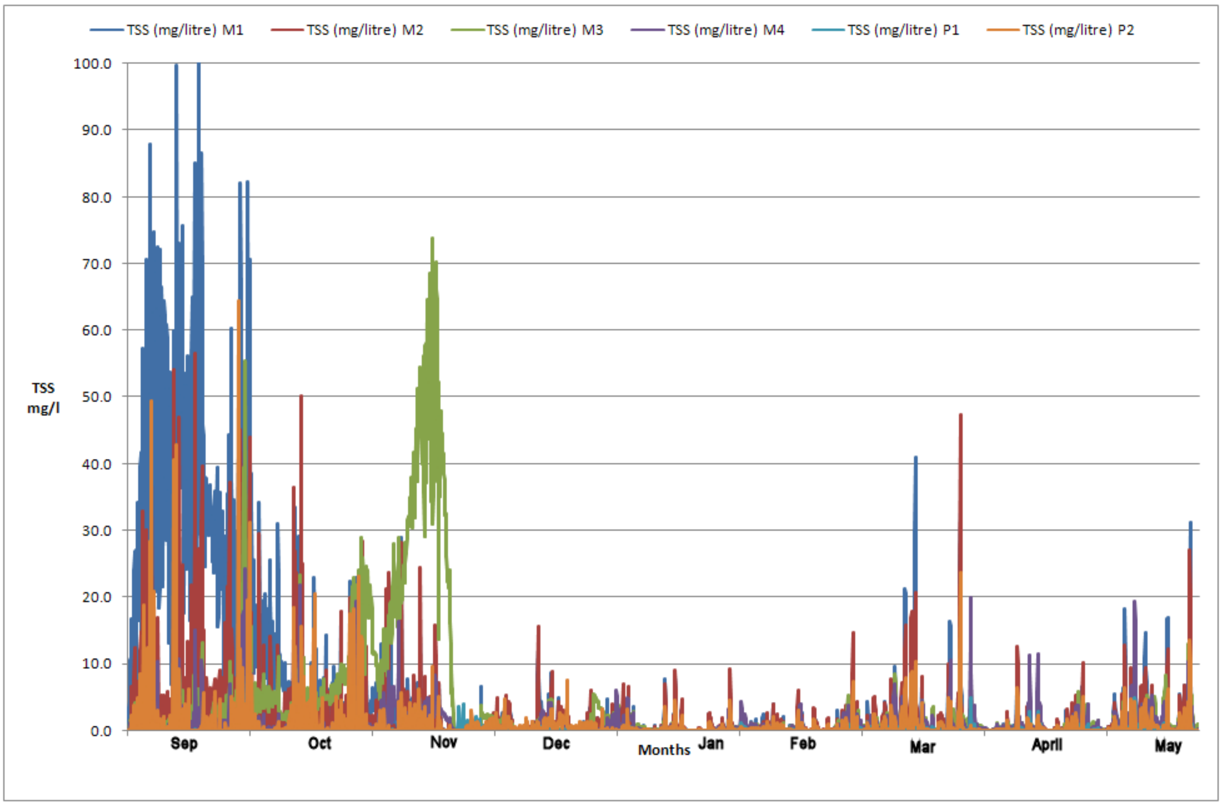



Figure 4.4: Time series of turbidity at the locations shown in figure 4.3.

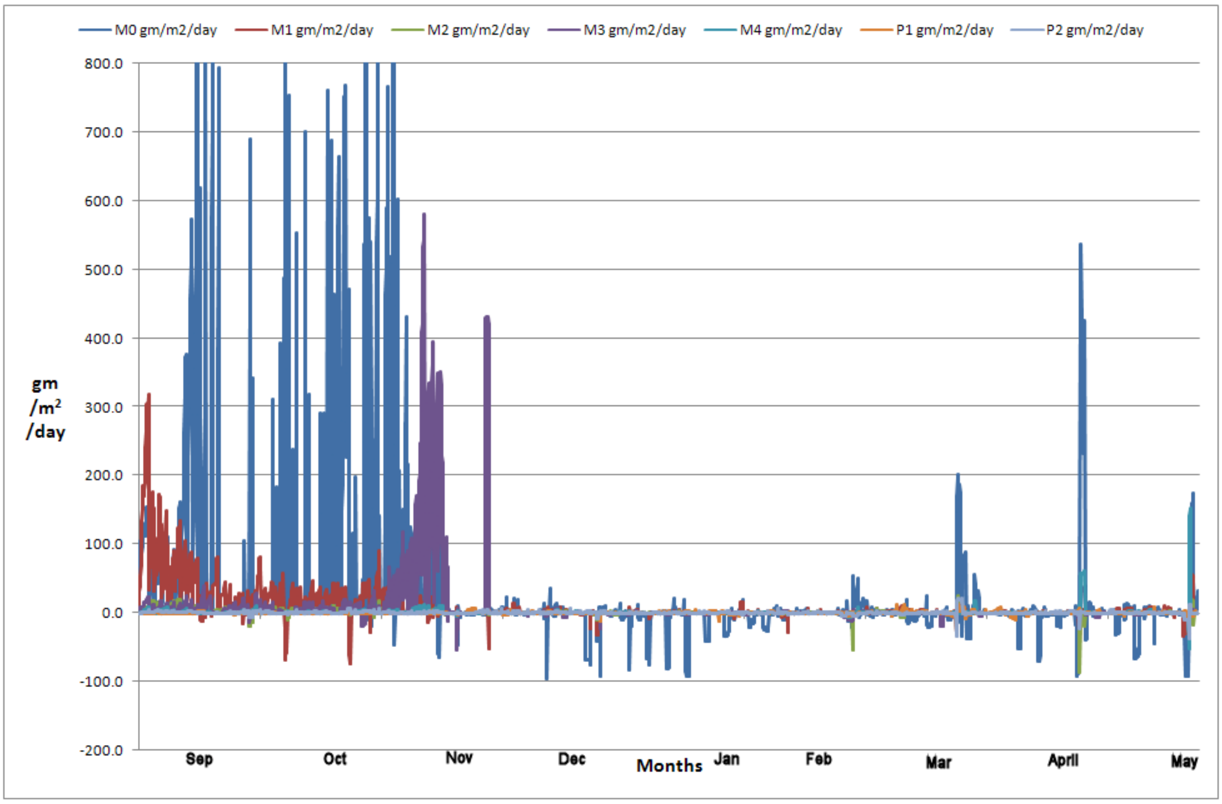



Figure 4.5: Time series of daily sedimentation at the locations shown in figure 4.3.

# 5 DISCUSSION

The revised dredge plumes appear similar in magnitude to previous estimates. While the dredging impact zones may be slightly smaller due to improvement in the accuracy of the detail included in the dredge log, and improvements to facility design, the model is not sufficiently precise to delineate minor differences. However, it can be assumed the impact zones will not be larger than those presented in the EIS/ERMP

Some areas of potential impact from sedimentation or turbidity that were identified in the EIS/ERMP are not predicted under the revised study. The changed alignment of the LNG channel removed the need to dredge the small ridge to the east of the turning basin and consequently the small impact zones around this area do not appear in the revised simulation outputs.

Similarly, the impact zones to the south of the MOF near Shark Point and the smaller moderate impact zone on the Lowendal Shelf, associated with dredging for the approved proposal (Figure 18; Chevron 2006), do not appear in the revised simulation.

These variations are probably a result of changes such as:

- The reduced amount of rock to be cut for the MOF due to its relocation further out to sea, resulting in less “rock flour” being produced.
- The improved flushing near the MOF due to the absence of the causeway from Barrow Island during the dredging.
- The reduction in the amount of dredging in shallow water and conversely the increased amount of dredging in deeper water allowing better flushing of fine material.
- The change from using overflowing barges for removing the material cut by the CSD in the LNG channel to leaving it on the seabed and removing the material later to the spoil ground with the TSHD
- The use of the SWAN wave model to simulate orbital velocities for resuspension of material from the seabed instead of the less accurate algorithms used in the previous studies. This improvement resulted in better simulations of the resuspension and flushing of fine materials from the region.
- The development of significantly more accurate dredge logs by Baggermanns reflecting much more fine detail of the dredge plan
- The changed alignment of the LNG channel.

# 6 REFERENCES

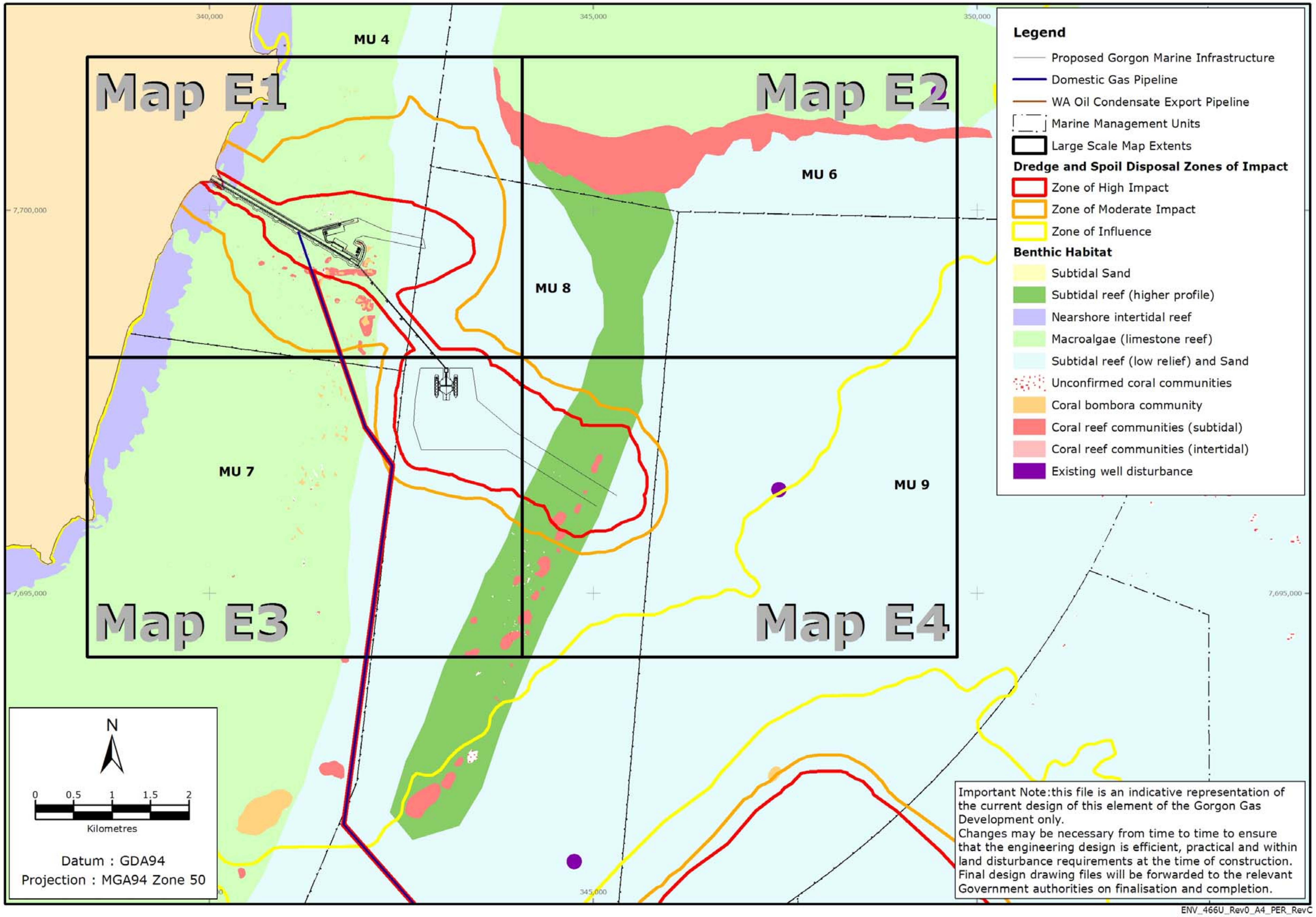

Chevron 2005. *Draft Environmental Impact Statement/Environmental Review and Management Programme for the Proposed Gorgon Development. Main Report Volume II.* Chevron Australia. Perth Western Australia. September 2005.

Chevron 2006. *Final Environmental Impact Statement/Response to Submissions on the Environmental Review and Management Programme for the Proposed Gorgon Development.* Chevron Australia. Perth Western Australia. May 2006

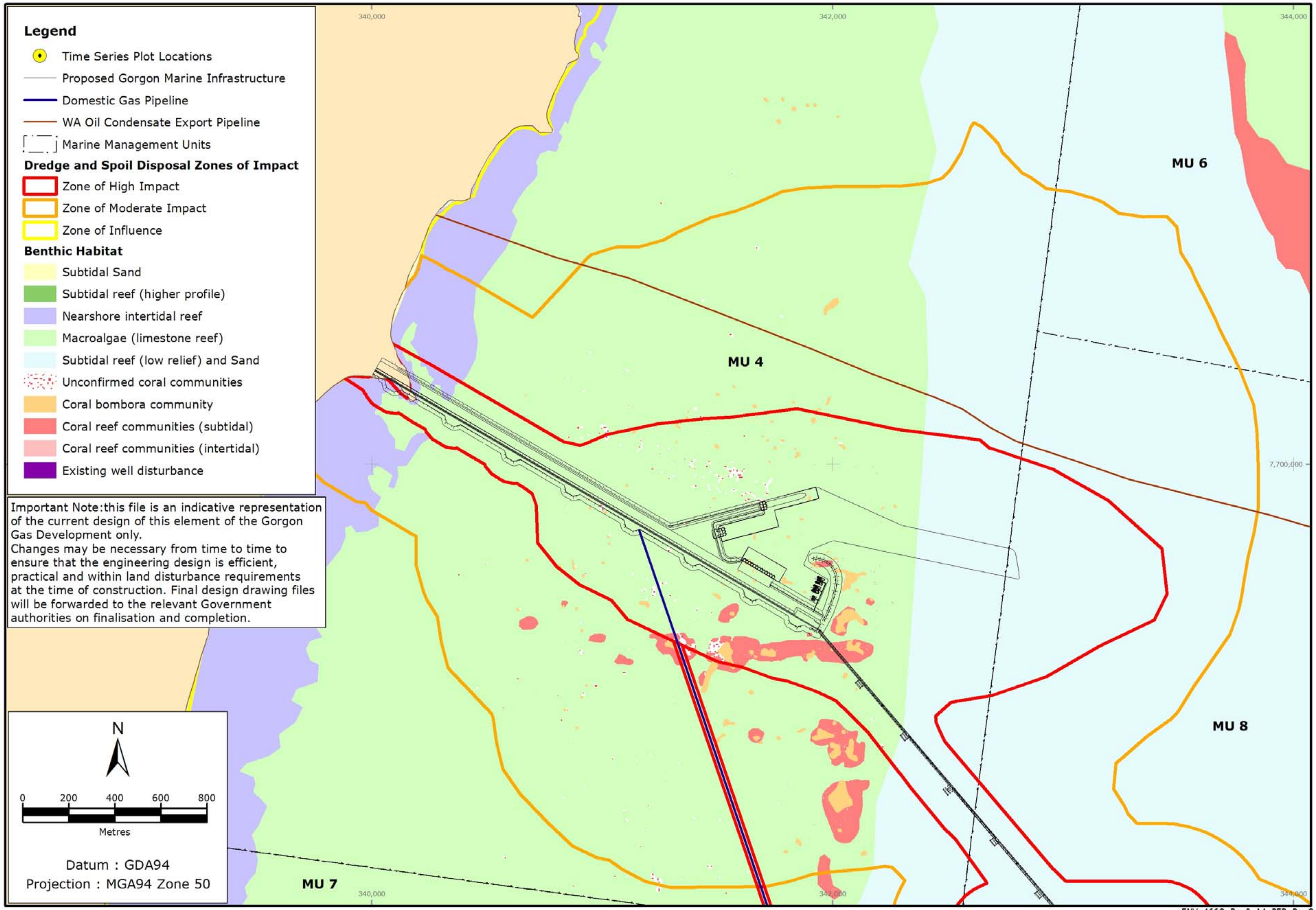
GEMS 2005a. *Gorgon Development Dredging Program Simulation Studies.* Global Environmental Modelling Systems. Perth, Western Australia. July 2005.

GEMS 2005b. *Gorgon Development Measurement and Model Prediction of Ocean Currents and Tides at Barrow Island, North Western Australia.* Global Environmental Modelling Systems. Perth, Western Australia. October 2005.

# Additional CMBSEIR Benthic Habitat Mapping at a Larger Scale.




**Index Map: CMBSEIR Benthic Habitat Mapping Presented at Larger Scale**

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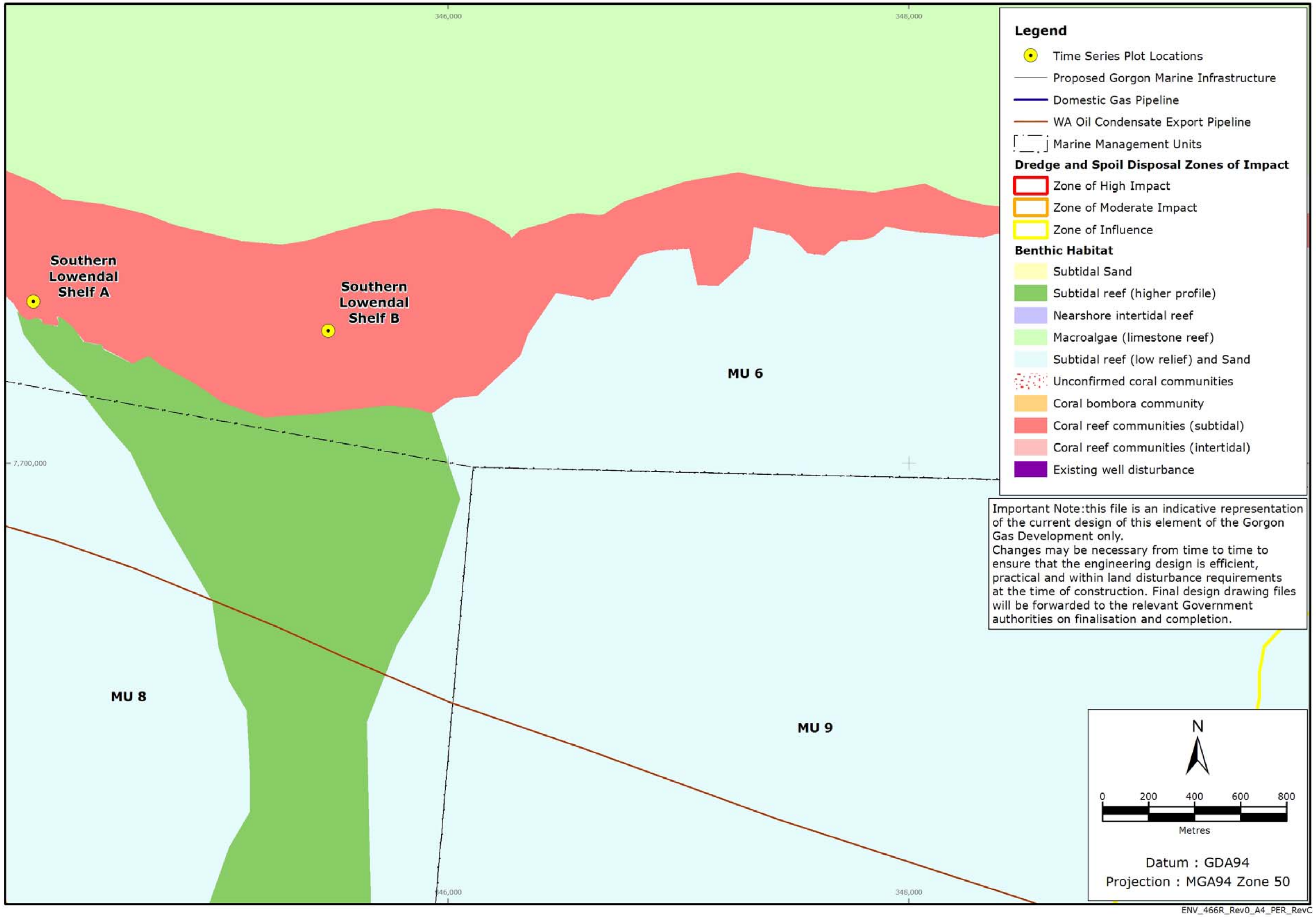
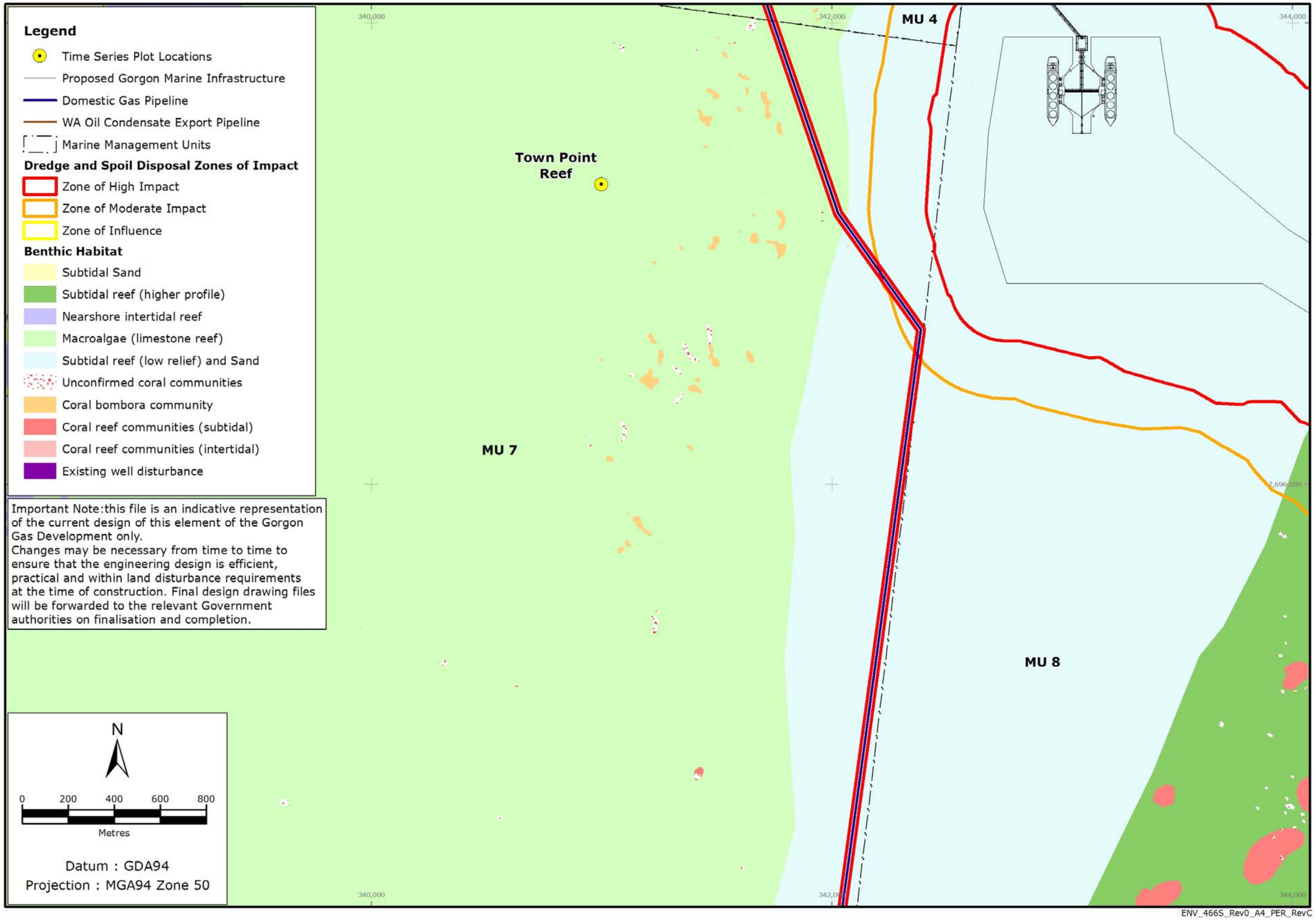
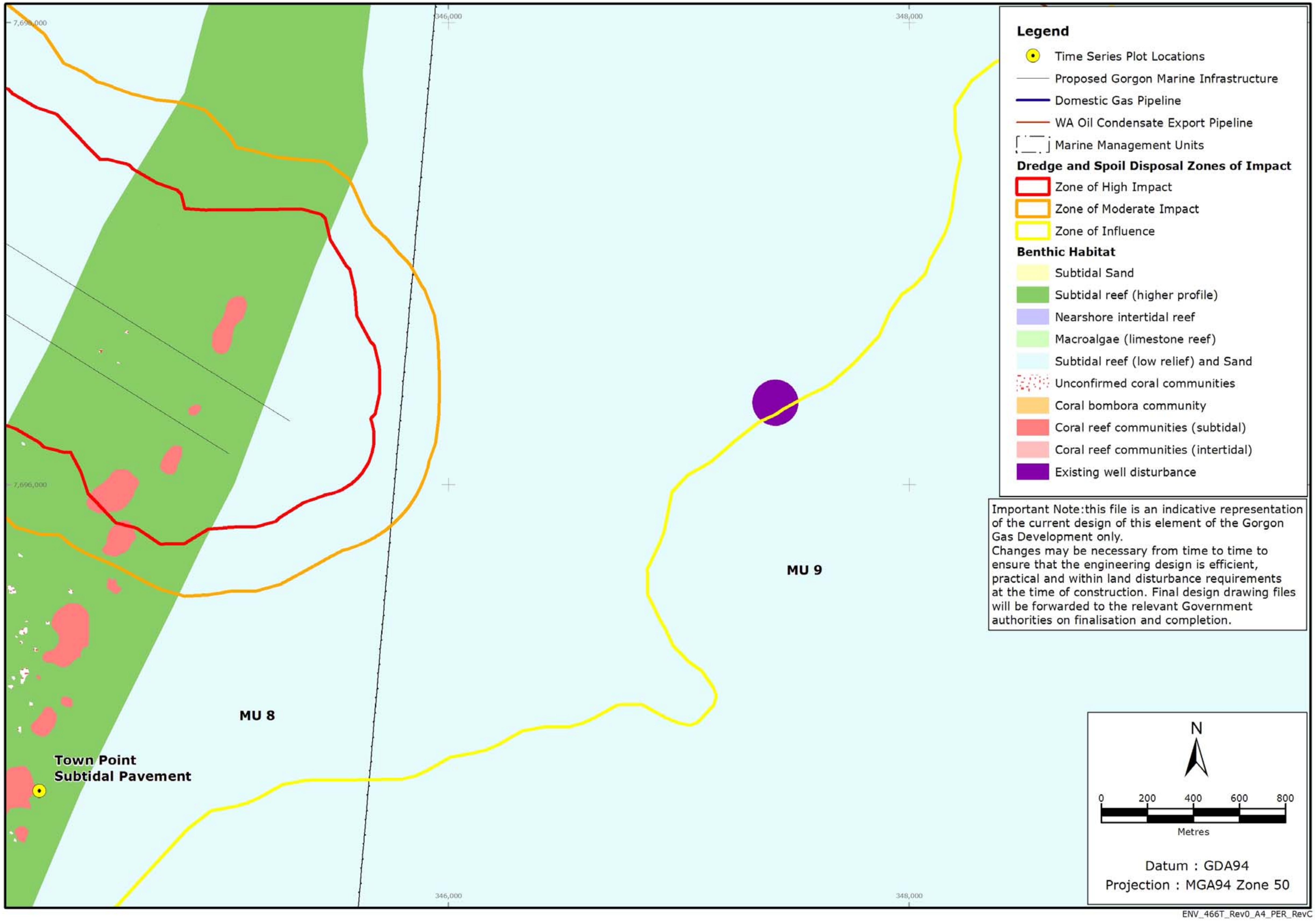
**Map E1: CMBSEIR Benthic Habitat Mapping Presented at Larger Scale**




**Map E2: CMBSEIR Benthic Habitat Mapping Presented at Larger Scale**




**Map E3: CMBSEIR Benthic Habitat Mapping Presented at Larger Scale**




**Map E4: CMBSEIR Benthic Habitat Mapping Presented at Larger Scale**

# APPENDIX F

## Coastal Processes Modelling Report For The Revised Marine Infrastructure

Please note that Appendix C (*Coastal Modelling – BWI – Metocean Report*) referenced in this appended Coastal Processes Modelling Report has not been included in this PER due to the size of the report. Electronic copies can be made available to reviewers upon request. Please see Chevron Australia contact details at the beginning of this PER

# CHEVRON AUSTRALIA PTY LTD

# MATERIALS OFFLOADING FACILITY - COASTAL PROCESS IMPACT STUDY

**For The**

# GORGON PROJECT
# BARROW ISLAND LNG PLANT

Document No.: G1-TE-T-7400-REP0501

| **Revision:** | **0** | **1** | | |
|---|---|---|---|---|
| Prepared by: | M Manning | M Manning | | |
| Reviewed by: | F Bicker | F Bicker | | |
| KJVG Approved by: | R Powers | R Powers | | |
| CVX Approved by: | G Prior<br>B Cash | G Prior<br>B Cash | | |
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Kellogg Joint Venture Gorgon

KBR JGC HATCH CLOUGH

Chevron

**SUMMARY OF DOCUMENT REVISIONS**

| Rev. No. | Date Revised | Section Revised | Revision Description |
|---|---|---|---|
| A | 30/05/08 | All | Issued for EDC Review |
| B | 12/06/08 | All plus Title Change | Issued for ICR Review<br>Document has had a title change from MOF Facility Marine Impact Study to MOF – Impacts on Coastal Process |
| 0 | 14/07/08 | All | Issued for Information – ICR and EDC comments incorporated.<br>Document template name change requested by CVX (ICR-1666) |
| 1 | 02/09/08 | Minor | Re-Issued for Information (IFI) with minor edits subsequent to further review |

# TABLE OF CONTENTS

# EXECUTIVE SUMMARY

As part of the Gorgon Project it is proposed to construct a Materials Offloading Facility (MOF), comprising of an earthworks causeway protected by rock and concrete armour, extending 2.1 km offshore from Town Point.

A coastal modelling programme has been undertaken to investigate the potential impact of the MOF on coastal processes. In particular the programme investigated changes in circulation and wave climate and the resulting changes to sediment transport due to the MOF during ambient and tropical cyclone events. The modelling programme used results of geophysical and geotechnical investigations.

Sea turtle, beach sand and coastal vegetation surveys have been conducted on Barrow Island in order to determine baseline characteristics influencing the choice of beaches for turtle nesting. This report provides an assessment of the potential impact of the MOF on coastal processes influencing some these baseline characteristics.

Town Point is a rocky headland extending 400 m from the beach, situated between two bays, with extended beaches, Terminal Beach and Bivalve Beach. The beaches to the north and south of Town Point are situated on a gently sloping rock platform, extending several kilometres offshore. Wave shoaling and breaking processes occur over the shallow rock platform and result in low wave energy at the beach face, with waves only reaching the foredune under spring high tide conditions. This results in reflective beaches, with mild gradient beach faces. The rock platform acts to restrict the direction of wave approach to close to orthogonal to the beach alignment, and reduces any opportunity for longshore sediment transport. The current regime is tidally driven and tides tend to propagate into the region from the north and south and converge mid-way along the east coast, resulting in a zone of low current speeds, as demonstrated by the coastal modelling (MetOcean, 2008).

Geophysical investigations indicate there is little sediment supply available within the littoral transport budget. The sediment layer over the rock platform is thin or absent and a ‘ridge’ of sediment further offshore is variably cemented and is considered a stable bathymetric feature, the results of the geophysical investigation are presented in Figure 2.6.

Historical photographs illustrate there is a stable sparse vegetation line present on the foredune and dense vegetation line on the steep face of the primary dune. The stability of the shoreline is further demonstrated by the lack of changes to sedimentary features. Historical photographs illustrate that there has not been significant accretion or erosion of the beaches or around Town Point.

The results of the coastal modelling programme demonstrate that the MOF structure will cause an acceleration of ambient current speeds in the direct vicinity of the MOF head, of the order of 0.7 – 0.8 m/s. It also induces residual eddies, of low magnitudes, to form on the flood and ebb tides in the lee of the MOF.

The magnitude of littoral transport is restricted by the limited sediment supply, angle of wave approach and low currents in the zone of tidal convergence. The modelling programme indicates that the MOF is not expected to have a significant impact on the ambient sediment transport.

There is no significant effect on the coastal process with the Material Offloading Facility in place. Eroded material during extreme events will return to the beach zone during ambient conditions in the same fashion as the material would return to the beach in its natural state, without the MOF in place.

Tropical cyclones are recognised as the most likely phenomena to cause dramatic change to the shoreline, beach profile and sediment transport at Town Point. Three

tropical cyclones, Bobby, Olivia and Monty have been selected as model cyclones, these cyclones have been 'time-shifted' to align the peak storm surge with a peak spring tide in order to represent the maximum potential for erosional impact on the shoreline. The model demonstrates the tropical cyclones waves break a significant distance offshore due to the shallow rock platform and this dissipates the energy reaching the beach face. The MOF creates an area of wave protection, referred to as the 'shadow zone'. The extent and magnitude of the zone is related to the angle and magnitude of wave approach.

The impact of the MOF on sediment transport during tropical cyclones is minimal and minor accretion of sand on either side of the MOF causeway may occur. The shadowing effect is shown to result in minor accretion in the shadow zone of magnitudes of 10 – 20 cm and also to provide protection to the Southern Beach reducing erosion during the modelled tropical cyclone Olivia. Following the passage of the cyclone the wave climate changes dramatically from a swell to fetch limited sea wave condition. This acts to move sediment onshore and re-create the original bathymetry.

The overall impact of the MOF on sediment transport during tropical cyclones and ambient conditions is minor and any changes in sedimentation will be manageable due to the low predicted rates of sediment transport in the area.

The 'base-case' design for the MOF comprised a shorter rock causeway and a coastal modelling study was undertaken in 2006 focusing on the impact of tropical cyclones on the shoreline stability with the MOF in place and the siltation of the dredge channel. This programme indicated that the MOF had very little impact on the shoreline stability. The Department for Planning and Infrastructure (DPI) assessed that the impact of the MOF causeway was likely to be modest. The DPI raised a number of issues in their review of their previous study which have been addressed in the scope of this modelling program.

Sea turtle tagging records demonstrate that flatback turtle nesting is focused on central east coast beaches including, Mushroom, Bivalve, Terminal and Yacht Club North hand South Beaches. 39 % of nests surveyed were situated on the beach berm, 30 % at the toe of the foredune and 23 % in the foredune. The monitoring programme has illustrated that individual turtles migrate up to 3,000 km away from Barrow Island and forage and nest in a range of regions. The particle size distribution and compaction of beach sand are important physical characteristics determining the selection of beaches for nesting.

The extreme wave set-up on the shore line resulting from the impact of tropical cyclones is mapped out in appendix B of the report. The wave set-up levels in the northern transect is similar with or without the MOF in place. In the southern transect the wave set-up with the MOF in place is one meter less because of the shadow effect of the MOF. As a result of that, the presence of the MOF is not expected to result in any changes to the vegetation on the foredune in the shadow zone of the MOF. The foredunes in that area constitutes 53 % of the turtle nesting area. The MOF is not expected to cause significant accretion or erosion of the shoreline and will not impact on the extent of the beach face and profile in terms of turtle nesting suitability.

The localised increase in current speeds around the MOF head is not expected to have an impact on the behaviour of adult turtles as there migratory behaviour indicates they are capable of travelling through strong currents for long distances. Hatchings may circulate in eddy formations during low tide near the MOF structure when exiting from the Yacht Club North beach, but this impact is localised and the tidally driven current flows meet the main current flow at high tide. The impact of the MOF on coastal processes, nearshore vegetation and turtle habitat is expected to be minimal.

The impact of the MOF on the beaches adjacent to Town Point will be monitored as part of the Coastal Stability Monitoring and Management Plan. The baseline data acquisition program will establish the status of five beaches and capture natural variation in the beach profiles. The program will profile five beaches every 3 months for 12 months and additionally after tropical cyclone events, prior to initial construction. Physical sand characteristics, particle size distribution and compaction will be sampled at 3 locations along each beach profile and 2 – 5 transects will be surveyed per beach.

A monitoring program will be undertaken throughout construction and operation of the marine facilities to detect any adverse changes to the beach structure and sediment characteristics. The sampling and surveying will be conducted in the same manner as the baseline data acquisition program. If no changes to the beach structure are detected throughout the construction period, the frequency of sampling and profiling will be reviewed. If monitoring results show a change to the adjacent beaches the Marine Turtle Expert Panel (MTEP) and Department of Environment and Conservation (DEC) will be integral parties in developing a management strategy.

## ABBREVIATIONS

| | |
|---|---|
| ASB | Above Sea Bed |
| BWI | Barrow Island |
| DPI | Department for Planning and Infrastructure |
| EIS | Environmental Impact Statement |
| ERMP | Environmental Review and Management Programme |
| EPA | Environmental Protection Authority |
| HAT | Highest Astronomical Tide |
| Hr | Hour |
| Hs | Significant Wave Height |
| Km | Kilometres |
| LAT | Lowest Astronomical Tide |
| LNG | Liquid Natural Gas |
| WA | Western Australia |
| m | Metres |
| MOF | Materials Offloading Facility |
| MPa | Megapascal |
| S | Seconds |
| Nm | Nautical miles |
| UCS | Uniaxial Compressive Strength |

# 1. BACKGROUND

As part of the Gorgon Project, an earthworks causeway protected by rock and pre-cast concrete armour is proposed to be constructed on the eastern side of Barrow Island. This structure is referred to as the MOF (Materials Offloading Facility). The function of the MOF during construction of the Gorgon gas treatment plant is to offload all plant, equipment and materials. During the operation of the plant it will be used to meet the marine transport needs of the facility. The MOF structure will also house a pipeline service corridor for the export of product.

The proposed causeway extends 2,132 m from the shoreline. A jetty structure extends another 2,000 m beyond the full MOF. A dredged channel extends from the MOF offshore approximately 750 m in length.

Figure 1.1 illustrates the proposed MOF causeway.

In order to investigate the potential impact of the MOF on coastal processes and the marine environment a number of studies have been undertaken:

- Coastal modelling
- Vegetation assessment, and
- Turtle habitat, population and behavioural investigations

The coastal modelling investigates changes in ambient and cyclonic wave and current conditions resulting from the presence of the MOF, and the impact this has on sediment transport and shoreline stability. The results of geophysical and geotechnical investigations have been used as an important input into the coastal model. The impact of these coastal process changes on the marine environment is determined using base line information gathered through the coastal vegetation and turtle studies.

## 1.1 History

The ‘base-case’ design for the MOF comprised of a shorter rock causeway, extending 1,300 m from the shoreline. This design encompassed a longer jetty structure and dredged channel. A coastal modelling study was undertaken focussing on:

- The impact of tropical cyclones on the shoreline stability with the MOF structure in place, and
- The siltation of the dredged channel due to tropical cyclones.

The results of the modelling programme illustrated that the MOF has very little impact on the shoreline stability. Small increases in accretion in the vicinity of the MOF head are demonstrated in the bed level plots and there is no significant change in sedimentation in the lee of the MOF, often referred to as the ‘shadow zone’. The modelling programme also demonstrated that very little siltation occurs in the channel, of the order of 30 – 50 mm accretion along the channel edges during tropical cyclone events.

The Department of Planning and Infrastructure (DPI) assessment of the coastal modelling and site investigation concluded that the impact of the MOF causeway on the adjacent beaches was likely to be modest and the magnitude of any changes should be manageable by Chevron.

The DPI assessment is presented in Appendix A.

A series of optimisations, to reduce the need for dredging including extensive drilling and blasting of a longer MOF entry channel, undertaken in early 2007 have resulted in the extension of the MOF to its current design length. As a result of this optimisation an additional modelling program has been undertaken to determine the impact of the longer MOF structure on the marine environment. The coastal modelling report by MetOcean Engineers is presented in Appendix B.

# 2. SITE DESCRIPTION

Barrow Island is situated off the north-west shelf of WA. The MOF is located at Town Point on the East side of the Island. Figure 2.1 is an aerial photograph illustrating Barrow Island and Town Point.

The coast of Barrow Island in the vicinity of the proposed MOF is comprised of several extended (200 - > 600 m length), almost linear sandy beaches, separated by short rocky headlands. The beaches are perched upon a gently sloping rock shore platform, extending almost 3 km from the beach. The water depth at the head of the MOF is approximately 3.0 m below LAT.

This section provides an overview of;

- Dominant oceanographic and meteorological conditions
- Coastal processes
- Geophysical characteristics
- Coastal Vegetation, and
- Sea Turtle nesting habitats and behaviour.

## 2.1 Meteorological and Oceanographic Conditions

Measurement and modelling programmes have been undertaken to determine, ambient, non-cyclonic and cyclonic wind, wave and current conditions at Barrow Island (MetOcean Report, 2006). Figure 2.2 presents a location plan of the measurement and model out put. A detailed over view of regional climatology is presented in Section 3 of MetOcean (2008) (presented in Appendix B).

### 2.1.1 Non-Cyclonic Winds

The mean ambient wind speed during the summer period, defined as October through March, is 6.6 m/s and the maximum summer wind speed is 16.2 m/s. The dominant direction is from the southwest and west.

Winter conditions, defined as the months of April through September, approach from the east, south and south-west and have a mean wind speed of 5.8 m/s and maximum speed of 19.4 m/s. Easterly gales occur between May and August with speeds in the range of 12.5 to 20 m/s.

Ambient wind statistics are based on 5 years of measured wind data from 1998 to 2002 and are a combination of measured Barrow Island winds, augmented with 18 years of modelled NCEP gridded winds to fill in any “gaps” in the measured data. Ambient wind model input in this modelling programme is 3 years of wind measurements undertaken at Barrow Island airport.

### 2.1.2 Waves

The ambient nearshore wave climate is dominated by locally generated sea states derived from sea breezes between the mainland and Barrow Island.

The mean significant wave height at the MOF wharf location is 0.47 m, with maximum wave heights of 2.11 m. Town Point is largely sheltered from westerly swell by Barrow Island, the Lowendal Shelf to the north and the shallow bathymetry between Barrow Island and the mainland.

Table 2.1 presents the ambient mean and maximum significant wave heights and general range of peak wave periods approaching from the prevalent wave directions (MetOcean 2006).

**Table 2.1 Ambient Wave Statistics at MOF Wharf Location (August 2003 – July 2004)**

| Direction | East | South-Southeast | Southwest |
|---|---|---|---|
| Mean Hs (m) | 0.56 | 0.51 | 0.16 |
| Max Hs (m) | 1.3 | 1.73 | 0.53 |
| Tp Range (s) | 4-8 | 2-6 | 2-4 |

Ambient wave statistics are based on 1 year of SWAN wave modelling, calibrated offshore to nearshore using 6 months of contemporaneous wave measurements (20m offshore, 10 m inshore) Measurement locations include a location offshore of Town Point at 16 m depth, and 6 months of wave and long wave measurements closer inshore at 10 m depth (MetOcean 2006).

Elevated wave heights may result from tropical cyclones, whereby the maximum wave heights at the MOF location will be depth limited. The impact and effect of tropical cyclones are discussed further in Section 2.1.4.

### 2.1.3 Currents

Ambient currents along the east shoreline of Barrow Island are complicated due to the nature of tidal propagation in the area. Local accelerations occur along deep channels between Barrow Island and Veranus Island. The tides tend to propagate into the region from the southern and northern sections of the island, meeting halfway along the east shore and reversing on the ebbing tide. This produces a zone midway along the eastern shore with very little current, illustrated in the current modelling (MetOcean, 2008). Current measurements (both those listed below and also datasets unavailable to Chevron) support and validate the model output. Geomorphic evidence of fine sediment deposited in regions of low currents speeds at the confluence of the tidal waves also corroborates this behaviour.

The tides at Town Point are semidiurnal, with a small diurnal inequality. The MOF location has a macro-tidal range of 4.75 m. Astronomical tide and local wind stress are likely to be the dominant contributors to the current regime on the east of Barrow Island.

Current measurements were undertaken at 4 locations, presented below, and these measurements were used in the calibration and validation of the current model applied at the nearshore locations.

- one year at 10 m ASB in 16 m water depth near Town Point
- one year 6 m ASB in 10 m water depth near Town Point
- 1.5 months at the MOF channel and LNG dredge channel (short MOF location)
- 1 months at 0.83 m ASB in 2.5 m water depth near WAPET Landing

### 2.1.4 Tropical Cyclones

Barrow Island is located in a region of high tropical cyclone frequency. Between 1960 and 2003 on average 3.84 cyclones pass within 400 nm of Barrow Island each year (MetOcean, 2006).

Tropical cyclones usually form in the Timor and Arafura seas between November and April. Westwards circulation of the tropical belt normally influences their initial path with southwards motion developed through oriolis. Their track becomes more variable to the south as they interact with high-pressure synoptic systems and the Australian land mass.

Tropical cyclones and other extreme storm events may create the most dramatic changes to beach profiles if storm surge raises water levels and exposes wave influence to higher parts of the beach not normally vulnerable to waves (SPM, 1984).

The three main components for influencing erosion or accretion of sediment on the east coast of Barrow Island are;

- sea level elevation (storm surge),
- wave action to suspend sediment,
- steady current to advect sediment.

Easterly winds cause a direct setup against Barrow Island and are the most effective in direction wave energy into the nearshore zone. Strong currents will ensure from regional pressure gradient setups. Northerly winds may cause a setup of sea level against the Lowendal shoals; it does not have the added Coriolis component of storm set up against the Barrow coast. Tropical cyclones passing east of Barrow Island will have the most significant impact (in this scenario the impact is minor) on beach profiles and sedimentation at Town Point as this track direction results in maximum storm surge.

Table 2.2 presents a table of tropical cyclones between 1977 and 2007 that have occurred in the vicinity of Barrow Island and their category rating in close proximity to Barrow Island.

The cyclone categories below related to the following maximum gust speeds (Bureau of Meteorology, Internet Site);

- Category 1: Less than 125 km/hr
- Category 2: 125 -170 km/hr
- Category 3: 170 -225 km/hr
- Category 4: 225 -280 km/hr
- Category 5: Greater than 280 km/hr

**Table 2.2 Tropical cyclone events which have occurred in the vicinity of Barrow Island (< 200 km) between 1976 and 2007.**

| Name | Date | Category When Cyclone is Nearest Barrow Island |
|---|---|---|
| Karen | 1977 | 2 |
| Mabel | January 1981 | 4 |
| Ian | March 1982 | 3 |
| Emma | December 1984 | 1 |
| Ilona | December 1988 | 3 |
| Orson | March 1989 | 5 |
| Ian | February / March 1992 | 3 |
| Bobby | February 1995 | 3 |
| Frank | December 1995 | 3 |
| Jacob | March 1996 | 3 |
| Olivia | March 1996 | 4 |
| Billy | December 1998 | 1 |
| Vance | March 1999 | 5 |
| Steve | March 2000 | 2 |
| Inigo | April 2003 | 1 |
| Monty | March 2004 | 2 |
| Daryl | January 2006 | 1 |
| Clare | January 2006 | 1 |
| Emma | February 2006 | 1 |
| Glenda | March 2006 | 3 |

| Name | Date | Category When Cyclone is Nearest Barrow Island |
|---|---|---|
| Hubert | April 2006 | 1 |
| Jacob | March 2007 | 1 |

## 2.2 Coastal Processes

The proposed MOF location is Town Point, illustrated in Figure 2.3, comprising of a rocky headland extending approximately 400 m from the beach, situated between two bays with extended, almost linear beaches, approximately 600 m in length. Figure 2.4 illustrates cross sections through the beaches to the north and south of Town Point in relation to the beach berm, rock platform and tidal planes. The long sections illustrate the steep primary dune, significantly above the high tide level and the gently sloping rock platform.

The coastal morphology at Town Point comprises of marine erosion and solution weathering of low sub-vertical limestone cliffs, up to 5 m in height, creating an unstable environment. Coastal erosion features present include:

- Unstable cliffs with rock fall debris
- Coastal sea cut caves and stacks, and
- Tension cracks

Areas of coastal limestone are also evident where strongly cemented beach rock has formed where calcium carbonated groundwater mixes with seawater.

Plate 2.1 illustrates the rocky headland at Town Point, the fallen boulders and rocks demonstrate the extent of weathering, and the sandy bay is evident in the background.

Plate 2.2 is a photo taken from the south looking towards Town Point demonstrating the extent of the headland.

Plate 2.3 illustrates the presence of smaller rocks along the north beach face.

Plate 2.1: Photo of Town Point looking from Point to Bivalve Beach

Plate 2.2: Photo from Town Point south side.

Plate 2.3: Photo of Town Point from Terminal Beach

The beaches to the north and south of Town Point are situated on a gently sloping rock platform extending several kilometres offshore. The depth of the rock platform 1.5 km offshore is -2 m at LAT. Plate 2.4 demonstrates the extent of exposure of the platform at low tide, approximately 250 m. The area comprises of marine sand and outcrops of coastal and upper limestone (described in Section 2.4), are exposed at the seabed.

Plate 2.4: Exposed Limestone Reef at Low Tide

Wave shoaling and breaking processes occur further offshore than the low tide terrace, the 'sudden' depth change at the edge of the platform is responsible for loss of a large portion of wave energy and the wave energy on the beach face is low. Waves typically only reach the foredune during spring high tide conditions. The shallow stable seabed restricts the direction of wave approach to close to orthogonal to the beach alignment.

Plate 2.5 illustrates the sandy bay to the north of Town Point, the beach face has a mild gradient indicating that the beach is reflective. There is a sparse vegetation line on the foredune and the steep face of the primary dune is covered in dense vegetation. The density of vegetation on the primary dune face suggests that the upper level of wave impact during ambient conditions is the toe of the primary dune. The stability of the shoreline is further discussed in Section 2.3.

Plate 2.5: Photo of Terminal beach North of Town Point

Drawing G1-TD-T-7400-SKH0705 shows a cross section of the beaches North and South of the planned MOF with the expected water levels during extreme events. The drawing illustrates that the wave set-up – derived from the MetOcean report in appendix C – is not significantly different with the MOF in place in comparison with the natural state. In terms of beach erosion this means that the erosive processes do not necessarily accelerate with a MOF in place.

### 2.2.1 Littoral Transport

Along the east coast of Barrow Island several rocky headlands exist, including Town Point, which are physically visible boundaries separating littoral transport. These boundaries delineate littoral cells within which alongshore sediment transport is primarily constrained (Inman, 2003). The littoral cell boundaries are delineated by distinct changes in longshore sediment transport rates (SPM, 1975).

Coastal erosion of the rocky headland at Town Point and the rock platform acts as a source of sediment in the littoral cell. Wetting and drying on the intertidal shore platform is an effective weathering agent and provides a sediment source within these littoral cells (Trenhaile, 2006). The plates presented in Section 2.2 demonstrate the coastal erosion occurring at Town Point and the slow drift of large eroded material short distances along the beach faces. The transport of this material is not a sustained progression and is characterised differently to sediment transport, as different bed stress and surface friction parameters apply. A significant source of the dune system is believed to be ephemeral creek discharges after extreme rainfall events from deltas to the north and south of Town Point. Plate 2.6 presented below demonstrates the sediment transport through the creek ocean outfall south of Town Point after a tropical cyclone and Plate 2.7 illustrates the scale of the sediment plume.


Plate 2.6: Ephemeral Creek Ocean Outfall North of Town Point after tropical cyclone

Plate 2.7: Sediment Plume from Ephemeral Creek outfall North of Town Point

The formation and nature of platform beaches is dependant on the relationship between the platform and beach-face gradients and the amount of available sediment (Trenahile, 2004). Surfaces of shore platforms, such as the platform offshore of Town Point, comprise of extensive areas of bare rock with sediment material trapped in topographic depressions.

It is recognised that during storms large steep waves and increased wave power can cause rapid beach erosion and transformation from a steeper to a more dissipative beach profile. The sediment that is moved nearshore during the storm is driven back onshore by waves of lower steepness and power after the storm event (Trenhaile, 2004). However in this case the shallow rock platform causes wave breaking to occur further offshore. In general the beach recovery of low energy beaches can be inhibited by restricted alongshore sediment supply and insufficient wave energy following a storm (Jackson et al, 2002).

The magnitude of longshore littoral transport on loose sedimentary beaches is a function of the wave approach angle and energy (Mangor, 2004). Waves refract due to the change in depth across the rock platform, the wave direction matches the platform gradient and approaches perpendicular to the beach, reducing the potential for longshore sediment transport.

## 2.3 Shoreline Stability

Figure 2.3 presents historical aerial photographs at Town Point taken in 1991, 1994, 1997 and 2001. These historical photographs demonstrate that the shoreline is stable over the time frame and not susceptible to change; there is no net erosion or accretion of the beaches to the north and south of Town Point or around the headland features. The lack of clear sedimentary features and accretion indicates that there is no significant offshore sediment source. During this period a significant number of tropical cyclones have passed in the vicinity of Barrow Island and the stability of the shoreline indicates that any impact is minor and short term (see Table 2.2).

Figure 2.5 is an aerial photograph taken in 2004 overlaying the dense and sparse vegetation lines from 1991, 1994, 1999 and 2001. The dense vegetation line is stable and continuous over the period, defining the upper limit of ocean impact and indicating that tropical cyclones do not impact significantly on the primary dune. The sparse vegetation line shows minor deviations, demonstrating that during storm or extreme events the upper limit may be subject to limited re-profiling due to the combination of surge and wave run-up. Note that the roadway is also illustrated on the image, demonstrating that there is some error in the resolution of the picture, resulting in minor distortions between the vegetation lines.

## 2.4 Geotechnical and Geophysical Investigation

A number of geotechnical and geophysical investigations have been undertaken near-shore and offshore Town Point, Barrow Island, (Fugro 2003, 2006, 2008).

Geotechnical characteristics surrounding the MOF facility at Town Point have been divided into the following three categories;

- Marine sediments, patchy thin veneer on the rock platform, very thin or absent in the vicinity of the MOF, comprising of carbonate sand with shells and shell fragments and minor silts and clays that may be locally cemented.
- Upper limestone extending from onshore outcropping to form nearshore rock platform extending approximately 2 to 4 km. This limestone comprises a broad range of carbonate rock types including conglomeratic limestone, crystalline limestone, siliceous limestone and argillaceous limestone, with bands of weaker material. The mean uniaxial compressive strength value for this material is 15 MPa with a maximum value of 101 MPa.
- Coastal limestone, located at depth near Town Point, with surface expression approximately 2 to 4 km offshore. This limestone is typically siliceous calcarenite or conglomeratic calclirudite formed as a result of secondary carbonate cementation of pre existing deposits in a coastal environment. The mean Uniaxial Compressive Strength (UCS) value is 7.7 MPa and maximum recorded value is 30 MPa

Figure 2.6 is taken from the Fugro 2006 report (Drawing No P0485_006) and shows Isopach contours of the depth to rock from the seabed. The light blue area represents the extent of the shallow rock platform where the superficial sediment layer is either very thin or absent. The extent of this platform has influenced the current proposed location of the MOF and its dredged access channel.

The white area further offshore is covered by a layer of either fine sand, medium sand or medium calcareous sand with occasional shell fragments. The depth of material ranges from 0 to 4 m and is situated in a distinct sea bed trough.

The pink area represents an area of partial masking of interpreted calcaranite layer possibly due to variable cementing of the seabed and underlying sediments. This material forms a distinct mound or ridge in the topography at approximately 7 – 8 m below LAT. The depth of material above the calcarinite layer ranges between 3 and 6 m and comprises of stable, variably cemented marine sediment. Further offshore the rock platform re-emerges at 14 – 15 m depth and is covered by a thin layer of sediment ranging 0 – 1 m thick.

A more recent geophysical survey carried out in 2007 and documented in Fugro 2008 comprised closely spaced refraction lines to develop an essentially 3 - dimensional model of the MOF and jetty area. The results of this recent, more detailed survey are broadly consistent with the discussion noted above that was based upon the results documented in the Fugro 2006 report.

## 2.5 Coastal Vegetation Assessment

Vegetation for the Gorgon Project has been assessed in accordance with the EPA Guidance Statement Number 51 and refined to vegetation associations for the draft EIS/ERMP (Chevron Australia 2005). These surveys show there is a clear coastal type of vegetation association at the foredune, and among the storm berm. No vegetation grows between the storm berm and the HAT waterline.

The primary foredune environment includes the seaward face of the foredune, the crest of the foredune and the landward side of the foredune. The vegetation codes relevant, as described in the EIS/ERMP, include C type vegetation. The EIS/ERMP estimates that 0.5 % of the combined 'C' types of vegetation on the island occur within the approved development gas treatment plant footprint.

Vegetation at the storm berm remains sparse and is dominated by *Spinifex longifolius*, although sparse annual species will grow following rainfall.

The importance of sandy beaches in the region is primarily related to their significance for turtle nesting, seabird nesting, roosting and foraging, and as foraging areas for terrestrial species, such the Perenti (*Varanus giganteus*), brushtail possum (*Trichosurus vulpecula*), golden bandicoot (*Isodon auratus*) and water rat (*Hydromys chrysogaster*).

The pedology of the dune environment is described as sand. At beaches near Town Point, the area from the beach berm to the primary foredune is where flatback turtles primarily excavate large body pits to lay their eggs. Sand movement is high during the main turtle nesting season from December to February, due to movement of sand by turtle excavation. This sand movement is dynamic and localised, with no net impact and the sand remains exposed to wind action at all times.

An intertidal area comprising of a rock platform approximately 600m wide exists either side of Town Point, the rock platform is narrower at Town Point. An intertidal survey was conducted during the EIS/ERMP preparation. Field surveys investigating the intertidal environment were undertaken during January 2004. The primary findings, as reported in the EIS/ERMP, were that the invertebrate assemblage of the upper intertidal boulder zone is relatively poorly developed. The limestone pavements support a relatively low diversity biotic assemblage.

## 2.6 Turtle Habitat

Sea turtle surveys have been conducted on Barrow Island since 1987. Systematic surveys undertaken for the Gorgon Project over the 2005/2006 to 2007/2008 seasons include the following:

- Turtle tagging
- Track counts on a monthly basis across the nesting season
- Nest emergences including hatchling orientation to the sea
- Nesting success
- Satellite tracking, and
- Beach nesting characteristics.

Surveys have shown that Flatback turtles prefer the sheltered low energy beaches along the east coast. Hawksbill turtles prefer shallow sandy beaches near coral habitat, though 16 hawksbill tracks have been recorded on east coast census beaches between 1999 and 2008.

The turtles nesting near the MOF along the central east coast beaches are almost exclusively flatback turtles. Flatback turtles prefer deep sandy beaches with 86% of nesting occurring in the December and January period, with hatchling emergence mid-January to late-March. Tagging records on census beaches show that flatback turtle nesting is focused on central east coast beaches which include: Mushroom, Bivalve, Terminal, and Yacht Club North and South beaches. Figure 2.1 presents the location of these beaches.

A systematic turtle tagging program on BWI alone has identified 894 nesting female flatback turtles during the 2005/06 season, 1658 in 2006/2007 and 1607 in 2007/2008.

The locations of nests on the beach at Barrow Island were recorded during the tagging program. From a total of 1,616 records in 2005/2006, 39% of nests were deposited on the beach berm, 30% at the edge of the Spinifex (foredune toe) and 23% in the Spinifex (foredune).

The number of eggs laid during nesting was counted during 26 nesting events on Barrow Island. An average of 51 ± 12 (std dev) eggs were laid, (range = 11-72 eggs).

A total of 15 satellite transmitters have been deployed as part of the Gorgon sea turtle research and monitoring program. Satellite tracking of adult (females) shows they travel approximately 70km to inter-nesting foraging sites near the mainland before returning to Barrow Island to lay another clutch of eggs, with an average inter-nesting period of 13-16 days. The results showed some flatback turtles leave the vicinity of Barrow Island for inter-nesting and spend most of their time in turbid near shore shallow waters in between nesting events. Following the nesting period, females have been shown to migrate up to 1500 km away from BWI, with many individuals migrating to waters off the Kimberley coastline. The information on the migratory routes and foraging ground locations indicate that the migration pathways used by the flat back turtles leaving Barrow Island are confirmed to the inner shelf waters, typically between 30 m and 70 m deep (Pendoley – Environmental, 2008).

A baseline study investigating the sand characteristics of flatback nesting beaches on Barrow Island found that the sand was relatively alkaline (pH between 8 and 9.6) with medium-size sand grains (0.2 to 0.6 mm) and low total organic carbon levels between 0.06 and 0.23 % (Pendoley – Environmental, 2008). The mean moisture content values recorded in sub-surface samples on Barrow Island east coast nesting beaches (2.9 to 3.38 %) were slightly lower than 2.6 to 7.9 %, values previously recorded for flatback nesting beaches at the Peak Island rookery in Queensland (Hewavisenthi and Parmenter, 2002). The parameters of pH, grain size and TOC were very consistent across all sample beaches and sample depths (Pendoley-Environmental, 2008). Beach sand characteristics for nesting beaches vary across sampled beaches, suggesting that turtles do not favour a strict beach sand parameter value but can tolerate a range of values for each parameter.

# 3. COASTAL MODELLING

## 3.1 Scope of Work

Coastal modelling was undertaken by MetOcean engineers in order to assess the impact of the proposed MOF on coastal processes. The coastal modelling scope of work entailed;

- Assessing the potential impact of the MOF on the stability of the shoreline during cyclonic conditions
- Assessing the potential impact of the MOF on the stability of the shoreline during ambient conditions
- Assessing the impact of the MOF on ambient circulation and wave patterns
- Assessing the impact of the MOF on ambient sediment transport characteristics offshore of the surfzone.

Appendix B presents the Coastal Modelling Report (MetOcean, 2008) a summary of which is contained in this chapter.

## 3.2 Model Descriptions

A range of numerical models have been applied to model the impact of the MOF on circulation, sediment transport and shoreline stability. A brief description of the models is presented below. Detailed descriptions, validation and technical information on the models are presented in Appendix B of MetOcean (2008).

The models fit together as described below:

**HYDRODYNAMIC**: ADCIRC > 3DD > POL3DD (Offshore Sediment)

**WAVES:** ADFA > SWAN > 2DBEACH (Surf zone waves and sediment)

### 3.2.1 CYCHOL

CYCHOL is a cyclonic simulation model that creates a wind and pressure field for a cyclone using historical cyclone track data and Holland model assumptions. The circumferential gradient level wind speeds and radial distances are resolved by balancing the centrifugal, pressure gradient and Coriolis forces, using the Holland cyclonic pressure field.

### 3.2.2 ADFA

ADFA is a spectral wind / wave transformation model used to hindcast tropical cyclone waves over the continental shelf. The output from CYCHOL is used to drive the ADFA model. The wave modelling was performed over three grid sizes increasing in resolution;

- “A” grid 50 km by 50 km, 25 by 20 grid points modelled at 60 minute time steps
- “B” grid, 10 km by 10 km grid, 56 by 46 grid points modelled at 10 minute time steps
- “C” grid, 2 km by 2 km grid, 41 by 41 grid points modelled at 2 minute time steps.

### 3.2.3 ADCIRC

ADCIRC is a nonlinear finite element depth averaged hydrodynamic model, it solves two dimensional shallow water equations for water elevation, wind, tide and atmospheric pressure induced current. ADCIRC uses three dimensional mass and momentum balance equations integrated vertically over the water column. Bottom shear stresses are represented by bed roughness using a standard quadratic law based on the current magnitude squared. There are no lateral mixing terms apart from numerical diffusion considered as lateral mixing effects are comparatively not important when considering tidal dynamics at scales ranging from one half to tens of kilometres (Blain and Preller, 2002).

Cyclonic wind and pressure forcing output from CYCHOL was used as surface boundary conditions for the ADCIRC model under cyclonic conditions. Open boundary tidal elevation conditions were interpolated using output from the global tidal model TPX0.7.1.

The model solves the field equations over a finite element grid; the grid dimensions vary in order to resolve the continental shelf, the extent of the cyclone influence and key bathymetric features.

### 3.2.4 SWAN

SWAN is a spectral wind and wave model that transforms the wave climate in the near shore surfzone. SWAN solves the wave energy density equation to provide estimates of the directional wave energy spectrum over complicated bathymetries. The SWAN model resolves wind wave generation, wave propagation, wave dissipation by breaking and bottom friction, refraction, spectral energy transformation, storm surge, tidal and current influences.

SWAN uses the storm surge / tide water levels and surface wind shear as boundary and field parameters and models surf zone wave dissipation. The output of SWAN provides key wave parameters for each cyclone modelled. The model separates components from the wave spectrum and can resolve the directionality and period of the wave throughout the passage of the cyclone.

Output from the ADFA model was used to model the transformation of deep water cyclonic wave climate data over the shallow topography on the eastern side of Barrow Island. Output from CYCHOL was applied to the SWAN model to define local wind generation. SWAN was modelled using a 13.2 km by 10.3 km grid, 200 m by 200 m grid sizes, comprising of 66 by 52 grid points modelled over 30 minute time steps.

The Swan model has been extensively calibrated offshore to nearshore using 6 months of contemporaneous wave measurements (20m offshore and 10m inshore) and provides the boundary conditions for the nearshore to coastline 2DBeach model.

### 3.2.5 2D Beach

2DBeach is a surfzone / sediment transport model used to estimate the impact of proposed coastal structures on the stability of the shoreline. 2DBeach incorporates a wave transformation module which transforms an offshore wave climate across the surfzone, incorporating wave set up and set down, resolves wave driven currents within the surfzone and outputs the hydrodynamics into a sediment transport module. The model uses mixed

Lagrangian and Eulerian equations which effectively handle discontinuity in wave heights due to wave breaking.

The model was applied to the shoreline north and south of the proposed MOF using two fine scale model grids. The first grid extended beyond the head of the MOF; on a 4 by 3.7 km grid, at 70 m by 70 m grid resolution. A more highly resolved grid was nested within the first grid extending 2.1 km by 1.6 km at 20 m by 20 m resolution. This grid is capable of resolving any sheltering due to the MOF, the dune system and the existing rock platform and channels in front of the beach.

The output from the SWAN wave model and ADCIRC storm surge model were applied at the open boundaries of the coarse grid.

No data are available for the calibration of the nearshore propagation model. 2DBeach model setup coefficients are based on "standard" depth limited (Madsen) breaking and viscosity numbers derived from numerous field measurements and calibration (from other sites). Note that this does not imply the application of a 'breaker index'. Rather, the breaking determination is based on a 'continuous energy flux method' which recognises changes in seabed morphology.

Any departure from standard parameterisations were derived from direct consultation with the model's author , whose 30 years of experience in littoral zone modelling is built into the physics and (importantly) the empiricism of this model. It is this experience and empiricism on which we can rely in the absence of site-specific (rock shelf) measurements. Note that the highly site-specific nature of seastate response to tropical cyclone forcing and the erratic nature of tropical cyclones themselves , would make application of any resultant calibration dubious .

Sediment thickness over the model domain was input to the model based on sediment thickness and characteristics illustrated in Figure 2.6. The geomorphic maps do not extend to the nearshore region.

The rock platform fronting the beach and foredunes shows no sediment cover. However , the 2DBeach model is constrained to use depth-averaged sediment transport parameterizations. Accordingly, a thin layer, 300 mm, of sediment was applied over the rock platform to provide a conservative but functional means of testing whether the presence of the proposed MOF might affect the beach - either by accretion of sediment from offshore , or by erosion. Note that it is the impact on the beach which is of relevance to this study. It is very important to correctly model the wave propagation across the rock platform , but the resulting sediment distribution on the platform is not of significance. It is important that a sediment source be available to the beach (via the 2DBeach model) if accretion was to occur.

Site inspection clearly indicated that significant impact of tropical cyclones on the foredunes (other than by wind erosion , which would occur regardless of MOF construction), would require a substantial sea level elevation , to allow the wave energy to directly access the beach and dunes. This limited attention to tropical cyclones which passed to the east of Barrow Island , with attendant sea level setup against the east coast of Barrow Island , and with significant wave energy directed onto the shore from the NE to SW quadrants. The most severe examples of such storms in our comprehensive in-house database were selected for simulation, to test the influence of the MOF construction. The potential impact of these storms was substantially enhanced by adjusting the arrival time of the peak storm surge to correspond with a peak spring tide.

### 3.2.6 3DD – Nearshore Hydrodynamic Modelling

3DD is a three dimensional circulation and mass transport numerical model, suited for application to vertically stratified and homogenous ocean, continental shelf and shallow water applications.

The model solves the momentum and continuity equations for circulation explicitly on a Eulerian grid; it resolves the flooding and drying of intertidal zones and a range of open boundary conditions. The model is linked to a sediment transport and wave refraction model.

The model has been applied to the eastern coastline off Barrow Island to model the influence of the proposed MOF on ambient currents and sediment transport variations offshore of the surf zone.

The model grid aperture is 100 m by 100 m and the orientation is aligned with the MOF causeway.

### 3.2.7 POL3DD – Offshore Sediment Transport

POL3DD is a three dimensional numerical dispersion model for application to the transport of sediments or other material. The model solves the transport and dispersion equations using Lagrangian particle tracking techniques, outputting gridded arrays of concentration, particle numbers, settlement, bed erosion and deposition and mean grain size.

The hydrodynamic output from the 3DD model is used as input into POL3DD. The influence of waves is incorporated in the model by applying SWAN model output to transform the existing measured directional wave spectra across the 3DD model domain. The measured wave spectra are available from a previous measurement program undertaken by MetOcean Engineers and described in Section 4 of MetOcean 2008 (presented in Appendix B).

### 3.2.8 Model Validation

A number of measurement programmes have been undertaken, against which MetOcean Engineers oceanographic models have been calibrated and validated. Current measurements can be difficult to extrapolate to different areas; however the oceanographic model was able to replicate field data with a sufficient degree of accuracy. Validation plots of measured data sets available to Chevron are presented in MetOcean (2008).

## 3.3 Modelling Methodology

### 3.3.1 Tropical Cyclones

In low energy beach environments the beach form is predominantly controlled by high energy conditions. The impact of elevated water levels and steep storm waves increases the potential for sediment transport (Hegge, et.al, 1996). Tropical cyclones are recognised as the main phenomena likely to cause dramatic change to the shoreline, beach profile and sediment transport at Town Point.

Therefore in order to investigate the maximum impact the MOF structure may have on shoreline stability, sedimentation and wave climate, tropical cyclone modelling has been undertaken.

Three tropical cyclones, Bobby, Olivia and Monty have been selected as appropriate model cyclones with and without the MOF structure. The candidate storms selected for detailed sediment redistribution analysis were drawing from over 100 candidate storms which have been modelled for other engineering purposes. Each storm represented a separate suite of characteristics enhancing potential for morphological change, through sea level elevation, wave action and steady current.

These cyclones have been selected as they are considered to represent the 'most severe' impact on the east coast of Barrow Island (MetOcean, 2008) for each track type. These tropical cyclones pass to the east of Barrow Island, resulting in maximum storm surge on the east coast and largest wave heights which represents the maximum potential for erosional impact on the shoreline.

In order to model the most severe plausible scenario of a tropical cyclone eroding the shoreline, the three historical tropical cyclone tracks were time shifted to align the peak storm surge with a peak spring tide. The simultaneous occurrence of peak storm surge and spring tide is a rare event and substantially increases the average recurrence interval (ARI) of the cyclone event. This provides a plausible description of an extreme erosion event that might occur at Town Point. The choice of cyclones models changes to the long term response of the shoreline due to the MOF causeway under extreme forcing events, and it is not required to model the full range of tropical cyclone conditions in order to demonstrate the benign impact of these forcing events.

The results are presented as a series of plots demonstrating the wave climate at the peak of the tropical cyclone with and without the MOF (Figures 5.13, 5.14, 5.23, 5.24, 5.33 and 5.34 presented in MetOcean, 2008)

The sediment transport is illustrated using the bathymetric contour lines, presented prior to the Tropical cyclone, subsequent to the tropical cyclone without the MOF structure in place and subsequent to the tropical cyclone with the MOF structure in place. The contour lines are plotted for at 'snap-shots' throughout the progression of the tropical cyclone and after the peak of the storm has passed. This allows the comparison of sedimentation with and without the MOF before, during and after the tropical cyclone. Figures 5.15, 5.16, 5.25, 5.26, 5.35 and 5.36 presented in MetOcean (2008), illustrate the bed level changes after the peak of Tropical cyclones Bobby; Monty and Olivia have passed with and without the MOF structure in place.

### 3.3.2 Ambient Circulation

The ambient circulation has been modelled for two months corresponding to peak spring tidal conditions. The model has been run over a short period of time, rather than the design life of the MOF, as the dominant ambient mechanism for sediment transport are the tidal currents and the forcing condition is repetitive. There is little benefit in running the model over the 30 year design life as there are not expected to be cumulative results.

The ambient circulation plots are presented in Appendix E of MetOcean (2008). The plots take 'snap-shots' every 30 minutes demonstrating the current speed and direction during two spring tidal conditions modelled in January and July for scenarios with tidal forcing and a scenario with combined tidal and wind forcing. The two periods were chosen to indicate the relative variation of prevailing winds. The modelling has been undertaken with and without the MOF in place.

The magnitude of the wind speed in January from the south-west, with modelled speeds based on data measured at Barrow Island Airport. The wind direction is variable and weaker during July. There is no significant difference between the modelled results in January and July for tidal conditions only.

The sediment transport under ambient conditions has been modelled for each of these conditions. The net monthly sediment transport with and without the MOF has been modelled during the months of January and July for combined wave and current conditions, plots are presented in Figures 6.14 – 6.17 in MetOcean 2008. The net annual bed level change without the MOF due to ambient conditions with and without the MOF causeway in place, are presented in Figures 6.41 and 6.46, MetOcean 2008.

## 3.4 Model Results

The results of the modelling programmes are detailed in Sections 5 and 6 of MetOcean (2008). The sections below provide a summary of the results.

### 3.4.1 Ambient Circulation Modelling

The circulation model illustrates the variation in current flow throughout the tidal cycle. The ambient currents are complicated due to the nature of the tidal propagation in the area. The tides propagate into the region from both the southern and northern sections of the island, meeting half way along the eastern shore and reversing on the ebbing tide. This results in a zone midway along the eastern shore with currents of smaller magnitudes than the rest of the island. To the north east of the MOF through the Lowendal shoals is an area of strong current flow, with maximum speeds in excess of 1.3 m/s.

The model output demonstrates that the current circulation on the east coast of Barrow Island near Town Point is tidally driven. The influence of the wind on current speed is accentuated at low and high tides, when current speeds are low. At low tide as the flood tide begins the current speed through the Lowendal Shoals is dampened due to the opposing wind direction. As the flood current strengthens the influence of the wind is less visible, however the extent of strong current flow is narrowed. During flood tides the shadowing influence of the MOF is decreased. During the ebb current the wind acts to accentuate the current flow to the north and the magnitude and extent of stronger currents is enhanced.

The shadowing effect of the MOF is most pronounced in the lee of the MOF to the north with combined wind and tidal forcing, due to the peak strength of the longshore current. The difference in current speeds in the lee is 0.375 m/s without the MOF and 0.125 m/s with the MOF. Current vector plots from January 23 20:00 with Wind and Tide Forcing illustrate the maximum impact of the MOF on ambient current circulation, presented in Figures 3.1 and 3.2.

The changes to the circulation patterns and magnitude due to the MOF are restricted to;

- Changes in direction in the vicinity of the MOF due to obstruction;
- Acceleration around the head of the MOF, with maximum current speeds reaching 0.7 – 0.8 m/s.
- Shadowing effect to the south of the MOF during flood tides, with changes in magnitude equal to 0.125 m/s.
- Shadowing effect to the north of the MOF during ebb tides, with maximum difference in speed equal to 0.25 m/s in the direct lee of the MOF.

- Low speed residual eddy formation during ebb and flood tides in the lee of MOF.

### 3.4.2 Ambient Sediment Transport Modelling

The plots demonstrate that there are significant areas where no net sediment transport occurs. The maximum quantities of sediment transport occur to the north of the MOF and correspond to the areas of peak current flow.

The modelling demonstrates that the current regime is dominated by tidal flow with reversing directional flow of equal magnitudes, and therefore there is no substantial net longshore movement of sediment, despite the predominance of north-south current directions.

There is a potential increase in ambient sediment transport in the region around the MOF head, where current acceleration occurs, this is demonstrated in Figures 3.3 and 3.4. There is a potential decrease in longshore sediment transport to the in the lee of the MOF, however the net quantity of longshore sediment transport is close to zero (i.e. 0.00054 $m^3$/m/annum).

Due to the presence of the shallow rock platform, waves are generally only able to reach the beach during spring high tide conditions and storm events where storm surge raises the water levels. The ambient wave conditions are benign and combined with the limited sediment on the rock platform, the impact of the MOF on shoreline stability and beach profile is demonstrated to be limited.

### 3.4.3 Tropical Cyclone Modelling

Tropical cyclones Bobby, Olivia and Monty wave approach is towards the west during the peak storm condition and shifts towards the north as the cyclone passes. The wave climate changes dramatically as the storm passes, from long period steep swell waves to short period fetch limited sea waves. Figures 5.5 – 5.7, MetOcean 2008, present time history plots of the wave heights, periods and directions.

The time-shifting of the tropical cyclones to correspond with peak spring tidal conditions resulted in an increase in the storm tide level during the cyclones. This corresponded to an increase in significant wave heights during both tropical cyclones Bobby and Olivia. The time-shift of tropical cyclone Monty resulted in a decrease to the significant wave height as the peak wind and wave conditions did not correspond to the time shifted storm tide. Table 3.1 presents the significant wave height and surge of the original and time-shifted models.

**Table 3.1 Tropical Cyclone Wave Parameters – Original and Time-Shifted**

| Tropical Cyclone | Hs (m) | Hs – shifted (m) | Storm Tide (m above MSL) | Storm Tide – Shifted (m above MSL) |
|---|---|---|---|---|
| TC Bobby | 3.8 | 4.5 | 1.5 | 3.5 |
| TC Olivia | 4 | 4.5 | 3 | 4.3 |
| TC Monty | 3.8 | 3 | 1.7 | 3 |

An animation of the time-shifted modelled wave climate during tropical cyclone Olivia (MetOcean, 2008 DVD animations, Olivia_shifted_waveheights.wmv) demonstrate the ability of higher wave energy to propagate further inshore as the surge level increases. During tropical cyclone Olivia the wave shadow during peak cyclonic conditions to the south of the MOF is at a 45 degree angle. In the shadow zone the significant wave height ranges from 2 – 2.5 m compared with 3.5 – 4 m outside of the zone, this is illustrated in Figures 3.5 and 3.6.

The shadowing effect during this tropical cyclone is the most pronounced of the modelled cases. The 'snap-shots' of time shifted wave climates during the peak of the modelled tropical cyclones with and without the MOF structure, illustrate that the waves break further offshore and reduced wave energy is incident on the beaches. The shadow zone is restricted during tropical cyclone Bobby and Monty due to the angle of incidence of the waves.

### 3.4.4 Shoreline Stability and Sediment Transport during Tropical Cyclones

A time series of bathymetric contours as each tropical cyclone passes demonstrates that the major impact occurs during the peak of the storm and the depth contours rapidly adjust to their original positions following the passage of the storm, which is a function of the wave climate (Appendix D, MetOcean 2008). The steep storm waves act to move sediment offshore and the shorter period sea waves, following the storm peak, short period waves act to move material back onshore (Trenhaile, 2004).

The results of tropical cyclone Bobby demonstrate no impact above the -1 m LAT contour and very minimal impact on the shoreline. Localised sediment transport at the -1 m and -2 m LAT contours occur during the storm peak and readjust to their original position after the storm.

Figures 3.7 and 3.8 illustrate the changes in bed level after the passing of tropical cyclone Bobby, with and without the MOF in place. These figures illustrate that there is a slight accentuation of accretion in the shadow zone of the MOF, of the order of 30 cm. There is also slight accentuation of erosion south of the MOF, approximately 10 cm.

The modelled results of tropical cyclone Bobby demonstrated the greatest change in sedimentation rates due to the presence of the MOF. It is interesting to note that despite tropical cyclone Olivia having the greatest peak water level, significant wave height and wave shadow zone, this did not correlate to a significant change in accretion and erosion rates. Figures 3.9 and 3.10 illustrate that there is no increase in accretion along the length of the MOF causeway and the wave shadow acted to protect the shoreline south of Town Point from erosion, of the order of 10 cm in magnitude.

At the peak of the storm without the MOF, the erosion of the beach and dune occurred to a greater extent on the beach south of Town Point. With the MOF in place the protection in the 'wave shadow' offered by the MOF acts to reduce erosion south of the MOF. After the passing of the cyclone the nearshore sediment transfers back to the original profile generally within 12 hours of the peak wave impacts, as a function of the changing wave climate, as demonstrated in the model output. The model demonstrates the MOF will have little impact on beach and coastline recovery.

# 4. MARINE IMPACT DISCUSSION

## 4.1 Coastal Processes and Shoreline Stability

The historical photographs of the shoreline and vegetation lines near Town Point demonstrate that currently the shoreline position is stable and there is no erosion of the primary dune during extreme events over the past 29 years. The tidally dominated current flow converges and diverges half way along the east coast of Barrow Island, resulting in a region of low current speeds.

The construction of the MOF extends the natural headland at Town Point a further two kilometres offshore. This creates a shadow zone during ambient circulation where the current speeds alter locally there is some sheltering from locally generated short period waves. Ambient current speeds accelerate around the head of the MOF generating some eddies around the head of the causeway. Ambient circulation patterns alter locally as the longshore current skirts around the MOF structure, illustrated by the figures in Appendix E (MetOcean, 2008). Directional changes are more obvious on an ebb tide, the current propagates around the MOF structure and a shadow zone forms to the north extending to the next headland. The directional change on the flood tide is more localised around the vicinity of the MOF head as the tide propagates south through the shallows.

As a result of the balance between ebb and flood tidal currents there is very little net longshore sediment transport along the east coast of the island. The changes in longshore transport rates due to the construction of the MOF are expected to be minimal.

During tropical cyclone events a significant wave shadow is demonstrated in the model; however this does not correspond to a region of significantly enhanced accretion. The model indicated that localised areas of erosion and accretion will occur during tropical cyclone events with the MOF in place, however the quantities are minimal and after the storm waves have passed the lower energy wave climate acts to restore the original bathymetry generally within a 12 hour period.

Sand may tend to accumulate in minor quantities from time to time on either side of the proposed MOF causeway. These accumulations will be mainly in response to the dominant wave, current and wind directions that occurred in the most recent cyclone. The magnitude of changes under extreme conditions are not expected to be great enough to warrant any maintenance program.

The geophysical investigations demonstrate that there is very little nearshore sediment available for transport during extreme events. The rock platform extends 2.5 km offshore and is covered in a thin veneer, between 5 and 30 cm, of sediment. This is a controlling feature affecting any potential shoreline change and strongly supports the indication that the shoreline will be relatively stable during storm and ambient conditions.

## 4.2 Impact on Turtle Habitats and Behaviour

The results of the above investigation demonstrate that the MOF will have very little impact on the profiles and vegetation on the incipient and primary foredune which are the areas where flatback turtles primarily excavate large body pits to lay their eggs.

The magnitude of changes to the ambient current speeds are generally less than 0.25 m/s. Behavioural studies have concluded that turtles can travel up to 1,500 km distance, migrating to waters off the Kimberley coastline. This suggests that the nearshore changes to current circulation will not have any impact on the adult turtle population.

Flatback turtle hatchlings are expected on Mushroom, Bivalve, Terminal and Yacht Club North and South beaches. The hatchlings use the currents to move offshore. The ambient circulation modelling demonstrates the impact of the MOF on the circulation is limited to

- Movement of longshore currents to skirt around the MOF structure
- Increased current speed around the MOF head
- Eddy formation during low tide offshore of yacht Club North Beach

Flatback turtles do not exhibit an oceanic phase in their life cycle. Juveniles grow to maturity in shallow coastal waters that are thought to be close to their natal beaches. There is evidence, however, that some flatbacks engage in long distance migrations between feeding grounds and remote nesting beaches and this has been confirmed by recent satellite tracking programs in WA which have shown flatback turtles migrate to foraging grounds 50 – 1,500 km from their nesting beaches.

# 5. INCREMENTAL CHANGES

The previous modelling programme was undertaken investigating the impact of the Short MOF configuration on coastal stability during tropical cyclone events (MetOcean, 2005). The same three tropical cyclones were modelled; however the tracks were not time-shifted. Therefore the magnitude of wave impact and surge levels is lower than that described in the current modelling programme.

For each cyclone the model was run with the short MOF causeway and without the short MOF causeway, in order to illustrate the impact of the MOF on sediment transport during extreme events. The modelled output illustrated the bed level changes and bed contours before and after the modelled cyclone, with and without the MOF.

Tropical cyclone Monty demonstrated small amount of accretion and erosion in pockets across the rock platform and offshore, of the order of 0.01 m. There are pockets of higher accretion and erosion to the north offshore and at small headlands to the north and south of Town Point, of the order of 0.03 m.

Tropical cyclone Bobby resulted in slightly more extensive erosion and accretion to the north of Town Point and in isolated pockets to the north and south on the coast; the changes were of the magnitude of 0.02 m.

Modelling of tropical cyclone Olivia illustrates the greatest area and rates of offshore erosion and accretion to the north of Town Point; of the order of 0.03 m. tropical cyclone Olivia demonstrated accentuation of accretion at the MOF head compared to the scenario without the MOF.

It is evident from the final bed elevation changes plotted for each of the cyclones that no significant sedimentation occurs in the wave shadowing at the MOF during extreme events. The accretion in the wave ‘shadow’ zone is less than 10 cm for all three modelled cyclones. This is aligned with the results of the modelling programme with the elongated MOF in place.

# 6. COASTAL STABILITY MANAGEMENT AND MONITORING PLAN

In order to ensure that construction and operation of the Marine Facilities at Town Point does not cause adverse changes to the adjacent beaches a coastal stability management and monitoring plan is in place.

To effectively monitor for change the baseline state of the adjacent beaches will be established. The plan comprises of a baseline data acquisition program and ongoing monitoring program.

The baseline data acquisition program will be undertaken for 12 months prior to initial construction. The purpose of this program is to collect data on the beach profile at 5 beaches along the east coast, adjacent to Town Point. The profiling will be undertaken every 3 months for a 12 month period, to ensure any natural variation that may occur in the beach structure is captured. The intent is also to survey after a cyclone event to capture the short term impact that such an event may have on the beach structure. Terminal and Bivalve beaches, situated closest to the MOF, will be surveyed along 5 beach profile transects spread evenly within the bays. Beach profiling will also be conducted at Inga, Yacht Club North and Yacht Club south, two transects will be surveyed at each of these beaches. The particle size distribution (PSD) and compaction will be sampled at all 5 beaches at three locations in the beach profile; the high water mark, insipient dune and between the storm berm and foredune. These physical parameters are integral characteristics that make the east coast beaches desirable turtle nesting locations. A primary focus of the management and monitoring plan will be to ensure that the adjacent beaches remain important flatback turtle nesting beaches.

Once the baseline data has been collected, a monitoring program will be implemented throughout the construction and operation of the Marine Facilities. The intent of the monitoring program will be to detect any adverse changes to the beach structure and sediment characteristics that may result through the presence of the Marine facilities. Beach surveying will be conducted on a quarterly basis throughout the construction period, in the same manner as for the baseline data acquisition program. Sand characteristics will be sampled in the event of a cyclone, or if beach profiling shows evidence of change. If no changes to beach structure are detected throughout construction, the frequency of both beach profiling and sand characteristic sampling will be reviewed.

In the case where monitoring results show a change to the adjacent beaches the Marine Turtle Expert Panel (MTEP) and Department of Environment and Conservation (DEC) will be integral parties in developing a management strategy.

# 7. CONCLUSIONS

The coastal modelling programme demonstrates that the impact of the MOF on the shoreline and coastal processes are expected to be minimal. The shoreline is currently stable, as the lack of available sediment and limited energy at the beach controls any shoreline changes. The historical photographs demonstrate the stability of the coastline and the geophysical investigation provided important input data for the model.

Minor accretion of sand on either side of the MOF causeway may occur after extreme events. However any changes in sedimentation are not expected to require any maintenance as the predicted rates of sediment transport in the area are low.

There is expected to be no changes to the vegetation on the primary and storm berms due to the MOF construction. Beach sand characteristics for nesting beaches varied across sampled beaches, indicating that turtles do not favour a strict beach sand parameter value but can tolerate a range of values for each parameter.

Turtle behaviour studies demonstrate that adult turtles have the capacity to travel significant distances and any localised changes to current circulation should not impact on their movements. Hatchlings may circulate in the eddy formations during low tide near the MOF structure when exiting from the Yacht Club North Beach, but this impact is short term and the tidally driven current flows meet the main current flow at high tide.

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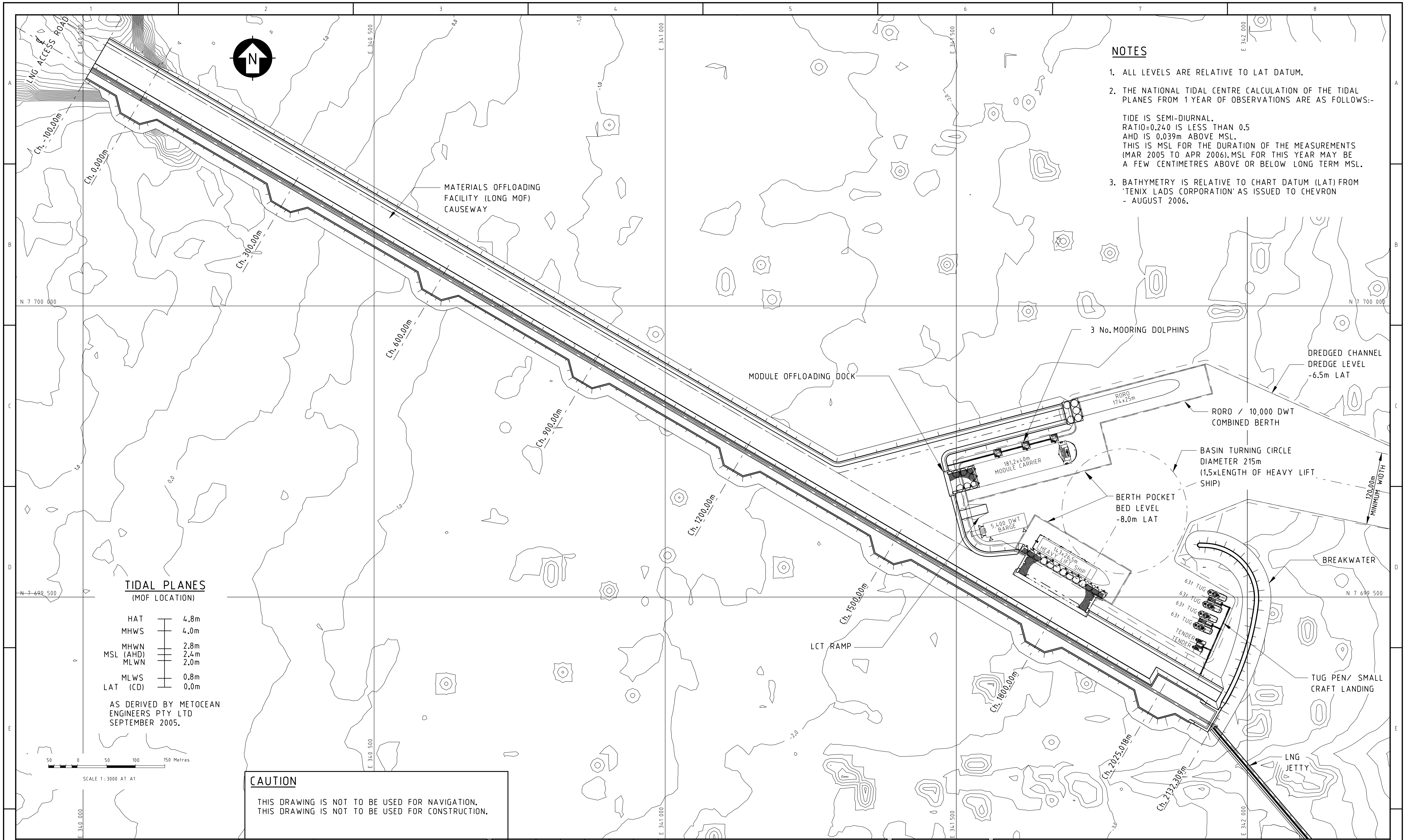
## 9. FIGURES

See over.

# FIGURES




Kellogg Joint Venture | Gorgon

KBR JGC HATCH CLOUGH

Kellogg Joint Venture - Gorgon (KJV-G)
ABN 57 687 810 426

A Joint Venture Between
KBR E&C Australia Pty.Ltd.- ABN 43 114 260 972
JGC Corporation - ABN 32 009 474 042
Clough Projects Australia Pty.Ltd.- ABN 26 109 444 215
Hatch Associates Pty. Limited - ABN 59 008 630 500

CVX GORGON A1.REF

**FIGURE 1.1 MATERIALS OFFLOADING FACILITY - GENERAL ARRANGMENT**

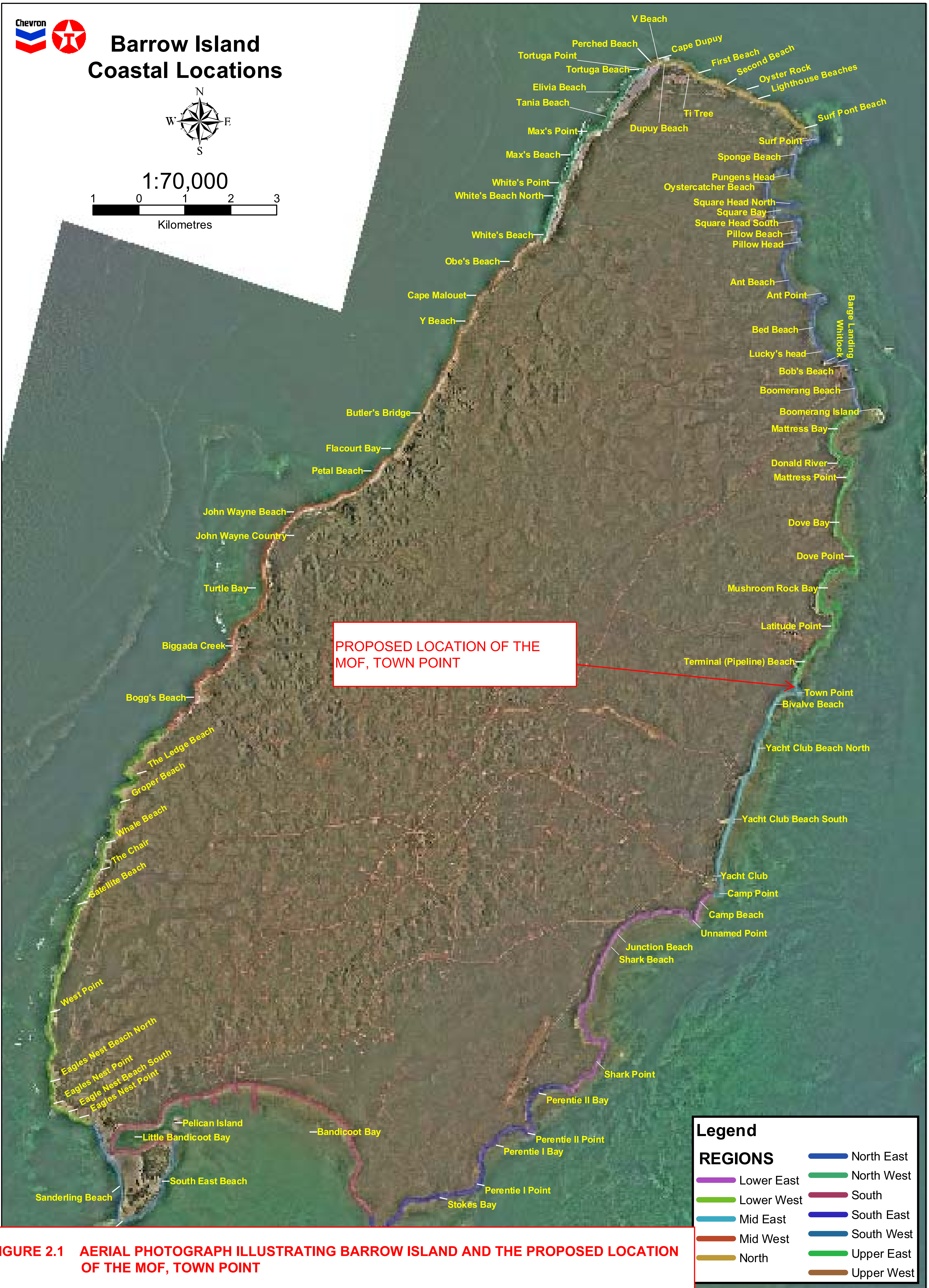
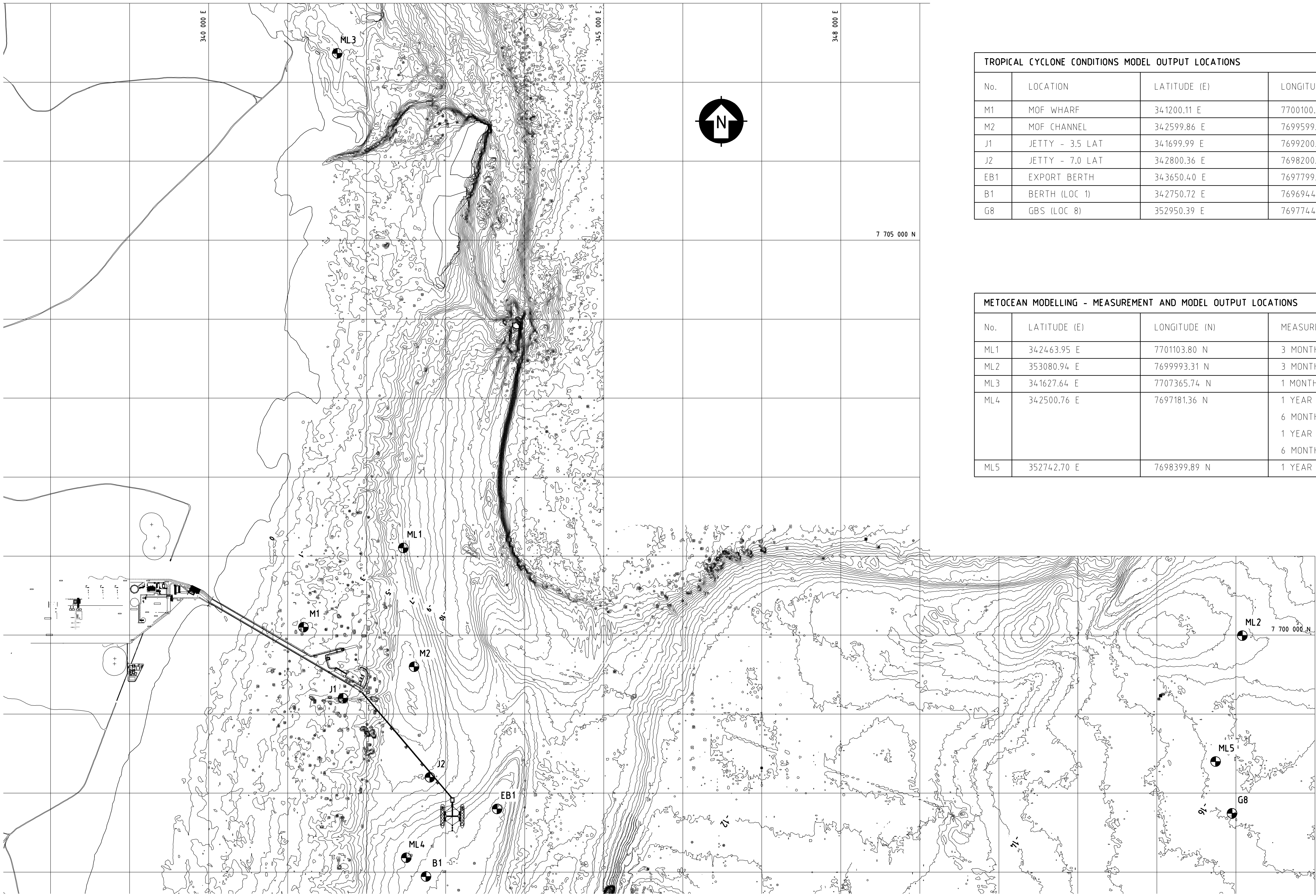



**FIGURE 2.1 AERIAL PHOTOGRAPH ILLUSTRATING BARROW ISLAND AND THE PROPOSED LOCATION OF THE MOF, TOWN POINT**

CHE020_env_034_BWI_coast_location_names_A3




| TROPICAL CYCLONE CONDITIONS MODEL OUTPUT LOCATIONS | | | | |
|---|---|---|---|---|
| No. | LOCATION | LATITUDE (E) | LONGITUDE (N) | WATER DEPTH (M LAT) |
| M1 | MOF WHARF | 341200.11 E | 7700100.31 N | 1.7 |
| M2 | MOF CHANNEL | 342599.86 E | 7699599.79 N | 4.8 |
| J1 | JETTY - 3.5 LAT | 341699.99 E | 7699200.53 N | 3.5 |
| J2 | JETTY - 7.0 LAT | 342800.36 E | 7698200.10 N | 7.0 |
| EB1 | EXPORT BERTH | 343650.40 E | 7697799.53 N | 8.4 |
| B1 | BERTH (LOC 1) | 342750.72 E | 7696944.19 N | 10 |
| G8 | GBS (LOC 8) | 352950.39 E | 7697744.13 N | 16 |

| METOCEAN MODELLING - MEASUREMENT AND MODEL OUTPUT LOCATIONS | | | | |
|---|---|---|---|---|
| No. | LATITUDE (E) | LONGITUDE (N) | MEASUREMENT | SENSOR HEIGHT |
| ML1 | 342463.95 E | 7701103.80 N | 3 MONTHS TIDE | 0m ASB |
| ML2 | 353080.94 E | 7699993.31 N | 3 MONTHS TIDE | 0m ASB |
| ML3 | 341627.64 E | 7707365.74 N | 1 MONTH CURRENT | 0.83m ASB |
| ML4 | 342500.76 E | 7697181.36 N | 1 YEAR DIRECTIONAL WAVE | - |
| | | | 6 MONTH LONG WAVE | - |
| | | | 1 YEAR CURRENT | 6m ASB |
| | | | 6 MONTH TIDE | - |
| ML5 | 352742.70 E | 7698399.89 N | 1 YEAR CURRENT | 10m ASB |

NOTES

1. HORIZONTAL DATUM IS GDA94
   PROJECTION IS MGA94 (ZONE 50)

FIGURE 2.2 LOCATION PLAN OF MEASUREMENT SITES AND MODEL OUTPUT SITES

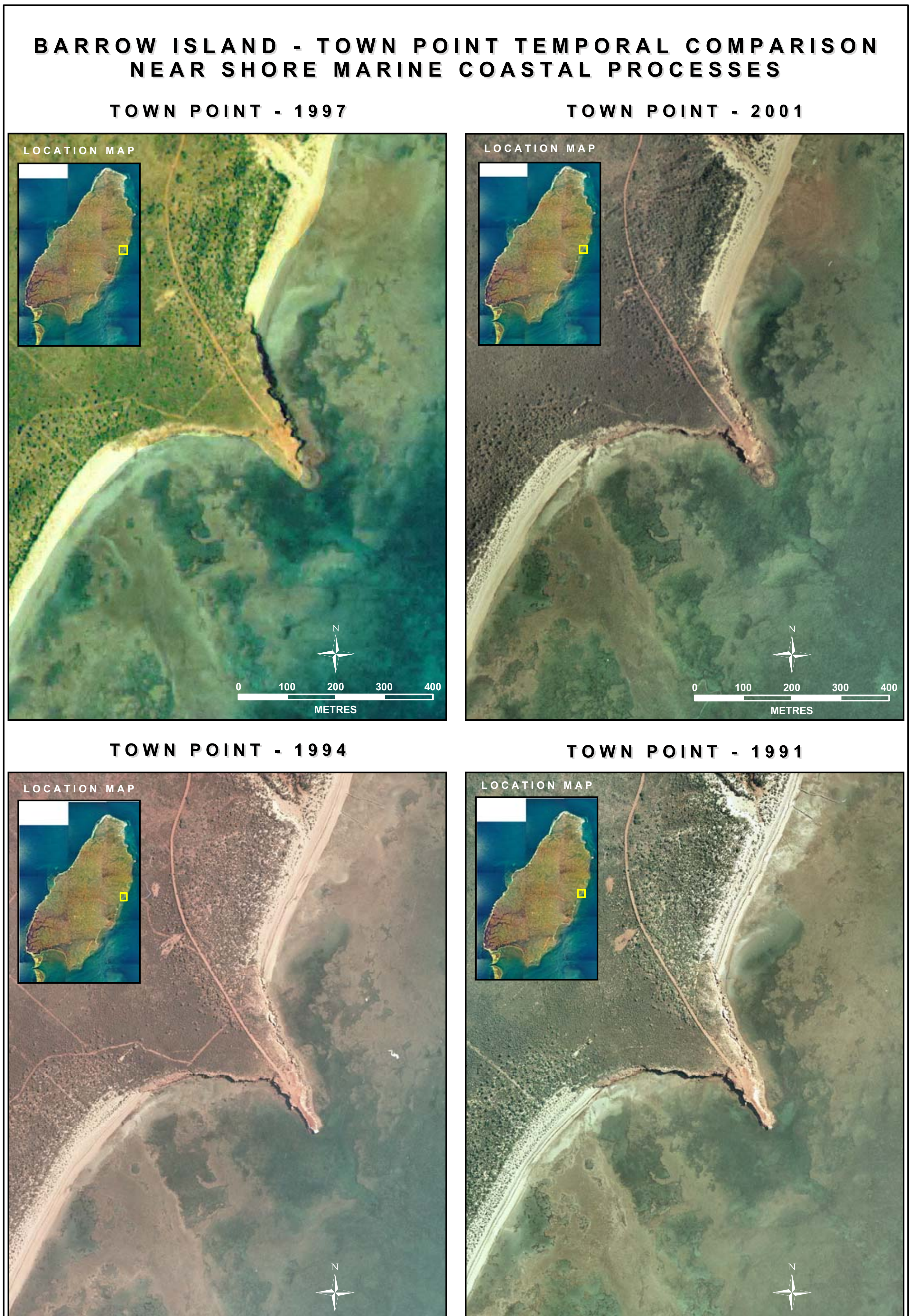
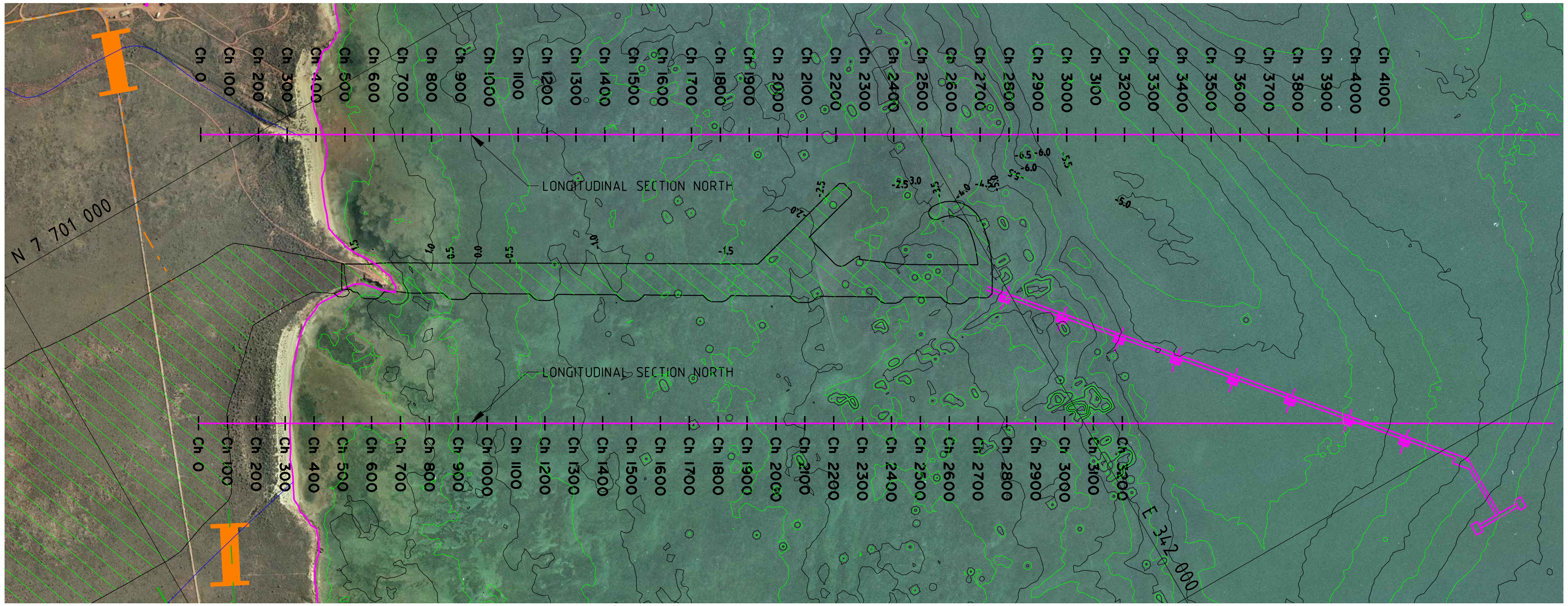
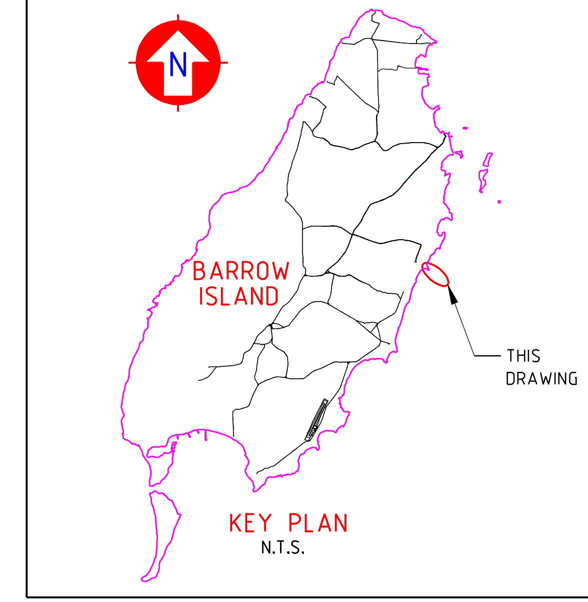
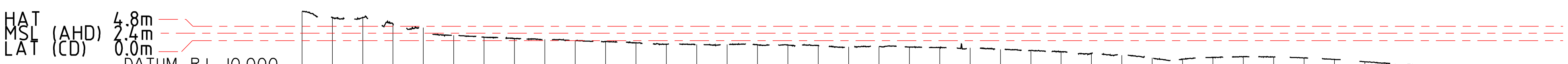



FIGURE 2.3 AERIAL PHOTOGRAPHS TAKEN IN 1991, 1994, 1997 AND 2001 AT TOWN POINT, BARROW ISLAND

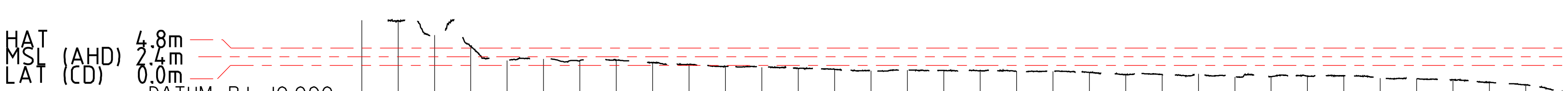



| CHAINAGE | SEABED RL (CD) |
|---|---|
| 0.000 | 9.675 |
| 100.000 | 7.724 |
| 200.000 | 7.663 |
| 300.000 | 5.345 |
| 400.000 | 4.346 |
| 500.000 | 1.813 |
| 600.000 | 1.116 |
| 700.000 | 0.660 |
| 800.000 | 0.346 |
| 900.000 | 0.054 |
| 1000.000 | -0.362 |
| 1100.000 | -0.686 |
| 1200.000 | -1.150 |
| 1300.000 | -1.233 |
| 1400.000 | -1.292 |
| 1500.000 | -1.355 |
| 1600.000 | -1.416 |
| 1700.000 | -1.546 |
| 1800.000 | -2.068 |
| 1900.000 | -1.937 |
| 2000.000 | -2.107 |
| 2100.000 | -2.263 |
| 2200.000 | -2.341 |
| 2300.000 | -2.815 |
| 2400.000 | -3.204 |
| 2500.000 | -3.640 |
| 2600.000 | -4.143 |
| 2700.000 | -4.756 |
| 2800.000 | -5.739 |
| 2900.000 | -6.106 |
| 3000.000 | -5.469 |
| 3100.000 | -5.249 |
| 3200.000 | -5.368 |
| 3300.000 | -5.717 |
| 3400.000 | -6.185 |
| 3500.000 | -6.971 |
| 3600.000 | -7.622 |
| 3700.000 | -8.115 |
| 3800.000 | -8.456 |
| 3900.000 | -8.627 |
| 4000.000 | -8.724 |
| 4100.000 | -8.578 |

LONGITUDINAL SECTION NORTH




| CHAINAGE | SEABED RL (CD) |
|---|---|
| 0.000 | |
| 100.000 | 12.357 |
| 200.000 | 8.286 |
| 300.000 | 5.373 |
| 400.000 | 1.407 |
| 500.000 | 1.832 |
| 600.000 | 1.378 |
| 700.000 | 1.505 |
| 800.000 | 0.742 |
| 900.000 | 0.263 |
| 1000.000 | -0.241 |
| 1100.000 | -0.428 |
| 1200.000 | -0.822 |
| 1300.000 | -1.044 |
| 1400.000 | -1.336 |
| 1500.000 | -1.215 |
| 1600.000 | -1.326 |
| 1700.000 | -1.358 |
| 1800.000 | -1.525 |
| 1900.000 | -1.481 |
| 2000.000 | -1.883 |
| 2100.000 | -2.434 |
| 2200.000 | -2.429 |
| 2300.000 | -2.270 |
| 2400.000 | -3.045 |
| 2500.000 | -2.974 |
| 2600.000 | -2.883 |
| 2700.000 | -2.760 |
| 2800.000 | -3.363 |
| 2900.000 | -3.577 |
| 3000.000 | -3.894 |
| 3100.000 | -4.582 |
| 3200.000 | -5.253 |
| 3300.000 | |

LONGITUDINAL SECTION SOUTH

## TIDAL PLANES

(MOF LOCATION)

| | |
|---|---|
| HAT | 4.8m |
| MHWS | 4.0m |
| MHWN | 2.8m |
| MSL (AHD) | 2.4m |
| MLWN | 2.0m |
| MLWS | 0.8m |
| LAT (CD) | 0.0m |

TIDAL INFORMATION EXTRACTED FROM CHEVRON B.O.D. G1-TE-Z-D0000-PDBX004

NOTE:

1. BATHYMETRY IS RELATIVE TO CHART DATUM (LAT)
2. GRID COORDINATES SHOWN:- MGA94 ZONE 50

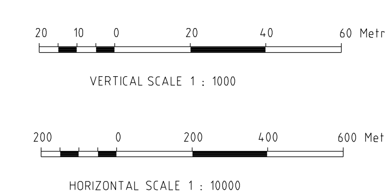



FIGURE 2.4 LONG SECTION NORTH AND SOUTH OF TOWN POINT illustrating MOF and Jetty

PRELIMINARY


FIGURE 2.5 OVERLAY OF DENSE AND SPARSE VEGETATION LINES FROM AERIAL PHOTGORAPHS TAKEN IN 1991, 1994, 1997, 2001 OVERLAYED ON AN AERIAL PHOTOGRAPH TAKEN IN 2004.

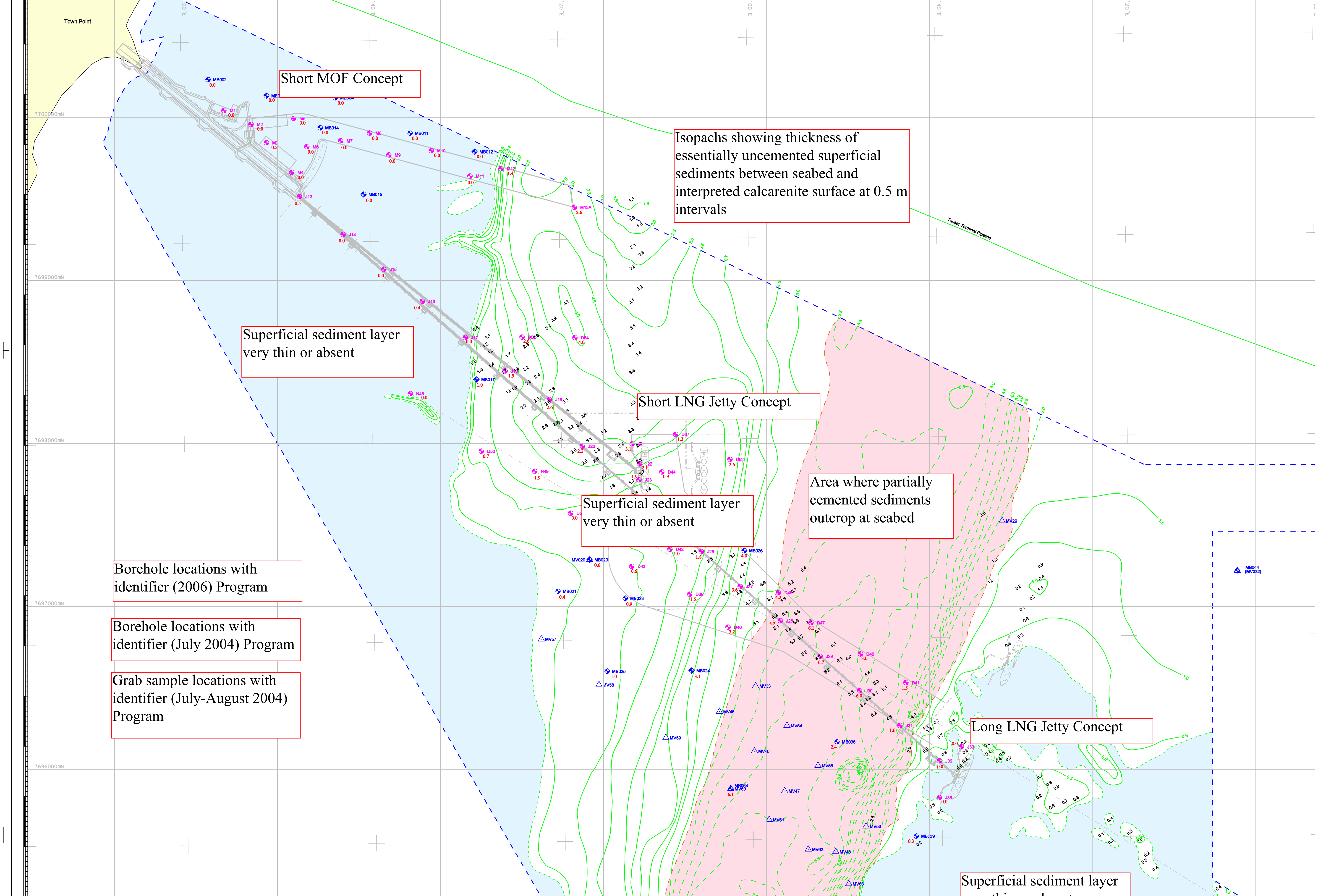



FIGURE 2.6 ISOPACHS OF SURVEY
GORGON PROJECT NEARSHORE GEOPHYSICAL SURVEY
ISOPACHS OF JETTY AREA
FUGRO SURVEY PTY LTD PO485_006 30/11/2006

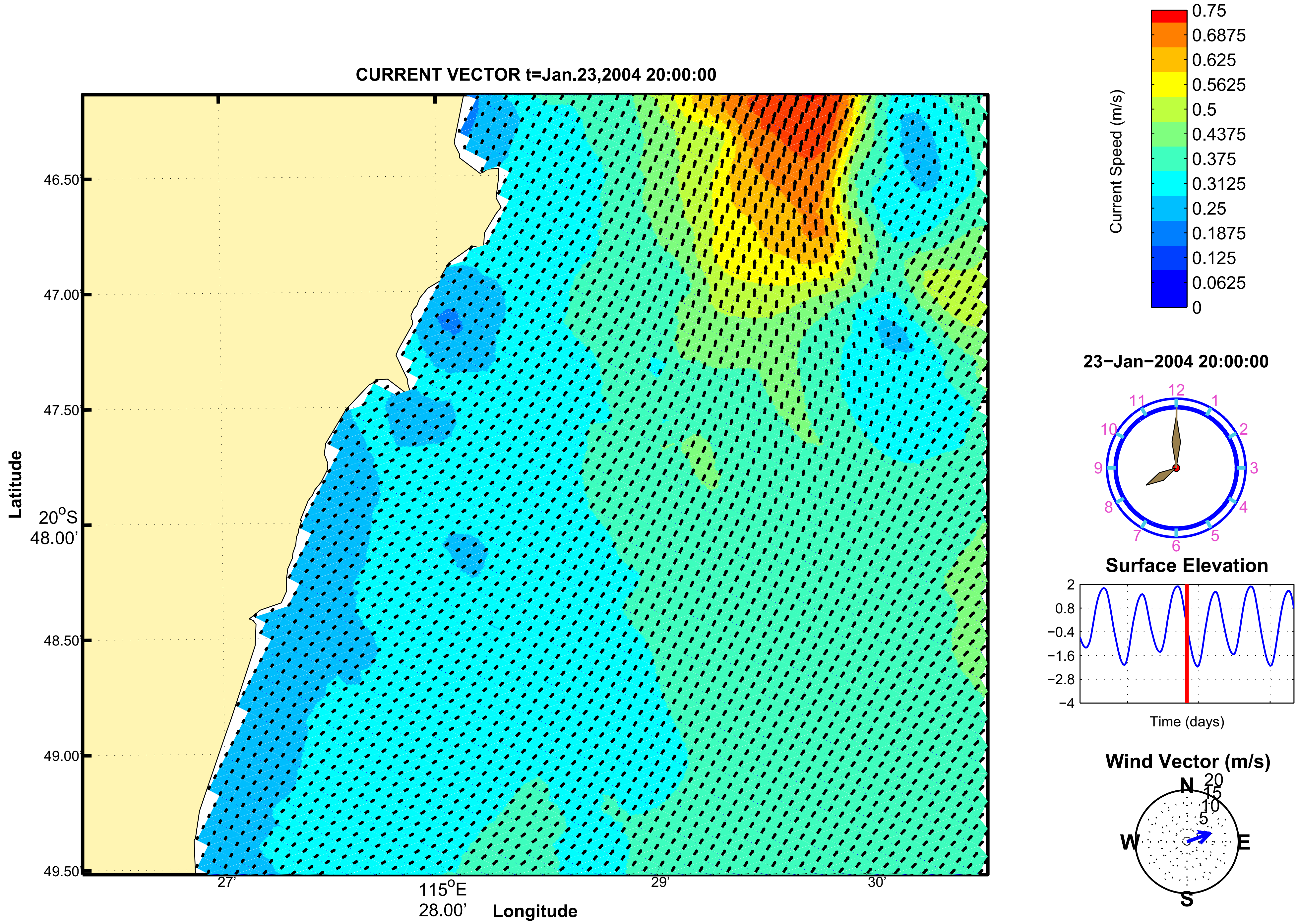



Figure 3.1 Ambient current circulation without MOF in January(wind and tide forcing)

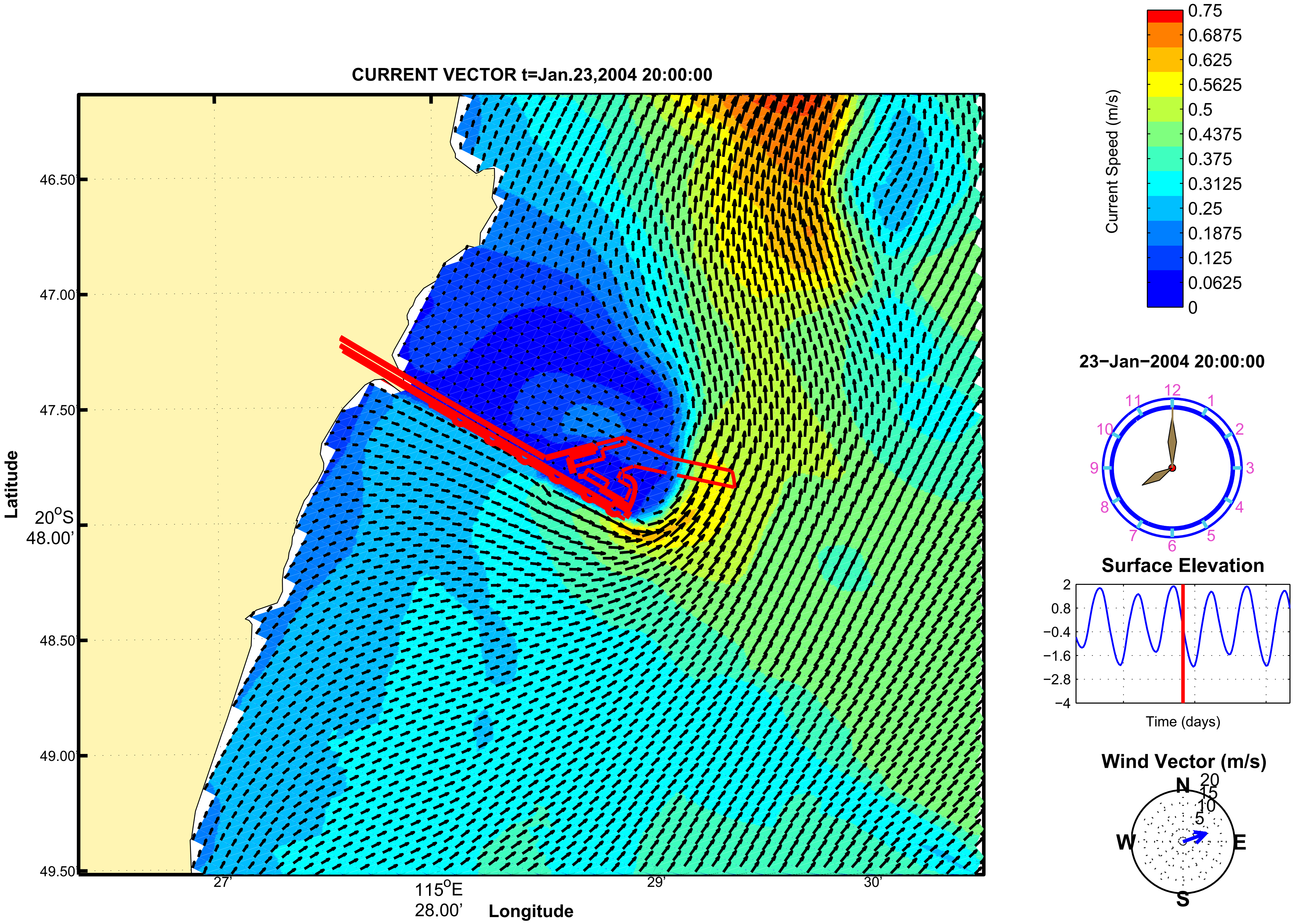



Figure 3.2 Ambient current circulation with MOF in place, January (wind and tide forcing)

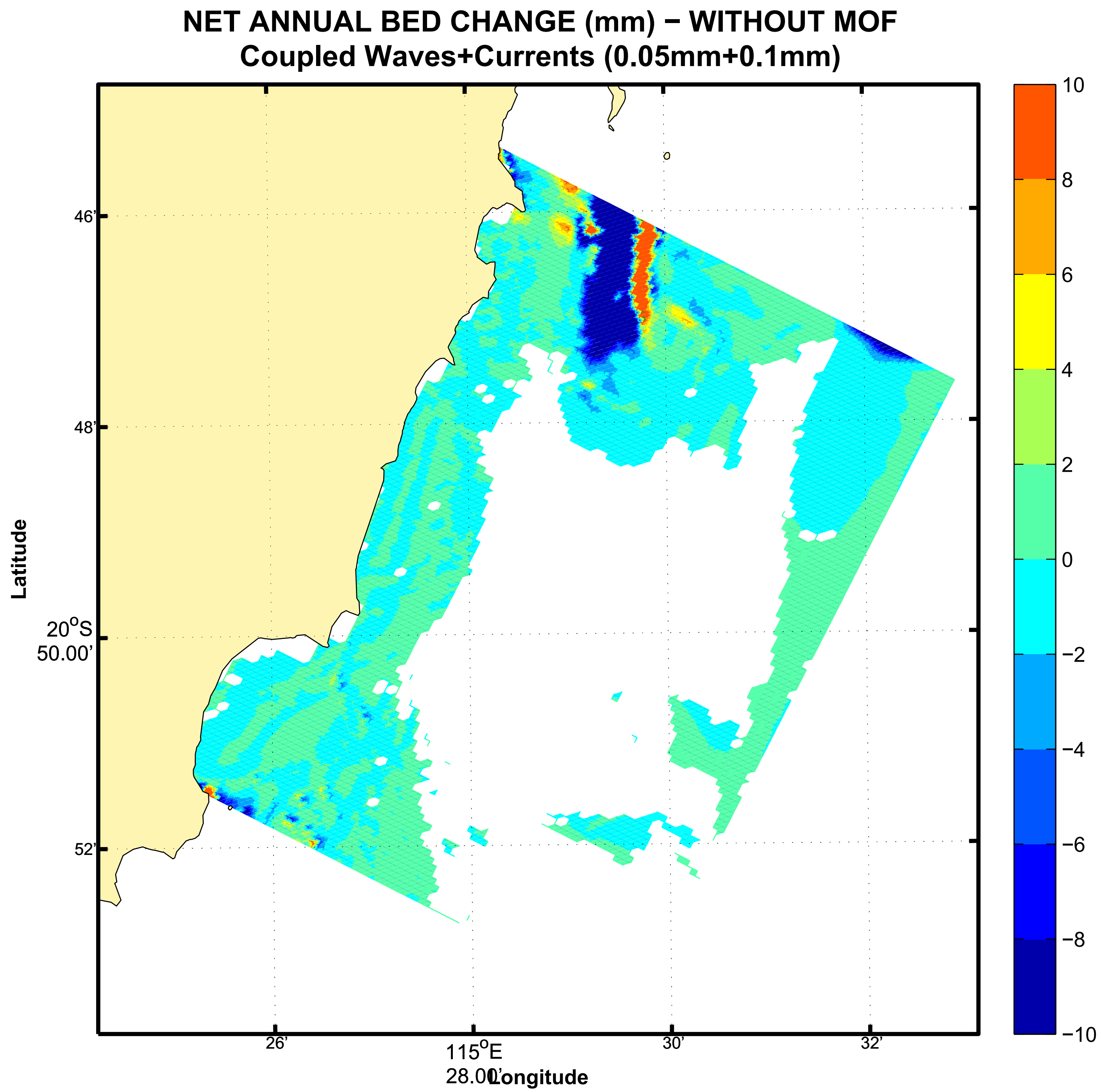



Figure 3.3 Ambient annual net sediment transport without MOF

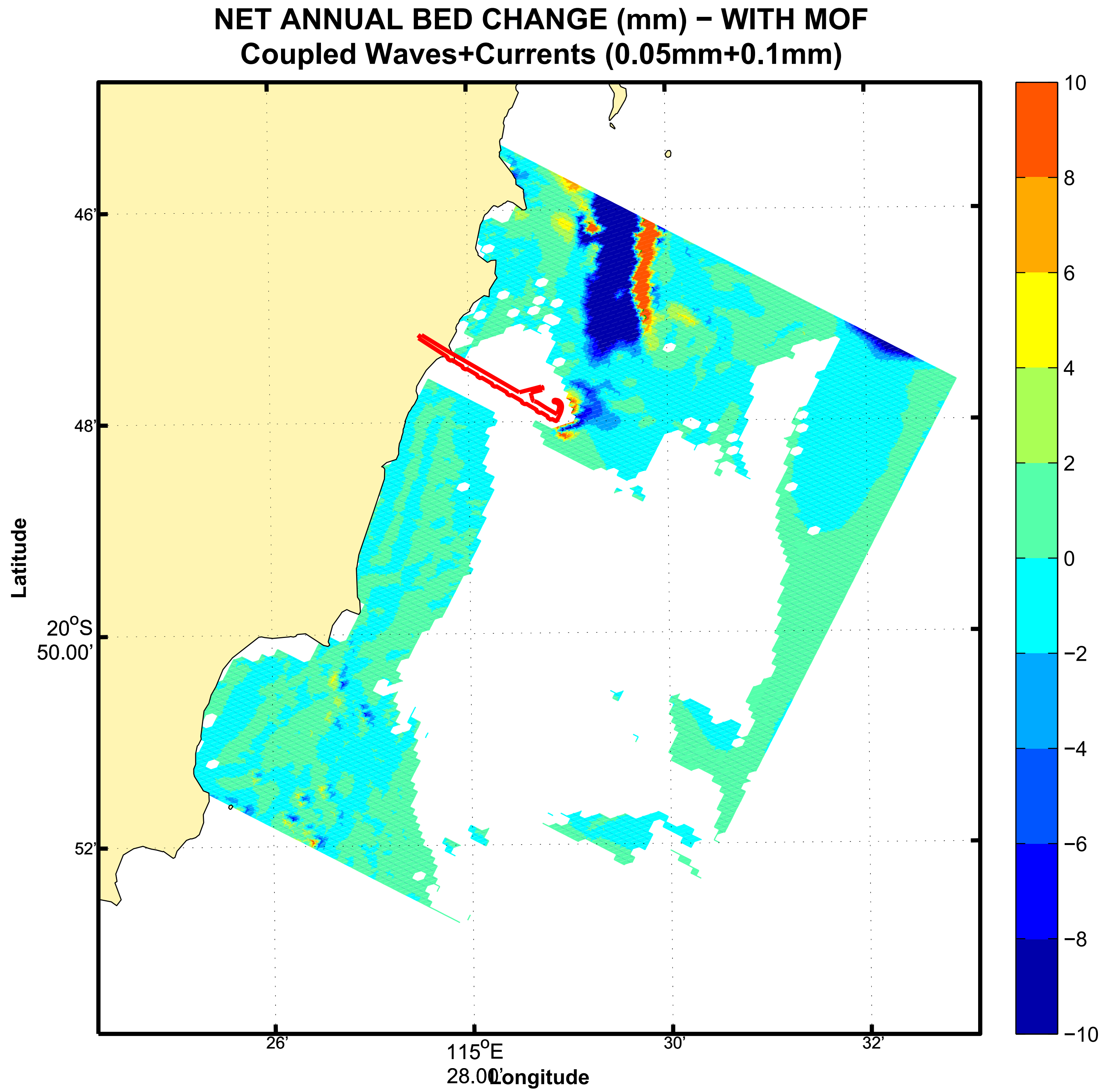



Figure 3.4 Ambient annual net sediment transport with MOF in place

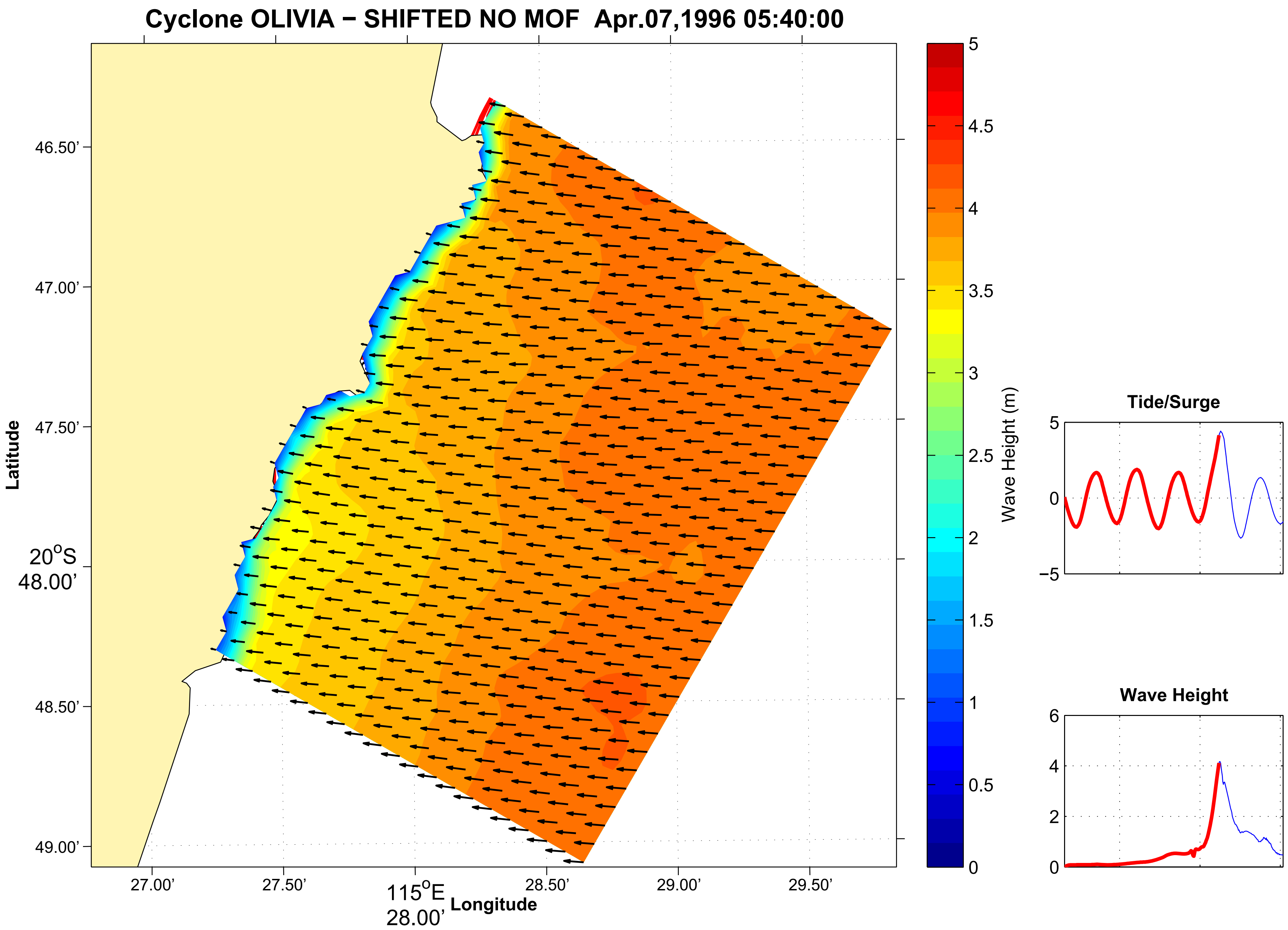



Figure 3.5 Modelled wave climate during (time-shifted) Tropical Cyclone Olivia

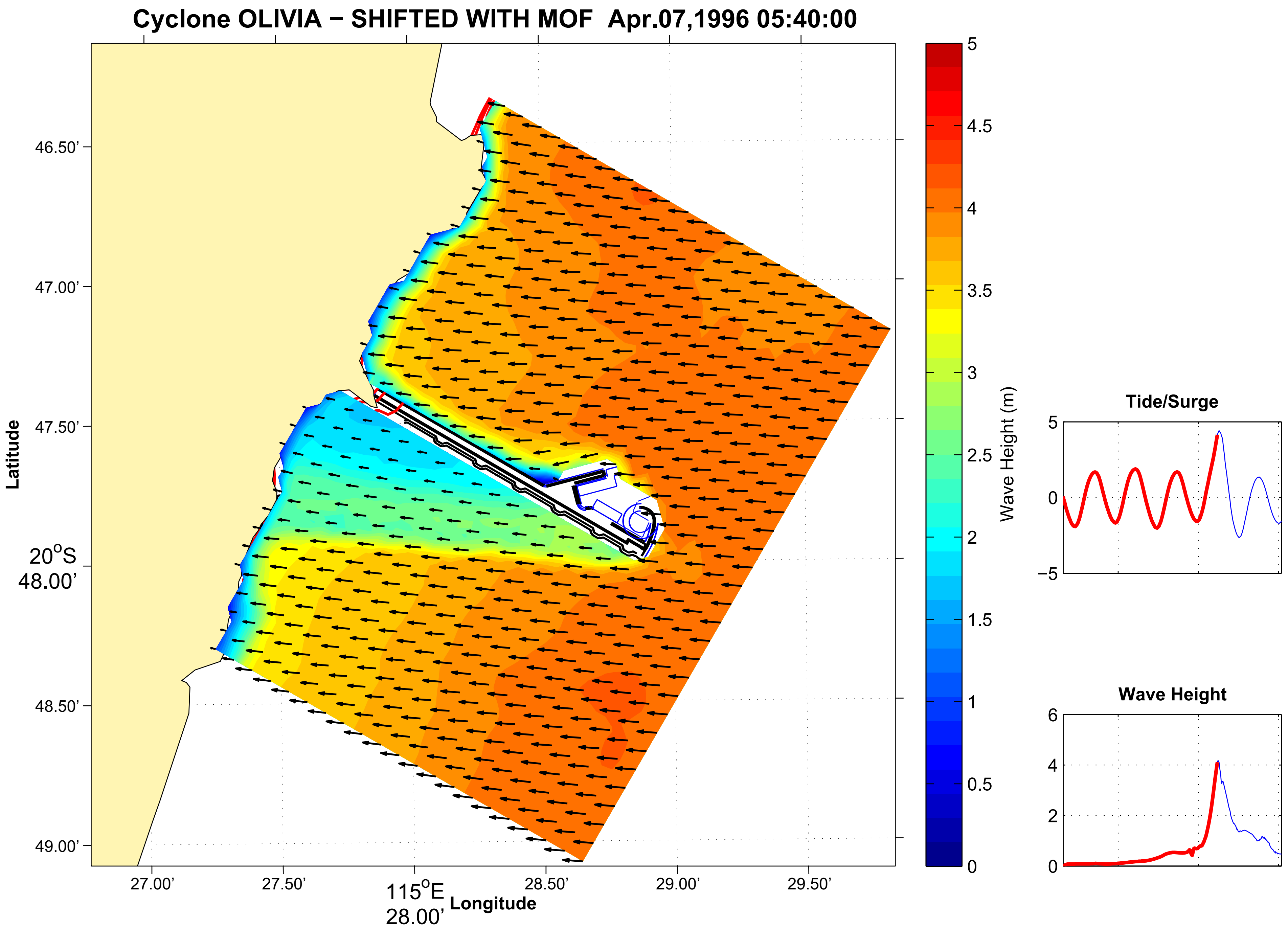



Figure 3.6 Modelled wave climate during (time-shifted) Tropical Cyclone Olivia with MOF in place

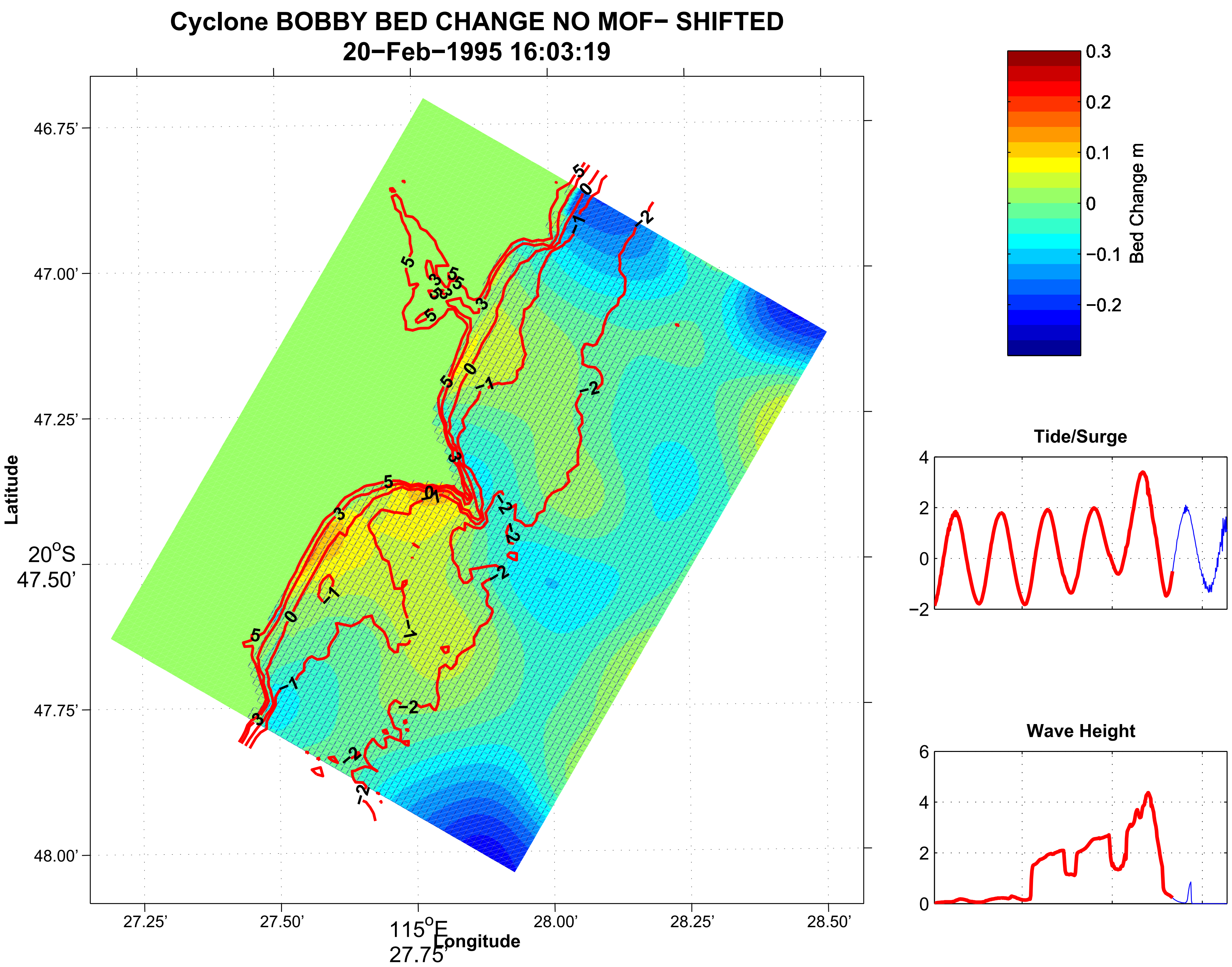


Figure 3.7 Modelled bed level changes after peak of Tropical Cyclone Bobby without MOF

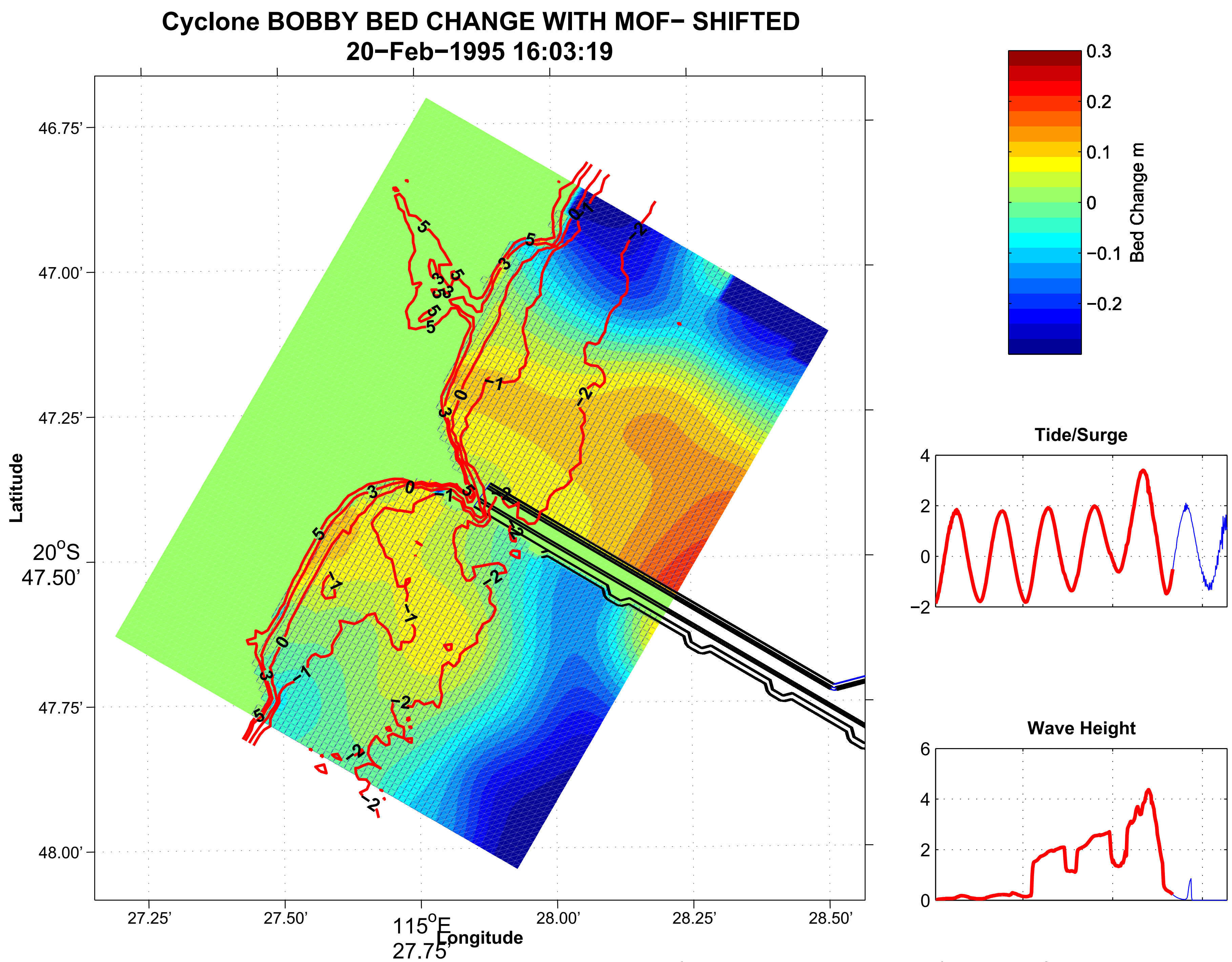



Figure 3.8 Modelled bed level changes after peak of Tropical cyclone Bobby with MOF in place

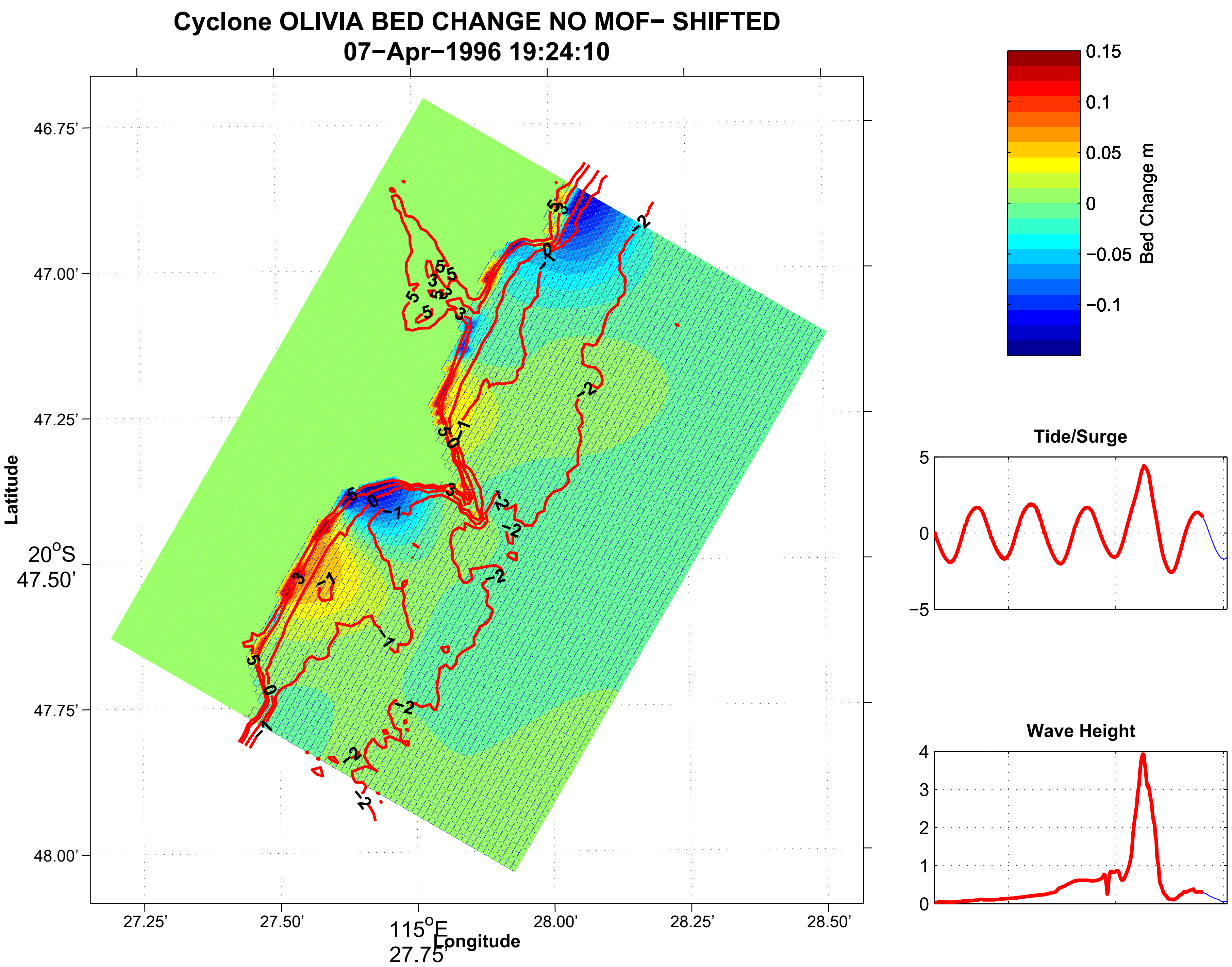



Figure 3.9 Modelled bed level changes after peak of Tropical Cyclone Olivia without MOF

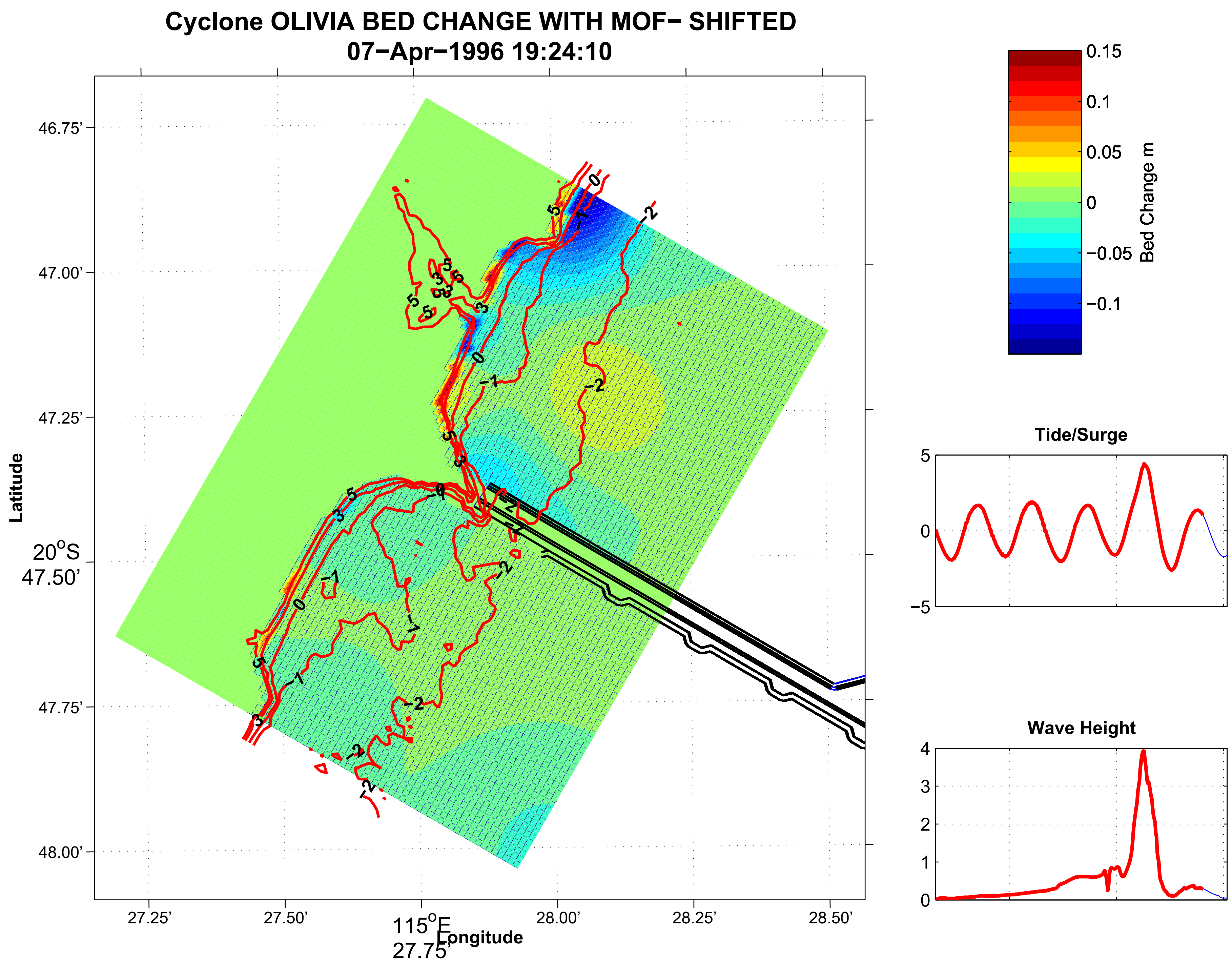
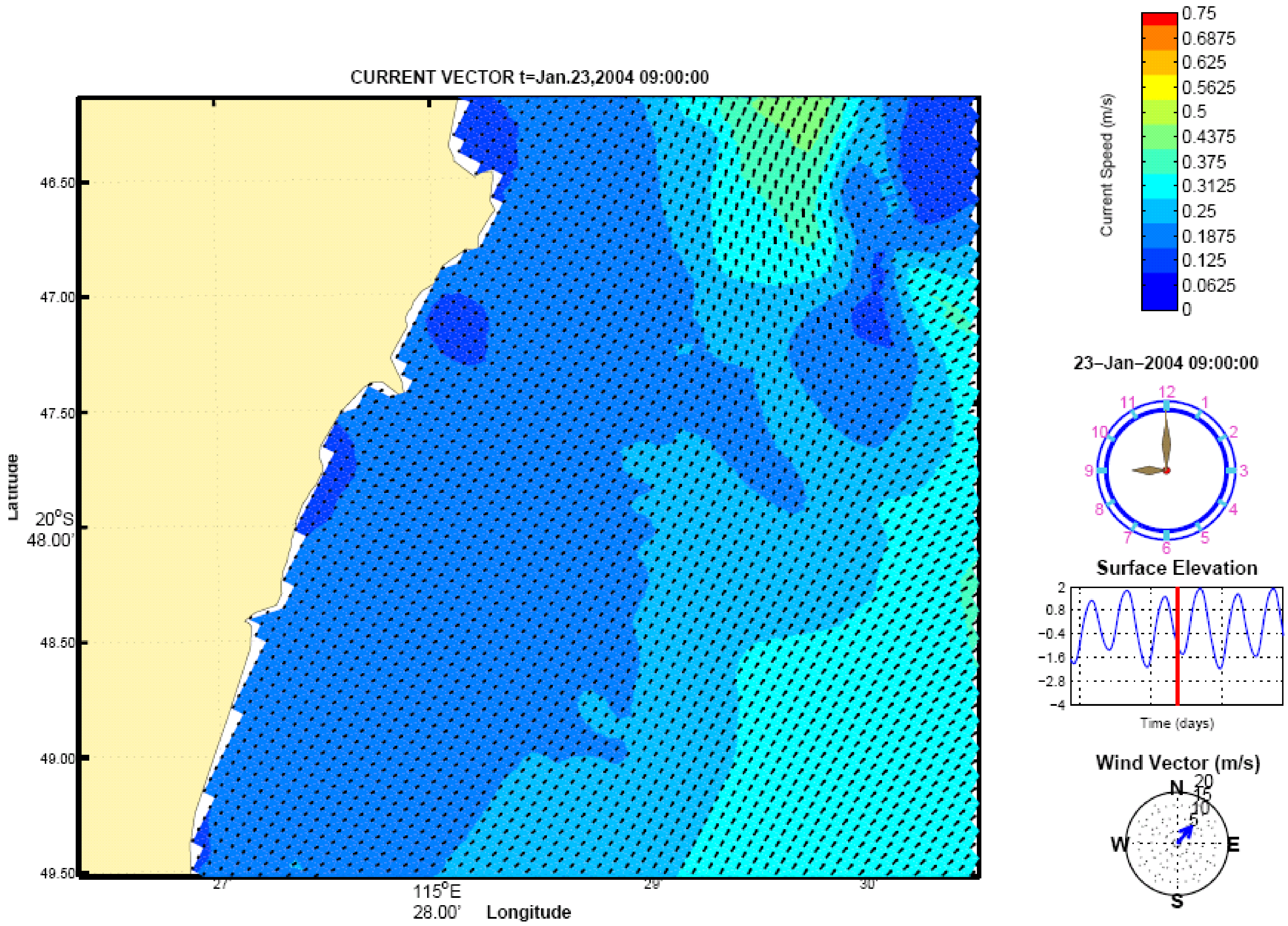



Figure 3.10 Modelled bed level changes after peak of Tropical Cyclone Olivia with MOF in place

**Schedule 5 – Coordinates that define the High Impact Zone, Moderate Impact Zone and Zone of Influence (Table 1)**

Additional Current and Wind Plots comparing scenario with revised MOF and without MOF (from Appendix C Coastal Modelling – BWI - Metocean Report).



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49.50
27'
115°E
28.00'
29'
30'
Current Speed (m/s)
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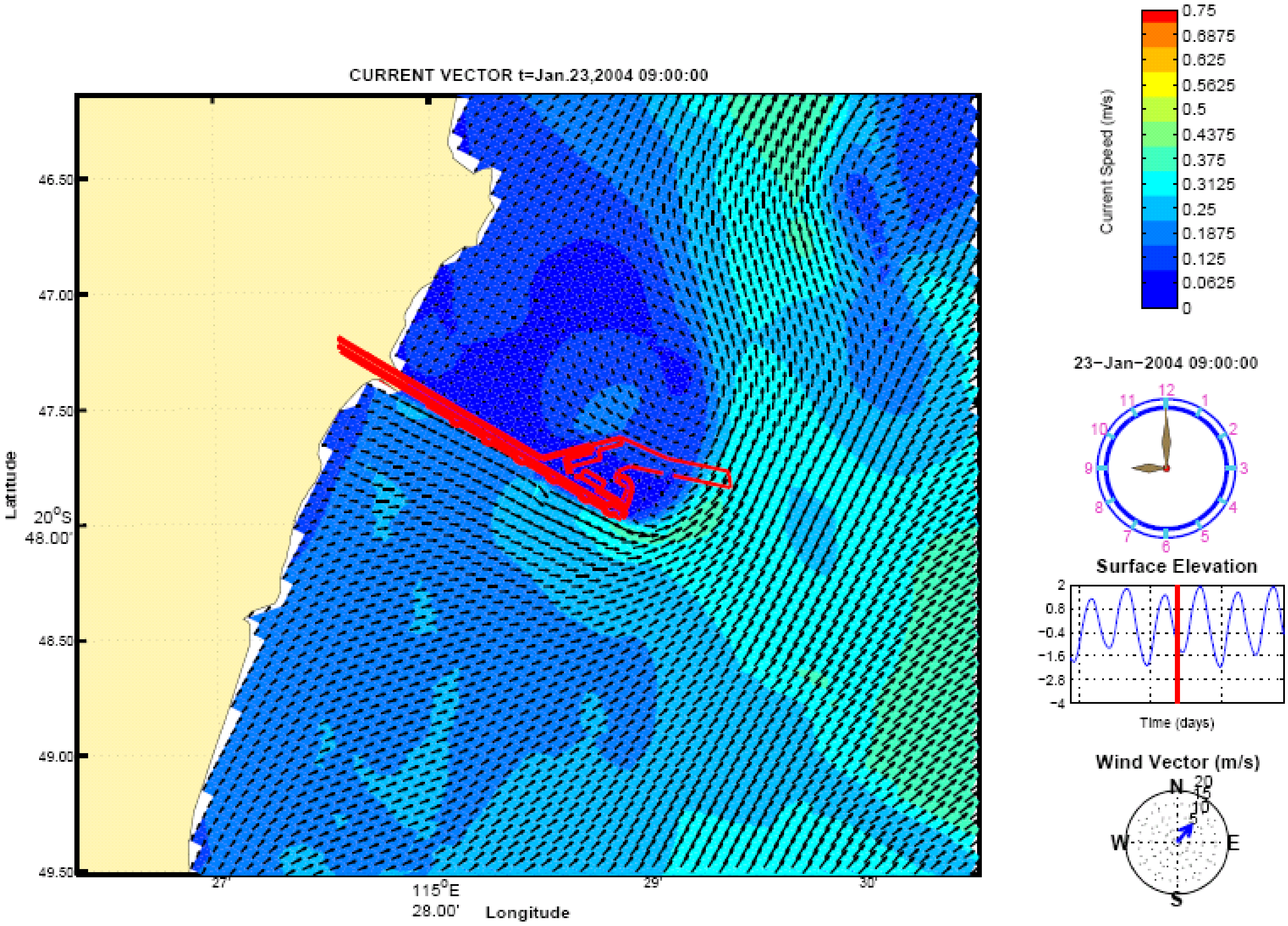

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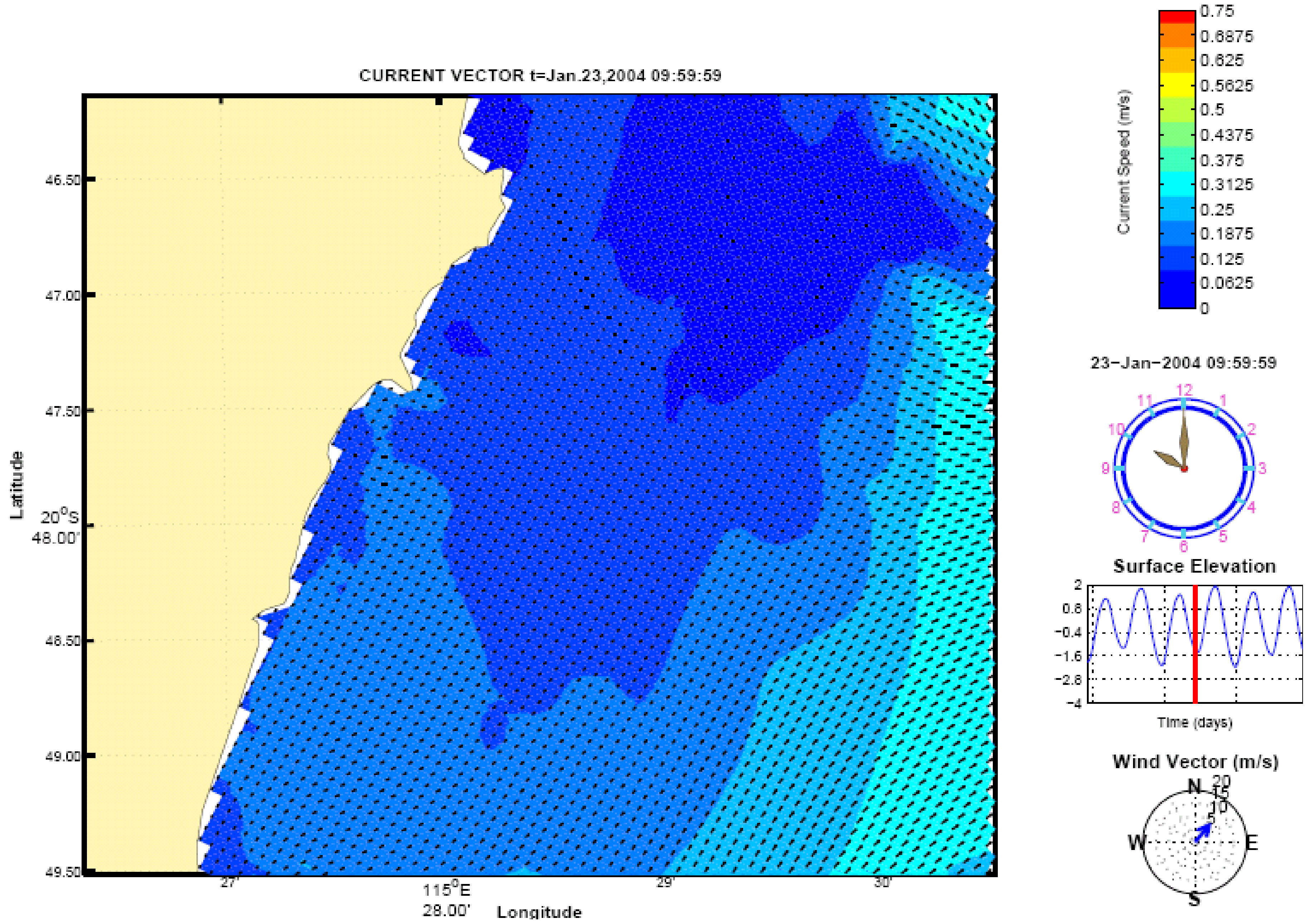
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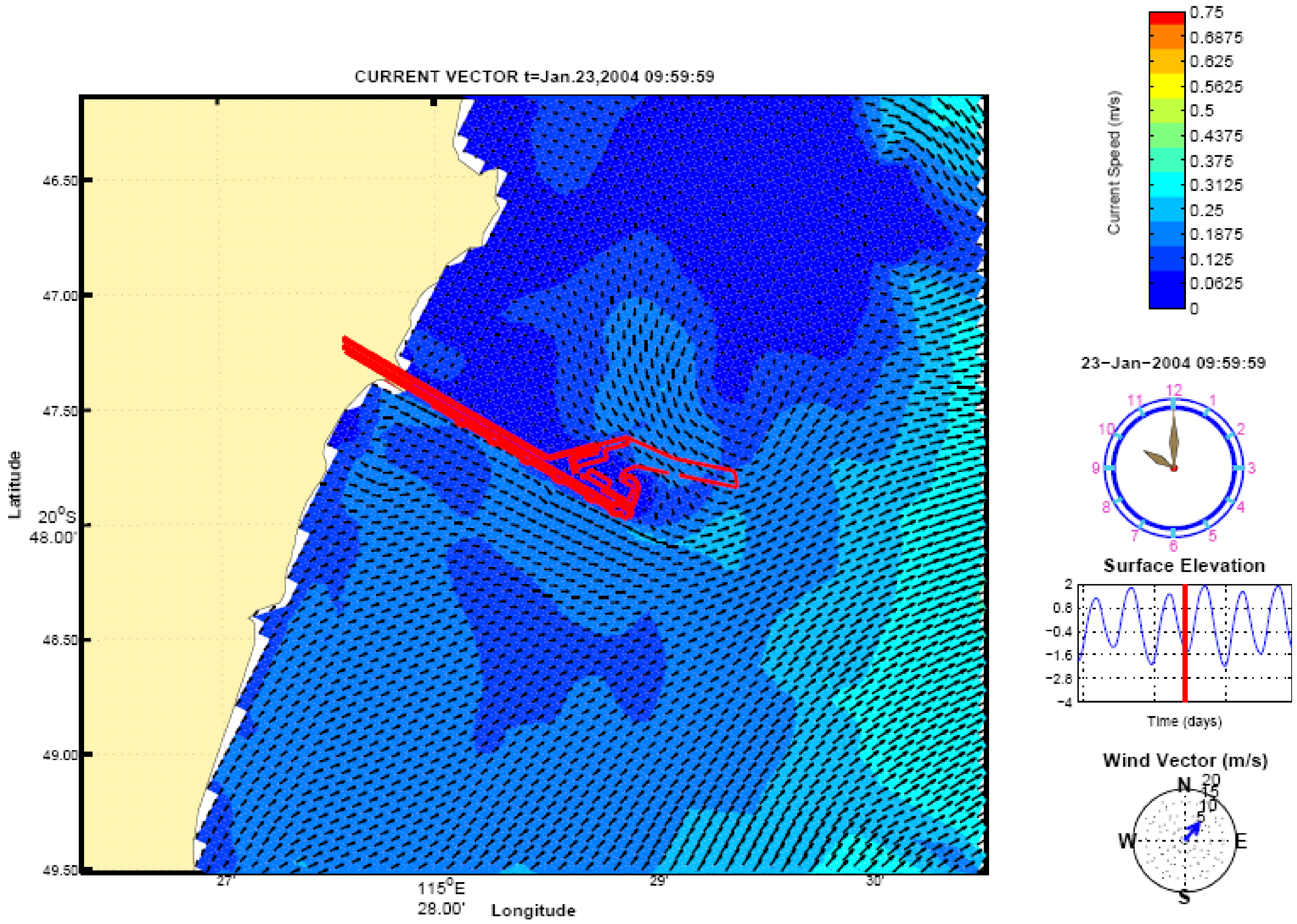
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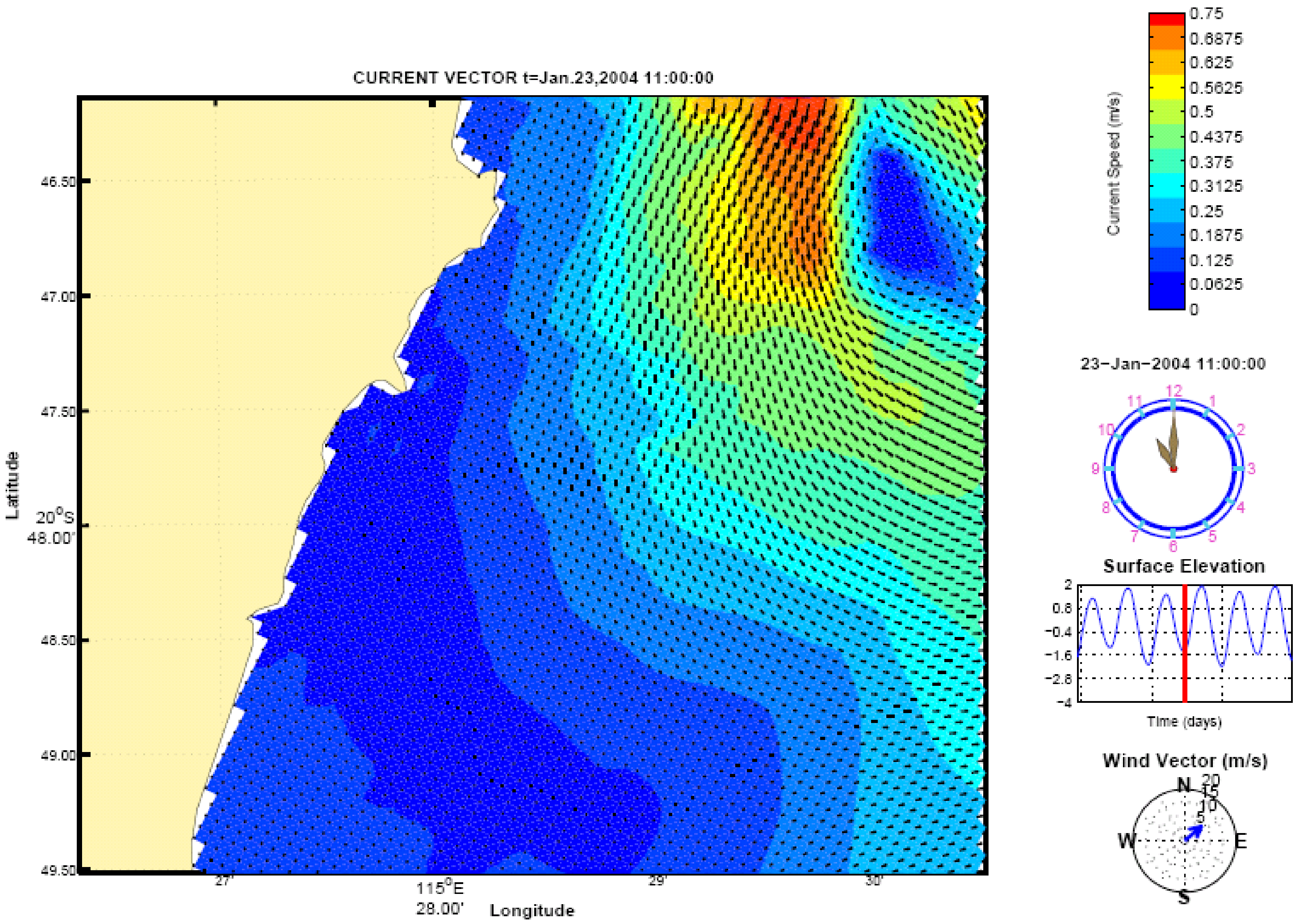

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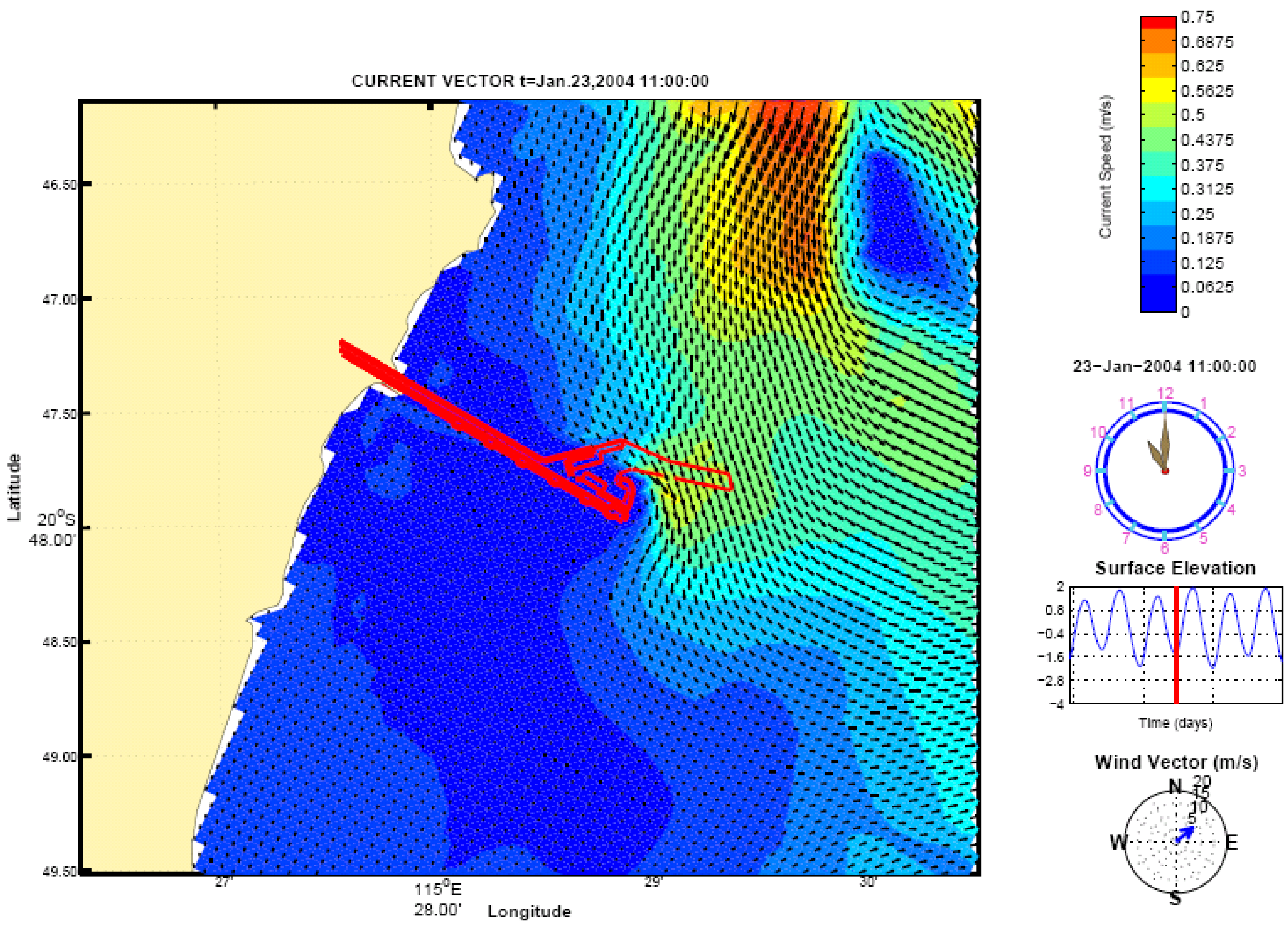

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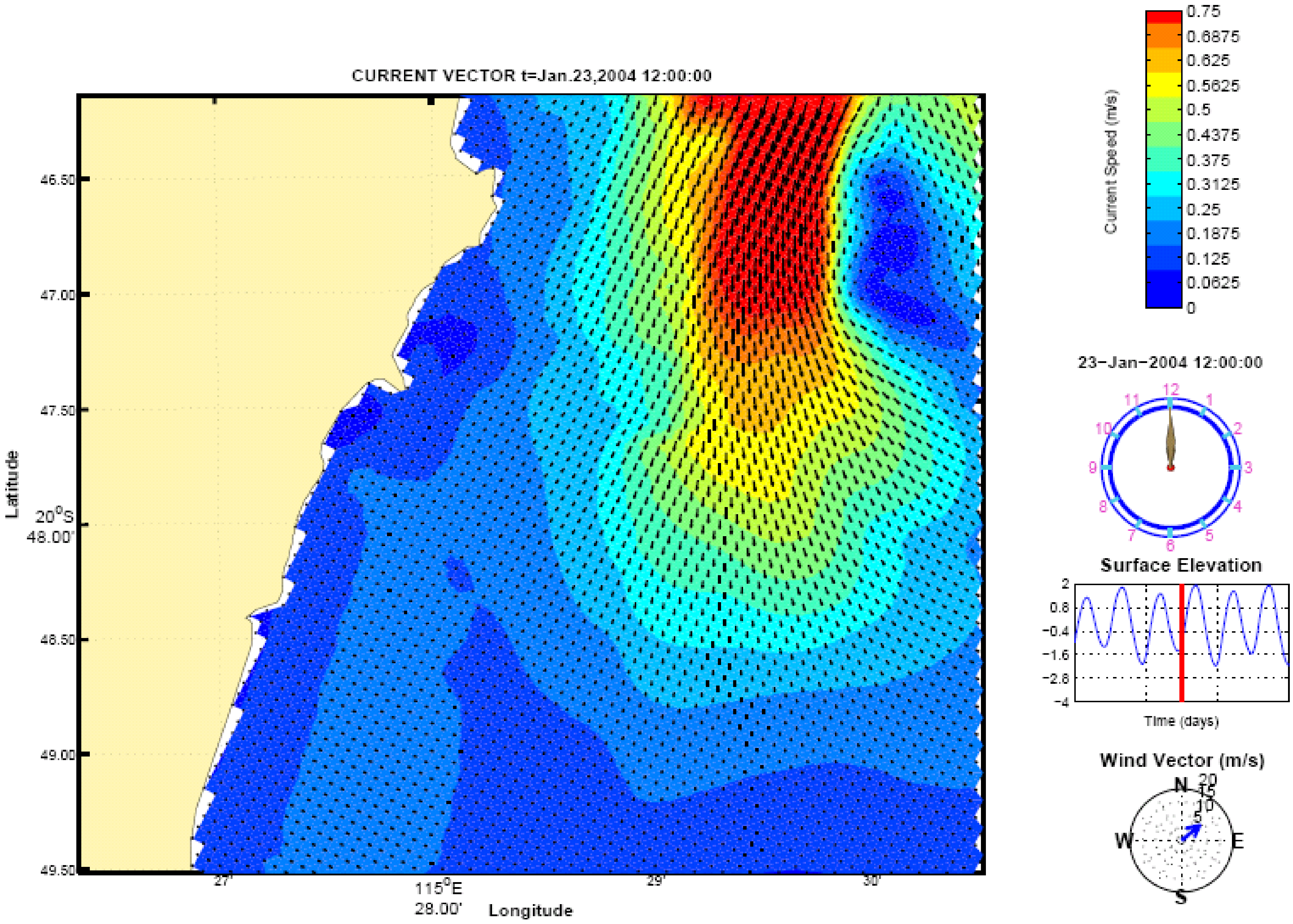

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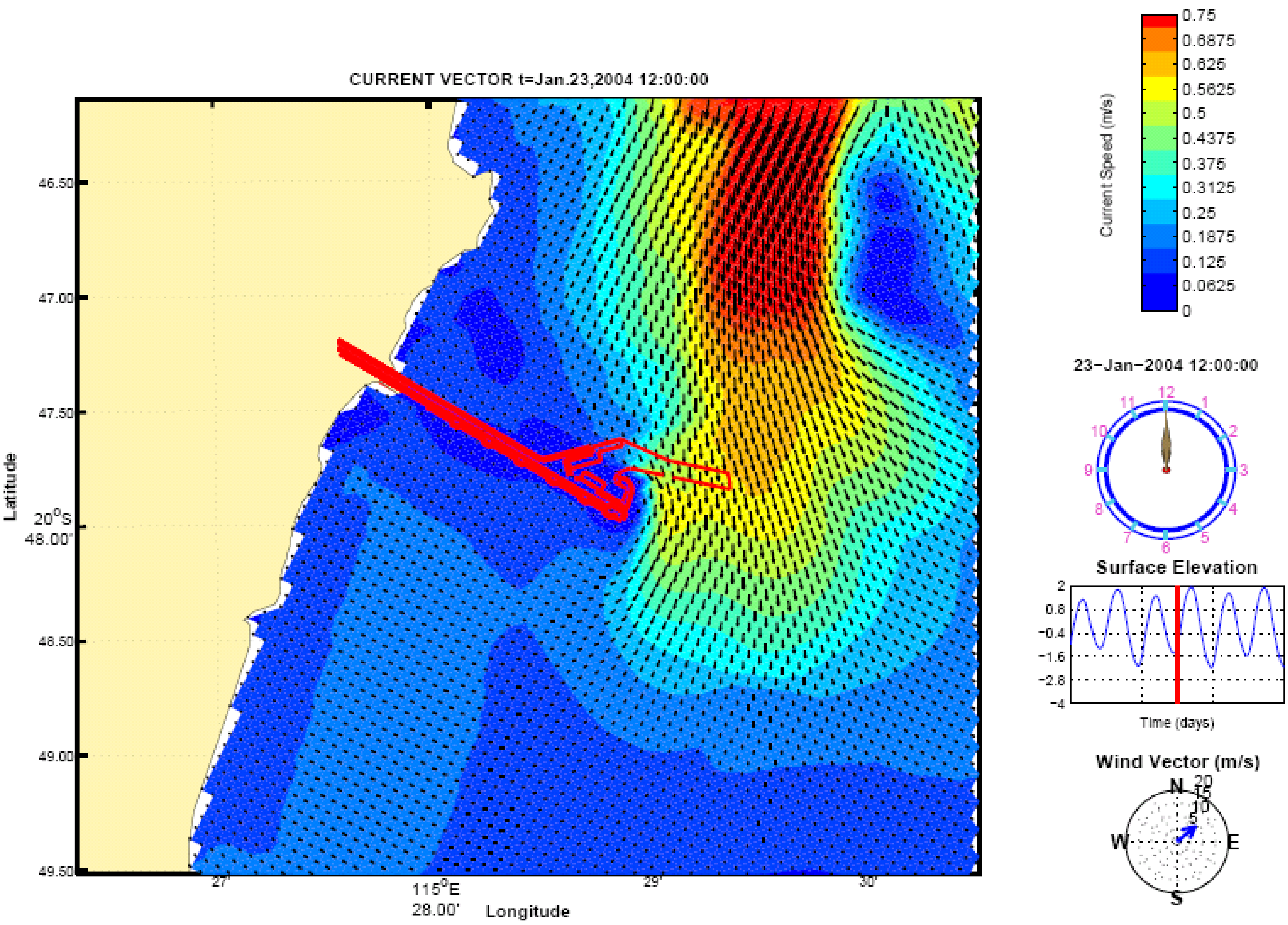

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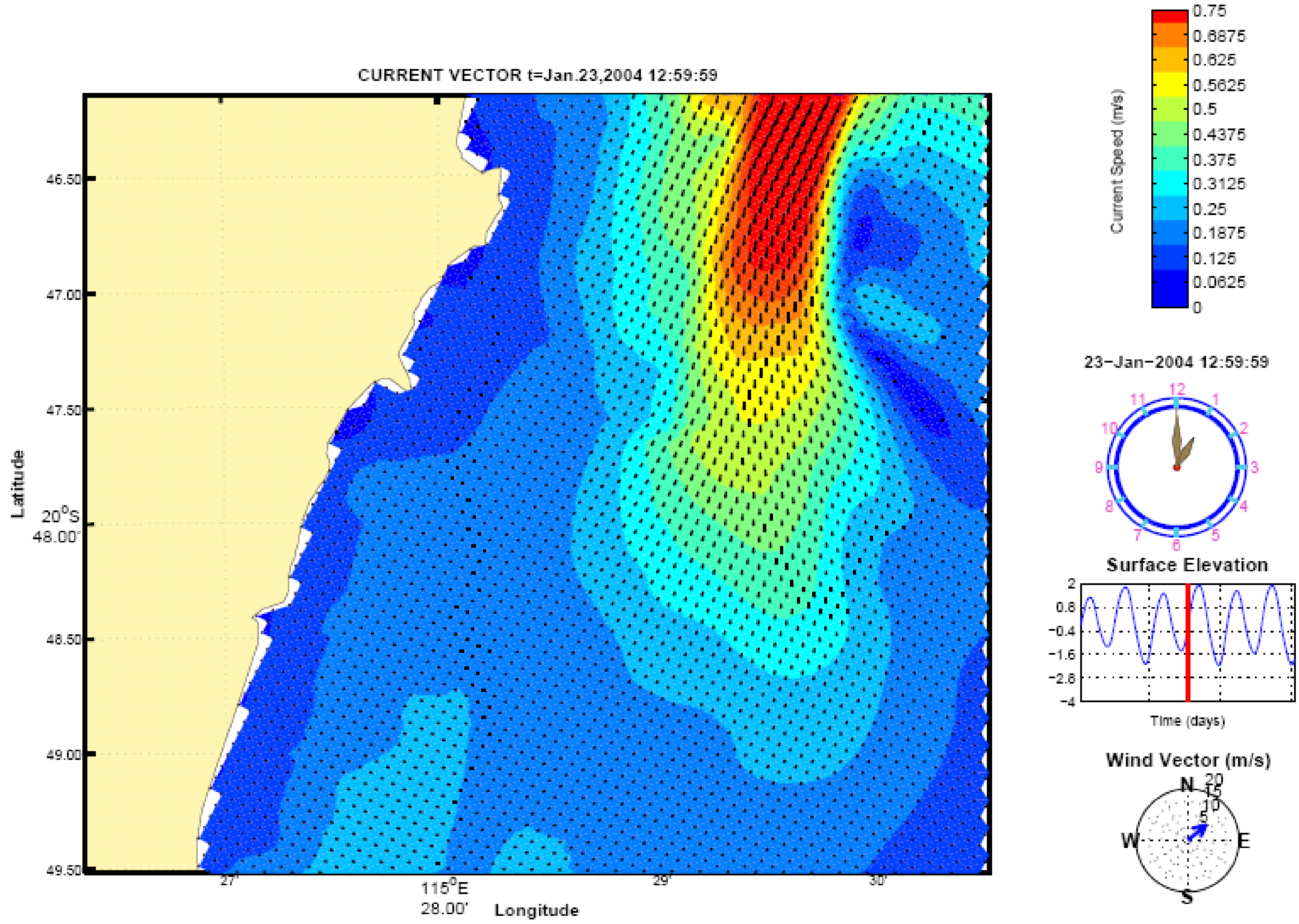
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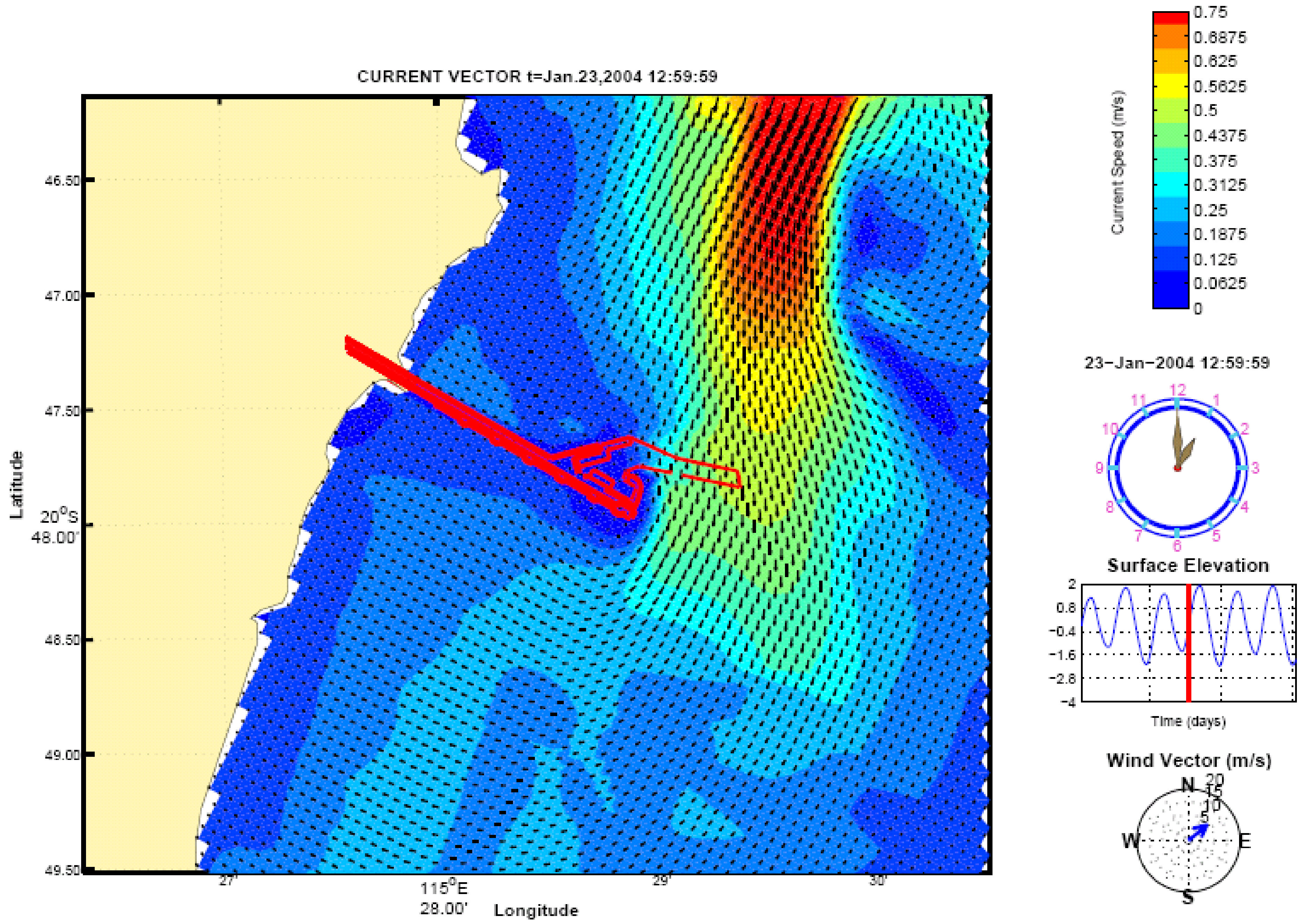
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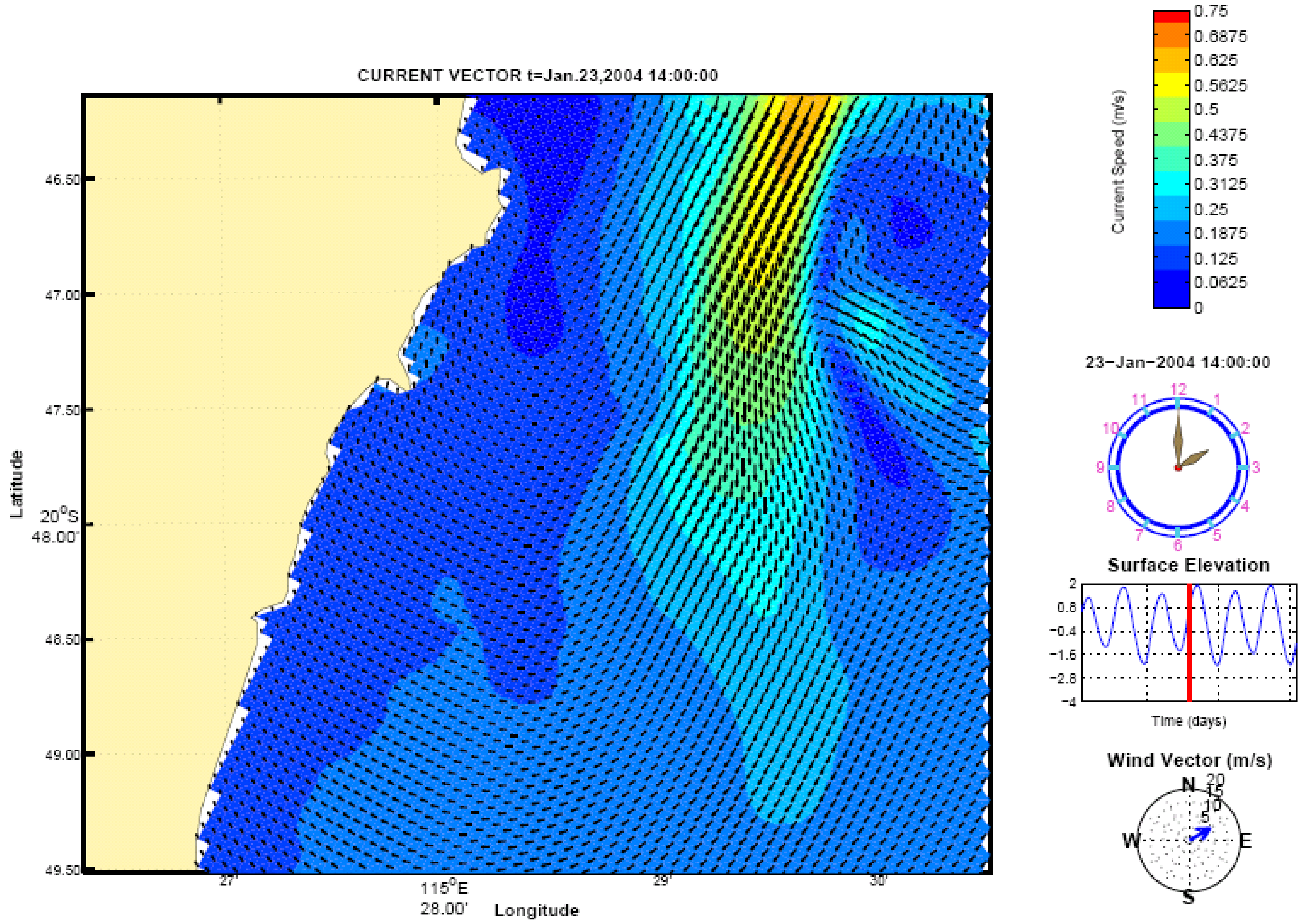
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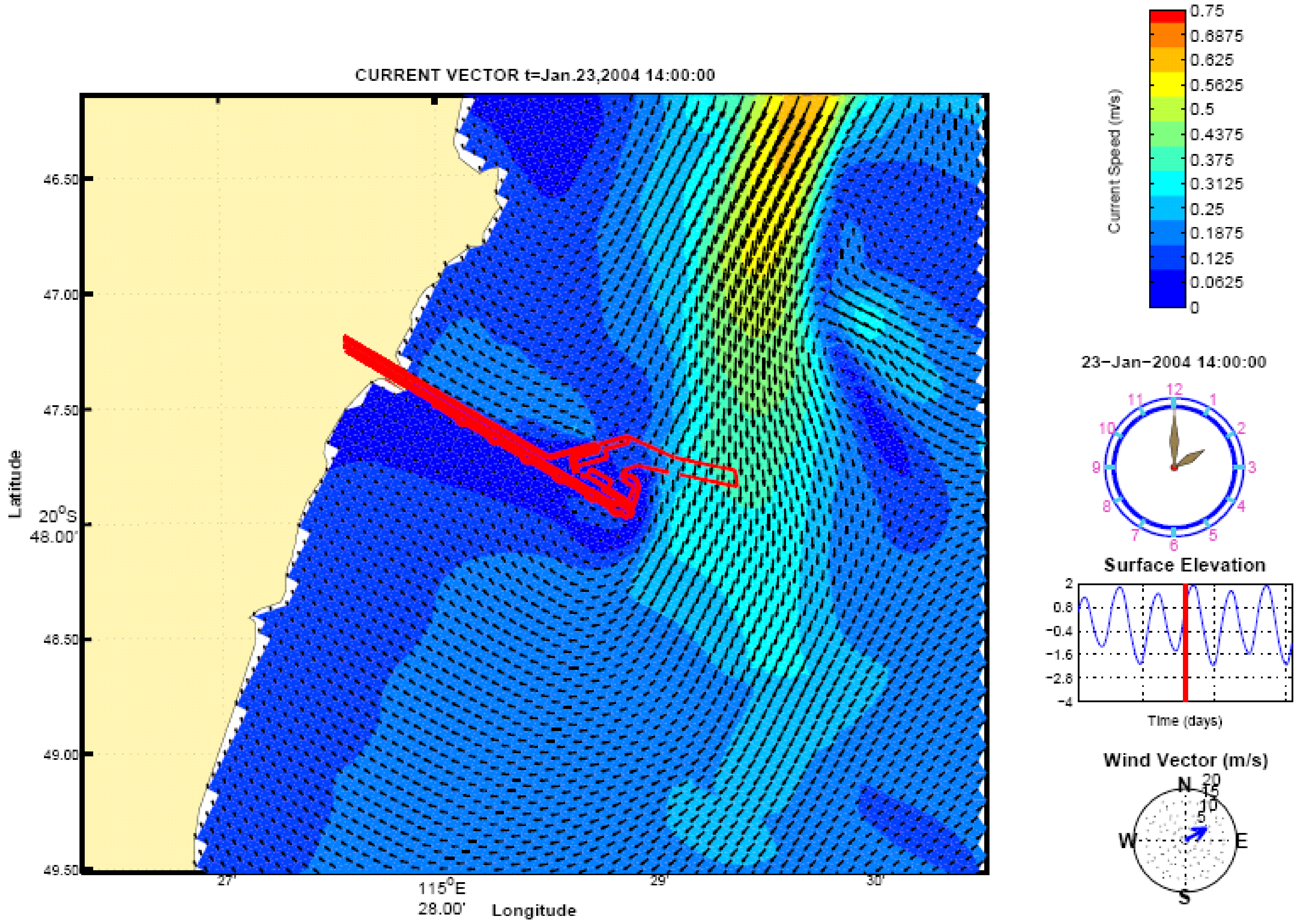
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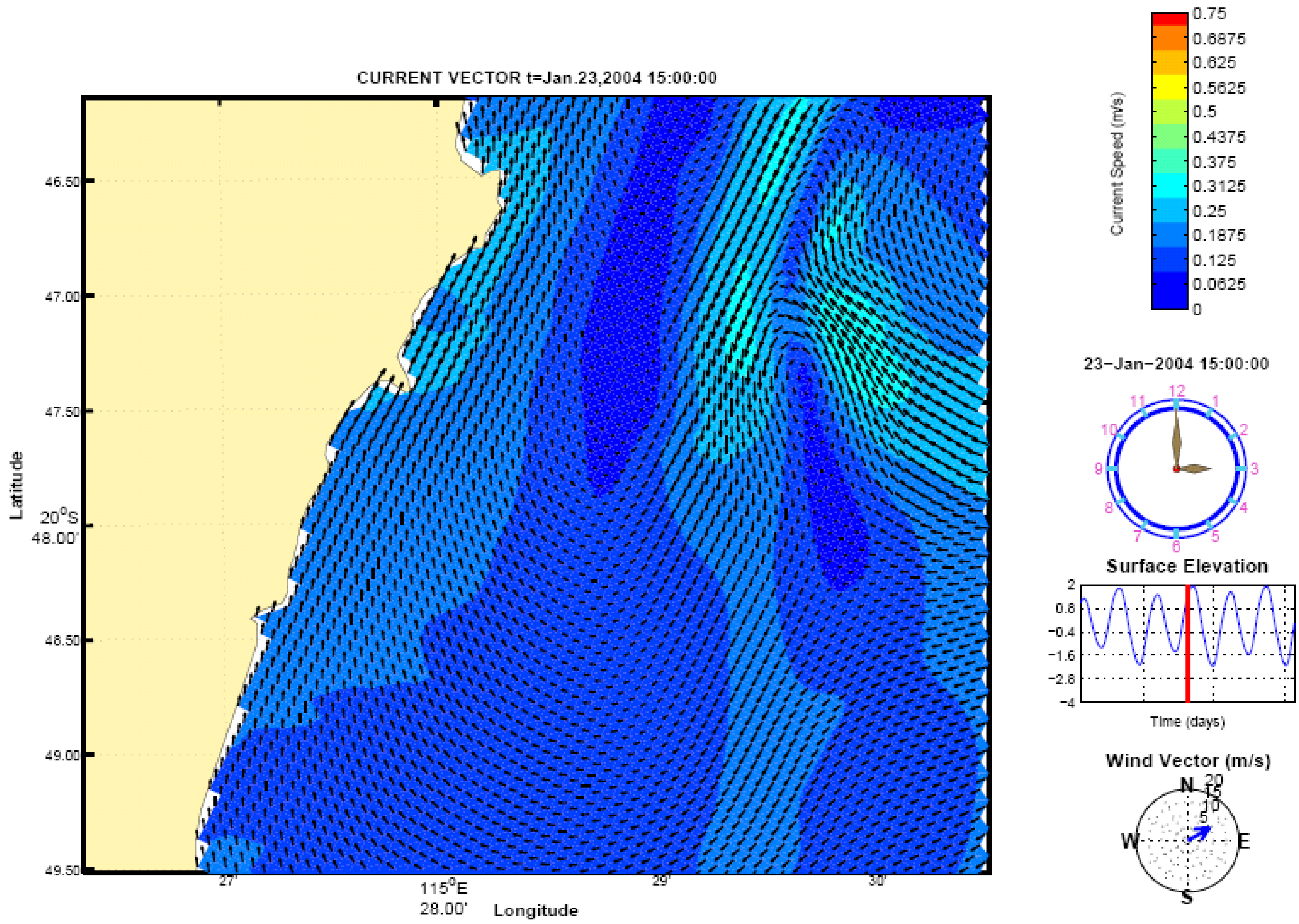
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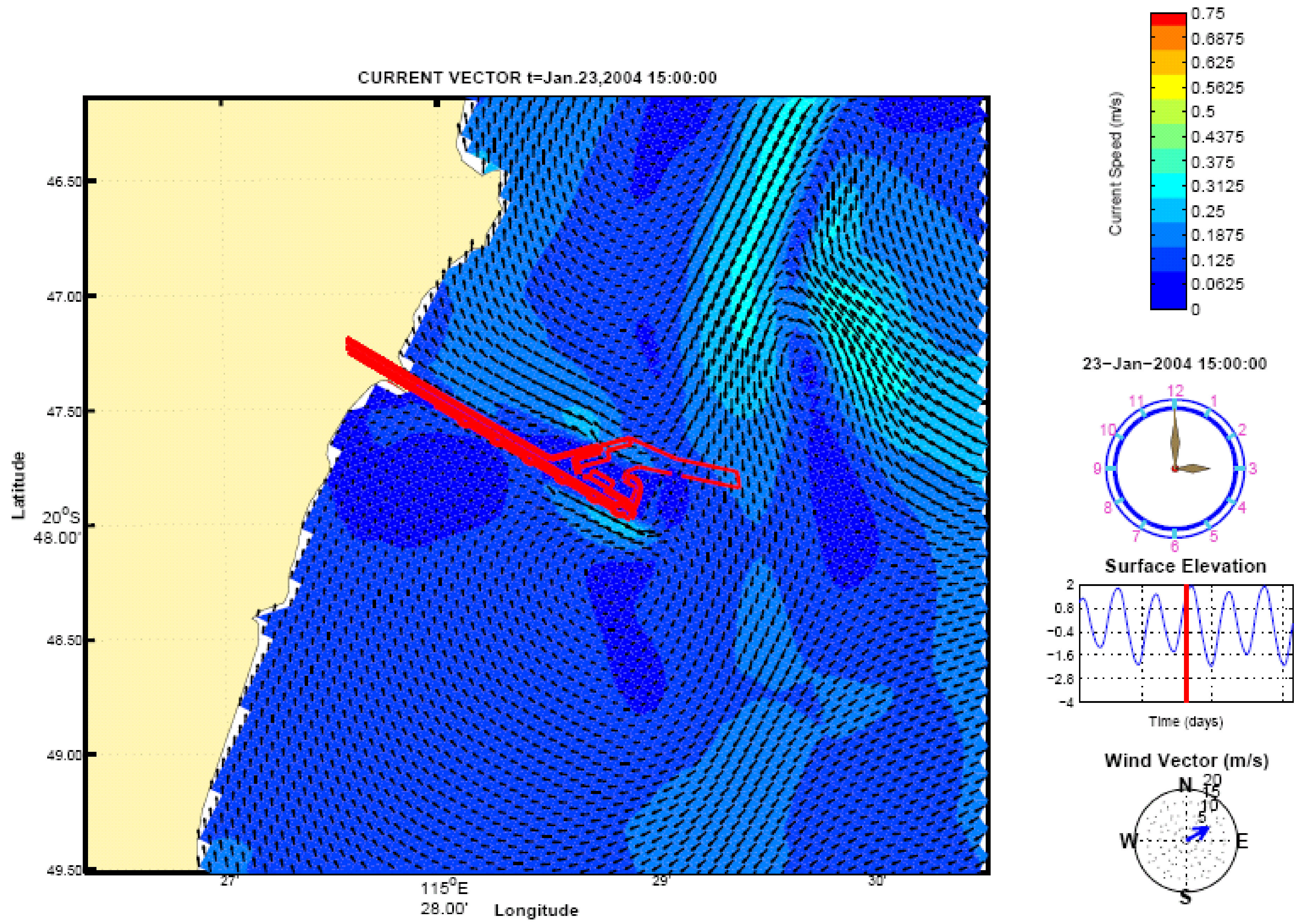
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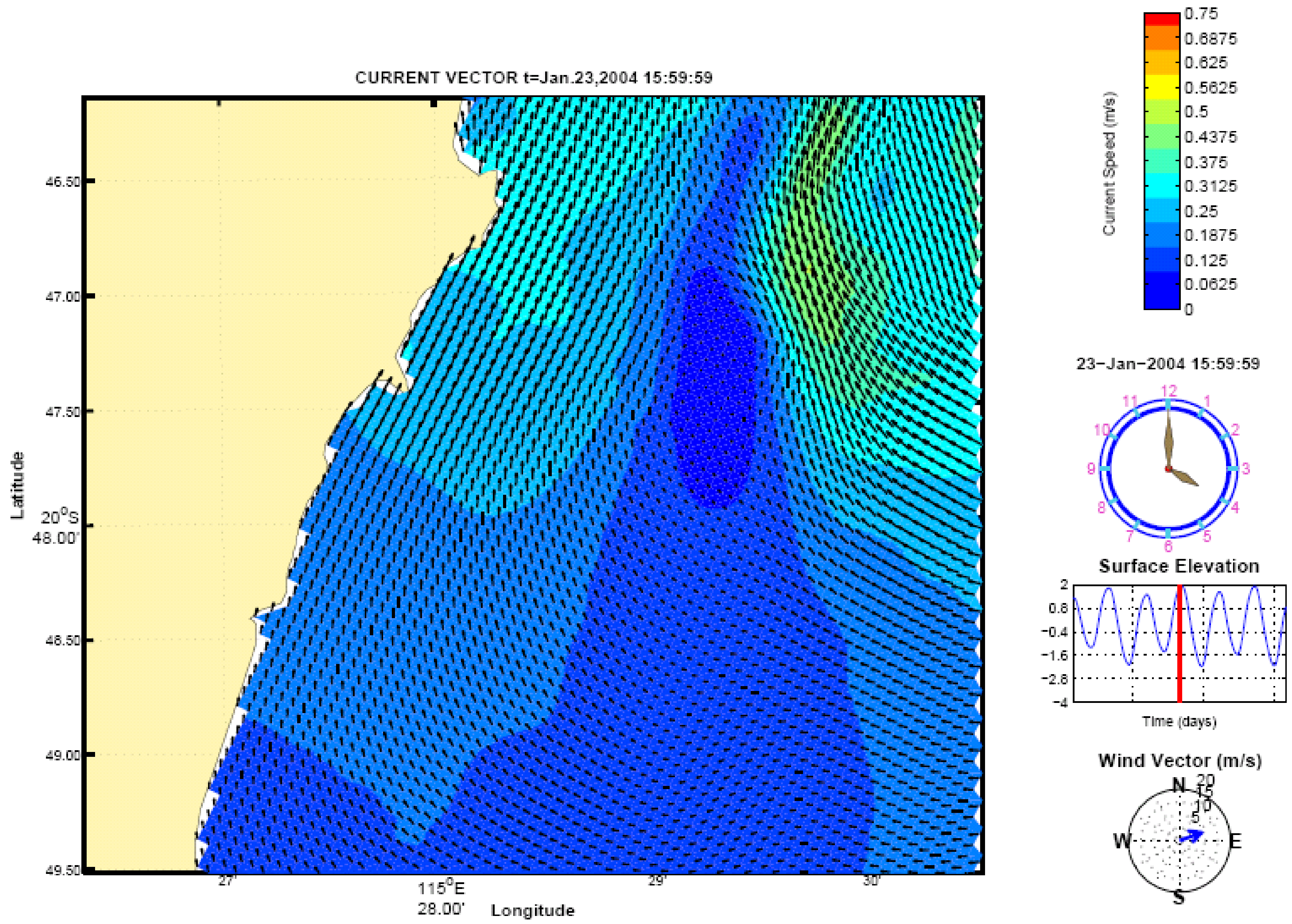
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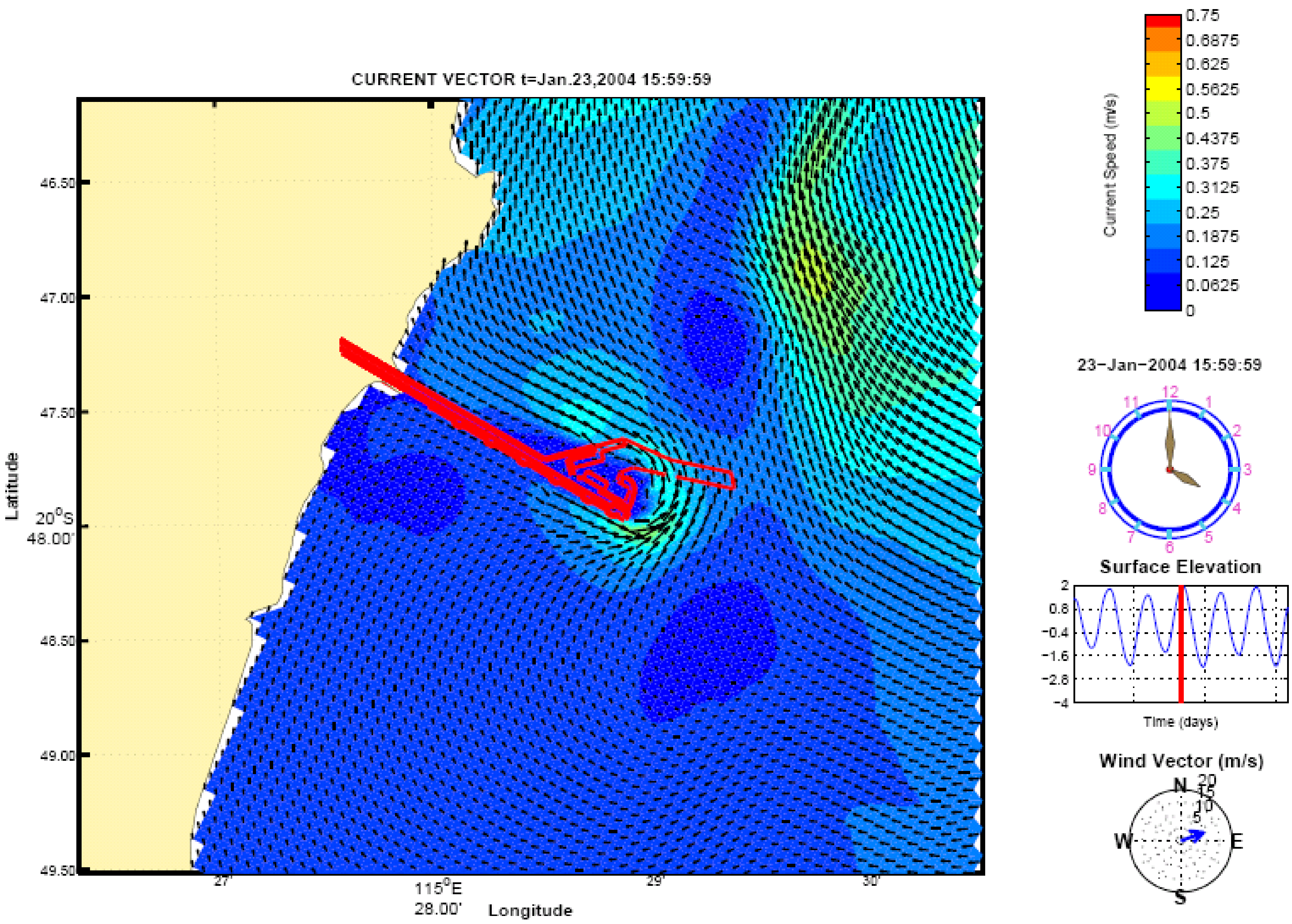
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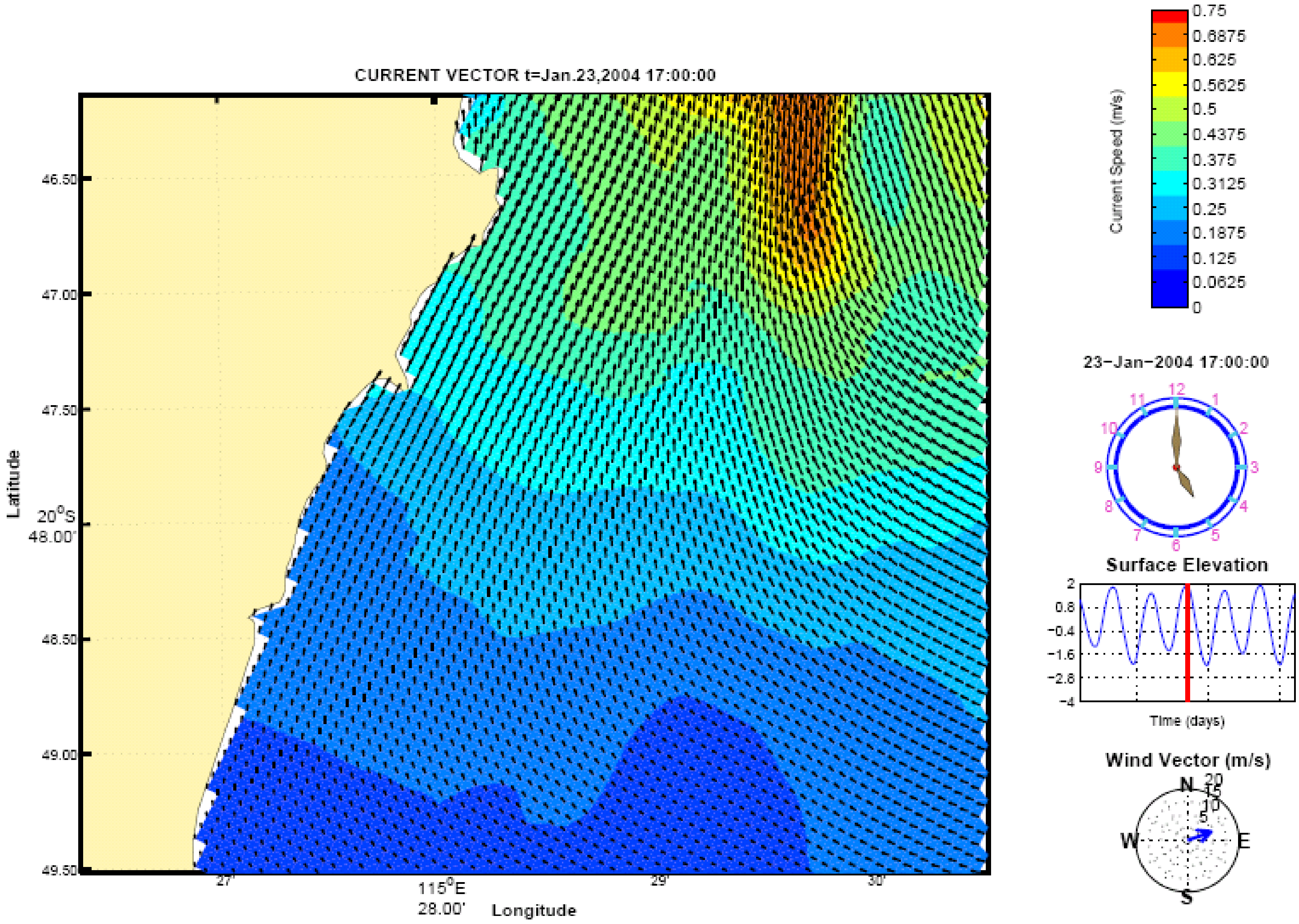
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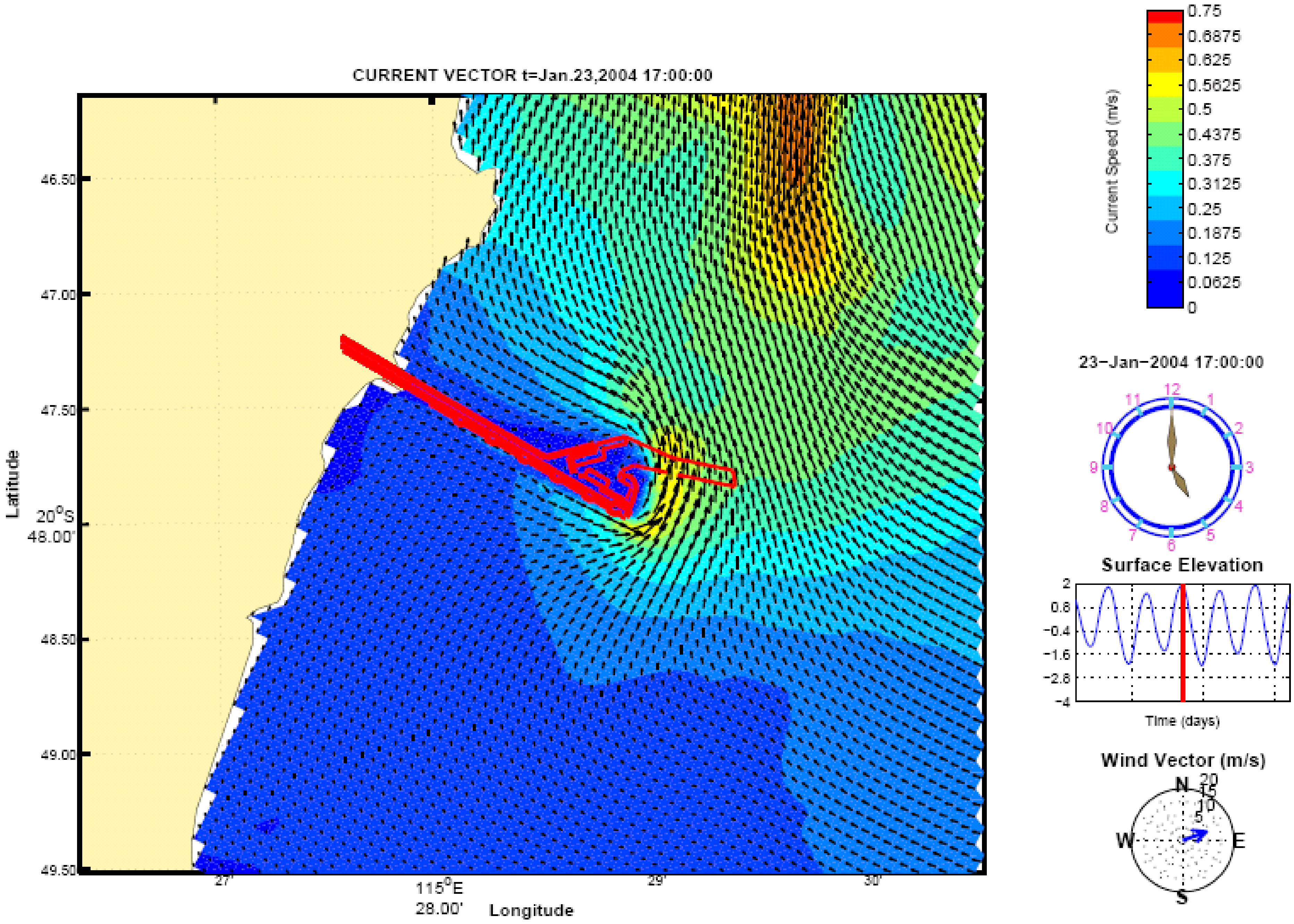
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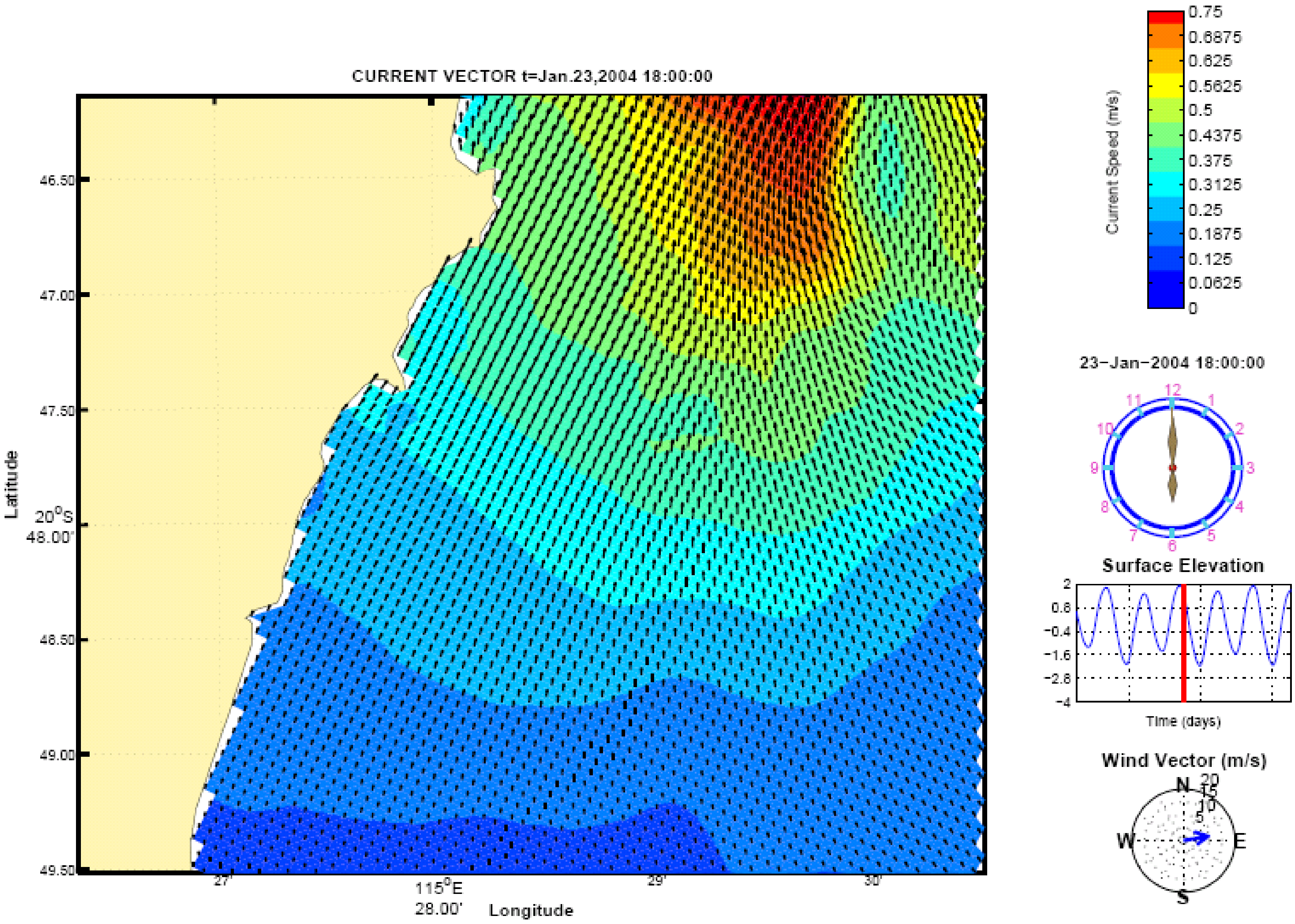

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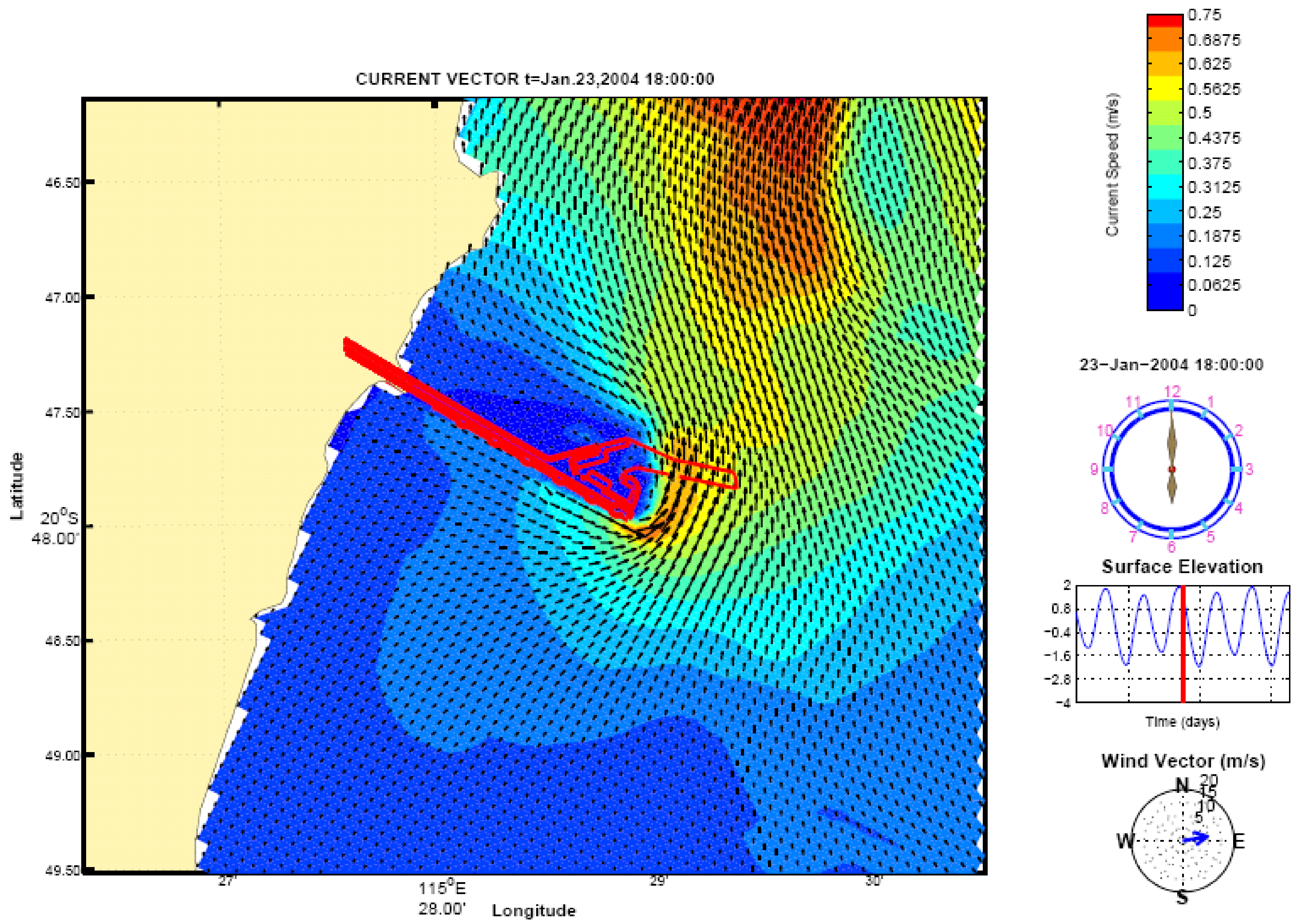

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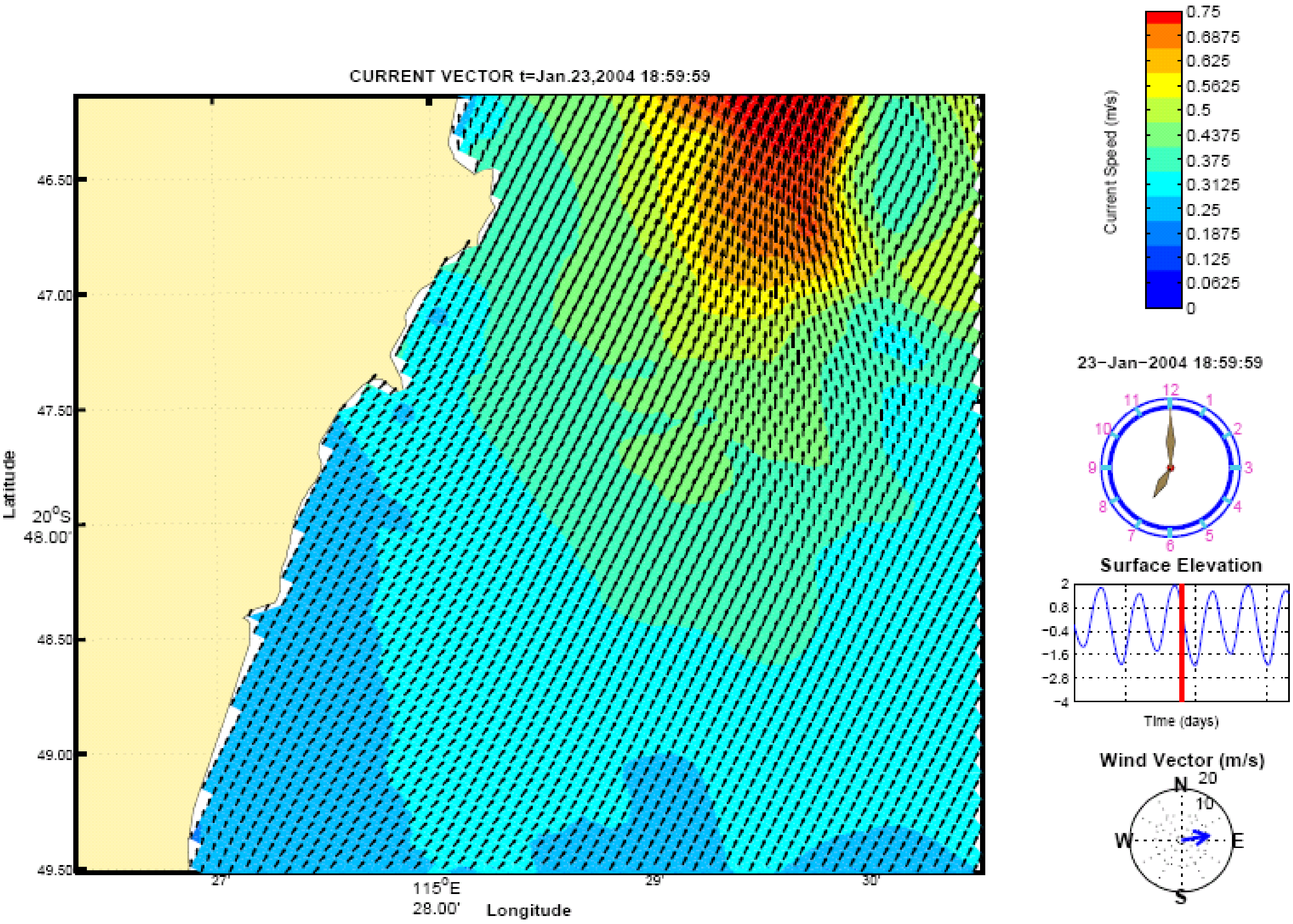
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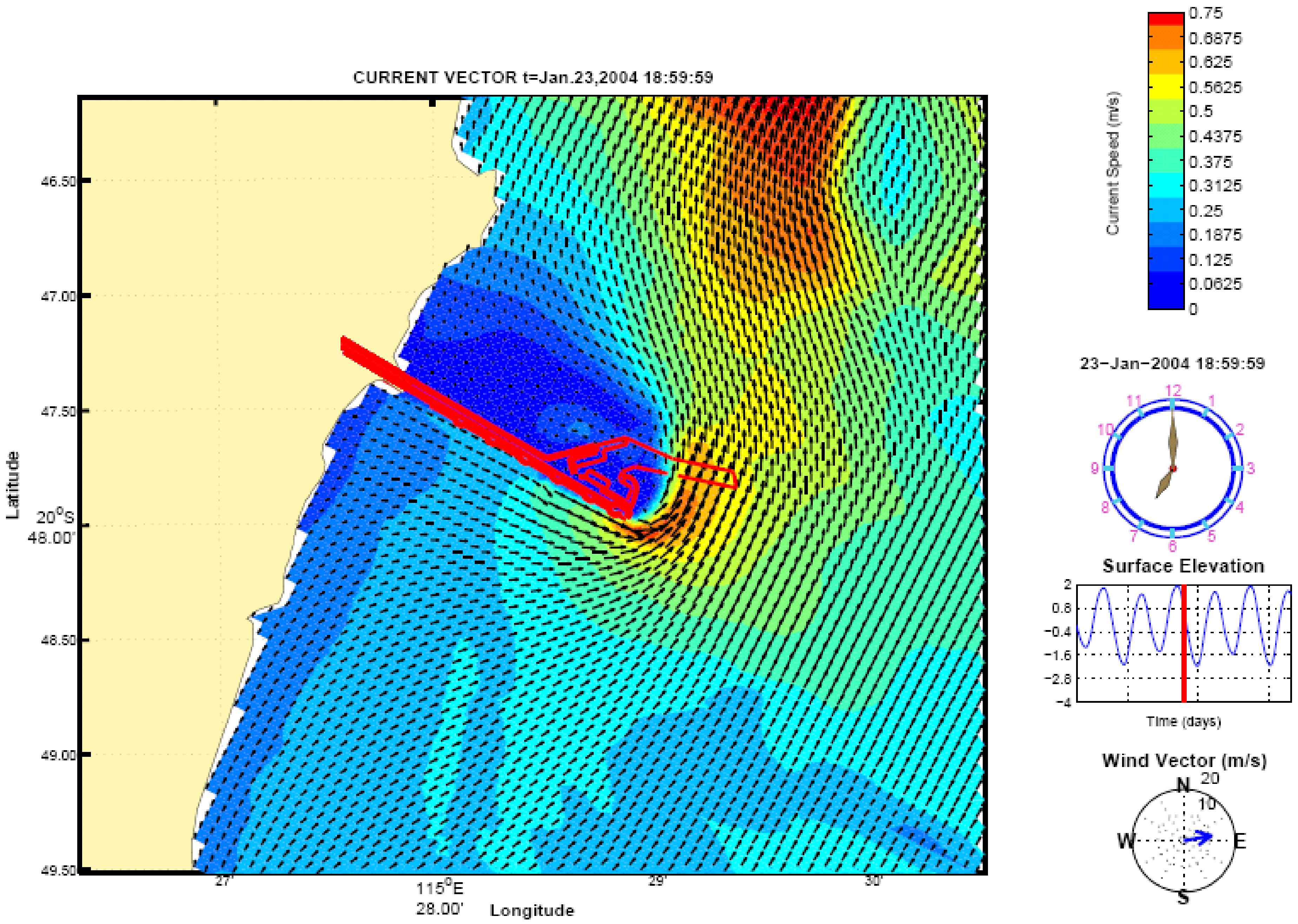
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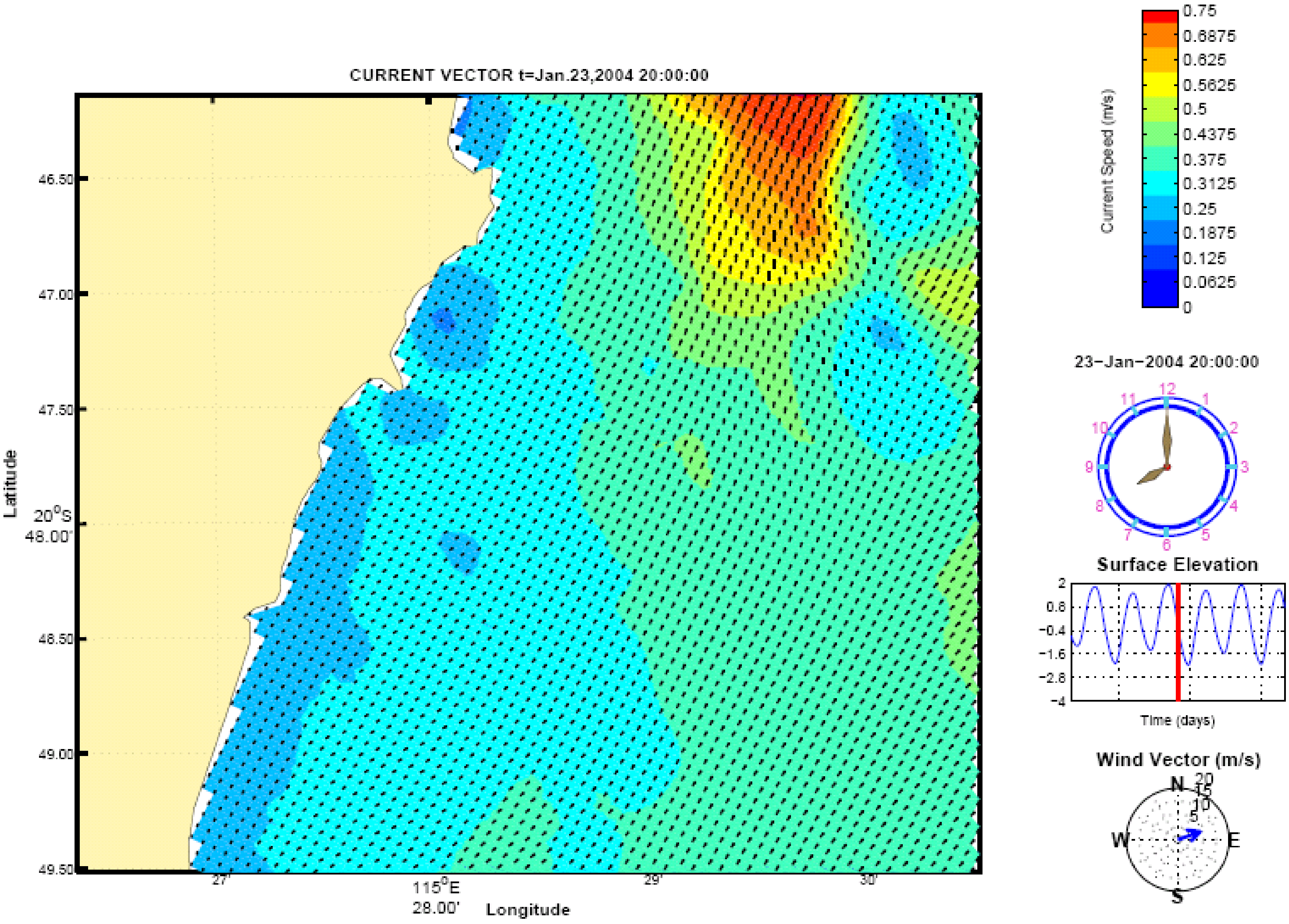
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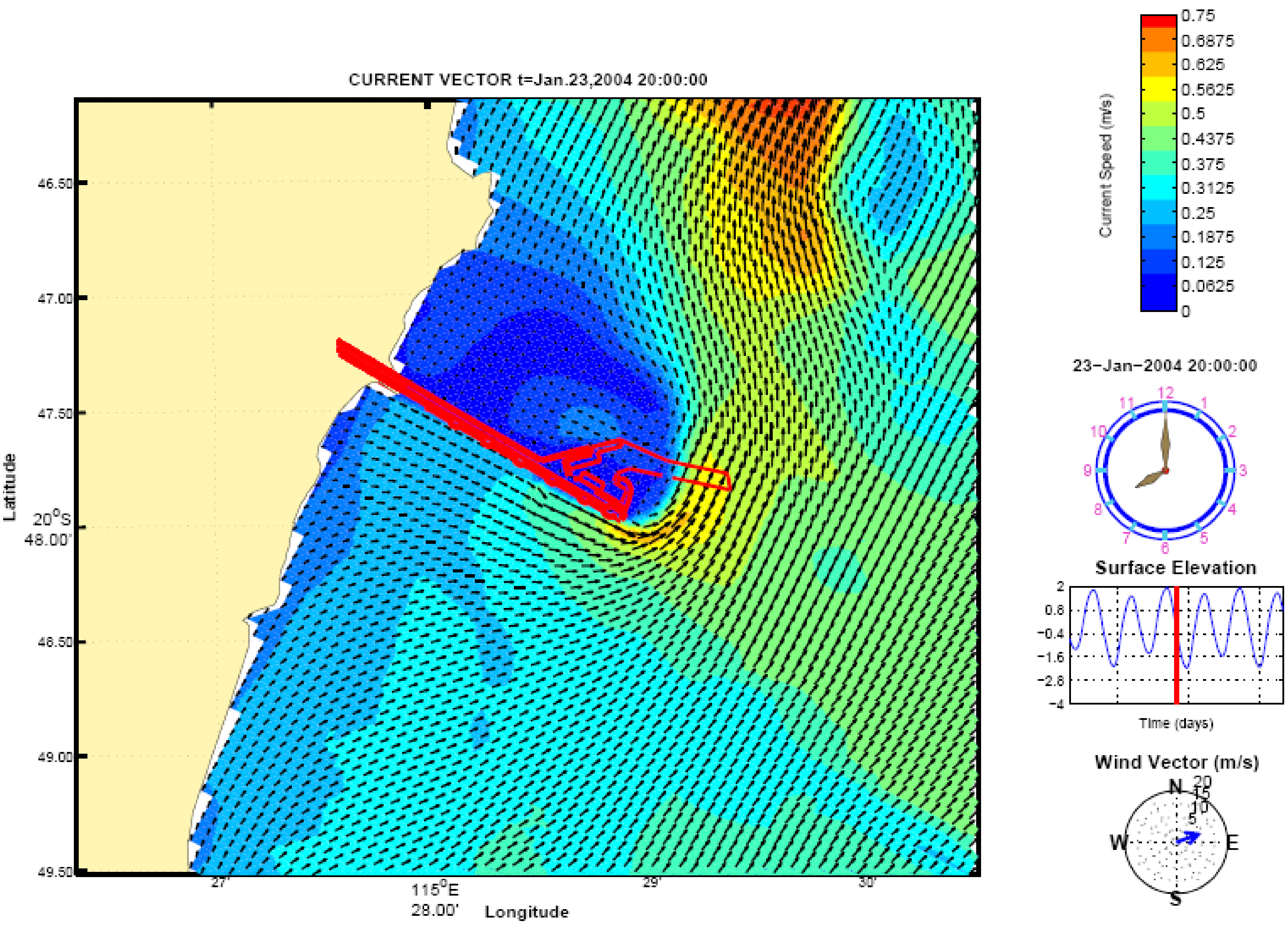
Time (days)
Wind Vector (m/s)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Longitude
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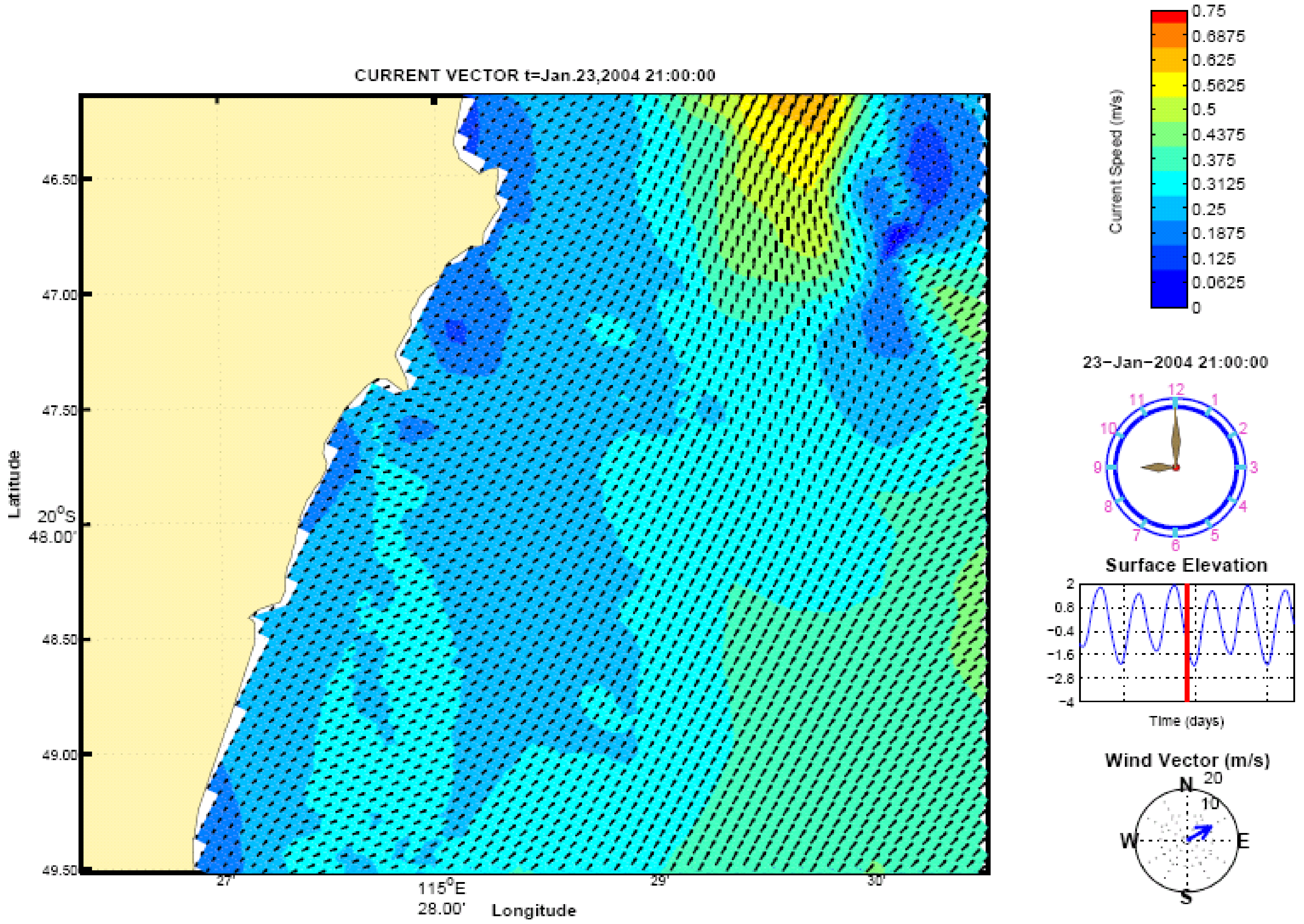
20°S
48.00'
Current Speed (m/s)
23-Jan-2004 20:00:00
Surface Elevation
Time (days)
Wind Vector (m/s)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Longitude
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47.00
47.50
48.50
49.00
49.50
27'
29'
30'
Current Speed (m/s)
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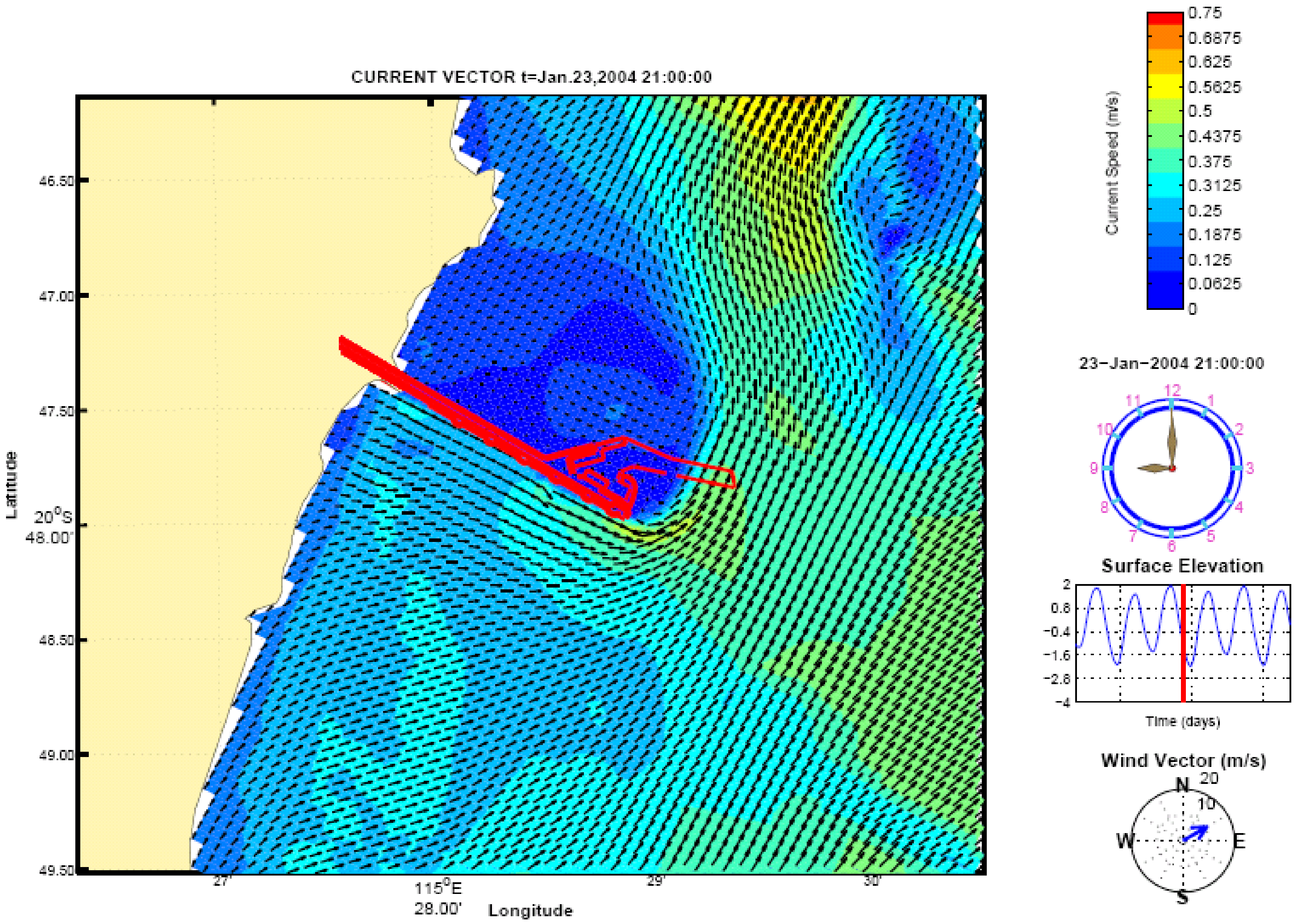
0.6875
0.625
0.5625
0.5
0.4375
0.375
0.3125
0.25
0.1875
0.125
0.0625
0
23−Jan−2004 21:00:00
Surface Elevation
Time (days)
Wind Vector (m/s)
N
S
E
W
20
10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Latitude
Longitude
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115°E 28.00'
46.50
47.00
47.50
48.50
49.00
49.50
27'
29'
30'
Current Speed (m/s)
0.75
0.6875
0.625
0.5625
0.5
0.4375
0.375
0.3125
0.25
0.1875
0.125
0.0625
0
23−Jan−2004 21:00:00
Surface Elevation
Time (days)
Wind Vector (m/s)
N
S
E
W
20
10

*Appendix A*

# DPI ASSESSMENT

2

ssets

Your ref: letter from GM 04/09/06
Our ref: DPI/06/0877
Enquiries: Stuart Barr, 9216 8847

20 October 2006

Office of the Appeals Convener
13th Floor Allendale Square
St. Georges Tce,
Perth, WA, 6000

RECEIVED 11/02/2008 (e-mail Geoff P.)

Attn: Mr Garry Middle

Dear Sir

***Proposed Gorgon Development and Possible Impact of Proposed Causeway and Jetty***

Thankyou for your letter dated 04th September 2006 seeking advice on this proposal.

The Department for Planing and Infrastructure (DPI) New Coastal Assets branch has reviewed the report provided (Metocean 2005). The review has been undertaken by Mr. Matt Eliot and overseen by myself. Our comments are given in the context of our visit to the site on 26th September 2006, data on coastal processes at Town Point, Barrow Island, provided by Mr. Geoff Prior from Chevron (Chevron 2006), and our own investigations.

A detailed assessment of the proposal is attached. However, in response to your specific queries:

- *Adequacy of the report in addressing the issue of cyclones, the causeway and the impact on the beach.*

The report as a stand-alone document does not adequately address the issue of cyclones, the causeway and the impact on the beach. The main deficiency is the lack of substantial coastal engineering interpretation of the model results. Whilst other model runs (such as a south west track) may show greater erosion of the beaches at Town Point, additional model runs would probably not add significantly to the understanding of the impact of the causeway on the beaches in the absence of better interpretation.

However, in the context of our visit to the site, subsequent information provided (Chevron 2006) and our own investigations, we would largely agree with the conclusion that the impact of the causeway on the adjacent beaches is likely to be modest. More importantly, the magnitude of any change to the beaches should be manageable by Chevron. This is discussed further below.

- *Is it reasonable to focus on cyclones being the predominant force that shapes beach profiles on Barrow Island, or should ongoing influences like tides, currents and wave patterns also have been looked into ?*

Beach profiles are apparently determined by ambient conditions. However, tropical cyclones are likely to be the only cause of dramatic change to the beach profile, for either erosion or accretion. Consequently, it is reasonable to focus upon cyclones being the major phenomena affecting beach dynamics.

The beaches adjacent to the causeway are perched beaches located on a broad, shallow rock platform. Such perched beaches are typically stable under ambient conditions (tides, currents & waves), but highly dynamic under elevated water levels. Depending on the track and coincidence of tides, cyclones presently have the capacity to cause significant erosion of the beaches adjacent to Town Point. The frequency of an event causing severe erosion is uncertain. However, at present, recovery of the beaches following a cyclone erosion event is likely to be relatively rapid.

Qualitative confirmation of relatively low currents is provided by the shoreline morphology. The relatively linear nature of the beaches and gradient of approximately 1 in 8-10 suggest that wave conditions are dominant. For beaches dominated by high currents, embayments are more smoothly curved and beach profiles generally steeper.

- *If these ongoing influences like tides, currents and wave patterns should have been considered, please provide comment or advice on what effect the causeway would have on the existing profile.*

Perhaps the most important effect on shoreline dynamics is the potential for the proposed causeway to create a 'shadow zone' within which there is low capacity for sediment transport. This zone may rapidly accrete, or may remain relatively stable until filled during a cyclonic event. The size of the shadow zone is dependent on the ambient wave and current climate and the dimensions of the barrier.

The existing rock platform causes a narrow directional range for ambient wave conditions near to shore, and they will approach nearly shore normal. This reduces the capacity for alongshore sediment transport, limits seasonal variations and minimizes the size of the wave shadow produced by the causeway. However, any material captured in this zone represents material lost from the beaches. Whilst it is recognized that effort has been made to minimize sediment transport shadowing, the expected response has not been explicitly demonstrated in the information provided to DPI.

The combined effect of some locally enhanced cyclonic set-up and a slowed beach recovery is likely to create a slightly modified plan form in the vicinity of the proposed causeway. This modification effectively broadens the area of the tidal berm and foredune in the vicinity of the headland.

In summary:

- The report as a stand-alone document does not adequately address the issue of cyclones, the causeway and the impact on the beach. However, in the context of our visit to the site, subsequent information provided (Chevron 2006) and our own investigations, we would largely agree with the conclusion that the impact of the causeway on the adjacent beaches is likely to be modest.

- The magnitude of any change to the beaches should be manageable by Chevron. We would expect that a coastal management plan for the adjacent beaches would cover things such as beach monitoring, management triggers and appropriate responses.

Yours sincerely

Stuart Barr

*Stuart Barr*
*Senior Coastal Engineer*
*New Coastal Assets*

Direct Tel: 9216 8847
Direct Fax: 9216 8983

# Gorgon Project - Review of Possible Impact of Proposed Causeway and Jetty

Chevron have provided a brief report by Metocean Engineers (February 2005) which purports to address the issues of dredged channel sedimentation and beach movements in response to cyclone events.

This report describes a sequence of models used to assess waves, circulation and sediment transport under the influence of three observed tropical cyclone events. The models are used to compare scenarios with and without the proposed MOF causeway and dredged channel. Few details of either the model algorithms or modeling process are included within the report, with much of the methodology apparently described from the model brochures. The report does not contain sufficient information to fully determine the adequacy of the model sequence for representing sedimentation of the dredged channel or beach mobility. In particular, the absence of any detail regarding the sediment transport algorithm completely obscures the model adequacy. However, apparent deficiencies in the overall modeling process include:

- No clear identification of the existing zones of mobile sediment, or the sediment properties;
- Use of a very restricted set of cyclone events, which are unlikely to represent the most severe scenarios of surge, wave height or sediment transport;
- Model scales are not consistent with active areas of mobilization. For example, under cyclonic conditions, wave breaking commences further offshore than the model domain and has the potential to mobilize sediment at the edge of the rock platform. Similarly, a 50-m scale is insufficient to resolve the complexity of channel sedimentation, particularly for bed transport;
- The report infers that a single point wind field drives the fine-scale circulation modeling. Over a 10-km x 13-km model domain, this provides a distorted representation of cyclonic wind fields;
- Verification testing is described only for the large-scale circulation modeling.

These apparent deficiencies are applicable to both the beaches and the dredged channel sedimentation; however, the following examination is focused solely upon the beach dynamics. The beaches adjacent to the proposed MOF causeway are located upon a broad and shallow rock platform. Such perched beaches are typically stable under ambient conditions, but highly dynamic under elevated water levels (Trenhaile 2004). Cyclones may cause deflation of the beach profile as it responds to enhanced wave conditions, or less commonly, sedimentation through the shoreward transport of material from off the rock shelf. Sedimentation is a common process on barrier systems through overwash (Stone & Orford 2004) and is similarly active on reef systems (Woodroffe 2002). A spectacular example of accretion with coral rubble occurred on the island of Funafuti, Tuvalu during the transit of TC Bebe (Maragos et al. 1973; Fitchett 1987). In terms of assessing the likely response of the beaches to cyclones, several deficiencies have been identified:

- The report suggests that the broad-scale circulation model resolves surges, which ignores near-shore processes including wave set-up and run-up;
- The beach model domain is too small to identify potential for mobility of material from off the shelf;

Although it is recognized that the beaches are most sensitive to cyclonic events, it is unlikely that the entire beach profile is determined by cyclonic events. Metocean (2005) estimate that the limit of the rock platform is approximately located at 1.3-m below mean sea level and consequently the beaches will be exposed to wave action and currents under the majority of tidal conditions. It is appropriate for the proponent to identify changes to the ambient hydrodynamic regime associated with the proposed structures.

Overall, the modeling presented is likely to be inadequate for the purpose of assessing the stability or dynamics of the beaches adjacent to the proposed MOF causeway.

To consider the potential effects of the proposed structures on the adjacent beaches, DPI staff undertook a site visit and liaised with Chevron representative Geoff Prior regarding available further information regarding coastal processes at the MOF causeway site. Specifically, Chevron provided information from geophysical and geotechnical testing, along with vegetation line analysis over the period 1976 to 2005. This information demonstrates the overall stability of the beaches over the last 30 years and the broad separation between the beaches and potentially mobile sediment off the edge of the rock platform. Discussion regarding the site selection included identification by Chevron that the northeast side of Chevron represented a zone of tidal convergence, resulting in comparatively low alongshore currents.

From the regional LADS survey, there appears to be a lobe of sediment offshore from the site, which is part of a sill on the eastern end of the channel between Barrow Island and the Lowendal shelf. This feature is geologically dynamic and may possibly respond to long-term changes of tides and mean sea level. Over geological time frames, it is possible that this feature can provide a conduit for onshore sediment movement. However, the absence of accretion over the last 30 years and the lack of any clear sedimentary features suggest that it is not active in the present climate.

Qualitative confirmation of relatively low currents is provided by the shoreline morphology. The relatively linear nature of the beaches and gradient of approximately 1 in 8-10 suggest that wave conditions are dominant. For beaches dominated by high currents, embayments are more smoothly curved and beach profiles generally steeper. A significant result of wave dominance on a rock shelf platform is that beach recovery under ambient conditions is normally rapid, providing that there is not a net loss of material either offshore or to an adjacent sediment cell.

In addition to the shelter provided by the rock platform, wave conditions at the site are restricted by the general shore aspect of Barrow Island relative to the prevailing winds. Analysis of the wind records from Barrow Island AWS from 1999 to 2004 demonstrates the dominance of southwest winds, for which the mass of Barrow Island provides complete protection. Seasonal change in the frequency of easterly winds is likely to generate slight changes in the beach grade. Considering the available wind fetches offshore from Town Point, only easterly winds, in combination with high tides, are capable of producing moderate waves. For the proposed MOF causeway, wave reflection from easterly winds may slightly deflate the beach grade on the north beach. This is expected to be a very minor effect, particularly with the porous revetment system proposed along the causeway.

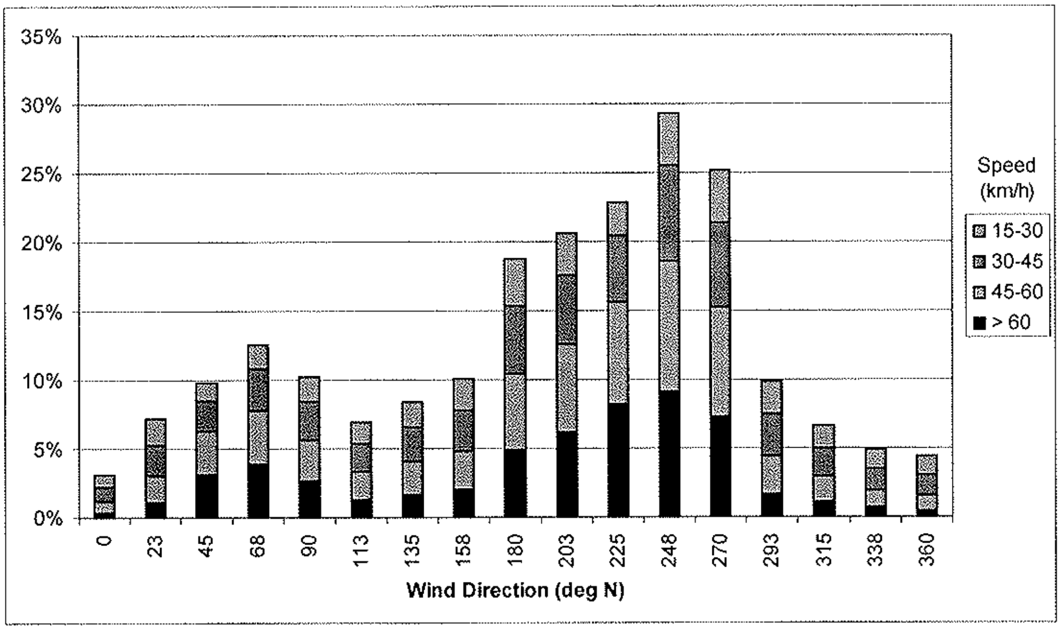



**Figure 1 – Barrow Island Wind Speed-Direction-Frequency Graph**

The existing rocky headland at Town Beach extends from the line of the adjacent beaches. A channel at the tip and basins adjacent to the sides of the headland suggest that strong scour occurs under ambient conditions. However, as these features are not directly connected to the beaches, sedimentary exchange around the headland is likely to be very low, relating to the thin bed layer occurring mainly in rock pools across the shelf. The proposed MOF causeway would create a permanent barrier to any exchange, but any resulting change will be minor, progressive and likely to be readily manageable. Further evidence of low sediment transport is suggested by the distribution of cobbles that have apparently been eroded from Town Point in the immediate vicinity of the headland.

Figure 2 provides a simplified description of the beach profile. The active beach face is approximately 2-m high, crested by a tidal berm and wrack line. A series of distinct low-level hummocks comprise the narrow foredune area. The salt-bush covering the foredune appears generally younger than the established coastal scrub on the primary dune, although this may reflect species character rather than stability.

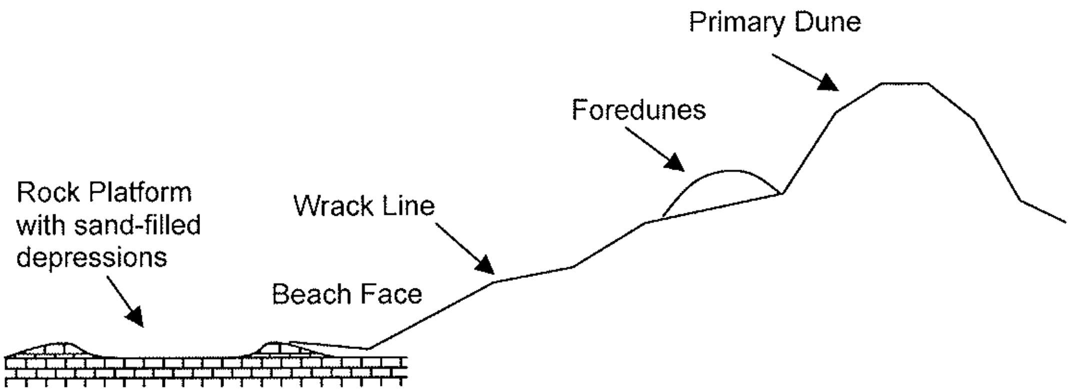



**Figure 2 – Schematic Beach Profile**

The elevation of the wrack line approximately corresponds to normal spring tides, suggesting that the foredune vegetation represents the limit of normal ocean impacts. The steep frontal face of the primary dune defines the apparent upper limit of ocean impact. The well-established dune vegetation and the narrow foredune area imply that the shore has not been dynamic over recent years. This confirms the aerial photograph interpretation, albeit over a shorter time frame.

Perhaps the most important effect on shoreline dynamics is the potential for the proposed MOF causeway to create a 'shadow zone' within which there is low capacity for sediment transport (Figure 3). This zone may rapidly accrete, or may remain relatively stable until filled during a cyclonic event. The size of the shadow zone is dependent on the ambient wave and current climate and the dimensions of the barrier.

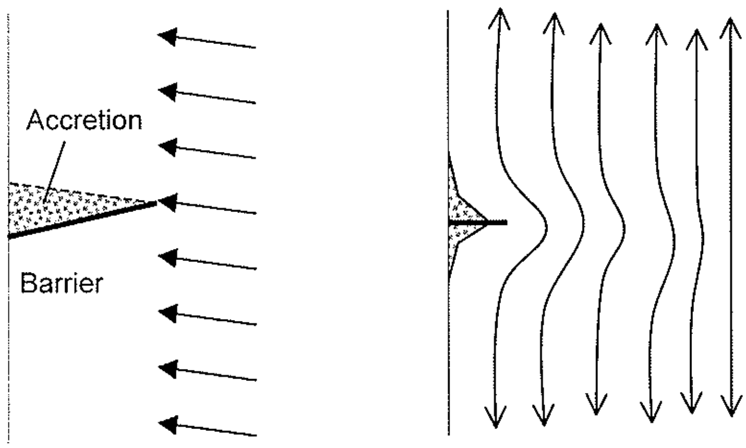



**Figure 3 – Schematic Shadow Zones for Waves & Currents**

The rock platform causes a narrow directional range for ambient wave conditions near to shore, and they will approach nearly shore normal. This reduces the capacity for alongshore sediment transport, limits seasonal variations and minimizes the size of the wave shadow produced by the causeway. Any material captured in this zone represents material lost from the beaches. It is noted that the alignment of the beaches either side of the causeway is slightly different, which provides uncertainty as to whether the proposed causeway is appropriately aligned (Figure 4).

Regardless of its alignment, the causeway is likely to slow the relative rate of beach recovery in the immediate vicinity of the structure. This may be through direct sheltering, or by locally enhanced offshore transport, where the structure creates a topographically controlled rip system.

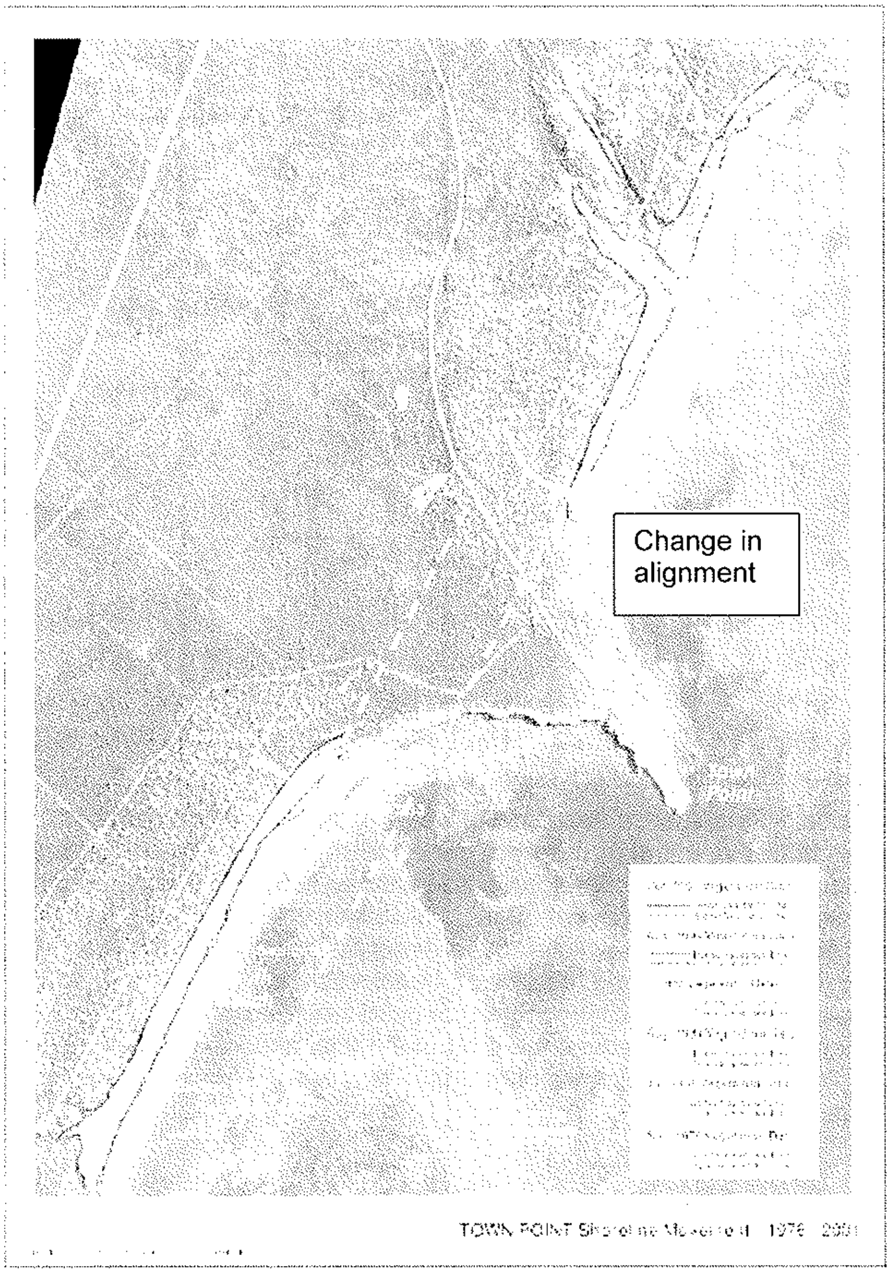



**Figure 4 – Comparison of Beach Alignments**

For tidal, surge or wind-induced currents, the effect of extending a shore feature, such as construction of the MOF causeway, will be to locally modify the flows upon the shelf platform (Figure 5). This includes a tendency for enhanced shear in the vicinity of the structure, set-up on the upstream side and set-down on the downstream side of the structure.

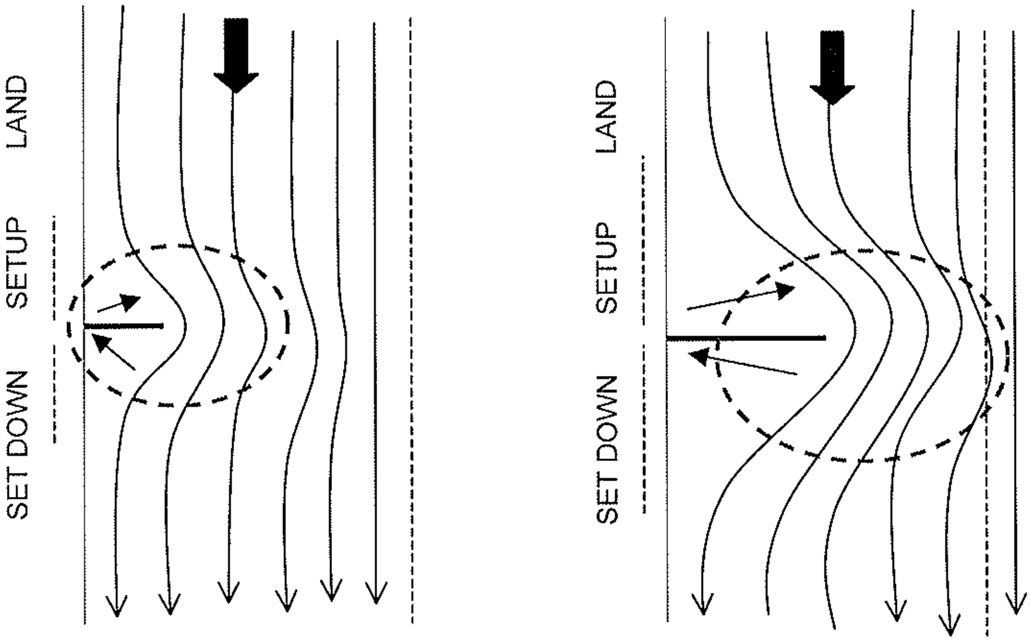



**Figure 5 – Schematic Effect of Extending a Shore Feature**

Under cyclonic conditions, shore parallel winds represent a high capacity for alongshore currents, but are unlikely to generate significant onshore waves or surges. Consequently, whilst the process illustrated in Figure 5 may locally enhance water levels during such an event, or in combination with tidal flows, it is unlikely to affect extreme water levels, which require direct onshore winds. The combined effect of this secondary process and the slowed beach recovery is likely to create a slightly modified plan form in the vicinity of the proposed causeway Figure 6. This modification effectively broadens the area of the tidal berm and foredune in the vicinity of the headland, which we understand is presently the zone used by turtles for nesting.

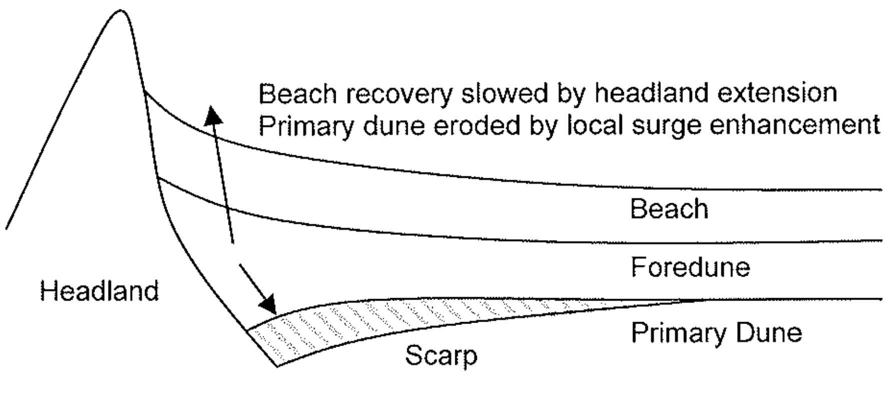


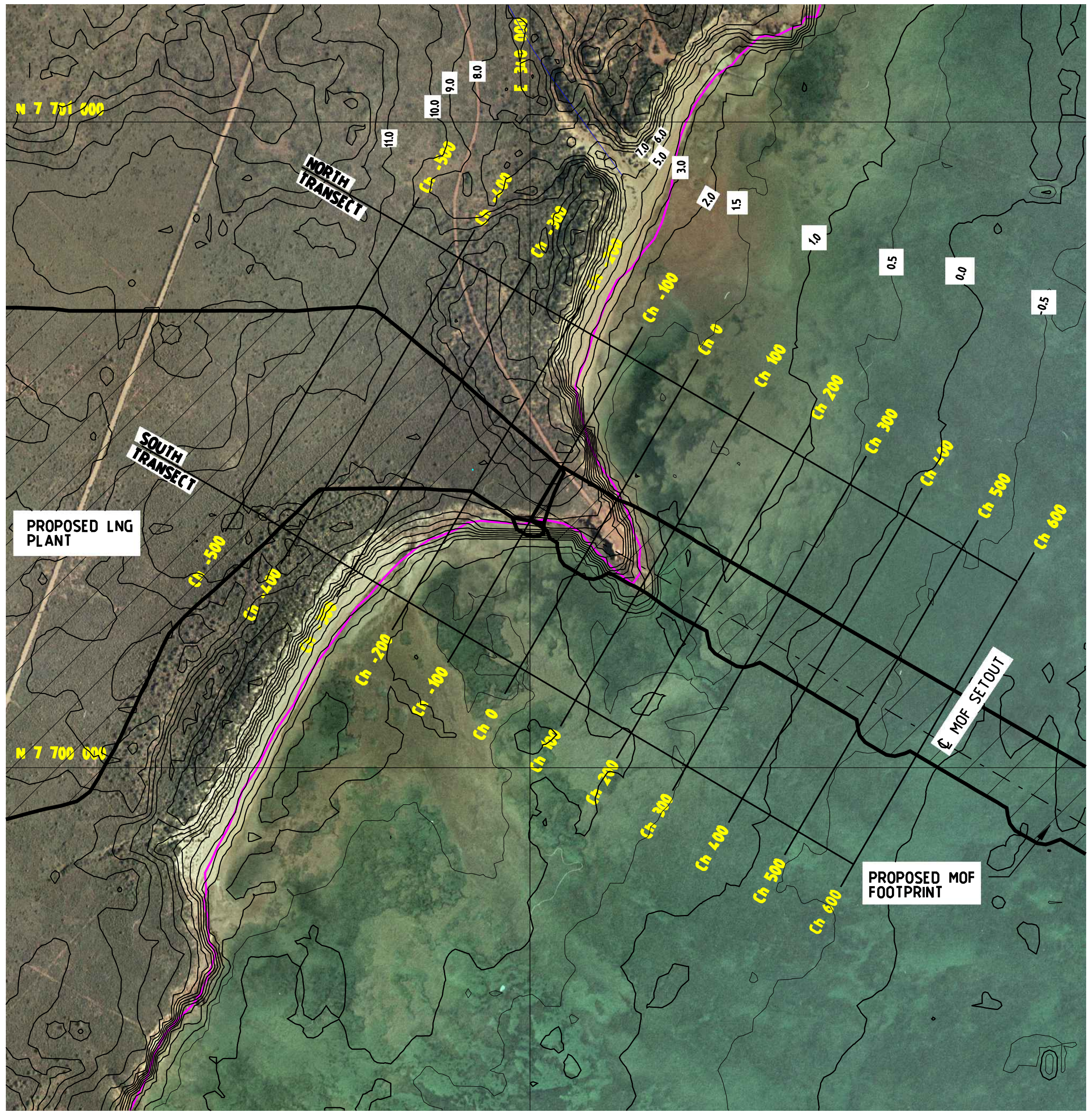

**Figure 6 – Schematic Plan Form Changes** (not to scale)

Overall, only the potential formation of a wave shadow potentially provides a significant impact to the beaches adjacent to the proposed MOF causeway. Although it is acknowledged that the proponent has considered this possible impact, it has not been clearly demonstrated in the information provided to DPI.

Other possible impacts are considered likely to be minor in scale, or episodic in nature. In most cases, it is likely that it will be almost impossible to distinguish between the natural dynamics and the enhancement or mitigation (if any) that may be caused by the proposed causeway. Given the future long-term involvement of the proponents at the site and the likely staff presence, it is appropriate for the proponent to be involved in the ongoing observation and management of the beaches adjacent to the proposed MOF causeway, regardless of the perceived cause of any foreshore impacts.

*Appendix B*

# DRAWING G1-TD-T-7400-SKH0705, MOF COASTAL IMPACT STUDY, PLAN AND LONGITUDINAL SECTIONS




## PLAN
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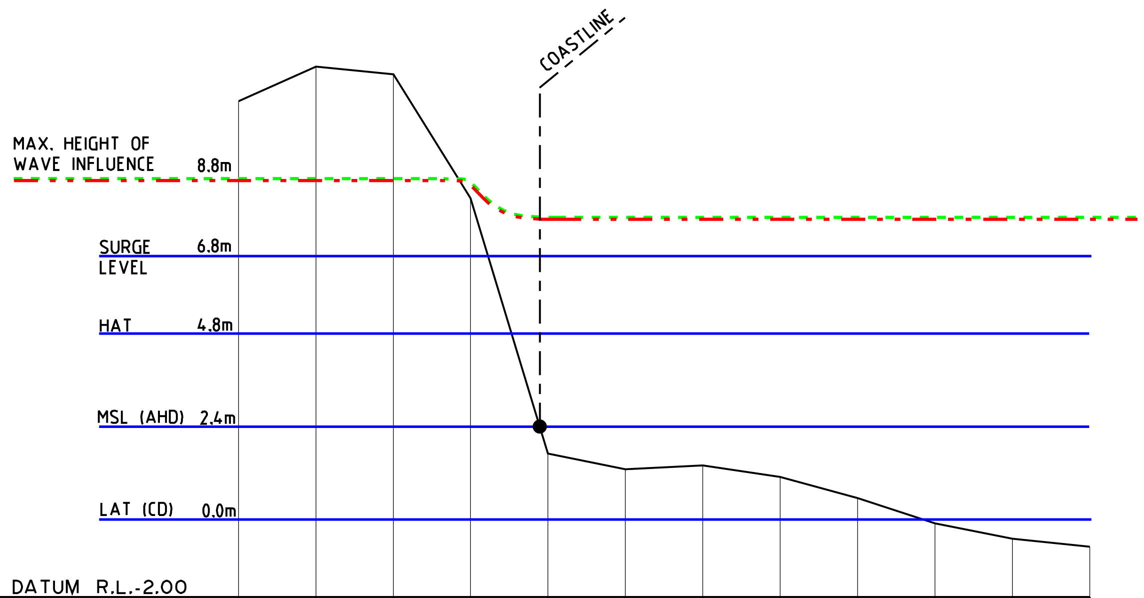


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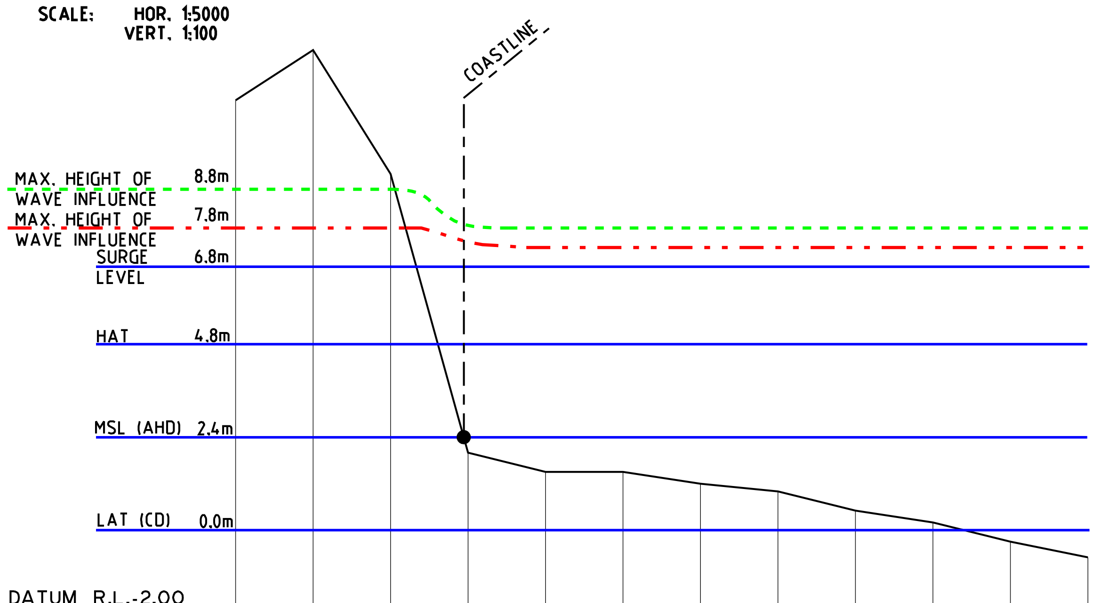
| CHAINAGE | -500.00 | -400.00 | -300.00 | -200.00 | -100.00 | 00.00 | 100.00 | 200.00 | 300.00 | 400.00 | 500.00 | 600.00 |

## LONGITUDINAL SECTION NORTH TRANSECT
SCALE: HOR. 1:5000
VERT. 1:100




| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SEABED RL (CD) | 11.10 | 12.40 | 9.20 | 2.00 | 1.50 | 1.50 | 1.20 | 1.00 | 0.50 | 0.20 | -0.30 | -0.70 |
| CHAINAGE | -500.00 | -400.00 | -300.00 | -200.00 | -100.00 | 00.00 | 100.00 | 200.00 | 300.00 | 400.00 | 500.00 | 600.00 |

## LONGITUDINAL SECTION SOUTH TRANSECT
SCALE: HOR. 1:5000
VERT. 1:100

## LEGEND

- WITH MOF IN PLACE
- WITHOUT MOF IN PLACE
- EXISTING SEABED

## TIDAL PLANES
(MOF LOCATION)

| | |
|---|---|
| HAT | 4.8m |
| MHWS | 4.0m |
| MHWN | 2.8m |
| MSL (AHD) | 2.4m |
| MLWN | 2.0m |
| MLWS | 0.8m |
| LAT (CD) | 0.0m |

TIDAL INFORMATION EXTRACTED FROM CHEVRON B.O.D. G1-TE-Z-D0000-PDBX004

## NOTE:

1. BATHYMETRY IS RELATIVE TO CHART DATUM (LAT)
2. GRID COORDINATES SHOWN:- MGA94 ZONE 50

100 0 100 200 300 Metres
HORIZONTAL SCALE 1 : 5000

2 1 0 2 4 6 Metres
VERTICAL SCALE 1 : 100

Kellogg Joint Venture | Gorgon
KBR JGC HATCH CLOUGH
Kellogg Joint Venture - Gorgon (KJV-G)
A Joint Venture Between
KBR E&C Australia Pty. Ltd. - ABN 43 114 260 972
JGC Corporation - ABN 32 009 474 042
Clough Projects Australia Pty. Ltd. - ABN 26 109 444 215
Hatch Associates Pty. Limited - ABN 59 008 630 500

REFERENCE DRAWINGS: DRAWING No. | TITLE

REVISIONS

| No | DATE | BY | DRAFT CHK'D | ENG. CHK'D | PROJ. APPR'L | CLIENT APPR'L | DESCRIPTION |
|---|---|---|---|---|---|---|---|
| A | 03SEP08 | PWi | RHi | FBi | | | EDC |

APPROVALS
PREPARED BY KJVG: DATE:
DRAFTING APPR'L: DATE:
PROJECT APPR'L: DATE:
CLIENT APPR'L: DATE:

**Chevron Australia Pty Ltd**
GORGON PROJECT
BARROW ISLAND LNG PLANT

MATERIALS OFFLOADING FACILITY
MOF COASTAL IMPACT STUDY
PLAN AND LONGITUDINAL SECTIONS

SCALE: AS SHOWN | DRAWN: JFo | DATE: 21AUG08 | PROJECT No: 6300 | DRAWING No: G1-TD-T-7400-SKH0705 | REVISION A

CVX_GORGON_A1.REF
ABN 29 086 197 757

*Appendix C*

# COASTAL MODELLING – BWI – METOCEAN REPORT

# APPENDIX G

## Air Emissions Modelling Report For The Revised Proposal

SINCLAIR KNIGHT MERZ

SKM

# Gorgon Gas Development, Revised Proposal

## AIR QUALITY ASSESSMENT

- Final
- 20 June 2008

# Gorgon Project, Barrow Island

## AIR QUALITY ASSESSMENT

- Final
- 20 June 2008

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## List of figures

SKM

## List of tables

# Document history and status

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|---|---|---|---|---|---|
| Rev A | 26/03/2008 | K.Rinaldi | J.Harper | 28/03/2008 | Draft |
| Rev B | 12/06/2008 | D Tuxford | J Harper | 12/06/2008 | Draft |
| Rev 1 | 18/06/2008 | D Tuxford | J.Harper | 20/6/2008 | Final |
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| **Project manager:** | Jon Harper |
| **Name of organisation:** | Chevron Australia Pty Ltd |
| **Name of project:** | Gorgon Project, Barrow Island |
| **Name of document:** | Air Quality Assessment |
| **Document version:** | Final |
| **Project number:** | WV03563 |

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# Abbreviation List

| | |
|---|---|
| AEC/NHMRC | Australian Environment Council/National Health and Medical Research Council |
| AGRU | Acid Gas Removal Unit |
| AWS | Automatic Weather Station |
| BOG | Boil Off Gas |
| BoM | Bureau of Meteorology |
| BTX | Benzene, Toluene and Xylenes |
| BTEX | Benzene, Toluene, Ethylbenzene and Xylenes |
| CSIRO | Commonwealth Science & Industrial Research Organisation |
| DEC | Department of Environment and Conservation |
| DEP | Department of Environmental Protection |
| DoE | Department of Environment |
| DLN | Dry Low $NO_x$ |
| DOE | Department of Environment |
| EET | Emissions Estimation Technique |
| EIS/ERMP | Environmental Impact Statement/Environmental Review and Management Programme |
| EPA | Environmental Protection Authority |
| EPP | Environmental Protection Policy |
| LNG | Liquefied Natural Gas |
| MTPA | Million Tonnes per Annum |
| NEPC | National Environmental Protection Council |
| NEPM | National Environmental Protection Measure |

| | |
|---|---|
| NOHSC | National Occupation Health and Safety Commission |
| NWSV | North West Shelf Venture |
| PER | Public Environmental Review |
| $PM_{10}$ | Particulate Matter 10 microns or smaller |
| SKM | Sinclair Knight Merz |
| STEL | Short Term Exposure Limit |
| TAPM | The Air Pollution Model |
| TSP | Total Suspended Particulate |
| TWA | Time Weighted Average |
| VOCs | Volatile Organic Compounds |
| WHO | World Health Organisation |

# 1. Executive Summary

### Project Description

The Gorgon Project involves developing the hydrocarbon reserves of the Gorgon and Jansz gas condensate fields through a Gas Treatment Plant to be located at Town Point on Barrow Island off the coast of Western Australia. The proposed Gas Treatment Plant will produce 15 million tonnes per annum (MTPA) liquefied natural gas (LNG) and condensate for export to the Australian and international markets and domestic gas supply to the natural gas distribution grid of Western Australia.

In September 2007, the Government of Western Australia approved with conditions the Gorgon Gas Treatment Plant based on a two 5 MTPA LNG development. Since that approval was granted, the Gorgon Joint Venture Partners (Chevron Australia Pty Ltd, Shell Development Australia and Mobil Australia Resources Company) conducted a number of studies that recommended that an additional 5 MTPA train (Gorgon Gas Development Expansion Proposal) be built along with the first two in order to improve project economics and execution.

For the purposes of assessing the environmental impacts associated with the proposed additional LNG train, an air quality assessment was undertaken to determine the predicted air quality impacts from the operation of the 3x5 MTPA Gas Treatment Plant.

### Overview of Project

Currently Barrow Island supports an oil production operation with a workforce of approximately 200 people and is a Class A nature reserve.

The operational phase of the Gorgon Project would result in emissions of atmospheric pollutants from the following sources: power generation gas turbines, process area gas turbines, heating furnaces, flaring of hydrocarbons and shipping movements. Atmospheric pollutants include oxides of nitrogen, ozone (as a secondary pollutant), sulfur compounds, airborne particulate matter and hydrogen sulfide.

Air quality criteria have been located from National Environment Protection Measure (NEPM), Australian Environment Council (AEC)/ National Health and Medical Research Centre (NHMRC), National Occupational Health and Safety Commission (NOHSC) and World Health Organisation (WHO) to assess whether pollutants are harmful to human health, the environment and/or through occupational exposure. The existing Chevron Australia Camp and the proposed Gorgon Construction/ Maintenance and Turnaround Camp are the selected sensitive receptor locations for the study.

## Existing Air Quality

Regional air quality in the vicinity of Barrow Island is influenced by emissions from the existing operations at Barrow Island, along with emissions from operations found on the mainland, and in proximity to the Burrup Peninsula. The key industrial activities influencing existing air quality are the existing WA Oil facility on Barrow Island (including the gas power generation station), the North West Shelf Venture (NWSV) Karratha Gas Plant (including the new Train 4 and Train 5), the approved Pluto gas Plant, Hamersley Iron power station at Parker Point near Dampier, and Burrup Fertiliser's ammonia plant.

The results of modelling predict no exceedences of the Ambient Air Quality NEPM are likely to occur for any of the pollutants due to the existing and approved sources in the region. The maximum predicted concentration for any pollutant was for ozone, which reached 63.6% of the relevant NEPM standard (4-hour average).

## Summary of results

During routine operations of the proposed expansion (additional LNG train), concentrations of all pollutants are predicted to increase. However the maximum predicted concentration for all pollutants remains under the NEPM criteria.

During start-up operations nitrogen dioxide ($NO_2$) is predicted to exceed the NEPM-1 hour criteria to the northeast of the proposed facility. This is predicted to continue for 1-hour and the second highest concentration is down to 72% of the NEPM criteria.

The maximum ozone concentration is predicted to increase significantly in the event that carbon dioxide (stripped from the natural gas) is vented as opposed to injected (upset condition 3). Under this scenario the maximum ozone concentration is predicted to be 127% of the relevant NEPM standard (1-hour average). However, as this upset scenario was modelled to occur every hour over the modelled year, it is highly improbable that the predicted maximum 1-hour ozone concentration will occur. As such, this value represents the most conservative approach to estimate impact.

Modelled concentrations of both particulates (as $PM_{10}$) and sulfur dioxde ($SO_2$) for the three non-routine operations are within the range of acceptable criteria.

## Conclusions

This air quality assessment concludes with the following key findings:

- Normal operations of the proposed Gorgon Gas Development Expansion Proposal are not predicted to cause any significant air quality impacts at Barrow Island and the surrounding area.

- During plant start-up, the maximum 1-hour concentration of $NO_2$ may be exceeded. This event is predicted to occur at a frequency of once a year.
- During $CO_2$ venting, the maximum 1-hour concentration of $O_3$ may be exceeded. As this upset scenario was modelled to occur every hour over the modelled year, it is highly improbable that the predicted maximum 1-hour ozone concentration will occur.
- No exceedence of the NEPM criteria or occupational health criteria is predicted at sensitive receptor locations modelled, under normal and upset conditions, for all pollutants.

# 2. Introduction

## 2.1 Overview

Chevron Australia Pty Ltd has engaged Sinclair Knight Merz (SKM) to provide consultancy services to complete an air quality assessment for the proposed expansion of the Gorgon Gas Development at Barrow Island.

This study comprises an assessment of the air quality impacts predicted from the construction and operation of the onshore development of gas processing facilities and associated infrastructure at Barrow Island. This report details the air quality assessment undertaken, and is presented as a technical appendix to the Gorgon Gas Development Expansion Proposal Public Environmental Review (PER). Only those specifications relevant to an air quality assessment are detailed in this report. For full project details reference should be made to the PER.

The air quality assessment was carried out in accordance with the Air Quality and Air Pollution Modelling Guidance Notes (DOE, 2006).

## 2.2 Project Description

Chevron Australia is developing gas processing facilities at Barrow Island. This includes a Liquefied Natural Gas (LNG) plant, condensate handling facilities, carbon dioxide ($CO_2$) injection facilities and associated utilities. The approved Gorgon Gas Development proposal (as described in the 2005 EIS/ERMP) comprised two LNG processing train with a combined capacity of 10 million tonnes per annum (MTPA). The EIS/ERMP also indicated that additional LNG trains and associated infrastructure were being considered for future development (Chevron Australia, 2005).

This air quality assessment considers Chevron Australia's proposal for an additional 5 MTPA LNG processing train. The Barrow Island facilities would therefore become a LNG plant comprising three trains capable of producing a total of 15 MTPA. The facility would separate gas and condensate (light oil) received from the Gorgon gas fields. After separation from the gas, the condensate would be stabilised prior to shipping to market. The gas component of the stream would be treated to remove carbon dioxide, hydrogen sulphide, trace amounts of mercury and water vapour. The gas would then be liquefied for export as LNG. Part of the gas will be exported to the mainland via a pipeline as domestic gas supply to the gas distribution grid of Western Australia.

## 2.3 Scope of Assessment and Objectives

The main objective of this air quality assessment is to determine the ground level impact of pollutants from the addition of a third train to the gas processing plant being constructed on Barrow Island. The development will consist of the construction and operation of three gas processing plants, each with a nominal output of 5 MTPA.

To achieve this objective the following tasks have been undertaken and are reported:

- Identification of key pollutants and relevant assessment criteria.
- Review, analysis and description of local meteorology (data from Bureau of Meteorology meteorological station, Barrow Island), covering long term trends of temperature, wind speed, wind direction, humidity and rainfall (**Section 6.1)**.
- Analysis and description of existing ambient air quality in the region (**Section 6.2)**.
- Development and description of project specific atmospheric model, including model set-up, model limitations and accuracy (**Section 7)**.
- Estimation of emissions of oxides of nitrogen, sulfur dioxide, particulates and ozone from the proposal during normal operations (**Section 7.6.2).**
- Estimation of emissions of oxides of nitrogen, sulfur dioxide, particulates and ozone from the proposal during defined upset conditions (**Section 7.6.3, Section 7.6.4, Section 7.6.5** and **Section 7.6.6)**.
- Determination of potential air quality impacts during normal and defined upset operating conditions though atmospheric dispersion modelling (TAPM) of oxides of nitrogen, sulfur dioxide, particulates, and comparison to assessment criteria (**Section 8**).

# 3. Project Description

This section briefly describes the key elements of the proposal, and places the project in context with its location and environmental setting. The air pollutants expected to arise from the construction and operation of the expanded gas processing plant on Barrow Island are also identified.

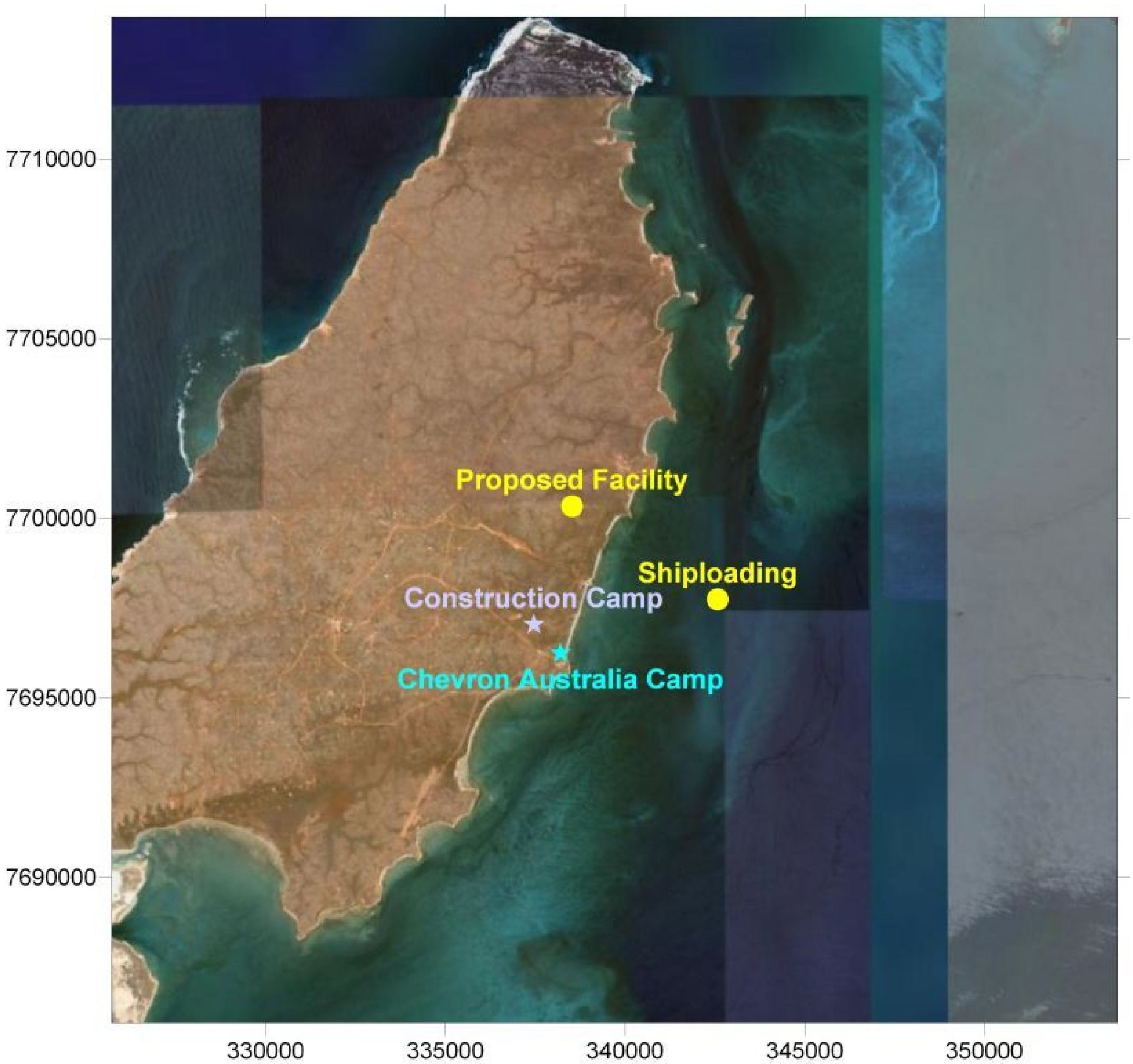
## 3.1 Overview

The area of the proposed Gorgon Development lies in the tropical waters of Australia's north-west shelf, approximately 1200 km north of Perth and 120 km west of Dampier and the Burrup Peninsula. This coastal environment is scattered with numerous small islands, the largest of which is Barrow Island. Barrow Island supports an oil production operation with a workforce of approximately 200 people and is a Class A nature reserve for the purpose of conservation of flora and fauna.

Landforms on Barrow Island are predominantly developed by coastal processes that are dominated by the effects of wind and water. The terrain along the island ranges from undulating sand dunes and plains on the eastern side to gently undulating rocky terrain on the western side. The terrain in the proposed development area is flat to undulating and gradually slopes upward from the coastline.

## 3.2 Project Setting

The proposed gas processing plant will be located at Town Point on the central-east coast of Barrow Island approximately four kilometres north of the existing Chevron Australia Camp. The location of the proposed facility is presented in **Figure 3-1** along with the location of the proposed LNG and condensate offloading facilities and the proposed Gorgon Construction/Turnaround Camp.




- **Figure 3-1 Location of Proposed Processing Facility and Accommodation Camps**

### 3.3 Project Implementation

Key project characteristics relevant to the air quality assessment are summarised in **Table 3-1** below. The table shows the key difference between the previously approved project and those proposed as part of this revision.

■ **Table 3-1 Project characteristics**

| Aspect | Description | As approved (2007) | As proposed (2008) |
|---|---|---|---|
| Gas Treatment Plant | Location | Town Point | Town Point |
| | Number of LNG trains | 2 | 3 |
| | Size of LNG train | 5 MTPA (nominal) | 5 MTPA (nominal) |
| | LNG tank size | 135,000 to 165,000 $m^3$ net each | 135,000 to 165,000 $m^3$ net each |
| | Compression turbines | 4 x 80 MW with waste heat recovery and DLN technology | 6 x 80 MW with waste heat recovery and DLN technology |
| | Power generation turbines | 4 x 116 MW with conventional burners | 5 x 116 MW with DLN technology |
| | Flares | Main plant flare - Ground flare<br>Storage and loading area boil off gas (BOG) – elevated flare (150m) | Main plant flare - Ground flare<br>2 Boil off Gas (BOG) elevated flares |
| | Domestic gas production rate | 300 TJ/day | 450 TJ/day |
| | Condensate production rate | 2,000 $m^3$/day | 3,000 $m^3$/day |
| | Condensate tank size | 2 x 60,000 $m^3$ | 2 x 60,000 $m^3$ |

### 3.3.1 Construction Phase

The key emission of concern during the construction phase of the proposed development is dust. Dust generation is associated with all the construction activities for the facility, including clearing of vegetation, soil and fill, excavation activities including blasting for site levelling and trenching, loading and dumping of material, wheel-generated dust from all vehicles active on site and wind erosion from exposed surfaces and stockpiles.

Other atmospheric emissions during the construction phase will be associated with marine vessel engines, additional airline flights to and from Barrow Island and from vehicles and equipment required to support the large construction crew on the island. Incidental to this will be the increased traffic and construction related to the mainland supply base. These sources will contribute to overall emission levels.

However, the volume and duration of the emissions from the marine vessels used during construction, the additional air traffic to Barrow Island and increased number of construction vehicles and equipment will not be significant in comparison to emission levels during the operation of the Gorgon Gas Development. Furthermore, they will not be concentrated in a single location for any extended period of time.

Air dispersion modeling has not been undertaken for the construction phase. The focus of the modeling is on the longer term operational phase impacts.

### 3.3.2 Operations Phase

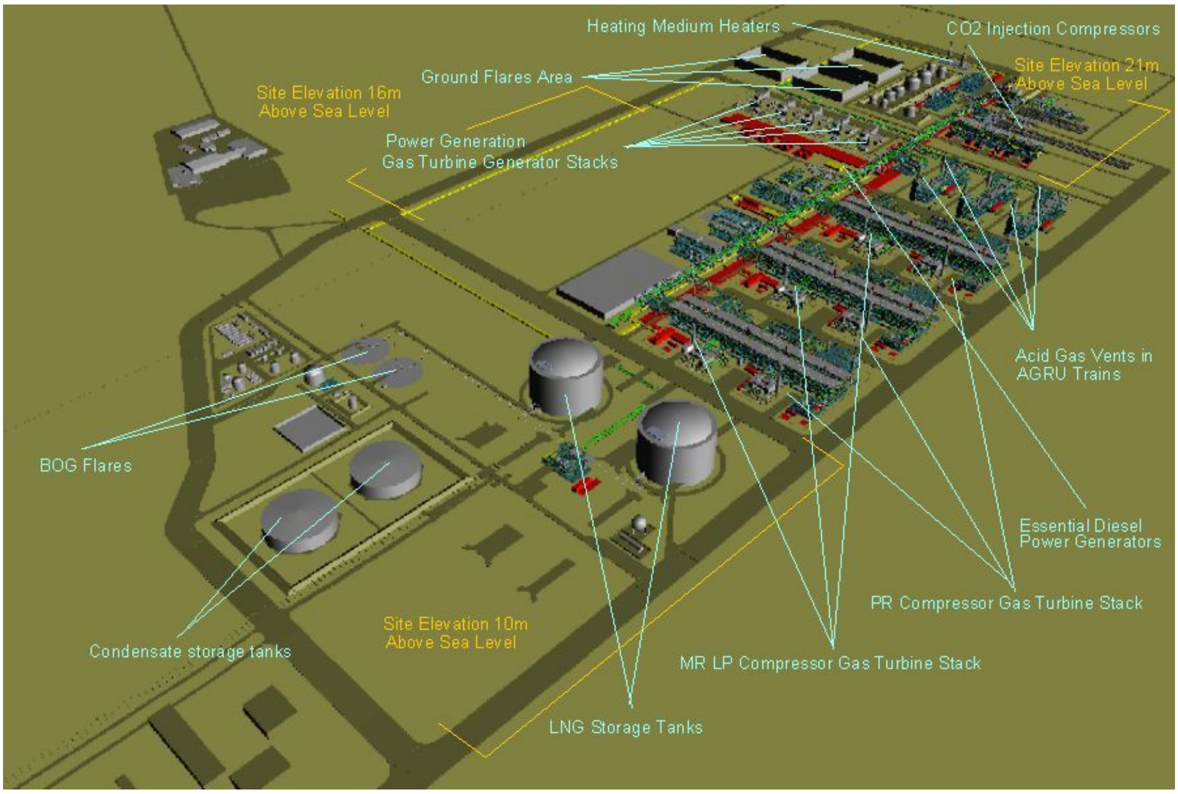
The proposed onshore processing facilities consist of the slug catcher, inlet facilities (condensate and LPG extraction), acid gas ($CO_2$) removal units (AGRUs) and LNG plant, with the slug catcher, inlet facilities and AGRUs being upstream of the LNG trains. Gas compression drivers will be 6 x 80 MW industrial gas turbines with dry low $NO_x$ (DLN) and waste heat recovery combustion technology. Power generation will be achieved using 5 x 116 MW industrial gas turbines with DLN technology. A conceptual layout of the proposed facility is presented in **Figure 3-2**.

The key sources of air emissions during the Operations phase include:

- Power generation;
- Process area gas turbines;
- Heating medium heaters (furnaces);
- Flaring of hydrocarbons; and
- Shipping (supply vessels and LNG and condensate tanker movements).

The key air emissions of concern from the proposed gas processing facility will be from the combustion of fuel gas in the process and power generation plant gas turbines and by flaring hydrocarbons during routine and non-routine plant operations. The key pollutants from natural gas combustion include $CO_2$ and $NO_x$ together with some carbon monoxide (CO) and non-combusted hydrocarbons or volatile organic compounds (VOCs). There may also be traces of particulate matter and sulfur dioxide ($SO_2$).

Atmospheric emissions from the gas processing facility will vary depending on the operating and tanker loading conditions. Non-routine operations such as commissioning, plant start-up and shut-downs have therefore also been modelled.




- **Figure 3-2 Conceptual Layout of the Proposed 3 x 5 MTPA Gas Processing Facility**

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# 4. Air Pollutants and Potential Impacts

This section outlines the potential impact of airborne particulate matter ($PM_{10}$), oxides of nitrogen ($NO_x$), sulfur compounds ($SO_2$ and $H_2S$) and ozone ($O_3$). These pollutants are considered the most relevant, based on the nature of the works to be undertaken during the overall development and operation of the proposal.

## 4.1 Oxides of Nitrogen

Oxides of nitrogen ($NO_x$) is the collective term for nitric oxide (NO), nitrogen dioxide ($NO_2$) and nitrous oxide ($N_2O$). Lightning and the oxidation of ammonia can form oxides of nitrogen naturally. However, the main source of $NO_x$ in the atmosphere is from the combustion of fossil fuels, primarily from automobiles and electricity production, and for this project, from the combustion of fuel gas. Nitrogen oxide is colourless and odourless but can oxidise in the atmosphere to form $NO_2$ and $NO_3$.

### 4.1.1 Human Health Impacts

$NO_2$ is a pungent, brown, acidic, highly corrosive gas and has significant effects on human health. $NO_2$ can have detrimental effects on the human respiratory tract, leading to increased susceptibility to asthma and respiratory infections.

### 4.1.2 Environmental Impacts

Vegetation is adversely affected by exposure to $NO_x$, in the form of retarded growth rates and crop yields. $N_2O$ is considered to be a greenhouse gas, trapping long wave radiation emitted by the earth and warming the atmosphere. Oxides of nitrogen are also some of the main contributors to ozone production and can also contribute to acid rain by the formation of nitrous and/or nitric acid in airborne water droplets.

## 4.2 Ozone

Ozone ($O_3$) is a colourless gas that is naturally found in the upper atmosphere. $O_3$ is also formed as a secondary pollutant at ground level by the reaction of nitrogen dioxide ($NO_2$) and sunlight which forms nitric oxide (NO) and a single oxygen atom (O). This oxygen atom (O) then combines with molecular oxygen ($O_2$) to form ozone ($O_3$).

Photochemical smog is characterised by the reaction of ozone ($O_3$), oxides of nitrogen ($NO_x$) and volatile organic compounds (VOCs) in sunlight and at high temperatures. A mixture of these chemicals forms a layer of visible, brown or white haze in the sky. Photochemical smog is a regional, and not localized, phenomenon in that ozone is produced relatively slowly over several hours after exposure to sunlight has been sufficient for the series of reactions to be completed.

Maximum ozone concentrations therefore tend to occur downwind of the main source areas of precursor emissions, and can become re-circulated within local and regional circulation patterns.

### 4.2.1 Human Health Impacts

The human health effects experienced from exposure to ozone includes irritation of the eyes and throat, and exacerbation of existing respiratory problems such as a worsening of asthma, emphysema and bronchitis. Exposure may lead to reduced lung function and may reduce the body's ability to fight infections in the respiratory system.

### 4.2.2 Environmental Impacts

Ozone can cause a range of negative impacts on vegetation, ranging from visible foliage injury, growth retardation and increased sensitivity to stresses (WHO, 2000). The effects of ground-level ozone on long-lived species, such as trees, are believed to combine over years so that whole forests or ecosystems can be affected. Nitrogen oxides, one of the key precursors in ozone formation, can contribute to fish kills and algae blooms in waterways (USEPA, 1997).

## 4.3 Sulfur Compounds

Sulfur dioxide is a colourless gas with an irritating odour that can contribute to or exacerbate respiratory illnesses (such as asthma or bronchitis), especially in elderly or young people.

### 4.3.1 Human Health Impacts

Sulfur dioxide has also been linked with the aggravation of existing heart and lung diseases (USEPA 2004). Sulfur dioxide can attach itself to small ambient particulates, which can then be inhaled deep into the lungs; this can intensify the health effects of sulfur dioxide.

### 4.3.2 Environmental Impacts

Sulfur dioxide can also have detrimental effects on the environment. Sulfur dioxide can contribute to the formation of acid rain, damaging crops, ecosystems, monuments and historic buildings.

## 4.4 Airborne Particulate Matter

Airborne or suspended particulate matter can be defined by its size, chemical composition or source. Particles can also be defined by whether they are primary particles, such as a suspension of the fine fraction of soil by wind erosion, sea salt from evaporating sea spray, pollens, soot particles from incomplete combustion; or secondary particles such as are formed from gas to particle conversion of sulphate and nitrate particles from sulfur dioxide and oxides of nitrogen.

Typically, particulate matter has been characterised by its size as measured by collection devices specified by regulatory agencies. The particulate size ranges specified in ambient air criteria are total suspended particulate (TSP), particulate matter below 10 µm in aerodynamic diameter ($PM_{10}$) and particulate matter below 2.5 µm in aerodynamic diameter ($PM_{2.5}$).

### 4.4.1 Human Health Impacts

The health effect of particulates in the $PM_{10}$ size range is mainly the exacerbation of respiratory problems. The population that is most susceptible include the elderly, people with existing respiratory and/or cardiovascular problems and children (NEPC, 2002). Larger particles, approximately greater than 10 µm in diameter, generally adhere to the mucus in the nose, mouth, pharynx and larger bronchi and can be removed by swallowing or clearing of the mouth or lungs.

### 4.4.2 Environmental Impacts

Particulate matter can also enhance some chemical reactions in the atmosphere and reduce visibility. The deposition of larger particles can have the following consequences: staining and soiling of surfaces; aesthetic or chemical contamination of water bodies or vegetation; and effects on personal comfort, amenity and health.

## 4.5 Hydrogen Sulfide

Hydrogen sulfide ($H_2S$) is a colourless gas with a distinctive odour of rotten eggs at low concentrations. The gas can be produced naturally from volcanoes, swamps and decaying organic matter. It is also a by-product of many industrial processes, such as petroleum refining and mining. Most of the $H_2S$ in the atmosphere has originated from natural sources (WHO, 2000).

### 4.5.1 Human Health Impacts

Hydrogen sulfide can act as both an irritant and an asphyxiant gas through exposure by inhalation, ingestion, eye contact and skin contact. Exposure to low levels causes eye irritation, with higher levels of exposure causing loss of the sense of smell and respiratory irritation.

### 4.5.2 Environmental Impacts

Hydrogen sulfide has been shown to have high acute toxicity to aquatic life, birds, and animals. Insufficient data are available to evaluate the acute toxicity of $H_2S$ on vegetation. (NPI, 2006).

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# 5. Air Quality Objectives in Western Australia

This section outlines air quality objectives (ambient, occupational and environmental (deposition)) relevant to this assessment. It also identifies the criteria against which the modelling results will be assessed to determine whether the specified pollutants may be considered harmful to human health and/or the environment.

## 5.1 Overview

The Western Australian Environmental Protection Authority (EPA) requires that 'all reasonable and practicable means should be used to prevent and minimise the discharge of waste' (EPA, 2003). For new proposals the EPA requires an assessment of the best available technologies for minimising the discharge of waste for the processes and justification for the adopted technology.

The EPA has developed a guidance statement for oxides of nitrogen emissions from gas turbines, which establishes limits for emissions that generally follow the AEC/NHMRC National Guidelines (EPA, 2000). These limits are summarised in **Table 5-1**.

**Table 5-1 Guidelines for Emissions of Oxides of Nitrogen from Gas Turbines**

| | Rated Electrical Output | Oxides of Nitrogen[1] | |
|---|---|---|---|
| | | $g/m^3$ | ppmv (approx) |
| Gaseous fuels | less than 10 MW | 0.09 | 44 |
| | greater than 10 MW | 0.07 | 34 |
| Other fuels | less than 10 MW | 0.09 | 44 |
| | greater than 10 MW | 0.15 | 73 |

[1] Calculated as $NO_2$ at a 15 per cent oxygen reference level, dry, at STP

## 5.2 Ambient Air Quality Criteria

In Western Australia, the EPA requires that air pollutants meet the national environment protection standards of the *National Environmental Protection (Ambient Air Quality) Measure* (Ambient Air Quality NEPM) (NEPC, 2003). The Ambient Air Quality NEPM standards and goals are enabled under the NEPC Act (WA) and specify maximum concentrations and goals to be achieved within 10 years. The Department of Environment and Conservation (DEC) and EPA routinely apply NEPM criteria to proposals. In the absence of a NEPM value, the applicable criterion for comparison is made on a case by case basis.

The air pollutants relevant to the proposed Gorgon Development are nitrogen dioxide, sulfur dioxide, particles as $PM_{10}$ and ozone. These pollutants are listed below in **Table 5-2**, along with their associated NEPM standard. In the absence of other standards relevant to Western Australia, it is considered appropriate to use the standards in **Table 5-2** as the criteria for comparison in this air quality assessment.

**Table 5-2 National Environment Protection Measure Standards and Goals**

| Pollutant | Averaging Period | Maximum Concentration | Compliance Goal for exceedences |
|---|---|---|---|
| Nitrogen Dioxide | 1 hour | 120 ppb (246 μg/m$^3$) | 1 day per year |
| | 1 year | 30 ppb (62 μg/m$^3$) | None |
| Photochemical oxidants (as ozone) | 1 hour | 100 ppb (214 μg/m$^3$) | 1 day per year |
| | 4 hours | 80 ppb (171 μg/m$^3$) | 1 day per year |
| Sulfur dioxide | 1 hour | 200 ppb (571 μg/m$^3$) | 1 day per year |
| | 1 day | 80 ppb (229 μg/m$^3$) | 1 day per year |
| | 1 year | 20 ppb (57 μg/m$^3$) | None |
| Particles as $PM_{10}$ | 1 day | 50 μg/m$^3$ | 5 days per year |

## 5.3 Occupational Exposure Criteria

Occupational air quality criteria are listed in **Table 5-3** as referred from Worksafe Australia's exposure standards (NOHSC, 1995). A standard criterion is a time weighted average (TWA) concentration, measured over an eight-hour working day and 5-day working week. A short term exposure standard (STEL) is a 15-minute average that is not to be exceeded. Inspirable dust is the size fraction below a nominal cut-off of 50 μm or similar to that as measured for total suspended particulate.

**Table 5-3 Exposure Standards for Atmospheric Contaminants in the Occupational Environment (NOHSC, 1995)**

| Substance | Averaging Period | TWA (ppm) | TWA (μg/m$^3$) | STEL (ppm) | STEL (μg/m$^3$) |
|---|---|---|---|---|---|
| Dust (Inspirable) | | n.a. | 10 000 | n.a. | n.a. |
| Nitrogen Dioxide | 8-hour | 3 | 5 600 | 5 | 9,400 |
| Sulfur Dioxide | 8-hour | 2 | 5 200 | 5 | 13 000 |
| Ozone | | 0.1 | 200 | Peak limitation[a] | |
| Hydrogen Sulfide | 8-hour | 10 | 14 000 | 15 | 21 000 |

a - For some rapidly acting substances and irritants, the averaging of airborne concentration over an eight hour period is inappropriate. These substances may induce acute effects after relatively brief exposure to high concentrations and so the exposure standard for these substances represents a maximum or peak concentration to which workers may be exposed.

The source of the NOHSC exposure standard for sulfur dioxide ($SO_2$) is the *American Conference of Governmental Industrial Hygienists* (ACGIH, 1986; ACGIH, 1991). The (US) Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) STEL for $SO_2$ is also 5 ppm (13 000 µg/m$^3$).

### 5.4 Environmental Criteria (Deposition on Vegetation)

Acid deposition ('acid rain') occurs when $SO_2$ and $NO_x$ react with water, oxygen and other oxidants in the atmosphere to form acidic compounds. These acid compounds precipitate in rain, snow and fog, or in dry form as gases and particles. The $SO_2$ and $NO_x$ gases and their particulate matter derivatives, sulfate and nitrate aerosols, may contribute to air quality impacts, for example, by the acidification of lakes and streams, damage to forest ecosystems and acceleration of the decay of building materials (USEPA, 2007).

Deposition processes relevant to the study region are expected to be dominated by dry deposition due to the generally dry climate of the region, although heavy rainfall occurs occasionally in the summer.

Previous deposition studies undertaken by SKM on the Burrup Peninsula, which is located in the Pilbara region of Western Australia, have indicated that there are large uncertainties with the depositions predicted by modelling (SKM, 2003a, SKM, 2005). The uncertainties in the modelled depositions are due to uncertainties in the water, soil and vegetation surface resistances employed in the calculations (Hurley, 2005). To reduce these uncertainties, further programs would be required including deposition measurements and model validations. As such, the deposition quantities provided in this assessment are considered 'indicative' of what may occur.

WHO (2000) provides critical loads for depositions for the assessment of nitrogen and 'acid equivalent' impacts on vegetation. Critical load is an estimate of exposure in the form of deposition, below which significant harmful effects on specified sensitive elements of the environment do not occur to the best present knowledge (WHO, 2000).

The sulfur critical load is 250–1500 eq/ha/annum (units are 'acid equivalents' per hectares per year), depending on the type of soil and ecosystem. The ecosystem example used for this assessment is, for sulfur critical load:

- 250–500 eq/ha/annum for fluvial and marine sediment
- 4–8 kg/ha/annum as sulfur
- 8–16 kg/ha/annum as $SO_2$.

The WHO (2000) nitrogen critical load is 5–35 kg/ha/annum, depending on the type of soil and ecosystem. The ecosystem example used for this assessment is:

- 15–20 kg/ha/annum for lowland dry heathlands as nitrogen
- 49–66 kg/ha/annum as $NO_2$.

There are no criteria available specific to Western Australian flora.

## 5.5 Criteria Used in this Assessment

For the purposes of this assessment the following criteria will be used to compare against modelled concentrations of air pollutants.

### 5.5.1 Ambient Criteria

The maximum pollutant concentration as specified by NEPM (see **Table 5-2**) will be used for the assessment.

**Nitrogen Dioxide**

- 246 μg/m$^3$ (1-hour average) and 62 μg/m$^3$ (annual average)

**Ozone**

- 214 μg/m$^3$ (1-hour average) and 171 μg/m$^3$ (4-hour average)

**Sulfur Dioxide**

- 572 μg/m$^3$ (1-hour average), 227 μg/m$^3$ (24-hour average) and 57 μg/m$^3$ (annual average)

**Particulate Matter (as PM10)**

- 50 μg/m$^3$ (24-hour average)

### 5.5.2 Occupational Criteria

The maximum pollutant concentration as specified by NEPM (see **Table 5-3**) will be used for the assessment.

**Nitrogen Dioxide**

- 5 600 μg/m$^3$ (8-hour TWA) and 9,400 μg/m$^3$ (15-minute STEL)

**Ozone**

- 200 μg/m$^3$ (8-hour TWA)

**Sulfur Dioxide**

- 5 200 µg/m$^3$ (8-hour TWA) and 13 000 µg/m$^3$ (15-minute STEL)

**Particulate Matter (as inspirable dust)**

- 10 000 µg/m$^3$ (8-hour TWA)

**Hydrogen Sulphide**

- 14 000 µg/m$^3$ (8-hour TWA) and 21 000µg/m$^3$ (15-minute STEL)

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# 6. Existing Environment

This section provides a description of environmental characteristics of Barrow Island relevant to the air quality assessment, including the meteorological conditions influencing the air dispersion modeling.

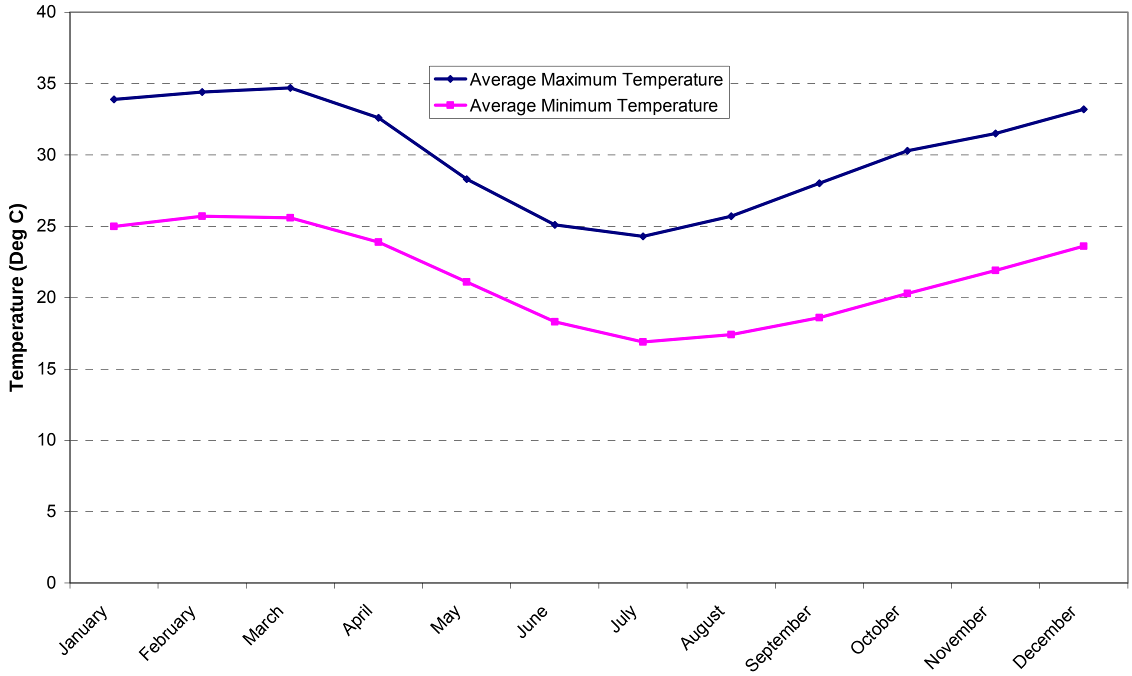
## 6.1 Climate and Meteorology

The southern portion of the north-west shelf, including Barrow Island, is characterised by an arid, sub-tropical climate. The summer season occurs from October to March and is characterised by high temperatures, high humidity and predominantly south-west winds (WNI, 2003). In contrast, the winter season, June to August, is characterised by clear skies, fine weather and predominantly strong east to south-east winds. The months of April, May and September are considered a transition season during which either the summer or winter weather regime may predominate or conditions may vary between the two (Chevron Australia, 2005).

The Bureau of Meteorology (BoM) operates a meteorological station on Barrow Island. Data obtained from this station has been used in the following description of meteorological factors.

### 6.1.1 Temperature

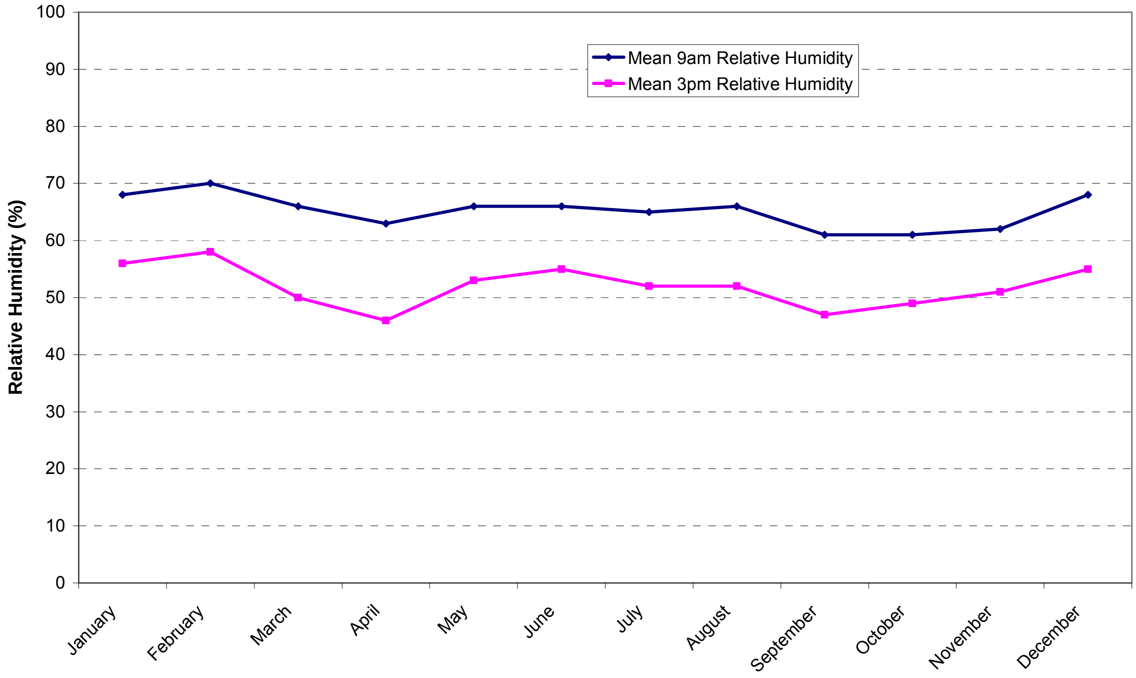
The average monthly maximum and minimum temperatures recorded at the BoM Automatic Weather Station (AWS) on Barrow Island are presented in **Figure 6-1**. From this figure it is apparent that Barrow Island experiences mean daily temperatures during summer ranging from 24°C to 34°C. During winter the mean daily temperatures range between 17°C and 26°C.




▪ **Figure 6-1 Average Temperatures at Barrow Island (BoM, 2008)**

### 6.1.2 Relative Humidity

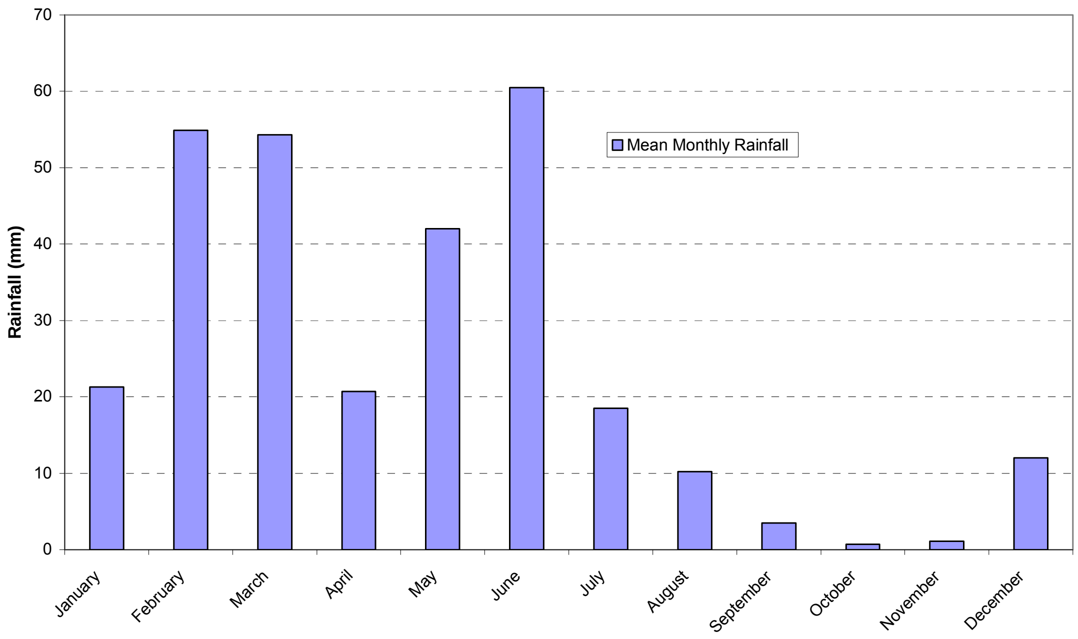
The 9am and 3pm mean relative humidity recorded at the BoM AWS on Barrow Island is presented in **Figure 6-2**. From this figure it is evident that Barrow Island experiences high relative humidity consistently throughout the year.




▪ **Figure 6-2 Mean Relative Humidity at Barrow Island (BoM 2008)**

### 6.1.3 Rainfall

Barrow Island has an annual average rainfall of 307 mm and the mean monthly rainfall is presented in **Figure 6-3**. From this figure it is evident that the majority of the rain received on Barrow Island falls between February and June. The rainfall on Barrow Island varies significantly from year-to-year and is dependent on rain-bearing low pressure systems, thunderstorm activity and passage of tropical cyclones. During the early winter months rainfall is received from frontal systems passing to the south. These events can result in up to 50 mm of rain and account for approximately 35% of annual rainfall (BoM, 2008a). In summer, cyclonic events range from storms of 300 mm to milder 30 mm events. Wet years typically receive a large portion of rainfall from tropical cyclones (Chevron Australia, 2005).




- **Figure 6-3 Mean Monthly Rainfall at Barrow Island (BoM, 2008)**

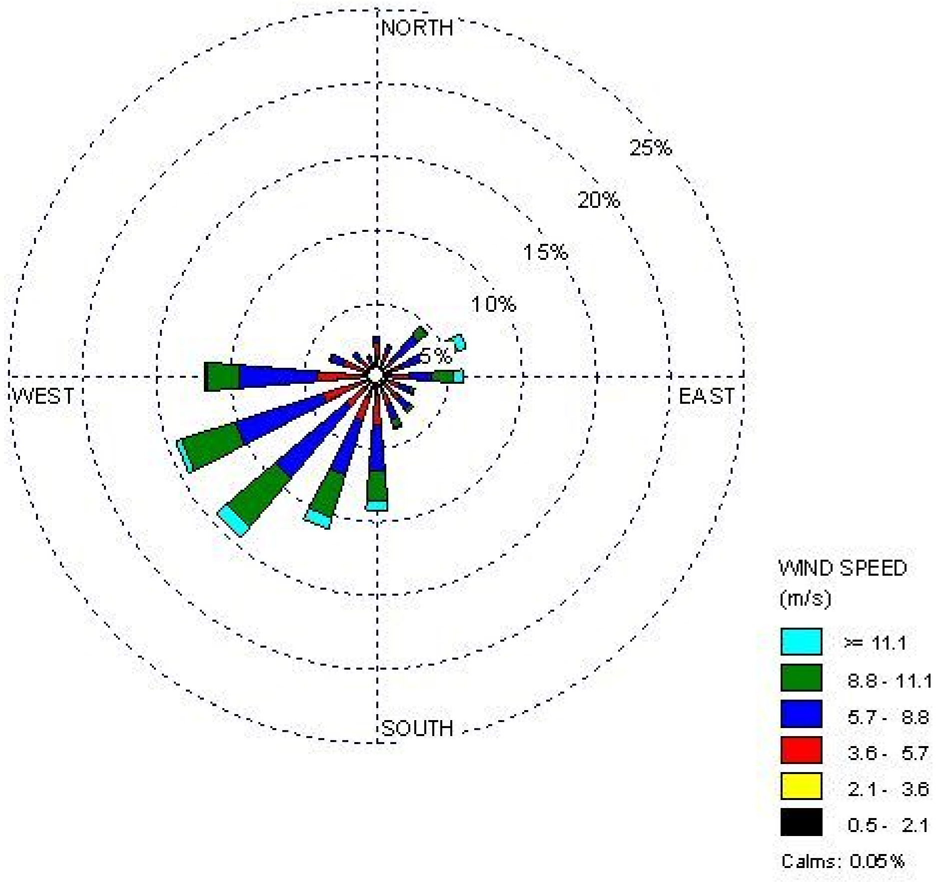
### 6.1.4 Evaporation

The annual evaporation rate is approximately 3 500 mm for the region (based on records from the Dampier Salt Weather Station). Daily evaporation rates range from about 11 mm/day during the summer months to 7 mm/day during winter months (Chevron Australia, 2005).

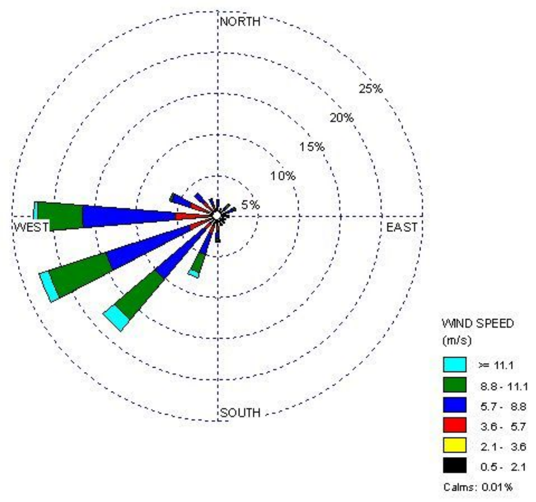
### 6.1.5 Wind Direction and Wind Speed

The annual average wind rose for Barrow Island is presented in **Figure 6-4**. This figure represents the hourly wind speed and direction from 1999 to 2007. From this figure it is evident that the dominant wind direction at this locality is from southerly through to westerly winds.

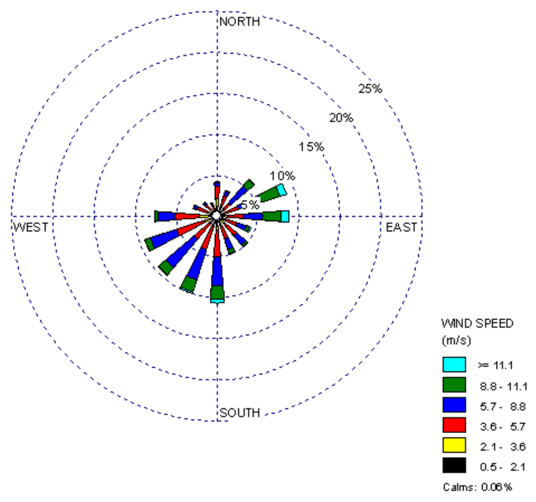
The seasonal wind roses are represented from **Figure 6-5** through to **Figure 6-8**. From these figures it can be seen that the dominant southerly to westerly winds occur primarily during the spring and summer periods. These wind patterns result from high pressure cells which also produce significant periods of wind speeds greater than 10 m/s. During winter high pressure cells located over central Australia result in north easterly to southerly winds



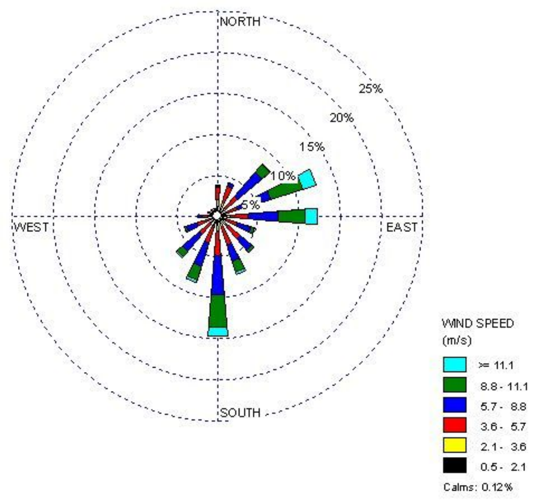

- **Figure 6-4 Wind Rose for Barrow Island from 1999 – 2007**



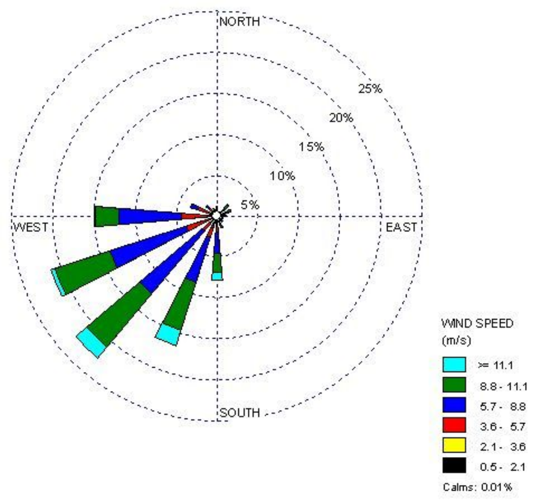

■ **Figure 6-5 Summer winds (1999 – 2007)**




■ **Figure 6-6 Autumn winds (1999 – 2007)**




■ **Figure 6-7 Winter winds (1999 – 2007)**




■ **Figure 6-8 Spring winds (1999 – 2007)**

## 6.2 Existing Air Quality

Previous air quality studies in the Barrow Island region have generally focused on the Burrup Peninsula and the predicted impacts of development on sensitive receptors in the Dampier and Karratha townships. These studies have identified oxides of nitrogen as one of the most important industrial emissions in the region (DEP, 2004).

Ambient air monitoring was undertaken for the Pilbara Air Quality Study at Dampier, King Bay, Karratha townsite and Boordarie (DEP, 2002). It was found that all measured nitrogen dioxide concentrations at Dampier and Karratha were below the NEPM standard for both the maximum 1-hour concentration and annual average concentration (DoE, 2004). Although within guideline levels, the ozone concentrations were noted to be well above natural levels (DoE, 2004). Physick and Blockley (2001) noted that the contribution of NOx and VOCs from fires in the Pilbara region can lead to the enhancement of anthropogenic levels of ozone and that further investigation into ozone levels in the area would be warranted.

Monitoring for benzene, toluene and xylenes (BTX) was undertaken in 2003/2004 at eight sites in Karratha and Dampier using a combination of canisters and ambient diffusion tubes (GHD, 2005). Comparison of ambient monitoring results with ambient air concentrations throughout Australia and national and international standards concluded that ambient exposure to BTEX compounds was no greater for residents of the Burrup Peninsula than for other populations in Australia (Toxikos, 2005).

The Burrup Peninsula Air Pollution Study, coordinated by the Burrup Rock Art Monitoring Management Committee, has reported on ambient air monitoring undertaken from August 2004 to September 2005, to assess the likelihood of damaging effects of air pollution on aboriginal rock etchings in the area (CSIRO, 2006). The study measured the concentration of sulfur dioxide ($SO_2$), nitrogen dioxide ($NO_2$), nitric acid, ammonia and the BTEX gases (benzene, toluene, ethylbenzene and xylenes). Concentrations of all were found to be low when compared to polluted urban areas. An enhancement of $NO_2$, $SO_2$ and nitric acid concentrations was found at monitoring sites considered to be representative of industrial locations when compared to those measured at sites assumed to represent background levels.

In its report and recommendations for the Burrup Fertiliser Ammonia Plant (EPA, 2001), the EPA noted that the proposed emissions from the plant were small, but that the increasing development in the area will require further research on cumulative impacts. The report also recognised the potential for ozone to be of increasing concern as the number of industries in the region increases.

Given the level of development in the region, this air quality assessment has taken into consideration existing and approved emission sources significant to the Barrow Island region, as well as the proposed Gorgon development. The industrial activities which have been included in the air pollutant dispersion modelling are:

- NWSV Karratha Gas Plant including the new Train 4 and Train 5;
- The approved Pluto gas Plant;
- Hamersley Iron power station at Parker Point near Dampier (2 stacks); and
- Burrup Fertiliser's ammonia plant (2 stacks).

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# 7. Air Quality Model

This section describes the meteorological and air dispersion model employed for this study and the methodology adopted to complete the assessment.

## 7.1 Model Selection

For pollutants released in near coastal environments, the following four dispersion processes are considered important:

1) Dispersion under convective conditions when the buoyant plumes can be mixed to ground level within a short distance of the stacks.
2) The influence of the sea breeze with the creation of the Thermal Internal Boundary layer (TIBL) where onshore winds can lead to complex vertical dispersion.
3) The influence of the buildings and structures around facilities that may lead to increased dispersion and reduced plume rise from the stacks.
4) The presence of terrain features like hills and ridges in the surrounding area that can impact on dispersion and be subject to elevated concentrations.

For this modelling assessment the atmospheric dispersion model TAPM (The Air Pollution Model) was utilised. TAPM is a prognostic three-dimensional model designed by CSIRO that can be used to predict meteorological and air pollution parameters on an hourly basis (Physick & Blockley, 2001). The model predicts flows that are of importance to local-scale air pollution such as sea breezes and terrain induced flows (Hurley, 2005). The meteorological parameters predicted by the model have been compared to actual readings recorded during the Kwinana Coastal Fumigation study (Hurley & Luhar, 2000) and the Pilbara Air Quality Study (Physick & Blockley, 2001). It was found that the model predicts near-surface parameters very well while the upper parameters were also well predicted.

## 7.2 Model Setup and Methodology

The TAPM modelling package consists of a model and databases of synoptic meteorology, terrain and land use categories for the Australasian region. For this assessment TAPM was configured as follows:

- Four grid domains (30km, 10km, 3km and 1km) with 31 by 31 cells per domain. The four grid domains are presented from **Figure 7-1** to **Figure 7-4.**
- All grids were centred at 115°27.5'E and 20°47'S, corresponding to 339700E and 7699950N in the local grid.

- The TAPM land/sea database was derived from the 9” Digital Elevation Model (DEM) data (Geoscience Australia, 2002) and was modified using the 1:100 000 topographical maps for the region (RASC, 1973).
- Standard 25 vertical levels from 10 metres to 8 000 metres in height.
- The default sea surface and deep soil temperatures were used. Default sea surface temperatures were checked against the recorded sea surface temperatures from the BoM (2008b). Examples of the sea surface temperatures for January and June are available in **Figure 7-5** and **Figure 7-6** respectively.
- Meteorological runs from 30 December 2002 to 31 December 2003, with the output only after 1 January 2004 being used in the assessment. This modelling period is the same as that used in the previous air quality modelling assessment for Chevron Australia (SKM, 2005).

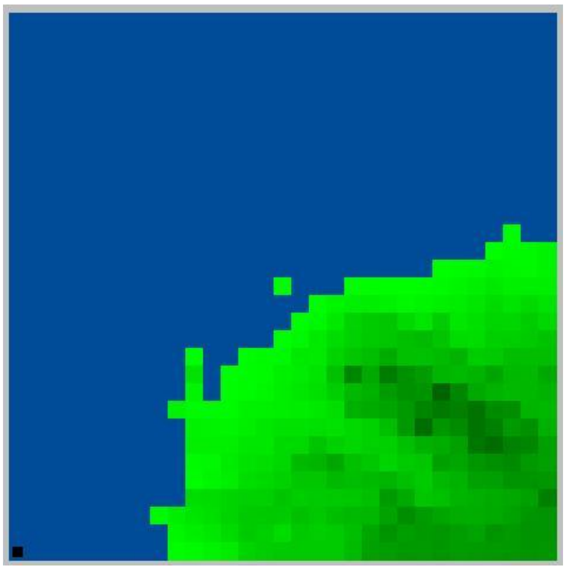


Figure 7-1 TAPM topography file at 30 000m grid spacing

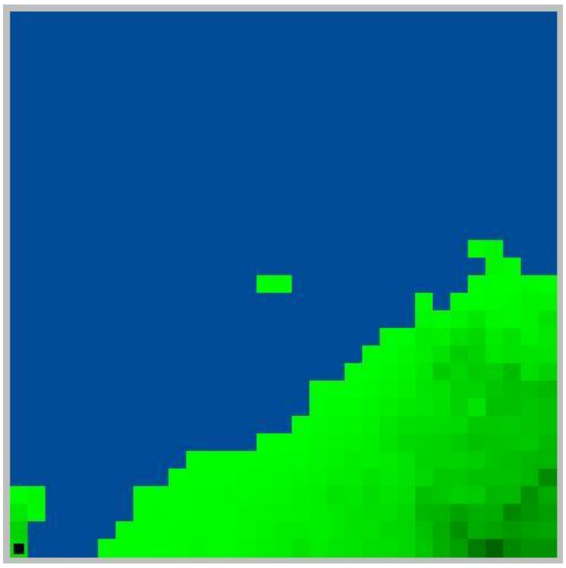


Figure 7-2 TAPM topography file at 10 000m grid spacing

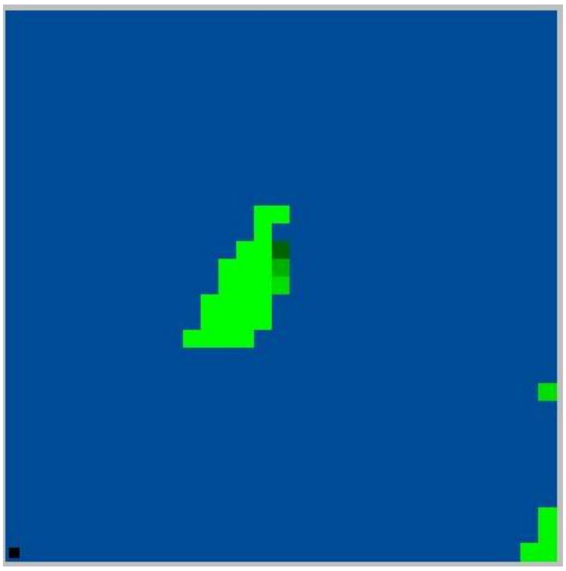


Figure 7-3 TAPM topography file at 3000m grid spacing

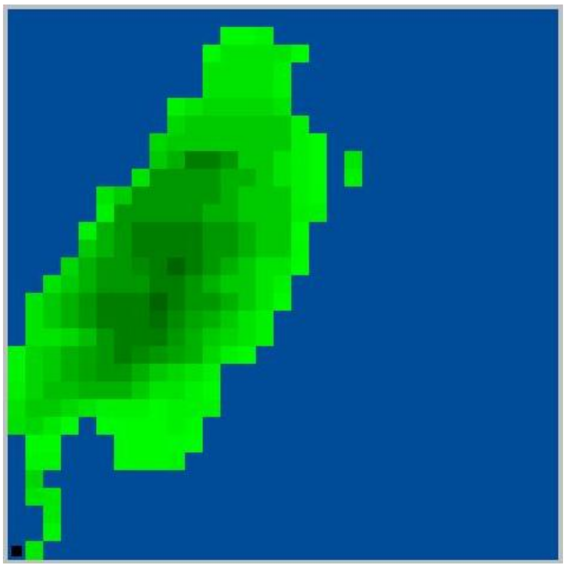
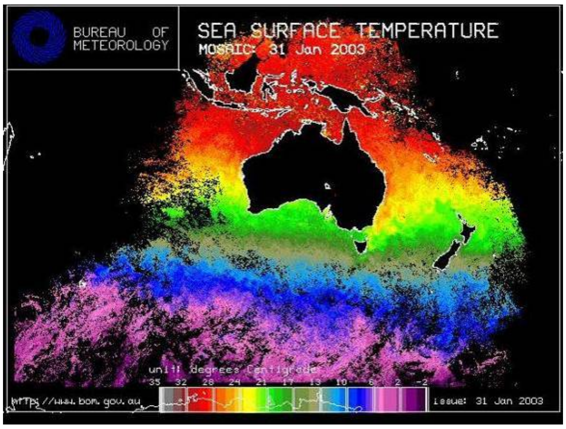
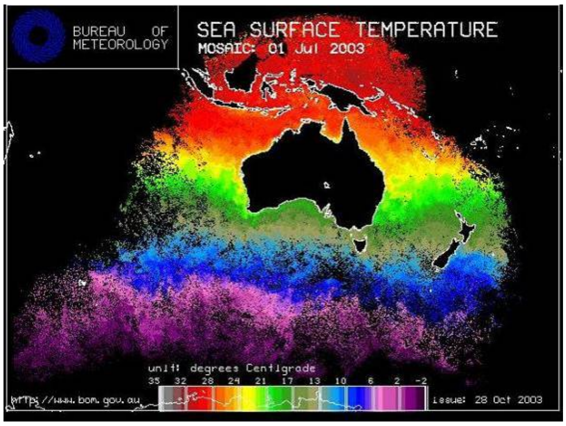


Figure 7-4 TAPM topography file at 1000m grid spacing




- **Figure 7-5 Sea surface temperature 31/1/2003 (BoM 2008)**




- **Figure 7-6 Sea surface temperature 1/7/2004 (BoM 2008)**

For atmospheric modelling of pollutants the following parameters were used:

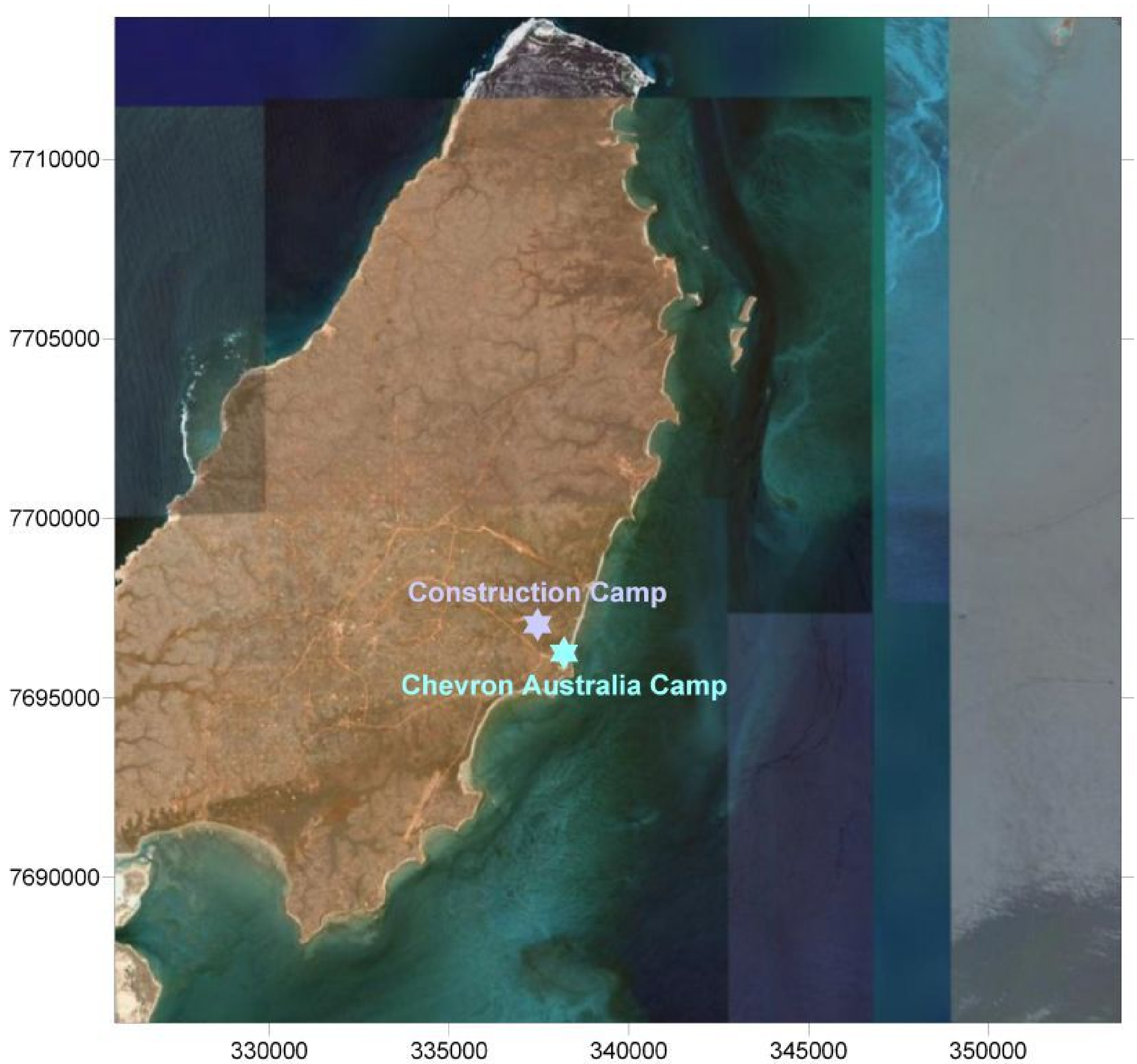
- atmospheric chemistry modelling mode with APM (Airborne Particulate Matter, $PM_{10}$), $NO_x$, $NO_2$, $O_3$, $SO_2$ and FPM (Fine Particulate Matter, $PM_{2.5}$);
- background ozone level – 20 ppb;
- background Rsmog – 0.2 g/s;
- background Fine Particulate Matter ($PM_{2.5}$) – 5µg/m$^3$ (estimate for clean air) ;
- pollution grid (inner), 49 x 49 (omitting boundary to reduce ‘edge effects’), with resolution of 500 metres; and
- Lagrangian (LPM) mode used to model the predicted ground level concentrations on the inner (1 km) grid.

## 7.3 Sensitive Receptors

For the area under consideration in this assessment, the relevant human receptors are those at the Chevron Australia camp and the proposed Gorgon Construction/Turnaround camp. The coordinates of these sensitive receptors on the modelled grid are presented in **Table 7-1.** The location of the two sites is presented in **Figure 7-7**.

- **Table 7-1 Sensitive receptor locations for model interpretation**

| Location | Sensitive Receptor | |
|---|---|---|
| | Easting | Northing |
| Barrow Island (Chevron Australia camp) | 338200 | 7696250 |
| Construction Camp | 337455 | 7697036 |




- **Figure 7-7 Location of sensitive receptors on Barrow Island**

## 7.4 Emission Characterisation

The following sections outline the emission parameters used in this modelling assessment. **Section 7.5** outlines how the emissions from commercial shipping sources were determined while **Section 7.6** outlines the emission parameters used for point source emissions for the proposed Gorgon Gas Treatment Plant on Barrow Island and additional sources in the coastal Pilbara region, particularly the Burrup Peninsula.

## 7.5 Shipping Emission Sources

### 7.5.1 Data Collection

To determine the emissions of pollutants from shipping the Emissions Estimation Technique (EET) Manual for Aggregated Emissions from Commercial Ships/Boats and Recreational Boats Version 1 (EA, 1999) was utilised. This manual outlines how to calculate emissions from these sources and contains a series of emission factors to assist in completing this process. The manual distinguishes between ships and boats by describing the former as cargo ships, chemical tankers, colliers and naval ships while the latter includes fishing boats, tugs and other small commercial activity craft. The emissions for ships are calculated on a per hour basis and depend upon time at berth and anchorage and speed and length of time in shipping channels. Boat emissions are calculated on fuel consumption which was estimated from the fuel usage for tugs and ships under 10 000 tonnes from the Aggregated Emissions Inventory for the Pilbara Airshed (SKM, 2003).

The number of ships was supplied by Chevron Australia (Sanderson, 2008) and includes 200 LNG tankers, and 12 condensate tankers, all of which are over 50 000 tonnes.

### 7.5.2 Commercial Shipping Calculations

Emissions from commercial shipping were calculated based on the prescribed methodology in the EET Manual (EA, 1999). **Equation 7-1** was used to estimate emissions at berth.

- **Equation 7-1** $$E_b = t_b * \sum_i (n_i * a_i)$$

Where,
$E_b$ = Annual emission at Berth from commercial ships (kg/yr)
$t_b$ = Average time of ships at berth (hr)
$n_i$ = Number of commercial ships visiting the port each year in the tonnage range i (/yr)
$a_i$ = Emission factor for auxiliary engines for ships in the tonnage range i (kg/hr)

The emission factors used to determine emissions from commercial ships are taken from the EET Manual (EA, 1999) and are presented in **Table 7-2**.

- **Table 7-2 Emission factors for commercial shipping**

| Substance | Emission Factor (kg/hr) for Commercial Ships of Different Tonnage Ranges[1] | | | | |
|---|---|---|---|---|---|
| | < 1000 | 1000 to 5000 | 5000 to 10 000 | 10 000 to 50 000 | > 50 000 |
| **Main Engines** | | | | | |
| Carbon monoxide | 0.481 | 1.63 | 3.03 | 13.5 | 28.5 |
| Oxides of nitrogen | 1.44 | 11.3 | 32.5 | 167 | 334 |
| Sulfur dioxide | 0.432 | 2.59 | 35.0 | 127 | 254 |
| Total Suspended Particulate (TSP) | 0.0374 | 0.224 | 0.561 | 16.8 | 33.7 |

| Substance | Emission Factor (kg/hr) for Commercial Ships of Different Tonnage Ranges[1] | | | | |
|---|---|---|---|---|---|
| | < 1000 | 1000 to 5000 | 5000 to 10 000 | 10 000 to 50 000 | > 50 000 |
| Total VOCs | 0.174 | 0.6 | 1.13 | 3.41 | 6.82 |
| **Auxiliary Engines** | | | | | |
| Carbon monoxide | 1.19 | 1.19 | 1.19 | 1.19 | 1.19 |
| Oxides of nitrogen | 6.66 | 6.66 | 6.66 | 6.66 | 6.66 |
| Sulfur dioxide | 1.42 | 2.83 | 4.25 | 5.66 | 7.08 |
| Total Suspended Particulate (TSP) | 0.12 | 0.12 | 0.12 | 0.9 | 0.9 |
| Total VOCs | 0.436 | 0.436 | 0.436 | 0.436 | 0.436 |

Notes:

1) Source: Table 4 of EET Manual for Aggregated Emissions from Commercial Ships/Boats and Recreational Boats (EA, 1999).

### 7.5.3 Commercial Shipping/Boating Results

NPI substance emission estimates for the airshed around Barrow Island for commercial shipping/boating activities during operations are summarised in **Table 7-3**.

- **Table 7-3 Emission summary for commercial shipping/boating (kg/yr)**

| Pollutant | Commercial Shipping |
|---|---|
| Oxides of nitrogen | 33 886 |
| Sulfur dioxide | 36 023 |
| Total suspended particulates (TSP) | 4 579 |
| VOC | 2 218 |

## 7.6 Point Source Emission Parameters

### 7.6.1 Existing and Approved Facilities

The industrial activities existing on Barrow Island and on the Burrup Peninsula that emit significant quantities of air pollutants and which have been included in the air pollutant dispersion modelling are:

- Existing WA Oil facility on Barrow Island, including the gas power generation station;
- North West Shelf Venture (NWSV) Karratha Gas Plant including the new Train 4 and Train 5;
- The approved Pluto Gas Plant;
- Hamersley Iron power station at Parker Point near Dampier (2 stacks); and
- Burrup Fertiliser's ammonia plant (2 stacks).

The emissions and stack data for these existing air emission sources are provided in **Table 7-4**. The columns of data are:

- Locations as easting and northing in Map Grid Australia 94 (MGA94) co-ordinates;
- Heights and radius of stacks in metres;
- Buoyancy Enhancement Factor data ('EF') (for example, refer to Hurley *et al* (2005a));
- Plume exit velocities (m/s), temperatures (degrees Kelvin); and
- Air pollutant emission rates:
  - $PM_{10}$ (g/s) (particulate matter with diameters less than 10 µm);
  - $NO_x$ (g/s) (oxides of nitrogen);
  - $SO_2$ (g/s), (sulfur dioxide); and
  - Rsmog (g/s), a reactivity coefficient multiplied by concentration of Volatile Organic Compounds (that is, hydrocarbons) (refer to Hurley *et al* (2005b)).

**Table 7-4 Air Emissions Data for Existing and Approved Sources used in Modelling**

| Source | Location (east) | Location (north) | Height (m) | Radius (m) | EF | Ex. Vel (m/s) | Temp (K) | PM10 (g/s) | $NO_x$ (g/s) | $SO_2$ (g/s) | Rsmog (g/s) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **NWSV Karratha Gas Plant** | | | | | | | | | | | |
| GT4001 | 476910 | 7722765 | 40 | 1.98 | 2.7 | 20.2 | 777 | 0 | 10.8 | 0.2 | 0 |
| GT4002 | 476910 | 7722800 | 40 | 1.98 | 2.7 | 20.2 | 777 | 0 | 10.768 | 0.24 | 0 |
| GT4003 | 476910 | 7722810 | 40 | 1.98 | 2.7 | 20.2 | 777 | 0 | 10.768 | 0.24 | 0 |
| GT4004 | 476910 | 7722845 | 40 | 1.98 | 2.7 | 20.2 | 777 | 0 | 13.46 | 0.24 | 0 |
| GT4005 | 476910 | 7722855 | 40 | 1.98 | 2.7 | 20.2 | 777 | 0 | 13.46 | 0.24 | 0 |
| GT4006 | 476910 | 7722890 | 40 | 1.98 | 2.7 | 20.2 | 777 | 0 | 13.46 | 0.24 | 0 |
| 1KT1410 | 476540 | 7722965 | 40 | 1.94 | 2.1 | 23.9 | 790 | 0 | 12.64 | 0.3 | 0 |
| 1KT1420 | 476590 | 7722965 | 40 | 1.94 | 2.1 | 23.9 | 790 | 0 | 12.48 | 0.27 | 0 |
| 1KT1430 | 476610 | 7722965 | 40 | 1.87 | 2.1 | 25.8 | 790 | 0 | 12.24 | 0.27 | 0 |
| 1KT1440 | 476660 | 7722965 | 40 | 1.87 | 2.1 | 26.3 | 806 | 0 | 12.4 | 0.27 | 0.4 |
| 1KT1450 | 476510 | 7722960 | 40 | 1.36 | 2.1 | 21.2 | 784 | 0 | 7.52 | 0.1 | 0 |
| 2KT1410 | 476540 | 7722845 | 40 | 1.94 | 2.1 | 23.9 | 790 | 0 | 12.64 | 0.3 | 0 |
| 2KT1420 | 476590 | 7722845 | 40 | 1.94 | 2.1 | 23.9 | 790 | 0 | 12.48 | 0.27 | 0 |
| 2KT1430 | 476610 | 7722845 | 40 | 1.87 | 2.1 | 25.8 | 790 | 0 | 12.24 | 0.27 | 0 |
| 2KT1440 | 476660 | 7722845 | 40 | 1.87 | 2.1 | 26.3 | 806 | 0 | 12.4 | 0.27 | 0.4 |
| 2KT1450 | 476510 | 7722840 | 40 | 1.36 | 2.1 | 21.2 | 784 | 0 | 7.52 | 0.1 | 0 |
| 3KT1410 | 476540 | 7722610 | 40 | 1.94 | 2.1 | 23.9 | 790 | 0 | 12.64 | 0.3 | 0 |
| 3KT1420 | 476590 | 7722610 | 40 | 1.94 | 2.1 | 23.9 | 790 | 0 | 12.48 | 0.27 | 0 |
| 3KT1430 | 476610 | 7722610 | 40 | 1.87 | 2.1 | 25.8 | 790 | 0 | 12.24 | 0.27 | 0 |
| 3KT1440 | 476660 | 7722610 | 40 | 1.87 | 2.1 | 26.3 | 806 | 0 | 12.4 | 0.27 | 0.4 |
| 3KT1450 | 476510 | 7722605 | 40 | 1.36 | 2.1 | 21.2 | 784 | 0 | 7.52 | 0.1 | 0 |

| Source | Location | | Height | Radius | EF | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (east) | (north) | (m) | (m) | | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| 1F2001 | 477152 | 7722915 | 33 | 0.73 | 1.7 | 6 | 700 | 0 | 0.3 | 0 | 0 |
| 2F2001 | 477152 | 7722905 | 33 | 0.73 | 1.7 | 6 | 700 | 0 | 0.3 | 0.01 | 0 |
| 3F2001 | 477152 | 7722895 | 33 | 0.73 | 1.7 | 6 | 700 | 0 | 0.3 | 0.01 | 0 |
| 4F2001 | 476968 | 7722880 | 33 | 0.73 | 1.7 | 6 | 700 | 0 | 0.3 | 0.01 | 0 |
| 5F2001 | 476968 | 7722870 | 33 | 0.73 | 1.7 | 6 | 700 | 0 | 0.3 | 0.01 | 0 |
| 1KT2420 | 477035 | 7722698 | 24 | 1 | 2.5 | 40.7 | 816 | 0 | 9.4 | 0.1 | 0 |
| 1KT2430 | 477050 | 7722698 | 24 | 1.45 | 2.5 | 30.6 | 620 | 0 | 20.3 | 0.2 | 0 |
| 2KT2420 | 477065 | 7722698 | 24 | 1 | 2.5 | 40.7 | 816 | 0 | 9.4 | 0.1 | 0 |
| 2KT2430 | 477080 | 7722698 | 24 | 1.45 | 2.5 | 30.6 | 620 | 0 | 20.3 | 0.2 | 0 |
| SealOil | 476500 | 7722500 | 20 | 1 | 1 | 0 | 400 | 0 | 0 | 0 | 0.1 |
| **KGP Flares** | | | | | | | | | | | |
| LNG | 477082 | 7722352 | 125 | 1.4 | 1 | 20 | 1273 | 0 | 3.02 | 0 | 0.0404 |
| Operational | 477092 | 7722511 | 46 | 135 | 1 | 20 | 1273 | 0 | 2.42 | 0 | 0.0324 |
| Store/Load | 476328 | 7722431 | 60 | 0.74 | 1 | 20 | 1273 | 0 | 0.74 | 0 | 0.0099 |
| LPG | 475943 | 7723061 | 50 | 0.5 | 1 | 20 | 1273 | 0 | 0.32 | 0 | 0.0043 |
| **NWSV Karratha Gas Plant Train 4:** | | | | | | | | | | | |
| 4KT1430a | 476664 | 7722465 | 40 | 1.45 | 2 | 28.2 | 490 | 0 | 5 | 0.3 | 0 |
| 4KT1430b | 476664 | 7722461 | 40 | 1.45 | 2 | 28.2 | 490 | 0 | 5 | 0.3 | 0 |
| 4KT1410 | 476650 | 7722461 | 40 | 3.05 | 1 | 23.4 | 814 | 0 | 10.6 | 0.6 | 0 |
| 1F1251 | 476933 | 7722944 | 40 | 1.46 | 1.8 | 23 | 694 | 0 | 3.3 | 0.2 | 0 |
| GT4007 | 476972 | 7722702 | 40 | 1.65 | 1.7 | 23 | 694 | 0 | 3.3 | 0.2 | 0 |
| GT4008 | 476972 | 7722668 | 40 | 1.65 | 1.7 | 23 | 694 | 0 | 3.3 | 0.2 | 0 |
| **NWSV Karratha Gas Plant Train 5** | | | | | | | | | | | |
| GT4009 | 476972 | 7722626 | 40 | 1.65 | 1.7 | 23 | 694 | 0 | 3.3 | 0.2 | 0 |
| GT4010 | 476972 | 7722592 | 40 | 1.65 | 1.7 | 28.2 | 490 | 0 | 5 | 0.3 | 0 |
| 5KT1430a | 476664 | 7722335 | 40 | 1.45 | 2 | 28.2 | 490 | 0 | 5 | 0.3 | 0 |
| 5KT1430b | 476664 | 7722331 | 40 | 1.45 | 2 | 23.4 | 814 | 0 | 10.6 | 0.6 | 0 |
| 5KT1410 | 476560 | 7722331 | 40 | 3.05 | 1 | 21.3 | 1373 | 0 | 0.8 | 2.8 | 0 |
| New BOG liquefaction turbine | 476337 | 7722631 | 40 | 1.65 | 1.7 | 23 | 694 | 0 | 3.3 | 0.2 | 0 |

| Source | Location |  | Height | Radius | EF | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  | (east) | (north) | (m) | (m) |  | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| **Hamersley Power Station** |  |  |  |  |  |  |  |  |  |  |  |
| HAM_stack1 | 471500 | 7717000 | 60 | 1.3 | 1 | 7 | 393 | 0 | 5.7 | 1 | 0 |
| HAM_stack2 | 471500 | 7717000 | 60 | 1.3 | 1 | 7 | 393 | 0 | 5.7 | 1 | 0 |
| **Burrup Fertilisers Ammonia Plant** |  |  |  |  |  |  |  |  |  |  |  |
| BF1 | 476915 | 7718833 | 36 | 1.78 | 1 | 12.7 | 413 | 0.3 | 15.4 | 0 | 0 |
| BF2 | 477060 | 7718820 | 15 | 0.85 | 1 | 5 | 450 | 0 | 1.3 | 0 | 0 |
| **Pluto** |  |  |  |  |  |  |  |  |  |  |  |
|  | 475609 | 7720460 | 40 | 1.75 | 2 | 23.5 | 493 | 0 | 3.85 | 0.3 | 0 |
|  | 475621 | 7720466 | 40 | 1.75 | 2 | 23.5 | 493 | 0 | 3.85 | 0.3 | 0 |
|  | 475509 | 7720422 | 40 | 2.5 | 1 | 23 | 816 | 0 | 7.7 | 0.6 | 0 |
|  | 475528 | 7720311 | 40 | 1.65 | 2.7 | 16.5 | 438 | 0 | 2.7 | 0.45 | 0 |
|  | 475565 | 7720329 | 40 | 1.65 | 2.7 | 16.5 | 438 | 0 | 2.7 | 0.45 | 0 |
|  | 475602 | 7720342 | 40 | 1.65 | 2.7 | 16.5 | 438 | 0 | 2.7 | 0.45 | 0 |
|  | 475646 | 7720360 | 40 | 2.25 | 2.7 | 16.6 | 821 | 0 | 2.7 | 0.45 | 0 |
|  | 475683 | 7720379 | 40 | 2.25 | 2.7 | 16.6 | 821 | 0 | 2.7 | 0.45 | 0 |
|  | 475963 | 7720205 | 40 | 1.9 | 2.7 | 25 | 791 | 0 | 3 | 0.3 | 0 |
|  | 475826 | 7720671 | 40 | 1.45 | 1.8 | 20 | 873 | 0 | 1.6 | 1 | 0 |
|  | 475590 | 7720677 | 33 | 0.75 | 1.8 | 11 | 761 | 0 | 0.8 | 0.1 | 0 |
|  | 475720 | 7720177 | 40 | 1.75 | 2 | 23.5 | 493 | 0 | 3.85 | 0.3 | 0 |
|  | 475733 | 7720183 | 40 | 1.75 | 2 | 23.5 | 493 | 0 | 3.85 | 0.3 | 0 |
|  | 475615 | 7720137 | 40 | 2.5 | 1 | 23 | 816 | 0 | 7.7 | 0.6 | 0 |
|  | 475547 | 7720280 | 40 | 1.65 | 2.7 | 16.5 | 438 | 0 | 2.7 | 0.45 | 0 |
|  | 475578 | 7720298 | 40 | 1.65 | 2.7 | 16.5 | 438 | 0 | 2.7 | 0.45 | 0 |
|  | 475621 | 7720317 | 40 | 1.65 | 2.7 | 16.5 | 438 | 0 | 2.7 | 0.45 | 0 |
|  | 475665 | 7720329 | 40 | 2.25 | 2.7 | 16.6 | 821 | 0 | 2.7 | 0.45 | 0 |
|  | 475702 | 7720348 | 40 | 2.25 | 2.7 | 16.6 | 821 | 0 | 2.7 | 0.45 | 0 |
|  | 475851 | 7720106 | 40 | 1.9 | 2.7 | 25 | 791 | 0 | 3 | 0.3 | 0 |
|  | 475975 | 7720301 | 40 | 1.45 | 1.8 | 20 | 873 | 0 | 1.6 | 1 | 0 |
|  | 475739 | 7720727 | 33 | 0.75 | 1.8 | 11 | 761 | 0 | 0.8 | 0.1 | 0 |
| **Ships at Berth** |  |  |  |  |  |  |  |  |  |  |  |
| KGP | 475500 | 7723500 | 40 | 1 | 1 | 5 | 573 | 0.057 | 0.453 | 0.847 | 0.0002 |
| KGP B | 475250 | 7723250 | 40 | 1 | 1 | 5 | 573 | 0.057 | 0.453 | 0.847 | 0.0002 |
| Pluto | 474500 | 7721500 | 40 | 1 | 1 | 5 | 573 | 0.057 | 0.453 | 0.847 | 0.0002 |
| King Bay | 473500 | 7720500 | 40 | 1 | 1 | 5 | 573 | 0.131 | 4.14 | 2.29 | 0.003 |
| Parker Point | 470500 | 7717500 | 40 | 1 | 1 | 5 | 573 | 0.019 | 1.55 | 1.48 | 0.0008 |
| EII | 466500 | 7716500 | 40 | 1 | 1 | 5 | 573 | 0.019 | 0.12 | 0.48 | 0.0012 |
| Mistaken Is | 464500 | 7716500 | 40 | 1 | 1 | 5 | 573 | 0.015 | 0.374 | 0.87 | 0.0003 |
| **Barrow Island** |  |  |  |  |  |  |  |  |  |  |  |
|  | 332000 | 7697000 | 30 | 1.98 | 2.7 | 20.2 | 777 | 0 | 25.3 | 0.3 | 0 |
|  | 332000 | 7697045 | 30 | 1.98 | 2.7 | 20.2 | 777 | 0 | 25.3 | 0.3 | 0 |
|  | 331900 | 7697150 | 20 | 1 | 1 | 0 | 400 | 0 | 0 | 0 | 0.1 |
|  | 332200 | 7697200 | 20 | 0.73 | 1.7 | 6 | 700 | 0 | 0 | 0 | 0.1 |

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### 7.6.2 Routine Operations

Emissions characteristics for the proposed Chevron Australia facility on Barrow Island operating during normal operations are summarised in **Table 7-5**. These emission parameters were obtained from Chevron Australia (Ratcheva, 2008). The modelling for the plant during normal operating conditions was conducted using the emissions outlined in this table as well as those listed in **Table 7-4**.

- **Table 7-5 Emission Parameters for Proposed Gorgon Gas Treatment Plant – Routine Operations**

| Source | Location | | Height | Radius | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|
| | (east) | (north) | (m) | (m) | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| 1KT-1510 | 338552 | 7700584 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1510 | 338554 | 7700473 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1510 | 338735 | 7700586 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 1KT-1530 | 338735 | 7700476 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1530 | 338921 | 7700588 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1530 | 338921 | 7700479 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| GT-4001 | 338406 | 7700246 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4002 | 338525 | 7700331 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4003 | 338527 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4004 | 338577 | 7700330 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4005 | 338579 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| F-4101A | 337840 | 7700146 | 39 | 0.5 | 0.3 | 394 | 0.00 | 0.02 | 0.00 | 0.00001 |
| F-4101B | 337857 | 7700146 | 39 | 0.5 | 0.3 | 394 | 0.00 | 0.00 | 0.00 | 0.00000 |
| A-6201 Routine | 337984 | 7700001 | 6 | 1.5 | 20.0 | 1273 | 0.00 | 0.01 | 0.00 | 0.00016 |
| A-6201 Non-Routine | 338087 | 7700001 | 6 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00000 |
| B-6210 Routine | 337984 | 7699863 | 6 | 2.5 | 20.0 | 1273 | 0.00 | 0.03 | 0.00 | 0.00028 |
| B-6210 Non-Routine | 338087 | 7699864 | 6 | 2.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00000 |
| A-6203A | 339173 | 7700238 | 45 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| A-6203B | 339175 | 7700177 | 45 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| 1V-1102 | 338337 | 7700473 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1V-1102 | 338337 | 7700553 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1V-1102 | 338337 | 7700633 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| Ship Emissions | 342579 | 7697736 | 40 | 1 | 5.0 | 573 | 0.15 | 1.07 | 1.14 | 0.00047 |

### 7.6.3 Non-Routine Operations

Non-routine operations, including process upset situations, requiring some plant or equipment depressurising to flare or shut-down may occur approximately 10 times per year. A shut-down for planned and emergency situations will normally result in less than one hour of peak flaring as the high pressure gas streams are stopped and the process equipment depressured. Flaring during a normal start-up will be approximately three hours in duration. Flaring during the initial plant commissioning will be more extensive, but this will be a once-only occurrence (Ratcheva, 2008).

Three upset scenarios have been identified for the purposes of this assessment, representing reasonable worst cases. These are associated with the start-up of the facility after a prolonged shut-down (i.e. a cold start-up), an emergency shut-down and $CO_2$ injection system failure resulting in $CO_2$ venting. The following sub-sections detail the emissions characteristics for these scenarios.

### 7.6.4 Non-Routine Operation 1 – Cold Start-up

It is expected that the gas processing plant will be shut-down for sufficient time to require a cold start at least once a year. A cold re-start is expected to take approximately six hours, during which time approximately 30% of the normal flow rate of a single LNG train may be directed to the flare as the LNG is brought to product specification (Chevron Australia, 2005).

Emissions characteristics for the first upset condition are summarised in **Table 7-6**.

- **Table 7-6 Upset Condition 1 Emissions Data**

| Source | Location | | Height | Radius | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|
| | (east) | (north) | (m) | (m) | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| 1KT-1510 | 338552 | 7700584 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1510 | 338554 | 7700473 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1510 | 338735 | 7700586 | 40 | 2.75 | 21.9 | 613 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1KT-1530 | 338735 | 7700476 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1530 | 338921 | 7700588 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1530 | 338921 | 7700479 | 40 | 2.75 | 21.9 | 613 | 0.00 | 0.00 | 0.00 | 0.00000 |
| GT-4001 | 338406 | 7700246 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4002 | 338525 | 7700331 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4003 | 338527 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4004 | 338577 | 7700330 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4005 | 338579 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.00 | 0.00 | 0.00 | 0.00000 |
| F-4101A | 337840 | 7700146 | 39 | 0.5 | 20.8 | 394 | 0.07 | 2.48 | 0.10 | 0.00082 |
| F-4101B | 337857 | 7700146 | 39 | 0.5 | 0.3 | 394 | 0.00 | 0.02 | 0.00 | 0.00001 |
| A-6201 Routine | 337984 | 7700001 | 6 | 1.5 | 20.0 | 1273 | 0.00 | 0.01 | 0.00 | 0.00016 |
| A-6201 Non-Routine | 338087 | 7700001 | 6 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00000 |
| B-6210 | 337984 | 7699863 | 6 | 2.5 | 20.0 | 1273 | 0.00 | 0.03 | 0.00 | 0.00028 |

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| Source | Location | | Height | Radius | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|
| | (east) | (north) | (m) | (m) | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| Routine | | | | | | | | | | |
| B-6210 Non-Routine | 338087 | 7699864 | 6 | 2.5 | 20.0 | 1273 | 0.00 | 243.00 | 0.00 | 0.21211 |
| A-6203A | 339173 | 7700238 | 45 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| A-6203B | 339175 | 7700177 | 45 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| 1V-1102 | 338337 | 7700473 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1V-1102 | 338337 | 7700553 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1V-1102 | 338337 | 7700633 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| Ship Emissions | 342579 | 7697736 | 40 | 1 | 5.0 | 573 | 0.15 | 1.07 | 1.14 | 0.00047 |

### 7.6.5 Non-Routine Operation 2 – Emergency Shut-down

The second upset condition scenario is based on a process emergency shut-down. Shut-downs of the gas processing facility will occur for different reasons. They will be required for planned maintenance programs, in which case there will be the opportunity to minimise emissions by reducing the amount of gas directed to the flare system.

Alternatively, there could be an unplanned shut-down of one train requiring some flaring. It is anticipated that such circumstances will occur less than ten times in the first year of operation and be of less than one hour peak flaring reducing to six events per year over the next five years. The design capacity of the flare system is expected to be approximately 1 600 t/hr. This capacity will be refined during subsequent design phases.

Emissions characteristics for the second upset condition scenario are summarised in **Table 7-7**.

- **Table 7-7 Upset Condition 2 Emissions Data**

| Source | Location | | Height | Radius | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|
| | (east) | (north) | (m) | (m) | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| 1KT-1510 | 338552 | 7700584 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1510 | 338554 | 7700473 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1510 | 338735 | 7700586 | 40 | 2.75 | 21.9 | 613 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1KT-1530 | 338735 | 7700476 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1530 | 338921 | 7700588 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1530 | 338921 | 7700479 | 40 | 2.75 | 21.9 | 613 | 0.00 | 0.00 | 0.00 | 0.00000 |
| GT-4001 | 338406 | 7700246 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4002 | 338525 | 7700331 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4003 | 338527 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4004 | 338577 | 7700330 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4005 | 338579 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.00 | 0.00 | 0.00 | 0.00000 |

| Source | Location | | Height | Radius | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|
| | (east) | (north) | (m) | (m) | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| F-4101A | 337840 | 7700146 | 38.5 | 0.5 | 0.3 | 394 | 0.00 | 0.02 | 0.00 | 0.00001 |
| F-4101B | 337857 | 7700146 | 38.5 | 0.5 | 0.3 | 394 | 0.00 | 0.00 | 0.00 | 0.00000 |
| A-6201 Routine | 337984 | 7700001 | 6 | 1.5 | 20.0 | 1273 | 0.00 | 0.01 | 0.00 | 0.00016 |
| A-6201 Non-Routine | 338087 | 7700001 | 6 | 18.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00000 |
| B-6210 Routine | 337984 | 7699863 | 6 | 2.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00000 |
| B-6210 Non-Routine | 338087 | 7699864 | 6 | 27 | 20.0 | 1273 | 0.00 | 405.60 | 0.00 | 0.21211 |
| A-6203A | 339173 | 7700238 | 45 | 5.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| A-6203B | 339175 | 7700177 | 45 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| 1V-1102 | 338337 | 7700473 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1V-1102 | 338337 | 7700553 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| 1V-1102 | 338337 | 7700633 | 15 | 1 | 0.0 | 0 | 0.00 | 0.00 | 0.00 | 0.00000 |
| Ship Emissions | 342579 | 7697736 | 40 | 1 | 5.0 | 573 | 0.00 | 0.00 | 0.00 | 0.00000 |

### 7.6.6 Non-Routine Operation 3 – $CO_2$ Venting

Reservoir $CO_2$ is proposed to be injected into the Dupuy formation beneath Barrow Island. Non-routine $CO_2$ venting may occur primarily due to two events:

- The $CO_2$ compression units are offline while the AGRU is operating, which is expected to occur for approximately 5% of the AGRU operating time; and
- The $CO_2$ reservoir (or wells) are not injecting at the assumed capacity while the AGRU and $CO_2$ compression units are operating. This upset condition is expected to occur for approximately 15% of the AGRU operating time.

In both cases it will be necessary to vent $CO_2$ from the AGRUs to the atmosphere. As trace amounts of $H_2S$ are also present in the feed gas and normally removed with $CO_2$, in these cases trace quantities of $H_2S$ will also be vented to atmosphere with the $CO_2$. It is estimated that approximately 66 kg/hr of non-combusted $H_2S$ will be vented under these circumstances. The gas processing facility will continue to operate normally whilst venting of the $CO_2$ and $H_2S$ occurs.

Emissions characteristics for the third upset conditions are summarised in **Table 7-7**. These emissions represent the worst case emissions which would occur when the $CO_2$ compression units are offline while the AGRU is operating. This scenario is only expected to occur for approximately 20% of the time that the AGRU is operating.

## Table 7-8 Upset Condition 3 Emissions Data

| Source | Location | | Height | Radius | Ex. Vel | Temp | PM10 | $NO_x$ | $SO_2$ | Rsmog |
|---|---|---|---|---|---|---|---|---|---|---|
| | (east) | (north) | (m) | (m) | (m/s) | (K) | (g/s) | (g/s) | (g/s) | (g/s) |
| 1KT-1510 | 338552 | 7700584 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1510 | 338554 | 7700473 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1510 | 338735 | 7700586 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 1KT-1530 | 338735 | 7700476 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 2KT-1530 | 338921 | 7700588 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| 3KT-1530 | 338921 | 7700479 | 40 | 2.75 | 21.9 | 613 | 0.58 | 3.87 | 1.48 | 0.00782 |
| GT-4001 | 338406 | 7700246 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4002 | 338525 | 7700331 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4003 | 338527 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4004 | 338577 | 7700330 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| GT-4005 | 338579 | 7700236 | 40 | 2.75 | 29.9 | 731 | 0.56 | 14.17 | 1.70 | 0.00931 |
| F-4101A | 337840 | 7700146 | 38.5 | 0.5 | 0.3 | 394 | 0.00 | 0.02 | 0.00 | 0.00001 |
| F-4101B | 337857 | 7700146 | 38.5 | 0.5 | 0.3 | 394 | 0.00 | 0.00 | 0.00 | 0.00000 |
| A-6201 Routine | 337984 | 7700001 | 6 | 1.5 | 20.0 | 1273 | 0.00 | 0.01 | 0.00 | 0.00016 |
| A-6201 Non-Routine | 338087 | 7700001 | 6 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00000 |
| B-6210 Routine | 337984 | 7699863 | 6 | 2.5 | 20.0 | 1273 | 0.00 | 0.03 | 0.00 | 0.00028 |
| B-6210 Non-Routine | 338087 | 7699864 | 6 | 2.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00000 |
| A-6203A | 339173 | 7700238 | 45 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| A-6203B | 339175 | 7700177 | 45 | 1.5 | 20.0 | 1273 | 0.00 | 0.00 | 0.00 | 0.00005 |
| 1V-1102 | 338337 | 7700473 | 15 | 1 | 16.5 | 322 | 0.00 | 0.00 | 0.00 | 0.75426 |
| 1V-1102 | 338337 | 7700553 | 15 | 1 | 16.5 | 322 | 0.00 | 0.00 | 0.00 | 0.75426 |
| 1V-1102 | 338337 | 7700633 | 15 | 1 | 16.5 | 322 | 0.00 | 0.00 | 0.00 | 0.75426 |
| Ship Emissions | 342579 | 7697736 | 40 | 1 | 5.0 | 573 | 0.15 | 1.07 | 1.14 | 0.00047 |

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# 8. Air Quality Modelling Results

This section presents the results of atmospheric dispersion modelling for the proposed plant under a series of scenarios, including the existing and approved sources, and the cumulative impacts from the combined set of sources. The modelling results are presented for the sensitive receptor locations and are compared to the relevant assessment criteria. The maximum predicted concentration anywhere within the defined air quality assessment area (grid) is also reported and compared to the assessment criteria.

## 8.1 Potential Impact on Human Health (sensitive receptors)

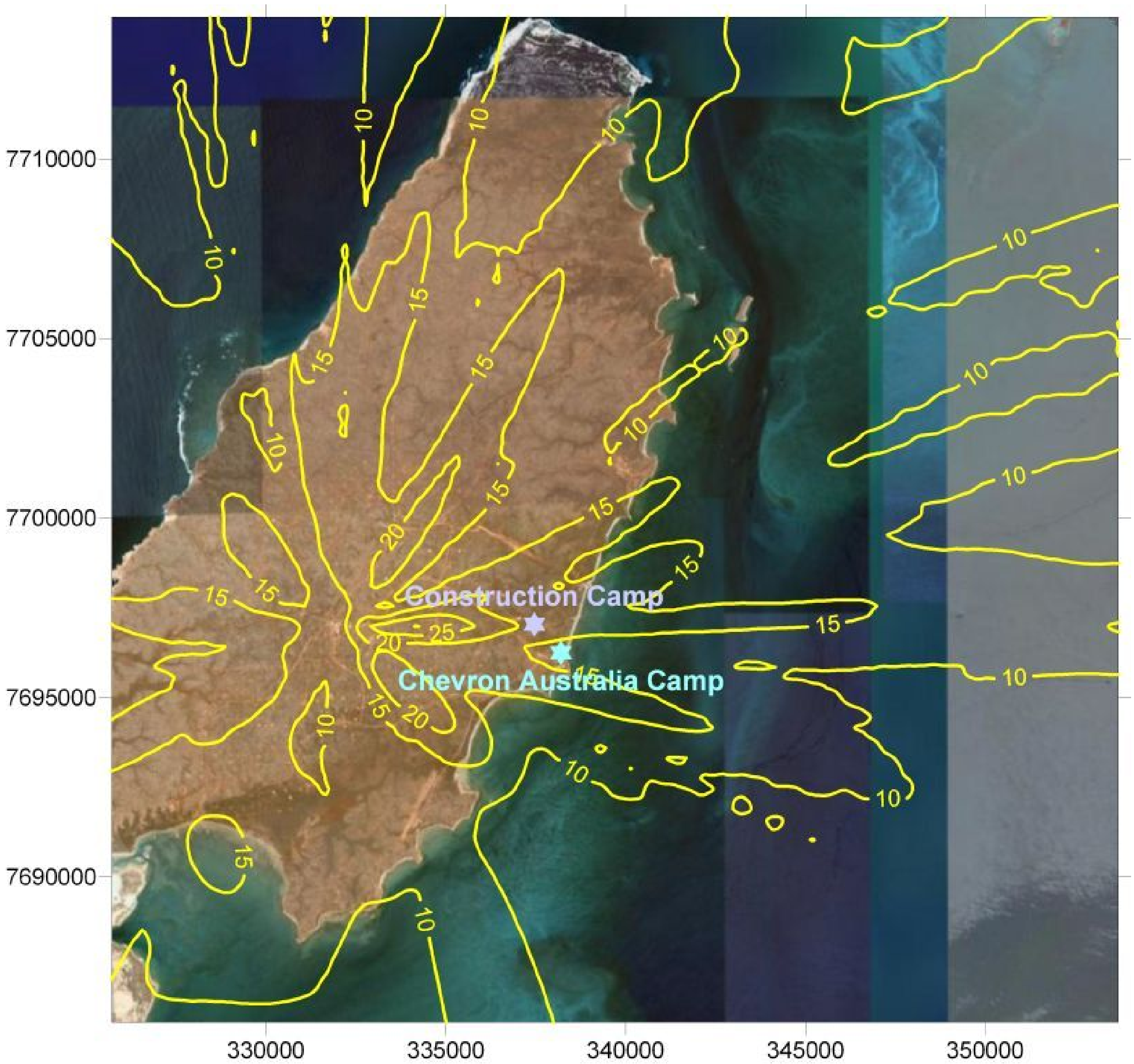
### 8.1.1 Existing Air Quality with Currently Approved Projects

Existing air quality for the existing and approved projects within the region was modelled and the results are presented in the following section. The emissions from the existing and approved projects are outlined in **Table 7-4** and include:

- NWSV Karratha Gas Plant (including trains 4 and 5);
- Approved Pluto project;
- Hamersley Iron Power Station;
- Existing operations on Barrow Island; and
- Burrup Fertilisers ammonia plant.

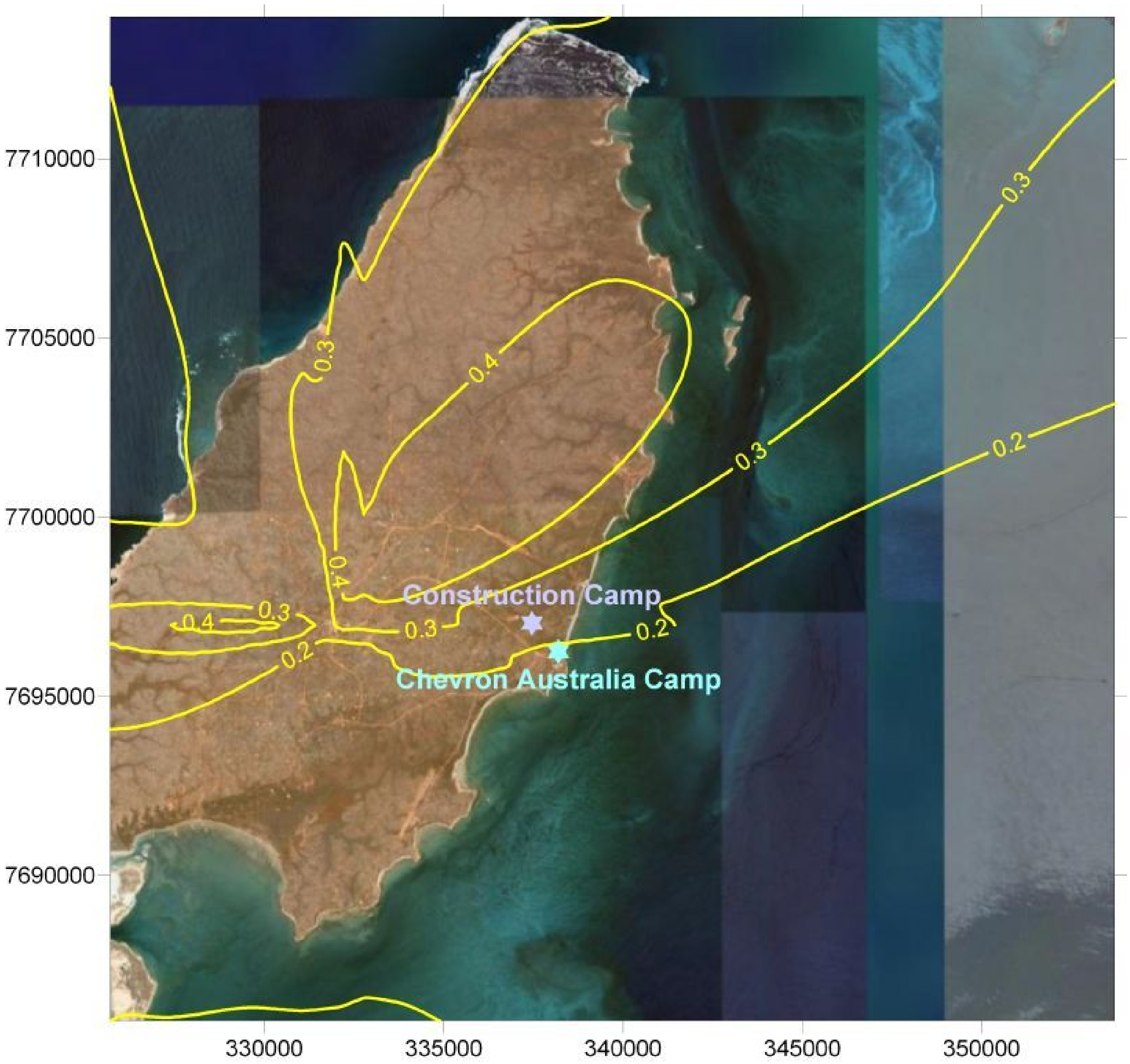
#### 8.1.1.1 Oxides of Nitrogen

The maximum predicted 1-hour $NO_2$ concentrations on Barrow Island for the existing and approved sources is presented in **Figure 8-1**. From this figure it is evident that Barrow Island experiences very low concentrations of $NO_2$ derived predominately from existing sources on the island. The Chevron Australia camp has a predicted maximum $NO_2$ concentration of 15 $\mu g/m^3$ which is 6.1% of the relevant NEPM criteria.




- **Figure 8-1 Maximum existing 1-hour $NO_2$ concentrations ($\mu g/m^3$)**

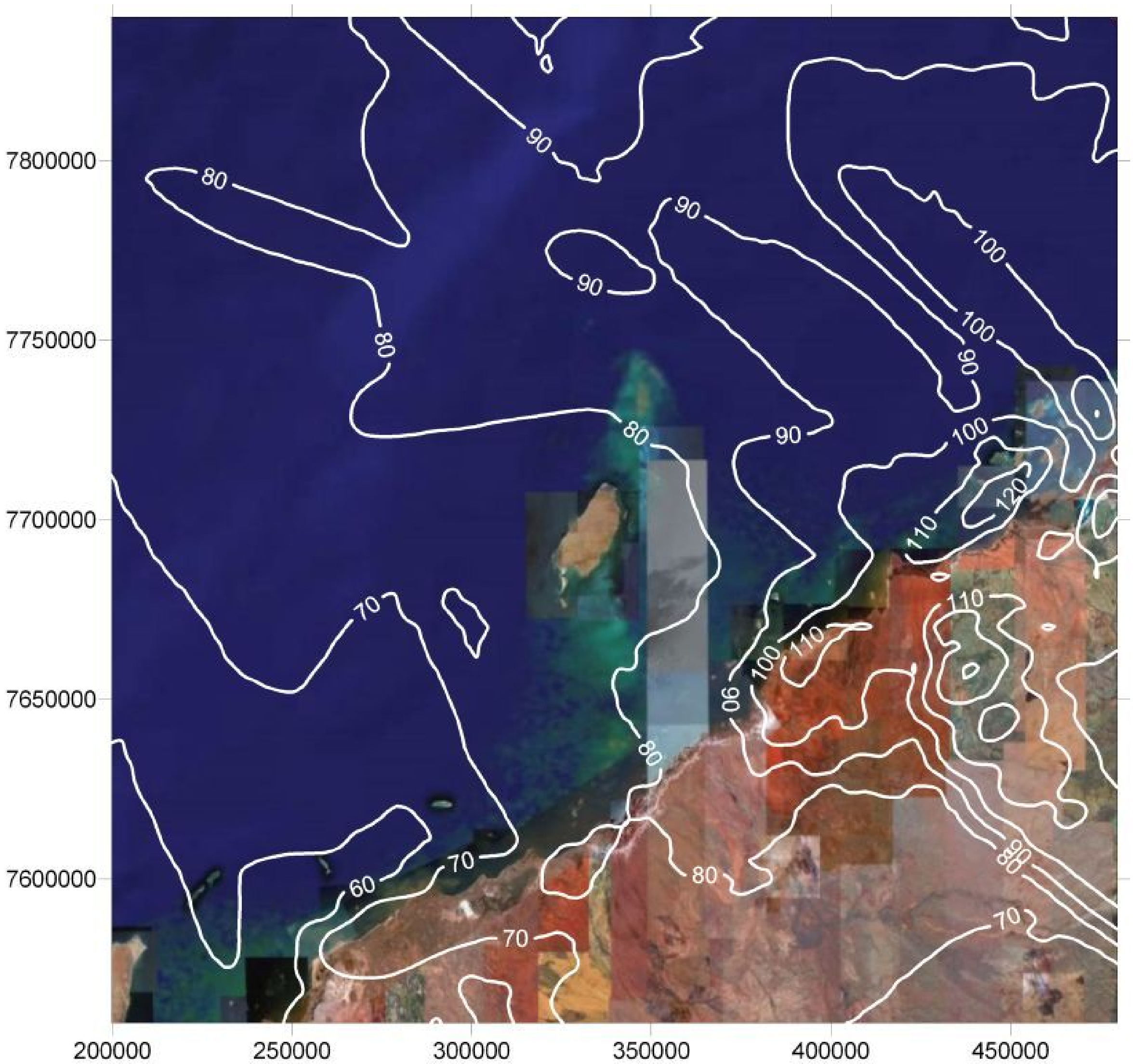
The annual average $NO_2$ concentrations on Barrow Island for the existing and approved sources is presented in **Figure 8-2**. From this figure it is evident that the annual average $NO_2$ concentration on Barrow Island from the existing and approved sources is very low. The Chevron Australia camp has a predicted maximum $NO_2$ concentration of approximately 0.18 $\mu g/m^3$ which is 0.3% of the relevant NEPM criteria.



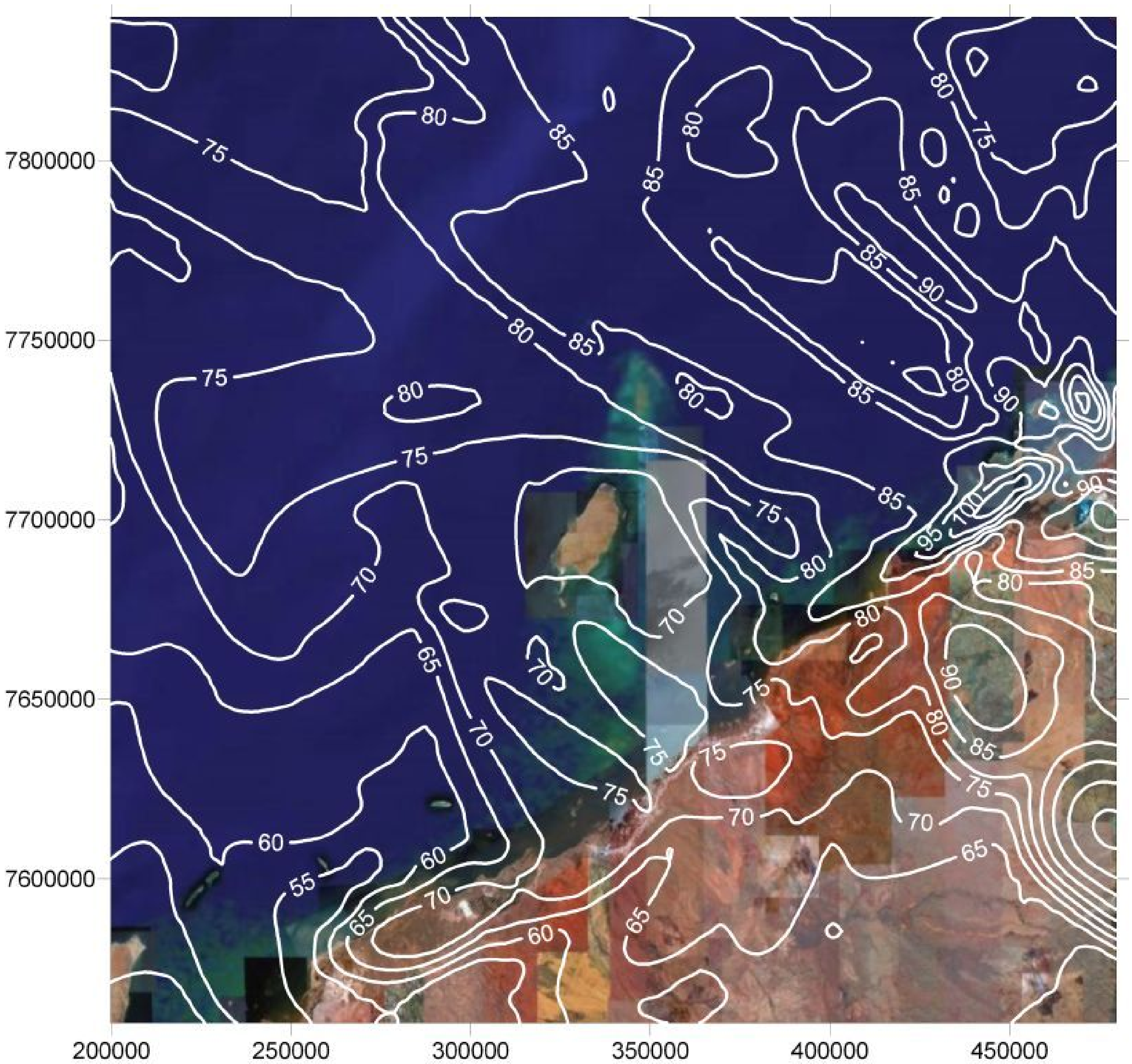

- **Figure 8-2 Predicted existing annual $NO_2$ concentrations ($\mu g/m^3$)**

#### 8.1.1.2 Ozone (as a Descriptor for Photochemical Smog)

The maximum predicted 1-hour ozone concentrations from the existing and approved sources in the coastal Pilbara region is presented in **Figure 8-3** while the predicted 4-hour ozone concentration is presented in **Figure 8-4**. From both of these figures it can be seen that the higher concentrations occur around the Burrup Peninsula and inland to the south of the Peninsula. These results are expected as nearly all of the $NO_x$ and VOC emissions are derived from sources located on the Burrup Peninsula (see **Section 7.6.1**).




- **Figure 8-3 Maximum existing 1-hour ozone concentrations (μg/m³)**

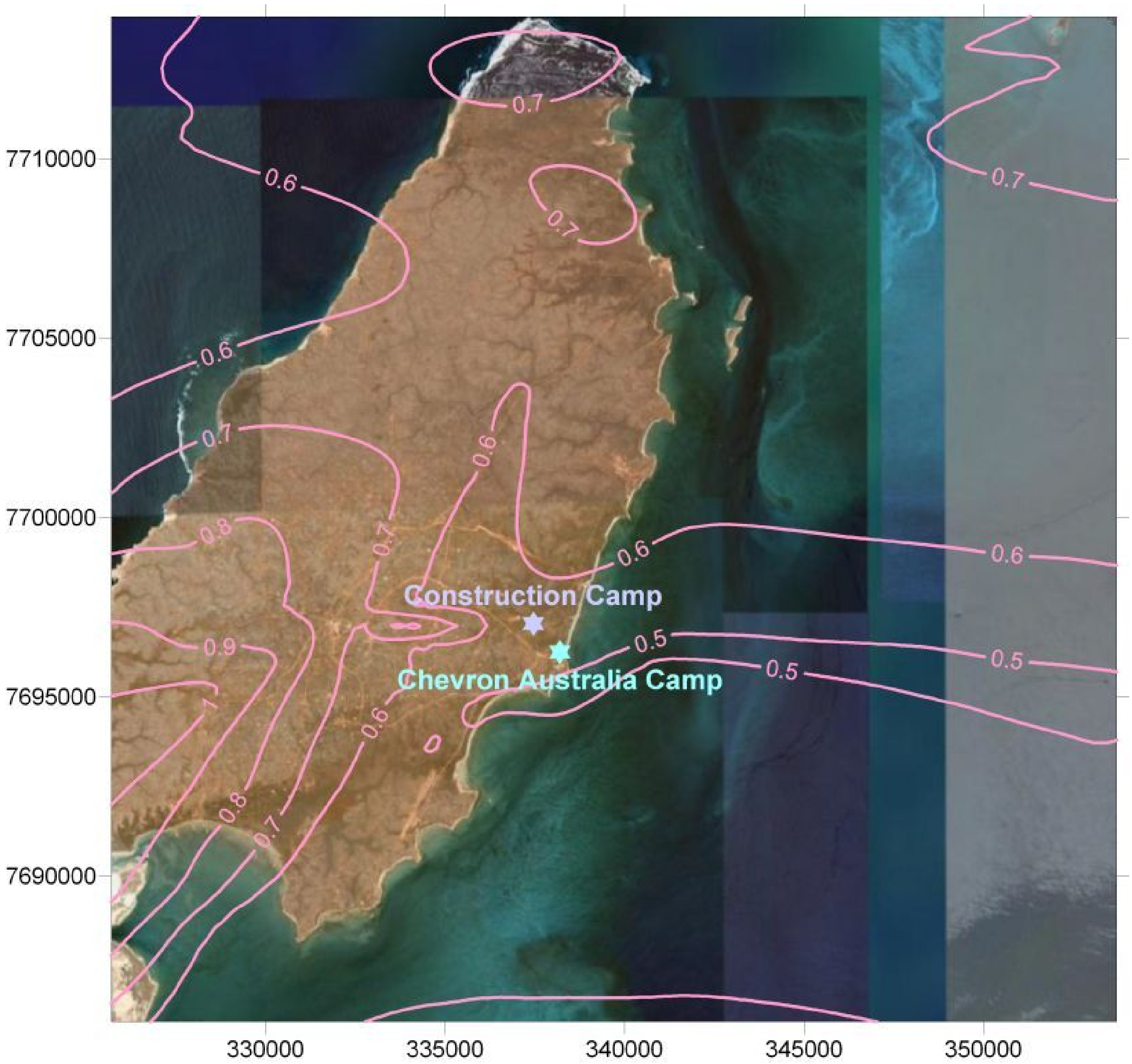



- **Figure 8-4 Maximum existing 4-hour ozone concentrations (μg/m$^3$)**

### 8.1.1.3 Sulfur Dioxide

The maximum predicted 1-hour $SO_2$ concentrations for the existing and approved sources on Barrow Island are presented in **Figure 8-5. Figure 8-6** and **Figure 8-7** represent the predicted 24-hour and annual average concentrations respectively. All three of these figures indicate that the predicted $SO_2$ concentrations on Barrow Island are very low for the existing and approved scenario.

The Chevron Australia Camp recorded a maximum 1-hour concentration of $SO_2$ of 0.52 μg/m$^3$ which is equivalent to 0.1% of the applicable NEPM criteria. The 24-hour and annual average concentrations at the Chevron Australia Camp were predicted to be 0.04% and 0.02% of the relevant NEPM criteria respectively.




▪ **Figure 8-5 Predicted existing 1-hour $SO_2$ concentrations ($\mu g/m^3$)**

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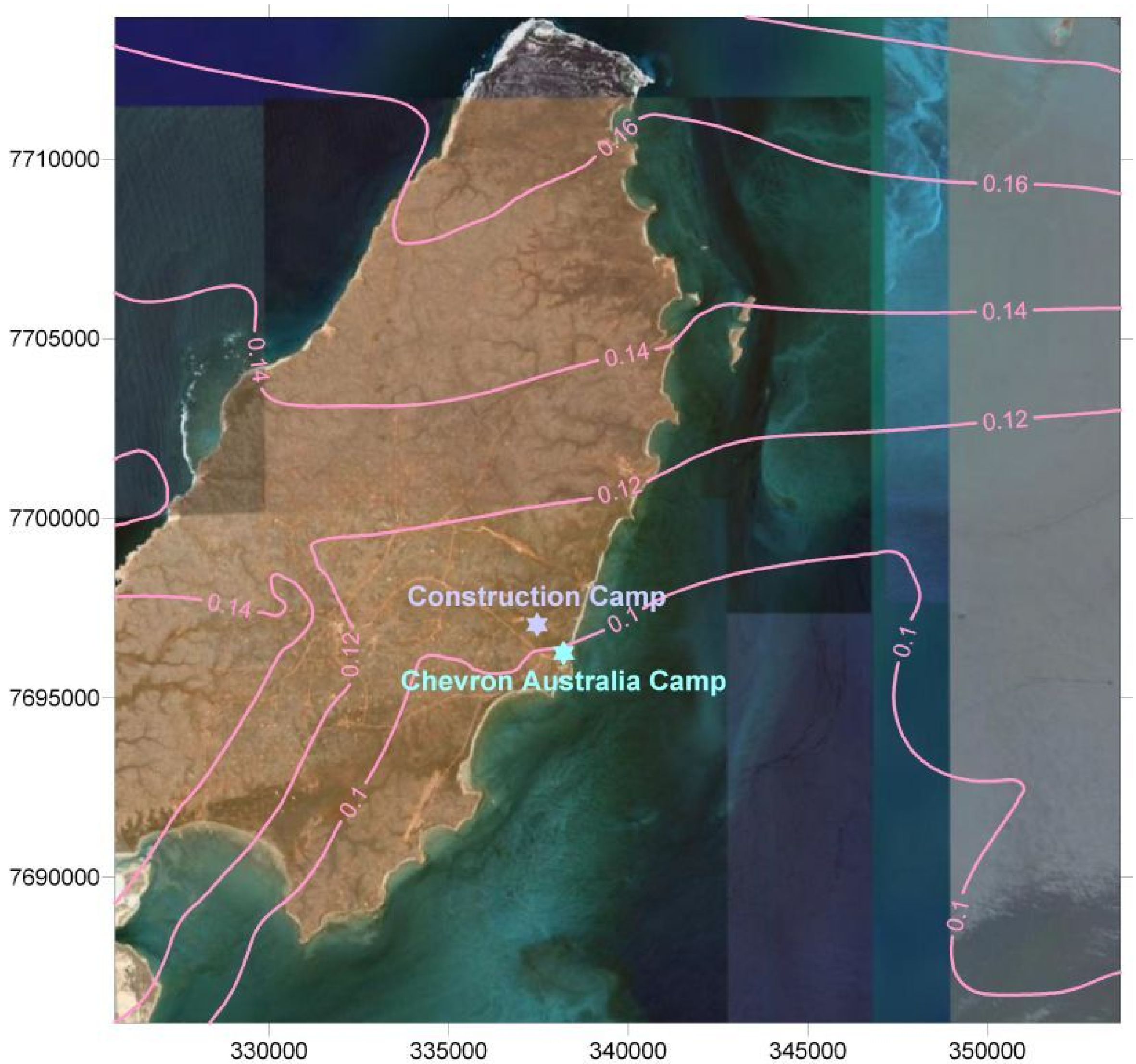
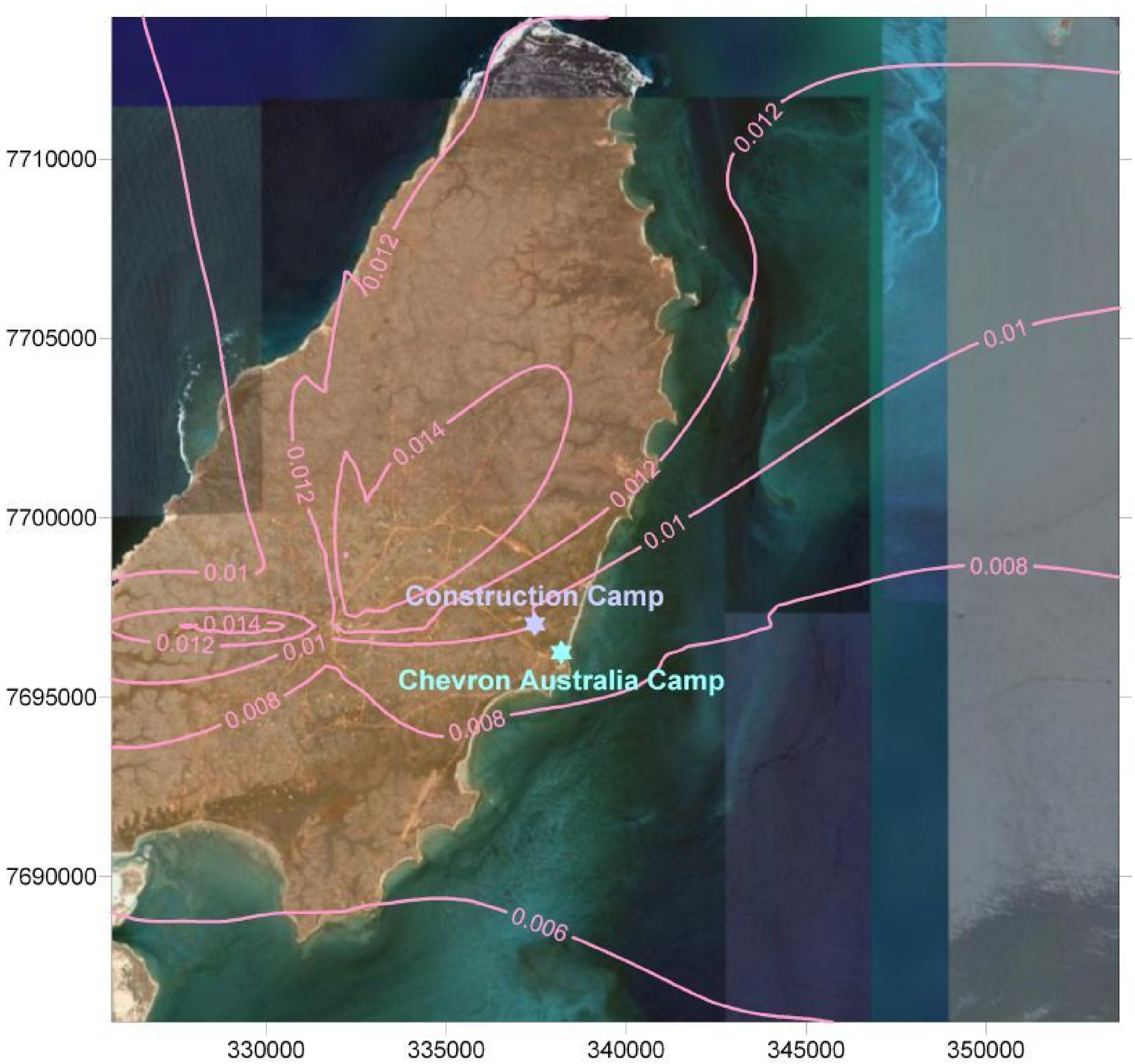



- **Figure 8-6 Predicted existing 24-hour $SO_2$ concentrations ($\mu g/m^3$)**




- **Figure 8-7 Predicted existing $SO_2$ concentrations ($\mu g/m^3$)**

#### 8.1.1.4 Maximum on Grids

The maximum predicted ground level concentrations from **Figure 8-1** to **Figure 8-7** are presented in **Table 8-1** along with their comparison to the applicable assessment criteria (as a percentage). From this table it can be seen that the maximum predicted concentrations of $NO_2$ and $SO_2$ are well below the applicable criteria for these pollutants on Barrow Island which is expected given the lack of anthropogenic sources currently on the island.

The maximum 1-hour and 4-hour ozone concentrations on the larger modelling grid are equivalent to 61.2% and 63.6% of the NEPM criteria for ozone. As was explained in **Section 8.1.1.2** these high concentrations occurred around the Burrup Peninsula as nearly all of the $NO_x$ and VOC emissions are derived from sources located in this area. On Barrow Island the existing ozone concentrations are predicted to be almost half the maximum predicted concentrations for each averaging period.

- **Table 8-1 Maximum predicted existing ground level concentration from approved projects on 3 km modelled grid**

| Pollutant | TAPM Grid | Averaging Period | Maximum on Grid ($\mu g/m^3$) | Assessment Criteria (NEPM) ($\mu g/m^3$) | Percentage of Assessment Criteria |
|---|---|---|---|---|---|
| $NO_2$ | 1 km | 1-hour | 30.9 | 246 | 12.5 |
| | | Annual | 0.49 | 62 | 0.8 |
| $O_3$ | 10 km | 1-hour | 130.9 | 214 | 61.2 |
| | | 4-hour | 108.8 | 171 | 63.6 |
| $SO_2$ | 1 km | 1-hour | 1.08 | 571 | 0.2 |
| | | 24-hour | 0.19 | 229 | 0.1 |
| | | Annual | 0.02 | 57 | 0.1 |

### 8.1.2 Predicted Air Quality – Routine Operations

The modelling for future air quality under routine operating conditions incorporates the existing and approved emission sources (**Section 7.6.1**) as well as the calculated emissions from the proposed Chevron Australia Gas Processing Facility on Barrow Island (**Section 7.6.2**). The pollutants taken into consideration in this section include $PM_{10}$, $NO_2$, $O_3$ and $SO_2$. The following sections present the results of this modelling.

#### 8.1.2.1 Oxides of Nitrogen

The maximum predicted 1-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia Gas Treatment Plant under routine operation is presented in **Figure 8-8**. When the results presented in this figure are compared to the existing scenario (**Figure 8-1**) it is evident that the concentration of $NO_2$ has increased throughout the modelled grid. The maximum on the grid has increased by 11.7 $\mu g/m^3$ to 42.6 $\mu g/m^3$ which is equivalent to 17.3% of the NEPM criteria.

The Chevron Australia camp has a predicted maximum $NO_2$ concentration of 20 $\mu g/m^3$, which represents an increase of 5 $\mu g/m^3$, and is 8.1% of the relevant NEPM criteria. The proposed construction camp has a predicted concentration of 21 $\mu g/m^3$ or 8.5% of the criteria.

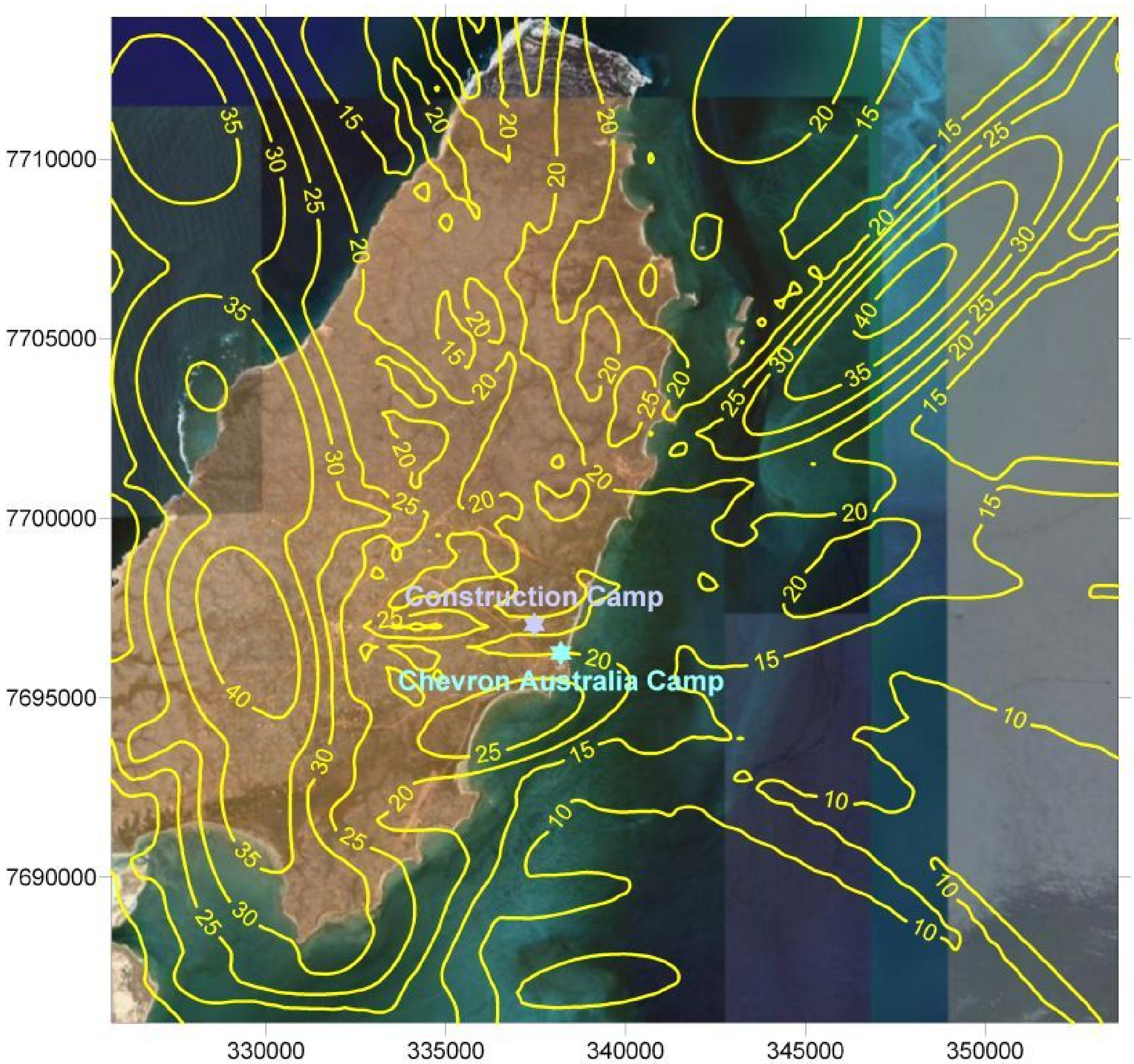
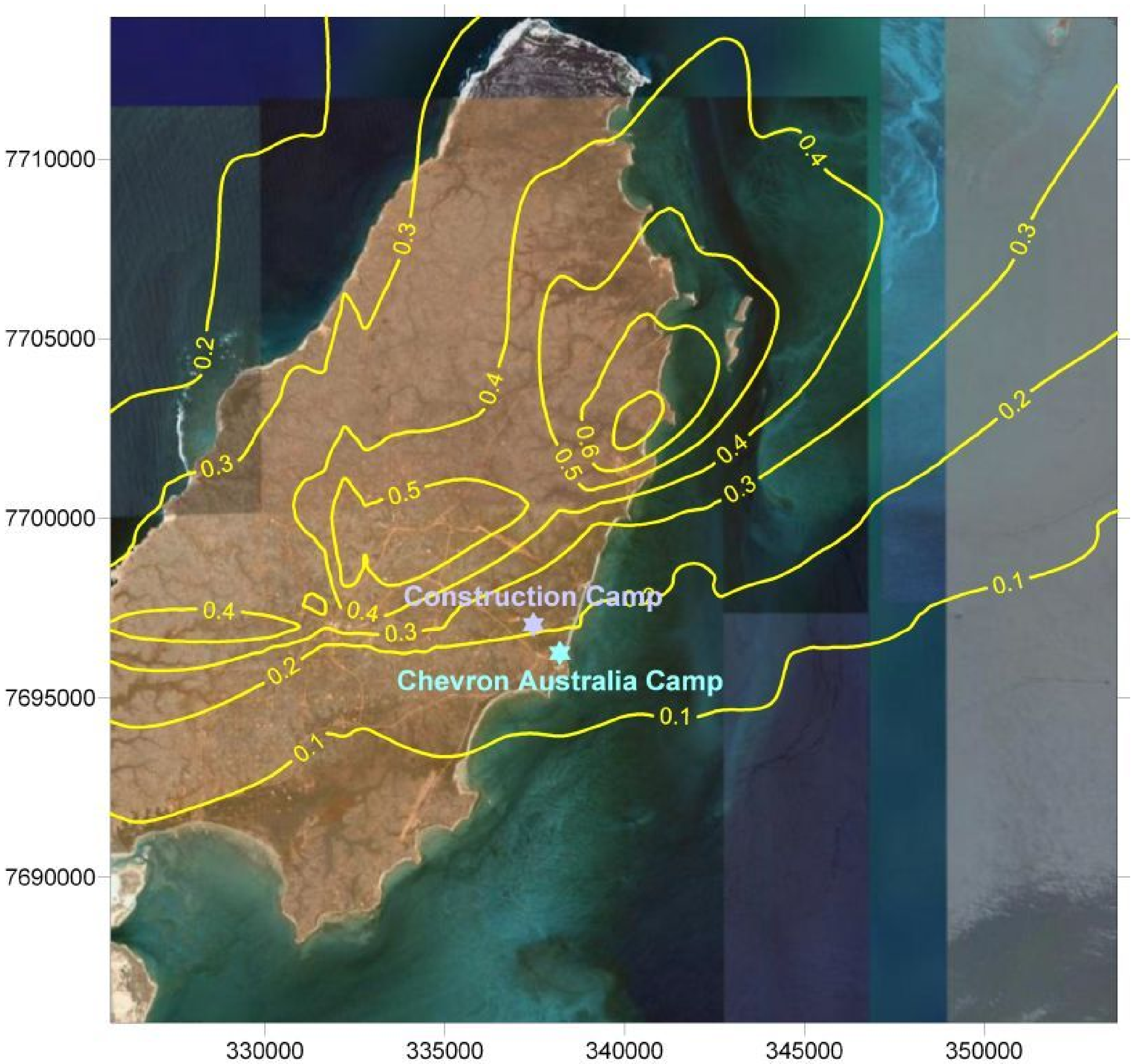



**Figure 8-8 Maximum predicted 1-hour $NO_2$ concentrations ($\mu g/m^3$)**

The annual average $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility operating under normal operating conditions is presented in **Figure 8-9**. When this figure is compared to the predicted annual average for the existing and approved scenario (**Figure 8-2**) it is apparent that there is an increase in $NO_2$.

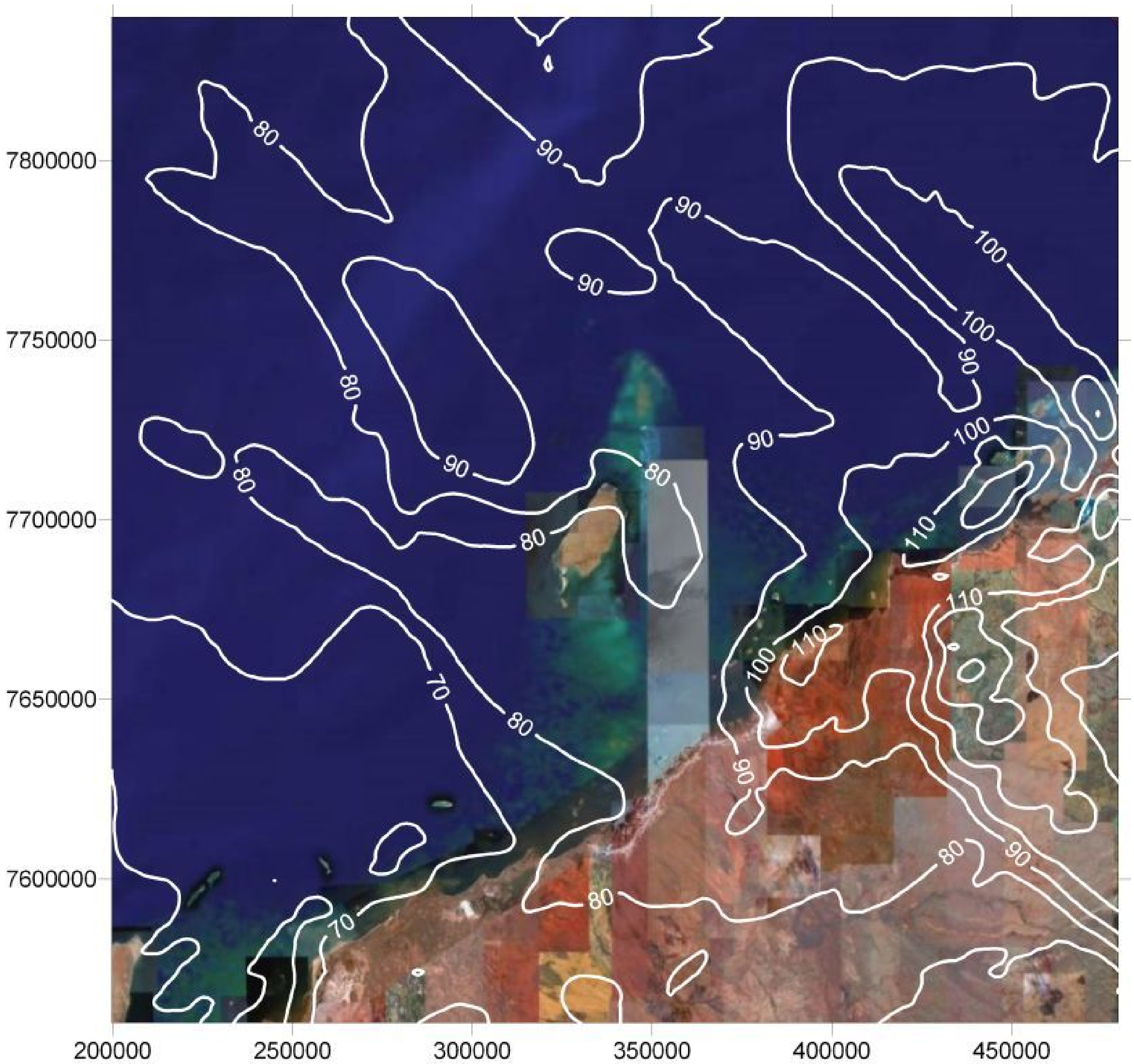
The Chevron Australia camp has a predicted maximum $NO_2$ concentration of approximately 0.18 $\mu g/m^3$ which is 0.3% of the relevant NEPM criteria while the proposed construction camp has a predicted annual average concentration of 0.22 $\mu g/m^3$ which corresponds to 0.4% of the NEPM criteria.




- **Figure 8-9 Maximum predicted annual $NO_2$ concentrations ($\mu g/m^3$)**

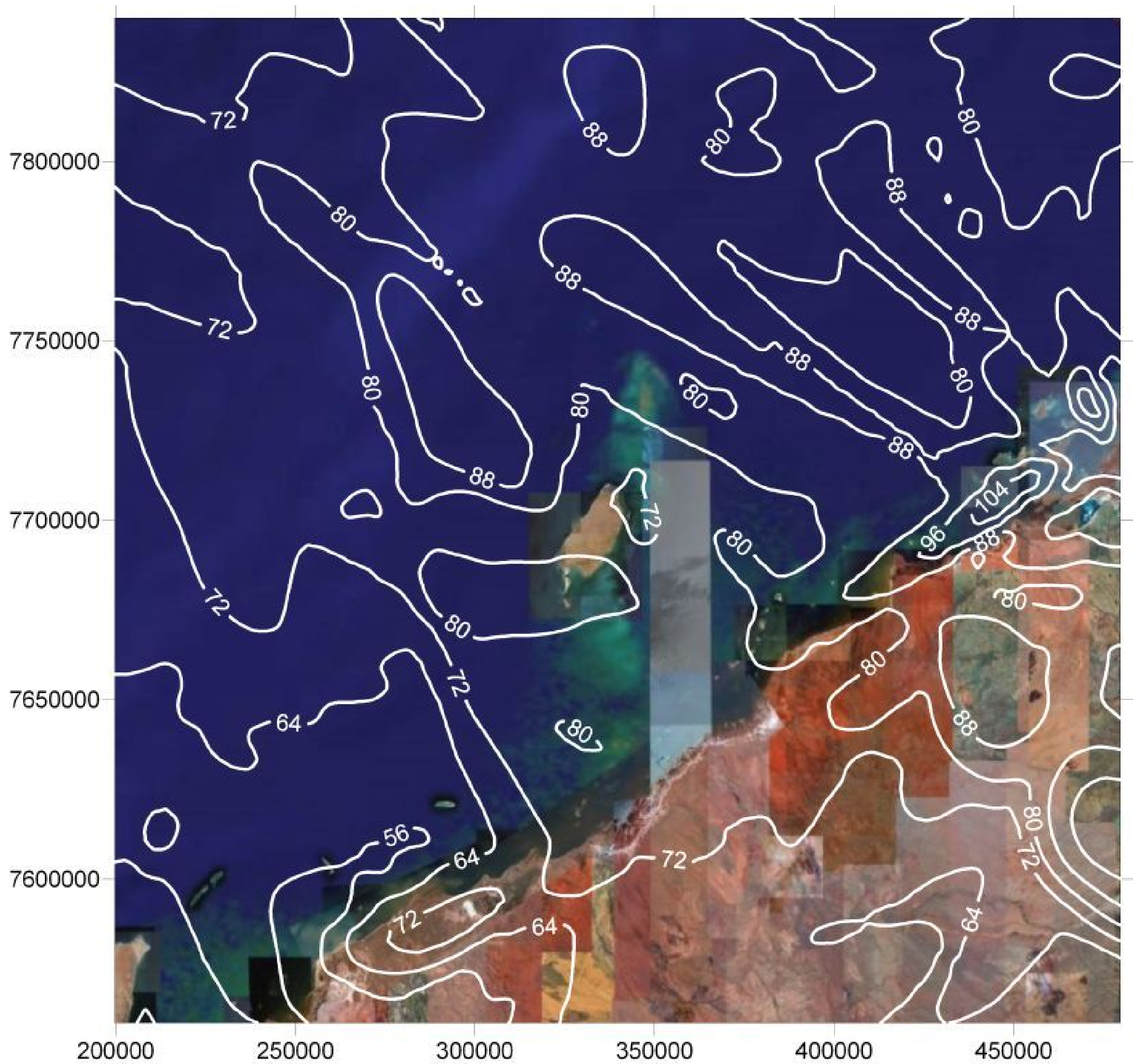
#### 8.1.2.2 Ozone (as a descriptor for photochemical smog)

The maximum predicted 1-hour ozone concentrations from the proposed Chevron Australia facility during routine operations (with the existing and approved sources) in the coastal Pilbara region is presented in **Figure 8-10**. When the concentrations in this figure are compared to that predicted to occur for the existing and approved scenario (**Figure 8-3**) it is apparent that the introduction of the proposed Chevron Australia facility results in a slight increase in the predicted 1-hour ground level concentrations of ozone to the north west of Barrow Island. There is little change in the predicted ground level concentrations towards the Burrup Peninsula and inland which is to be expected considering the volume of $NO_x$ and VOC emission sources located within the Burrup Peninsula (see **Section 7.6.1**).




▪ **Figure 8-10 Maximum predicted 1-hour ozone concentrations (μg/m³)**

The maximum predicted 4-hour ozone concentrations from the proposed Chevron Australia facility (with the existing and approved sources) in the coastal Pilbara region is presented in **Figure 8-11**. When the concentrations in this figure are compared to that predicted to occur for the existing and approved scenario (**Figure 8-4**) it is apparent that the introduction of the proposed Chevron Australia facility results in an increase in the predicted 4-hour ground level concentrations of ozone around Barrow Island. Around the Burrup Peninsula and inland Pilbara there are some subtle changes to the predicted ground level concentrations with some localities recording a slight decrease with minor increases at other locations.

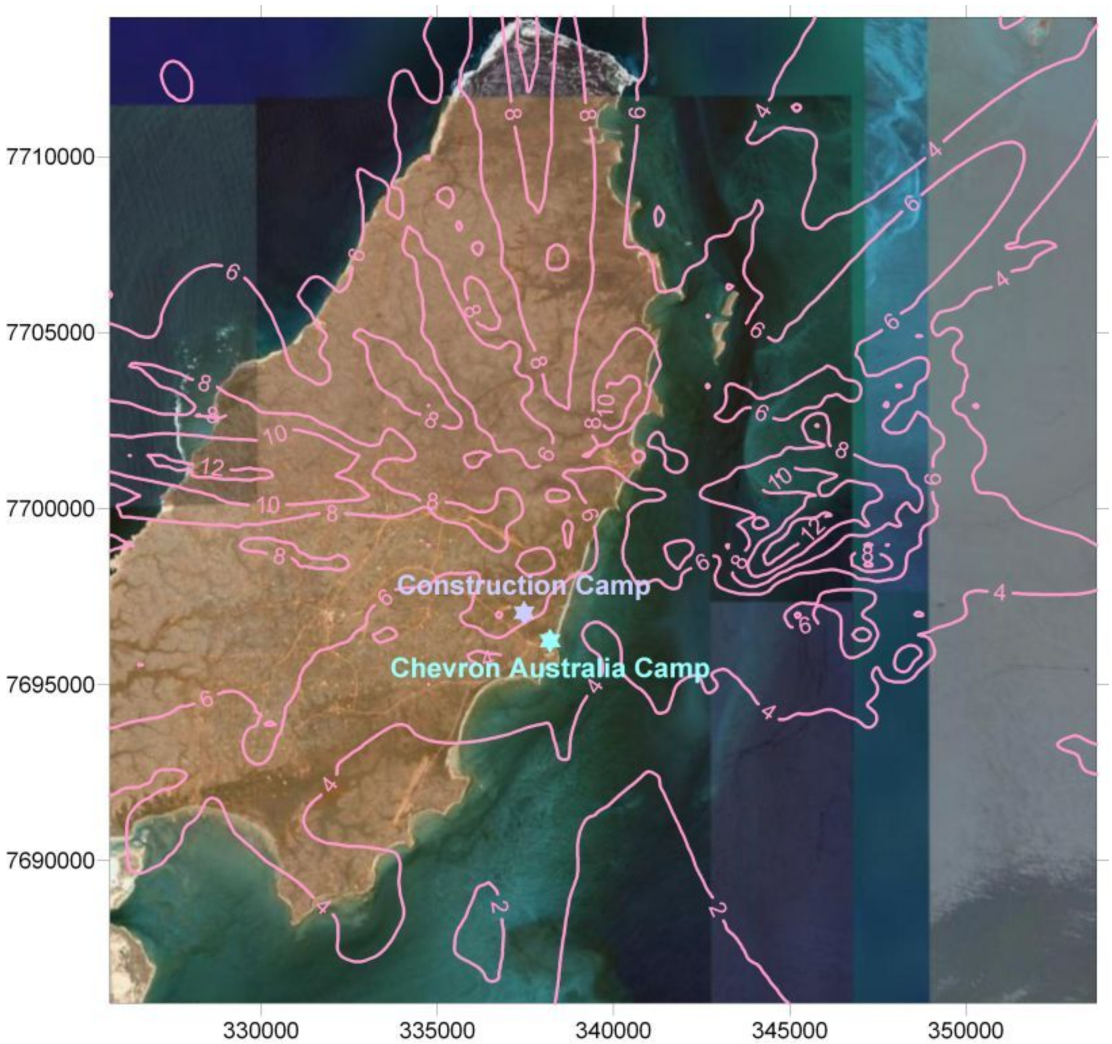



- **Figure 8-11 Maximum predicted 4-hour ozone concentrations (µg/m³)**

#### 8.1.2.3 Sulfur Dioxide

The maximum predicted 1-hour $SO_2$ concentrations for the proposed Chevron Australia facility operating during normal conditions (with existing and approved sources) on Barrow Island are presented in **Figure 8-12**. When the predicted results in this figure are compared to that predicted to occur during the existing scenario (**Figure 8-5**) it is apparent that there is an increase in the predicted ground level concentrations over Barrow Island. This increase in ground level concentrations is expected due to the increase in emissions of $SO_2$ from sources within the proposed facility (**Table 7-5**).

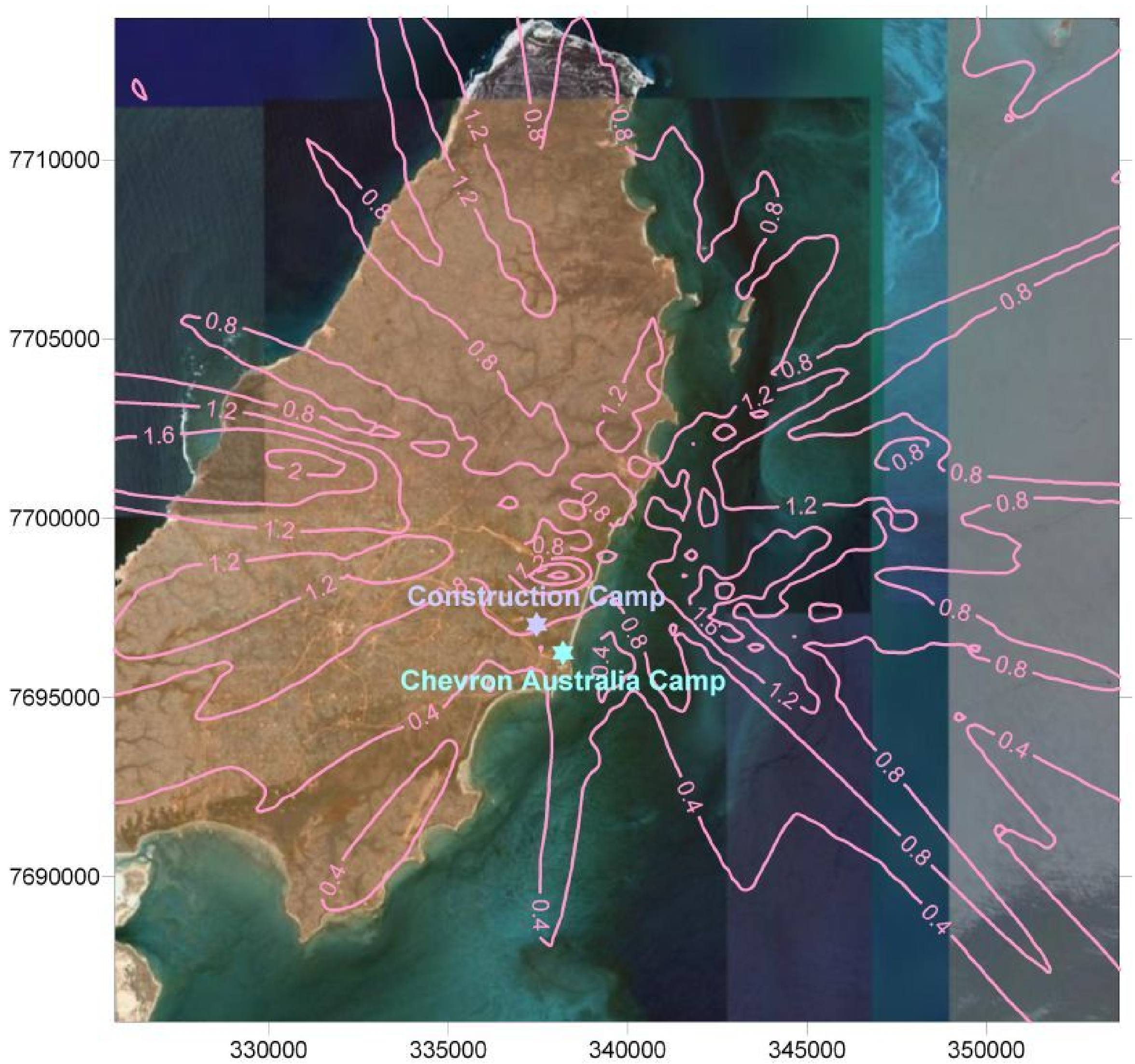
The Chevron Australia Camp has a maximum predicted 1-hour concentration of $SO_2$ of 5 µg/m$^3$ while the proposed construction camp has a predicted concentration of 6.1 µg/m$^3$ which is equivalent to 0.9% and 1.1% of the applicable NEPM criteria, respectively.



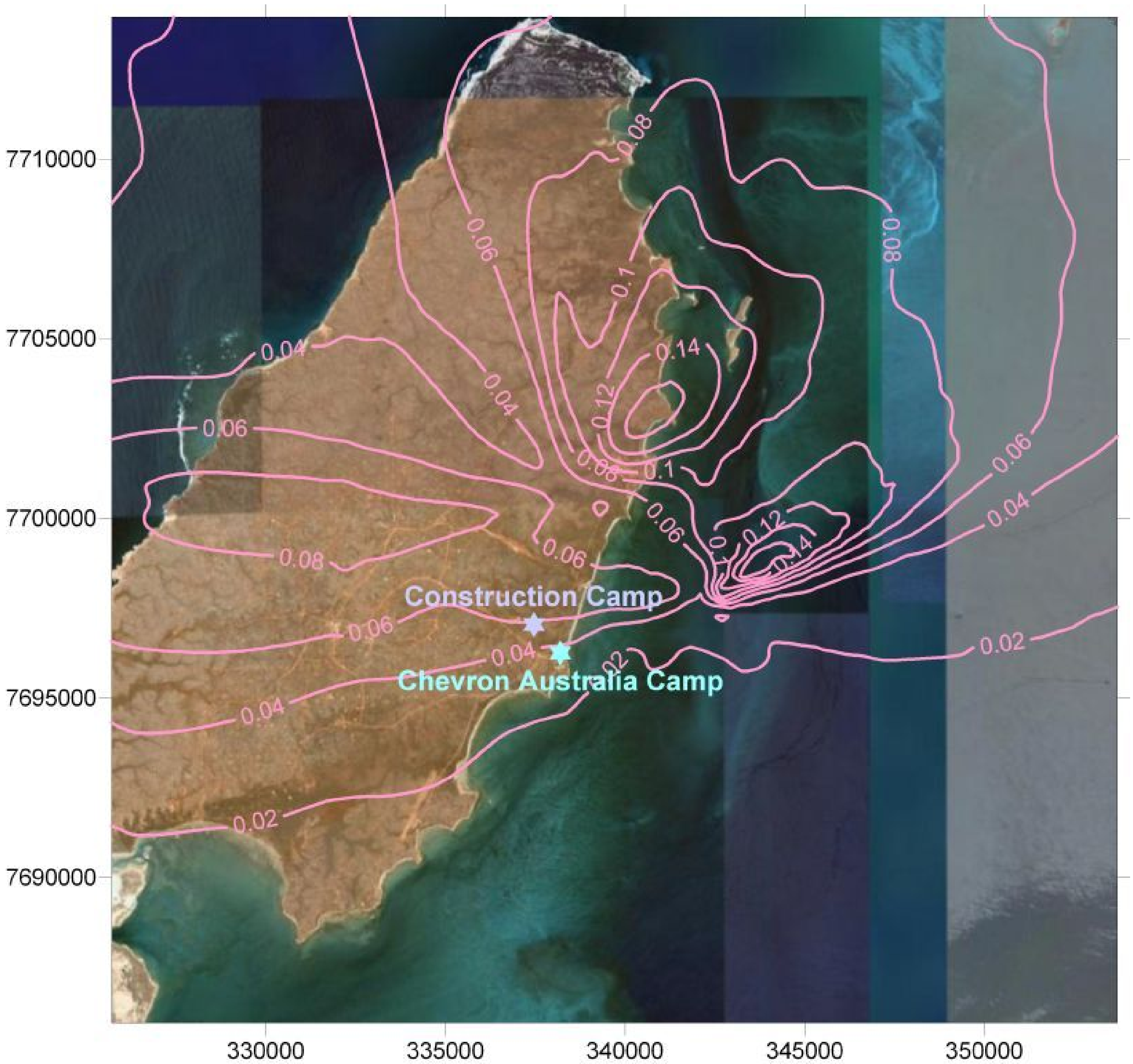

- **Figure 8-12 Maximum predicted 1-hour $SO_2$ concentrations (µg/m$^3$)**

The predicted 24-hour and annual average ground level concentrations are presented in **Figure 8-13** and **Figure 8-14** respectively. As with the predicted 1-hour concentrations there is an increase in the predicted 24-hour and annual average concentrations on Barrow Island.

The 24-hour and annual average concentrations at the Chevron Australia Camp were predicted to be 0.2% and 0.1% of the relevant NEPM criteria, respectively. At the proposed construction camp the 24-hour and annual average concentrations are predicted to be 0.3% and 0.1% of the relevant NEPM criteria, respectively.




▪ **Figure 8-13 Maximum predicted 24-hour $SO_2$ concentrations ($\mu g/m^3$)**

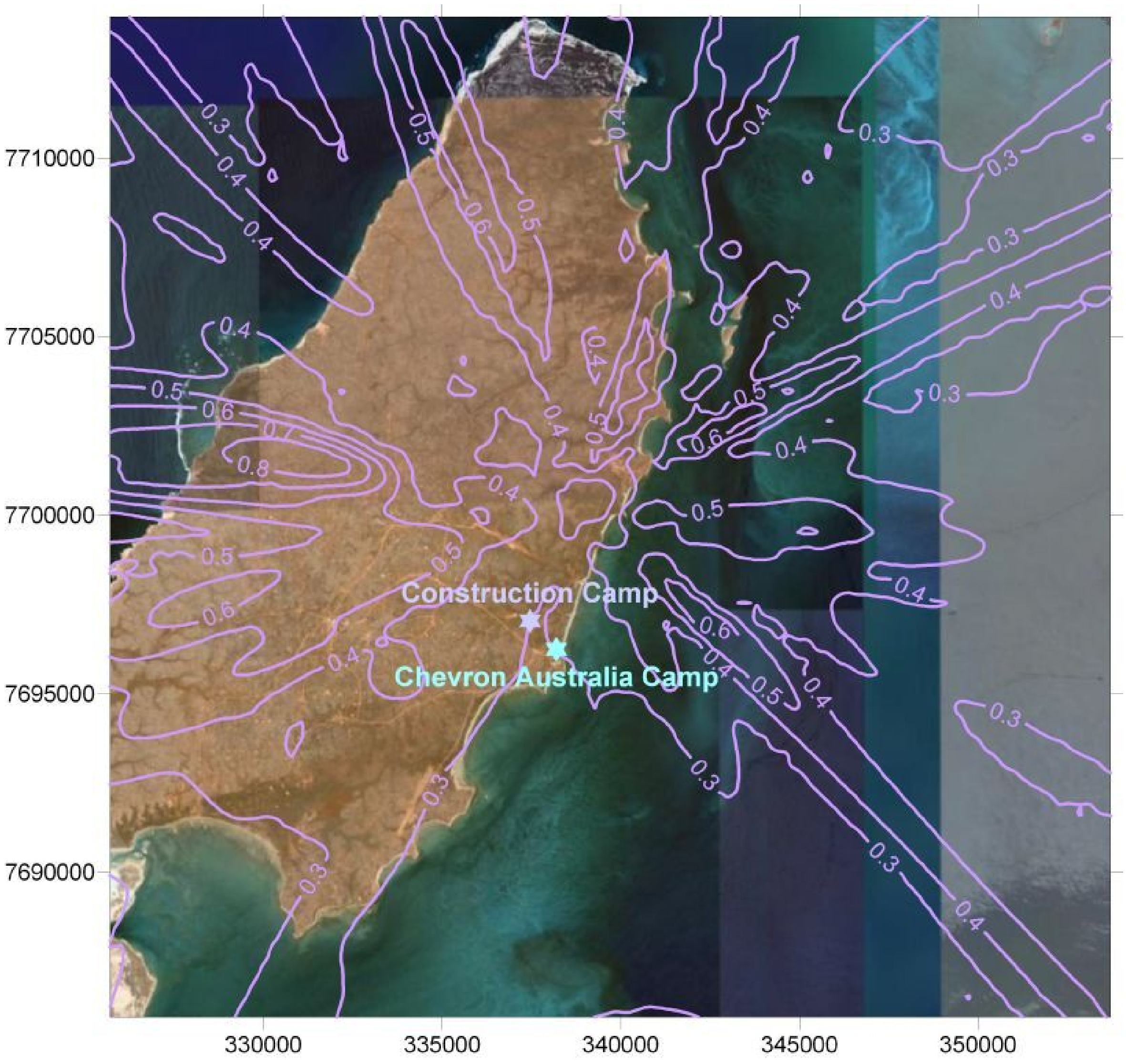



- **Figure 8-14 Predicted annual $SO_2$ concentrations ($\mu g/m^3$)**

### 8.1.2.4 Particulate Matter ($PM_{10}$)

The ground level concentrations of $PM_{10}$ that are predicted to result during normal operations of the proposed Chevron Australia facility are presented in **Figure 8-15**. From this figure it is evident that during normal operations the emissions of $PM_{10}$ from the proposed Chevron Australia facility will result in only a minor increase in ground level concentrations. It should be noted that the results presented in this figure do not include background concentrations of $PM_{10}$.

The maximum 24-hour ground level concentration of $PM_{10}$ at both the Chevron Australia Camp and the proposed construction camp is predicted to be 0.3 µg/m$^3$ which is equivalent to 0.6% of the NEPM criteria.




▪ **Figure 8-15 Maximum predicted 24-hour $PM_{10}$ concentrations (µg/m$^3$)**

#### 8.1.2.5 Maximum on Grid

The maximum predicted ground level concentrations from **Figure 8-8** to **Figure 8-15** are presented in **Table 8-2** along with the percentage of the applicable NEPM criteria. When the results presented in this table are compared to the results from the existing and approved scenario (**Table 8-1**) the increase in the ground level concentrations of $NO_2$ and $SO_2$ as a result of the proposed

Chevron Australia facility is apparent. It should be noted that even though it is predicted that the maximum ground level concentrations of $NO_2$ and $SO_2$ are predicted to increase they are still well within the relevant NEPM criteria.

The maximum 1-hour and 4-hour ozone concentrations on the larger modelling grid are equivalent to 61.6% and 64.1% of the NEPM criteria for ozone. This represents only a minor increase above that predicted to occur for the existing and approved scenario (**Table 8-1**) with the maximum concentrations occurring adjacent to the Burrup Peninsula.

**Table 8-2 Maximum predicted future ground level concentration on the modelled grid under routine operating conditions**

| Pollutant | TAPM Grid | Averaging Period | Maximum on Grid ($\mu g/m^3$) | Assessment Criteria ($\mu g/m^3$) | Percentage of Assessment Criteria |
|---|---|---|---|---|---|
| $NO_2$ | 1 km | 1-hour | 42.6 | 246 | 17.3 |
| | | Annual | 0.7 | 62 | 1.2 |
| $O_3$ | 10 km | 1-hour | 131.9 | 214 | 61.6 |
| | | 4-hour | 109.6 | 171 | 64.1 |
| $SO_2$ | 1 km | 1-hour | 14.6 | 571 | 2.6 |
| | | 24-hour | 2.6 | 229 | 1.2 |
| | | Annual | 0.2 | 57 | 0.3 |
| $PM_{10}$ | 1 km | 24-hour | 0.9 | 50 | 1.8 |

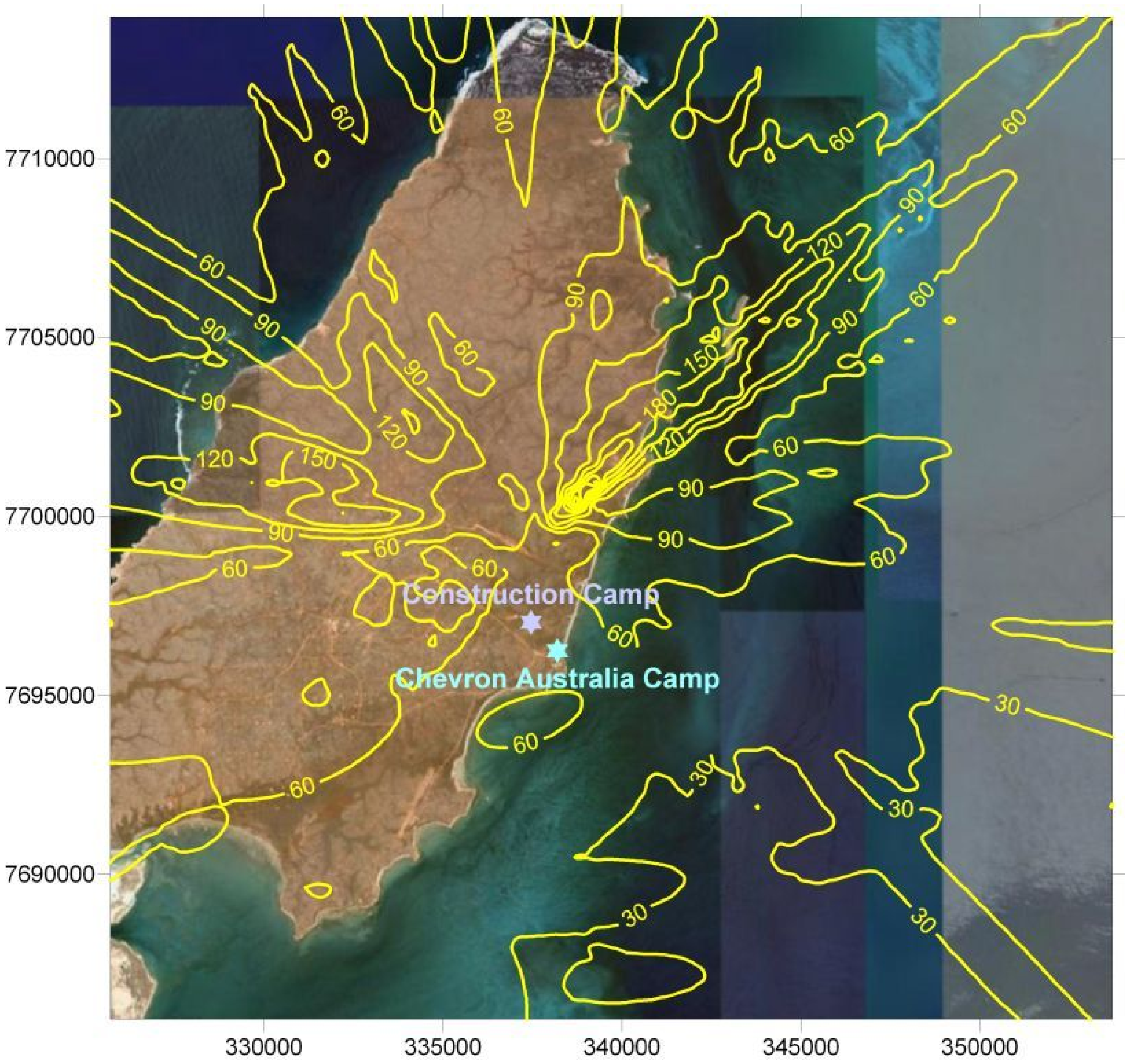
### 8.1.3 Predicted Air Quality – Non-Routine Operation 1 – Start-up

The modelling for future air quality during the first upset condition incorporates the existing and approved emission sources (**Section 7.6.1**) as well as the calculated emissions from the proposed Chevron Australia gas processing facility during start up (**Section 7.6.4**). The pollutants taken into consideration in this section include $PM_{10}$, $NO_2$, $O_3$ and $SO_2$. The following sections present the results of this modelling.

#### 8.1.3.1 Oxides of Nitrogen

The maximum predicted 1-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during start up operations is presented in **Figure 8-16**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-8**) it is evident that the concentrations of $NO_2$ have increased significantly. The maximum $NO_2$ concentration is 135% of the NEPM criteria and occurs immediately to the northeast of the proposed facility. The cause of this high concentration is due to the high $NO_2$ emissions as approximately 30% of the normal flow rate of a single LNG train may be directed to the flare as the LNG is brought to product specification (**Section 7.6.4**). Analysis of the output file indicates that this high concentration only occurs for a single hour as the second highest concentration is 72% of the NEPM.

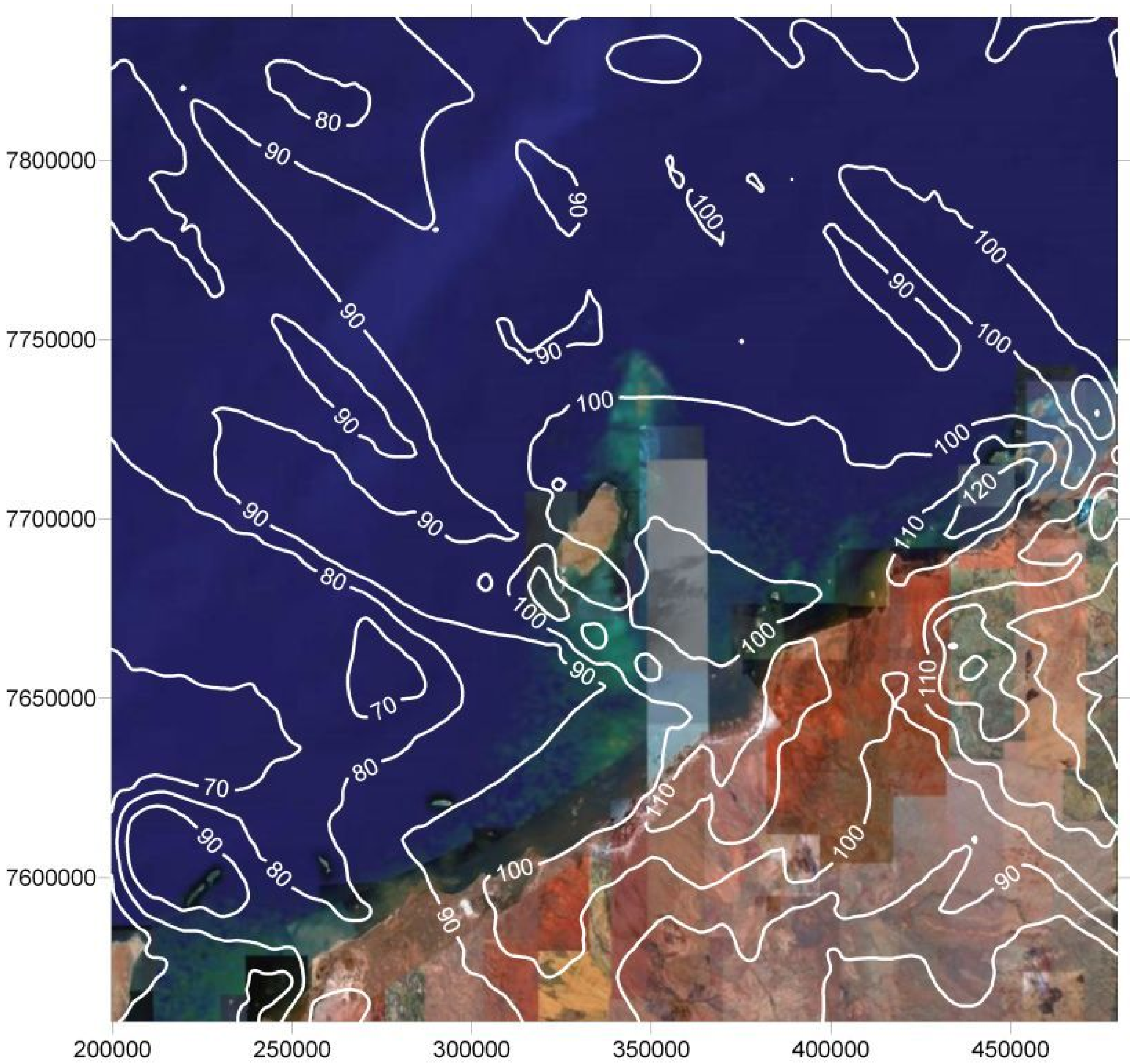
Both the Chevron Australia and proposed construction camps have a predicted maximum $NO_2$ concentration of 82 µg/m$^3$ during start up, which is 33.3% of the relevant NEPM criteria.




▪ **Figure 8-16 Maximum 1-hour ground level concentrations of $NO_2$ during start-up**

#### 8.1.3.2 Ozone (as a descriptor for photochemical smog)

The maximum predicted 1-hour ozone concentrations from the proposed Chevron Australia facility during start up conditions (with the existing and approved sources) in the coastal Pilbara region is presented in **Figure 8-17**. When the concentrations in this figure are compared to that predicted to occur for the facility during normal operating conditions (**Figure 8-10**) it is apparent that the main change in the predicted ground level concentrations occurs immediately to the south of Barrow Island. There is basically no change to the predicted concentrations over the Burrup Peninsula or inland areas of the Pilbara.

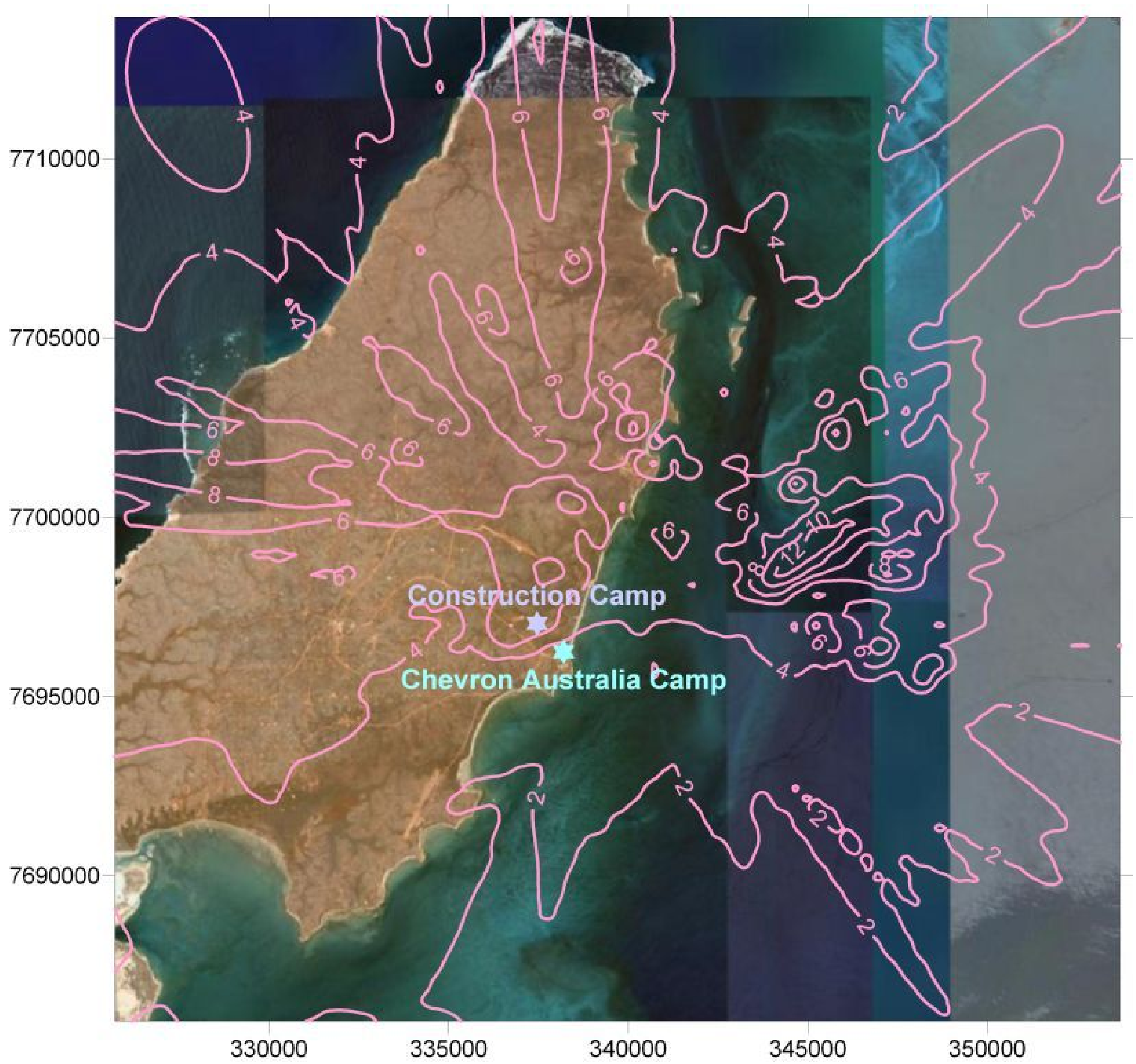



- **Figure 8-17 Maximum 1-hour ground level concentrations of $O_3$ during start-up**

### 8.1.3.3 Sulfur Dioxide

The maximum predicted 1-hour $SO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during start up operations is presented in **Figure 8-18**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-12**) it is evident that there is very little change on the predicted concentrations of $SO_2$.

The Chevron Australia camp has a predicted maximum $SO_2$ concentration of 3.9 $\mu g/m^3$ during start up, while the construction camp has a predicted concentration of 6.4 $\mu g/m^3$ both of which are well within the relevant NEPM criteria.

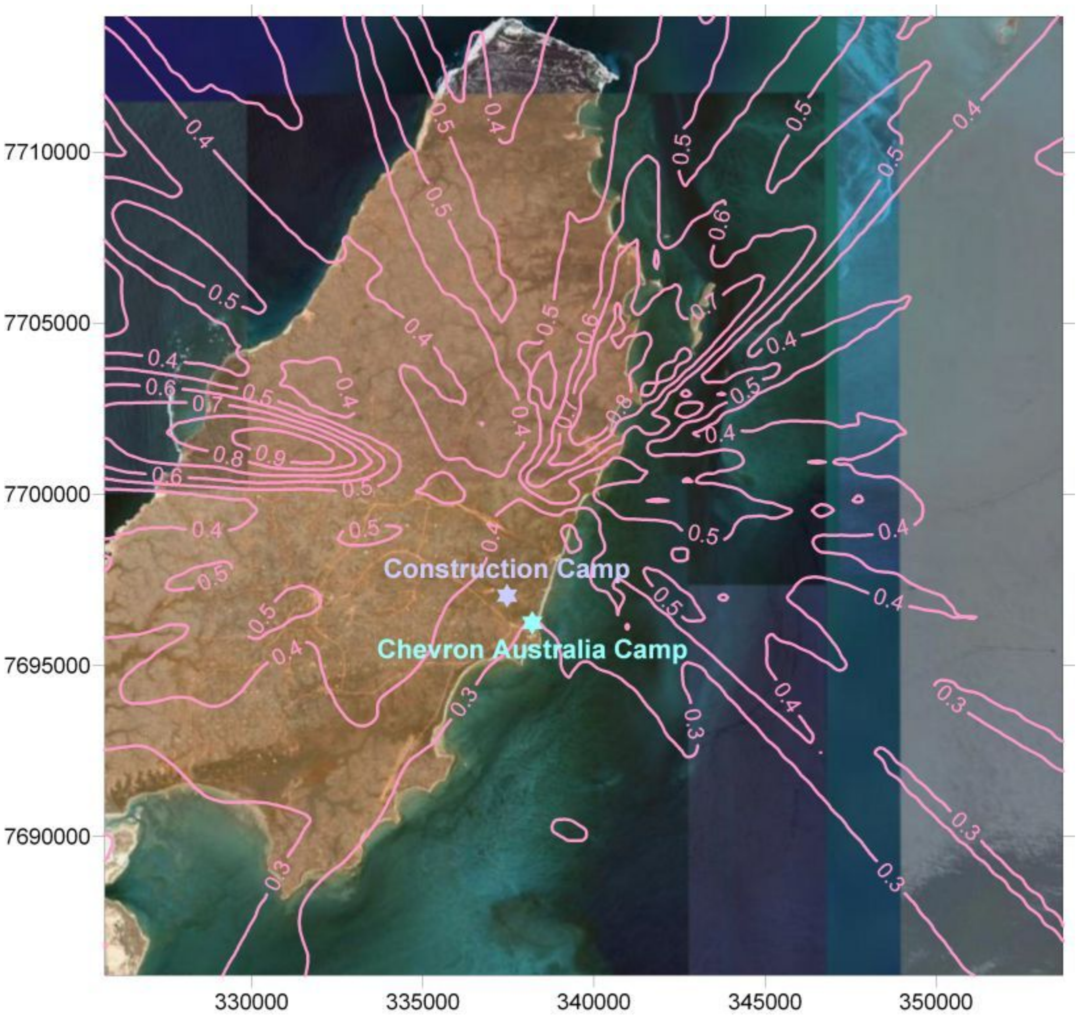



- **Figure 8-18 Maximum 1-hour ground level concentrations of $SO_2$ during start-up**

### 8.1.3.4 Particulate Matter ($PM_{10}$)

The maximum predicted 24-hour $PM_{10}$ concentrations on Barrow Island for the proposed Chevron Australia facility during start up operations is presented in **Figure 8-19**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-15**) it is evident there are only subtle differences between the two scenarios.

Both camps are predicted to have a maximum $PM_{10}$ concentration below 1% of the relevant NEPM criteria during start up.




- **Figure 8-19 Maximum 24-hour ground level concentrations of $PM_{10}$ during start-up**

#### 8.1.3.5 Maximum on Grid

The maximum predicted ground level concentrations from **Figure 8-16** to **Figure 8-19** are presented in **Table 8-3** along with the percentage of the applicable NEPM criteria. When the results presented in this table are compared to the results from the proposed facility during normal operating conditions (**Table 8-2**) it is noticeable that the only significant increase occurs with $NO_2$. The main cause of this increase is the dramatic increase in $NO_2$ emissions from flaring that occurs during start up.

The maximum 1-hour ozone concentrations on the larger modelling grid is 61.8% of the NEPM criteria for ozone and represents a very minor increase above that predicted to occur for the proposed facility during normal operating conditions (**Table 8-2**).

- **Table 8-3 Maximum predicted future ground level concentration on the modelled grid during start-up**

| Pollutant | TAPM Grid | Averaging Period | Maximum on Grid ($\mu g/m^3$) | Assessment Criteria ($\mu g/m^3$) | Percentage of Assessment Criteria |
|---|---|---|---|---|---|
| $NO_2$ | 1 km | 1-hour | 341 | 246 | 139 |
| $O_3$ | 10 km | 1-hour | 132.2 | 214 | 61.8 |
| $SO_2$ | 1 km | 1-hour | 14.8 | 571 | 2.6 |
| $PM_{10}$ | 1 km | 24-hour | 1 | 50 | 2 |

### 8.1.4 Predicted Air Quality – Non-Routine Operation 2 – Emergency Shut-down

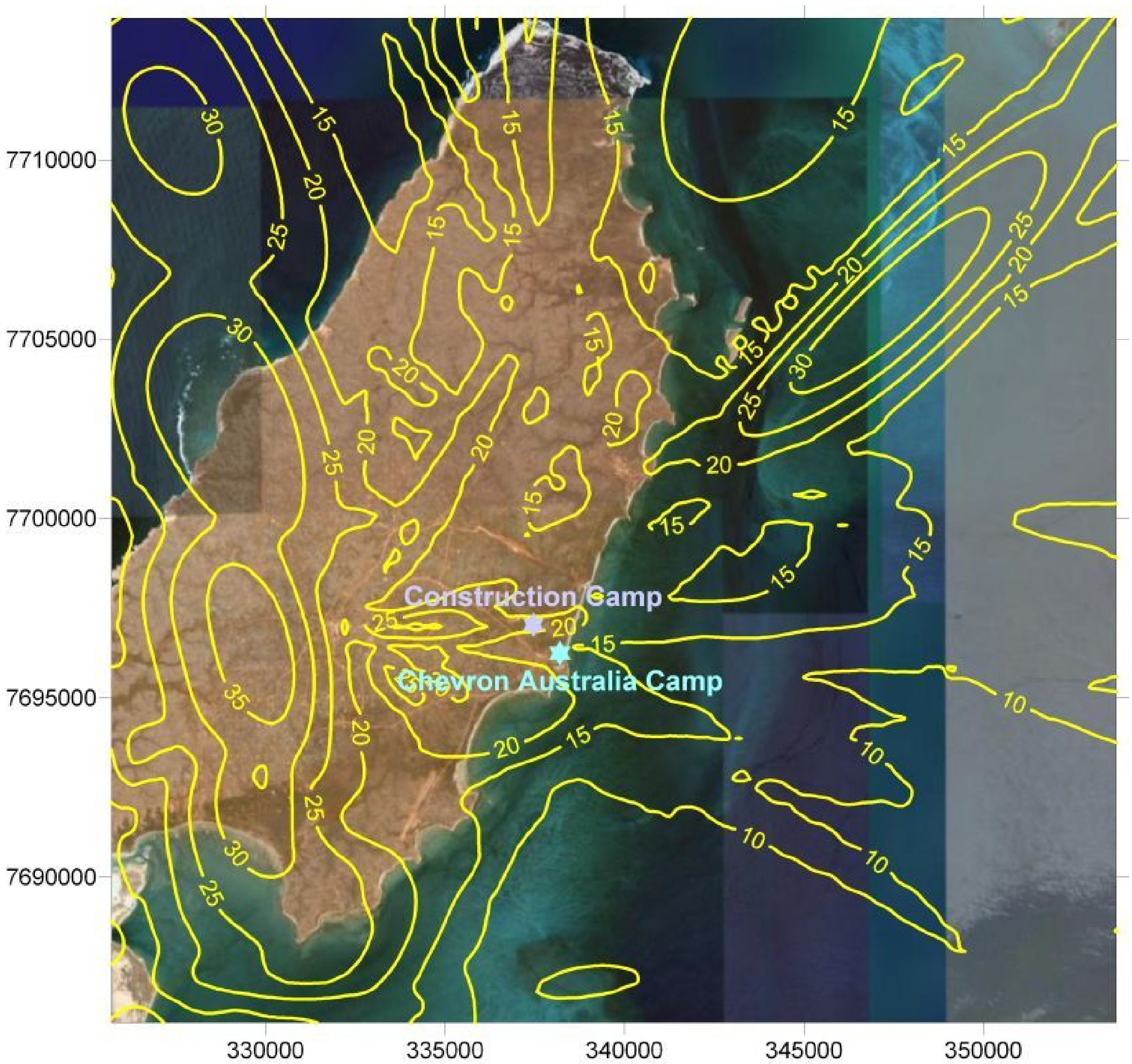
The modelling for future air quality during the second upset condition incorporates the existing and approved emission sources (**Section 7.6.1**) as well as the calculated emissions from the proposed Chevron Australia gas processing facility during an emergency shut-down (**Section 7.6.5**). The pollutants taken into consideration in this section include $PM_{10}$, $NO_2$, $O_3$ and $SO_2$. The following sections present the results of this modelling.

#### 8.1.4.1 Oxides of Nitrogen

The maximum predicted 1-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during an emergency shut-down is presented in **Figure 8-20**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-8**) it is evident that there is a reduction in the concentrations of $NO_2$ throughout the modelled grid.

The maximum on the grid has decreased from 42.6 $\mu g/m^3$ to 37.5 $\mu g/m^3$ which is equivalent to 15.3% of the NEPM criteria.

The Chevron Australia and the construction camps have a predicted maximum $NO_2$ concentration of 16 $\mu g/m^3$ and 21 $\mu g/m^3$ respectively during an emergency shut-down, both of which are well within the relevant NEPM criteria.




- **Figure 8-20 Maximum 1-hour ground level concentrations of $NO_2$ during emergency shut-down**

### 8.1.4.2 Ozone (as a descriptor for photochemical smog)

The maximum predicted 1-hour ozone concentrations from the proposed Chevron Australia facility during an emergency shut-down (with the existing and approved sources) in the coastal Pilbara region is presented in **Figure 8-21**. When the concentrations in this figure are compared to that

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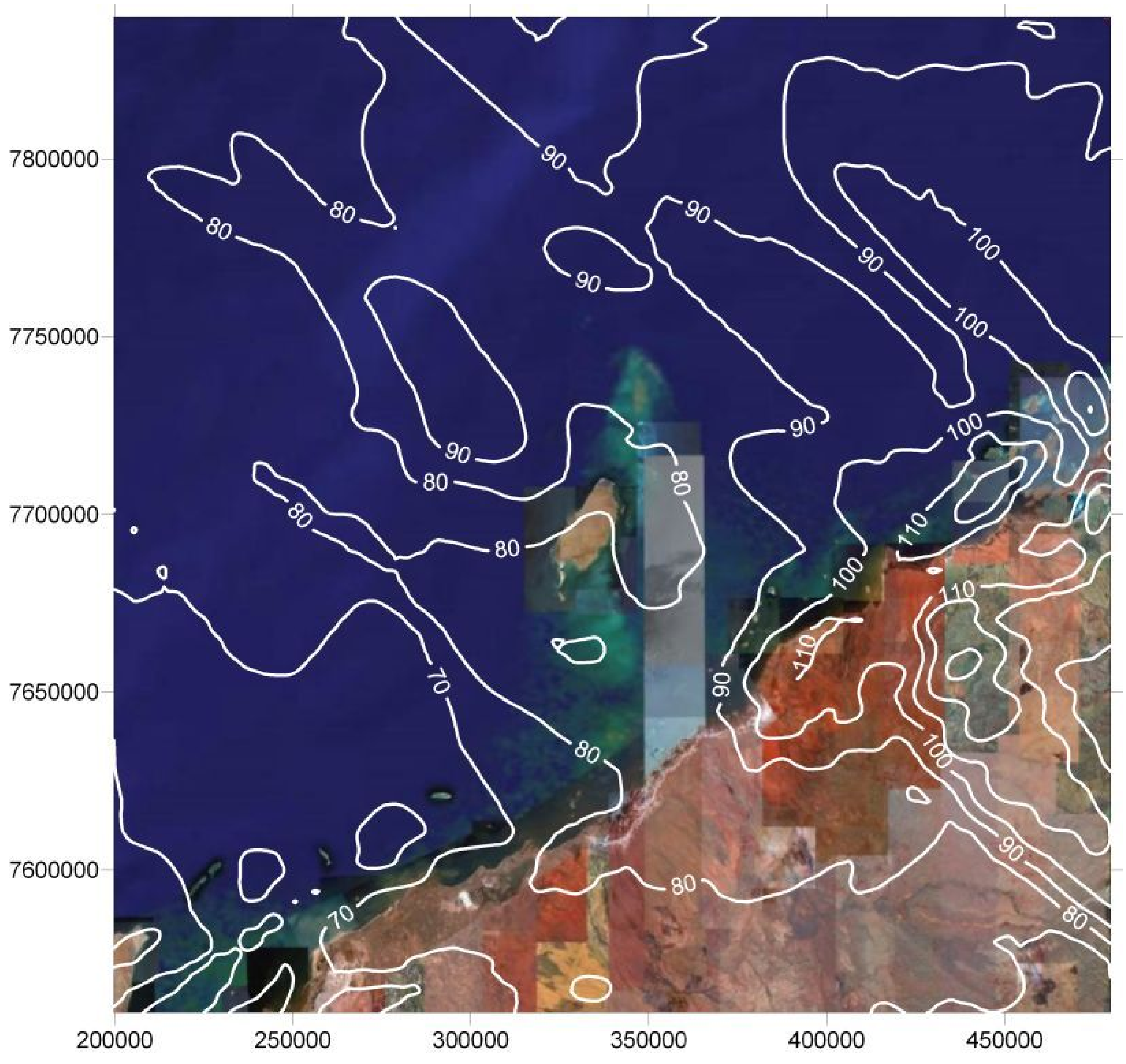
predicted to occur for the facility during normal operating conditions (**Figure 8-10**) it is apparent that it is predicted that there will be almost no change in the predicted ozone concentration on the modelled grid.

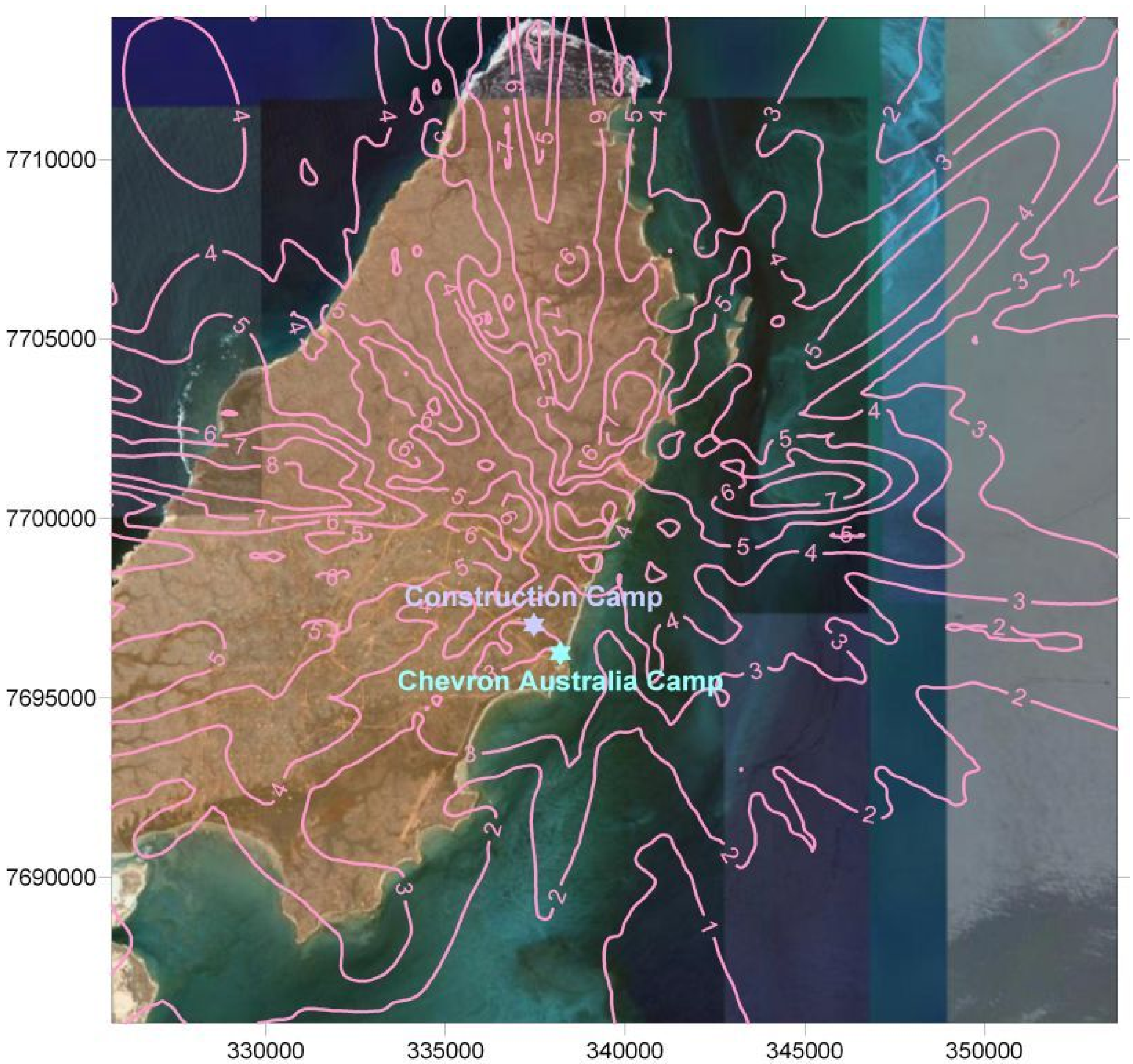



- **Figure 8-21 Maximum 1-hour ground level concentrations of $O_3$ during upset emergency shut-down**

### 8.1.4.3 Sulfur Dioxide

The maximum predicted 1-hour $SO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during start up operations is presented in **Figure 8-18**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-12**) it is evident that the concentrations of $SO_2$ have decreased. The cause of this reduction is due to the shut-down of two of the compressor gas turbine drivers and the cessation of shipping emissions during this period.

Both the Chevron Australia and construction camps have a predicted maximum $SO_2$ concentration of 3µg/m$^3$ during start up, which is 0.5% of the relevant NEPM criteria.

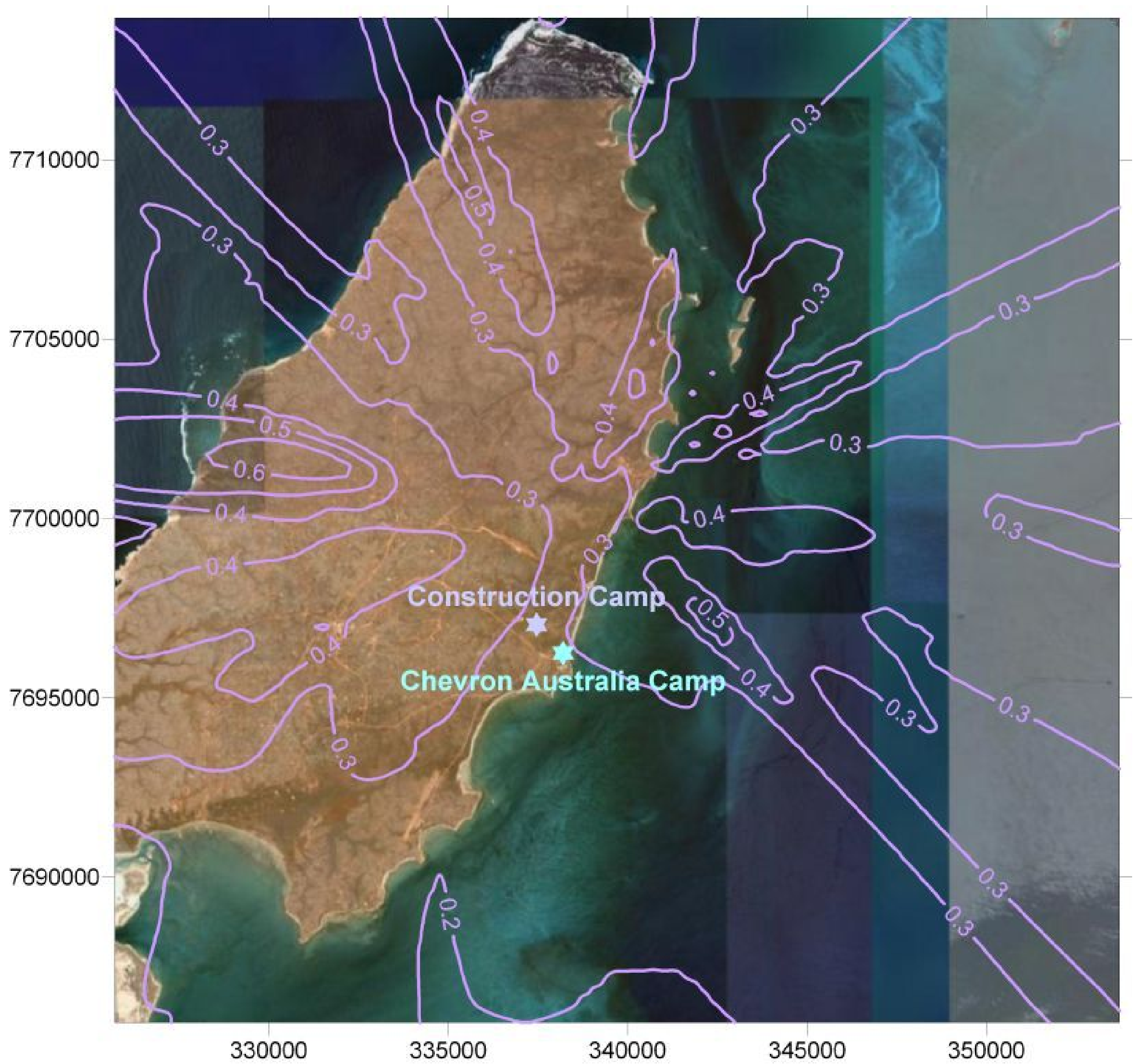



- **Figure 8-22 Maximum 1-hour ground level concentrations of $SO_2$ during emergency shut-down**

#### 8.1.4.4 Particulate Matter ($PM_{10}$)

The maximum predicted 24-hour $PM_{10}$ concentrations on Barrow Island for the proposed Chevron Australia facility during an emergency shut-down is presented in **Figure 8-23**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-15**) it is evident that the concentrations of $PM_{10}$ have decreased slightly.

Both the Chevron Australia and construction camps have a predicted maximum $PM_{10}$ concentration of 0.29 $\mu g/m^3$, which is 0.6% of the relevant NEPM criteria.




- **Figure 8-23 Maximum 24-hour ground level concentrations of $PM_{10}$ during emergency shut-down**

### 8.1.4.5 Maximum on Grid

The maximum predicted ground level concentrations from **Figure 8-20** to **Figure 8-23** are presented in **Table 8-4** along with the percentage of the applicable NEPM criteria. When the results presented in this table are compared to the results from the proposed facility during normal operating conditions (**Table 8-2**) it is noticeable that there is a slight reduction in ground level concentrations.

The maximum 1-hour ozone concentrations on the larger modelling grid is 62.2% of the NEPM criteria for ozone and represents a very minor increase above that predicted to occur for the proposed facility during normal operating conditions (**Table 8-2**).

- **Table 8-4 Maximum predicted future ground level concentration on the modelled grid under emergency shut-down**

| Pollutant | TAPM Grid | Averaging Period | Maximum on Grid ($\mu g/m^3$) | Assessment Criteria ($\mu g/m^3$) | Percentage of Assessment Criteria |
|---|---|---|---|---|---|
| $NO_2$ | 1 km | 1-hour | 37.5 | 246 | 15.3 |
| $O_3$ | 10 km | 1-hour | 133.2 | 214 | 62.2 |
| $SO_2$ | 1 km | 1-hour | 9.1 | 571 | 1.6 |
| $PM_{10}$ | 1 km | 24-hour | 0.7 | 50 | 1.3 |

### 8.1.5 Predicted Air Quality – Non-Routine Operation 3 – $CO_2$ venting

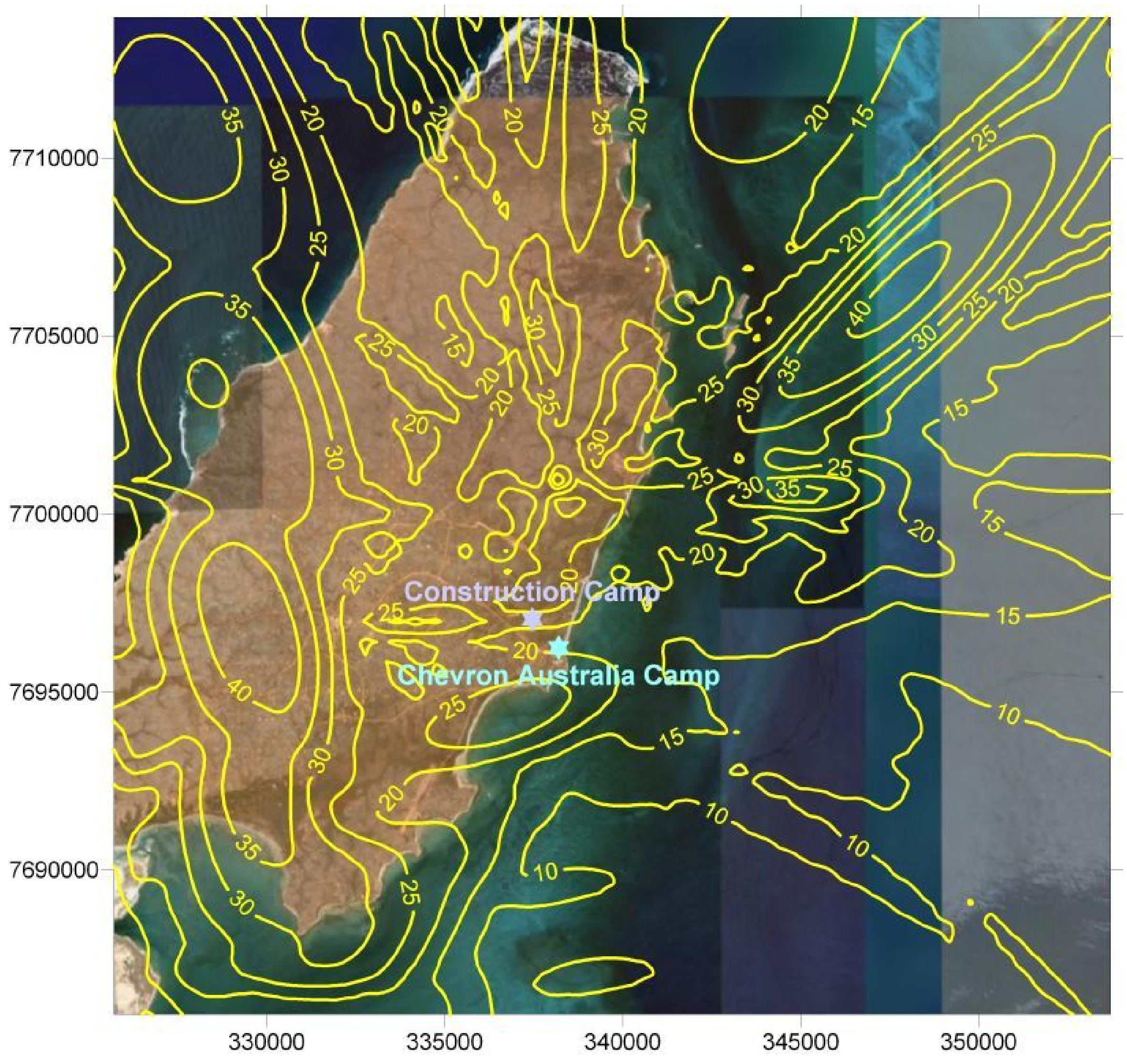
The modelling for future air quality during the second upset condition incorporates the existing and approved emission sources (**Section 7.6.1**) as well as the calculated emissions from the proposed Chevron Australia gas processing facility during periods when the $CO_2$ reservoir is not injecting at the assumed capacity while the AGRU and $CO_2$ compression units are operating (**Section 7.6.6**). The pollutants taken into consideration in this section include $PM_{10}$, $NO_2$, $O_3$ and $SO_2$. The following sections present the results of this modelling.

### 8.1.5.1 Oxides of Nitrogen

The maximum predicted 1-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during $CO_2$ venting is presented in **Figure 8-24**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-8**) it is evident that there are only minor changes in the concentrations of $NO_2$ throughout the modelled grid.

The maximum on the grid has stayed constant at 42.6 $\mu g/m^3$ which is equivalent to 17.3% of the NEPM criteria.

The Chevron Australia camp has a predicted maximum $NO_2$ concentration of 19 $\mu g/m^3$ while the construction camp has a predicted concentration of 21 $\mu g/m^3$ during $CO_2$ venting both of which are well below the relevant NEPM criteria.

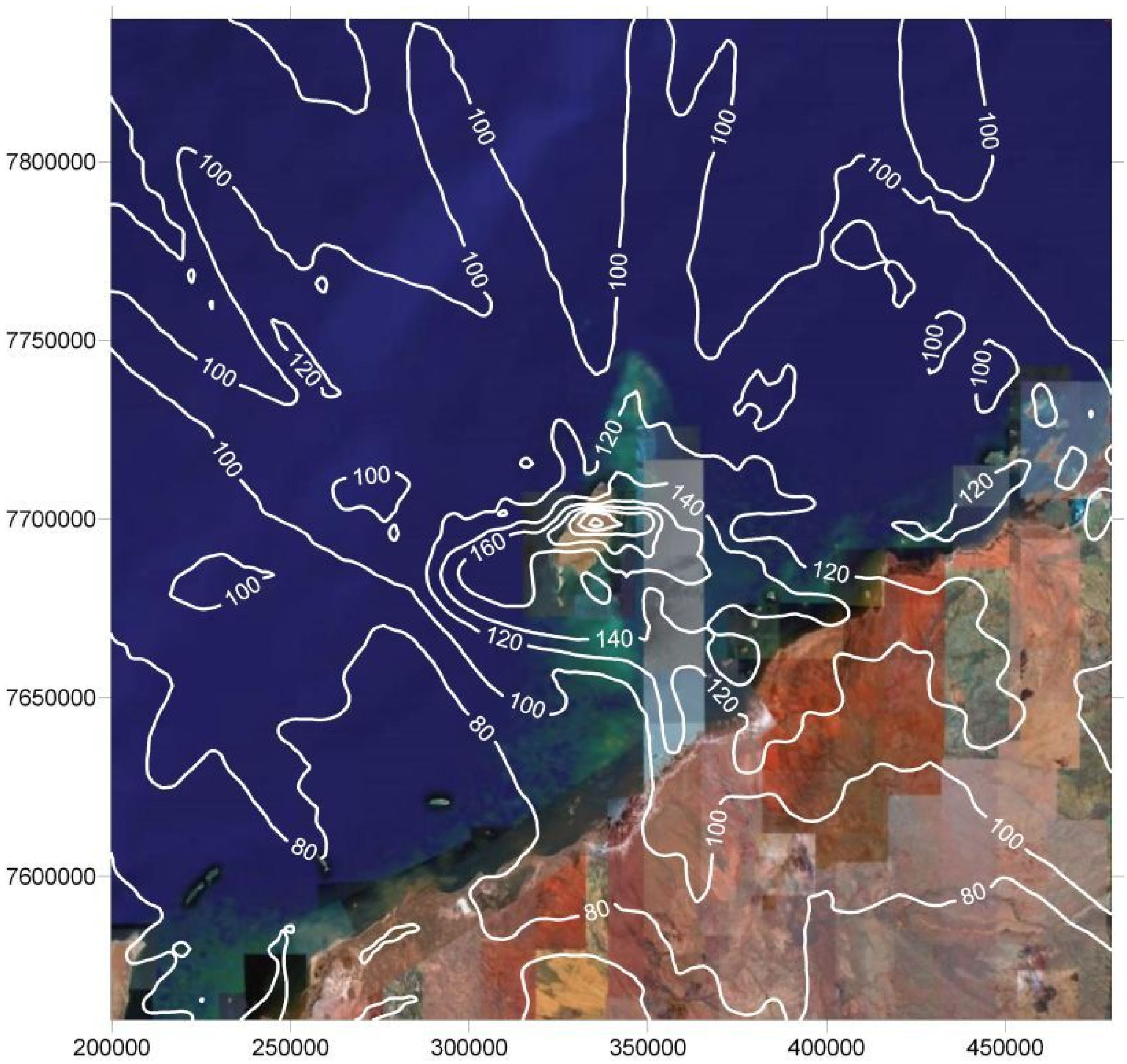



■ **Figure 8-24 Maximum 1-hour ground level concentrations of $NO_2$ during $CO_2$ venting**

### 8.1.5.2 Ozone (as a descriptor for photochemical smog)

The maximum predicted 1-hour ozone concentrations from the proposed Chevron Australia facility during $CO_2$ venting (with the existing and approved sources) in the coastal Pilbara region is presented in **Figure 8-25**. When the concentrations in this figure are compared to that predicted to occur for the facility during normal operating conditions (**Figure 8-10**) it is apparent that it is predicted that there will be an increases in the maximum 1-hour ozone concentrations across the modelled grid, particularly over Barrow Island. These high ozone concentrations result from the increased emissions of VOC from the Amine Regenerator Reflux Drum vent (**Table 7-8**).

Both the Chevron Australia and construction camps have a predicted maximum 1-hour $O_3$ concentration of 200 µg/m$^3$ during $CO_2$ venting, which is 93.5% of the relevant NEPM criteria.

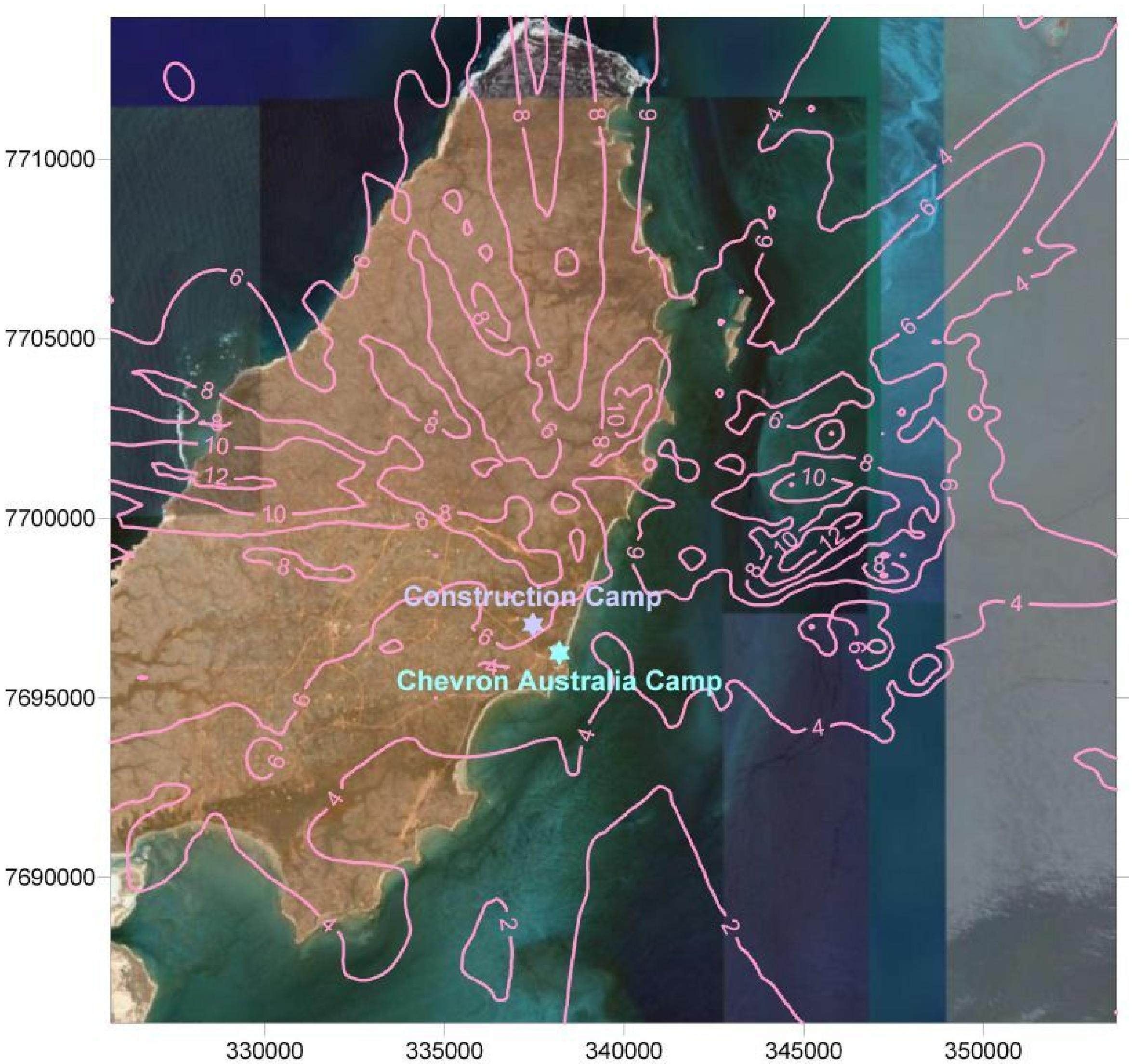



■ **Figure 8-25 Maximum 1-hour ground level concentrations of $SO_2$ during $CO_2$ venting**

### 8.1.5.3 Sulfur Dioxide

The maximum predicted 1-hour $SO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during $CO_2$ venting is presented in **Figure 8-26**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-12**) it is evident that there has been no change in concentrations of $SO_2$.

The Chevron Australia Camp has a maximum predicted 1-hour concentration of $SO_2$ of 5 µg/m$^3$ while the proposed construction camp has a predicted concentration of 6.1 µg/m$^3$ which is equivalent to 0.9% and 1.1% of the applicable NEPM criteria respectively.

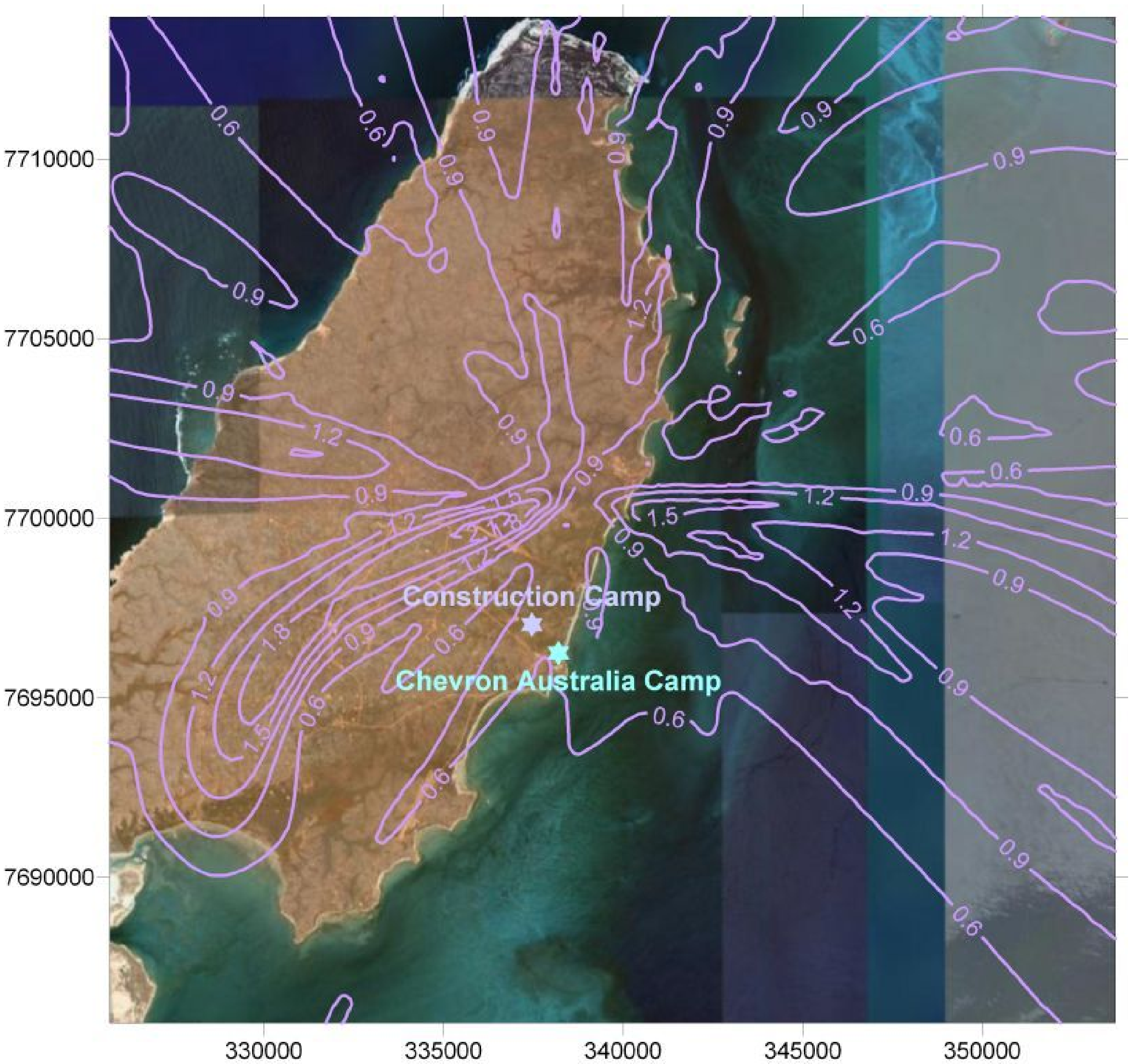



- **Figure 8-26 Maximum 1-hour ground level concentrations of $SO_2$ during $CO_2$ venting**

### 8.1.5.4 Particulate Matter ($PM_{10}$)

The maximum predicted 24-hour $PM_{10}$ concentrations on Barrow Island for the proposed Chevron Australia facility during $CO_2$ venting is presented in **Figure 8-27**. When the results presented in this figure are compared to the proposed operations during normal operating conditions (**Figure 8-15**) it is evident that the concentrations of $PM_{10}$ have increased throughout the modelled grid, particularly to the south west of the proposed facility.

Both the Chevron Australia and the construction camps are predicted to have a maximum $PM_{10}$ concentration of 0.8 μg/m$^3$, which is 1.6% of the relevant NEPM criteria.




■ **Figure 8-27 Maximum 24-hour ground level concentrations of $PM_{10}$ during $CO_2$ venting**

#### 8.1.5.5 Maximum on Grid

The maximum predicted ground level concentrations from **Figure 8-24** to **Figure 8-27** are presented in **Table 8-5** along with the percentage of the applicable NEPM criteria. When the results presented in this table are compared to the results from the proposed facility during normal operating conditions (**Table 8-2**) it is noticeable that the only significant increase occurs with ozone. The maximum ground level concentration of ozone increases from 132 µg/m$^3$ during normal operations to 272 µg/m$^3$ during $CO_2$ venting. As stated in **Section 8.1.5.2** the primary reason for this increase is due to the increased emissions of VOC from the Amine Regenerator Reflux Drum vent. As the modelling for this upset condition was conducted for every hour of the year it is highly improbable that the predicted maximum 1-hour ozone concentrations will occur.

- **Table 8-5 Maximum predicted future ground level concentration on modelled grids during $CO_2$ venting**

| Pollutant | TAPM Grid | Averaging Period | Maximum on Grid (µg/m$^3$) | Assessment Criteria (µg/m$^3$) | Percentage of Assessment Criteria |
|---|---|---|---|---|---|
| $NO_2$ | 1 km | 1-hour | 42.6 | 246 | 17.3 |
| $O_3$ | 10 km | 1-hour | 272 | 214 | 127 |
| $SO_2$ | 1 km | 1-hour | 14.9 | 571 | 2.6 |
| $PM_{10}$ | 1 km | 24-hour | 2.3 | 50 | 4.7 |

## 8.2 Potential Impact on Human Health (occupational)

### 8.2.1 Future Air Quality – Normal Operations

#### 8.2.1.1 Oxides of Nitrogen

The maximum predicted 8-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during normal operations is presented in **Figure 8-28**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is apparent that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $NO_2$.

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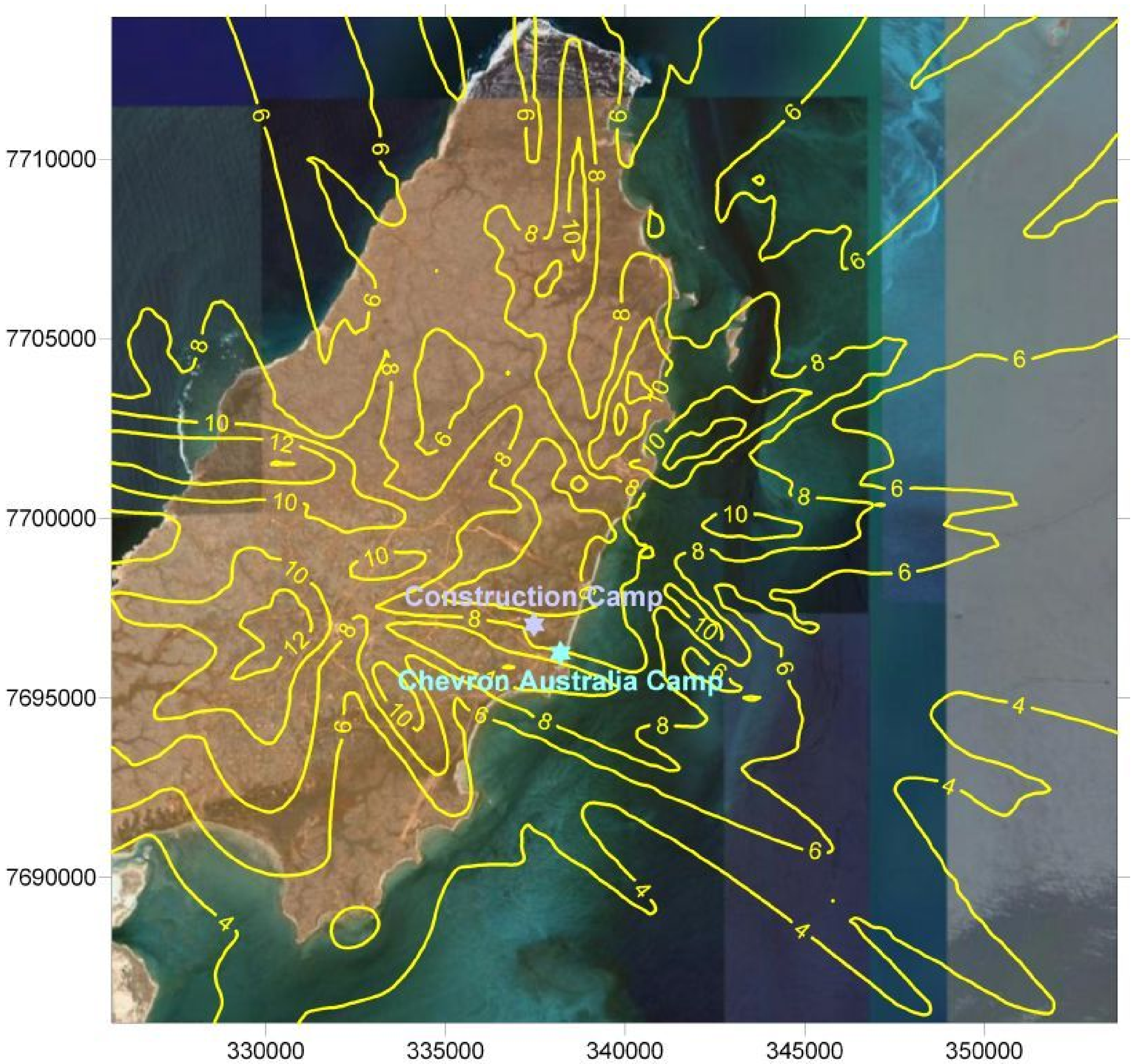
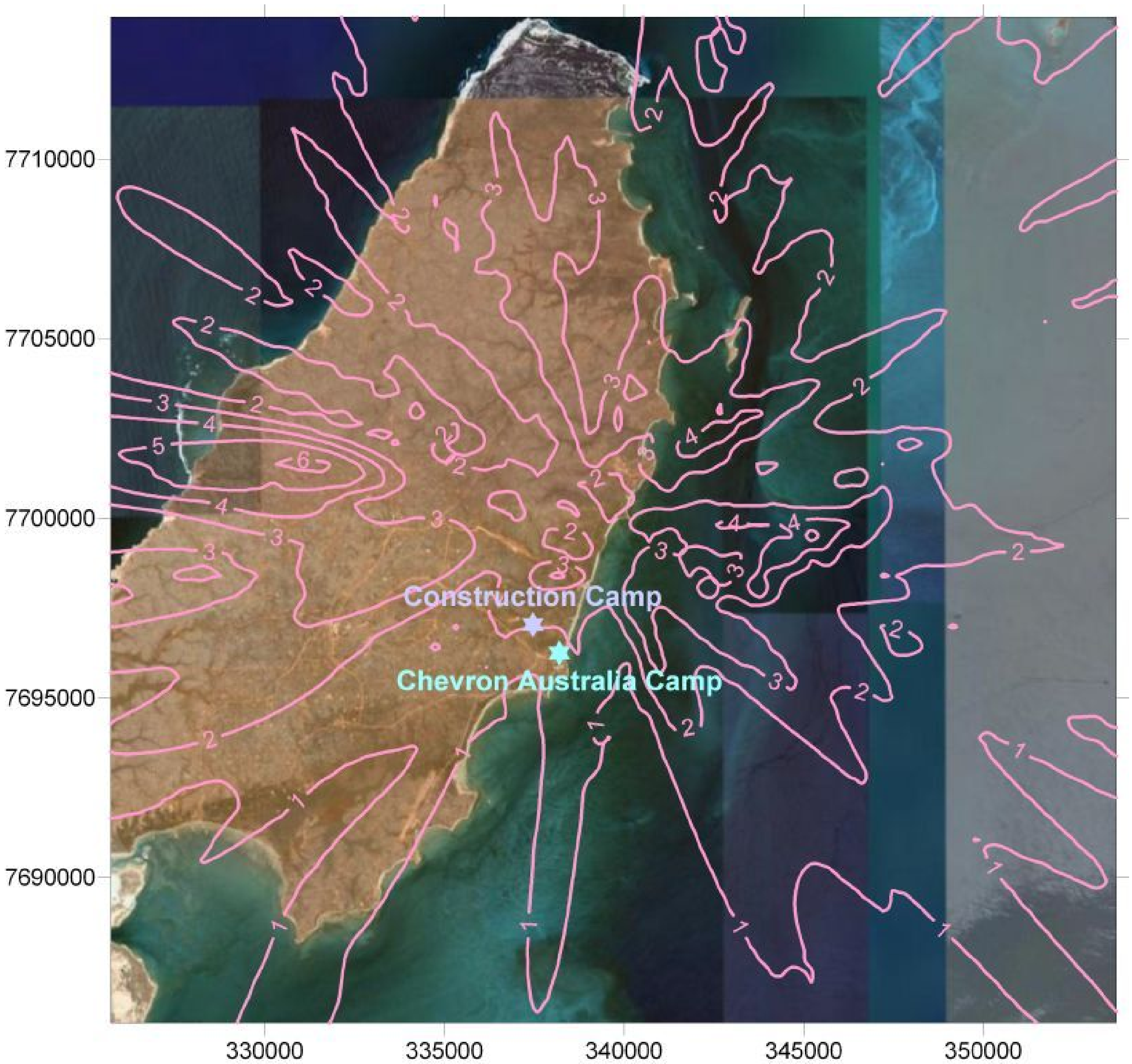



- **Figure 8-28 Maximum predicted 8-hour $NO_2$ concentrations ($\mu g/m^3$)**

### 8.2.1.2 Sulfur Dioxide

The maximum predicted 8-hour $SO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during normal operations is presented in **Figure 8-29**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is apparent that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $SO_2$.




- **Figure 8-29 Maximum predicted 8-hour $SO_2$ concentrations ($\mu g/m^3$)**

### 8.2.1.3 Maximum on 1-km Grid

The maximum predicted ground level concentrations from **Figure 8-28** and **Figure 8-29** are presented in **Table 8-6** along with the percentage of the applicable occupational criteria. When the maximum predicted 8-hour concentrations are compared to the occupational exposure limits it is clear that the maximum predicted ground level concentrations of $NO_2$ and $SO_2$ are well within their respective occupational criteria.

- **Table 8-6 Maximum predicted ground level concentration on 1-km modelled grid under normal operating conditions**

| Pollutant | Averaging Period | Maximum on Grid ($\mu g/m^3$) | TWA ($\mu g/m^3$) | Percentage of Criteria |
|---|---|---|---|---|
| $NO_2$ | 8-hour | 14.1 | 5 600 | 0.25 |
| $SO_2$ | 8-hour | 6.3 | 5 200 | 0.12 |

### 8.2.2 Predicted Air Quality – Non-Routine Operation 1 – Start-up

#### 8.2.2.1 Oxides of Nitrogen

The maximum predicted 8-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during plant start up is presented in **Figure 8-30**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is evident that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $NO_2$.

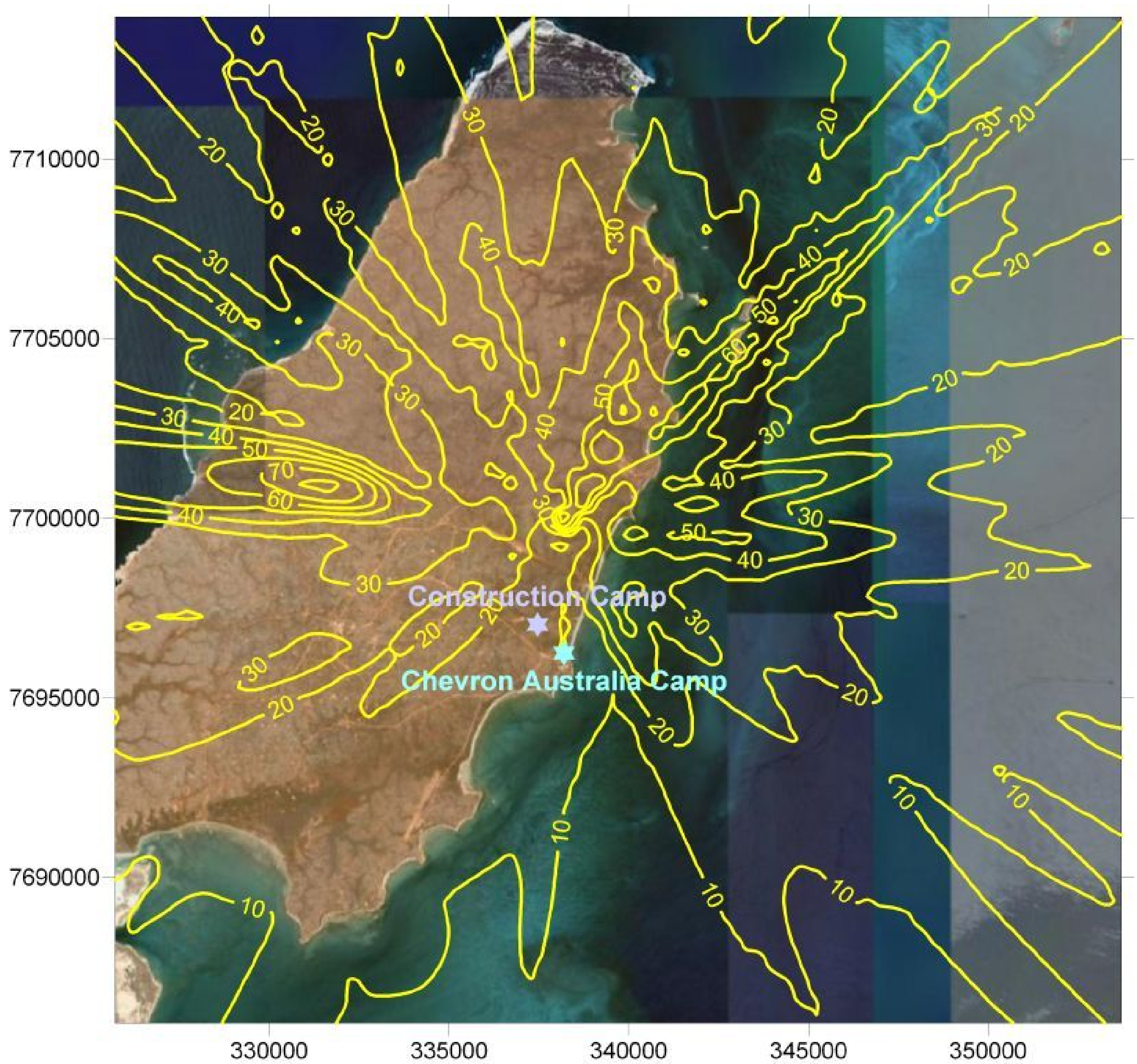
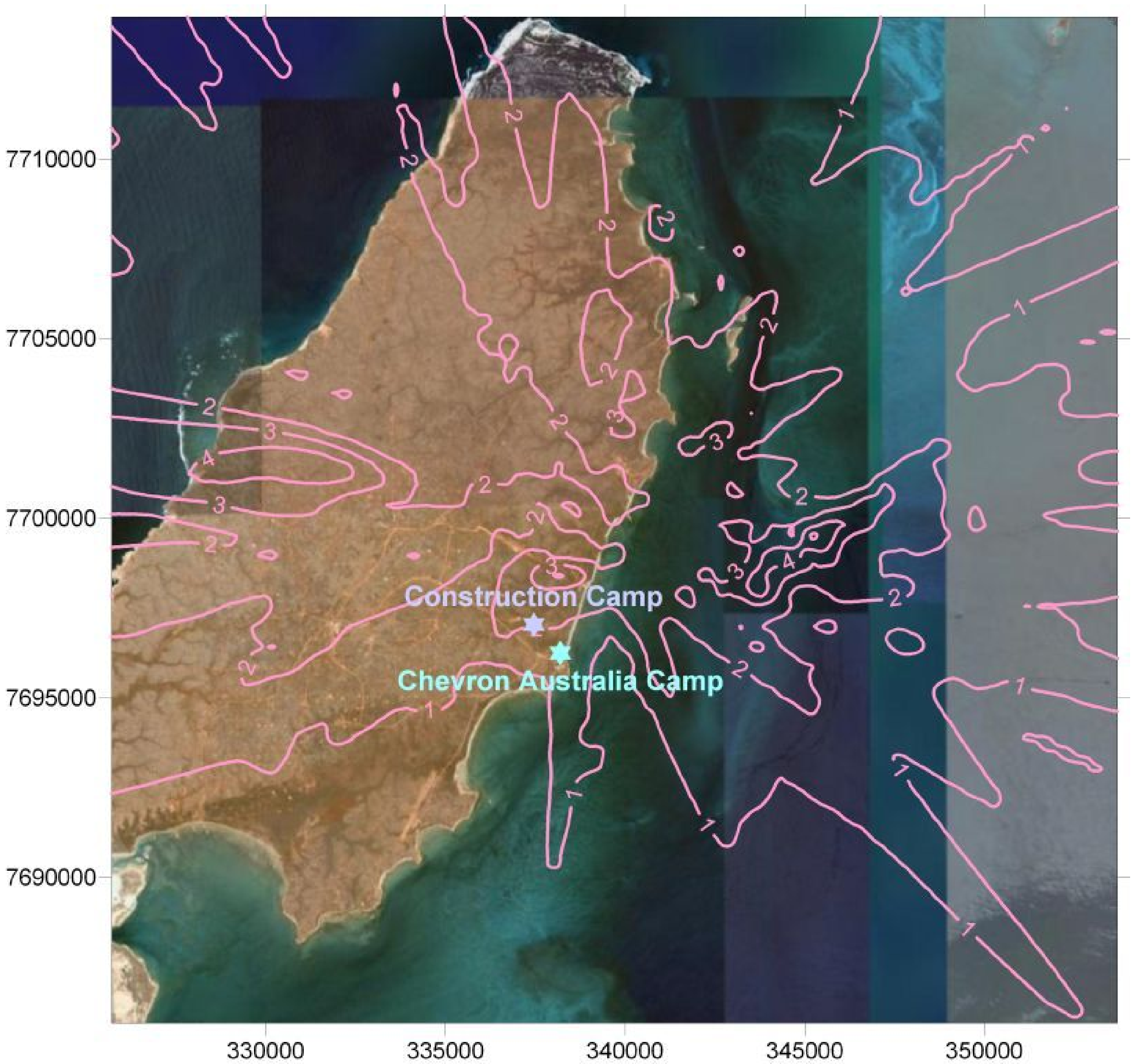



Figure 8-30 Maximum 8-hour ground level concentrations of $NO_2$ during start-up ($\mu g/m^3$)

#### 8.2.2.2 Sulfur Dioxide

The maximum predicted 8-hour $SO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during plant start up is presented in **Figure 8-31**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is evident that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $SO_2$.




- **Figure 8-31 Maximum 8-hour ground level concentrations of $SO_2$ during start-up ($\mu g/m^3$)**

#### 8.2.2.3 Maximum on 1-km Grid

The maximum predicted ground level concentrations from **Figure 8-30** and **Figure 8-31** are presented in **Table 8-7** along with the percentage of the applicable occupational criteria. When the maximum predicted 8-hour concentrations are compared to the occupational exposure limits it is clear that the maximum predicted ground level concentrations of $NO_2$ and $SO_2$ are well within their respective occupational criteria.

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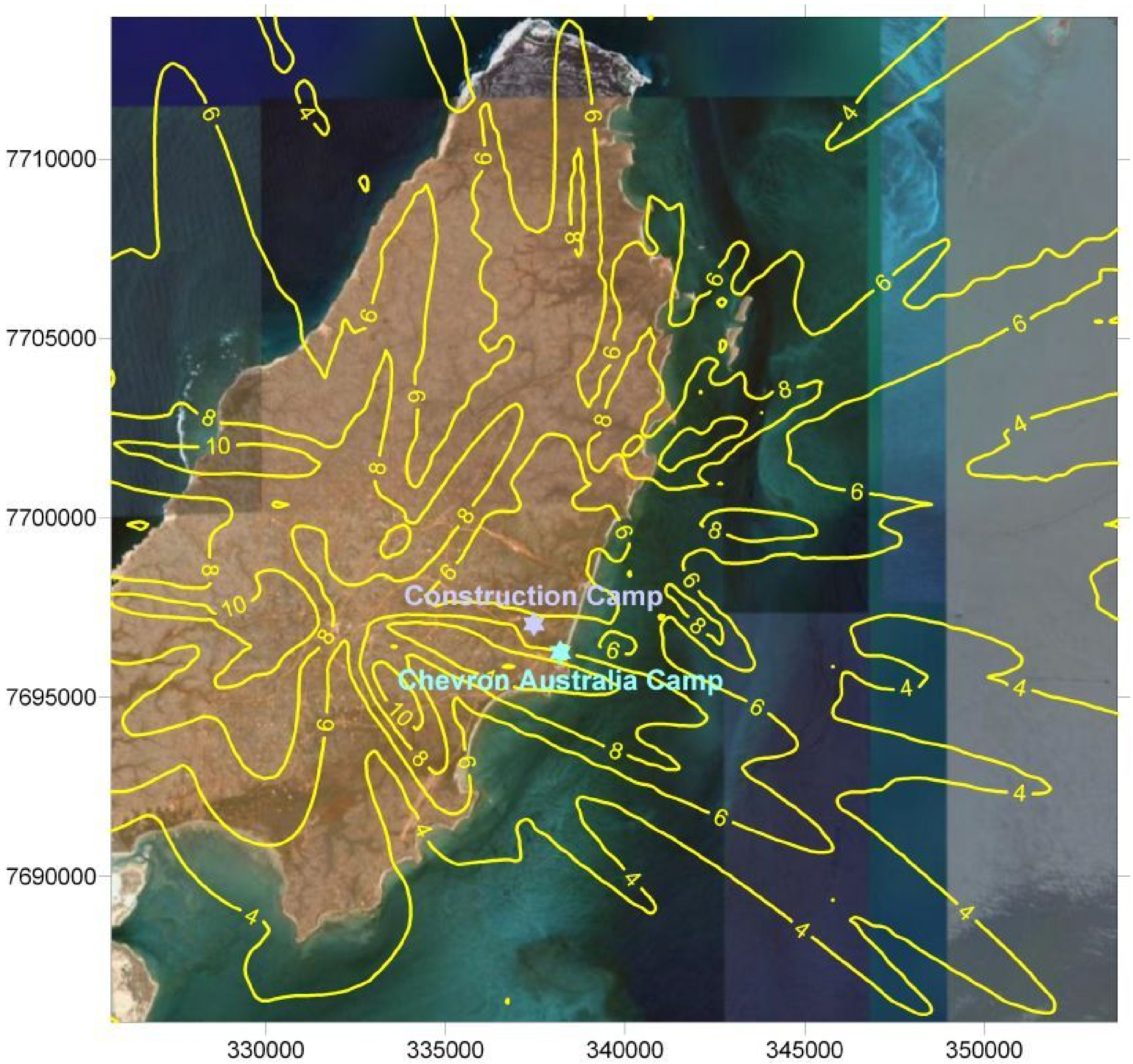
**Table 8-7 Maximum predicted ground level concentration on 1 km modelled grid during start-up**

| Pollutant | Averaging Period | Maximum on Grid ($\mu g/m^3$) | TWA ($\mu g/m^3$) | Percentage of Criteria |
|---|---|---|---|---|
| $NO_2$ | 8-hour | 86.6 | 5 600 | 1.5 |
| $SO_2$ | 8-hour | 5.7 | 5 200 | 0.11 |

### 8.2.3 Predicted Air Quality – Non-Routine Operation 2 – Emergency Shut-down

#### 8.2.3.1 Oxides of Nitrogen

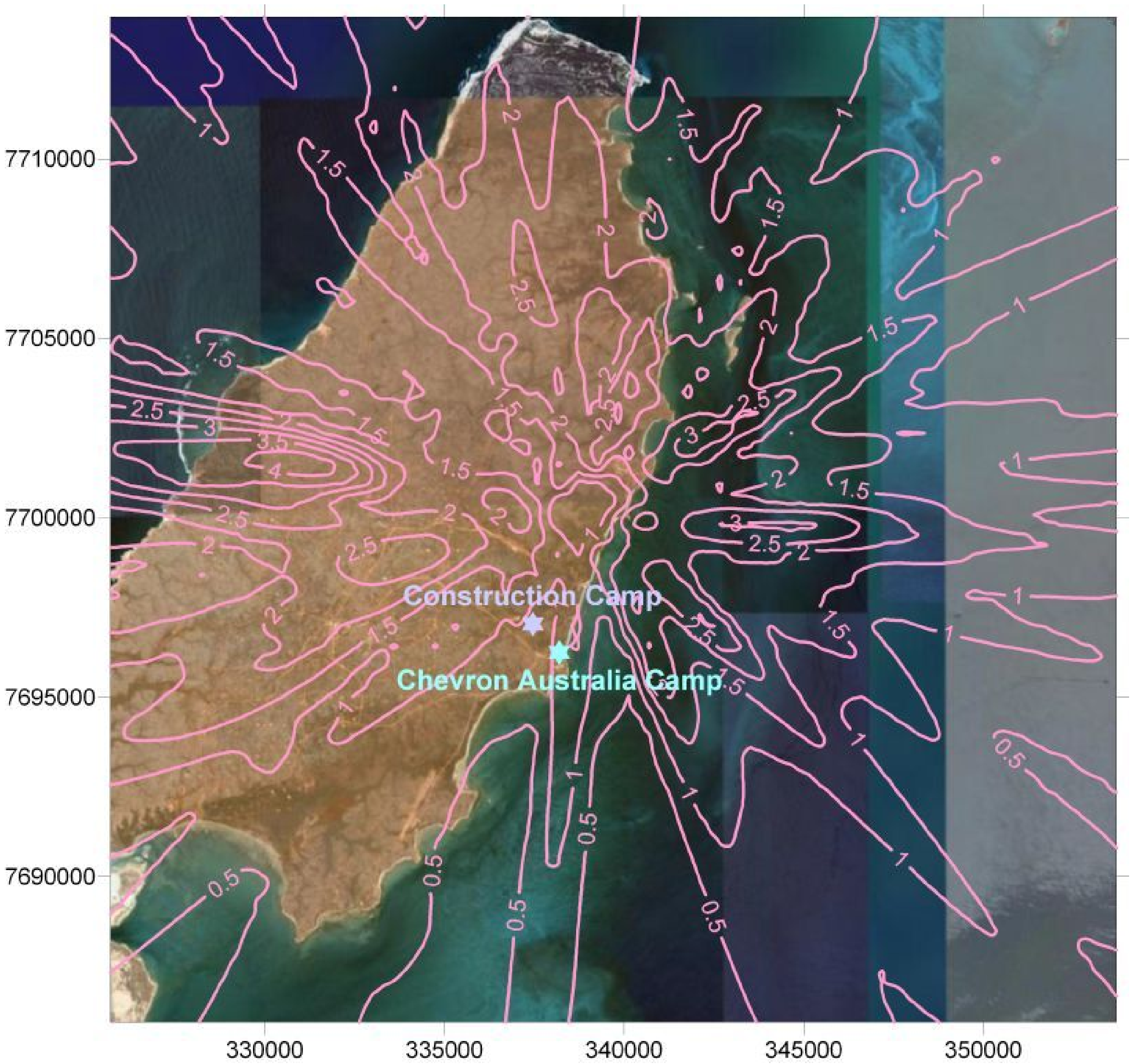
The maximum predicted 8-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during an emergency shut-down is presented in **Figure 8-32**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is clear that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $NO_2$.




▪ **Figure 8-32 Maximum 8-hour ground level concentrations of $NO_2$ during emergency shut-down ($\mu g/m^3$)**

### 8.2.3.2 Sulfur Dioxide

The maximum predicted 8-hour $SO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during an emergency shut-down is presented in **Figure 8-33**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is clear that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $NO_2$.




- **Figure 8-33 Maximum 8-hour ground level concentrations of $SO_2$ during emergency shut-down ($\mu g/m^3$)**

### 8.2.3.3 Maximum on 1-km Grid

The maximum predicted ground level concentrations from **Figure 8-32** and **Figure 8-33** are presented in **Table 8-8** along with the percentage of the applicable occupational criteria. When the maximum predicted 8-hour concentrations during an emergency shut-down are compared to the occupational exposure limits it is evident that the maximum predicted ground level concentrations of $NO_2$ and $SO_2$ are well within their respective occupational criteria.

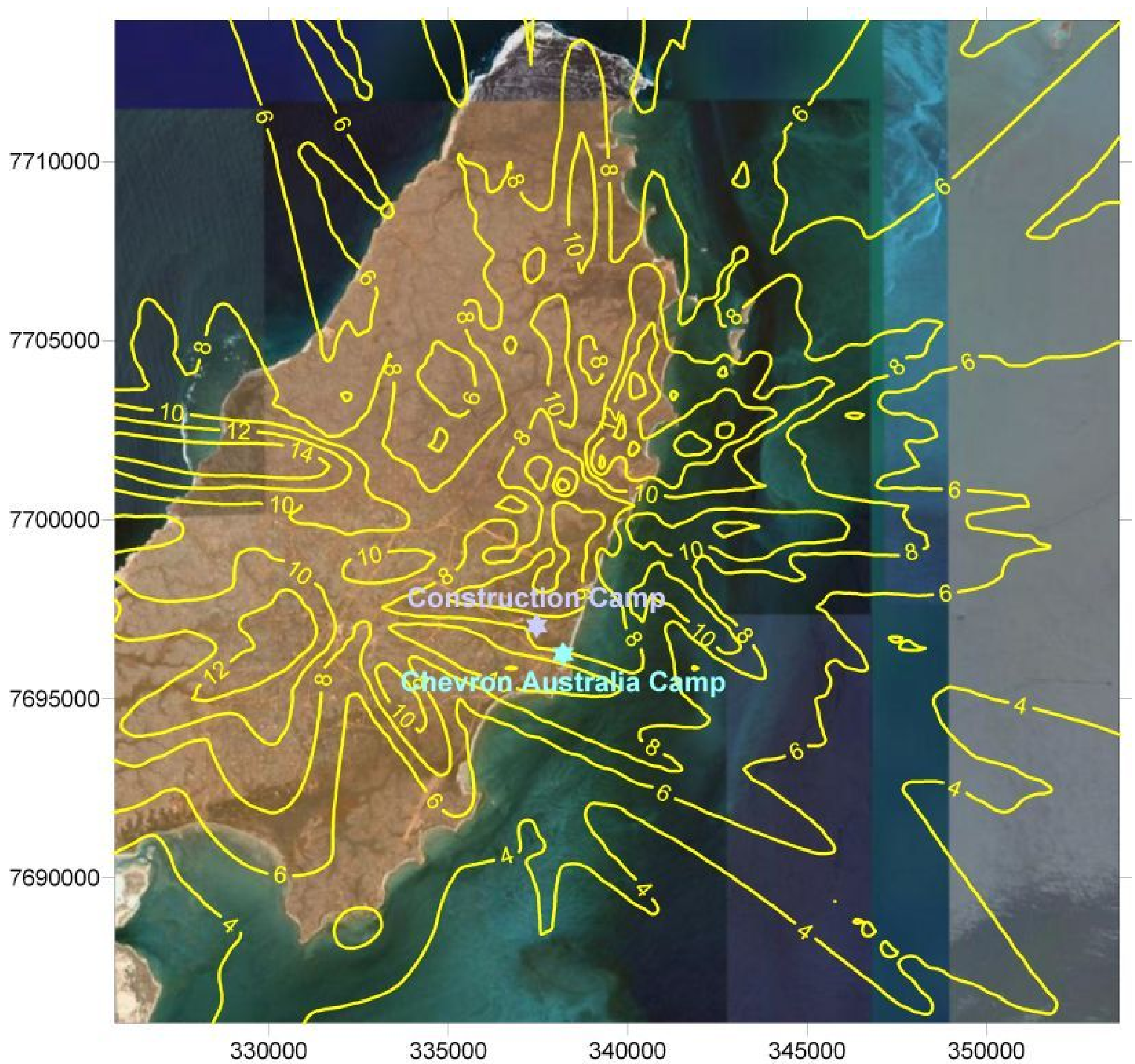
- **Table 8-8 Maximum predicted ground level concentration on 1 km modelled grid during an emergency shut-down**

| Pollutant | Averaging Period | Maximum on Grid ($\mu g/m^3$) | TWA ($\mu g/m^3$) | Percentage of Criteria |
|---|---|---|---|---|
| $NO_2$ | 8-hour | 12.4 | 5 600 | 0.22 |
| $SO_2$ | 8-hour | 4.4 | 5 200 | 0.08 |

### 8.2.4 Predicted Air Quality – Non-Routine Operation 3 – $CO_2$ Venting

#### 8.2.4.1 Oxides of Nitrogen

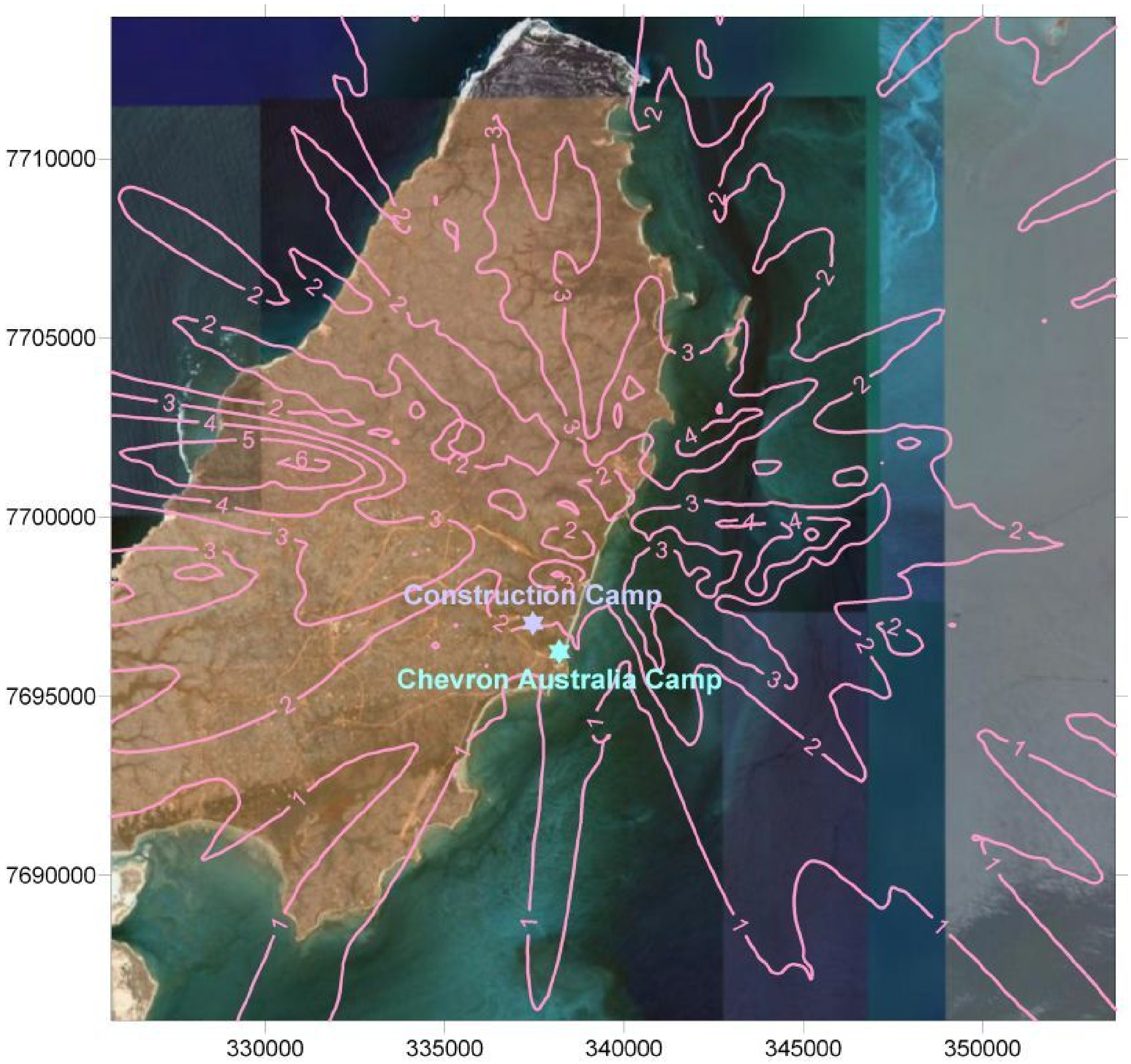
The maximum predicted 8-hour $NO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during $CO_2$ venting is presented in **Figure 8-34**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is obvious that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $NO_2$.




- **Figure 8-34 Maximum 8-hour ground level concentrations of $NO_2$ during $CO_2$ venting ($\mu g/m^3$)**

### 8.2.4.2 Sulfur Dioxide

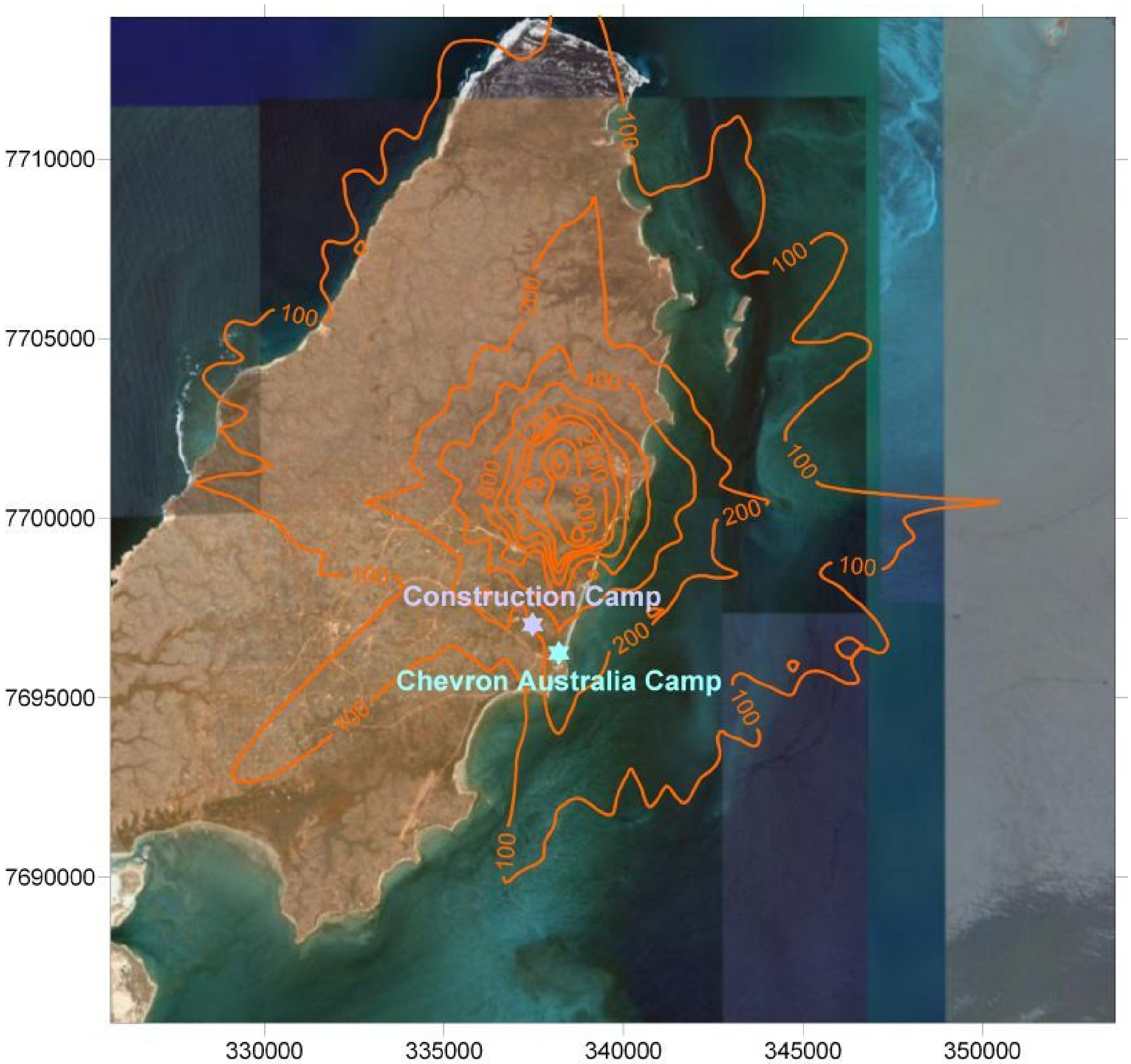
The maximum predicted 8-hour $SO_2$ concentrations on Barrow Island for the proposed Chevron Australia facility during $CO_2$ venting is presented in **Figure 8-35**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is obvious that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $SO_2$.




- **Figure 8-35 Maximum 8-hour ground level concentrations of $SO_2$ during $CO_2$ venting ($\mu g/m^3$)**

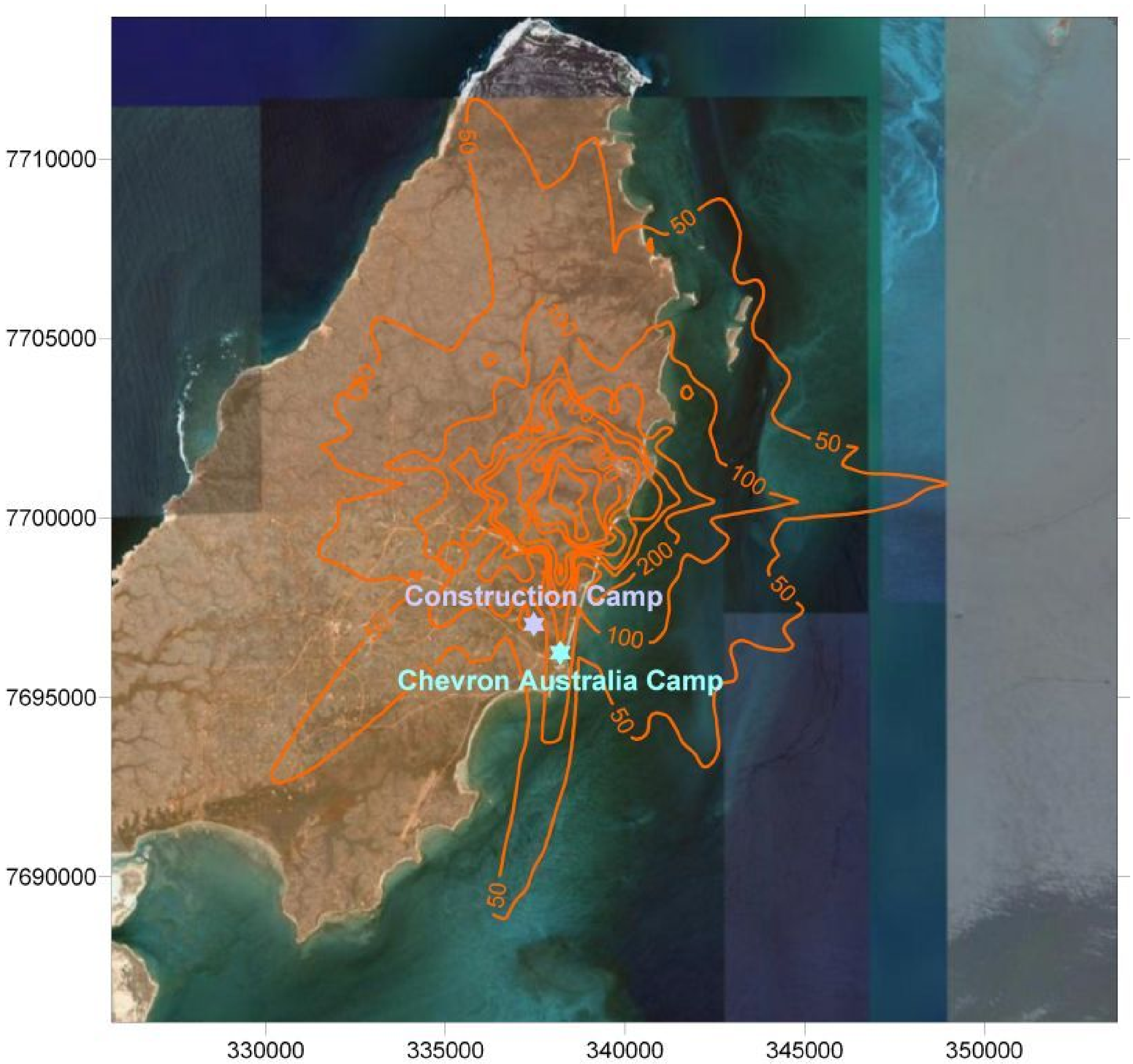
#### 8.2.4.3 Hydrogen Sulphide ($H_2S$)

The maximum predicted 1-hour $H_2S$ concentrations on Barrow Island for the proposed Chevron Australia facility during $CO_2$ venting is presented in **Figure 8-36**. Although there is no occupational criteria for $H_2S$ at 1-hour it can be compared to either the 8-hour TWA occupational criteria or the odour threshold presented in **Table 5-3**. From this table it is apparent that the maximum 1-hour concentrations are well below the exposure standards set by Worksafe Australia for $H_2S$. However during a $CO_2$ venting event there is the possibility that the odour of $H_2S$ will be detectable.




- **Figure 8-36 Maximum 1-hour ground level concentrations of $H_2S$ during $CO_2$ venting ($\mu g/m^3$)**

The maximum predicted 8-hour $H_2S$ concentrations on Barrow Island for the proposed Chevron Australia facility during $CO_2$ venting is presented in **Figure 8-37**. When the results presented in this figure are compared to the occupational criteria for pollutants listed in **Table 5-3** it is obvious that the predicted maximum 8-hour concentrations are well below the exposure standards set by Worksafe Australia for $H_2S$.




- **Figure 8-37 Maximum 8-hour ground level concentrations of $H_2S$ during $CO_2$ venting ($\mu g/m^3$)**

#### 8.2.4.4 Maximum on 1-km Grid

The maximum predicted ground level concentrations from **Figure 8-34** to **Figure 8-37** are presented in **Table 8-9** along with the percentage of the applicable occupational criteria. When the maximum predicted 8-hour concentrations during a $CO_2$ event are compared to the occupational exposure limits it is evident that the maximum predicted ground level concentrations of $NO_2$, $SO_2$ and $H_2S$ are well within their respective occupational criteria.

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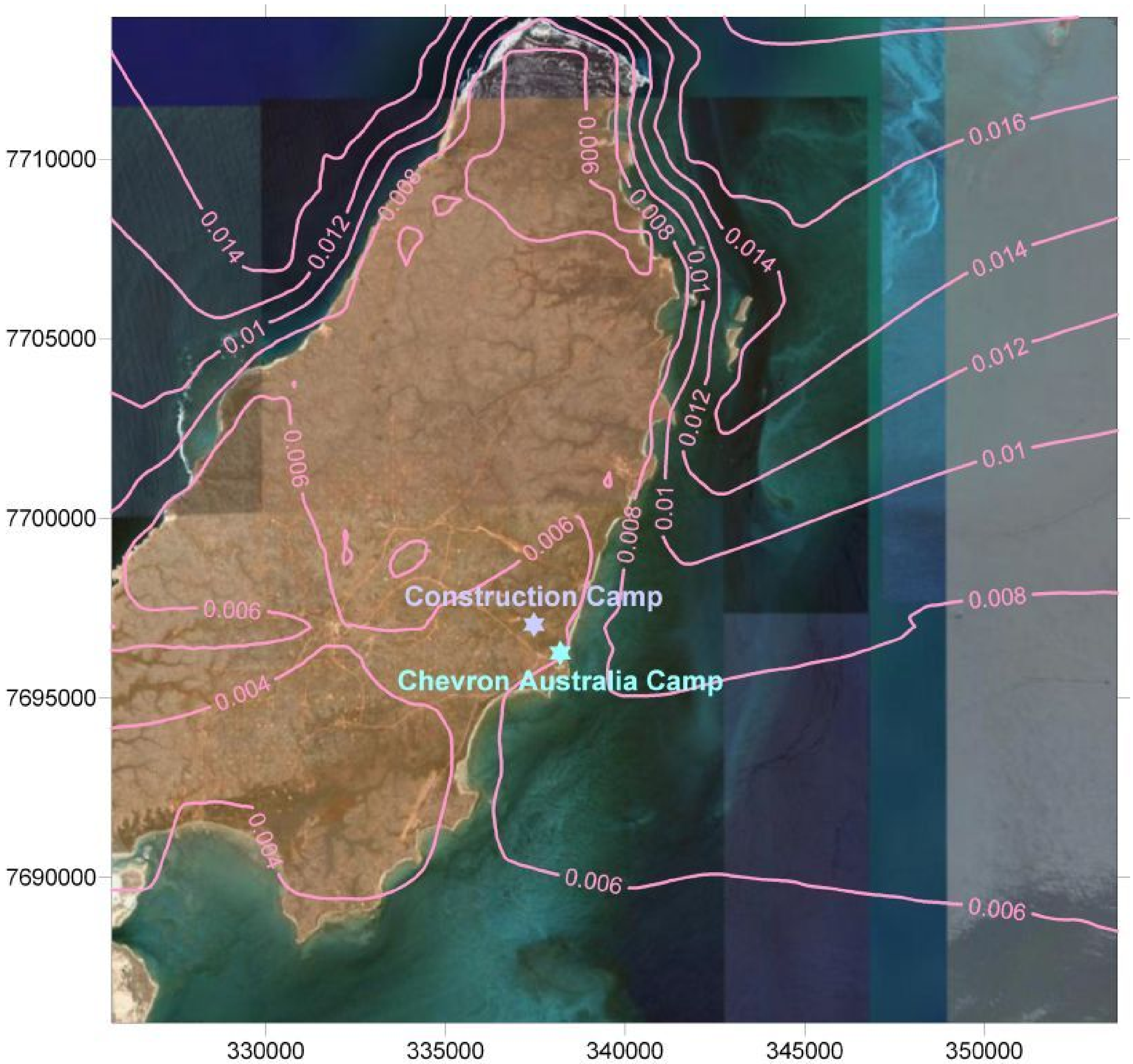
**Table 8-9 Maximum predicted ground level concentration on 1-km modelled grid during $CO_2$ venting**

| Pollutant | Averaging Period | Maximum on Grid ($\mu g/m^3$) | TWA ($\mu g/m^3$) | Percentage of Criteria |
|---|---|---|---|---|
| $NO_2$ | 8-hour | 15.7 | 5 600 | 0.28 |
| $SO_2$ | 8-hour | 6.3 | 5 200 | 0.12 |
| $H_2S$ | 8-hour | 1774 | 14 000 | 12.7 |

## 8.3 Potential Impact on Environment (deposition on vegetation

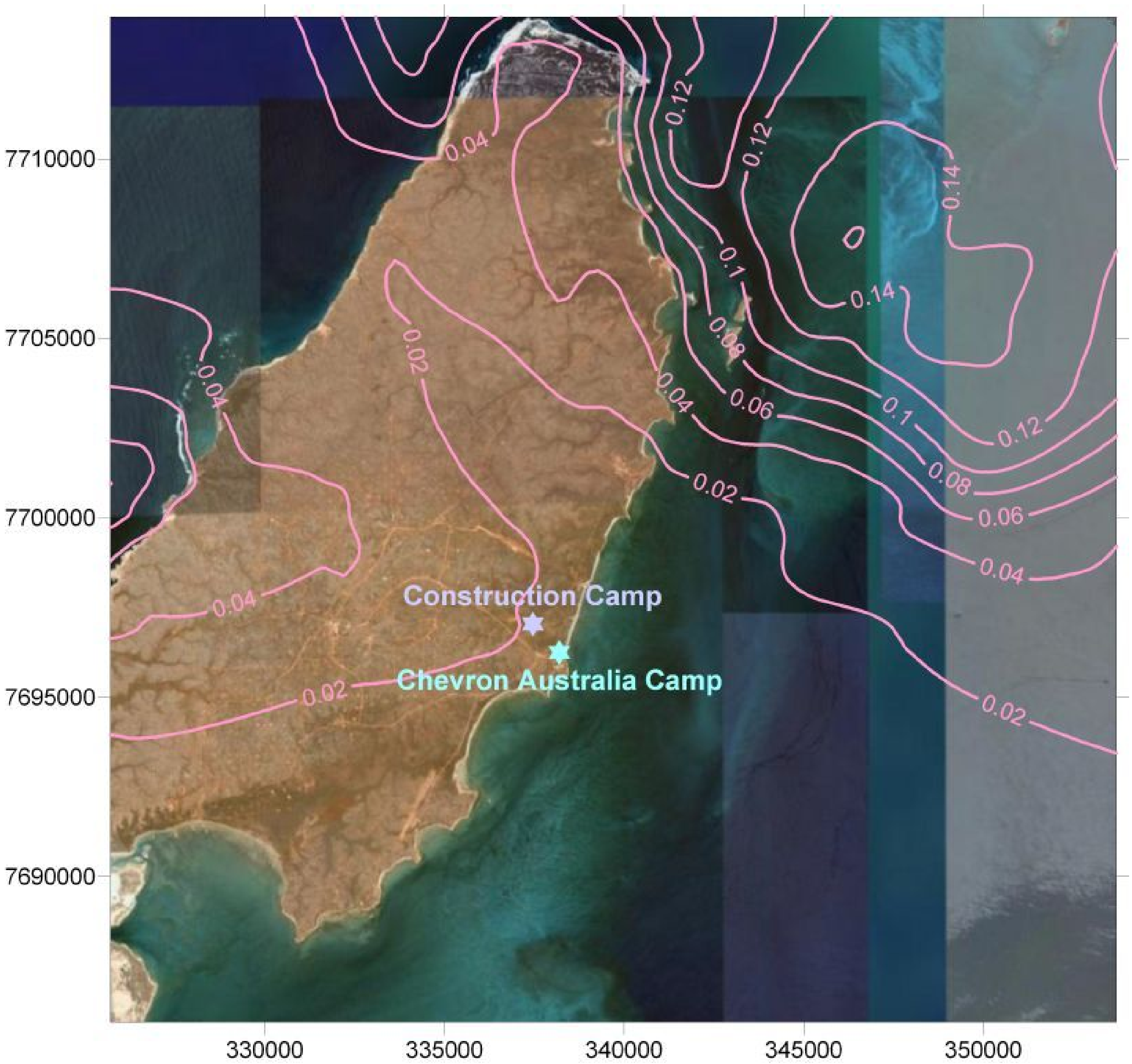
### 8.3.1 $SO_2$ Deposition

The TAPM predictions for $SO_2$ deposition (kg/ha/annum) for the existing and approved sources listed in **Table 7-4** are provided in **Figure 8-38**. From this figure it can be seen that higher depositions occur over the sea, due to the high solubility of $SO_2$. The higher predicted $SO_2$ deposition to the north east of Barrow Island reaches a maximum 0.02 kg/ha/annum.




■ **Figure 8-38 Predicted Existing Annual $SO_2$ Deposition (kg/ha/annum)**

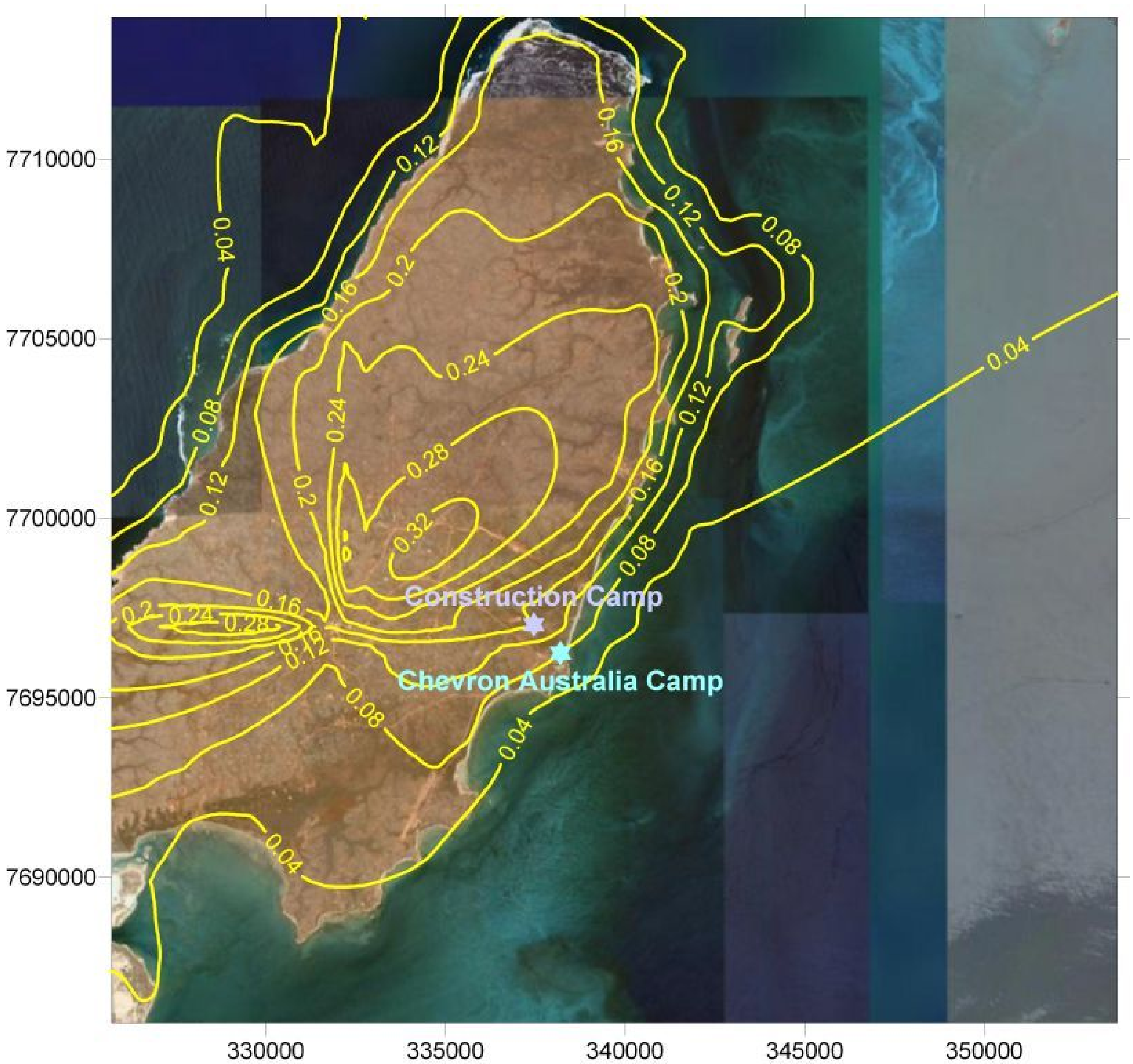
The TAPM predictions for $SO_2$ deposition (kg/ha/annum) with the introduction of the proposed Chevron Australia facility during normal operations (sources listed in **Table 7-4** and **Table 7-5**) are provided in **Figure 8-39**. When this figure is compared to the existing and approved scenario (**Figure 8-38**) it is apparent that there will be an increase in the deposition rate of $SO_2$. The maximum predicted deposition rate of $SO_2$ is 0.16 kg/ha/annum which is well within the WHO guideline value of 8–16 kg/ha/annum as $SO_2$.




- **Figure 8-39 Predicted Future Annual $SO_2$ Deposition (kg/ha/annum)**

### 8.3.2 $NO_2$ Deposition

The TAPM predictions for $NO_2$ deposition (kg/ha/annum) with the existing and approved sources are provided in **Figure 8-40**. The highest $NO_2$ deposition rate of 0.34 kg/ha/annum was recorded towards the centre of Barrow Island. It must be noted that the results are strongly dependent on the $NO_2$ solubility used in the calculations.




■ **Figure 8-40 Predicted Existing Annual $NO_2$ Deposition (kg/ha/annum)**

The TAPM predictions for $NO_2$ deposition (kg/ha/annum) with the introduction of the proposed Chevron Australia facility during normal operations (with existing and approved sources) is presented in **Figure 8-41**. When this figure is compared to the existing and approved scenario (**Figure 8-40**) it is apparent that there will be an increase in the deposition rate of $NO_2$. The maximum predicted deposition rate of $NO_2$ is 0.61 kg/ha/annum which is well within the WHO critical load for nitrogen of 5–35 kg/ha/annum for nitrogen and the 15–20 kg/ha/annum specified by WHO for lowland dry heathlands as nitrogen.

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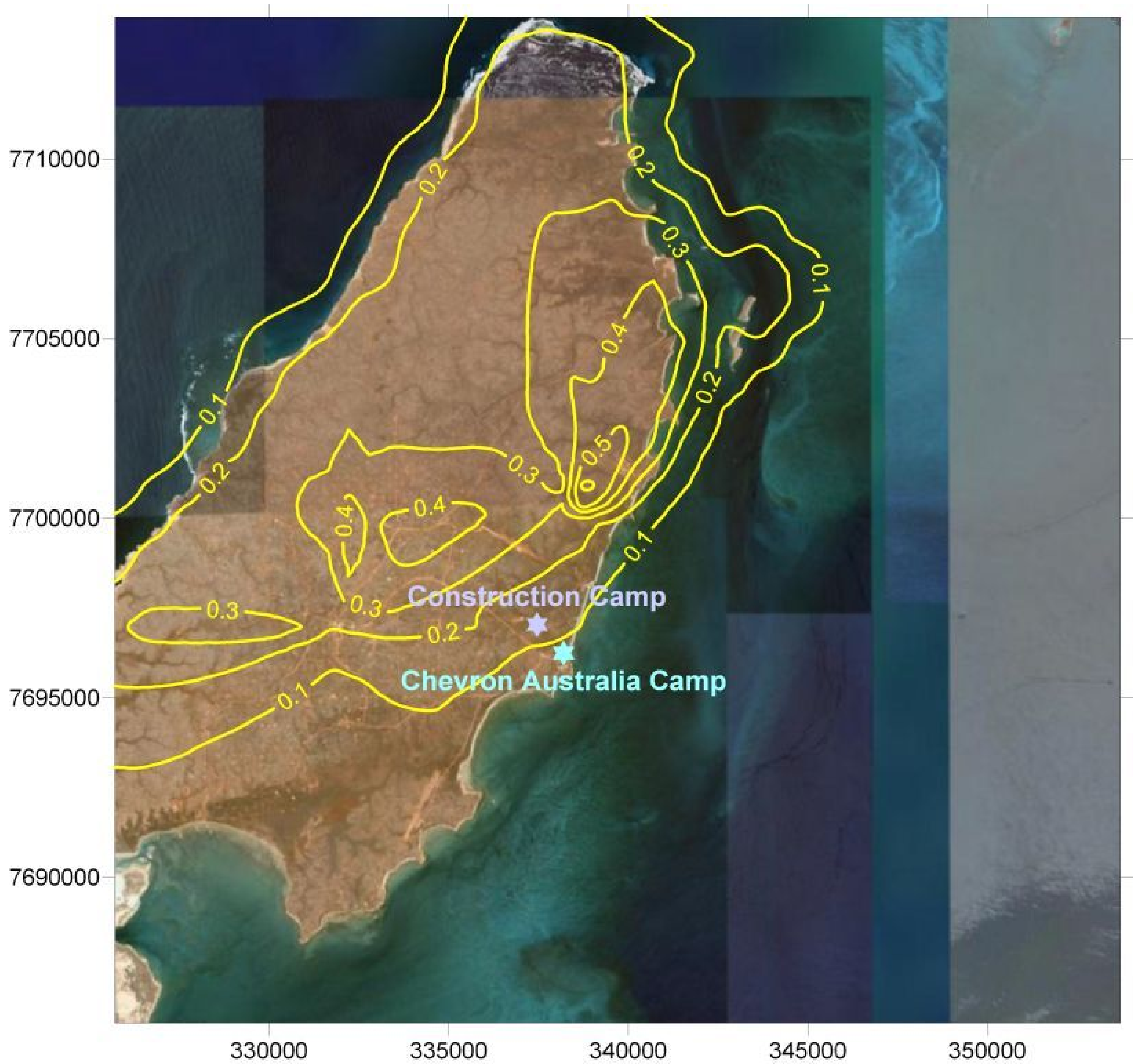


- **Figure 8-41 Predicted Future Annual $NO_2$ Deposition (kg/ha/annum)**

## 8.4 Discussion of Results

The key pollutants identified for detailed examination in this assessment are nitrogen dioxide ($NO_2$), ozone ($O_3$), particulate matter (as $PM_{10}$) and sulfur dioxide ($SO_2$).

### 8.4.1 Potential Impact on Human Health (Sensitive Receptors)

Modelling at the sensitive receptor location of the Chevron Australia camp on Barrow Island showed that no exceedences of the NEPM criteria for any pollutant were predicted. The maximum concentration predicted at the Chevron Australia camp for all pollutants was for ozone (1-hour average) under Non-Routine Operation 3 ($CO_2$ venting). This was predicted to be 93.5% of the NEPM standard. However, as mentioned in **Section 8.1.5.2**, the modelling for this non-routine condition was conducted for every hour of the year, making it highly improbable that the predicted maximum 1-hour ozone concentrations will occur. The maximum percentage of the applicable NEPM criteria predicted at the Chevron Australia camp under each scenario is presented in **Table 8-10**.

- **Table 8-10 Maximum predicted percentages of the NEPM criteria at the Chevron Australia camp.**

| Pollutant | Averaging Period | Percentage of Assessment Criteria | | | | |
|---|---|---|---|---|---|---|
| | | Existing | Future - normal | Future - Upset 1 | Future - Upset 2 | Future - Upset 3 |
| $NO_2$ | 1-hour | 6.1 | 8.1 | 33.3 | 6.5 | 7.7 |
| $O_3$ | 1-hour | n/a | n/a | n/a | n/a | 93.5 |
| $SO_2$ | 1-hour | 0.1 | 0.9 | 0.7 | 0.5 | 0.9 |
| $PM_{10}$ | 24-hour | n/a | 0.6 | 0.6 | 0.6 | 1.6 |

The maximum percentage of the applicable NEPM criteria predicted at the proposed construction camp under each scenario is presented in **Table 8-11**. Modelling at this sensitive receptor location showed that no exceedences of the NEPM criteria for any pollutant were predicted. The maximum concentration predicted at the proposed construction camp for all pollutants was for ozone (1-hour average) under Non-Routine Operation 3 ($CO_2$ venting). This was predicted to be 93.5% of the NEPM standard. However, as mentioned in **Section 8.1.5.2**, the modelling for this non-routine condition was conducted for every hour of the year, making it highly improbable that the predicted maximum 1-hour ozone concentrations will occur.

- **Table 8-11 Maximum predicted percentages of the NEPM criteria at the proposed construction camp.**

| Pollutant | Averaging Period | Percentage of Assessment Criteria | | | | |
|---|---|---|---|---|---|---|
| | | Existing | Future - normal | Future - Upset 1 | Future - Upset 2 | Future - Upset 3 |
| $NO_2$ | 1-hour | 7.3 | 8.5 | 33.3 | 8.5 | 8.5 |
| $O_3$ | 1-hour | n/a | n/a | n/a | n/a | 93.5 |
| $SO_2$ | 1-hour | 0.1 | 1.1 | 1.1 | 0.5 | 1.1 |
| $PM_{10}$ | 24-hour | n/a | 0.6 | 0.7 | 0.6 | 1.6 |

### 8.4.2 Potential Impact on Human Health (occupational)

Modelling undertaken to predict the potential impacts of occupational exposure of the workforce at the proposed Chevron Australia development has shown that concentrations of all pollutants are expected to be well below the relevant occupational exposure criteria. The maximum concentration predicted for all pollutants was 12.7% of the relevant criteria ($H_2S$ 8-hour TWA).

### 8.4.3 Potential Environmental Impact (deposition on vegetation)

This assessment includes estimates of dry deposition of $SO_2$ and $NO_2$ for the region surrounding Barrow Island, incorporating all emissions associated with the proposed gas processing facility as well as existing and approved sources. The results of the TAPM modelling indicate that 'typical high' $SO_2$ and $NO_2$ deposition in the region around Barrow Island are 0.16 kg/ha/annum and 0.61 kg/ha/annum respectively, which are well under World Health Organisation (WHO, 2000) standards for assessing the risks of impacts on vegetation; that is, WHO standards 8 to16 kg/ha/annum ($SO_2$) and 5–35 kg/ha/annum for nitrogen and the 15–20 kg/ha/annum specified for lowland dry heathlands as nitrogen.

It is important to that that while these deposition rates are much less than the WHO guideline, the relevance of the WHO guideline to Barrow Island's vegetation is uncertain (EPA, 2006).

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# 9. Conclusions

## 9.1 Overview

As part of the proposed expansion of the Gorgon Project at Barrow Island, an air quality assessment was undertaken to determine the predicted air quality impacts from operation of the development. The air quality assessment was carried out in accordance with the Air Quality and Air Pollution Modelling Guidance Notes (DOE, 2006).

The assessment included an analysis and description of existing air quality in the region and determination of potential air quality impacts during normal and defined upset operating conditions though atmospheric dispersion modelling of oxides of nitrogen, sulfur dioxide, ozone and particulates, and comparison to relevant assessment criteria. Atmospheric dispersion modelling included incorporation of existing and approved developments on the Burrup Peninsula considered significant for air emissions in the region.

## 9.2 Existing Air Quality

Modelling of the existing air quality of the Barrow Island region incorporated the following emission sources:

- NWSV Karratha Gas Plant including the new Train 4 and Train 5;
- The approved Pluto gas Plant;
- Hamersley Iron power station at Parker Point near Dampier (2 stacks); and
- Burrup Fertiliser's ammonia plant (2 stacks).

The results of the modelling predicted no exceedences of the Ambient Air Quality NEPM are likely to occur for any of the pollutants due to existing and approved sources on the Burrup Peninsula. The maximum predicted concentration for any pollutant was for ozone, which reached 63.6% of the relevant NEPM standard (4-hour average)

## 9.3 Predicted Air Quality

With addition of the proposed Gorgon Gas Development Expansion Proposal to the existing scenario, concentrations of all pollutants are predicted to increase under normal operating conditions. The most significant of these increases is predicted to occur for $NO_2$ and $SO_2$, which are both more than double the maximum concentrations predicted for the existing scenario. However the maximum predicted concentrations of both remains well below the relevant NEPM standard. Under normal operating conditions, the maximum predicted concentration for any pollutant was for ozone, which reached 64.1% of the relevant NEPM standard (4-hour average).

During start up operations the model is predicting that the NEPM 1-hour criteria for $NO_2$ will be exceeded to the northeast of the proposed facility. An analysis of the output file highlights that this excursion only occurs for one hour and the second highest concentration is down to 72% of the NEPM criteria.

The maximum ozone concentration is predicted to increase significantly for upset condition 3 ($CO_2$ venting). Under this scenario the maximum is predicted to be 127% of the relevant NEPM standard (1-hour average). However, as this upset scenario was modelled to occur every hour over the modelled year, it is highly improbable that the predicted maximum 1-hour ozone concentration will occur. As such, this value represents the most conservative estimate of impact.

It is predicted by the model that both particulates (as $PM_{10}$) and $SO_2$ will not be an issue during the three non-routine operations that were modelled.

This air quality assessment concludes with the following key findings:

- Normal operations of the proposed Gorgon Gas Development Expansion Proposal are not predicted to cause any significant air quality impacts at Barrow Island and the surrounding area.
- The maximum 1-hour concentration of $NO_2$ during start up operations is predicted to be 139% of the relevant NEPM criteria. Excursion of the NEPM criteria is predicted to occur only once during this scenario as the second highest concentration recorded was down to 72% of the criteria.
- One exceedence of the NEPM criteria was predicted under $CO_2$ venting conditions. This exceedence was predicted to be 127% of the relevant NEPM criteria. As this upset scenario was modelled to occur every hour over the modelled year, it is highly improbable that the predicted maximum 1-hour ozone concentration will occur.
- No exceedence of the NEPM criteria or occupational health criteria is predicted at sensitive receptor locations modelled, under normal and upset conditions, for all pollutants.

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# Appendix A TAPM *.lis File Output

```
|---------------------------------------|
| THE AIR POLLUTION MODEL (TAPM V3.0.7). |
| Copyright (C) CSIRO Australia.         |
| All Rights Reserved.                   |
|---------------------------------------|

----------------
RUN INFORMATION:
----------------
NUMBER OF GRIDS=            4
GRID CENTRE (longitude,latitude)=(   115.4583     ,  -20.78333     )
GRID CENTRE (cx,cy)=(      339700 ,      7699950 ) (m)
GRID DIMENSIONS (nx,ny,nz)=(          31 ,          31 ,          20 )
NUMBER OF VERTICAL LEVELS OUTPUT =          17
DATES (START,END)=(    20021230 ,    20030331 )
DATE FROM WHICH OUTPUT BEGINS =    20030101
LOCAL HOUR IS GMT+   7.700000
SYNOPTIC WIND SPEED MAXIMUM =          30 (m/s)
SYNOPTIC PRESSURE-GRADIENT SCALING FACTOR =   1.000000
SYNOPTIC PRESSURE-GRADIENT FILTERING FACTOR =   1.000000
VARY SYNOPTIC WITH 3-D SPACE AND TIME
INCLUDE VEGETATION
EXCLUDE NON-HYDROSTATIC EFFECTS
EXCLUDE PROGNOSTIC RAIN EQUATION
EXCLUDE PROGNOSTIC SNOW EQUATION
INCLUDE PROGNOSTIC EDDY DISSIPATION RATE EQUATION
POLLUTION : CHEMISTRY (APM,NOX,NO2,O3,SO2,FPM)
EXCLUDE POLLUTANT CROSS-CORRELATION EQUATION
EXCLUDE POLLUTANT VARIANCE EQUATION
EXCLUDE 3-D POLLUTION OUTPUT (*.C3D)
POLLUTANT GRID DIMENSIONS (nxf,nyf)=(          57 ,          57 )
BACKGROUND APM     =  0.0000000E+00 (ug/m3)
BACKGROUND NOX&NO2=  0.0000000E+00 (ppb)
BACKGROUND O3      =   20.00000     (ppb)
BACKGROUND Rsmog  =  0.2000000     (ppb)
BACKGROUND SO2     =  0.0000000E+00 (ppb)
BACKGROUND FPM     =  0.0000000E+00 (ug/m3)
pH of liquid water=   4.500000

---------------------------------
START GRID           4 D:\TAPM_Run\Chevron\AppChev_ShipVOC0_Lang\BIAppChev03010
a
METEOROLOGY IS BEING INPUT FROM *.M3D FILES
GRID SPACING (delx,dely)=(        1000 ,        1000 ) (m)
POLLUTANT GRID SPACING (delxf,delyf)=(         500 ,          500 ) (m)
NO CONCENTRATION BACKGROUND FILE AVAILABLE
NO BUILDING FILE AVAILABLE
NUMBER OF pse SOURCES=         109
NO lse EMISSION FILE AVAILABLE
NO ase EMISSION FILE AVAILABLE
```

```
NO gse EMISSION FILE AVAILABLE
NO bse EMISSION FILE AVAILABLE
NO whe EMISSION FILE AVAILABLE
NO vpx EMISSION FILE AVAILABLE
NO vdx EMISSION FILE AVAILABLE
NO vlx EMISSION FILE AVAILABLE
NO vpv EMISSION FILE AVAILABLE
INITIALISE
LARGE TIMESTEP =   300.0000
METEOROLOGICAL ADVECTION TIMESTEP =   300.0000     (s)
 Deep Soil Moisture Content (kg/kg)=  0.1500000
 Deep Soil & Sea Temperatures (K)  =   298.4000       298.4000
POLLUTION ADVECTION TIMESTEP =   33.33333     (s)
pse KEY :
is    = Source Number
ls    = Source Switch (-1=Off,0=EGM,1=EGM+LPM)
xs,ys = Source Position (m)
hs    = Source Height (m)
rs    = Source Radius (m)
es    = Buoyancy Enhancement Factor
fs_no = Fraction of NOX Emitted as NO
fs_fpm= Fraction of APM Emitted as FPM
INIT_pse
 is,  ls,       xs,       ys,       hs,       rs,       es,    fs_no,   fs_fpm
  1,   0,  476910., 7722765.,    40.00,     1.98,     2.70,     0.90,     0.50,
 Note: source           1  is off the pollution grid
  2,   0,  476910., 7722800.,    40.00,     1.98,     2.70,     0.90,     0.50,
 Note: source           2  is off the pollution grid
  3,   0,  476910., 7722810.,    40.00,     1.98,     2.70,     0.90,     0.50,
 Note: source           3  is off the pollution grid
  4,   0,  476910., 7722845.,    40.00,     1.98,     2.70,     0.90,     0.50,
 Note: source           4  is off the pollution grid
  5,   0,  476910., 7722855.,    40.00,     1.98,     2.70,     0.90,     0.50,
 Note: source           5  is off the pollution grid
  6,   0,  476910., 7722890.,    40.00,     1.98,     2.70,     0.90,     0.50,
 Note: source           6  is off the pollution grid
  7,   0,  476540., 7722965.,    40.00,     1.94,     2.10,     0.90,     0.50,
 Note: source           7  is off the pollution grid
  8,   0,  476590., 7722965.,    40.00,     1.94,     2.10,     0.90,     0.50,
 Note: source           8  is off the pollution grid
  9,   0,  476610., 7722965.,    40.00,     1.87,     2.10,     0.90,     0.50,
 Note: source           9  is off the pollution grid
 10,   0,  476660., 7722965.,    40.00,     1.87,     2.10,     0.90,     0.50,
 Note: source          10  is off the pollution grid
 11,   0,  476510., 7722960.,    40.00,     1.36,     2.10,     0.90,     0.50,
 Note: source          11  is off the pollution grid
 12,   0,  476540., 7722845.,    40.00,     1.94,     2.10,     0.90,     0.50,
 Note: source          12  is off the pollution grid
 13,   0,  476590., 7722845.,    40.00,     1.94,     2.10,     0.90,     0.50,
 Note: source          13  is off the pollution grid
 14,   0,  476610., 7722845.,    40.00,     1.87,     2.10,     0.90,     0.50,
 Note: source          14  is off the pollution grid
 15,   0,  476660., 7722845.,    40.00,     1.87,     2.10,     0.90,     0.50,
 Note: source          15  is off the pollution grid
```

```
16,   0,  476510., 7722840.,    40.00,     1.36,     2.10,     0.90,     0.50,
Note: source          16  is off the pollution grid
17,   0,  476540., 7722610.,    40.00,     1.94,     2.10,     0.90,     0.50,
Note: source          17  is off the pollution grid
18,   0,  476590., 7722610.,    40.00,     1.94,     2.10,     0.90,     0.50,
Note: source          18  is off the pollution grid
19,   0,  476610., 7722610.,    40.00,     1.87,     2.10,     0.90,     0.50,
Note: source          19  is off the pollution grid
20,   0,  476660., 7722610.,    40.00,     1.87,     2.10,     0.90,     0.50,
Note: source          20  is off the pollution grid
21,   0,  476510., 7722605.,    40.00,     1.36,     2.10,     0.90,     0.50,
Note: source          21  is off the pollution grid
22,   0,  477152., 7722915.,    33.00,     0.73,     1.70,     0.90,     0.50,
Note: source          22  is off the pollution grid
23,   0,  477152., 7722905.,    33.00,     0.73,     1.70,     0.90,     0.50,
Note: source          23  is off the pollution grid
24,   0,  477152., 7722895.,    33.00,     0.73,     1.70,     0.90,     0.50,
Note: source          24  is off the pollution grid
25,   0,  476968., 7722880.,    33.00,     0.73,     1.70,     0.90,     0.50,
Note: source          25  is off the pollution grid
26,   0,  476968., 7722870.,    33.00,     0.73,     1.70,     0.90,     0.50,
Note: source          26  is off the pollution grid
27,   0,  477035., 7722698.,    24.00,     1.00,     2.50,     0.90,     0.50,
Note: source          27  is off the pollution grid
28,   0,  477050., 7722698.,    24.00,     1.45,     2.50,     0.90,     0.50,
Note: source          28  is off the pollution grid
29,   0,  477065., 7722698.,    24.00,     1.00,     2.50,     0.90,     0.50,
Note: source          29  is off the pollution grid
30,   0,  477080., 7722698.,    24.00,     1.45,     2.50,     0.90,     0.50,
Note: source          30  is off the pollution grid
31,   0,  476500., 7722500.,    20.00,     1.00,     1.00,     0.90,     0.50,
Note: source          31  is off the pollution grid
32,   0,  477082., 7722352.,   125.00,     1.40,     1.00,     0.90,     0.50,
Note: source          32  is off the pollution grid
33,   0,  477092., 7722511.,    46.00,   135.00,     1.00,     0.90,     0.50,
Note: source          33  is off the pollution grid
34,   0,  476328., 7722431.,    60.00,     0.74,     1.00,     0.90,     0.50,
Note: source          34  is off the pollution grid
35,   0,  475943., 7723061.,    50.00,     0.50,     1.00,     0.90,     0.50,
Note: source          35  is off the pollution grid
36,   0,  476664., 7722465.,    40.00,     1.45,     2.00,     0.90,     0.50,
Note: source          36  is off the pollution grid
37,   0,  476664., 7722461.,    40.00,     1.45,     2.00,     0.90,     0.50,
Note: source          37  is off the pollution grid
38,   0,  476650., 7722461.,    40.00,     3.05,     1.00,     0.90,     0.50,
Note: source          38  is off the pollution grid
39,   0,  476933., 7722944.,    40.00,     1.46,     1.80,     0.90,     0.50,
Note: source          39  is off the pollution grid
40,   0,  476972., 7722702.,    40.00,     1.65,     1.70,     0.90,     0.50,
Note: source          40  is off the pollution grid
41,   0,  476972., 7722668.,    40.00,     1.65,     1.70,     0.90,     0.50,
Note: source          41  is off the pollution grid
42,   0,  476972., 7722626.,    40.00,     1.65,     1.70,     0.90,     0.50,
Note: source          42  is off the pollution grid
```

```
43,   0,  476972., 7722592.,    40.00,     1.65,     1.70,     0.90,     0.50,
Note: source          43  is off the pollution grid
44,   0,  476664., 7722335.,    40.00,     1.45,     2.00,     0.90,     0.50,
Note: source          44  is off the pollution grid
45,   0,  476664., 7722331.,    40.00,     1.45,     2.00,     0.90,     0.50,
Note: source          45  is off the pollution grid
46,   0,  476560., 7722331.,    40.00,     3.05,     1.00,     0.90,     0.50,
Note: source          46  is off the pollution grid
47,   0,  476337., 7722631.,    40.00,     1.65,     1.70,     0.90,     0.50,
Note: source          47  is off the pollution grid
48,   0,  477097., 7722741.,    33.00,     0.73,     1.70,     0.90,     0.50,
Note: source          48  is off the pollution grid
49,   0,  471500., 7717000.,    60.00,     1.30,     1.00,     0.90,     0.50,
Note: source          49  is off the pollution grid
50,   0,  471500., 7717000.,    60.00,     1.30,     1.00,     0.90,     0.50,
Note: source          50  is off the pollution grid
51,   0,  476915., 7718833.,    36.00,     1.78,     1.00,     0.90,     0.50,
Note: source          51  is off the pollution grid
52,   0,  477060., 7718820.,    15.00,     0.85,     1.00,     0.90,     0.50,
Note: source          52  is off the pollution grid
53,   0,  475609., 7720460.,    40.00,     1.75,     2.00,     0.90,     0.50,
Note: source          53  is off the pollution grid
54,   0,  475621., 7720466.,    40.00,     1.75,     2.00,     0.90,     0.50,
Note: source          54  is off the pollution grid
55,   0,  475509., 7720422.,    40.00,     2.50,     1.00,     0.90,     0.50,
Note: source          55  is off the pollution grid
56,   0,  475528., 7720311.,    40.00,     1.65,     2.70,     0.90,     0.50,
Note: source          56  is off the pollution grid
57,   0,  475565., 7720329.,    40.00,     1.65,     2.70,     0.90,     0.50,
Note: source          57  is off the pollution grid
58,   0,  475602., 7720342.,    40.00,     1.65,     2.70,     0.90,     0.50,
Note: source          58  is off the pollution grid
59,   0,  475646., 7720360.,    40.00,     2.25,     2.70,     0.90,     0.50,
Note: source          59  is off the pollution grid
60,   0,  475683., 7720379.,    40.00,     2.25,     2.70,     0.90,     0.50,
Note: source          60  is off the pollution grid
61,   0,  475963., 7720205.,    40.00,     1.90,     2.70,     0.90,     0.50,
Note: source          61  is off the pollution grid
62,   0,  475826., 7720671.,    40.00,     1.45,     1.80,     0.90,     0.50,
Note: source          62  is off the pollution grid
63,   0,  475590., 7720677.,    33.00,     0.75,     1.80,     0.90,     0.50,
Note: source          63  is off the pollution grid
64,   0,  475720., 7720177.,    40.00,     1.75,     2.00,     0.90,     0.50,
Note: source          64  is off the pollution grid
65,   0,  475733., 7720183.,    40.00,     1.75,     2.00,     0.90,     0.50,
Note: source          65  is off the pollution grid
66,   0,  475615., 7720137.,    40.00,     2.50,     1.00,     0.90,     0.50,
Note: source          66  is off the pollution grid
67,   0,  475547., 7720280.,    40.00,     1.65,     2.70,     0.90,     0.50,
Note: source          67  is off the pollution grid
68,   0,  475578., 7720298.,    40.00,     1.65,     2.70,     0.90,     0.50,
Note: source          68  is off the pollution grid
69,   0,  475621., 7720317.,    40.00,     1.65,     2.70,     0.90,     0.50,
Note: source          69  is off the pollution grid
```

SKM

```
 70,   0,  475665., 7720329.,    40.00,     2.25,     2.70,     0.90,     0.50,
 Note: source          70  is off the pollution grid
 71,   0,  475702., 7720348.,    40.00,     2.25,     2.70,     0.90,     0.50,
 Note: source          71  is off the pollution grid
 72,   0,  475851., 7720106.,    40.00,     1.90,     2.70,     0.90,     0.50,
 Note: source          72  is off the pollution grid
 73,   0,  475975., 7720301.,    40.00,     1.45,     1.80,     0.90,     0.50,
 Note: source          73  is off the pollution grid
 74,   0,  475739., 7720727.,    33.00,     0.75,     1.80,     0.90,     0.50,
 Note: source          74  is off the pollution grid
 75,   0,  475500., 7723500.,    40.00,     1.00,     1.00,     0.90,     0.50,
 Note: source          75  is off the pollution grid
 76,   0,  475250., 7723250.,    40.00,     1.00,     1.00,     0.90,     0.50,
 Note: source          76  is off the pollution grid
 77,   0,  474500., 7721500.,    40.00,     1.00,     1.00,     0.90,     0.50,
 Note: source          77  is off the pollution grid
 78,   0,  473500., 7720500.,    40.00,     1.00,     1.00,     0.90,     0.50,
 Note: source          78  is off the pollution grid
 79,   0,  470500., 7717500.,    40.00,     1.00,     1.00,     0.90,     0.50,
 Note: source          79  is off the pollution grid
 80,   0,  466500., 7716500.,    40.00,     1.00,     1.00,     0.90,     0.50,
 Note: source          80  is off the pollution grid
 81,   0,  464500., 7716500.,    40.00,     1.00,     1.00,     0.90,     0.50,
 Note: source          81  is off the pollution grid
 82,   0,  332000., 7697000.,    30.00,     1.98,     2.70,     0.90,     0.50,
 83,   0,  332000., 7697045.,    30.00,     1.98,     2.70,     0.90,     0.50,
 84,   0,  331900., 7697150.,    20.00,     1.00,     1.00,     0.90,     0.50,
 85,   0,  332200., 7697200.,    20.00,     0.73,     1.70,     0.90,     0.50,
 86,   1,  338552., 7700584.,    40.00,     1.98,     1.00,     0.90,     0.50,
 87,   1,  338554., 7700473.,    40.00,     1.98,     1.00,     0.90,     0.50,
 88,   1,  338735., 7700586.,    40.00,     1.98,     1.00,     0.90,     0.50,
 89,   1,  338735., 7700476.,    40.00,     1.98,     1.00,     0.90,     0.50,
 90,   1,  338921., 7700588.,    40.00,     1.98,     1.00,     0.90,     0.50,
 91,   1,  338921., 7700479.,    40.00,     1.98,     1.00,     0.90,     0.50,
 92,   1,  338406., 7700246.,    40.00,     2.00,     1.00,     0.90,     0.50,
 93,   1,  338525., 7700331.,    40.00,     2.00,     1.00,     0.90,     0.50,
 94,   1,  338527., 7700236.,    40.00,     2.00,     1.00,     0.90,     0.50,
 95,   1,  338577., 7700330.,    40.00,     2.00,     1.00,     0.90,     0.50,
 96,   1,  338579., 7700236.,    40.00,     2.00,     1.00,     0.90,     0.50,
 97,   1,  337840., 7700146.,    38.50,     0.50,     1.00,     0.90,     0.50,
 98,   1,  337857., 7700146.,    38.50,     0.50,     1.00,     0.90,     0.50,
 99,   1,  337984., 7700001.,     6.00,     1.50,     1.00,     0.90,     0.50,
100,   1,  338087., 7700001.,     6.00,     1.50,     1.00,     0.90,     0.50,
101,   1,  337984., 7699863.,     6.00,     2.50,     1.00,     0.90,     0.50,
102,   1,  338087., 7699864.,     6.00,     2.50,     1.00,     0.90,     0.50,
103,   1,  339173., 7700238.,    45.00,     1.50,     1.00,     0.90,     0.50,
104,   1,  339175., 7700177.,    45.00,     1.50,     1.00,     0.90,     0.50,
105,   1,  338337., 7700473.,    15.00,     1.00,     1.00,     0.90,     0.50,
106,   1,  338337., 7700553.,    15.00,     1.00,     1.00,     0.90,     0.50,
107,   1,  338337., 7700633.,    15.00,     1.00,     1.00,     0.90,     0.50,
108,   1,  342579., 7697736.,    40.00,     1.00,     1.00,     0.90,     0.50,
109,   1,  342579., 7697736.,    20.00,     1.00,     1.00,     0.90,     0.50,
LAGRANGIAN (LPM) MODE IS ON FOR THIS GRID
LPM ADVECTION TIMESTEP =   60.00000     (s)
```

```
IN_pse
DATE=20021230,HOUR= 1
IN_pse
REWIND_pse
IN_SYNOPTIC
 Deep Soil Moisture Content (kg/kg)=  0.1500000
 Deep Soil & Sea Temperatures (K)  =   298.4000       298.4000
DATE=20021230,HOUR= 2
IN_pse
REWIND_pse
DATE=20021230,HOUR= 3
IN_pse
REWIND_pse
DATE=20021230,HOUR= 4
IN_pse
REWIND_pse
DATE=20021230,HOUR= 5
IN_pse
REWIND_pse
DATE=20021230,HOUR= 6
IN_pse
REWIND_pse
DATE=20021230,HOUR= 7
IN_pse
REWIND_pse
IN_SYNOPTIC
 Deep Soil Moisture Content (kg/kg)=  0.1500000
 Deep Soil & Sea Temperatures (K)  =   298.4000       298.4000
DATE=20021230,HOUR= 8
IN_pse
REWIND_pse
DATE=20021230,HOUR= 9
IN_pse
REWIND_pse
DATE=20021230,HOUR=10
IN_pse
REWIND_pse
DATE=20021230,HOUR=11
IN_pse
REWIND_pse
DATE=20021230,HOUR=12
IN_pse
REWIND_pse
DATE=20021230,HOUR=13
IN_pse
REWIND_pse
IN_SYNOPTIC
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IN_pse
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REWIND_pse
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# APPENDIX H

## Application Of The State Ministerial Conditions To The Elements Of The Revised Proposal

# APPLICATION OF THE WA STATE MINISTERIAL CONDITIONS (STATEMENT NO. 748) TO THE REVISED PROPOSAL

| Aspect | Element | Description of Proposed Change | Relevant Conditions and their Applicability to Proposed Changes* | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 5 | 6 | 7 | 8 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| Gas Treatment Plant | Number of LNG trains | Addition of 1 x 5 MTPA LNG train | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Gas Processing Drivers | Addition of two ~80 MW DLN gas turbines | ✓ | ✓ | | | | ✓ | | ✓ | | | ✓ | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Power Generation | Addition of one nominal ~116 MW gas turbine to support the addition of one 5 MTPA LNG Train All 5 turbines will be fitted with DLN burners. | ✓ | ✓ | | | | ✓ | | ✓ | | | ✓ | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Carbon Dioxide ($CO_2$) Injection System | $CO_2$ pipeline | Increased length of approximately 3 km to a total of 8 km<br>Increased area of easement approximately 3.6 ha to a total of 9.6 ha | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | ✓ | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | $CO_2$ injection wells | Addition of one injection well directionally drilled from 3 surface locations | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | ✓ | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Pressure management wells | Approximately 4 pressure management wells (or water production wells) will be required to provide pressure relief in the Dupuy formation | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | ✓ | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Water Injection Wells | Approximately 3 water injection wells are required for the re-injection of produced water from the Pressure Management Wells | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | ✓ | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Anode wells | Approximately 23 shallow drilled anode wells for the purposes of cathodic protection | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | ✓ | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Feed Gas Pipeline | Length onshore (Barrow Island) | No change to approved pipeline length. Minor realignment over a distance of approximately 500 m to accommodate changes to the Gas Treatment Plant footprint. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Construction Easement (onshore) | No change to approved pipeline length. Minor realignment over a distance of approximately 500 m to accommodate changes to the Gas Treatment Plant footprint. | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | | | | | | | | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Marine Offloading Facility (MOF) | Causeway length | Re-alignment and lengthening of the MOF structure (causeway and offloading facilities) by 800 m to a total length of ~2,120 m | ✓ | ✓ | | | | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | | | | | | ✓ | ✓ | ✓ |
| | MOF length | | ✓ | ✓ | | | | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | ✓ | ✓ | | | | | | | | | ✓ | ✓ | ✓ |
| | MOF access | Decrease in length of channel by approximately 850 m to 750 m long<br>Increase in width of channel from 120 m to 165 m wide over a length of approximately 500 m | ✓ | ✓ | | | | ✓ | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | ✓ | ✓ | ✓ |
| LNG Jetty | LNG jetty length | Decrease in LNG Jetty length of approximately 600 m to a total length of 2.1 km | ✓ | ✓ | | | | ✓ | | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | ✓ | | | | | | | | | | ✓ | ✓ | ✓ |
| | Turning basin and access channel design | Shape of turning basin has been optimised as shown in Figure 4 and Figure 5 in Appendix A (Note that dredging volumes remain the same as for approved Gorgon Gas Development, i.e. 6.5 million $m^3$)<br>Dual berth facility (redesigned to meet safety requirements) | ✓ | ✓ | | | | ✓ | | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | ✓ | ✓ | ✓ |
| Dredging | MOF volume | The dredging requirement for the MOF access channel may reduce as a result of extending the MOF into deeper water. Dredging volume will not exceed the volume approved for the Gorgon Gas Development (i.e. 1.1 million $m^3$). | ✓ | ✓ | | | | ✓ | | | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | | | | | | | | | ✓ | ✓ | ✓ |

## A3.1 *Relevant State Conditions (Statement No. 748) and their Applicability to Proposed Changes

Condition 1 Proposal Implementation
This Condition nominates that the Proposal shall be built as per Schedule 1 (Summary of Key Proposal Characteristics). Schedule 1 will need to be updated to reflect the changes.

Condition 5 Environmental Performance Reporting
This Condition requires the annual submission of an Environmental Performance Report relating to key receptors.

Condition 6 Terrestrial and Subterranean Baseline State and Environmental Impact Report
This Condition requires the submission of a report detailing the baseline environmental condition of terrestrial locations that will be disturbed as a result of the Gorgon Proposal. This Report must nominate the Terrestrial Disturbance Footprint (TDF) and must be submitted to the satisfaction of the Minister.

Condition 7 Terrestrial and Subterranean Protection Plan
This Condition requires the nomination of environmental protection measures for ensuring that impacts to terrestrial flora and fauna are minimised as far as practicable. The aim of the Plan is to reduce impacts within the TDF and to stop any material or serious environmental harm occurring outside the TDF.

Condition 8 Terrestrial and Subterranean Monitoring Program
This Condition requires the establishment of statistically valid methodologies for the determination of impact to flora and fauna external to the TDF.

Condition 10 Terrestrial and Marine Quarantine Management System
This Condition requires the Proponent to design, document and submit to the Minister a System that has the overall aim of stopping introductions or proliferations of non-indigenous terrestrial species and marine pests to or within Barrow Island or the water surrounding Barrow Island as a consequence of the Proposal.

Condition 11 Short Range Endemics and Subterranean Fauna Monitoring Plan
This Condition requires a plan for further survey and monitoring that aims to identify those species known only to occur on the Gas Treatment Plant site.

Condition 12 Fire Management Plan
This Condition requires the Proponent to submit a plan with the objectives of ensuring that the Proposal does not cause material or serious environmental harm outside of the TDF as a result of fire and that fire risk reduction measures are built into the design of the terrestrial facilities.

14 Coastal and Marine Baseline State and Environmental Impact Report
This Condition requires the submission of a report detailing the baseline environmental condition of marine locations that will be disturbed as a result of the Gorgon Proposal. This Report must nominate the Marine Disturbance Footprint (MDF) and must be submitted to the satisfaction of the Minister.

Condition 15 Establishing a Marine Turtle Expert Panel (MTEP)
This Condition requires the establishment of an expert panel to advise the Proponent and the Minister regarding monitoring and management of marine turtles.

Condition 16 Long-term Marine Turtle Management Plan
This Condition requires the Proponent, in conjunction with the MTEP, DEC and DEW (DEWHA) to establish the baseline information for marine turtle use of Barrow Island beaches that may be affected by the Proposal and to address long-term management of the marine turtles.

Condition 17 Marine Facilities Construction Environmental Management Plan
This Condition requires the Proponent to prepare a plan to manage the impacts of construction of the marine facilities to the satisfaction of the Minister. The aim of the Plan is to reduce impacts within the MDF and to stop any material or serious environmental harm occurring outside the MDF.

Condition 18 The Limits of Environmental Impacts (Marine)
This Condition (and Schedule 5) set the Limits of Acceptable Change as a result of the construction of Marine Facilities. Schedule 5 defines the Zone of High Impact, the Zone of Moderate Impact and the Zone of Influence.

Condition 19 Establishing a Construction Dredging Environmental Expert Panel
This Condition requires the establishment of an expert panel to advise the Proponent and the Minister regarding construction dredging and spoil disposal monitoring and management.

Condition 20 Dredge and Spoil Disposal Management and Monitoring Plan
This Condition requires the Proponent to prepare and submit a Plan to ensure that the Limits of Acceptable Impact are not exceeded (to the satisfaction of the Minister).

Condition 21 Management Triggers (Marine)
This Condition requires the Proponent to develop a plan to monitor corals within the nominated Zones of Impact and Influence to gauge impacts (in relation to baseline data collection work).

Condition 24 Post-development Coastal and Marine State and Environmental Impact Report
This Condition requires the Proponent to repeat baseline surveys following the completion of construction of the marine facilities and report the actual impacts of the works. The Proponent must continue to complete surveys for 3 years or until the measured impact has stabilised to a level consistent with acceptable limits.

Condition 25 Coastal Stability and Monitoring Plan
This Condition requires the Proponent to establish monitoring methodology capable of detecting change to the stability of the beaches adjacent to the Marine facilities (Causeway and MOF). If impacts are detected then the Proponent must present a report to the Minister nominating how the changes can be mitigated.

Condition 26 Reservoir Carbon Dioxide Injection System

This Condition requires the Proponent to design and construct $CO_2$ injection system capable of disposing 100% of the produced reservoir $CO_2$ via injection. This Condition sets a target of 80% injection based on a 5 year rolling average and requires the Proponent to prepare and submit a monitoring program for assessing the performance of the $CO_2$ Injection System.

Condition 27 Greenhouse Gas Abatement Program

This Condition requires the Proponent to prepare and submit to the Minister, a GHG Abatement Plan with an aim of ensuring that the Gas Treatment Plant is designed and operated in a manner that achieves reductions in GHG emissions as far as practicable.

Condition 28 Best Practice Pollution Control Design

This Condition requires the submission of a Best Practice Pollution Control Design Plan with the Proponents application for a Works Approval for the Gas Treatment Plant. The plan shall demonstrate that best practice design has been applied and shall state target emissions rates.

Condition 29 Air Quality Management Plan

This Condition requires the submission of an Air Quality Plan with the Proponents application for a Works Approval for the Gas Treatment Plant. The Plan shall aim to ensure that all relevant standards are met and that no material or serious environmental harm occurs as a result of plant air emissions.

Condition 30 Solid and Liquid Waste Management Plan

This Condition requires the submission of a Solid and Liquid Waste Management Plan detailing the management approach for all solid wastes, waste from the wastewater treatment plant and other liquid waste produced during the construction and operation of the terrestrial facilities on Barrow Island. The objective of the plan is to ensure that waste disposal does not cause Material or Serious Environmental Harm.

Condition 31 Aboriginal and Cultural Heritage Management Plan

This Condition requires the submission of a plan for completing cultural heritage surveys within the TDF and management measures if any cultural heritage material is located.

Condition 32 Post-construction Rehabilitation Plan

This Condition requires the Proponent to submit a plan for the suitable rehabilitation of those areas disturbed during construction within the TDF but no longer required for use.

Condition 33 Project Site Rehabilitation Plan

This Condition requires the Proponent to submit a plan for the suitable rehabilitation of those areas disturbed during construction and operation of the Proposal following the cessation of the Projects life.

Condition 34 Decommissioning and Closure Plan

This Condition requires the Proponent to submit a plan for the removal of plant or the management of plant left in-situ following the cessation of the Projects life.

Condition 35 Public Availability of Plans, Programs etc

This Condition requires the Proponent to make all plans, programs etc available to the public.

Condition 36 Submission of Plans, Programs etc

This Condition defines that the requirement for submission of a plan etc to the Minister is not deemed to be met until the Minister finds that the aims and objectives or purposes of that plan etc have been met.

# APPENDIX I

## Carbon Dioxide Injection Project Uncertainty Management Plans

# APPENDIX I: CARBON DIOXIDE INJECTION PROJECT – UNCERTAINTY MANAGEMENT PLANS

## 1.1 Uncertainty Management Plans – Revised From Approved Gorgon Development

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| **Well Injectivity** | | | | | | |
| It may be difficult to inject $CO_2$ at the required rate in the case of a worse than expected geological outcome such as low permeability. | $CO_2$ cannot be injected at the required rates. | Unexpected bottom hole pressure increase (>6.9 MPa above virgin pressure in three months).<br><br>Test injection wells as they are drilled for injectivity. | Wellhead pressure; down hole pressure gauges; flow rate gauges. | Should be identifiable within six months of commencing injection. | Increase/alter monitoring activities to verify cause of bottom hole pressure increase and assess impact/implication and determine if management action is required. | |
| | | | | | 1) Re-complete injection wells; fracture stimulate. | |
| | | | | | 2) Re-complete and perforate over entire interval if not already done. | |
| | | | | | 3) Change well design for subsequent injection wells (e.g. horizontal). | Horizontal wells are not considered feasible beyond 30 degrees in the Dupuy formation (due to geomechanical properties of formations to be drilled through). Deviated wells or wells incorporating revised completions may be considered. |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | 4) Re-consider bottom hole locations for subsequent injection wells, based on additional knowledge of reservoir heterogeneity acquired from previous drilling. | |
| | | | | | 5) Drill additional injection wells. | |
| | | | | | 6) Complete injectors in another stratigraphic unit as well as the Dupuy Formation (e.g. Malouet 6000 ft Sand) to facilitate injection at the required rate. | |
| | | | | | | Uncertainty related to the ability to inject reservoir $CO_2$ at the required rates will be further narrowed with a planned series of production and injection tests on the GDW1 well towards the end of 2008, early 2009. |
| | | | | | | Additional geochemical modelling has been undertaken which confirms that chemical precipitation around the injection wells is unlikely. |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | Initially injection rate meets expectations, but overall ability for increased pressures to be dissipated throughout the reservoir is less than expected. | Gradual increase in bottom hole pressure at injector wells in excess of expected pressure increase. | Wellhead pressure; downhole pressure gauges; flow rate gauges | Should be identifiable within 10 years of commencing injection. | 1) Produce water from the Dupuy Formation to offset pressure increase (see Pore Volume and Compartmentalisation). | The ability to manage higher than anticipated reservoir pressure by the production of formation water from the Dupuy Formation outside the $CO_2$ Plume area was included in the Uncertainty Management Plan documented in the EIS/ERMP for the Approved Gorgon Gas Development.<br><br>The increased rate of $CO_2$ injection associated with the Revised Proposal is likely to require this pressure management strategy to be implemented shortly following the commencement of injection operations. This should ensure that reservoir pressure in the Dupuy formation remains below acceptable levels. |
| | $CO_2$ cannot be injected at the required rates due | Unexpected bottom hole pressure increase (> | Wellhead pressure; down hole pressure gauges; flow rate | Identifiable over the operating life of the injection | 1) Work over well and acid stimulate (depending on the | A strategy of regular back flushing of injection |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | to chemical reaction with the formation. | 6.9 MPa in 3 months), and significant change in formation water chemistry near injectors. | gauges; fluid samples & geochemical analysis. | operations. | specific change in water chemistry e.g. carbonate precipitation around the well bore). | wells has been developed to ensure well injectivity is maintained.<br><br>This strategy has been developed following lessons learned from enhanced oil recovery operations.<br><br>Back flushing removes dust, oil and other contaminants that that may be transported with the reservoir $CO_2$ to the injection wells and can block the well perforation interval.<br><br>Well work-overs and chemical stimulation remain fall back options if loss of injectivity is observed. |
| | | | | | 2) Re-complete injection wells; either fracture stimulate, or cavity complete. | Consider completion of injectors in another stratigraphic unit as well as the Dupuy Formation (e.g. Malouet 6000 ft Sand) to facilitate |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | | injection at the required rate.<br><br>Injection into alternative stratigraphic layers would require obtaining additional environmental and other regulatory approvals. |
| | | | | | | Additional geochemical modeling has been undertaken which confirms that chemical precipitation around the injection wells is unlikely. |
| **Existing Well Failure** | | | | | | |
| Containment failure via existing well penetrations.<br><br>The actions in this table are in addition to the planned assessment and remediation of existing well penetrations. | $CO_2$ migrates into overlying stratigraphy. | Seismic and/or borehole monitoring show $CO_2$ in stratigrapic layers above the Dupuy Fm in proximity to existing well penetration(s). | Surface and borehole geophysics. | Ongoing | Containment failure via existing well penetrations.<br><br>The actions in this table are in addition to the planned assessment and remediation of existing well penetrations. | |
| | $CO_2$ leakage at surface. | Surface monitoring indicates increased levels of $CO_2$ in proximity to well(s). | Atmospheric and soil gas $CO_2$ detectors, vegetation surveys, visual inspection of well heads. | Ongoing | 1) Remediate leaking well(s). | |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | 2) Implement appropriate environmental remediation. | |
| | Leakage of displaced formation water into higher stratigraphy via well penetrations. | Fluid sampling indicates Dupuy Formation water in overlying stratigraphy (above Malouet zone of intermediate salinity) and in proximity to existing well penetration(s). | Surface and borehole geophysics (fluid sampling from overlying stratigraphic unit). | Risk is greatest over the operating life of the injection operations. | Increase/alter monitoring activities to verify cause of displaced water and assess impact/implications and determine if management action is required. | |
| | | | | | 1) Remediate leaking wells, particularly if leaking well is along the expected migration path of $CO_2$ plume | |
| **Fault Seal Failure** | | | | | | |
| Containment failure via fault migration. | Faults act as a migration pathway for $CO_2$ into higher stratigraphy. | Monitoring via well bores between injectors and faults in the Dupuy formation. Seismic and/or borehole monitoring show $CO_2$ in stratigraphy above the Dupuy Formation in proximity to fault(s). | Surface and borehole geophysics, fluid sampling, down hole gauges. | Ongoing | Increase/alter monitoring activities to verify fault leakage. Assess impact/implication and determine if management action is required (some fault leakage may not result in surface leakage and may be acceptable). | |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | 1) Modify injection pattern to drive migration away from 'problem' fault. | |
| | | | | | 2) Produce water near the fault to lower pore pressure and control vertical leakage. | Inject water near the fault to change migration of $CO_2$ plume away from fault. |
| Faults acts as a migration pathway for $CO_2$ to surface. | Atmospheric $CO_2$ in proximity of fault expression at surface.<br><br>Ecological impacts observed as a result of increased levels of $CO_2$. | Surface monitoring. | Ongoing | Faults acts as a migration pathway for $CO_2$ to surface. | 1) Modify injection pattern to drive migration away from 'problem' fault. | |
| | | | | | 2) Use water production well(s) near the fault to lower pore pressure and control fluid leakage up fault. | |
| | | | | | | Consider orientation of seismic survey to better image northeast-southwest trending faults that may be open to leakage as indicated by geotechnical and regional stress field studies. These studies show that faults trending southeast- |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | | northwest are less inclined to leak.<br><br>Update geomechanical models with pressure data. |
| | Faults are impermeable both laterally and vertically | Unexpected pressure increase in a part of the Dupuy Formation that is thought to be isolated from the rest (fault bounded). | See Compartmentalisation | | | Faults are impermeable both laterally and vertically |
| **Pore Volume and Distribution** | | | | | | |
| Reduced formation pore volume or distribution may limit $CO_2$ injection. | Insufficient capacity for full volume of $CO_2$. | Rate of long term pressure build up greater than expected. | Wellhead pressure; down-hole pressure gauges; flow rate gauges. | Identifiable over the operating life of the injection operations.<br><br>May become apparent after 5 to 10 years of injection. | Increase/alter monitoring activities to verify cause of pressure build and determine that is due to limited pore volume and distribution. Assess impact/implication and determine if management action is required. | |
| | | | | | 1) Complete injection wells over full Dupuy Formation interval and higher in stratigraphy (e.g. Malouet 6000 ft Sand). | Injection into alternative stratigraphic layers would require obtaining additional regulatory approvals. |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | 2) Produce water from the Dupuy Formation to offset pressure increase. | |
| | | | | | 3) Do not inject the full volume of Gorgon reservoir $CO_2$. | |
| | | | | | | Alter the development plan to include additional injector and pressure relief wells. |
| **Permeability and Permeability Heterogeneity** | | | | | | |
| Permeability and permeability heterogeneity may limit $CO_2$ injection. | $CO_2$ cannot be injected at the required rates. | Unexpected bottom hole pressure increase (>6.9 MPa increase in three months). | Wellhead pressure; down hole pressure gauges; flow rate gauges | See Well injectivity. | | |
| | Unexpected migration of the $CO_2$ plume. | Seismic and/or borehole monitoring show unexpected $CO_2$ distribution, possibly related to stratigraphic or depositional geometry which may allow rapid migration (> 5 km in 10 yrs; see high permeability layers) related to lower than expected bottom hole pressure (~1.7 MPa vs. | Surface and borehole monitoring (well head pressure/down hole pressure gauges) production logging. | Should become apparent within 5–10 years of injection operations commencing. | Increase/alter monitoring activities to verify cause of unexpected migration. Assess impact/implication and determine if management action is required (other uncertainties that may contribute include: structure, thief zones, hydrodynamic flow). | |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | expected ~4.8 MPa). | | | | |
| | | | | | 1) Re-enter well and squeeze off perforations associated with high permeability units. | |
| | | | | | 2) Lower injection rate (drill additional injection wells). | |
| | | | | | 3) Re-locate injection wells. | |
| **Structure** | | | | | | |
| Structural uncertainty is primarily a reference to the geometry of the base seal surface, which is likely to be a significant control on $CO_2$ migration rate and direction.<br><br>Areas of poor or limited data increase structural uncertainty. | Migration path not as expected. | Significant volumes of $CO_2$ move off structure (north, east or west). | Surface (seismic) and borehole monitoring. Flow rate monitoring of injection wells. | Identifiable over the operating life of the injection operations. | Increase/alter monitoring activities to determine if unexpected migration is caused by structure. Assess impact/implication and determine if management action is required ($CO_2$ may not move to structural spill point and may not represent a risk). | |
| | | | | | 1) Modify injection pattern to drive migration in desired direction. | |
| | | | | | 2) Use water production wells to deviate course of $CO_2$ plume. | |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | Insufficient capacity for full volume of $CO_2$. | Unexpected pressure increase during injection. | See Pore volume. | | | |
| **Compartmentalisation** | | | | | | |
| Compartmentalisation (vertical & horizontal) may limit $CO_2$ injection.<br><br>Either fault or stratigraphic compartmentalisation. | $CO_2$ can only migrate into an isolated part of the Dupuy Formation. | Unexpected bottom hole pressure increase, pressure transient analysis suggests hydraulically isolated wells. | Surface and borehole monitoring. | Identifiable over the operating life of the injection operations. | Increase/alter monitoring to verify compartmentalisation. Assess impact/implication and determine if management action is required. | |
| | | | | | 1) Re-complete and perforate injection wells over entire interval if not already done (Dupuy Formation upper and lower massive sands). | |
| | | | | | 2) Drill additional injection wells outside the compartmentalised area. | |
| | | | | | 3) Produce water from the Dupuy Formation to lower pore pressure in compartmentalised area. | |
| **High Permeability Layers** | | | | | | |
| Presence of high permeability layers in reservoir.<br>Thin, high permeability layers within the injection interval may result in rapid lateral migration of $CO_2$. | $CO_2$ migrates preferentially along a specific stratigraphic interval or layer (unpredicted rapid migration). | Seismic monitoring and/or borehole monitoring shows $CO_2$ migrating rapidly in a vertically thin unit (migration of >5 km in 10 yrs).<br>Production logging. | Surface and borehole monitoring (production logging). | Identifiable over the operating life of the injection operations. | Increase/alter monitoring to verify that unexpected migration is a result of high permeability layers. Assess impact/ implications and determine if management action is | |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | required (preferential migration of $CO_2$ along high permeability layers may not represent a containment risk and are likely to result in less pore pressure build up at the injectors). | |
| | | | | | 1) Re-enter well and seal off perforations associated with the high permeability layer. | |
| | | | | | 2) Modify injection pattern to allow for high permeability layers. | |
| | | | | | 3) Do not inject the full volume of reservoir $CO_2$. | |
| | | Lower than expected bottom hole pressure (~1.7 MPa vs. expected ~4.8 MPa). | Wellhead pressure; down hole pressure gauges; flow rate gauges. | Should be identifiable within first 12 months of injection operations. | 1) Re-enter well and seal off perforations associated with the high permeability layer. | |
| | | | | | 2) Modify injection pattern to allow for high permeability layers. | |
| | | | | | 3) Do not inject the full volume of reservoir $CO_2$. | |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | $CO_2$ moves off structure as a result of migration along high permeability layer. | Seismic shows $CO_2$ saturation in a vertically thin unit (~2 km offshore); may also be associated with lower than expected bottom hole pressure (see above). | Seismic data, wellhead pressure; down hole pressure gauges; flow rate gauges. | Identifiable over the operating life of the injection operations. | 1) Re-enter well and seal off perforations associated with the high permeability layer. | |
| | | | | | 2) Modify injection pattern to allow for high permeability layers. | |
| | | | | | 3) Do not inject the full volume of reservoir $CO_2$. | Reduce injection rate. |
| **Monitoring** | | | | | | |
| Ability to image $CO_2$. | Subsurface $CO_2$ is not resolvable using a range of geophysical techniques. | $CO_2$ is being injected but cannot be imaged using surface geophysics or well logs. | Borehole geophysics. | Should become apparent within 5–10 years of injection operations commencing. | 1) Alter monitoring activities to determine if geophysical methods can be used. Evaluate impact. | |
| | | | | | 2) Alter monitoring strategy to fulfil reservoir surveillance objectives. For example develop an observation well based monitoring strategy. | |
| **Micro-seismicity** | | | | | | |
| All fluid injection operations (e.g. water flood, gas injection) are associated with micro-seismicity | | | | | | Workshop participants did not consider micro-seismicity to be a subsurface uncertainty. Micro- |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| Objective is to control events to low level.<br><br>$CO_2$ injection may result in fracturing or fault reactivation. | | | | | | seismicity occurs with all injection operations such as the enhanced oil recovery operations currently being undertaken on Barrow Island by the Barrow Island Joint Venture.<br><br>Issue is to ensure that $CO_2$ injection operations do not result in creation of faults and fractures that could result in a leak (refer discussion under Well Injectivity and Fault Seal Failure).<br><br>Propose to review micro-seismic monitoring from the Otway Basin Pilot Project to better assess issues related to the Gorgon Gas Development.<br><br>Micro Seismic may be able to be used to image $CO_2$ plume.. In effect micro seismic provides the seismic energy |

| Uncertainty | Worse Than Expected Outcome | Signpost | Reservoir Surveillance | Timing | Management Action (Approved Project) | Changes Since EIS/ERMP Publication |
|---|---|---|---|---|---|---|
| | | | | | | source. |
| **Residual Hydrocarbon Saturation ($S_{or}$)** | | | | | | |
| There is some evidence for residual oil saturation in the Dupuy Formation.<br><br>Residual oil saturations may reduce the relative permeability to $CO_2$. | Poor injectivity due to reduction in relative permeability to $CO_2$. | Unexpected bottom hole pressure increase (>6.9 MPa in three months). | Well head pressure; down hole pressure gauges; flow rate gauges. | Should become apparent within first few years of injection operations commencing. | Increase/alter monitoring activities to verify cause of pressure increase. Assess impact/ implication and determine if management action is required. | |
| | | | | | 1) Undertake actions identified for unexpected pressure increase related to reduced well injectivity. | |
| | | | | | | $CO_2$ data well revealed that the Dupuy formation has low residual oil saturation. |

## 1.2 Failure Modes and Effects Assessment – Revised from Approved Gorgon Development

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| **Release of $CO_2$ – Facility Leakage (compressor, pipeline, well head)** | | | |
| Mechanical failure of $CO_2$ compressors and pumps resulting in release of $CO_2$ to the atmosphere.<br><br>Likelihood: Possible | Design and operate the $CO_2$ compressors and pumps in accordance with petroleum industry standards. Preventative maintenance program.<br>Apply industry operational experience with $CO_2$ compressors from North America.<br><br>Design automatic shut-down and isolation of $CO_2$ injection equipment to limit release of $CO_2$ to volume contained within that part of the facility.<br><br>Many of the potential failure scenarios would occur within the compressor or pump and would only result in controlled release to atmosphere as equipment was repaired limiting health or environmental impacts.<br><br>Design $CO_2$ detection system and alarms.<br><br>Utilise appropriate personal protective equipment for people working around $CO_2$ compressors and pumps. | Analogous to existing oil and gas operational risk.<br><br>Dependent upon nature of failure, there is a potential for release to atmosphere of that volume of $CO_2$ contained within the compressors and related facilities (several tonnes to several tens of tonnes of $CO_2$). Many failures would occur within the compressor or pump and would only result in controlled release to atmosphere as equipment was repaired. | |
| Mechanical failure of $CO_2$ pipeline caused by either below standard operating practice or external factors such as unauthorised excavation resulting in release of $CO_2$ to the atmosphere.<br><br>Likelihood: Unlikely | Design and operate $CO_2$ pipeline in accordance with Australian Standards for petroleum pipelines AS2885. Regular monitoring of pipeline.<br>Apply industry operational experience with $CO_2$ pipelines from North America.<br><br>Design automatic shut-down and isolation of pipeline to limit release of $CO_2$ to volume contained within the pipeline.<br>Pipeline damage by external factors such as unauthorised excavation (which is a significant risk factor for most pipeline operators) are lessened by isolation of Barrow Island, and locating pipeline above ground. | Analogous to existing oil and gas operational risk.<br><br>Dependent upon nature of failure, there is a potential for release to atmosphere of a moderate volume (several tens of tonnes to several hundred tonnes) of $CO_2$. | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| Leakage at the well head caused by worn gaskets, valves or by corrosion resulting in release of $CO_2$. Failure of well casing at the top of ground water table resulting in release of $CO_2$ into the near surface.<br><br>Likelihood: Possible | Implement a wellhead inspection, preventative maintenance program and annular pressure monitoring.<br>Design automatic isolation of wellhead to limit release to volume of $CO_2$ contained within the wellhead and upper portion of the injection well.<br>Once failure is identified, well will be worked over and leak repaired limiting volume of $CO_2$ released.<br>Manage ground water level casing corrosion by active cathodic protection.<br>Leakage prevented by multiple casing strings and tubing. | Analogous to existing oil and gas operational risk.<br><br>Dependent upon nature of failure, there is a potential for release of minor volume (several tonnes to tens of tonnes) of $CO_2$ to the atmosphere and/or the near surface cave systems.<br><br>A consequence of well casing leakage at the top of the ground water table is that $CO_2$ could leak into the near surface cave systems with detrimental impact on the fauna in these systems. | |
| **Unplanned Migration of $CO_2$ – Baffles and Barriers** | | | |
| Migration of $CO_2$ through intra Dupuy Formation baffles such as the Perforans Shale, faster than expected.<br><br>Buoyant $CO_2$ migrating over tens of years (or less) towards the upper Dupuy Formation baffles.<br><br>Likelihood: Possible (Revised from Likely in the EIS/ERMP)<br><br>Requires a variation in baffle architecture from that defined in the stratigraphic model. | Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow $CO_2$ migration.<br><br>Nature of baffle provides tortuous migration path enhancing the ability for the migrating $CO_2$ to become trapped. | Intra Dupuy Formation seals are likely to behave as flow baffles. Many of these units are unable to be resolved on seismic data due to limited thickness so distribution is uncertain.<br><br>$CO_2$ not trapped prior to leaking through the intra Dupuy formation shales will migrate upward towards the upper Dupuy Formation shales.<br><br>May lead to contamination of oil and gas resources within the upper Dupuy Formation (undiscovered). | Physical properties of the Perforans Shale confirmed by the GDW1 Well. |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| Migration of $CO_2$ through upper Dupuy Formation baffles faster than expected.<br>Buoyant $CO_2$ expected to migrate over tens of years to hundreds of years towards the base Barrow Group shale.<br><br>Likelihood: Possible<br>Requires a variation in baffle architecture from that defined in the stratigraphic model. | Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow $CO_2$ migration.<br><br>Nature of baffle provides tortuous migration path enhancing the ability for the migrating $CO_2$ to become trapped. | Shales in the upper Dupuy Formation are lithologically similar to those in the intra Dupuy Formation but thicker and more laterally extensive.<br><br>$CO_2$ not trapped prior to leaking through the intra Dupuy formation shales will migrate upward towards the base Barrow Group shales.<br><br>May lead to contamination of oil and gas resources within the upper Dupuy Formation (undiscovered). | Occurrence of upper Dupuy Formation siltstone and baffles confirmed in the GDW1 well. |
| Reservoir $CO_2$ migrates to the base Barrow Group shale, with leakage of base Barrow Group shale barrier. Buoyant $CO_2$ migrates over tens to hundreds of years into Barrow Group.<br><br>Likelihood: Unlikely (Revised from Likely in the EIS/ERMP)<br><br>Base Barrow Group shale thins out to the east, but overlain by 100 m unit with barrier properties. | Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow $CO_2$ migration.<br><br>Nature of barrier provides tortuous migration path enhancing the ability for the migrating $CO_2$ to become trapped. | Shales at the base of the Barrow Group are 10s of metres thick and can be correlated over the Barrow Island region. There is some uncertainty as the extent of this shale in the area to the east of Barrow Island.<br><br>Modelling indicates that the rate at which the $CO_2$ can migrate through shales will be very low (generally less than one micromole/m2/sec) (Benson 2004).<br><br>$CO_2$ not trapped prior to leaking through the base Barrow Group shale becomes trapped in the Barrow Group and below the Muderong Shale.<br><br>May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered). | Results form the GDW1 well confirmed the presence of the base Barrow Group shale barrier and the ability of this unit to act as a barrier, if not breached by faulting, to the migration of $CO_2$. GDW1 and further hydrodynamic studies have shown the overlaying units (bottom 100 m) in the lower parts of the Barrow Group also represent a significant barrier to the vertical migration of $CO_2$. This significantly increases the thickness of the sealing (barrier) package overlying the Dupuy Formation. |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| Reservoir $CO_2$ migrates to the Muderong Shale, leakage of Muderong Shale barrier.<br><br>Note: Leakage of the Muderong Shale (300-500 m thickness) was not considered during the Failure Modes and Effects Workshop as it was considered highly remote that the $CO_2$ would have leaked past the previous three sets of baffles and barriers.<br><br>Buoyant $CO_2$ migrating over thousands of years into the Windallia Sandstone Member and the Gearle Siltstone.<br><br>Likelihood: Remote | Selection of Dupuy Formation provides multiple baffles and barriers to prevent/slow $CO_2$ migration.<br><br>Nature of barrier provides tortuous migration path enhancing the ability for the migrating $CO_2$ to become trapped. | The Muderong Shale occurs across the entire Barrow Sub Basin and is the sealing lithology of many (majority) of the hydrocarbon accumulations in the sub basin.<br><br>Modelling indicates that the rate at which the $CO_2$ can migrate through shales will be very low (generally less than one micromole/m2/sec) (Benson 2004).<br><br>$CO_2$ not trapped prior to leaking through the Muderong Shale becomes trapped in the overlying Windallia Member and the Gearle Siltstone.<br><br>May lead to contamination of oil and gas resources within the Muderong Shale and Windallia Sandstone Member (both existing and undiscovered). | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| **Unplanned Migration or Release $CO_2$ – Fault Leakage** | | | |
| Leakage along the Barrow Fault.<br>Leakage of $CO_2$ to higher levels in the stratigraphy, and leakage of $CO_2$ to surface over hundreds to thousands of years. The location of this fault is shown on Figure 13-11.<br><br>Likelihood of migration of $CO_2$ to the Barrow Fault: Remote Requires a failure of the uncertainty management plan process.<br><br>Assuming $CO_2$ reaches the Barrow Fault, the likelihood of leakage of $CO_2$ up the Barrow Fault to higher stratigraphy: Possible<br><br>Assuming $CO_2$ reaches the Barrow Fault, likelihood of leakage of $CO_2$ to the surface via the Barrow Fault: Possible (without quantifying volume of $CO_2$ emitted at surface) | Select the injection location such that $CO_2$ plume is not anticipated to approach the Barrow Fault.<br><br>Reservoir modelling requires highly pessimistic scenario for $CO_2$ to migrate in proximity to the fault.<br><br>For leakage to occur $CO_2$ would need to migrate to the Barrow Fault then fault would have to act as migration path.<br><br>Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present. | The Barrow Fault is distant from injection location.<br><br>Barrow Fault is currently sealing with respect to several hydrocarbon accumulations.<br><br>Studies indicate that leakage along faults may occur at rates of between 1 x 102 and 1 x 106 micromole/m2/sec but over relatively small areas (Benson 2004).<br><br>Naturally occurring hydrocarbon seeps are geographically limited in area.<br><br>May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered).<br><br>$CO_2$ migration to the surface could result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A consequence of migration along faults is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | Only the combined likelihood of leakage along the Barrow Fault was considered in the EIS/ERMP.<br><br>In this assessment the likelihood of migration of $CO_2$ to the fault has been considered separately to the likelihood of leakage along the fault.<br><br>The cumulative likelihood needs to be considered when assessing the likelihood of failure with an associated environmental consequence. |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| Leakage along the Godwit and Plato Faults over hundreds to thousands of years.<br><br>Leakage of $CO_2$ to higher levels in the stratigraphy.<br><br>Likelihood of migration of $CO_2$ to the Godwit and Plato Faults: Likely<br>(not explicitly assessed in the EIS/ERMP)<br>Requires a failure of the uncertainty management plan process<br><br>Assuming $CO_2$ reaches the Godwit and Plato Faults, the likelihood of leakage of $CO_2$ up the Godwit and Plato Faults to higher stratigraphy: Possible (Revised from Likely in the EIS/ERMP)<br><br>Assuming $CO_2$ reaches the Godwit and Plato Faults, likelihood of leakage of $CO_2$ to the surface via the Godwit and Plato Faults: Possible (without quantifying volume of $CO_2$ emitted at surface) (not explicitly assessed in the EIS/ERMP). | Select the injection location such distant from the Godwit and Plato faults. The $CO_2$ plume is not anticipated to reach these faults for 1000 years by which time much of the $CO_2$ will have become trapped.<br><br>For leakage to occur $CO_2$ would need to migrate to these faults then the faults would have to act as migration path.<br><br>Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present. | Plato and Godwit Faults are distant from injection location.<br><br>May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered).<br><br>Impacts on surface and near surface flora and fauna are not anticipated as faults are only identified from seismic and do not show any surface expression. This indicates that these faults may not extend to the surface.<br><br>Should $CO_2$ migrate to the surface may result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A consequence of migration along faults is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | The change in layout of the injection wells to accommodate this higher injection rate places the CO2 plume in closer proximity to these faults. Note however that the regional dip in the formation results in preferred migration path to the south away from these faults<br><br>It is uncertain whether these faults extend to the surface. It is likely that these faults may not penetrate the surface so any migration along these faults might only result in leakage into the overlying stratigraphy.<br><br>There is no identified structural trap in the Dupuy formation which may prevent the development of a $CO_2$ accumulation against the fault limiting the ability for increased pressure to reopen the fault plane.<br><br>Ongoing technical studies will be undertaken so as to position the anticipated extent of the CO2 plume further from these faults. |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| Leakage along faults or fractures that have not been detected on seismic. This requires the faults to be relatively small.<br><br>Leakage of $CO_2$ to higher levels in the stratigraphy.<br><br>Likelihood of migration to higher stratigraphy: Unlikely<br><br>Likelihood of migration to near-surface karst or surface emission: Remote<br>(Revised from Unlikely in the EIS/ERMP) | If faults are present they must be small relative to the Barrow, Godwit and Plato Faults as they are not resolvable on seismic. Potential $CO_2$ migration flux would also be correspondingly less.<br><br>Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present. | Potential for fault migration thought to be less than for mapped faults discussed above given smaller nature of the faults.<br><br>Leakage rates are anticipated to be lower and more localised than for leakage along the Barrow Fault.<br><br>May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered).<br><br>$CO_2$ migration to the surface could result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A consequence of migration along faults is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | |
| Leakage along offshore faults to north and east of Barrow Island.<br><br>Leakage of $CO_2$ to higher levels in the stratigraphy.<br><br>Likelihood: Remote<br>(Revised from Possible in the EIS/ERMP). | Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present.<br><br>Faults are located some distance from the anticipated extent of the $CO_2$ plume. | May lead to contamination of oil and gas resources within the Barrow Group in the area of Double Island. (Both existing and undiscovered).<br><br>Impacts on marine fauna are not anticipated as faults are only identified from seismic and do not extend to the surface. | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| Leakage along offshore faults to the north and west of Barrow Island.<br>Leakage of $CO_2$ to higher levels in the stratigraphy.<br><br>Speculation that these faults may be connected to the Godwit Fault.<br><br>Likelihood: Remote | Select the injection location such that $CO_2$ plume is not anticipated to approach these faults.<br><br>Reservoir modelling indicates that it is almost impossible for $CO_2$ to migrate in proximity to these faults.<br><br>Pressure gradient and salinity differences between the Dupuy Formation and the Barrow Group suggest that faults are not fluid conduits at present.<br><br>Potential for effective dissipation of leaking $CO_2$ in marine water column. | May lead to contamination of oil and gas resources within the Barrow Group (both existing and undiscovered). | |
| Operational error resulting in injection at pressure exceeding fracture gradient. Potential to fracture reservoir rock and overlying baffles and barriers leading to unpredicted migration to higher levels in the stratigraphy.<br><br>Failure of multiple down hole pressure gauges to monitor pressure.<br><br>Likelihood: Unlikely | The selection of the Dupuy Formation injection target as it has multiple barriers between injection reservoir and surface.<br><br>Design the compressor operating pressure to remain below fracture pressure of reservoir rock.<br><br>Develop operational management plans covering high reservoir pressure identified in injection wells. Refer Section 13.4.8. | Existing hydrostatic pressure is approximately 10.3 MPa less than fracture threshold pressure.<br><br>Higher than expected pressures in the formation may lead to faults that are currently sealing becoming migration pathways and fracturing of the overlying sealing units allowing $CO_2$ to migrate vertically into overlying stratigraphy. | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| Lack of formation capacity to accommodate injected $CO_2$.<br>If capacity of the reservoir to contain the injected CO2 is exceeded, $CO_2$ migration will be more aerially extensive than predicted and ultimately reservoir pressure will increase potentially exceeding fracture gradient. | | | This failure modes was documented as part of the EIS/ERMP assessment.<br>The Technical Panel considered this to be a reservoir uncertainty and to be adequately captured in the discussion around uncertainty management above. Hence no likelihood or consequences have been defined. |
| **Unplanned Migration or Release of $CO_2$ – Well Leakage** | | | |
| Inability to re-enter to successfully abandon existing well bores that penetrate the Dupuy.<br><br>Existing well penetrations may act as conduit for leakage of $CO_2$ to higher levels in the stratigraphy. Potential leakage of $CO_2$ to surface over hundreds to thousands of years.<br><br>Leakage rates could be higher than leakage through faults.<br><br>Likelihood of leakage to higher stratigraphy (e.g. Barrow Group): Possible<br><br>Likelihood of leakage to the surface: Unlikely | Existing decommissioned wells did not contemplate $CO_2$ injection operations and will require workover to ensure suitability for $CO_2$ service. Plans to manage well penetrations and ensure they are fit for service have been developed. Refer Section 13.4.8.<br><br>If well does ultimately leak then well will be re-entered and leakage stopped. | Condition of wells and potential for leakage is understood and plans in place for remediation prior to $CO_2$ intersecting well.<br><br>Limited release (tens to thousands of tonnes) of $CO_2$ until well re-entered and leakage stopped.<br><br>May lead to contamination of oil and gas resources (both existing and undiscovered).<br><br>$CO_2$ migration to the surface could result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A significant consequence of leakage is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| $CO_2$ leakage through $CO_2$ injection or monitoring wells. Conduit for leakage of $CO_2$ to higher levels in the stratigraphy. Potential leakage of $CO_2$ to surface.<br>Leakage rates could be higher than leakage through faults. Modern design and materials resistant to corrosion, and modern abandonment.<br><br>Likelihood of leakage to higher stratigraphy (e.g. Barrow Group): Unlikely<br><br>Likelihood of leakage to the surface: Unlikely | Implement wellhead maintenance program and monitoring of annular pressures.<br><br>Design $CO_2$ injection and monitoring wells for $CO_2$ service.<br><br>Utilise $CO_2$ service design from industry experience in enhanced oil recovery and $CO_2$ injection operations.<br>If well does ultimately leak then well will be re-entered and leakage stopped. | Initial design and decommissioning procedures for $CO_2$ injection and monitoring wells will accommodate $CO_2$ service.<br><br>Limited release (tens to thousands of tonnes) of $CO_2$ until well re-entered and leakage stopped.<br><br>May lead to contamination of oil and gas resources (both existing and undiscovered).<br>$CO_2$ migration to the surface could result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A significant consequence of leakage is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| $CO_2$ leakage through future hydrocarbon exploration or development wells.<br><br>Conduit for leakage of $CO_2$ to higher levels in the stratigraphy. Potential leakage of $CO_2$ to surface.<br><br>Leakage rates could be higher than leakage through faults. Modern design and materials resistant to corrosion, and modern abandonment.<br><br>Likelihood of leakage to higher stratigraphy (e.g. Barrow Group): Unlikely<br><br>Likelihood of leakage to the surface: Unlikely | Ensure that future hydrocarbon wells will be designed for $CO_2$ service.<br>Utilise $CO_2$ service design from industry experience in enhanced oil recovery and $CO_2$ injection operations.<br><br>If well does ultimately leak then well will be re-entered and leakage stopped. | Initial design and decommissioning procedures for future exploration and development wells will accommodate $CO_2$ service.<br><br>Limited release (tens to thousands of tonnes) of $CO_2$ until well re-entered and leakage stopped.<br><br>May lead to contamination of oil and gas resources (both existing and undiscovered).<br><br>$CO_2$ migration to the surface could result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A significant consequence of leakage is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | |
| $CO_2$ leakage during routine workovers of injection or monitoring wells.<br><br>Potential leakage of $CO_2$ to surface (e.g. loss of well control during workover).<br><br>Likelihood: Possible (minimal volume of $CO_2$ to surface) | Adhere to three barrier rule during workovers (maintain three barriers to fluid escape at all times).<br><br>Adopt best practice lessons learned from other enhanced oil recovery and $CO_2$ injection operations. | Equivalent to failure rates for workovers in the oil and gas industry.<br><br>Failure is likely to lead to limited release of $CO_2$ to atmosphere until well can be shut in. Analogies with oil and gas operations indicate that release would be stopped within days or weeks. | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| $CO_2$ leakage via water source wells in Barrow Group to the south of the expected plume location. Note these wells provide saline water for reverse osmosis plants.<br><br>Potential leakage of $CO_2$ to surface.<br><br>Water supply wells produce $CO_2$.<br><br>Likelihood: Unlikely | Existing water source wells do not contemplate $CO_2$ injection operations and will require decommissioning to ensure suitability for $CO_2$ service.<br><br>Manage water source wells in accordance with Existing Well Remediation Plan. Refer Section 13.4.8.<br><br>If well does ultimately leak then well will be re-entered and leakage stopped. | Requires $CO_2$ to have migrated into upper parts of the Barrow Group.<br><br>Condition of wells and potential for leakage is understood and plans in place for remediation prior to $CO_2$ intersecting well.<br><br>May require decommissioning of water source wells and drilling of alternative water source wells away from the $CO_2$ plume.<br><br>Limited release (tens to thousands of tonnes) of $CO_2$ until well re-entered and leakage stopped.<br><br>May lead to contamination of oil and gas resources (both existing and undiscovered).<br><br>$CO_2$ migration to the surface could result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A consequence of leakage is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | |

| Description of Potential Failure Mode | Safeguards, Mitigation or Management Measures | Residual Risk | What's Changed? |
|---|---|---|---|
| $CO_2$ leakage through Dupuy water production wells, positioned outside of the expected $CO_2$ plume location.<br>Conduit for leakage of $CO_2$ to higher levels in the stratigraphy.<br>Potential leakage of $CO_2$ to surface.<br>Leakage rates could be higher than leakage through faults.<br><br>Likelihood of leakage to higher stratigraphy (e.g. Barrow Group): Unlikely<br><br>Likelihood of production to the surface: Unlikely | Implement wellhead maintenance program and monitoring of annular pressures.<br>If well does ultimately leak then well will be abandoned. | Limited release (tens to thousands of tonnes) of $CO_2$ until well is abandoned.<br><br>May lead to contamination of oil and gas resources (both existing and undiscovered).<br><br>$CO_2$ migration to the surface could result in the localised build up of $CO_2$ concentrations within the soil profile to the point where flora could be detrimentally impacted.<br><br>A consequence of leakage is that $CO_2$ could migrate into the near surface cave systems with detrimental impact on the fauna in these systems. | Failure mode not considered as part of the EIS/ERMP assessment. |
| **Unplanned Migration or Release of $CO_2$ – Reduced Well Injection** | | | |
| Precipitation of minerals in the formation in close proximity to the injection well bore. Repeated reduction in well/reservoir partial pressure may facilitate mineralisation.<br>Reduced ability to inject $CO_2$ into well, requires increase in injection pressure to dispose of required volume of $CO_2$.<br>Increased injection pressure may exceed fracture gradient as discussed above. | | | This failure modes was documented as part of the EIS/ERMP assessment.<br>The Technical Panel considered this to be a reservoir uncertainty and to be adequately captured in the discussion around uncertainty management above.<br>Hence no likelihood or consequences have been defined. |

# APPENDIX J

## Ministerial appeal determination letter (December 2006)

Hon Mark McGowan MLA
Minister for the Environment;
Racing and Gaming

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Our Reference: 229/06

Mr Colin Beckett
General Manager
Greater Gorgon Area
Chevron Australia Pty Ltd
GPO Box S1580
PERTH WA 6845

Dear Mr Beckett

**APPEAL AGAINST ENVIRONMENTAL PRTOPECTION AUTHORITY'S REPORT AND RECOMMENDATIONS, BULLETIN 1221 – GORGON GAS DEVELOPMENT, BARROW ISLAND NATURE RESERVE**

Thank you for your letter dated 19 June 2006 appealing the report and recommendations of the Environmental Protection Authority (EPA) in relation to your proposal to develop a Liquefied Natural Gas (LNG) plant on Barrow Island, together with associated infrastructure. I received 10 other appeals in relation to this matter.

To assist with the investigation and consideration of the appeals and pursuant to section 106(2) of the *Environmental Protection Act 1986* (the Act), I appointed Mr Garry Middle and Mr Jean-Pierre Clement as an Appeals Committee in June 2006. The Committee finalised its report to me in November 2006, a copy of which is attached for your information.

In addition to the report of the Committee, I have also received advice from the EPA in relation to the matters raised in appeals. Advice was also received from the Conservation Commission of Western Australia and the Department for Industry and Resources (DoIR). I also note that the Committee consulted with a wide range of people during its investigation, including the Department of Environment and Conservation (DEC), the Commonwealth Department of Environment and Heritage (DEH), the Department for Planning and Infrastructure (DPI), DoIR, the Chair and Deputy Chair of the EPA, Dr Colin Limpus (Queensland Environmental Protection Agency) and Dr Bernard Bowen (Quarantine Advisory Committee).

I am also advised that the Committee arranged joint sessions in relation to flatback turtles, dredging management and quarantine. These sessions were attended by key third party appellants (WWF Australia and the Conservation Council of WA), your representatives and representatives of relevant government authorities.

**Background**

The Appeals Committee's Report and the EPA's Bulletin sets out the background to this proposal in detail. By way of summary, you as proponent propose to develop a LNG processing plant on Barrow Island to process natural gas from offshore reserves, most notably the Gorgon and Jansz-lo gas fields to the west of the island. Infrastructure associated with the plant includes feed pipelines from the gas fields, a materials offloading facility (MOF) and shipping facility together with associated jetty and dredging works.

Barrow Island is a class A nature reserve. It is acknowledged by all parties to the appeal that Barrow Island possesses significant environmental values, attributable to (among other things) the absence of introduced species present on the mainland.

The level of assessment set for the proposal was Environmental Review and Management Programme (ERMP) which was presented to the EPA by the proponent in the first half of 2006. In June, the EPA published its report and recommendations in relation to the proposal. As you are aware, the EPA recommended that the project not proceed, based on its conclusion that the project was environmentally unacceptable.

It was from the EPA's report and recommendations that the appeals were received.

As noted above, the Appeals Committee has prepared a comprehensive report on its appeal investigation. In relation to the key grounds of appeal, the Committee identified a range of options for my consideration. I have taken the Committee's report and recommendations into account in my determinations of the appeals, the details of which follow.

**Grounds of appeal**

Two appeals (yours and the Chamber of Minerals and Energy (CME)) submitted that the project was environmentally acceptable and that as a result, the EPA was incorrect to recommend the project not proceed. The remaining appeals were all largely supportive of the EPA's recommendations in relation to the unacceptability of the proposal, but raised additional concerns about aspects of the EPA's report.

For ease of reference and consistent with the Report from the Appeals Committee, I will address the grounds of appeal by relevant subject matter, which are identified as follows:

1. Dredging, dumping and pipelines;
2. Impacts on flatback turtles;
3. Introduction of non-indigenous organisms;
4. Subterranean fauna and short range endemics;
5. Greenhouse gases;
6. Alternative site selection processes;
7. Economic and social advantages to a mainland site;
8. Use of Jansz-lo gas;
9. Precedent for future developments on Barrow Island;
10. Aboriginal heritage assessment;
11. Impacts on dugong;
12. Cumulative impacts;
13. Waste management; and
14. Content of the draft framework environmental conditions.

**Ground 1 – Dredging, dumping and pipelines**

The project requires dredging of the MOF and shipping channel, as well as a spoil disposal area and establishment of pipelines on the ocean floor with associated shore crossing points.

The EPA's report stated that the management system proposed for the project would not allow the proponent to respond decisively and early enough to ensure that unacceptable impacts relating to dredging do not occur, including particularly important concentrations of coral communities on the Lowendal shelf and at Batman and Dugong reefs. The EPA expressed the view that even with best endeavours, the level of uncertainty surrounding the prediction of impacts associated with dredging, reclamation and spoil disposal remains high. The EPA considered that the proposed scale of dredging impacts should not be approved.

You raised a number of objections to this aspect of the EPA's report including that the EPA did not consider some relevant evidence, did not place adequate weight on some evidence, and placed undue weight on other evidence. Had the EPA correctly considered and applied the evidence, you submitted that it would have concluded that there would not be significant long term harm to the marine ecosystem and that any impacts can be managed to an acceptable level.

Third party appellants contended that inadequate information was given in the EPA report about the impacts of sea dumping of dredged material on benthic habitat. Some appellants submitted that full fauna surveys of the benthic habitat and plume modelling should be carried out for the offshore dumping as well as the near-shore habitat. Concerns were also raised about the adequacy of the information provided in relation to feed pipelines to the west of Barrow Island. It was submitted that the project must be required to avoid coral bomboras and areas of high benthic productivity. Two appellants submitted that very little evidence was provided by the proponent to support the claim that 'temporary' marine habitats will recover in 30 years.

The full details of the grounds of appeal are contained in the Committee's report.

Having considered the information raised in the appeals, together with the advice of the EPA other public authorities and the advice of the Appeals Committee, it is clear that dredging and dumping activities have the potential to cause a significant impact on the environment. Given the scale of the proposed works and the presence of large coral communities within close proximity to the proposed marine facilities, I am of the view that the EPA was justified in identifying dredging as a key environmental concern associated with the project.

In its report, the Committee identified four key issues relating to dredging which are central to this ground of appeal, viz:

1. Degree of uncertainty in relation to the prediction of impacts;
2. Acceptability of predicted impacts;
3. Possible modifications to the proposal to reduce impacts; and
4. Extent to which conditions can improve certainty and reduce predicted impacts.

In relation to the uncertainty of the predicted impacts, you submitted that you will manage the project within the impact range it has predicted: if greater impacts are demonstrated, you stated that you will modify your works or suspend dredging until the conditions improve or the environment recovers. As such, you argued that irrespective of any modelling uncertainties, the public can have confidence that the impacts of the proposal will be managed to within the limits it has identified and which could be included in any conditions of approval. You also stated that the modelling of impacts will be further refined with real-time data once dredging commences. It stated that data gathered through this process will provide validation and calibration of the modelling, leading to an improvement in impact prediction.

As to the acceptability of the predicted impacts, the EPA's Guidance Statement No 29 *Benthic Primary Producer Habitat Protection for Western Australia's Marine Environment* (the Guidance Statement) establishes a framework for assessing impacts on marine communities. The Statement provides that where impacts to benthic primary producer habitat (BPPH) cannot be avoided, the impacts of a project should be managed within identified limits, the value of which varies according to the classification of marine ecosystem in question. Your ERMP identified 11 management units which included estimates of permanent coral BPPH loss. This information showed that permanent coral loss would exceed the cumulative loss thresholds in two of the 11 management units. You submitted that the predicted impacts are consistent with the Guidance Statement, noting that it predicts no impact in nine of the management units, which is below the loss thresholds identified in the Guidance Statement.

I agree with the advice of the Committee that the intent of the Guidance Statement is to identify impacts within specific management zones. In this case, the ERMP predicts that the implementation of the proposal will result in a permanent loss of coral in two of the management units in excess of the cumulative loss thresholds in the Guidance Statement. It is noted however that you have committed to having no permanent impact on coral assemblages in nine of the 11 management units. These unaffected management units include significant coral assemblages such as at Lowendal Shelf, Batman Reef and Dugong Reef. It is also acknowledged that the management units do not (and are not intended to) strictly delineate different ecosystem boundaries. In addition, the area of coral impact is confined to the area designated as a port under the *Shipping and Pilotage Act 1967.*

The EPA's report and recommendations estimated the total coral loss from the project would be 129 hectares. You advised that this calculation included 102 hectares of loss of 'unconfirmed coral communities' on the Lowendal shelf. You advised that these communities have subsequently been identified as macroalgal dominated, and that as a consequence, the total impact of dredging operations on coral habitat (both direct and indirect) was estimated to be 22 hectares. Including the horizontal direct drilling (HDD) impacts on the west coast, the total area of coral loss is predicted to be 23.2 hectares.

From the information provided to me in relation to this matter, there appears to be general agreement that the marine environment around Barrow Island is of high conservation value, accepting also that a portion of the waters are designated for port operations. The coral assemblages present off the east coast are considered to be especially valuable, being large and generally undisturbed. It is also noted that corals are generally more susceptible to impacts from dredging than other marine species, and are likely to take significantly longer to recover than other habitats, such as macroalgal-dominated communities. In these circumstances, the ERMP and Bulletin appropriately focused on the potential impacts on coral communities.

You advised that the total area of coral BPPH within the 11 management units is 770 hectares. The area of predicted permanent loss is 23.2 hectares, or approximately 3%. None of the significant coral assemblages identified through the assessment process are predicted to be impacted, and you have committed to ensuring the loss does not exceed that amount through the Ministerial conditions in the event that the project is approved. In relation to the Guidance Statement, it is noted that whilst the project exceeds the cumulative loss threshold in two of the management units, you have stated that there will be no impact in any other management unit.

Taking into account the foregoing, it is my view that the permanent loss of 23.2 hectares of coral in the Barrow Island marine area is environmentally acceptable based on the loss being approximately 3% of the total coral present in all of the management units and that conditions can be set for the proposal to ensure this level of impact is not exceeded.

In relation to conditions, I agree with the option recommended by the Committee which requires the level of approved impact to be stated and for you to implement a comprehensive monitoring program with conservative coral health monitoring triggers. This approach will you to undertake reactive coral health monitoring where water quality triggers are exceeded. Due to the uncertainty about the links between coral health and water quality in the Barrow Island area, the initial water quality triggers will be set at a conservative level (for example, a percentage above background). Once you can establish a scientific link between coral health and water quality, the conditions will provide a mechanism for the water quality triggers to be amended. Using this approach, the onus will be on you as the proponent to monitor coral health at small exceedances of water quality, and to establish better information on the link between the two. Unless and until the proponent is able to establish less conservative water quality indicators for coral health, it will be required to undertake coral health monitoring as often as required to ensure that the impacts are being managed to acceptable levels. I also agree with the recommendation of the Committee that any decision to change the water quality indicators will need to be established to the satisfaction of the Minister on the advice of appropriately qualified and independent scientific experts.

It is my view that the conditions should also require you as the proponent to implement a management response when impacts on coral health reach certain levels. In this regard, the Committee has identified a two-stage mechanism that I believe has merit. Under the first stage, the proponent would be required to prepare and submit an impact management plan to the Minister where coral health levels meet a certain threshold. In relation to the moderate impact zone (where 30% loss of coral is predicted), the requirement might be triggered where coral mortality reached 15%. The purpose of the condition would be twofold: to require you to review operating procedures and how these can be modified to reduce impacts, and secondly, to provide the Minister with oversight as to dredging operations and the compliance with the Ministerial conditions.

The second stage of the conditions would require you as the proponent to report to the Minister where the approved impact limits are close to being exceeded. In addition to any powers the Minister has under the Act, this condition would authorise the Minister to direct you to suspend dredging in an area or generally where the trigger value is reached or exceeded. The purpose of this provision would be to ensure that the impacts of the project do not exceed approved levels. The conditions would also provide a mechanism to recommence dredging where the Minister considers the impacts are not likely to exceed the approved impact levels.

In my view, the above model provides a robust mechanism to ensure that you as the proponent adhere to its commitments in relation to dredging impacts. The initial water quality values will be set conservatively to ensure that coral health impacts are identified in sufficient time to implement management responses. The conditions will also set in place a mechanism for the Minister to direct a suspension of dredging before approved impact levels are exceeded. Importantly, the conditions place the onus on you as the proponent to prove the associations between coral health and water quality. If you are unable to establish the links, the conditions should require you to undertake extensive coral health monitoring for the duration of the dredging operation. Whilst this is likely to be resource intensive for you, I believe that in the absence of clear links between coral health and reduced water quality around Barrow Island, and given the important conservation values of the area, you should bear the onus of establishing the links through intensive monitoring when operations commence.

It follows from the above that I find that the proposed dredging and dumping operations can be implemented in an environmentally acceptable manner, with the level of impact on coral assemblages not to exceed to 23.2 hectares in extent and provided adequate conditions are set for the dredging program. I have therefore allowed your appeal in relation to this ground. The precise detail of the conditions that will apply will be developed with relevant decision-making authorities in accordance with section 45 of the Act.

**Ground 2 – Impacts on flatback turtles**

It is common ground that the project has the potential to directly and indirectly impact on flatback turtles and other marine fauna. Flatback turtles are classified as vulnerable under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and rare or likely to become extinct under the *Wildlife Conservation Act 1950*. It is noted that there are four major aggregations of flatback turtle, being the southern Great Barrier Reef; Gulf of Carpentaria; Arnhem Land/Kimberley; and the Pilbara region, which includes Barrow Island.

In its Bulletin, the EPA stated that both the green and flatback turtle stocks in the Barrow Island region are already subjected to a range of negative impacts from human activities within their nesting, migratory and foraging ranges. It stated that due to the limited level of knowledge, multiple threats, probability of impacts, potentially high consequences and low level of certainty about how any impact could be effectively managed, it does not consider that the risk of significant environmental impacts to the flatback turtle population can be judged to be acceptably low.

Your appeal questioned the EPA's conclusion that the potential impacts of the proposal could not be managed to avoid an unacceptable environmental impact. You contended that in reaching these conclusions the EPA:

- placed too much weight on the significance of the Barrow Island population;
- overstated possible population-level impacts directly attributable to the Gorgon project; and
- did not adequately consider the effectiveness of proposed lighting strategies and other mitigation measures.

Some third party appellants raised concerns about the impacts the project may have on flatback turtle nesting on Barrow Island. The Conservation Council specifically noted the importance of Barrow Island for flatback turtles, and submitted that conservation efforts should be directed at increasing turtle numbers so that they are no longer endangered. The Conservation Council stated that it would be unacceptable for this project to further reduce the conservation status of the species, when it is already under threat from existing impacts.

A number of appellants submitted that if the project is approved, and monitoring reveals that light is impacting on turtle hatchling survival and nesting behaviour, the proponent should be required to black out offending lights until such time as an independent audit establishes that turtle breeding is no longer compromised.

From its consideration of the appeals, the Committee identified the following key issues:

1. the significance of the Barrow Island population of flatback turtles in an international, national and regional context;
2. possible impacts on the species through the construction and operation of the facility; and
3. the extent to which proposal can be modified to reduce impacts.

In relation to significance, you questioned the EPA's conclusion that a third of the Pilbara flatback turtle population nested at Barrow Island. You provided additional information to the Appeals Committee on the relative size of Australian rookeries which suggested that between 12 to 15% of the Pilbara/north west population of the species nest on Barrow Island, not the 33% referred to by the EPA.

In addition to further advice from the EPA, the Committee sought advice from Dr Colin Limpus of the Queensland Environment Protection Agency on relative rookery sizes. In his advice, Dr Limpus expressed the view that whilst the additional information you provided contained a number of methodological shortcomings, the information was sufficient to indicate that the Barrow Island population was likely to comprise 12 to 15% of the north west breeding stock. Dr Limpus emphasised however that at this level, the population remained significant, and that given the conservation status of the species, Barrow Island warranted special conservation management.

Taking into account the information presented in appeals, it appears to be common ground that Barrow Island represents a significant nesting site for flatback turtles. Whilst the estimate of the population size in the Bulletin appears to overstate the population, the revised estimate from you indicates the island is a significant habitat for the species.

The second issue raised in appeals relates to the extent to which the proposal is likely to have a significant impact on flatback turtles. Threats posed by the Gorgon project are described in detail in the Appeals Committee's report. One of the key threats relates to unshielded light emissions from the MOF, causeway, jetty and ship loading area. Glow from the processing area may also have an impact. It is accepted that light emissions have the potential to impact on nesting behaviour of females, disorientation of hatchlings and increased predation where hatchlings are attracted to light sources. You have identified a number of management and design options for addressing light impacts. These include:

- Replacing two elevated flares with a ground flare array;
- Designing plant and infrastructure to reduce light spill, including using non-reflective surfaces for buildings, prohibiting all non-essential lighting; preferentially locating lights facing west; and use of covered and reduced spectrum lighting;
- During peak hatching period, relocating disoriented hatchlings to dark beaches on an outgoing tide;
- Monitoring impacts on turtles, and implementing adaptive management responses in the event impacts are identified (for example, establishing a turtle hatchery, relocating eggs and hatchlings); and
- Managing construction and loading activities to avoid (where practicable) nesting periods.

The EPA acknowledged that measures taken to attenuate lighting (including flaring) could reduce light emissions; however, it stated that the proponent did not demonstrate that it could, nor that it is possible to, reduce the impact of light emissions to an acceptable level.

Measures to address impacts on flatback turtles are identified in the Appeals Committee's report, and include modifying the design of the facility (for example, to achieve greater darkness) and changing the management of operations (for example, by requiring the jetty and MOF to be blacked out during turtle nesting and hatching season). The Appeals Committee also noted advice from the EPA that offsets to enhance species survival would be critical in the event the project is approved. The EPA came to this position noting that in its view, it was inevitable that flatback turtles would be impacted, and that you as the proponent should be required to undertake other activities to counteract those impacts.

In response to the EPA's comments on offsets, and subsequent to the Appeal Committee reporting to me, you have put forward a proposal to fund a North West Flatback Turtle Conservation Program to increase protection of the population at other locations within the Pilbara. You have also put forward a proposal to fund further actions to improve recruitment to the population, including establishing hatcheries, should it be demonstrated that the project is having a significant impact on the flatback turtle population.

Taking into account your additional undertakings referred to above and the capacity to apply strict conditions to the proposal in relation to light management, beach access, vessel movement and ongoing monitoring and adaptive management, I am satisfied that any adverse impacts in relation to the flatback turtles population can be acceptably managed. It follows that I have allowed your appeal in relation to flatback turtles. The final detail of the conditions that may be applied to the project will be developed through the consultation process with decision-makers under section 45 of the Act, but I expect these to contain clear requirements on you as the proponent to monitor turtle numbers, instigate an adaptive management program to improve performance and report regularly on outcomes of monitoring and management programs.

**Ground 3 – Introduced non-indigenous organisms**

According to your ERMP, activities associated with the proposed development would increase the volume of cargoes and number of personnel movements compared to historical or current oilfield operations. These numbers would be particularly pronounced during the construction phase, and would remain at higher than current levels during ongoing operations. The higher number of personnel and cargo movements to Barrow Island therefore presents a substantial increase in the potential for non-indigenous organisms to be transported to the island.

The EPA identified introduced invasive organisms as the most significant potential hazard to the terrestrial flora, fauna and vegetation values of Barrow Island. The EPA noted that the operators of the existing Barrow Island oil field had recorded 27 breaches of quarantine from 1964 to 2003. Using past incursion data, and assuming only the current level of control, the EPA concluded that a quarantine breach would be described as "virtually certain" using the descriptors set out in the proponent's Quarantine Risk Assessment.

Taking into account these risks, and the proposed mechanisms to deal with them, the EPA considered that the residual risk of the introduction of non-indigenous species to Barrow Island is environmentally unacceptable as the risk has not been demonstrated to be acceptably low and no feasible additional quarantine barriers or other control conditions have been proposed to achieve an environmentally acceptable outcome.

In your appeal, you contended that in reaching its conclusions in relation to quarantine risk, the EPA did not:

- correctly apply the precautionary principle as defined in the Act;
- correctly interpret the results of the assessment conducted by the proponent;
- give sufficient weight to advice of independent experts; and
- adequately consider the likelihood of success of detection and eradication measures.

Third party appeals contended that Chevron Australia has a poor record of quarantine on Barrow Island with at least 27 breaches, many of which have not been measured, contained or eradicated and that the existing Barrow Island operation is small in comparison with the Gorgon proposal.

Appellants also contended that the Terrestrial and Marine Quarantine Management Plans should be backed up by a bonding system with adequate financial reserves for the Government to manage a reasonable worst case biological invasion of Barrow Island or the surrounding Marine Conservation Reserve, in the case where the proponent fails to take action within a specified time limit. The Conservation Council suggested that there should also be a legally enforceable penalty for failure to report a quarantine breach.

The Conservation Council also submitted that the proponent should also be required to eradicate existing introduced species before commencement of works.

Another appellant expressed concern that given the size of the workforce and the amount of materials to be brought to the island, quarantine measures were unlikely to be successful.

By virtue of its scale, the Gorgon proposal presents a significantly greater quarantine risk than the existing oil operation on Barrow Island. Given the significant terrestrial conservation values of the island, ensuring these risks are acceptably low is a key consideration in the determination of this ground of appeal. In this regard, you noted the advice of the Quarantine Advisory Committee (QAC) which was that the barriers proposed for the three higher risk pathways are likely to result in a low risk of incursions, provided they are implemented in a timely, efficient and effective manner. You also submitted additional information on survival, detection and eradication measures which it contended would satisfy the Minister that the proposal could be implemented without compromising the biodiversity values of Barrow Island.

The Committee formed the view that the risk of the Gorgon proposal (in and of itself) leading to the introduction and establishment of a non-indigenous species is low. However, the Committee agreed with the EPA that given the scale of the proposal and its 60+ year life, it is probable that introductions will occur. The Committee also noted that whatever quarantine system is put in place, human error or other failures may occur.

The Committee also noted that third party use of the island is not subject to the same quarantine standards as proposed by the Gorgon Joint Venturers. Given quarantine measures are only as effective as the weakest link in the chain, the Committee considered that the risks of introductions of non-indigenous species could be reduced by all users of the island adhering to a single, high standard quarantine regime.

In the event the project is approved, the Committee recommended that consideration be given to extending the proposal definition to encompass the airport and existing barge landing facility, given both facilities will be used by the proponent, and are critical quarantine pathways.

In relation to the acceptability of the quarantine risk, the Committee noted that the question of whether the risk posed by the proposal is 'acceptably low' was not resolved through the assessment process, with the EPA only noting the community expectations in relation to the level of risk. In the absence of the EPA making a recommendation as to what is acceptably low risk for introductions, and given the your advice that it is not meaningful to score the survival, detection and eradication elements of the quarantine assessment, it is considered highly unlikely that a risk assessment could ever be completed. Consequently, the acceptability of the proposal on this factor requires a different consideration. In this regard, and given the significance or the conservation values of Barrow Island, the Committee expressed the view that the standard that should be applied is that it would be unacceptable for a non-indigenous species to be introduced and become established on the island. To achieve this standard, the Committee considered that in the event that the proposal is approved:

- the Quarantine Management Plan needs to be finalised and subject to regular review and adaptation;
- an expert body should be established to audit/advisory role;
- an adequate on-site and off-site monitoring program needs to be established;
- all users of the island need to be subject to the same standards;
- in the event that a species is detected on the island, a coordinated approach to eradication involving all users on the island, including DEC, needs to be established; and
- all users establish appropriate protocols and working arrangements with DEC.

Having regard to the information presented to me in relation to this ground of appeal, I agree with the Committee that the risk of a non-indigenous organism being introduced to Barrow Island as a result of the implementation of the Gorgon proposal is low. The quarantine measures proposed are considered to be comprehensive and represent a significant advancement over the measures applying to existing operators on the island. Furthermore, I am also confident that the detection and eradication measures put forward will make it unlikely that a non-indigenous species will become established on Barrow Island.

Subsequent to the Appeal Committee reporting to me, you have put forward a proposal to fund monitoring and eradication of non-indigenous species located on Barrow Island following the commencement of the project. Further, you have also provided a financial guarantee to cover Government costs for eradication of non-indigenous species located on Barrow Island following the commencement of the project. As well, you have agreed to fund a Threatened Species

Translocation and Reintroduction Program for selected species from Barrow Island to other Pilbara islands.

In these circumstances, I am of the view that the risk of introduction and establishment of non-indigenous species on Barrow Island as a result of the implementation of the Gorgon proposal is acceptably low.

To achieve this outcome, I agree with the measures recommended by the Committee to ensure that no non-indigenous species are introduced to and become established on Barrow Island. This includes requiring you as the proponent to finalise and implement a Quarantine Management Plan which should be the subject of review from an independent expert panel.

A key factor raised by this ground of appeal is requiring all users of Barrow Island to meet the high quarantine standards. In this regard, I note that the existing oil operations pre-date the Act and its predecessor, as a result of which, no Ministerial conditions apply to the operation. Whilst any Ministerial conditions applying to the Gorgon proposal will only be binding on the Gorgon Joint Venture Partners, it is my view that similar standards should also apply to other island users. The Appeals Committee advised that the Barrow Island Coordinating Committee under the Agreement to the *Barrow Island Act 2003* is a potential mechanism to achieve consistent quarantine standards. In addition, section 62 of the *Conservation and Land Management Act 1984* (CALM Act) could be used to establish a "whole of island" quarantine regime that applies to all visitors to the island, irrespective of whether they are associated with the Gorgon project, or other operations on the island. Arrangements for a "whole of island" quarantine regime should be discussed through the consultation process under section 45 of the Act.

It follows form the foregoing that I have allowed your appeal to the extent that I am of the view that the risk of the Gorgon proposal resulting in the introduction and establishment of a non-indigenous species is acceptably low provided that appropriately worded conditions are developed which reflect the intent of the objectives identified by the Appeals Committee.

**Ground 4 – Subterranean fauna and short range endemics**

The EPA stated that surveys conducted prior to the release of the Bulletin showed that up to seven subterranean taxa (two troglofauna and five stygofauna) found beneath the proposed plant site have not been located elsewhere. Two taxa of terrestrial invertebrates (a scorpion and a pseudo-scorpion) have also been found only within the development footprint.

The EPA stated that if any of these taxa are not found elsewhere, then it is almost certain that they would become extinct when the site is cleared and developed. The terrestrial taxa would be lost because their habitat would be removed by clearing. The subterranean taxa would have to be regarded as lost because cutting and filling would destroy much of the troglobitic habitat, construction would impede the infiltration of rainfall and associated nutrients on which stygofauna depend and operations are likely to lead eventually to the infiltration of spilt hydrocarbons. Given the risk that these taxa would be lost if the project is implemented, the EPA concluded that clearing of the sites where these taxa occur is environmentally unacceptable.

Through your appeal, you submitted that the EPA gave insufficient weight to the fact that subterranean fauna surveys typically experience considerable species accumulation over time. You also submitted that the EPA did not adequately consider the hydrogeological environment, which indicates that there is no physical impediment to species dispersal that would restrict a species to the plant footprint. In relation to hydrocarbon spills, you contended that the EPA placed too much weight on the risks to subterranean fauna as a result of potential hydrocarbon contamination of groundwater. You stated that the proposed facility will be a sophisticated, modern gas plant, and will pose a significantly lower risk compared to oil spills from traditional oil industry facilities. You stated that it is committed to appropriate measures to prevent contamination, many of which are standard industry practice and can be expected to be successful with a very high degree of certainty.

Through the appeal investigation, you submitted updated survey information which showed that only four subterranean taxa and one terrestrial taxa are now known only from the development site. That is, in the six months since the EPA conducted its assessment, the number of taxa thought to be found only on or under the plant site has reduced from nine to five. You stated that it is likely the five remaining taxa will be found from other locations on Barrow Island, and that the karstic features of the island do not suggest that species distribution is limited to the plant site. You have indicated that it will be undertaking further surveys to identify the species at other locations outside the development footprint.

Having considered the information presented in the appeals, I am of the view that with further surveying, it is likely that the five remaining taxa found only at the plant site will be located elsewhere on Barrow Island. As such, I am of the view that there is only a small risk that the taxa will not be found elsewhere. To this end, I have allowed your appeal in respect to this ground to the extent that it is likely the taxa will be found elsewhere on the island and that the conditions should require you to undertake surveys until the species are located.

**Ground 5 – Greenhouse gas emissions**

Gas from the Gorgon gas field contains a high proportion of carbon dioxide, which you as the proponent have committed to inject in a suitable formation beneath Barrow Island unless the option is "technically infeasible or cost prohibitive". Even with geosequestration of this carbon dioxide, the EPA noted that the Gorgon development would result in significant greenhouse gas emissions, expected to be in the order of 4 million tonnes per annum (MTPA) after reservoir carbon dioxide is injected. The EPA recognised however that the LNG produced would have a benefit over some alternative primary energy fuel sources such as coal and oil, in terms of the full life cycle greenhouse gas emissions.

Given one of the benefits identified in locating the gas processing facilities at Barrow Island was the potential to inject carbon dioxide into the subsurface, the EPA considered that the project would not be environmentally acceptable if it did not include a scheme designed to inject a high percentage of the reservoir carbon dioxide or otherwise mitigate an equivalent amount of carbon dioxide. If injection was infeasible or not practicable for cost reasons, the EPA advised that alternative measures to abate or mitigate the equivalent amount of reservoir carbon dioxide vented to the atmosphere would be necessary.

In your appeal, you submitted that in deciding that the project would only be acceptable with the injection scheme, the EPA effectively concluded that a project emitting approximately 4 MTPA of carbon dioxide would be environmentally acceptable but one emitting between 4 and 6.7 MTPA of carbon dioxide would not be. You stated that the EPA has not provided any rationale to support what is essentially an arbitrary judgement.

You added that the EPA's conclusion fails to consider that its actions to reduce greenhouse gas emissions would fully satisfy current law and Western Australian Government policy and the EPA's Guidance Statement on minimising greenhouse gas emissions even if all the reservoir carbon dioxide was vented to the atmosphere. Additionally, you advised that there is no requirement within other Australian jurisdictions for such consideration.

A number of the third party appellants contended that you as the proponent should be required to re-inject the carbon dioxide extracted from the produced gas. If this is not technically feasible, the appellants submitted that there is no justification for the project to remain on Barrow Island. The question of legal liability should the gas leak from the Dupuy saline aquifer was also raised by the Conservation Council.

The key issue raised by this aspect of the appeal is whether you as the proponent should be required to inject approximately 2.7MTPA of carbon dioxide generated from the processing of gas from the Gorgon gas field. Your position is that you are committed to this outcome except where it is technically infeasible or cost prohibitive. This qualifier effectively means that the objective of sequestering 2.7MTPA of carbon dioxide may not occur.

It is also apparent that the other gas fields which are expected to be developed and processed at the Barrow Island facility (such as Jansz-Io, Clio and Chandon) have low levels of carbon dioxide and are unlikely to require any form of geosequestration.

You expressed concern at any condition requiring it to inject 2.7MTPA carbon dioxide under Barrow Island, as the generation of carbon dioxide will vary for different gas fields, there may be technical reasons for not proceeding with geosequestration and such a condition fails to provide operational flexibility in the event of equipment downtime. On the requirement to offset the equivalent of 2.7MTPA of carbon dioxide (whether by geosequestration or other means) you indicated that such a condition would create an unacceptable intangible liability for the project.

It is clear that a key driver for the location of the plant on Barrow Island was the availability of subsurface geology suitable for geosequestration of carbon dioxide. In these circumstances, I believe the EPA was justified in recommending that geosequestration should be a requirement of any conditions of approval.

Taking into account the foregoing, I am of the view that you as the proponent should be required to design, construct and operate infrastructure on Barrow Island to geosequester the carbon dioxide from gas processed at the site (estimated at 2.7MTPA of carbon dioxide from the Gorgon gas field). It is acknowledged that the amount of carbon dioxide actually injected may be less than the full amount. I expect that you as the proponent should be required to prepare regular reports on the implementation of the geosequestration activities. In the event that the amount of carbon dioxide injected does not meet a defined level, I believe the conditions should require you to report to the Minister on what measures it proposes to address or offset the deficit, and how this is proposed to be implemented.

I have also determined to require you as the proponent are to prepare a Greenhouse Gas Abatement Program to address the remaining carbon dioxide produced as a result of the processing of the gas on Barrow Island.

It follows from the above that I have allowed third party appeals to the extent that you as the proponent be required to develop geosequestration infrastructure on Barrow Island to inject carbon dioxide from the Gorgon gas stream beneath Barrow Island. As noted, the conditions will require you to report on compliance with the condition, and where there is a deficit between the amount of carbon dioxide extracted and injected (as determined by the Minister), you as the proponent are to report to the Minister. You will also be required to address the remaining greenhouse gas emissions from the plant through the preparation of a Greenhouse Gas Abatement Program.

This is an appropriate response having regard to the conservation status of Barrow Island, and noting the importance of government, industry and the community generally maximising opportunities for reducing greenhouse gas emissions.

**Ground 6 – Alternative sites**

A number of appellants questioned your decision to locate the facility on Barrow Island, identifying other locations on the mainland as having a significantly lower environmental impact.

WWF stated that the assessment guidelines required the ERMP to provide a source of information from which interested individuals and groups may gain an understanding of the proposal, the need for the proposal and the alternatives. WWF contended that inadequate information was supplied on the site selection alternatives, both in regards to Barrow Island, and also in relation to Town Point.

A number of appellants contended that alternative sites and layout options should have been given consideration in the ERMP and EPA's report and recommendations. For example, an option of carbon dioxide stripping and re-injection on Barrow Island and the LNG plant and port located on the mainland.

In response to this ground of appeal, the EPA stated that from an environmental point of view, alternative sites to Barrow Island could be found acceptable in the sequence (most to least desired location) of brown-fields mainland sites, green-fields mainland sites and Thevenard Island. Trimouille Island could be considered, provided marine values could be adequately protected.

You stated that the Environmental, Social and Economic (ESE) Review process conducted in 2003 confirmed that Barrow Island, the closest landfall to the gas fields, was the only commercially viable development location for the Gorgon project. It identified a cost disadvantage in the order of $1 billion for mainland options. You indicated that its findings were verified by an independent review conducted for the Western Australian Government by the Allens Consulting Group.

You advised that to get gas to the mainland for processing and then transport carbon dioxide to Barrow Island for injection would be a significant impact on project economics from the cost of hundreds of kilometres of additional pipeline that would be required from both the Gorgon and Jansz fields. In addition to the issue of cost, you stated that there are engineering and greenhouse gas emissions implications that caused you to conclude that this was not a viable option. For example, you stated that geographically separating the carbon dioxide removal and LNG processing would result in an approximate 40% increase in the overall amount of energy required to manufacture the LNG with a corresponding increase in greenhouse gas emissions.

In its report on this ground of appeal, the Committee noted that the comparison of key cost drivers for the alternative sites assumed that all carbon dioxide from the processing of gas would be injected into the Dupuy formation under Barrow Island. As a result, each site includes the cost of a carbon dioxide pipeline from the site to Barrow Island. The Committee observed that if geosequestration does not proceed, the cost of building carbon dioxide pipelines from alternative sites to Barrow Island would be removed, which would therefore change the relative cost values of the various options.

The issue of alternative sites has been the subject of an earlier assessment process. From that process, you have put forward the current proposal to develop an LNG facility on Barrow Island. The issues relating to the selection of this site for the geosequestration of carbon dioxide were considered under the previous ground of appeal, in which I have determined that you as the proponent be required to establish geosequestration facility on the island and prepare a Greenhouse Gas Abatement Program.

As to the options presented in appeals to locate the processing plant on the mainland, and geosequestration infrastructure on Barrow Island, I note the advice from you that this would result in an increase of 40% in energy requirements for processing LNG, with a resultant increase in carbon dioxide emissions. I note also that the proposal under consideration is for the proposal as put forward by you as proponent. The question therefore is whether the project should proceed on Barrow Island.

It follows from the above that I have dismissed this ground of appeal.

**Ground 7 – Economic benefits of a mainland site**

The Conservation Council contended that siting the LNG plant on the mainland would have significant advantages for downstream processing and value adding that are not available on the footprint allocated by the *Barrow Island Act 2003*. The Council also noted that there is also potential for social benefits through downstream jobs creation and a regional workforce rather than fly-in fly-out workforce. The Council also stated that there are likely to be strategic environmental benefits from having defined gas processing industrial hubs, rather than ad hoc scattering of LNG facilities.

Another appellant submitted that the operational cost of freight and transportation of personnel to Barrow Island would be greater than for a mainland site.

The EPA stated that it can only provide comment on environmental matters and therefore made no comment on the economic and social issues raised by this ground of appeal. The EPA added that it has not performed any analysis of the strategic environmental benefits of a gas processing hub, but agreed that there could be environmental benefits associated with a mainland rather than a Barrow Island location.

The Committee agreed with the position taken by the EPA that the economic advantages or otherwise of other locations are not something that can be considered by the Committee.

As noted under the previous ground of appeal, site selection was the subject of a review process in 2003. I have accordingly dismissed this ground of appeal.

**Ground 8 – Use of Jansz-Io gas**

In its appeal, WWF noted that the possibility of processing gas from the Jansz-Io fields was introduced after finalisation of the scoping document. Whilst it acknowledged that the Jansz-Io development and pipeline have triggered a separate assessment process, WWF expressed concern with the change from the scoping document because the characteristics the Jansz-Io gas field may be important to the design of the Barrow Island proposal including site selection.

The EPA responded that the addition of gas from the Jansz-Io fields did not materially change the Barrow Island development proposal such that the scoping document would need to be revised. In relation to whether the addition of Jansz-Io gas might have influenced the site selection process, the EPA noted that the addition of Jansz gas does not diminish the geo-sequestration opportunity for the Gorgon gas of the original proposal.

You advised that the fact that the processing of gas from the Jansz–Io field was not included in the scoping document did not impact on the EPA's ability to assess the aspects of the Jansz-Io field which are relevant to the Gorgon project, or on the Minister's ability to determine whether the Gorgon Project should go ahead. You stated that the only way that failure to identify these aspects earlier in the assessment process could have impacted on the EPA's assessment would have been if the EPA had determined a lower level of assessment without the inclusion of Jansz-Io, but then wished to raise the level of assessment once Jansz-Io was included. You noted that this is not relevant in this case as the Gorgon Project was already subject to the highest level of assessment.

In its report, the Committee agreed that the addition of the Jansz-Io gas did not materially change the potential impacts of the proposal such that the scoping document would require revision. In relation to the question as to whether knowledge of the addition of Jansz-Io gas (being lower in carbon dioxide than the Gorgon field) would have led to a different conclusion in relation to the site selection process, the Committee noted that there appears to be no capacity to mix the Gorgon and Jansz gas streams off shore in the manner contemplated by WWF. The Committee also noted the EPA's advice that irrespective of the addition of Jansz-Io gas, the requirement for geosequestration of the Gorgon gas would remain. The Committee concluded therefore that the addition of the Jansz-Io gas did not require a fresh scoping process or any change to the level of assessment.

The Committee acknowledged however that there may be cases where incremental changes to proposals, or the division of proposals into smaller components, can have the effect of diminishing the ability of the environmental impact assessment process to assess cumulative impacts. The Committee expressed a view that it may be useful for the EPA to be asked to provide advice on how cumulative impacts can be better assessed. In this regard, the Committee considered that the concept of 'cumulative impact analysis' under the United States *National Environmental Policy Act 1969* may provide a useful precedent for consideration in Western Australia.

Having regard to the information presented to me in relation to this ground of appeal, I am of the view that the EPA was justified in not requiring a fresh scoping process for the addition of the Jansz-Io gas to the proposal. In my view, the issues raised by the proposal in respect to the geosequestration of carbon dioxide from the Gorgon gas field remains. It follows that I have dismissed this ground of appeal.

On the broader issue of how cumulative impacts are assessed, I will raise this matter with the Chairman of the EPA and obtain his advice on how this issue might best be reviewed.

**Ground 9 – Further expansion of activities on Barrow Island**

By this ground of appeal, the Conservation Council submitted that the approval of the Gorgon project will set a precedent leading to further development of Barrow Island and the cumulative impacts from further development will substantially diminish the conservation values of the island.

In its response, the EPA restated its position that this proposal cannot meet its environmental objectives and therefore should not proceed. It also stated that in its view, Barrow Island is not a suitable location for industrial development.

You stated that the question of future developments is not relevant to the Minister's decision on the Gorgon project. You submitted that all future developments must be considered on their own merits, and it would not be lawful to refuse permission for development of the Gorgon project on the basis of what speculative future projects may be proposed, let alone approved, on Barrow Island. You also noted that industrial development on Barrow Island is limited by *Barrow Island Act 2003* with an area 100 hectares reserved for expansions or other projects using gas from the Greater Gorgon area.

In my view, the question of any future development needs to be addressed on its merits at the time any proposal is put forward. That being said, the *Barrow Island Act* (as you point out) restricts development to an area of 300 hectares. In these circumstances, I do not believe an approval of the Gorgon proposal represents a precedent for further development on Barrow Island. I have therefore dismissed this ground of appeal.

**Ground 10 – Aboriginal heritage**

In its appeal, the Yamatji Marlpa Barna Baba Maaja Aboriginal Corporation (Yamatji) on behalf of the Kuruma Marthudunera native title claimants questioned how the EPA reached the conclusion that Aboriginal heritage is not a relevant factor, given that the surveys required to properly delineate Aboriginal heritage sites in the project area have not been completed. Yamitji stated that there appears to have been very little or no consultation with indigenous stakeholders, and that there has been no application of the precautionary principle to deal with the lack of scientific certainty.

The EPA responded that Aboriginal heritage was a relevant environmental factor, but that it could be managed to meet its environmental objectives and therefore did not require further detailed assessment.

You advised that you had developed and commenced execution of an indigenous engagement strategy to support the Draft Cultural Heritage Management Plan, and that it had commenced consultation with three native title claimant groups with an aim of entering into heritage agreements which would provide an agreed framework for the groups' participation in archaeological and ethnographic surveys on Barrow Island. You advised that the surveys will provide the basis for the development of several reports to support an application for section 18 approval under the *Aboriginal Heritage Act.*

The Committee formed the view that the concerns raised by this ground of appeal can be managed to meet the EPA's environmental objectives, through an appropriately worded condition requiring the production and implementation of a Cultural Heritage Management Plan.

I have considered the Committee's advice in relation to this ground of appeal, and agree that the question of Aboriginal heritage can be managed in the manner set out in its report. It follows that I believe the EPA's position in relation to this aspect of the appeal was justified, and I have dismissed the appeal accordingly.

**Ground 11 – Impacts on dugong**

In its appeal, the Conservation Council stated that the possible impacts of the proposal on dugong remain unclear.

The EPA's Bulletin stated that activities associated with the proposal (such as pile drivers for jetty construction, seismic activities and possible blasting for channel construction) are likely to generate significant percussion locally and underwater sound pulses that may travel many kilometres. The Bulletin stated that the significance of impacts of noise and percussion on marine life including dugongs will vary according to distance from source, timing and management measures put in place. Even with the proposed management measures, the EPA stated that impacts will be unavoidable and there is significant residual risk to marine species from noise and vibration from underwater sources. The EPA stated that available data suggests dugong numbers are probably low but information on the potential impacts on this species of the various stressors imposed by the proposal is sparse.

You submitted that marine survey work in the waters off the east coast of Barrow Island between 2002 and 2006 recorded only one dugong near Dugong Reef several kilometres to the south of the development area. You stated that the absence of major seagrass meadows on which these animals feed indicates they are unlikely to aggregate in significant numbers anywhere in this locality. Notwithstanding this, you submitted that its marine mammal management strategies for the development, including vessel watches and shepherding large fauna out of areas to be dredged or where blasting will occur, will protect dugong, turtles and cetaceans.

In its report, the Committee noted that there appears to be some uncertainty about the extent to which dugong will be affected by the proposed development. Whilst the Joint Venturers have identified strategies for addressing potential impacts, the Committee stated that uncertainty remains as to whether such strategies will be successful, given the potentially large impact area. In the event the project is approved, the Committee recommended that you as the proponent be required to implement current best practice techniques for limiting impacts to dugong and other marine fauna from activities including dredging, blasting and seismic testing.

Having considered the information presented to me in relation to this ground of appeal, I am of the view that the risks posed by the proposal in relation to dugongs can be managed through appropriately drafted implementation conditions. Consistent with the recommendation of the

Committee, I am of the view that these conditions should include the requirement for you as the proponent to implement best management practices when undertaking activities that may impact on marine fauna species, such as blasting, pile driving, dredging and seismic testing. The conditions should also require you as the proponent to undertake a comprehensive monitoring program for marine fauna for the life of the project so that any impacts on the species can be detected and responded to.

**Ground 12 – Cumulative impacts of proposal**

In its appeal, the Conservation Council contended that a number of environmental impacts of the proposal were understated and that many smaller impacts of the proposal were not given adequate attention by the EPA. The Council contended that these cumulative impacts add considerable weight to the argument against the Gorgon project being approved on Barrow Island. No specific examples of these cumulative impacts were set out in the Council's appeal.

The EPA responded to this ground of appeal by noting that the Conservation Council's position does not conflict with its conclusion that the proposal is unacceptable.

The Committee noted that the question of cumulative impacts is consistent with the EPA's conclusion that the proposal not proceed. In the absence of information in the appeal as to the specific cumulative impacts that were alleged not to have be given sufficient weight, the Committee concluded that the EPA's assessment in this regard was adequate.

I agree with the recommendation of the Committee and have dismissed this ground of appeal accordingly. In relation to cumulative impacts more generally, I noted above my intention to raise this issue with the Chairman of the EPA with a view to identifying assessment methodologies for addressing cumulative impacts.

**Ground 13 – Waste management**

One appeal questioned the methods of disposal of rubbish and waste generated by the proposal.

The EPA considered that waste management issues can be managed to meet its environmental objectives through the proposed Waste Management Plan. The EPA stated that the requirement for approval and implementation of the Waste Management Plan should be included in the Ministerial Conditions if the proposal is approved.

The Committee noted that waste management was not identified by the EPA as a significant environmental factor. Subject to appropriate conditions, the Committee expressed the view that waste management could be appropriately managed.

Having considered the advice of the EPA and the Committee, I am of the view that waste management does not present a significant risk to the environment, and can be adequately managed through conditions. I have therefore dismissed this ground of appeal.

**Ground 14 – Draft framework conditions**

A number of appellants raised objections to the content and form of the draft framework for environmental conditions which the EPA recommended be applied to the project in the event it is approved.

Your appeal raised objections to all suggested conditions in the draft framework. The grounds of your appeal included that the conditions are imprecise, uncertain, unreasonable, unenforceable and in some cases, legally invalid. Similar objections were raised by the WWF.

The Committee agreed that conditions imposed under Part IV of the Act should be expressed in clear language, which clearly identify the obligations of the proponent. The Committee also recognised that a project of the scale under consideration raises significant complexities and interrelationships.

It is noted that in its appeal advice, the EPA stated that the draft framework conditions were not intended to be 'final', and should be the subject of further refinement and discussion in the event the project is approved.

In my view, the EPA draft framework conditions would require significant revision along the lines discussed above: that is, they are clear, robust and legally enforceable. In this regard, I agree with the objectives put forward by the Committee for drafting the conditions.

It follows from the above that I have allowed appeals to the extent that any conditions developed through the section 45 process are appropriately worded to ensure they meet community expectations and noting the 60 year life of the project as well as the outcomes of this appeal determination.

The precise detail of the conditions will be developed as part of the consultation process under section 45 of the Act.

**Conclusion**

I have determined to allow certain grounds of appeal in the manner described above. Overall, I am of the view that the project could proceed subject to the implementation of rigorous environmental conditions, and taking into account the additional proposals submitted by you as the proponent subsequent to me receiving the Appeals Committee report.

In relation to dredging, I am confident that the proposed framework dredging conditions, in setting onerous monitoring requirements on the proponent, ensures that any impacts on coral will be detected at an early stage allowing management responses to be adopted to ensure impacts do not exceed approved levels. In this regard, the area of approved coral mortality will be restricted to 23.2 hectares, a significant reduction from the estimate of almost 130 hectares in the EPA's Bulletin.

For flatback turtles, it is accepted that the beaches of the east coast of Barrow Island are a significant nesting site for the species. I have determined in this regard to require you as the proponent to develop and implement a turtle monitoring program that is statistically validated and aimed at identifying any changes to the Barrow Island turtle population and incorporating baseline information, indicators of change, beach management plan, and light management. There will also be a requirement for continuous improvement and adaptive management, with oversight provided by an expert advisory group. I have also taking into account the two additional proposals relating to flatback turtles submitted by you as the proponent subsequent to the Appeal Committee reporting to me.

In relation to introduced non-indigenous organisms, I have concluded that it would be unacceptable for a non-indigenous species to be introduced and become established on Barrow Island. The Gorgon proposal of itself increases the risk of this happening. However, the risk can be reduced to an acceptable level through the implementation of robust conditions relating to quarantine management including the development of a quarantine management plan and establishment of a quarantine expert panel. I have also taken into account the three additional proposals relating to introduced non-indigenous organisms submitted by you as the proponent subsequent to the Appeal Committee reporting to me.

For short-range endemics and subterranean fauna, I have formed the view that there is only a small risk of the species identified on the plant site not being located elsewhere on the island. This will require confirmation through you as the proponent undertaking further surveys for the five remaining taxa.

I have allowed third party appeals in relation to greenhouse gas issues to the extent that you as the proponent be required to construct and implement a geosequestration facility to inject a high proportion of carbon dioxide from the processing of gas on the island. This removes the qualifications contained in the proponent's ERMP in relation to technical feasibility and cost.

My decision on the other grounds of appeal are detailed above.

Thank you for bringing your concerns to my attention.

Yours sincerely

**HON MARK McGOWAN MLA**
**MINISTER FOR THE ENVIRONMENT;**
**RACING AND GAMING; PEEL AND THE SOUTH WEST**

Encl.

12 DEC 2006

# APPENDIX K

## Vegetation Associations And Descriptions

## Gorgon Gas Development Revised Proposal –
## List of Vegetation Associations and Descriptions

| Vegetation Association Code | Vegetation Association Description |
|---|---|
| **Coastal Communities** | |
| C1e | Grassland of *Spinifex longifolius* over Low Open Shrubland of *Threlkeldia diffusa* with scattered *Rhagodia preissii* subsp. *obovata* and *Frankenia pauciflora* var. *pauciflora* on ridges and back slopes of white sandy foredunes. |
| C2a | Shrubland to Tall Shrubland of *Acacia coriacea* over Low Open Shrubland to Open Shrubland of *Acacia bivenosa* with low scattered *Olearia dampieri* subsp. *dampieri* shrubs over Open Hummock Grassland to Grassland of *Triodia angusta* on dune swales, slopes and ridges. |
| C2b | Open Shrubland of *Acacia coriacea* over Low Open Shrubland of *Acacia bivenosa* and *Pentalepis trichodesmoides* with scattered *Acanthocarpus verticillatus* over Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on red/brown sandy flats. |
| C2f | Open Shrubland of *Acacia coriacea* over Low Open Shrubland of *Olearia dampieri* subsp. *dampieri* and *Acacia bivenosa* with occasional *Stylobasium spathulatum* over Hummock Grassland of *Triodia epactia* on sandy dune ridges (over scattered *Heliotropium glanduliferum* and *Diplopeltis eriocarpa* on back of red/brown sandy flats and dunes). |
| C2h | Low Shrubland of *Acacia coriacea* with *Rhagodia preissii* subsp. obovata over Very Open Herbland of *Threlkeldia diffusa* over Grassland to Hummock Grassland of *Triodia epactia* and *Spinifex longifolius* on secondary dune slopes and ridges. |
| C2j | Low open shrubland of *Acacia coriacea* and *Threlkeldia diffusa* over Closed Hummock Grassland of *Triodia epactia* on beige sands on the back slopes of secondary dune slopes and ridges. |
| C5a | Low scattered *Frankenia pauciflora* var. *pauciflora* shrubs with scattered *Oldenlandia crouchiana* herbs and *Cyperus cunninghamii* subsp. *cunninghamii* sedges on coastal limestone cliffs and in major drainage lines in coastal areas. |
| **Drainage and Creekline Communities** | |
| D1a | Scattered tall *Acacia coriacea* shrubs over Low Shrubland to Shrubland of *Stylobasium spathulatum* and *Acacia bivenosa* over Very Open Herbland of *Acanthocarpus verticillatus* over Closed Hummock Grassland of *Triodia angusta* with scattered *Triodia wiseana* on valley floors and deep gullies. This unit contains occasional *Hakea lorea* subsp. *lorea.* Unit also contains areas of scoured drainage channel in areas of heavy seasonal flow. |
| D1d | Low Open Shrubland of *Pentalepis trichodesmoides* over Hummock Grassland of *Triodia epactia* with patchy *Triodia angusta* and *Triodia wiseana* on lower slopes and broad drainage flats. |
| D1e | Open Shrubland of *Stylobasium spathulatum, Pentalepis trichodesmoides with Trichodesma zeylanicum* over Closed Hummock Grassland of *Triodia angusta* and *Triodia wiseana* over Low Open Shrubland of *Acacia bivenosa* and *Acacia gregorii* in some locations on lower slopes, drainage flats and wide drainage lines. |
| D1f | Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum* with patchy *Petalostylis labicheoides* over Hummock Grassland to Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* in major drainage lines. This unit contains occasional *Hakea lorea* subsp. *lorea.* |
| D2d | Low Open Shrubland of *Pentalepis trichodesmoides* over Closed Hummock Grassland of *Triodia epactia* and *Triodia wiseana* over Low Shrubland of *Acacia gregorii* in minor creek and drainage lines. |
| D2f | Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Stylobasium spathulatum* with patchy *Petalostylis labicheoides, Acacia gregorii and Acacia bivenosa* over Hummock Grassland to Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* in minor drainage lines. This unit contains occasional *Hakea lorea* subsp. *lorea.* |

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| **Flats Communities** | |
| F4b | Low Open Woodland of *Erythrina vespetilio* over Low Open Shrubland of *Pentalepis trichodesmoides, Solanum lasiophyllum and Trichodesma zeylanicum* over Hummock Grassland of *Triodia epactia* with patches of *Triodia wiseana* on red sandy flats with some limestone outcropping. |
| F8a | Low Open Shrubland to Open Shrubland of *Acacia bivenosa,* with occasional scattered *Pentalepis trichodesmoides, Stylobasium spathulatum* and *Acanthocarpus verticillatus* shrubs over Hummock Grassland to Closed Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* on flats and valley floors. |
| **Limestone Communities** | |
| L3a | Low Open Shrubland of *Stylobasium spathulatum* with *Petalostylis labicheoides* over Closed Hummock Grassland of *Triodia angusta* with patchy *Triodia wiseana* over Low Open Shrubland of *Acacia gregorii* on limestone slopes and ridges. |
| L3f | Low scattered *Petalostylis labicheoides* and *Indigofera monophylla* shrubs over Hummock Grassland of *Triodia wiseana* on limestone ridges and upper slopes. |
| L3i | Low Open Shrubland to Low Shrubland of *Acacia bivenosa* with occasional low scattered *Stylobasium spathulatum* and *Petalostylis labicheoides* shrubs over Hummock Grassland of *Triodia angusta* with occasional *Triodia wiseana* on limestone slopes, small rises and flats. |
| L4a | Open Shrubland of *Acacia pyrifolia* over Low Open Shrubland of *Acacia bivenosa* with scattered *Petalostylis labicheoides and Stylobasium spathulatum* over Hummock Grassland of *Triodia wiseana* on limestone ridges and midslopes with patches of *Triodia angusta* . This unit contains occasional *Hakea lorea* subsp. *lorea.* |
| L5a | Scattered *Hakea lorea* subsp. *lorea* tall shrubs over low scattered *Petalostylis labicheoides* shrubs over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* over low scattered *Acacia gregorii* and *Corchorus interstans* shrubs on limestone ridges. |
| L6b | Scattered low *Ficus brachypoda* trees over Low Open Shrubland of *Grevillea pyramidalis* ?subsp. *leucadendron* with occasional *Pentalepis trichodesmoides, Trichodesma zeylanicum* with scattered *Acacia gregorii* over Closed Hummock Grassland of *Triodia epactia* and *Triodia wiseana* and *Eriachne* sp. over Low Open Shrubland of *Acacia gregorii* on upper slopes and midslopes of small rises. |
| L6c | Low Open Shrubland of *Pentalepis trichodesmoides* with *Grevillea pyramidalis* ?subsp. *leucadendron* (*Grevillea* only in eastern section of community) over Hummock Grassland of *Triodia wiseana* with patchy *Triodia epactia* over Low Open Shrubland of *Diplopeltis eriocarpa* on mid to upper slopes with red/brown sands and occasional limestone outcropping on rocky rises and slopes. |
| L6d | Low Open Shrubland of *Pentalepis trichodesmoides* with *Indigofera monophylla* and scattered *Grevillea pyramidalis* ?subsp. *leucadendron* over Hummock Grassland of *Triodia epactia* in minor drainage lines. |
| L7a | Low Shrubland of *Melaleuca cardiophylla, Stylobasium spathulatum, Pentalepis trichodesmoides, Trichodesma zeylanicum* over Hummock Grassland of *Triodia wiseana* with *Triodia angusta* over Low Open Shrubland of *Acacia gregorii, Acacia bivenosa* shrubs on rocky limestone ridges, slopes and minor gullies, with occasional pockets of *Gossypium robinsonii.* |
| L7b | Low Shrubland of *Melaleuca cardiophylla* over Hummock Grassland of *Triodia wiseana* with occasional *Triodia angusta* over low scattered shrubs to Low Open Shrubland of *Acacia gregorii* on limestone upper slopes and ridges. |
| **Valley Slopes and Escarpment Slopes Communities** | |
| V1d | Low Open Shrubland of *Acacia bivenosa* with low scattered *Pentalepis trichodesmoides* shrubs over Hummock Grassland of *Triodia angusta* and *Triodia wiseana* on limestone slopes and low ridges with occasional *Melaleuca cardiophylla.* |
| V1k | Scattered *Hakea lorea* subsp. *lorea* shrubs over Low Open Shrubland to Low Shrubland of *Melaleuca cardiophylla* over Hummock Grassland of *Triodia wiseana* with patchy *Triodia angusta* over low scattered *Acacia gregorii* shrubs on limestone hillslopes and minor drainage lines. |
| V1m | Low Open Heath of *Melaleuca cardiophylla* with *Acacia bivenosa, Sarcostemma viminale* |

| | |
|---|---|
| | subsp. *australe* over Hummock Grassland of *Triodia wiseana* and *Triodia angusta* on limestone ridges and slopes. |

Chevron

Gorgon Gas Development Revised and Expanded Proposal