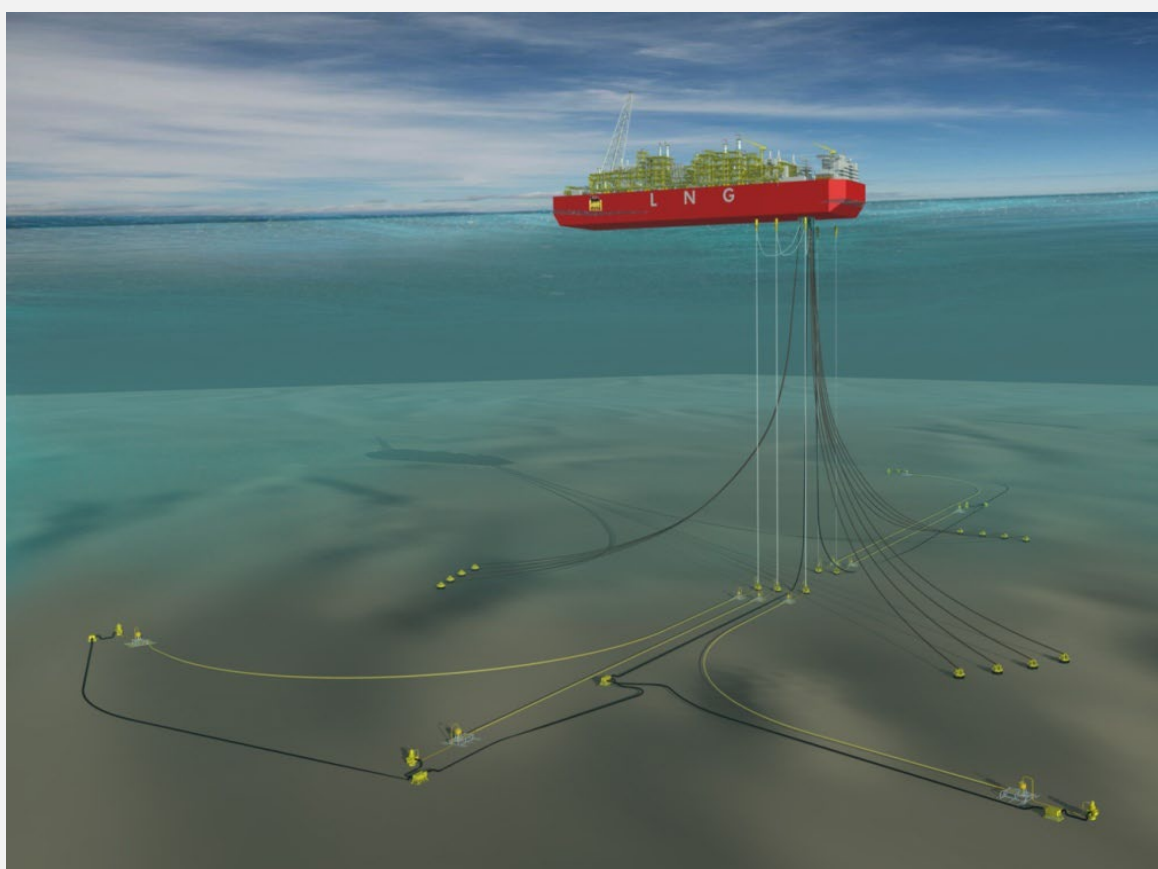


# CORAL NORTH DEVELOPMENT PROJECT

## ENVIRONMENTAL IMPACT STUDY

### FINAL REPORT

#### VOLUME IV – ANNEXES



JANUARY 2025

Prepared for:

**MRV**

Mozambique Rovuma Venture

*Mozambique Rovuma Venture S.p.A.*

Prepared by:

  
**CONSULTEC**

*Consultec – Consultores Associados, Lda.*

# CORAL NORTH DEVELOPMENT PROJECT

## ENVIRONMENTAL IMPACT STUDY

### FINAL REPORT

### VOLUME IV – ANNEXES

**Mozambique Rovuma Venture S.p.A.**

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**January 2025**

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## **Annex I – Consultec’s Registration as Environmental Consultor with MAAP**

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República de Moçambique  
**MINISTÉRIO DA TERRA E AMBIENTE**

**CERTIFICADO DE CONSULTOR AMBIENTAL**

N.º. 47 / 2022

O Ministério da Terra e Ambiente, ao abrigo do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto n.º 54/2015, de 31 de Dezembro, certifica que o (a) sr (a) \_\_\_\_\_

Consultec – Consultores Associados, Limitada

está devidamente credenciado (a) a exercer funções de Consultor Ambiental em Moçambique.

Maputo, aos 31 / 08 / 2022 Validade até 31 / 08 / 2025

  
A Ministra



## Annex II – Correspondence with MAAP

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REPÚBLICA DE MOÇAMBIQUE  
PROVINCIA DE CABO DELGADO  
SERVIÇO PROVINCIAL DE AMBIENTE

À

CONSULTEC- CONSULTORES ASSOCIADOS, LDA

Maputo

Nota 386/SPA/DA-RLA/220/023

Pemba, 07 de Junho de 2023

ASSUNTO: Instrução de Processo de Avaliação do Impacto Ambiental do Projecto de Coral Norte,  
Província de Cabo Delgado.

Exmos. Senhores,

Em resposta ao requerimento submetido por V. Excias, a 23 de Maio do ano em curso, através do qual solicitam-nos que lhes seja instruído um processo de Avaliação do Impacto Ambiental do projecto supra citado, de acordo com o previsto no Decreto nº 54/2015, de 31 de Dezembro (Regulamento sobre o Processo de Avaliação Ambiental).

Da análise e apreciação dos documentos que compõe o Processo de Instrução e incluindo o Relatório de Instrução de Avaliação de Impacto Ambiental, a estes anexo, e previstos no nº 1 do artigo 7º, do Decreto 54/2015, de 31 de Dezembro (Regulamento sobre o Processo de Avaliação do Impacto Ambiental), e à luz do Decreto 56/2010, de 22 de Novembro, (Regulamento Ambiental para as Operações Petrolíferas), a actividade enquadra-se na Categoria "A", o que significa que, V. Excias deverá elaborar e apresentar um Estudo de Impacto Ambiental (EIA) do projecto em referencia, e submeter à Direcção Nacional do Ambiente (DINAB-Maputo) e ao Serviço Provincial

do Ambiente (SPA-CD), antecedido pela apresentação de um Estudo de Pré-viabilidade Ambiental e Definição do Âmbito (EPDA) e Termos de Referência (TdR), em oito (08) exemplares impressas a cores e uma(01) em versão electrónica; e para o SPA deverá submeter quatro (04) cópias impressas a cores e uma (01) em versão electrónica. De salientar que a elaboração dos documentos acima referenciados devem obedecer o previsto no do nº 2 do artigo 11 do Decreto 56/2010, de 22 de Novembro, (Regulamento Ambiental para as Operações Petrolíferas), sem no entanto, discurar do previsto pelo artigo 19 do Decreto 56/2010 de 22 de Novembro, (Regulamento Ambiental para as Operações Petrolíferas).

Cordiais Saudações

O DIRECTOR DO SERVIÇO PROVINCIAL



Salém Muzena Afonso Lopes

(Técnico Superior N1)

Eni Rovuma Basin Bv  
Mozambique Branch  
RECEBIDO  
DATA 27/07/2023



REPÚBLICA DE MOÇAMBIQUE  
MINISTÉRIO DA TERRA E AMBIENTE  
GABINETE DO MINISTRO

À:  
Mozambique Rovuma Venture

Maputo

N/Refª N °/MTA/ 377 183 /GM/220/23

Maputo: 26/09/2023

**Assunto: Estudo de Pré-Viabilidade Ambiental e Definição do Âmbito e Termos de Referência do Projecto de Infra-estrutura Petrolífera Coral Norte**

Exmos Senhores,

O Ministério da Terra e Ambiente (MTA) recebeu o documento de V.Excias referente ao Projecto em epígrafe, tendo merecido a devida análise técnica.

Após a revisão feita nos termos do Artigo 16, do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro, o MTA comunica à V.Excias que o presente documento está aprovado mas, recomenda para o Relatório de Estudo de Impacto Ambiental (REIA), o cumprimento integral do EPDA e TdR e das questões apresentadas no relatório de revisão em anexo.

Informa-se ainda que o REIA deverá ser submetido à DINAB em dez (10) exemplares em formato físico e um (01) em formato electrónico. Cinco (05) exemplares do mesmo documento em formato físico e um (01) em formato electrónico deverão ser submetidos ao Serviço Provincial de Ambiente de Cabo Delgado.

Com os melhores cumprimentos.

A Ministra

Ivete Joaquim Maibaze

CC: Suas Excelências:

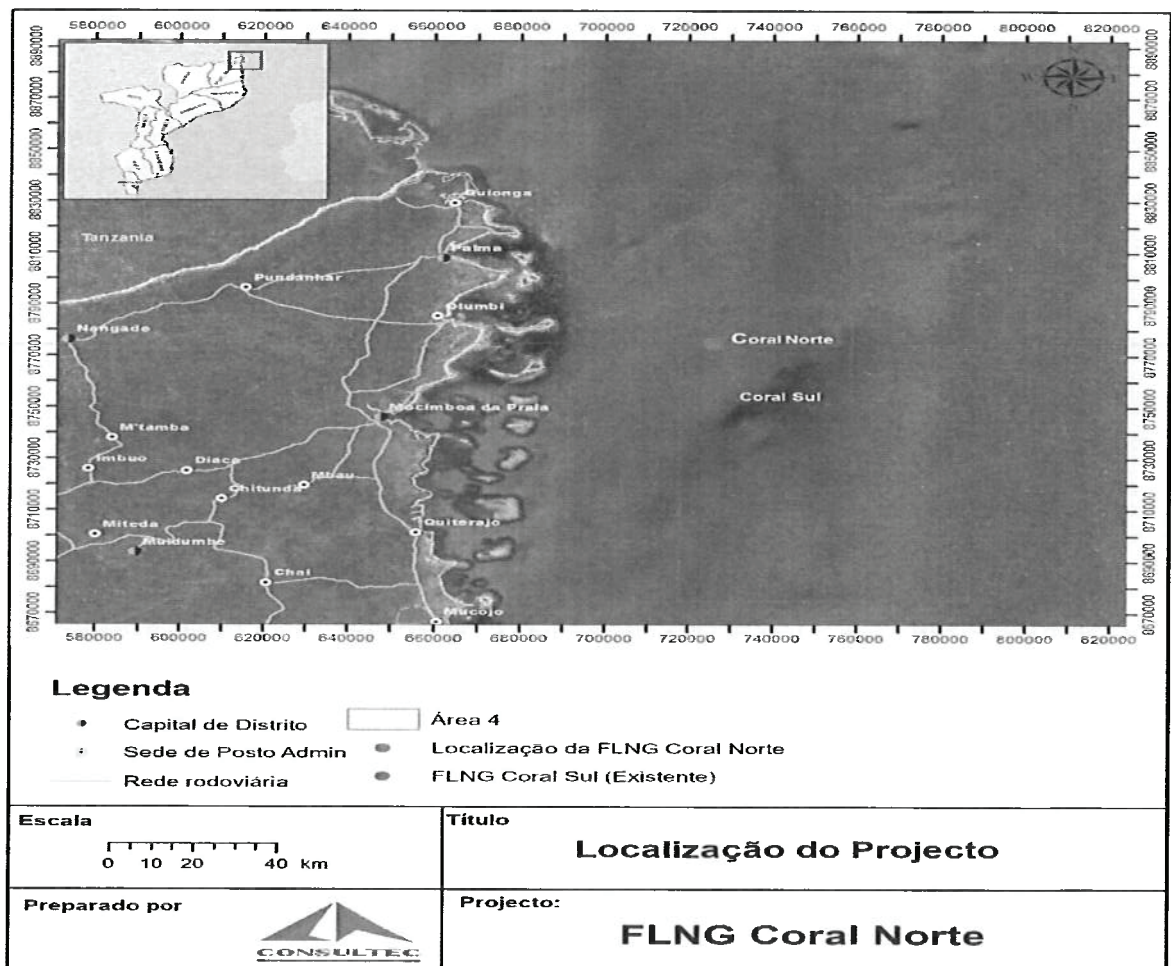
- O Ministro dos Recursos Minerais e Energia
- A Ministra do Mar, Águas Interiores e Pescas
- O Ministro dos Transportes e Comunicações
- O Ministro da Saúde
- O Secretário de Estado da Província de Cabo Delgado

C.C: O Magnífico Reitor da Universidade Eduardo Mondlane

# Relatório de Revisão do Estudo de Pré-Viabilidade Ambiental e Definição do Âmbito e Termos de Referência do Projecto de Infra-estrutura Petrolífera Coral Norte

## 1. Introdução

A Mozambique Rovuma Venture (MRV) é o Operador (com uma participação de 70%) da Área 4 (Figura 1.1), localizada nas águas profundas da Bacia do Rovuma ao Largo da Costa Norte de Moçambique, próximo da fronteira com a Tanzânia. A Empresa Nacional de Hidrocarbonetos, E.P. (10%), a Galp Energia (10%) e a KOGAS Mozambique Ltd. (10%) são parceiros do consórcio da Área 4. A Eni, através da sua subsidiária Eni Rovuma Basin (ERB), é o Operador Delegado do Projecto Coral Norte. A FLNG Coral Norte proposta está localizada na Área 4, dentro das águas profundas da Bacia de Rovuma, na porção norte do reservatório Coral, aproximadamente 10 km ao norte da FLNG Coral Sul e a mais de 50 km do litoral do Distrito de Palma, Província de Cabo Delgado, como ilustra a imagem abaixo.



Fonte: EPDA do Projecto

A profundidade da água no local proposto da FLNG é de aproximadamente 2 000 m.

### 1.1. Descrição do Projecto

A implementação do projecto incluirá as seguintes fases sequenciais:

- **Fase de perfuração e completação:** Será utilizado um navio de perfuração para perfurar e completar os seis (6) poços de produção submarina;
- **Fase de instalação:** Será instalado o sistema de produção submarina (SPS) (incluindo preparação do leito marinho e instalação de elementos submarinos, correntes de amarração e âncoras) e a FLNG será rebocada para o local e ligada ao SPS. A embarcação FLNG será construída no estrangeiro, uma vez que nenhum estaleiro nacional tem capacidade para o fazer;
- **Fase de comissionamento e arranque:** A FLNG e todos os seus equipamentos serão testados, para confirmar que está pronta para iniciar as operações. Tal inclui hidrotestes e drenagem das linhas de fluxo submarinas e tubagens da instalação GNL;
- **Operação e manutenção:** O gás natural será extraído dos poços, tratado, condensado e exportado. Isto inclui operações de poços, linhas de fluxo dentro do campo e colunas de ascensão flexíveis, e operação da FLNG, incluindo exportação do GNL e actividades de manutenção;
- **Fase de desactivação:** O SPS será desactivado (descarga de linhas de fluxo submarinas, fecho/tamponamento de poços) e a FLNG será desligada do SPS e rebocada.

## 1.2. Principais Componentes e Actividades do Projecto

O Projecto FLNG Coral Norte inclui componentes e actividades em alto mar e em terra. Os componentes em alto mar incluem:

- Poços de produção - Seis (6) poços submarinos para extracção de gás natural do reservatório Coral;
- Sistema submarino de produção com umbilicais, colunas de ascensão e linhas de fluxo (SURF) - infra-estrutura submarina para fornecer gás à instalação FLNG;
- Embarcação FLNG ancorada no mar, a mais de 50 km da costa. A FLNG é uma embarcação flutuante *offshore* de tratamento, liquefação, armazenamento e descarga de gás com uma capacidade de produção de 3,5 MPTA (milhões de toneladas por ano).

As actividades *offshore* estão relacionadas com a produção e exportação de GNL, e actividades de apoio, incluindo:

- Produção de GNL - recepção de gás natural a partir dos poços, através do sistema SURF; processamento, liquefação e armazenamento temporário de gás natural a bordo da FLNG;
- Exportação de GNL e condensado - descarga do GNL e condensado para embarcações de transporte para exportação;
- Actividades de apoio e logística - operação de embarcações de abastecimento provenientes da base logística em terra, operação de embarcações de reboque

e embarcações multi-funções perto da FLNG e atracação e movimentação de material de/para a FLNG/embarcações de abastecimento.

Todos estes componentes e actividades *offshore* estão localizados na Área 4, a mais de 50 km da costa de Cabo Delgado. Os componentes em terra do projecto estão relacionados com o pessoal em terra e com operações logísticas de apoio à FLNG *offshore* e serão realizados a partir dos seguintes centros principais:

- ✓ Instalações no Porto de Pemba, nomeadamente posto de atracagem para navios de abastecimento;
- ✓ Instalações do Aeroporto de Pemba, nomeadamente a operação de serviços de helicópteros existentes;
- ✓ Estaleiro de logística em Pemba;
- ✓ Escritórios em Pemba;
- ✓ Escritórios em Maputo.

As actividades em terra incluirão:

- ✓ Actividades administrativas, tanto nos escritórios de Pemba como de Maputo;
- ✓ Operação da base de logística em Pemba, que incluirá a recepção e armazenamento temporário de materiais e mercadorias a serem transportados para a FLNG;
- ✓ Operação de uma área de atracagem no Porto de Pemba, incluindo atracagem e abastecimento de navios de abastecimento, rebocadores, embarcações de segurança e polivalentes, e carregamento de navios de abastecimento com mercadorias e materiais a transportar para a FLNG;
- ✓ Operação de serviços dedicados de helicóptero nas instalações existentes do Aeroporto de Pemba. A maioria, senão todas, as actividades *onshore* serão realizadas dentro da área de implementação física das instalações existentes (escritórios de Maputo e Pemba, e Porto e Aeroporto de Pemba).

## 2. Formação da equipe de revisão do EPDA

Para a revisão do projecto constituiu-se a respectiva Comissão Técnica de Avaliação composta pelas seguintes instituições: (i) Ministério da Terra e Ambiente (Direcção Nacional do Ambiente, Administração Nacional das Áreas de Conservação e Serviço Provincial do Ambiente de Cabo-Delgado); (ii) Ministério da Saúde (Direcção Nacional de Saúde Pública); (iii) Ministério dos Recursos Minerais e Energia (Instituto Nacional de Petróleo); (iv) Ministério do Mar, Águas Interiores e Pescas (Instituto Nacional do Mar, IP, Instituto Oceanográfico de Moçambique e Instituto de Desenvolvimento de Pesca e Aquacultura, IP); (v) Ministério dos Transportes e Comunicações (Instituto de Transporte Marítimo, IP) e (vi) Universidade Eduardo Mondlane (Faculdade de Ciências).

### 3. Contexto de realização do EPDA

O presente estudo foi realizado na fase de planeamento da actividade.

### 4. Participação Pública

Foram realizadas duas reuniões de consulta pública na fase do EPDA, nomeadamente uma reunião em Pemba e outra em Maputo segundo a tabela abaixo:

Local	Sala	Data	N° de Participantes
Maputo	Hotel Radisson	30.06.23	64
Pemba	Avani Pemba Beach Hotel	04.07.23	34

### 5. Equipa de consultores responsável pelo EPDA

OEPDA foi elaborado por uma equipe de consultores da Consultec, Lda, registada pelo MTA nos termos do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto n° 54/2015, de 31 de Dezembro e encontra-se registada na Cidade de Maputo, com sede na Rua Tenente General Oswaldo Tazama, n.° 169, Maputo, contactável pelo Tel: +258 21 491 555. A equipe responsável pelo EPDA e TdR tem a seguinte composição:

Nome	Função	Qualificações
Tiago Dray	Director do Projecto	Licenciatura em Biologia. Director da Consultec e Gestor do Departamento do Ambiente
Emanuel Viçoso	Coordenador de Projecto	Licenciatura em Biologia. Mestrado em Avaliação de Impacto Ambiental e Gestão Ambiental.
Miguel Barra	Clima, Qualidade do Ar e Ruído	Licenciatura em Engenharia do Ambiente.
Marta Henriques	Ecologia Costeira e Marinha	Licenciatura em Biologia. Pós-graduação em Política de Gestão Ambiental.
Rafael Noronha	Socioeconomia e Pescas	Mestrado em Política e Gestão Social.
Yussuf Adade	GIS e Mapeamento	Técnico de GIS.

### 6. Comunicação dos Resultados

O EPDA e TdR cumprem com o preceituado no artigo 10 do Regulamento sobre o Processo de Avaliação de Impacto Ambiental, aprovado pelo Decreto n.º 54/2015 de 31 de Dezembro.

### 7. Comentários/Constatações

- i. O documento não apresenta Título de uso Privativo do Mar;
- ii. Na página 2, no 4º paragrafo, refere-se que "...a Eni está empenhada em adoptar padrões acima dos requisitos legais, para a integração da conservação da

biodiversidade e a retenção dos serviços de ecossistema produtivos em todas as áreas de operações e em todas as fases do ciclo de vida de um projecto...”. Para efeitos de monitoramento ambiental devem ser descritos no REIA os padrões acima dos requisitos legais que serão adoptados pelo proponente;

iii.O EPDA não apresenta o valor de investimento do projecto;

iv.Na página 11, referente ao quadro legislativo, não indica as datas das respectivas publicações, devendo-se fazer menção;

v.Ainda no capítulo sobre enquadramento legal o documento não apresenta os seguintes instrumentos legais:

- ✓ Lei nº 3/2022, de 10 de Fevereiro, Lei que Estabelece os Mecanismos de Protecção e Promoção da Saúde, de Prevenção e de Controlo das Doenças, bem como das Ameaças e dos Riscos para a Saúde Pública;
- ✓ Lei nº 10/2020, de 24 de Agosto, que aprova o Regime Jurídico de Gestão e Redução do Risco de Desastres;
- ✓ Lei nº 24/2009, de 28 de Setembro, que aprova a Lei do Exercício da Medicina Privada;
- ✓ Decreto nº 53/2008, de 30 de Dezembro, que aprova o Regulamento de Construção e Manutenção de Dispositivos Técnicos de Acessibilidade, Circulação e Utilização dos Sistemas dos Serviços Públicos a Pessoa Portadora de Deficiência ou de Mobilidade Condicionada.

vi.Na página 19, sobre as Convenções Internacionais, descreve-se que "Moçambique ratificou a ConvençãoMarpol através da Resolução nº 5/2003, de 18 de Fevereiro,tendo ractificado os anexos com a excepção do Anexo VI", no entanto importa salientar que os Anexos IV e V ainda não foram igualmente rectificadoss, devendo fazer a correcção desta descrição;

vii.Na página 20, ainda na tabela sobre as Convenções Internacionais, é descrita a Convenção Internacional para Segurança da Vida no Mar (SOLAS 74), importa referir que a designação correcta é Convenção Internacional para Salvaguarda da Vida Humana no Mar, devendo fazer a devida correcção;

viii.Na página 40, ponto 4.2.4, Fases do Projecto, faz-se menção que a embarcação FLNG será construída no estrangeiro, uma vez que nenhum estaleiro nacional tem capacidade para o fazer. Adicionalmente, não faz menção em que país será construída, ou prováveis países”;

ix.Nas páginas 56, 57, 58 e 59, faz-se menção sobres as descargas das águas residuais para o Mar, no entanto esta não é uma prática normal, pois para que

ocorra uma descarga para o Mar, deve ser com excepções e quando sejam satisfeitas as condições adequadas;

- x. Ainda na mesma pagina, refere que "...a água do mar será devolvida ao mar a uma temperatura média de 30,6°C, em cumprimento dos requisitos nacionais e do IFC para águas térmicas. A descarga da água de refrigeração será feita a uma profundidade estimada de 0,5 a 7,5 metros abaixo do nível médio do mar. A descarga será feita de forma contínua e a uma velocidade de 5 m/s e poderá conter possíveis contaminantes;
- xi. De acordo com o EPDA, na fase operacional o projecto irá operar durante 25 anos e considerando que este Projecto é semelhante ao Coral Sul e estando próximos, há necessidade de realização de estudos detalhados dos impactos cumulativos que poderão advir destes Projectos;
- xii. Na página 62, Mão-de-Obra, o documento refere que "provavelmente 1.400 trabalhadores nacionais sejam empregados directa ou indirectamente, incluindo através de serviços contratados..." ao longo da duração do Projecto. A necessidade será de pessoal altamente especializado (engenheiros, técnicos), bem como pessoal para actividades de apoio. Contudo não apresenta a distribuição por origem e género;
- xiii. Na página 66 do EPDA, tabela 5.1. Áreas de Influência Directa para componentes ambientais relevantes, refere-se à direcção dos ventos predominantes de Norte-Sul e que não afectará o continente (Oeste), Este posicionamento contradiz o efeito dos ventos resultantes dos eventos extremos que são de Este para Oeste (mar para terra);
- xiv. Na página 66/67 sobre Iluminação, refere-se que os impactos para os receptores da biodiversidade na área de influência, é inferior a 500 m, contudo, não indica as espécies sensíveis que ocorrem naquela área;
- xv. Ainda na página 67, na componente do Ruido Subaquáticos, faz menção a emissão de ruídos num raio de 10 km, sem indicação da intensidade;
- xvi. Na página 80, ponto 6.2. Meio Biótico, faz referência que "*A costa de Cabo Delgado e do Norte de Moçambique alberga extensos habitats, incluindo florestas de mangais, costas rochosas e arenosas, estuários e deltas, recifes de coral, pradarias de ervas marinhas e uma zona pelágica dinâmica*" que é de elevado valor de biodiversidade podendo as linhas de escoamento causar a decapagem e variações no meio biótico;
- xvii. O documento refere que há espécies que serão afectadas num raio de 4 km da área, como impacto directo sobre os habitats bentónicos e fauna associada na fase de perfuração;

xviii.O EPDA, não apresenta a descrição dos sistemas de tratamento e gestão das descargas de todos os efluentes;

xix.Na página. 100, na tabela sobre a identificação dos impactos, faz referência a libertação de água de lastro recolhida noutra lugar para as águas locais;

xx.Na página 107, onde é apresentada a análise sobre os potenciais impactos do projecto, referente as descargas marinhas, o documento faz referências que as descargas dos efluentes líquidos da operação da FLNG podem impactar a qualidade das águas marinhas receptoras, com impactos subsequentes no ecossistema marinho. O documento refere ainda que será realizado um estudo especializado para investigar estas descargas e os seus potenciais impactos no ambiente marinho. Atendendo que o presente projecto é similar ao Coral Sul, onde foram constatados elevados níveis do fenol e nitratos que representam uma grande preocupação nas descargas da FLNG, estes não são especificamente referidos no EPDA em análise;

xxi. Ainda na página 107, o documento refere que devido à localização *offshore* da área do projecto, não se espera que o Projecto Coral Norte tenha interacções significativas com o ambiente socioeconómico. Refere ainda que a única actividade presente no ambiente *offshore* é a pesca comercial em águas profundas. Esta afirmação deverá ser confirmada com base num estudo, pois sabe-se que para além da pesca comercial e artesanal, há ocorrência da actividade de transporte marítimo e turismo. Importa referir que o sector pesqueiro está neste momento a implementar o projecto de promoção da pesca em mar aberto como medida para reduzir o esforço de pesca nas zonas pouco profundas;

xxii.Para além dos estudos especializados a serem conduzidos na fase do EIA listados na página 142, não constam os estudos relacionados com:

- ✓ Aterros para o tratamento das lamas nos locais de depósito e meio envolvente;
- ✓ Operações do projecto na pesca e outras actividades socioeconómicas;
- ✓ Corredores de mamíferos marinhos;
- ✓ Influência das operações na distribuição de mamíferos marinhos e rotas de espécies migratórias;
- ✓ Qualidade de água;
- ✓ Perda líquida de biodiversidade marinha (para efeitos de compensação nos termos da Lei) e medidas no plano de contrabalanços de biodiversidade.

- xxiii.Os TdR não apresentam os Programas/Planos que farão parte do Plano de Gestão Ambiental (PGA);
- xxiv.Na página 128 sobre modelação de descarga de hidroteste e descargas de água produzidas, há necessidade de apresentar resultados da modelação efectuada. A descarga de hidroteste deve ser precedida pela realização de uma análise de risco ambiental e redução do uso de químicos. Assim, considera-se que há necessidade de descrever informação relativa à aplicação dessas medidas, ou seja, o relatório de análise de risco e a optimização ou redução das quantidades dos químicos a serem usados devem cumprir com as boas práticas internacionais aplicáveis na indústria;
- xxv.O documento em análise faz menção que o Plano de Gestão de Resíduos Radioactivos (caso existam) será incluído no PGA, no entanto deve-se clarificar detalhadamente as formas de gestão;
- xxvi.O documento em análise não apresenta especificidades da ETAR (dimensionamento, capacidade, tamanho, e outras componentes);
- xxvii.Na página 13 do Relatório do Processo de Consulta Pública, é apresentada como resposta da questão número 22 “... Todas as lamas e aparas das secções inferiores serão recolhidas até ao navio de perfuração e transferidas para terra para tratamento e eliminação”. Contudo, não indica o local de tratamento.

## 8. Conclusões e Recomendações

Não obstante as constatações e comentários acima apresentados, que não inviabilizam a aprovação do EPDA e TdR, assim como, o prosseguimento dos passos subsequentes do licenciamento ambiental, a Comissão Técnica de Avaliação conclui que o mesmo reúne requisitos suficientes para sua aprovação. Contudo, para o Estudo de Impacto Ambiental, recomenda-se:

- a) A observância do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro, do Regulamento Ambiental para as Operações Petrolíferas, aprovado pelo Decreto nº 56/2010, de 22 de Novembro e das Directivas Gerais para a Elaboração de Estudos de Impacto Ambiental e para o Processo de Participação Pública no processo de Avaliação do Impacto Ambiental, aprovadas pelos Diplomas Ministeriais nºs 129/2006 e 130/2006, ambos de 19 de Julho;
- b) A apresentação do Título de uso Privativo do Mar de acordo com Decreto nº 21/2017, de 24 de Maio, que estabelece o Regime Jurídico de Utilização do Espaço Marítimo (RJUEM), conjugado com o Diploma Ministerial nº 99/2023, de 24 de Julho, para aquisição do Título de Utilização de Espaço Marítimo e Costeiro;
- c) A apresentação do valor de investimento do Projecto;

d) A inclusão no quadro legal, dos seguintes instrumentos legais:

- Lei nº 3/2022, de 10 de Fevereiro, Lei que Estabelece os Mecanismos de Protecção e Promoção da Saúde, de Prevenção e de Controlo das Doenças, bem como das Ameaças e dos Riscos para a Saúde Pública;
- Lei nº 10/2020, de 24 de Agosto, que aprova o Regime Jurídico de Gestão e Redução do Risco de Desastres;
- Lei nº 24/2009, de 28 de Setembro, que aprova a Lei do Exercício da Medicina Privada;
- Decreto nº 53/2008, de 30 de Dezembro, que aprova o Regulamento de Construção e Manutenção de Dispositivos Técnicos de Acessibilidade, Circulação e Utilização dos Sistemas dos Serviços Públicos a Pessoa Portadora de Deficiência ou de Mobilidade Condicionada.

- e) A indicação do local de tratamento e deposição final das lamas e aparas que serão produzidas e transferidas para a terra;
- f) A apresentação da intensidade do ruído subaquático no raio de 10 km desenvolvido para FLNG durante a sua fase operacional;
- g) A realização de um estudo mais abrangente sobre o impacto do ruído nas espécies marinhas nas diferentes fases do projecto, assim como, a apresentação de uma tabela de dispersão/redução das ondas sonoras;
- h) A descrição pormenorizada dos sistemas de tratamento e gestão das descargas de efluentes incluindo do fenol, do nitrato, das águas domésticas e da salmoura resultante da dessalinização da água do mar da FLNG;
- i) Para além do cumprimento das directrizes da OMI, a elaboração do Plano de Gestão das Água de Lastro;
- j) A inclusão no Plano de Gestão de Resíduos Radioactivos, de esclarecimentos sobre como os resíduos radioactivos serão manuseados, armazenados e eliminados;
- k) A caracterização pormenorizada dos efluentes, incluindo os níveis de Fenol e Nitratos, de forma a avaliar os riscos de poluição das águas receptoras assim como permitir escalonar a planta de tratamento de efluentes com vista ao cumprimento dos padrões de emissão estabelecidos pela legislação nacional/internacionais;
- l) A observância do Decreto 45/2006 de 30 de Novembro que aprova o Regulamento para a Prevenção da Poluição e Protecção do Ambiente Marinho e Costeiro, sobre as descargas das águas residuais, Decreto nº 18/2004 de 02 de Junho e nº 67/2010 de 31 de Dezembro, que aprova o Regulamento sobre Padrões de Qualidade Ambiental e de Emissão de Efluentes;

- m) A Avaliação dos impactos da água de arrefecimento tendo em conta a temperatura, profundidade, volume descarregado e velocidade, sobre o ecossistema marinho;
- n) A apresentação dos impactos relacionados com o efeito da iluminação em espécies sensíveis e vulneráveis durante todas as fases do Projecto, com as respectivas medidas de mitigação/minimização;
- o) A apresentação de todos os impactos previstos directa ou indirectamente na cadeia de valores da pesca, devendo ser analisadas e propostas as respectivas medidas de mitigação de modo a garantir a continuidade das actividades da pesca;
- p) A elaboração do Mapa de sensibilidade ambiental com vista a protecção das áreas sensíveis ou de alto valor ecológico nas proximidades da instalação dos poços;
- q) A inclusão no Plano de Gestão Ambiental dos seguintes Planos/Programas:
- Plano de contingência individual para o combate a poluição por óleos e substâncias nocivas ou perigosas;
  - Programa de Higiene, Saúde e Segurança no Trabalho;
  - Programa de Educação Ambiental;
  - Programa de Gestão de Sedimentos;
  - Programa de Gestão do Meio Biótico/Ecológico;
  - Programa de Gestão de Produtos Químicos;
  - Programa de Recrutamento e Capacitação;
- r) A apresentação do Mecanismo de Diálogo e Reclamação;
- s) A indicação das substâncias químicas (aditivos químicos) para incorporação na água de hidrotestes do equipamento submarino, nas diferentes fases do projecto tendo em conta a concentração, toxicidade, biodegradabilidade e potencial de acumulação dos mesmos. Adicionalmente deve ser fornecida informação relativa a instalação de tratamento de águas residuais da água de hidrotestes;
- t) A apresentação do impacto relacionado com a destruição dos habitats bentónicos devido a decapagem provocada por movimentos das linhas de escoamento e inclusão de medidas concretas de mitigação do mesmo;

- u) A investigação do espectro de luz adequado para reduzir a atração por aves marinhas e propor os principais locais para colocação deste tipo de iluminação dos navios do projecto de forma a reduzir este impacto;
- v) A apresentação de um cronograma específico e detalhado atinente a todas as fases do projecto por forma a melhorar as medidas de gestão propostas;
- w) A inclusão da informação sobre a periodicidade da realização das auditorias internas durante as fases de perfuração e completação e a comunicação das não conformidades ao MTA, INAMAR, ITRANSMAR, AQUA e INP;
- x) A apresentação de acções que serão implementadas para assegurar que os detritos de perfuração (LTOBM) após o tratamento atendem aos critérios de redução de risco em relação a sua periculosidade nas diferentes etapas do seu tratamento;
- y) A apresentação de um fluxograma do processo produtivo que permita relacionar cada resíduo ao seu processo de geração;
- z) A apresentação da planta da fábrica detalhada, com a localização das fontes geradoras de resíduos e os tipos de resíduos gerados nas respectivas fontes;
- aa) A apresentação das coordenadas geográficas das áreas de perfuração, características dos equipamentos e tipo de sinalização usada;
- bb) Que se encontrem outras alternativas tecnológicas no uso das plataformas implantadas, para fazer face a possíveis descobertas de reservatórios futuros, para reduzir os impactos ambientais e sociais cumulativos com outras actividades na área do projecto;
- cc) A identificação do país onde será construída a embarcação da FLNG;
- dd) A indicação da quantidade da mão-de-obra destacando o número de mulheres e homens que o projecto irá contractar, sua origem, período de início de mobilização e necessidades de formação;
- ee) O licenciamento da plataforma e de todo equipamento e material marítimo, que deverá ser anexa a mesma, de acordo com a alínea viii) do nº2 do artigo 6 do Decreto 87/2021 de 28 de Outubro, que cria o Instituto Nacional do Mar, Instituto Público;
- ff) A apresentação de propostas de medidas que possam reduzir os riscos associados a eventos extremos, os quais podem impactar as infraestruturas do projecto e resultar em danos sobre as infraestruturas ou vidas humanas;
- gg) A identificação da vulnerabilidade da área de inserção do projecto aos efeitos as mudanças climáticas.

A Equipa Técnica de Revisão

N.	Nome do Técnico	Instituição	Especialidade	Assinatura
1	Josefa Jussar	MTA/DINAB	Eng <sup>a</sup> . Química	Josefa Jussar
2	Nilsa Racune	DINAB/DAA	Bióloga	Nilsa Racune
3	Eunice Rafael Cuna	INTRANSMAR, IP	Enga. Ambiental	Eunice Rafael
4	Atália Muvelo	MTA/DINAB	Tec. Sup. Ad. Pública	Atália Muvelo
5	Leonardo Guirruta	MTA/DGR	Químico	Leonardo Guirruta
6	Anselma Munguambe	MIMAIP/INAMAR, IP	Educadora Ambiental	Anselma Munguambe
7	Maria Perpétua Scarlet	UEM/Fac. De Ciências	Bióloga Marinha	Maria Perpétua Scarlet
8	Paulo Albano	DINAB/DAA	Meteorologista	Paulo Albano
9	Leonor Machiana	MIMAIP/IDEPA, IP	Gestora Ambiental e Des. Comunitário	Leonor Machiana
10	Niyitegeka Maurice	MISAU/DNSP	Téc. Saúde Ambiental	NIYITEGEKA MAURICE
11	Armando Araman	MTA/ANAC	Ecologia e Conservação da Natureza	Araman
12	Sidónia Muhorro	MTA/DGA	Bióloga/Química	Sidónia Muhorro
13	Emídio Raul	InOM	Biólogo	Emídio Raul
14	Lígia Filomena Chamo	DINAB/RAACB	Tec. Sup. Ad. Pública	Lígia Filomena Chamo

Maputo, Agosto de 2023



REPÚBLICA DE MOÇAMBIQUE

MINISTÉRIO DA TERRA E AMBIENTE  
GABINETE DO MINISTRO

À:

Mozambique Rovuma Venture S.p.A.  
(MRV)

Exma Senhora Marica Calabrese

Maputo

N/Refª N ° 399 /MTA/ 183 /GM/220/24

Maputo: 20/11/2024

**Assunto: Relatório do Estudo do Impacto Ambiental e Social (REIA) do Projecto de Infraestrutura Petrolífera Coral Norte**

Exma Senhora,

O Ministério da Terra e Ambiente recebeu o documento de V.Excia referente ao Projecto em epígrafe, tendo merecido a devida análise técnica.

Após a revisão feita nos termos do Artigo 17, do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro, o MTA comunica à V.Excia que o presente documento está aprovado mas, recomenda o cumprimento integral das medidas de mitigação constantes no REIA e nos Planos de Gestão e Monitorização Ambiental da actividade, bem como, das questões apresentadas no relatório de revisão em anexo e de toda a legislação vigente no País, pertinente à actividade.

Para o efeito, o proponente deverá proceder o pagamento da taxa de licenciamento ambiental de 0.01% de 7.000.000.000,00USD (sete mil milhões de dólares americanos), em conformidade com o n.º 1, do Artigo 22, do Regulamento Ambiental para as Operações Petrolíferas, aprovado pelo Decreto nº 56/2010 de 22 de Novembro.

Os valores da taxa acima referida deverão ser pagos via Transferência Bancaria para a Conta da RECEBEDORIA DE FAZENDA DO 1º BAIRRO FISCAL DE MAPUTO, de acordo com as referências abaixo:

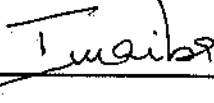
Conta: 00544.510.014  
NIB: 0000022100544.510.014.91  
IBAN: MZ 59 000002210054451001491  
SWIFT CODE: BMOCMZMA

Nos termos da alínea a), do nº 1, do Artigo 21, do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro, o pagamento deverá ser efectuado até 90 dias contados a partir da data da recepção da presente nota.

Efectuado o pagamento, o proponente deverá submeter à DINAB o respectivo comprovativo para a emissão da Licença Ambiental. Referir ainda que, a nota de submissão do comprovativo deverá indicar o nome do Proponente, NUIT do Proponente, telefone e e-mail da empresa.

Com os melhores cumprimentos.

A Ministra



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Ivete Joaquim Maibaze

*C.C. Suas Excelências*

*O Ministro dos Recursos Minerais e Energia*

*O Ministro dos Transportes e Comunicações*

*A Ministra do Mar, Águas Interiores e Pescas*

*O Ministro da Saúde*

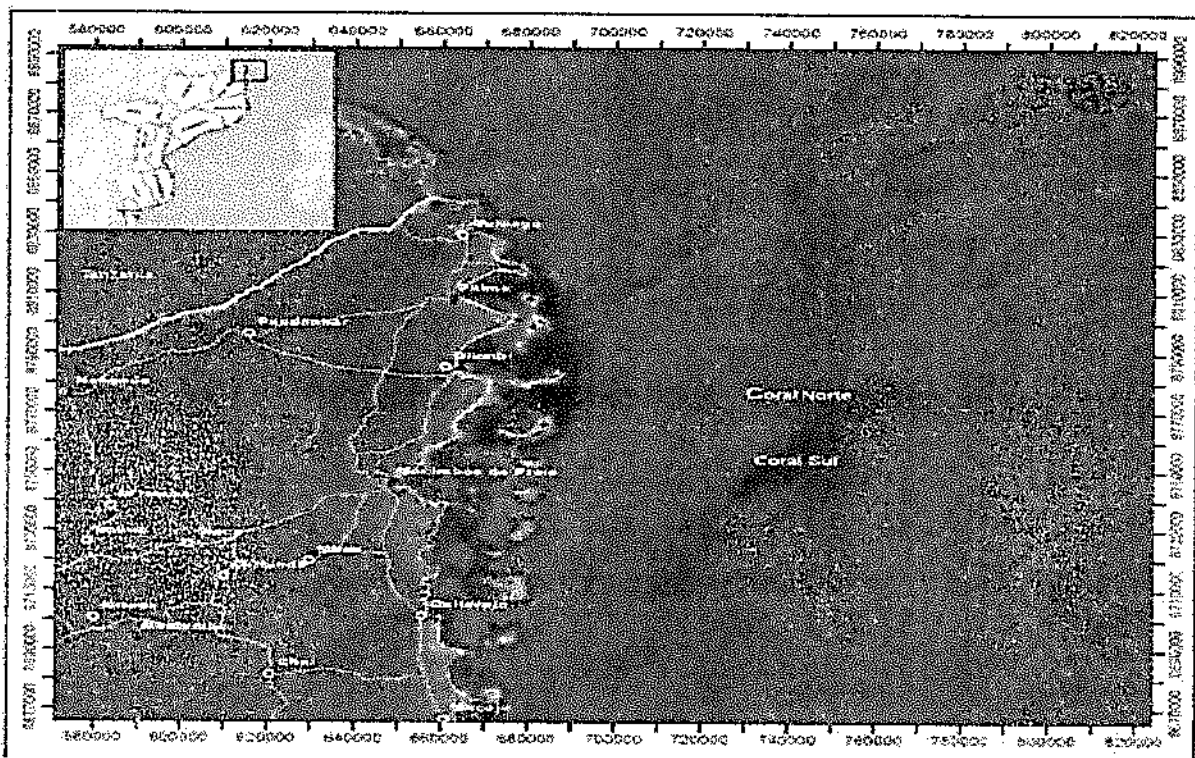
*O Magnífico Reitor da Universidade Eduardo Mondlane*

*O Secretário de Estado da Província de Cabo Delgado*

# Relatório de Revisão do Relatório de Estudo de Impacto Ambiental (REIA) do Projecto de Infraestrutura Petrolífera Coral Norte

## 1. Introdução

O Projecto FLNG da Coral Norte submetido à Direcção Nacional do ambiente (DINAB) para apreciação e tomada de decisão sobre a viabilidade ambiental, localizar-se-á na Área 4, nas águas profundas da Bacia de Rovuma, na porção norte do Reservatório Coral, aproximadamente 10 km ao norte da FLNG Coral Sul, a cerca de 250 km a Nordeste de Pemba e a 50 km da costa do Distrito de Palma, Província de Cabo Delgado, como ilustra a imagem abaixo.



Fonte: REIA do Projecto

O proponente do Projecto é a Mozambique Rovuma Venture (MRV), Operador da Área 4 no âmbito do Contracto de Concessão de Pesquisa e Produção (EPCC). A MRV detém uma participação de 70% no consórcio da Área 4, compartilhado pela Empresa Nacional de Hidrocarbonetos, E.P., a Galp Energia e a KOGAS Mozambique Lda., com 10% de participação cada.

Estima-se que serão investidos cerca de 7.000.000.000,00USD (sete mil milhões de dólares americanos) para o desenvolvimento da FLNG Coral Norte.

### Contextualização

O Relatório do Estudo de Impacto Ambiental do Projecto FLNG Coral Norte, enquadra-se na implementação da estratégia de desenvolvimento do reservatório Coral que resultou da descoberta de recursos significativos de gás natural recuperáveis na Concessão da Área 4, da qual está em execução na parte sul, o Projecto FLNG Coral Sul. No âmbito desta estratégia serão necessários mais projectos, para desenvolver

plenamente e maximizar a recuperação e rentabilização dos recursos de gás do reservatório Coral.

O Projecto FLNG Coral Norte terá os seguintes componentes:

1. Uma embarcação flutuante de tratamento, liquefação, armazenamento e descarga de gás offshore igual à FLNG de Coral Sul;
2. Poços submarinos, sistemas de produção e controlo submarinos e colunas de ascensão para a FLNG.

O Projecto FLNG Coral Norte será desenvolvido de forma independente do projecto Coral Sul.

### 1.1. Principais Componentes e Actividades do Projecto

O Projecto FLNG Coral Norte inclui componentes e actividades em alto mar e em terra.

Os componentes em alto mar incluem:

- **Poços de produção**- seis (6) poços submarinos para extracção de gás natural do Reservatório Coral;
- **Sistema submarino de produção com umbilicais**, colunas de ascensão (*risers*) e linhas de fluxo (SURF) - infraestrutura submarina para fornecer gás à instalação FLNG;
- **Navio FLNG** ancorado no mar, a mais de 50 km da costa, com capacidade de produção de 3,55 MPTA (milhões de toneladas por ano).

As actividades em alto mar estão relacionadas com a produção e exportação de GNL, e actividades de apoio, incluindo:

- **Produção de GNL** - Recepção de gás natural a partir de poços através do sistema SURF; processamento, liquefação e armazenamento temporário de gás natural a bordo da FLNG;
- **Exportação de GNL e condensado** - descarga do GNL e condensado para embarcações de transporte, para exportação;
- **Actividades de apoio e logística** - Operação de embarcações de abastecimento provenientes da base logística em terra, operação de rebocadores e embarcações multifunções perto da FLNG e atracação e movimentação de material de e para a FLNG e/ou embarcações de abastecimento.

Os componentes do Projecto em terra estão relacionados com o pessoal em terra e as operações logísticas de apoio à FLNG, e serão realizados a partir dos seguintes centros principais:

- Instalações no Porto de Pemba - Posto de atracagem para navios de abastecimento;
- Instalações do Aeroporto de Pemba - Operação de serviços de helicópteros existentes;
- Estaleiro de logística em Pemba;

- Escritórios em Pemba;
- Escritórios em Maputo.

As actividades em terra incluirão:

- Actividades administrativas, tanto nos escritórios de Pemba como de Maputo;
- Operação da base de logística em Pemba, que incluirá a recepção e armazenamento temporário de materiais e mercadorias a serem transportados para a FLNG;
- Operação de um posto de atracagem no Porto de Pemba, incluindo atracagem e abastecimento de navios de abastecimento, rebocadores, embarcações de segurança, multifunções, carregamento de navios de abastecimento com mercadorias e materiais a transportar para a FLNG;
- Operação de serviços dedicados de helicóptero nas instalações existentes do Aeroporto de Pemba.

## 2. Formação da equipe de revisão do REIA

Para a revisão do REIA constituiu-se a Comissão Técnica de Avaliação composta pelas seguintes instituições: (i) Ministério da Terra e Ambiente (Direcção Nacional do Ambiente, Administração Nacional das Áreas de Conservação e Serviço Provincial do Ambiente de Cabo-Delgado); (ii) Ministério da Saúde (Direcção Nacional de Saúde Pública); (iii) Ministério dos Recursos Minerais e Energia (Instituto Nacional de Petróleo, IP); (iv) Ministério do Mar, Águas Interiores e Pescas (Instituto Nacional do Mar, IP, Instituto Oceanográfico de Moçambique e Instituto de Desenvolvimento da Pesca e Aquacultura, IP); (v) Ministério dos Transportes e Comunicações (Instituto de Transporte Marítimo, IP) e (vi) Universidade Eduardo Mondlane (Faculdade de Ciências - Departamento de Ciências Biológicas).

## 3. Contexto de realização do EIA

O EIA foi realizado na fase de planeamento da actividade, e foi sujeito a uma actualização de modo a incorporar a instalação da unidade de tratamento de águas produzidas.

## 4. Atendimento aos TdR

O EIA foi realizado em conformidade com os Termos de Referência anteriormente aprovados, e que serviram de guião para o efeito.

## 5. Participação Pública

Na fase do EIA foram realizadas duas sessões de reunião de consulta pública, uma na Cidade de Pemba e outra na Cidade de Maputo. Na Cidade de Pemba, foi realizada no dia 30 de Abril de 2024, no Avani Pemba Beach Hotel e contou com a participação de 59 pessoas, e na Cidade de Maputo, no dia 05 de Maio de 2024 no Hotel Radisson Blu, com a participação de 62 pessoas. A informação sobre a reunião de Consulta Pública consta no anexo V do REIA.

## 6. Equipa de consultores responsável pelo REIA

O REIA foi elaborado por uma equipa de consultores da Consultec, Lda, registada pelo MTA nos termos do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro e encontra-se registada na Cidade de Maputo, com sede na Rua Tenente General Oswaldo Tazama, nº 169, Maputo, contactável pelo Tel: +258 21 491 555. A equipa responsável pelo EIA tem a seguinte composição:

Nome	Função	Qualificações
Tiago Dray	Director do Projecto	Lic. em Biologia. Director da Consultec e Gestor do Departamento do Ambiente
Emanuel Viçoso	Coordenador de Projecto	Lic. em Biologia. Mestrado em Avaliação de Impacto Ambiental e Gestão Ambiental.
Nuno Silva	Gestor de projecto	Lic. em Engenharia do Ambiente.
Susana Rosa	Coordenação da equipa da biodiversidade (Biota)	Lic. em Biologia e Doutoramento em Ecologia, Monitorização de Biodiversidade, Planeamento Experimental e Análise Estatística e Planos de Acção de Biodiversidade.
Isabel Silva	Ecologia tropical (BIOTA) Doutoramento em ecologia marinha	Ecologia tropical (BIOTA) Doutoramento em ecologia marinha
Hélder Araújo	Fauna Marinha (Biota)	Lic. em Biologia, Mestrado em Ecologia, Biodiversidade e Ecosistemas e Doutoramento em Ecologia Marinha
Gelica Inteca	Fauna Marinha (Biota)	Lic. em Ciências Biológicas. Mestrado em Gestão de Recursos Naturais. É uma observadora de Fauna Marinha
Raquel Fernandes	Tartarugas marinhas (BIOTA)	Mestrado em biologia aquática e ecossistemas costeiros, com foco em tartarugas marinhas.
Daniel Pires	Triagem e Avaliação de Habitats Críticos (Biota)	Lic., mestrado e doutoramento em biologia. Triagem e Avaliação de Habitat Críticos sob o PD6 da IFC
Sónia Malveiro	Habitat e Flora (Biota)	Licenciatura em Botânica e especialista em flora e habitat.
Manuel Santiago	Clima e qualidade do ar (ADVISIAN)	Engenheiro químico
Tomas Ostolaza	Clima e qualidade do ar (ADVISIAN)	Estudos de Poluição Atmosférica (Modelação de Dispersão do Ar), Avaliações de Ruído, Modelação Marinha, Estudos Meteorológicos, Efeitos da Poluição do Ar nas Florestas e Verificação Prévia para vários sectores da indústria.

Alexander Stephen	Avaliação de GEEs (ADVISIAN)	Especialista em projectos, que abrangem estudos de elegibilidade do RCLE-UE, desenvolvimento de planos de Gestão de Carbono, situação de referência de emissões, previsão de carbono e outros trabalhos de quantificação relacionados com os GEE.
James Assem	Avaliação de Riscos Associados às Mudanças Climáticas (ADVISIAN)	Especialista fornecendo soluções para hidrocarbonetos, minerais e metais, Actualmente é gestor num projecto de adaptação às mudanças climáticas para um investidor de impacto.
Matthias Thomsen	Avaliação de Riscos Associados às Mudanças Climáticas (ADVISIAN)	Cientista Ambiental, Doutoramento em ecologia marinha. Perda de biodiversidade e implicações do ecossistema, microplásticos e mudanças climáticas a impactos ambientais e qualidade da água.
Miguel Barra	Ruído atmosférico	Lic. em Engenharia Ambiental, Pós-Graduação em Gestão e Políticas Ambientais e Pós-Graduação em Coordenação de Segurança na Construção Civil.
Peter Ward	Ruído subaquático (ADVISIAN)	experiência em estudos de propagação acústica subaquática, avaliação de impacto ambiental com referência ao impacto do ruído subaquático no ambiente.
Francois Smit	Descargas Marítimas e Modelação de Eventos não Planeados (ADVISIAN)	Engenheiro costeiro, projectos de hidrocarbonetos, petroquímica, centrais de energia e desenvolvimento portuário. modelagem de processos costeiros e mesoceânicos, gestão de zonas costeiras, monitorização costeira e projecto de estruturas costeiras e litorais.
Siviwe Mabija	Avaliação de descargas marinhas (ADVISIAN)	Engenheiro costeiro / Gestor de Projectos
Marcus Kretschmer	Avaliação de descargas marinhas (ADVISIAN)	Engenheiro civil com mestrado em engenharia portuária e costeira. Projectos de engenharia costeira, incluindo modelação costeira.
Annabel Krípe	Avaliação da iluminação (ADVISIAN)	Investigação ecológica quantitativas e de investigação em ciência aplicada fornecem uma base sólida para a interpretação da literatura científica e relatórios de modelação (ruído

		subaquático, derrame de petróleo, luz artificial) e aplicação das conclusões às avaliações de impactos de forma adequada para as partes interessadas e reguladores.
Francisco Peño	Avaliação da iluminação (ADVISIAN)	Sistema de Informação Geográfica (SIG)
Aurora Finiguerra	Avaliação paisagística e visual (ERM)	Especialista em avaliação paisagística e visual com experiência em SIG, CAD, modelos 3D e Fotomontagens relacionadas com Avaliação, Paisagística e Visual.
Rafael Noronha	Socioeconomia e saúde	Mestrado em Política Social e Gestão, Planos de Acção de Reassentamento, monitorização e avaliação de Programas de Desenvolvimento Social.
Horácio Cuna	Pesca	Lic. em Administração de Empresas, Analista Económico e Financeiro, Auditor Corporativo
Bram Naidoo	Direitos Humanos	Mestrado em Estudos de Desenvolvimento especializados em Direitos Humanos e de Género
Miguel Nazareth	SIG e mapeamento	Experiência em SIG e Teledeteção aplicada à Gestão Integrada de Recursos Naturais e Avaliação de Impacto Ambiental.

## 7. Comunicação dos Resultados

O EIA cumpre com o preceituado no artigo 11 do Regulamento sobre o Processo de Avaliação de Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro.

## 8. Plano de Gestão Ambiental

O Plano de Gestão Ambiental faz uma avaliação dos potenciais impactos e apresenta as medidas para a sua mitigação.

## 9. Constatações/Comentários

### 9.1. Constatações/Comentários Gerais

- a) Não foi submetido o Resumo Não Técnico, conforme estipulado na alínea a), do número 2, do Artigo 11 do Regulamento sobre o Processo de Avaliação de Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro e na alínea c), do número 1, do Artigo 13 do Regulamento Ambiental para as Operações Petrolíferas, aprovado pelo Decreto nº 56/2010, de 22 de Novembro;

- b) No geral, alguns mapas e figuras são apresentados em tamanho menor, o que dificulta a sua leitura. Deve-se apresentar os mapas e figuras em tamanho que permita melhor leitura e interpretação;

## 9.2. Constatações/Comentários Específicos

### Volume I - Introdução, Descrição do Projecto e Situação de Referência

- c) Na subsecção 2.4. Quadro Legislativo, faz-se menção a Lei de Trabalho, Lei nº 23/2007, de 1 de Agosto, no entanto, a mesma foi revogada pela Lei nº 13/2023, de 25 de Agosto;
- d) Ainda na subsecção sobre o Quadro Legislativo foi omissa a seguintes legislação:
- Decreto nº 5/80, de 22 de Outubro, que regula a obtenção e porte de boletins de Sanidade pelos Trabalhadores;
  - Decreto nº 40/2024, de 12 de Junho, que aprova o Regulamento para o Exercício da Actividade de Agenciamento de Navios, Carga e Serviços Complementares;
  - Decreto nº 71/2017, de 20 de Dezembro, que aprova o Regulamento do Código Internacional de Protecção de Navios e Instalações Portuárias;
  - Decreto nº 88/2021, de 28 de Outubro, que cria o Instituto Nacional do Mar, IP;
  - Convenções Internacionais, foi omissa a Resolução 36/2023, de 21 de Setembro, que ratifica a Convenção de Minamata sobre o Mercúrio, adoptada e assinada a 10 de Outubro de 2013 em Kumamoto, no Japão, uma vez que na unidade de FLNG haverá geração de resíduos de Mercúrio numa das suas operações;
  - Resolução nº 58/2023, de 29 de Dezembro, que adopta a Convenção Internacional para o Controlo e Gestão das Águas de Lastro e Sedimentos dos Navios, 2004.
- e) Na página 12, sobre "entidades marítimas" o documento descreve " *Instituto de Transporte Marítimo (ITRANSMAR, IP) recentemente criado pelo Decreto nº 83/2021, de 18 de Outubro, é a entidade responsável por garantir que todas as actividades de transporte marítimo sejam desenvolvidas em conformidade com as normas aplicáveis*", no entanto importa ressaltar que o ITRANSMAR no exercício das suas atribuições também tem o papel de realizar inspecção das embarcações e certificações marítimas;
- f) Na página 42, o documento apresenta coordenadas da área do Projecto no sistema UTM. Tendo em conta que os campos da licença ambiental usam o sistema de coordenadas geográficas, solicita-se a conversão das coordenadas UTM para o sistema geográfico;
- g) Na página 43, na subsecção 4.2.4. Fases do Projecto, está referenciado que na fase de desactivação a plataforma FLNG será desligada do SPS e rebocada,

contudo, o documento deveria indicar para onde seria rebocada e para que finalidade;

- a) Na mesma página, na subsecção 4.2.5.2. Alternativas tecnológicas, o documento faz referência ao uso do refrigerante duplo misto (DMR) sem o uso de Propano para limitar o armazenamento e instalações associadas de tratamento de gás evaporado que serão apenas para o (Metano e Butano). Solicita-se esclarecimento sobre o destino do Propano uma vez que também faz parte da composição do gás;
- b) Na página 44, na subsecção 4.2.5.2 Alternativas Tecnológicas, faz se referência aos Tanques de GNL, contudo, não há informação sobre o número de tanques e suas respectivas capacidades, o que seria um indicativo da capacidade instalada de armazenamento da produção de GNL;
- c) Na página 45, subsecção 4.3.1.3: Unidade FLNG, faz-se menção que o desenho da FLNG Coral Norte replicará o da FLNG Coral Sul e arrolam-se as instalações que compõem a unidade. No entanto, apesar do documento fazer menção na página 67, à existência de duas Unidades de Tratamento de Água Produzida, as mesmas não constam da lista de instalações arroladas e do Layout apresentado na figura 4.5. Recomenda-se a inclusão das Unidades de Tratamento de Água Produzida na lista das instalações arroladas e no Layout das infraestruturas da FLNG Coral Norte (figura 4.5);
- d) Na página 49, relativamente à Potência, faz-se menção que *o navio FLNG estará equipado com 4 geradores de turbina a gás com capacidade de gerar 30 a 35 MW de electricidade cada. Se por exemplo apenas duas destas turbinas estiverem a funcionar em simultâneo produziriam cerca de 60 a 70 MW de electricidade. Uma vez que a plataforma FLNG dista cerca de 50 km da costa de Palma gostaríamos de saber se haveria alguma possibilidade de, havendo electricidade em excesso, ser fornecida a Vila de Palma como responsabilidade social ou simplesmente ser lançada na Rede Eléctrica Nacional (da EDM) para apoiar o desenvolvimento do país;*
- e) Na página 66, a Tabela 4.5 referente ao limite de emissões de efluentes de esgotos tratados, não contempla todos os parâmetros que poderão estar potencialmente presentes no esgoto tratado do projecto;
- f) Na página 68. Estação de tratamento da água produzida, é referido que *a unidade de tratamento de fenol que irá integrar o sistema de tratamento de água produzida é concebido para reduzir as concentrações de fenol na água produzida até 0,5 mg/l. Contudo, o parâmetro fenol e padrões do Projecto para este parâmetro não constam na Tabela 4.7 que apresenta os limites de emissões de efluentes de água produzida tratada;*
- g) Na subsecção 4.4.4.4. *Tratamento de Águas Residuais*, é referido que o esgoto tratado será armazenado dentro de um tanque e descarregado para o mar através de um emissário. Adicionalmente, o PGA (Vol. III), prevê na tabela 9.24, algumas acções para o controlo e mitigação face a gestão de águas residuais das embarcações, sendo referido a aplicação dos requisitos da MARPOL. Contudo, o

REIA não integra os requisitos da legislação nacional para prevenção e controlo da poluição no mar, de descargas advindas de navios e plataformas detalhados no Regulamento para a Prevenção da Poluição e Protecção do Ambiente Marinho e Costeiro, aprovado pelo Decreto nº 45/2006, de 30 de Novembro;

h) A subsecção 6.9.1.7. *Áreas de Conservação*, não inclui informação sobre a Área de Protecção Ambiental (APA) de Palma-Quirimbas, recentemente criada através do Decreto nº 71/2024, de 5 de Setembro, e a possível interferência do Projecto Coral Norte e as actividades relacionadas ao mesmo (como por exemplo, a navegação) nesta APA;

i) Nas páginas 61 e 63, subsecção 4.4.4.2. Processo de produção de GNL, no processo de pré-tratamento vem referenciada a remoção do Mercúrio para cumprir com as especificações do teor deste de  $0.01\mu\text{g}/\text{m}^3$  e na página 64, Remoção do Mercúrio vem referenciado que os resíduos deste serão enviados para a terra de modo a serem encaminhados para a unidade de tratamento de resíduos perigosos licenciada. Solicita-se que se indique o nome desta empresa que fará a deposição dos resíduos de Mercúrio;

j) Na página 65, o documento refere que *“a operação da FLNG irá gerar vários fluxos de águas residuais que serão descarregadas para o mar, a saber: água de lastro: em condições normais, a água de lastro trocada é um efluente limpo”*. Importa referir que as águas de lastro podem transportar espécies exóticas que podem danificar o meio marinho em que forem depositados, pelo que, não se pode afirmar que estas águas são limpas;

k) Ainda sobre a questão acima, no contexto do documento, considera-se as águas de lastro como tendo a sua proveniência na FLNG. No entanto, é nosso entender que estas águas não provêm da FLNG, mas de embarcações de apoio a esta, sendo necessária uma clarificação;

l) Na página 66, Sistemas de tratamento de águas residuais domésticas (esgoto), a Tabela 4.5, faz referência aos limites de emissões de efluentes de esgotos tratados em conformidade com a Convenção da MARPOL. Contudo, o número 3, do Artigo 16 do Regulamento sobre Padrões de Qualidade Ambiental e de Emissão de Efluentes aprovado pelo Decreto nº 18/2004, de 2 de Junho (com Emendas introduzidas pelo Decreto nº 67/2010, de 31 de Dezembro) refere que, se o meio receptor for o oceano há que garantir que os efluentes emitidos obedeçam aos padrões estabelecidos no referido decreto. Assim sendo, deve ser incluído na referida Tabela como limite de emissão de efluentes de esgotos tratados, o parâmetro Nitrato, com o limite de emissão de  $10\text{ mg}/\text{l}$  (máximo), em conformidade com a legislação nacional;

m) Na página 71, o documento refere que *a desactivação e o abandono serão realizados através de um Plano de Desactivação desenvolvido de acordo com o Artigo 15 do EPCC da Área 4, Padrões internos da Eni e Códigos e Padrões Internacionais relevantes para as actividades petrolíferas offshore*. Mais adiante refere que *“(…) para actualização do Plano de Desactivação”*. No entanto, o PGA não apresenta o Plano de desactivação;

- n) Na página 83, subsecção 6.2.2. Padrões e Directrizes da Qualidade de Ar, embora o monitoramento das emissões do Metano não faça parte da legislação nacional sobre Padrões de Qualidade Ambiental e de Emissão de Efluentes, e uma vez que o principal produto de GNL é o Metano, recomenda-se que com base nas directrizes internacionais sejam providenciados os valores limites de emissão deste para que sirvam de referência;

## Volume II - Avaliação de Impactos e Medidas de Mitigação

- o) Na página 6, subsecção 7.2.2. Modelação da Qualidade do Ar, o documento menciona que para a avaliação dos potenciais impactos do Projecto na qualidade do ar foi feita a modelação de dispersão atmosférica baseada em quatro cenários, nomeadamente:
- Cenário 1 - Durante a primeira fase do arranque;
  - Cenário 2 - Durante a fase Operacional;
  - Cenário 3 - Durante um evento de queima de Emergência;
  - Cenário 4 - Devido a operação simultânea com a FLNG Coral Sul.

Embora o documento tenha mencionado que os potenciais impactos do Projecto na qualidade do ar estão principalmente associados às fases de arranque e operação, recomenda-se que seja apresentada também a avaliação dos impactos durante a fase de perfuração, instalação e comissionamento;

- p) Relativamente a metodologia de modelação com base nos cenários acima mencionados, o estudo refere ter considerado como período temporal de modelação um máximo de 3 anos. No entanto, nos resultados apresentados na Tabela 7.9, não está claro sobre a duração de cada fase e o volume de gás queimado, considerados durante a aplicação do modelo de dispersão. Ademais, não se pode ignorar a lição tida aquando do Projecto Coral Sul, cuja fase de arranque levou cerca de 8 meses;
- q) Na página 6, subsecção 7.2.1 “Poluentes Atmosféricos”, é referido que as concentrações do principal poluente emitido pelas chaminés, o CO, e outros poluentes COC, é de cerca de duas ordens de magnitude mais baixa que os padrões. Contudo, não são indicadas as respectivas concentrações emitidas que suportam esta afirmação.
- r) Ainda na subsecção 7.2.2, refere-se que *a modelação foi feita para uma base de 3 anos, tendo-se concluído que os impactos são de baixa significância e não é necessária nem recomendada nenhuma mitigação, para além dos procedimentos de manutenção padrão do equipamento de combustão, para manter as emissões projectadas, incluindo a implementação de um programa, com campanhas anuais de monitorização das emissões e da qualidade do ar ambiente, para garantir que as emissões reais não são superiores ao esperado e para confirmar as conclusões da modelação.* Contudo, a modelação é teórica e feita para curto período de tempo e o documento devia avançar com algumas medidas de mitigação para sua implementação caso os resultados da monitorização sejam elevados. Esta recomendação é aplicável a todos impactos avaliados;

- s) Na página 14, subsecção 7.3.1.3. Avaliação do Impacto (Impacto GEE1: Emissões de GEE do Projecto), sobre as emissões do GEE do Projecto, apesar de não ser obrigatório por lei, uma vez que o principal componente do gás produzido na plataforma FLNG é o gás Metano, sugere-se que também sejam contabilizadas as emissões de Metano durante a fase de operação para fazer parte da informação do Governo nas comunicações nacionais dos GEE;
- t) Na página 43, subsecção 7.5, sobre qualidade de água, na sequência da análise sobre o impacto do derrame de hidrocarbonetos causados por eventos não planeados (derrames acidentais de gásóleo devido a colisão da embarcação, derrame acidental de condensado de gás e derrame de LTOBM devido a uma desconexão acidental de um ascensor), foram considerados em geral de significância média os impactos da fracção de hidrocarbonetos com espessura superior a 1  $\mu\text{m}$ , fracção que pode causar danos físicos a vida selvagem (por exemplo, contaminação, sufocamento) e que segundo a modelação tem dispersão localizada. Todavia, é omissa a análise do impacto socioeconómico, sobretudo relativamente aos activos turísticos da fracção visível (com espessura inferior a 1  $\mu\text{m}$ ) que os modelos projectam uma dispersão substancial. É importante que se considerem para além de medidas de contingência caso ocorram estes eventos não previstos, medidas que reduzam cada vez mais a probabilidade de ocorrência de tais eventos;
- u) Na página 45 do volume II, subsecção 7.5.2. Fases de Perfuração e Instalação, Gestão de aparas e LTOBM (lamas a base de óleo de baixa toxicidade), o documento refere que *“se não for possível a transferência das aparas para terra por algum constrangimento técnico ou operacional não planeado, pode ser necessário um procedimento de gestão alternativo, que implicaria a eliminação em alto mar”*. Relativamente a este aspecto, recomenda-se que seja descartada a possibilidade de fazer as descargas das aparas e lamas (LTOBM) no mar para evitar poluição das águas e prejudicar a vida marinha;
- v) No que concerne a avaliação dos impactos resultantes das descargas de água de refrigeração, é mencionado na subsecção 7.5.3 (Vol. II) e na subsecção 4.4.4.3 (Vol. I), que *prevê-se um caudal de descargas térmicas em média máxima de 27225 MT/h (toneladas métricas por hora) perfazendo cerca de 7,6236 m<sup>3</sup>/s, com uma temperatura de 30,64°C, que segundo os resultados de modelação realizada é esperado um aumento de temperatura da água do mar receptora, a 100m do ponto da descarga em cerca de 0,39°C e no limite da zona de mistura de 300m um aumento inferior a 0,1°C, e que, de acordo com as directrizes da IFC adoptadas pelo Projecto, o Estudo considera que o aumento da temperatura da água do mar receptor será relativamente baixo, pois as directrizes da IFC referem que qualquer descarga térmica não deve resultar num aumento de temperatura superior a 3°C no limiar da zona de mistura. Considerando que já existe a Plataforma Coral Sul FLNG a operar, recomenda-se que a modelação seja feita com base em dados reais do Projecto Coral Sul, uma vez que já existem relatórios de monitoria das descargas actuais;*
- w) Ainda na subsecção 7.5.3, faz-se menção que será feita a monitoria semestral da temperatura da água do mar receptora para garantir a conformidade com o padrão limiar da zona de mistura. Portanto, deve-se indicar os pressupostos que

determinaram o estabelecimento da periodicidade (semestral) para a referida monitoria;

- x) Na página 49, 7.5.3 Fase de Operação Impacto QAG2: Aumento potencial da temperatura da água do mar devido à descarga da água de refrigeração da FLNG, é apresentada a análise dos impactos das descargas de água de refrigeração, fazendo recurso a modelação das descargas a uma profundidade média de 5 m, num cenário de baixas correntes, concluindo que, neste cenário de descarga, não se observa aumento de temperatura superior ao recomendado pelos padrões no limiar da zona de mistura de 100m de raio. Contudo, esta análise é apenas ao nível de dispersão horizontal. Seria importante analisar também a dispersão no eixo vertical tendo em conta que a temperatura afecta a estabilidade e estrutura vertical das massas de água e, portanto, a sua distribuição circulação vertical. Gráficos de perfis verticais da temperatura em diferentes posições ao longo de um transecto da zona de mistura seria muito útil nesta análise;
- y) Na página 56, sobre qualidade de água, é feita seguinte afirmação: *“a localização da FLNG Coral Norte também não é susceptível ao enriquecimento excessivo de nutrientes (eutroficação). Os sistemas mais susceptíveis à eutroficação são aqueles com troca de marés e mistura limitadas, longo tempo de retenção, massas de água estratificadas verticalmente e concentrações de fundo relativamente baixas de sedimentos em suspensão”* como justificativa de descarga de nitratos de cerca de 1 mg/l. Entende-se que estas descargas se conformam com a legislação nacional em relação a este poluente. Contudo, esta afirmação deve ser suportada com evidências científicas ou referências bibliográficas;
- z) Quanto a avaliação do impacto de degradação da qualidade da água do mar devido a descarga de água produzida na fase de operação, a tabela 7.29 (subsecção 7.5.3 -Vol. II) apresenta as concentrações de descarga, e nota-se que os parâmetros estão muito acima dos limites estabelecidos na legislação, principalmente no que tange ao parâmetro DBO5. De referir que, com o Projecto Coral Sul em implementação, já existe experiência adquirida. Deste modo, o presente estudo deverá apresentar alternativas viáveis face ao tratamento da água produzida, por forma a que os parâmetros estejam em conformidade com a legislação, antes da sua descarga;
- aa) Na página 81, o documento refere que irá se “garantir o manuseamento, tratamento e eliminação adequados de resíduos sólidos perigosos, não perigosos e biomédicos, de forma a cumprir as normas nacionais ambientais aplicáveis (Decreto n.º 13/2006), normas técnicas, normas internacionais e melhores práticas. De referir que o Decreto nº 13/2006 foi revogado pelos Decretos nº 94/2014, de 31 de Dezembro, que aprova o Regulamento sobre a Gestão de Resíduos Sólidos Urbanos, e nº 83/2014, de 31 de Dezembro, que aprova o Regulamento sobre a Gestão de Resíduos Perigosos. Por outro lado, os resíduos biomédicos deverão ser geridos em conformidade com o Regulamento sobre a Gestão de Lixo biomédico, aprovado pelo Decreto nº 8/2003, de 18 de Fevereiro;
- bb) O documento em análise não fornece informação sobre a capacidade da clínica a bordo da FLNG, serviços que serão fornecidos, nem o número de trabalhadores

que estarão afectos a esta clínica. Deve-se apresentar a informação sobre a capacidade da clínica a bordo da FLNG, serviços que serão fornecidos, incluindo o número de trabalhadores que estarão afectos a esta clínica;

- cc) Nas páginas 101 e 102, na subsecção 7.7.3.2. Avaliação de Impactos, relativamente ao Impacto BIO9: Efeitos da descarga de drenagem de convés, água de porão e esgotos na ecologia marinha devido a mudanças na qualidade da água, nas medidas de mitigação faz-se referência que *o esgoto deve ser tratado na (estação de tratamento a bordo) antes da descarga em conformidade com regulamento da MARPOL 73/78 e apresentam valores limites de emissão para parâmetros de pH, SST, DBQ e coliformes*. Recomenda-se a apresentação do parâmetro de emissão de Azoto deste mesmo regulamento para efeitos de referência;
- dd) Na página 145, faz-se menção que a FLNG terá uma clínica a bordo que tratará de questões menores de saúde dos trabalhadores. No entanto, não clarifica de que questões menores se trata;
- ee) Ainda na página 145, na subsecção 7.8.1, sobre actividades geradoras de impacto, o documento refere que *“...para os serviços sociais, a grande maioria da mão-de-obra do Projecto Coral Norte terá uma interacção muito limitada com a estrutura sanitária de Pemba e/ou com as populações locais, e como tal não foram identificados impactos a este nível”*. Não obstante esta afirmação, o pessoal em terra afecto a Base Logística em Pemba, ligado aos serviços de apoio (terminal marítimo, oficinas de manutenção, escritórios, instalações logísticas, etc.), pode ter algum impacto no perfil de saúde local, geralmente no aumento da incidência de doenças, incluindo as sexualmente transmissíveis. Por esta razão, julgamos ser pertinente que este impacto seja avaliado, de modo que se perceba como é que se modificam os indicadores de saúde nas áreas afectadas pelos trabalhadores do projecto;
- ff) Na página 177, na Tabela 7.4.1. Resumo dos Impactos do Projecto, nas principais medidas de mitigação do impacto BIO10, refere-se que os resíduos alimentares serão tratados de acordo com os regulamentos da MARPOL: 73/78, recomenda-se a descrição do procedimento de tratamento destes resíduos.

### **Volume III - - Plano de Gestão Ambiental**

- gg) Na página 1, subsecção 1.1.1. Contexto, a sigla EPCC não consta na lista de acrónimos e abreviaturas;
- hh) Na página 25, subsecção 4.3.1.1: Esgoto/Água Sanitária, a Tabela 4.2 apresenta-se os limites de emissões do Projecto para descarga de esgotos, de acordo com as directrizes da MARPOL, remetendo-nos ao Decreto nº 45/2006, de 30 de Novembro, que aprova o Regulamento sobre a Prevenção da Poluição e Protecção do Ambiente Marinho e Costeiro. Recomenda-se a consideração dos Decretos nº 18/2004, de 2 de Junho, que aprova o Regulamento sobre Padrões de Qualidade Ambiental e de Emissão de Efluentes e nº 67/2010, de 31 de Dezembro, que introduz emendas ao primeiro. Os padrões constantes nestes instrumentos legais

não podem ser interpretados como sendo apenas relativos a descargas para águas superficiais/interiores ou terra;

- ii) Na página 26, subsecção 4.3.1.2: *Água Produzida*, vem referenciado no documento que as regulamentações nacionais não especificam limites de emissão para descargas de efluentes industriais em mar alto, e que para estes casos, aplicam-se as Directrizes SSA da IFC para Projectos de Petróleo e Gás Offshore, estas directrizes que abordam apenas parâmetros de teor de gorduras, para águas de porão como ilustrado na tabela 4.3. Uma vez que a água produzida no processo de exploração de petróleo e gás, é um efluente industrial que não contém apenas teor de óleos e gorduras, apresenta uma série de outros contaminantes, recomenda-se a consideração de outros parâmetros, para além dos teores de óleos e gorduras, e a observância do Decreto nº 67/2010, de 31 de Dezembro;
- jj) Na página 61, a Tabela 9.10: Acções de monitorização, descrição e cronograma de implementação - gestão de efluentes de embarcações, apresenta como acção de monitorização *a preparação de um Plano de Gestão de Água de Lastro e manter um Livro de Registro de Água de Lastro, onde todas as operações de lastro são registadas; e a garantia de que nenhuma actividade de lastro ocorrerá na área próxima à costa e sobre a plataforma continental*, sendo limitada a águas profundas em alto mar. Temos a referir que o acima descrito não corresponde a acções de monitoria, mas sim de mitigação, devendo merecer um melhor alinhamento no documento. Adicionalmente, o Plano de Gestão das Águas de Lastro é parte integrante do PGA, e a sua elaboração não se pode remeter ao futuro.
- kk) Relativamente ao Programa de Formação Ambiental e Social, na página 112, subsecção 9.5.6.2, faz-se menção que o programa de formação terá como grupo-alvo todos os empregados relevantes e na subsecção 9.5.6.1: (Justificação e Objectivos) refere-se que “todas as actividades do projecto serão conduzidas de modo a prevenir e minimizar impactos negativos. Para esse efeito, é necessário treinar todos os trabalhadores.” Deve-se harmonizar as duas citações;
- ll) Os Planos de Resposta a Emergências Médicas e para Pandemias constantes na página 116 e seguintes, não fornecem detalhes sobre, como a clínica a bordo da FLNG encontra-se organizada para que possa dar resposta a possíveis situações de emergência que exijam isolamento, como também, não esclarece sobre os procedimentos de evacuação e transporte para uma unidade sanitária em terra, caso a situação o exija. Recomenda-se que os Planos de Resposta a Emergências Médicas e para Pandemias forneçam detalhes sobre aspectos organizacionais da clínica a bordo da FLNG com vista a dar resposta a possíveis situações de emergência que exijam isolamento, incluindo os procedimentos de evacuação e transporte para uma unidade sanitária em terra, caso a situação o exija;
- mm) Na página 183, Tabela 7.43: Resumo dos impactos do Projecto - Eventos não planeados faz-se menção que *“um Plano de Contingência de Derrame de Hidrocarbonetos específico para o Projecto Coral Norte será preparado e submetido para aprovação do regulador”*. Estando na fase de avaliação do REIA e considerando que o Plano de Contingência de Derrame de Hidrocarbonetos é

parte integrante do PGA, este deve ser preparado e submetido para a sua avaliação;

nn) Em relação a monitoria de Fauna Marinha, o PGA centra-se sobre registos visuais (directos ou por ROV) como únicos métodos para aferir a presença ou ausência de determinadas espécies. Isto poderá ser o resultado de não ter avaliado no REIA todos os impactos que advêm de efeitos acústicos. Assim sendo, recomenda-se a inclusão de outros métodos para a monitoria da fauna marinha tendo em conta que os ruídos também tem sobre a mesma os seguintes impactos:

✚ Efeito físico em peixes

- Para algumas espécies é letal o uso de sons de baixa-frequência (<500 Hz) com repercussão de som sob um nível de exposição de 24 horas a uma acústica >170 dB. (Níveis de pressão dos 120 dB são considerados não saudáveis e níveis da ordem dos 150 dB causam danos físicos).

✚ Efeitos no comportamento dos Peixes;

- Ocorre uma mudança na velocidade e padrão de nado;
- Altera completamente a distribuição vertical embora ocorra apenas no período da repercussão do som.

✚ Efeitos nas Tartarugas Marinhas

- Perda auditiva

✚ Efeitos sobre os mamíferos marinhos

- Abandono das áreas de reprodução, rotas migratórias;
- Interferência com o comportamento alimentar e seu padrão;
- Alteração nos padrões de mergulho e respiratórios nas baleias;
- Mudança na socialização aumentando os níveis de agressividade;
- Mudança nos padrões de vocalização;
- Mudança do padrão de ecolocalização.

## Volume IV - ANEXOS

oo) Na subsecção, AIV.1.4.1. Fonte de Emissões, refere-se que *os dados de emissão para cada cenário de modelação foram obtidos a partir das estimativas preparadas para o Projecto Coral Sul FLNG, considerando que as condições operacionais e fontes de emissão para os dois Projectos são idênticas e, na subsecção AIV.1.4.1.2. Cenário 2 (Fase Operacional), refere-se que não foram consideradas emissões fugitivas, e foram excluídas as emissões descontínuas planeadas, assim como, foram consideradas as mesmas fontes de emissão do cenário 2, para o cenário 4 (cumulativo das Operações simultâneas do Coral Norte e o Coral Sul).*

Tendo em consideração que a fase operacional (cenário 2) levará um longo período temporal (mais ou menos 25 anos) tanto para o Coral Norte, assim como para o Coral Sul, associado ainda ao efeito cumulativo dos dois Projectos estarem a operar simultaneamente (cenário 4). Recomenda-se que seja feita a avaliação

dos impactos na qualidade do ar tanto para o cenário 2 assim como para o cenário 4, e que sejam consideradas as emissões fugitivas e as descontínuas planeadas. É pertinente ainda, que se apresente as estimativas das quantidades de queima a serem consideradas no caso das emissões planeadas.

## **Volume V - Relatório do Processo de Participação Pública**

Na Tabela 4.1: Principais comentários recebidos ao longo do PPP (EPDA e EIA) do Projecto Coral Norte, na pág. 16, no 36 da Tabela, refere-se que “Este requisito não é aplicável ao Projecto Coral Norte, conforme ofício do INAMAR à MRV (ofício n.º 240/175/INAMAR, IP/CA, de 05/06/2023), que confirma a inaplicabilidade do Regulamento que Estabelece o Regime Jurídico de Utilização do Espaço Marítimo (“RJUEM”) nacional, aprovado pelo Decreto n.º 21/2017, de 24 de Maio, ...”. Contudo, o Ofício em referência não é apresentado em anexo ao REIA;

### **10. Conclusões e Recomendações**

Analisada a documentação submetida no âmbito da Avaliação do Impacto Ambiental do Projecto, conclui-se que a mesma fornece informação aceitável para a tomada de uma decisão favorável à aprovação do REIA. Contudo, para além dos aspectos previstos no Relatório de Estudo do Impacto Ambiental e no respectivo Plano de Gestão e Monitorização Ambiental recomenda-se:

- a) A observância do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto n.º 54/2015, de 31 de Dezembro e do Regulamento Ambiental para as Operações Petrolíferas, aprovado pelo Decreto n.º 56/2010, de 22 de Novembro;
- b) A observância dos Decretos n.º 18/2004, de 2 de Junho, que aprova o Regulamento sobre Padrões de Qualidade Ambiental e de Emissão de Efluentes e n.º 67/2010, de 31 de Dezembro, que introduz emendas ao primeiro. Adicionalmente, os padrões constantes nestes instrumentos legais não podem ser interpretados como sendo apenas relativos a descargas para águas superficiais/interiores ou terra;
- c) Que após a concepção do projecto da Unidade de Tratamento de Água Produzida, o mesmo seja submetido à Autoridade de Avaliação de Impacto Ambiental e ao INP para a devida apreciação e para que conste do processo;
- d) O cumprimento da cota estabelecida pela Lei do Trabalho na contratação da mão-de-obra estrangeira;
- e) A submissão à Autoridade de Avaliação do Impacto Ambiental, do “ofício do INAMAR à MRV (ofício n.º 240/175/INAMAR, IP/CA, de 05/06/2023), que confirma a inaplicabilidade do Regulamento que Estabelece o Regime Jurídico de Utilização do Espaço Marítimo (“RJUEM”) nacional, aprovado pelo Decreto n.º 21/2017, de 24 de Maio”, referido na página 16 do volume V (Relatório de Participação Pública);
- f) A submissão à Autoridade Marítima, do Plano de Contingência Individual para derrames de hidrocarbonetos para apreciação e posterior aprovação, em

cumprimento ao disposto no nº 7 do Regulamento para a Prevenção da Poluição e Protecção do Ambiente Marinho e Costeiro, aprovado pelo Decreto nº 45/2006, de 30 de Novembro;

- g) A implementação rigorosa dos Planos de Gestão de Resíduos e de Efluentes proposto, de modo a assegurar que sejam alcançados os propósitos almejados com a concepção do Projecto e a implementação de medidas de mitigação e optimização aplicáveis para reduzir a significância dos potenciais impactos negativos e aumentar os benefícios dos potenciais impactos positivos;
- h) A submissão de dados sobre a composição química do gás, do condensado e da água produzida no Projecto Coral Sul para a sua consideração como referência no presente Projecto, uma vez que o Projecto Coral Norte ainda não dispõe de dados, e partilha o mesmo reservatório com a Coral Sul.
- i) A realização de análises da composição química da água produzida tratada antes da sua descarga no mar, uma vez que o REIA se refere a este como meio receptor;
- j) Que seja garantida na Gestão de Resíduos de Perfuração (aparas e LTOBM), a aplicação do método de tratamento da unidade de dessorção térmica (TDU) realizado em terra e que é mais seguro, como também referenciado no presente REIA como sendo a opção do Projecto para o tratamento destes resíduos em operações normais;
- k) O tratamento de resíduos de acordo com o Regulamento sobre a Gestão de Resíduos Sólidos Urbanos (Decreto nº 94/2014, de 31 de Dezembro) e com o Regulamento sobre a Gestão de Resíduos Perigosos (Decreto nº 83/2014, de 31 de Dezembro);
- l) A realização ao longo do período de desenvolvimento do Projecto, de auditorias ambientais independentes, em conformidade com o Regulamento sobre o Processo de Auditoria Ambiental, aprovado pelo Decreto nº 45/2024, de 26 de Junho;
- m) A quantificação dos combustíveis usados no empreendimento, tanto pelas viaturas, embarcações e pelas máquinas/equipamentos diversos, de modo a permitir a quantificação dos gases com efeito estufa emitidos, incluindo as emissões de Metano geradas durante a fase de operação do Projecto;
- n) A comunicação ao MTA e MIREME, de qualquer eventualidade não prevista na presente avaliação;
- o) A observância dos objectos dos Decretos nº 83/2021, de 18 de Outubro, que cria o Instituto de Transporte Marítimo (ITRANSMAR, IP) e nº 88/ 2021, de 28 de Outubro, que cria o Instituto Nacional do Mar, IP (INAMAR, IP), visto que ambas entidades se complementam nas suas funções;
- p) Que o proponente do Projecto coordene com as entidades marítimas competentes, para acautelar questões de sinalização das rotas na área de influência do Projecto para evitar potenciais acidentes, tendo em conta que está previsto um aumento do tráfego marítimo para e/da plataforma FNLG;

- q) Que o proponente do Projecto entre em contacto com a Autoridade Marítima, para a certificação e licenciamento de todo o equipamento marítimo a ser usado em todas as fases do Projecto, em cumprimento à Resolução nº 15/2022, de 19 de Setembro, que aprova o Estatuto Orgânico do INAMAR, IP;
- r) Que seja garantida a implementação de acções de responsabilidade social para as comunidades circunvizinhas à área do Projecto, de acordo com Política de Responsabilidade Social Empresarial para a Indústria Extractiva de Recursos Minerais, aprovada pela Resolução nº 21/2014, de 16 de Maio;
- s) A recuperação de danos ambientais que possam ser causados pelas actividades do empreendimento, incluindo a restauração de ecossistemas que possam ser destruídos durante a vigência do Projecto.

## 11. Considerações Finais

Feita a revisão do REIA pela Comissão Técnica de Avaliação e tendo em conta as constatações e recomendações acima apresentadas e que não inviabilizam a sua aprovação, e tratando-se ainda de um documento de consulta e de natureza pública, o proponente deverá submeter à DINAB, em seis exemplares em formato físico e seis em formato electrónico, o REIA revisto tendo em conta os comentários e constatações apresentados no ponto 9 do presente relatório de revisão, no prazo de 45 dias após a recepção da nota de aprovação. Um exemplar nos formatos físico e electrónico deverá ser submetido ao SPA de Cabo Delgado.

Para o acompanhamento do desempenho ambiental da actividade, o MTA juntamente com outros sectores visados, reserva o direito de realizar auditorias e fiscalização ambientais periódicas à actividade. Adicionalmente, o proponente deverá submeter semestralmente, o Relatório de Desempenho Ambiental à AQUA, DINAB, INP, ITRANSMAR, IP, INAMAR, IP, InOM, Serviço Provincial do Ambiente de Cabo Delgado, Serviço Provincial de Infraestruturas de Cabo Delgado, Governo do Distrito de Palma e noutros sectores chave.

O Relatório de Desempenho Ambiental deverá incluir para além de outros dados pertinentes, dados sobre efluentes e resíduos sólidos gerados e tratados, localização dos pontos de colecta, periodicidade das amostragens, consumos de combustíveis, incluindo incidentes, aspectos ambientais críticos e monitoria de conflitos, parâmetros monitorados, com ênfase nos resultados das análises da composição química da água produzida tratada antes da sua descarga.

A FLNG da Coral Norte, sendo uma réplica da FLNG da Coral Sul, o proponente deve acautelar as fraquezas que esta demonstrou, sobretudo no ambiente marinho.

O não cumprimento das recomendações acima mencionadas, constitui infracções administrativas e puníveis por lei, com penas pré-estabelecidas no Artigo 28 do Regulamento sobre o Processo de Avaliação do Impacto Ambiental, aprovado pelo Decreto nº 54/2015, de 31 de Dezembro.

## A Equipa Técnica de Revisão

N.	Nome do Técnico	Instituição	Especialidade	Assinatura
1	Josefa Jussar	MTA/DINAB	Eng <sup>a</sup> . Química	Josefa Jussar
2	Nilsa Racune	DINAB/DAA	Bióloga	Nilsa Racune
3	Eunice Rafael Cuna	INTRANSMAR, IP	Enga. Ambiental	Eunice Rafael
4	Atália Muvelo	MTA/DINAB	Tec. Sup. Ad. Pública	Atália Muvelo
5	Leonardo Guirruta	MTA/DGR	Eng. Químico	Leonardo Guirruta
6	Anselma Munguambe	MIMAIP/INAMAR, IP	Educadora Ambiental	Anselma Munguambe
7	Maria Perpétua Scarlet	UEM/Fac. De Ciências	Bióloga Marinha	Maria Perpétua Scarlet
8	Guilhermina Honwana	INP	Enga. Ambiental	Guilhermina Honwana
9	Paulo Albano	DINAB/DAA	Meteorologista	Paulo Albano
10	Gércia Lopes	MIMAIP/IDEPA, IP	Socióloga	Gércia Lopes
11	Calton Lençol	MISAU/DNSP	Saúde Pública	Calton Lençol
12	Armindo Araman	MTA/ANAC	Ecologia e Conservação da Natureza	Armindo Araman
13	Manuel Poio	MTA/DGA	Geógrafo	Manuel Poio
14	Emídio Raul	InOM	Biólogo	Emídio Raul
15	Lígia Filomena Chamo	DINAB/RAACB	Tec. Sup. Ad. Pública	Lígia Filomena Chamo

Maputo, Outubro de 2024

## Annex III – Calculation of Project GHG Emissions

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## AIII.1. GHG and Energy Calculation Methodology

### AIII.1.1. Reference Guidance

The calculation methods and factors used to generate the Project greenhouse gases (GHG) values have been sourced from internationally accepted guidance and standards and are referenced throughout the sections, where appropriate. The guidance originates from four main organisations:

- Intergovernmental Panel on Climate Change (IPCC) – Guidelines for National GHG Inventories;
- American Petroleum Institute (API) – Compendium of Greenhouse gas Estimation methodologies;
- United States Environmental Protection Agency (US-EPA) – AP-42;
- Institute of Petroleum (IoP) - Guidelines for the Calculation of Estimates of Energy use and Gaseous Emissions in the Decommissioning of Offshore Structures.

In addition to the above, ISO 6976:2016: Natural Gas – ‘Calculation of calorific values, density, relative density and wobble composition’ was referenced for standard calculation methods of the compositional parameters (i.e., lower heating values (LHV)).

### AIII.1.2. GHG Scope Definitions

The following definitions are applied for the inventory, as aligned with the GHG Protocol:

- SCOPE 1: Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment;
- SCOPE 2: Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organisational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated;
- SCOPE 3: Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are extraction and production of purchased materials; transportation of purchased fuels; and use of sold products and services.

The Scope 3 category has been sub-divided into Upstream and Downstream emissions.

- Upstream emissions sources include the marine vessels and helicopter flights;
- Downstream Scope 3 is associated with the transport and use of the LNG product.

### AIII.1.3. Assessment Boundary

Although the primary focus of this assessment is to quantify the yearly and lifetime operational emissions (including start-up, maintenance, and turn-over), a high-level magnitude estimate has been prepared for the other phases of the project including drilling, installation, and decommissioning.

The GHG assessment covers Scope 1 and Upstream Scope 3 emissions sources. Scope 2 is not applicable for the project as the FLNG does not import electricity.

Downstream Scope 3 emissions (i.e., from end use of the LNG product) are excluded as those emissions are associated with operations outside the remit of MRV to manage.

The boundary of the assessment is illustrated in the figure below, showing the phases within the boundary of this assessment (blue) and those excluded (grey). The individual sources in each phase are discussed in the following section.



Figure AIII.1: GHG assessment boundary

### AIII.1.4. Emission Sources

This assessment is scoped to cover the emissions from the drilling, installation, operations, and decommissioning phases of the project, discussed in the following sections:

#### AIII.1.4.1. Drilling and Installation

Emissions during the drilling and installation phases of the project will primarily arise from the fuel use in the marine vessels involved in the subsea and installation works. Smaller amounts of emissions will be associated with the helicopter flights for the offshore work crew changes. The vessel types and numbers during each phase have been given in Table AIII.1 as provided by MRV.

Table AIII.1: Drilling and installation vessels

Activity	Type of Vessel	Number
Drilling	Drill Ship	1
	Platform Supply Vessel	3
Subsea/pre-mooring Installation	Installation Vessel	2
	Platform Supply Vessel	3
	Multi-Purpose Vessel	1

### **AIII.1.4.2. Operational Emission Sources**

#### **AIII.1.4.2.1. Scope 1 Emissions**

The various operational emission sources on the Coral North facility include:

- 4 x Gas Turbine Generators (GTG);
- 4 x Gas Turbine Compressors (GTC) 2 x MR1 train, 2 x MR2 train;
- 1 x CO<sub>2</sub> Thermal Incinerator;
- Flares: 2 x High Pressure (HP), 2 x Low Pressure (LP) and 1 x Low-Low Pressure (LLP);
- Intermittent diesel usage (i.e., during start-up prior to fuel gas availability, emergency diesel generators during Turnarounds (TARs) and for other short use items such as the Fire Water Pumps);
- Fugitive emissions.

Coral North has been designed for zero flaring during routine operations with emissions from the flare limited to combustion of the pilot and purge (natural gas) flow. Non-routine flaring will only occur during start-up, TAR, and upset (unplanned) conditions.

There are no Scope 2 emissions planned as there will be no imported power or heat from purchased energy sources.

#### **AIII.1.4.2.2. Scope 3 Emissions**

Other sources of emissions during operation include the following marine support/supply vessels:

- 1 x Flotel (for initial commissioning phase only);
- 3 x Platform Supply Vessels (sailing between FLNG and Pemba);
- 3 x Tugs<sup>1</sup>.

In addition to the above, there will be helicopter flights for crew change overs.

### **AIII.1.4.3. Decommissioning Sources**

Similar to the installation phase, the decommissioning phase emissions will be associated with use of marine vessels for the removal of the FLNG and crew change flights over the decommissioning period.

The assessment does not include the emissions from the deconstruction and/or recycling of the vessel and associated equipment once the FLNG is brought to the decommissioning site

For the purpose of this assessment, it is assumed the subsea infrastructure will be left in situ for a “cut and sail” method of removal.

The assumed vessel spread is given in Table AIII.2 below.

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<sup>1</sup> It is understood 6 x tugs will be in operation, shared with Coral South. For the purpose of this assessment it is assumed an equal split.

**Table AIII.2: Decommissioning vessels**

Type of Vessel	Number
Flotel	1
Installation Vessel	2
Multi-purpose Vessel	3
Tug	5
Platform Supply Vessel	1

### AIII.1.5. Quantification Approach

Quantification of GHG emissions has been undertaken using approaches recognised by the International Finance Corporation (IFC) and the European Bank for Reconstruction and Development (EBRD) for development of GHG Inventories, i.e., the approach is aligned with the GHG protocol standard for project carbon accounting.

Industry GHG quantification guidance (i.e., API GHG Compendium) preference the use of emission factors derived from available fuel compositions over that of default averaged values to increase accuracy and relevance to actual operations.

For standard (internal) combustion sources, fuel specific CO<sub>2</sub> emission factors were calculated using provided fuel composition data and assuming 100% oxidation (see following Section). As per industry best practice guidance (i.e., API GHG compendium) it is conservative to assume some methane emissions even when 100% oxidation factor is used. To this end, fuel specific GHG emission factors for CH<sub>4</sub> and N<sub>2</sub>O were sourced from the US-EPA and IPCC guidance.

For flaring, CO<sub>2</sub> and CH<sub>4</sub> were calculated, based on a 98% oxidation factor. The N<sub>2</sub>O emissions are assumed as being trace amounts.

Annual emissions are calculated based on standard emission factor approach, summarised as follows:

$$E = EF_{GHG} \times C_{Fuel} \times A \times OF \quad \text{Equation 1}$$

where

- $E$  is the annual emissions (kg/h);
- $EF_{GHG}$  is the emission factor for the particular GHG (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>) given in kgGHG per kg fuel;
- $C_{fuel}$  is the fuel consumption in kg/h;
- $A$  is the activity factor (hours);
- $OF$  is the oxidation factor (also known as combustion efficiency).

### AIII.1.5.1. Standard Combustion

The CO<sub>2</sub> emission factor for each fuel was calculated using available fuel gas compositions (Annex III.A) following the method presented in the latest API GHG Compendium guidance<sup>2</sup> based on the stoichiometric combustion reaction and assumed oxidation factor.

This is expressed in simplified form as:

$$EF_{CO_2} = \frac{\sum_g [MOLS_{CO_2,g} \times MW_{CO_2} \times OF] + [mol\%_{CO_2} \times MW_{CO_2}]}{MW_{fuel}} \quad \text{Equation 2}$$

where

- $EF_{CO_2}$  is the CO<sub>2</sub> emission factor (kgCO<sub>2</sub> per kg fuel combusted);
- $MOLS_{CO_2,g}$  is the number of moles of CO<sub>2</sub> produced from combusting 1 mole of fuel component “g”;
- $MW_{CO_2}$  is the molar weight of CO<sub>2</sub> (44.01 kg/kmol);
- $mol\%_{CO_2}$  is the mol% content of CO<sub>2</sub> in the fuel composition;
- $MW_{fuel}$  is the molar weight of the fuel;
- $OF$  is the oxidation factor.

### AIII.1.5.2. Flaring

For flaring, the oxidation factor is 98%, meaning 2% of the fuel's methane content will escape combustion without being converted to CO<sub>2</sub>. Therefore, the CH<sub>4</sub> emission factor can be calculated from the fuel's methane content as follows:

$$EF_{CH_4} = \frac{(1 - OF) \times mol\%_{CH_4} \times MW_{CH_4}}{MW_{Fuel}} \quad \text{Equation 3}$$

where

- $EF_{CH_4}$  is the CH<sub>4</sub> emission factor (kgCH<sub>4</sub> per kg fuel combusted);
- $mol\%_{CH_4}$  is the mol% content of methane in the fuel composition;
- $MW_{CH_4}$  is the molar weight of methane (16.01 kg/kmol);
- $MW_{fuel}$  is the molar weight of the fuel;
- $OF_{flare}$  is the oxidation factor for flaring (98%).

The CO<sub>2</sub> emission factor for flaring is calculated as per method for standard combustion (Section AIII.1.2.1) albeit with the use of 98% oxidation factor in the equation.

<sup>2</sup> API, Compendium of Greenhouse gas Estimation methodologies (2021) (Online).

### AIII.1.5.3. Oxidation Factor

The oxidation factor is the measure of how complete the conversion of gas constitutes into CO<sub>2</sub> during combustion. This assessment has aligned with the recommended oxidation factors from the API GHG compendium guidance with values as follows:

**Table AIII.3: Oxidation factors**

Type	Oxidation Factor
Standard Combustion (Heaters, boilers, pilots)	100%
Flaring	98%

### AIII.1.5.4. Global Warming Potentials

Global Warming Potentials (GWPs) is a tool to weigh and contrast the impact of each GHG to the atmosphere in relation to the baseline of CO<sub>2</sub>. GWPs exist for 20-year and 100-year impact values. The use of the 20-year GWP gives more weight to the short-lived GHGs (i.e., methane, which resides in the atmosphere for decades) and underestimates the detrimental effect of longer lasting GHGs (i.e., CO<sub>2</sub>). Therefore, international guidance places preference for use of the 100-year GWP in GHG inventory calculations, which strikes a balance between the impact of the short-lived and long-lived GHGs.

The use of the 100-year GWP in GHG inventories is internationally accepted through the GHG Protocol for Project Accounting<sup>3</sup> standard for quantifying and reporting GHG emissions. The Protocol references the Environmental Protection Agency (EPA) guidance which uses the 100-year GWP to align with the United Nations Framework Convention on Climate Change (UNFCCC) requirements.

### AIII.1.5.5. Carbon Dioxide Equivalents

For each combustion activity covered in this scope of work, the CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O tonnage emissions are calculated. It is standard practice to convert each emissions value into a CO<sub>2</sub> equivalent (CO<sub>2e</sub>) by multiplying by the corresponding GWP for the respective GHG. In formula form this includes the following:

$$E_{CO2e} = E_{s,CO2} + (GWP_{CH4} \times E_{s,CH4}) + (GWP_{N2O} \times E_{s,N2O}) \quad \text{Equation 4}$$

where

- $GWP_{CH4}$  and  $GWP_{N2O}$  are the global warming potentials for CH<sub>4</sub> and N<sub>2</sub>O respectively;
- $E_{s,CO2}$ ,  $E_{s,CH4}$  and  $E_{s,N2O}$  CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, determined for each GHG source.

<sup>3</sup> GHG Protocol, Corporate Standard for Carbon Accounting (Online). <https://ghgprotocol.org/corporate-standard>

This assessment has aligned with the GWP's given in the IPCC AR-5 report<sup>4</sup>, with the following values:

- CO<sub>2</sub> – 1;
- CH<sub>4</sub> – 28;
- N<sub>2</sub>O – 265.

### AIII.1.5.6. Marine Vessel Emissions

For the vessels, the emissions were calculated as follows:

$$E_{Vessel} = A \times Fuel_{Vessel} \times 3.11 \text{ tCO}_2/t \quad \text{Equation 5}$$

where

- $E_{Vessel}$  is the CO<sub>2</sub> emissions (tonnes) from the vessel;
- $A$  is the activity duration (days);
- $Fuel_{Vessel}$  is the fuel consumption rate for the specific vessel (see below);
- 3.11 is the emission factor for marine fuel oil<sup>5</sup>.

The Institute of Petroleum (IoP) has published guidelines for estimating energy and emissions from offshore decommissioning<sup>6</sup>. The guidance document provides estimates for the fuel consumption for typical marine vessels, broken down by type and activity covering fuel consumption while sailing and on location working and/or station keeping.

A summary of the consumption fuel factors from IoP for the relevant vessels used in this estimate has been given in Table AIII.4 below.

**Table AIII.4: Vessel average fuel consumption rates**

Vessel	Fuel Consumption (tonnes / day)	
	Sailing	Working
Tug	14	25
Flotel	40	30
Drill Ship (a)	22	18
Installation Vessel (b)	50	5
Multi-purpose Vessel	50	5
Platform Support Vessel	15	1.5

Note (a): Assumed Diving support vessel

Note (b): Assumed to be equivalent to an Anchor Haulage Vessel type

<sup>4</sup> IPCC, AR-5 Synthesis Report (Online) <https://www.ipcc.ch/report/ar5/syr/>

<sup>5</sup> CO<sub>2</sub> and sulphur emissions from the shipping industry (online) [LINK](#)

<sup>6</sup> IoP, Guidelines for the Calculation of Estimates of Energy use and Gaseous Emissions in the Decommissioning of Offshore Structures.

### AIII.1.5.7. Service Helicopter Flights

Emissions from the Helicopter flights were calculated as such:

$$E_{Flight} = \frac{Distance}{Speed} \times FuelRate \times 3.1 tCO_2/tonne \quad \text{Equation 6}$$

where

- *Distance* is the flight distance (miles);
- *Speed* is the average air speed of the helicopter (see below);
- *Fuel Rate* is the average fuel usage of the helicopter;
- 3.1 is the aviation emission factor (tCO<sub>2</sub>/tonne fuel)<sup>7</sup>.

Helicopter fuel and speed statistics were sourced from IoP guidance speed statistics for three types of common helicopter models as given in the table below.

The Sikorsky was chosen for this estimation as it represented the worst-case fuel economy out of the options provided.

**Table AIII.5: Helicopter fuel and flight speeds (IoP)**

Type	Speed (knots)	Speed (mph) <sup>(a)</sup>	Fuel Usage (ltr/h)
Sikorsky	120	138.1	625

Note a) Based on conversion of 1 knot = 1.15078 miles per hour (mph)

### AIII.1.5.8. Decommissioning Emissions

Decommissioning emissions were estimated in the same manner as installation, using known fuel rates and anticipated decommissioning schedule (See Section AIII.6.7) to determine fuel usage which can then be converted to CO<sub>2</sub> using the reference emission factor.

Decommissioning duration is assumed to only include the disconnection of the FLNG from the riser and cutting of the anchors. Recovery of subsea infrastructure is not included.

## AIII.1.6. Input Data

### AIII.1.6.1. Reference Data

The Coral North FLNG is a replicate of the Coral South FLNG and consequently, the Coral South data including prior studies are applicable to Coral North. Therefore, the following sections have used the Coral South documentation and information to supplement as inputs to the GHG and energy calculations for Coral North.

<sup>7</sup> Verifavia, How are Aircraft CO<sub>2</sub> emissions Calculated (online) <https://www.verifavia.com/greenhouse-gas-verification/fq-how-are-aircraft-co2-emissions-calculated-11.php>

### AIII.1.6.2. Operational Particulars

The following parameters have been used, as per the Project description (see Volume I):

- Lifetime LNG Production: 88.24 million tones;
- Project Lifetime: 25 years.

### AIII.1.6.3. Operational Scenarios

The assessment includes emissions from the following operational events:

- Commissioning & Start-up;
- Operation (holding);
- Operation (offloading);
- Annual maintenance;
- TAR: 1 per 3 years.

Coral North will operate with similar philosophy i.e., online machinery, loadings, durations, and schedule) as used for Coral South. Therefore, the operational philosophy for each event has been aligned with that given in the Coral South *Atmospheric Emissions Estimation Study*<sup>8</sup>, as detailed in the tables below.

**Table AIII.6: Commissioning and start-up**

Emitting Source	Fuel Type	Number and Loading	Loading	Efficiency	Run hours
			kW	%	hr
Gas Turbine Generators	Diesel	2 x 20%	6,000	20%	Unit 1: 1,752 Unit 2: 1,704
Gas Turbine Generators	Fuel Gas	3 x 80%	23,970	35.4	Unit 1: 1,848 Unit 2: 1,728 Unit 3: 1,584
MR1 / MR2 Compressors	Fuel Gas	2 x 75%	22,650	33.3	Unit 1: 2,256 Unit 2: 2,112
Essential Diesel Generator (EDG)	Diesel	2 x 100%	8,000	44%	Unit 1: 1,920 Unit 2: 2,088
CO <sub>2</sub> Incinerator	Fuel Gas & Waste Stream	1 x 50%			2,568
Flare	Intake Flow Rate				Duration
Flaring	Flaring start-up (unburnt raw gas and nitrogen with a flow rate of 80 MMSCFD)				24
	Flaring start-up (unburnt raw gas and nitrogen with a flow rate of 120 MMSCFD)				120
Raw Gas Flaring <sup>(Note a)</sup>	268,900 Nm <sup>3</sup> /h				1,776

**Note (a):** Raw gas flaring aligned with "Flare Scenario 2" as worst case emission wise.

<sup>8</sup> Technical Note Sustainability KPIS Calculation (000412\_DV\_EX.FAC.0682.000) Rev 05.

**Table AIII.7: Normal operation (holding)**

Emitting Source	Fuel Type	Number & Loading	Loading	Efficiency	Run hours
			kW	%	Hourly
Gas Turbine Generator	FG	3 x 70%	20,960	32.5%	6,934
MR1 Compressor	FG	2 x 100%	30,225	37.3%	6,934
MR2 Compressor	FG	2 x 100%	30,195	37.3%	6,934
CO <sub>2</sub> Incinerator	FG & Waste Stream	1 x 100%			6,934
Flares (Continuous Pilot and Purge)	Intake Flow Rate			Run hours	
	Nm <sup>3</sup> /h	kg/h		Hourly	
HP Flare 1	51.2	35.92		6,934	
HP Flare 2	83.6	58.65		6,934	
LP Flare 1	36.4	2.55		6,934	
LP Flare 2	29.7	20.84		6,934	
LLP Flare	21.6	15.15		6,934	

**Table AIII.8: Normal operation (offloading)**

Emitting Source	Fuel Type	Number & Loading	Loading	Efficiency	Run hours
			kW	%	Hourly
Gas Turbine Generator	Fuel Gas	4 x 80%	23,970	35.4%	1,300
MR1 Compressor	Fuel Gas	4 x 100%	30,225	37.3%	1,300
CO <sub>2</sub> Incinerator	FG & Waste Stream	1 x 100%			1,300
Flare (Continuous Pilot and Purge)	Intake Flow Rate			Run hours	
	Nm <sup>3</sup> /h	kg/h		Hourly	
HP	51.2	35.92		1,300	
HP	83.6	58.65		1,300	
LP	36.4	2.55		1,300	
LLP	29.7	20.84		1,300	
LP	21.6	15.15		1,300	

**Table AIII.9: Annual maintenance**

Emitting Source	Fuel Type	Number & Loading	Loading	Efficiency	Run hours
			kW	%	Hourly
Essential Diesel Gen.	Diesel	1 x 100%	2,600	35.4%	26
EDG	Diesel	3 x 100%	8,000	33.3%	26
Firewater Pump	Diesel	3 x 100%	1,765	40% (Note a)	26

Note a) 40% estimated to meet vendor emission rate

**Table AIII.10: Turn around (TAR)**

Emitting Source	Fuel Type	Number & Loading	Loading	Efficiency	Run hours
			kW	%	Hour/y
Gas Turbine Generator	Fuel Gas	2 x 80%	23,970	35.4%	672
MR1 Compressor	Fuel Gas	4 x 75%	22,670	33.3%	48
Essential Diesel Generator	Diesel	1 x 100%	8,000	44%	672
CO <sub>2</sub> Thermal Incinerator	FG & Waste Stream	1 x 50%			48
Flare	Flow Rate			Run hours	
	Nm <sup>3</sup> /h	kg/h		Hour/y	
HP Flare (20% production capacity)	33,554	23,541.01		48	
HP Flare (10% production capacity)	16,777	11,770.53		48	
HP Flare (80% production capacity)	134,215	94,163.57		48	
Process Unit gas emptying operation	10,399.6	--		72	

**AIII.1.6.2.1. Event Schedule**

Table AIII.11 shows the schedule used for the GHG estimation for the operational phase.

- TAR is given as a 3-year rolling cycle, assumed to commence from year 3;
- It is assumed that annual maintenance will be rolled into the TAR activities for each 3<sup>rd</sup> year to minimise downtime;
- Fugitives from the asset are considered continuous.

**Table AIII.11: Yearly schedule**

Emissions from	Year												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Start-up													
Operation													
Offloading													
TAR													
Annual Maintenance													
Fugitives													
Emissions from	14	15	16	17	18	19	20	21	22	23	24	25	
Start-up													
Operation													
Offloading													
TAR													
Annual Maintenance													
Fugitives													

### AIII.1.6.4. Fuel Parameters

The fuel and flare parameters have been given in Table AIII.12. Fuel and flare LHV's were calculated using the compositions given in Annex III.A. Due to the similarity of the flare compositions, Unit 360's flare composition and LHV has been assumed for all flare calculation emissions, chosen to produce a conservative estimation based on the slightly higher overall GHG emission (i.e., higher CH<sub>4</sub> emissions per kg flared). Emission factors are given in the following section.

Default diesel parameters were assumed (sourced from IPCC guidance) while the marine diesel and aviation fuel parameters were taken from IoP guidance as per Table AIII.12 below.

**Table AIII.12: Fuel parameters**

Fuel	Molar Weight (kg/kmol)	LHV (MJ/kg)
Fuel Gas	16.63	47.44
Flared Gas (unit 360)	16.61	49.56
Flared Gas (unit 335)	16.92	49.46
Diesel (note a)		45.60
Marine Diesel		43.10
Aviation Fuel		46.10

Note a) IPCC 2019 Guidance default value.

Note b) Preferred guidance value from IoP (Guidelines for the Calculation of Estimates of Energy use and Gaseous Emissions in the Decommissioning of Offshore Structures).

### AIII.1.6.5. Emission Factors

The emission factors per fuel type have been summarised in Table AIII.13. Emission factors have been calculated from provided compositions using the API mass balance approach unless otherwise noted. Emission factors for the Unit 360 flare has been used for all flare estimations due to the higher CH<sub>4</sub> content to form a more conservative estimation.

**Table AIII.13: Emission factors**

Source	CO <sub>2</sub> (kg/kg)	CH <sub>4</sub> (kg/TJ)	N <sub>2</sub> O (kg/TJ)
Fuel Gas	2.61	3.70 (note a)	1.29 (note a)
Diesel	3.19	3.0 (note b)	0.6 (note b)
Flare (unit 360)	2.68	376.67 (note c)	(Trace)
Flare (unit 335)	2.69	367.04 (note c)	(Trace)

Note (a): sourced from US-EPA AP-42, Chapter 3.1 for Gas Turbines. Original units CH<sub>4</sub>: 0.0086 lb/mmBTU; N<sub>2</sub>O: 0.0030 lb/mmBTU.

Note (b): sourced from IPCC 2019 Guidance, Chapter 2, Table 2.3.

Note (c): Calculated, based on 98% oxidation factor. 0.019 kgCH<sub>4</sub>/kg gas; LHV 49.56 MJ/kg.

### AIII.1.6.6. Fugitive Emissions

Fugitive emissions refer to the leaks from components on the pipelines such as valves, flanges, seals etc.. A fugitive emissions estimation was performed previously in the Coral South Atmospheric Emissions Estimation<sup>9</sup>. Due to the replicate design, it is anticipated Coral North will feature the same potential fugitive sources and therefore, the Coral South assessment for fugitive emissions has been used.

**Table AIII.14: Fugitive emission rates**

	Hourly Emissions (kg/h)			Assumed uptime
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	h/y
Fugitive Emissions	0	92.22	0	8,760

### AIII.1.6.7. Marine Vessel Utilisation

The vessel utilisation for each phase is given in Table AIII.15 below, based on the marine vessel spread and high-level schedule for the drilling and installation phases provided by MRV. The decommissioning vessel requirements and durations are based on experience from prior projects.

Coral North will be constructed in South Korea and towed to location in Mozambique using 5 tug vessels. Forty-five (45) days sailing has been assumed based on an approximate distance of 8,690 nautical miles with an 8-knot towing speed.

The support and/or construction vessels will be mobilised from Pemba, Mozambique. The estimation does not account for travel time to Pemba from their home berth.

The duration of the decommissioning has been aligned with experience from prior projects, based on a shorter “cut-and sail” removal of the FLNG vessel, where the subsea infrastructure is left *in situ*. Preparatory work is assumed to occur prior to onset of decommissioning phase by the operational crew.

**Table AIII.15: Vessel schedule**

Activity		No. Vessels	Duration	Combined Workdays
			Days/each	
Towing FLNG from Shipyard	Tug	5	45	225
Drilling and Installation	Drill Ship	1	200	200
	Installation Vessel	2	400	800
	Multi-purpose Vessel	1	400	400
	Tug (station keeping)	5	35	175
	Platform Supply Vessel (Note a)	3	57	171
Commissioning and Operation	Flotel (Commissioning only)	1	278	228
	Tug (station keeping)	3 (Note b)	9,125	27,375

<sup>9</sup> Coral South, Atmospheric Emissions Estimation, 4404GGBFEZ4003T, Rev 04.

Activity	No. Vessels	Duration	Combined Workdays	
		Days/each		
Platform Supply Vessel <sup>(Note a)</sup>	3	1,300	3,900	
Decommissioning	Installation Vessel	42	84	
	Flotel	42	42	
	Multi-Purpose Vessel	42	126	
	Tug (station keeping)	14 <sup>(Note c)</sup>	70	
	Platform Supply Vessel <sup>(Note a)</sup>	5	5	
Towing FLNG to local Port	Tug	5	2	10

Note a) assumes supply vessels make 1 round trip per week.

Note b) it is understood 6 tugs will be shared between North and South FLNGs, therefore assumed average 3 for Coral North

Note c) assumed 2 weeks station keeping as moorings are disconnected.

### AIII.1.6.8. Helicopter Flights

Flight requirements are calculated as per Table AIII.16 on the assumption of a standard 2-week shift period. Assuming 60 crew and flight capacity of 15 gives roughly four flights per shift.

For each flight, it is assumed the helicopter will mobilise from Pemba, at roughly 256 km (159 miles) distance. This equates to circa 2.3 hours flight time per round trip, based on the assumed flight speed of 138 miles per hour.

**Table AIII.16: Helicopter usage**

Phase	Basis	Duration (wks)	No. Shifts (2 wk shift)	Flights per shift	Total Return Flights
Drilling and Installation	4 Flights Per shift	57	28	4	112
Commissioning & Operation		1,300	650	4	2,600
Decommissioning		6	3	4	12

### AIII.1.7. Assumptions

A number of assumptions have been made in this assessment as highlighted in Table AIII.17.

**Table AIII.17: Assumptions used in the GHG assessment**

Aspect	Description
Emission Scopes	This assessment focuses on Scope 1 and upstream Scope 3 emissions (i.e., emissions from marine /support vessels). Coral North design does not include import of power hence Scope 2 emissions are not applicable.
Marine Vessels	All marine vessels will use Pemba as mobilisation base for the duration of the installation / decommissioning works. i.e., this assessment does not account for sailing time from home berths other than Pemba.

Aspect	Description
	Coral North will be constructed in South Korea shipyards and towed to Mozambique by 5 tug vessels.
Helicopter Flights	Flights originate from Pemba region (circa 256 km from site).
Decommissioning	Scope of decommissioning estimation ends when Coral North is returned to the decommissioning port. No allocation has been made for emissions arising from the dismantling and any other decommissioning activities
Operation	Maintenance – emissions have been estimated for annual emissions with annual maintenance planned for year 1 (start-up year) or any year coinciding with a TAR.
	Flaring Emissions- due to similar flaring compositions for the flares serving unit-360 flare and unit-335, the assessment used emission factors calculated for unit-360's composition and applied for all flaring emission estimates. The unit-360 flare was chosen due to slightly higher GHG potential (higher CH <sub>4</sub> emissions) to achieve a conservative estimation of flare emissions.
	Start-up Flaring – there are two scenarios for flaring start-up. For a conservative estimate this assessment has aligned with Scenario 2 (40% capacity of single well) as this is the highest flare rate of the two.
	Fire Water Pump (FWP) – the motor efficiency of the FWP is unknown, therefore 40% has been estimated to meet anticipated emission rate levels. As the FWP would only be used for handful of hours each year during maintenance, this assumption will not overly alter the estimation.
	Fugitive Emissions – Estimation of fugitive emission contribution was aligned with the Coral South study. For a conservative estimation of these emissions, fugitive rates are considered continuous throughout the year (i.e., 8,760 hours per year) regardless of facility operational phase.
Exclusions	Unplanned events – Due to the nature of these events, emissions arising from unplanned events were not included within the baseline emissions assessment.
	Downstream Scope 3 Emissions (end user) have been excluded on the basis that those fall outside the remit of MRV to manage.

## AIII.2. Results

### AIII.2.1. Energy Consumption

#### AIII.2.1.1. Preamble

This section summarises the energy requirements of the Coral North project during operations. As energy in traditional units of Joules is a conceptual measurement, it is more common to discuss energy in terms of relevant material quantities, such as tonnages of fuel. Therefore, this section provides both units of measurement.

#### AIII.2.1.2. Energy Requirements by Operational Mode

The Coral North FLNG fuel and energy requirements per mode of operation and/or event have been summarised in Table AIII.18 below.

**Table AIII.18: Annual fuel and energy per mode of operation**

Mode	Fuel Gas	Diesel	Annual Energy Intake
	t/y	t/y	TJ
Start-up (1st year only)	49,650.28	13,938.37	2,990.82
Operation (Holding)	275,610.42	-	13,073.94
Operation (Offloading)	59,321.12	-	2,813.98
Turnaround (1 per 3 years)	7,909.92	964.59	419.20
Annual Maintenance	-	151.26	6.90

During standard operation, fuel gas requirements range from 334.9 kt to 342.8 kt per year, with the higher value associated with the TAR years. Similarly, diesel requirements range from 0.15 kt (no TAR) to 0.96 kt (with TAR) per year.

### AIII.2.1.3. Support Vessel and Flights Fuel by Project Phase

The fuel usage for the marine vessels and helicopter flights during each of the phases is provided in Table AIII.19 below, based on the schedule/spread of vessels given in Table AIII.15 and flights of Table AIII.16. During operations, it is estimated 17.9 kt of marine diesel and 125 t aviation fuel will be used per year for the supply/support vessels and flights respectively.

**Table AIII.19: Support vessel and flight fuel usage**

Phase	Source	Usage
		t
Drilling and Installation	Vessels	27,696
	Flights	134.4
Commissioning and Operation	Vessels	448,590
	Flights	3,119.4
Decommissioning	Vessels	6,795
	Flights	14.4

### AIII.2.1.4. Operation Lifetime Consumption

Based on the operational schedule (Table AIII.11), lifetime fuel requirements for Coral North have been calculated and presented in Table AIII.20 below for each project phase. Support vessel and flight fuel requirements have been presented in Table AIII.21.

Across the project life, including start-up activities, Coral North is estimated to consume circa 8.49 million tonnes (MMt) of fuel gas and 24.1 kilotonnes (kt) diesel. Based on the LHV's given in Table, the overall energy intake has been estimated to be 403,653 Terajoules (TJ) across the Project life.

During start-up, Coral North will be relying on diesel as the primary fuel source (in the GTGs and EDG). This results in a significant volume of diesel (circa 13.9 kt) being used in a short period of time, equivalent to 137% normal operational diesel requirements.

**Table AIII.20: Fuel requirements summary**

Event	Annual Requirements (kt/y)		Lifetime Events	Operational Lifetime (kt)	
	Fuel Gas	Diesel		Fuel Gas	Diesel
Start-up (1st year only)	49.65	13.94	1	49.65	13.94
Operation (Holding)	275.61	-	25	6,890.26	
Operation (Offloading)	59.32		25	1,483.03	
Turnaround (1 per 3 years)	7.91	0.96	8	63.28	7.72
Annual Maintenance <sup>(note a)</sup>	0	0.15	16	0	2.42
All inclusive (Start-up, operation, TAR, maintenance)			Total Fuel (kt)	8,486.2	24.1
			Energy by fuel (TJ)	402,554.9	1,097.8
			Total Energy (TJ)	<b>403,652.7</b>	
Excluding Start-up year			Total Fuel (kt)	8,101.6	10.1
			Energy by fuel (TJ)	384,311.7	480.9
			Total Energy (TJ)	<b>384,792.6</b>	

Note a) Estimate assumes annual maintenance is not needed on year 1, nor years with TAR i.e., 16 occurrences

Based on the high-level estimation for support vessel usage (tugs and supply ships), it is estimated approximately 449 kt of marine diesel will be used across the project 25-year lifetime. Similarly, ~3 kt of aviation fuel will be used for crew flights.

**Table AIII.21: Support vessel and flight fuel requirements during operations**

Source	Annual Usage		Operational Lifetime	
	Tonnes	Energy (TJ)	kt	TJ
Support/Supply Vessels	17,943.6	818.2	448.6	20,455.7
Helicopter Flights	124.8	172.8	3.1	134.5
			<b>Total Energy</b>	<b>20,590.2</b>

## AIII.2.2. Project GHG Emissions

### AIII.2.2.1. Overview

Overall project GHG emissions across all phases are anticipated to be around 26.5 MMt of CO<sub>2e</sub>, with the operational phase accounting for circa 99.6% of the total. The remaining 0.4% (0.11 MMt CO<sub>2e</sub>) is associated with drilling, installation, and decommissioning.

The table below summarises the contribution of each phase of the project to the overall GHG estimation. Each phase is considered in more detail with the breakdown of emissions, in the following sections.

**Table AIII.22: Lifetime emission summary**

Phase	ktCO <sub>2e</sub>
Drilling & Installation <sup>(note a)</sup>	91.9
Commissioning & Operation	26,374.3
Decommissioning	22.8
<b>Total Emissions</b>	<b>26,489.0</b>

*Note a) includes emissions from towing FLNG from shipyard to Mozambique.*

### AIII.2.2.2. Drilling, Installation, and Decommissioning

It is estimated drilling and installation will account for circa 92 ktCO<sub>2</sub> emissions while decommissioning will generate just short of 23 ktCO<sub>2</sub>. Table AIII.23 gives a high-level summary of the emissions during these phases. Detailed supporting calculation sheets have been included as part of Annex III.B.

**Table AIII.23: Drilling, Installation, and Decommissioning emissions**

Source	Emissions (tCO <sub>2</sub> )	
	Drilling & Installation	Decommissioning
Marine Vessel	91,520.7	22,732.2
Helicopter	427.4	45.8
<b>TOTAL</b>	<b>91,948.1</b>	<b>22,778</b>

### AIII.2.2.3. Operational Phase

#### AIII.2.2.3.1. Overview

Emissions from the Coral North 25-year operations have been estimated to be circa 26.4 MMtCO<sub>2e</sub> with circa 1.5 MMtCO<sub>2e</sub> attributed to Scope 3 based on anticipated vessel/helicopter fuel requirements during operation (Table AIII.24). A breakdown by constitute gas has been provided in the table below.

**Table AIII.24: Overall operational emissions**

Scope	Life-time Emissions kt			
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>
Scope 1	24,068.4	24.42	0.51	24,888.3
Scope 3 (note a)				1,486.0
<b>Total</b>	<b>24,068.4</b>	<b>24.42</b>	<b>0.51</b>	<b>26,374.3</b>

*Note a) Scope 3 based on emission factors provided as combined CO<sub>2e</sub>, therefore it is not possible to provide breakdown by constitute GHG.*

### AIII.2.2.3.2. Breakdown by Mode of Operation (Scope 1)

A breakdown of the Scope 1 contribution by each mode of operation has been given in the following table. Emissions during each phase have been further broken down to each point source in the tables of Annex III.B.

**Table AIII.24: Scope 1 emissions by mode of operation**

	Annual (kt)				Lifetime (kt)			
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>
Start-up (1st year only)	1,175.24	1.32	0.00	1,213.08	1,175.2	1.32	0.00	1,213.1
Operation (Holding)	742.69	0.06	0.02	748.93	18,567.3	1.62	0.42	18,732.2
Operation (Offloading)	159.21	0.01	0.00	160.54	3,980.2	0.34	0.09	4,013.5
Turnaround (1 per 3 years)	42.23	0.12	0.00	45.67	337.8	0.94	0.00	365.4
Annual Maintenance <small>(note a)</small>	0.48	0.00	0.00	0.48	7.7	0.00	0.00	7.7
Fugitives (continuous)	-	0.81	-	22.62	0.0	20.20	-	565.5
<b>TOTAL</b>					<b>24,068.4</b>	<b>24.42</b>	<b>0.51</b>	<b>24,888.3</b>

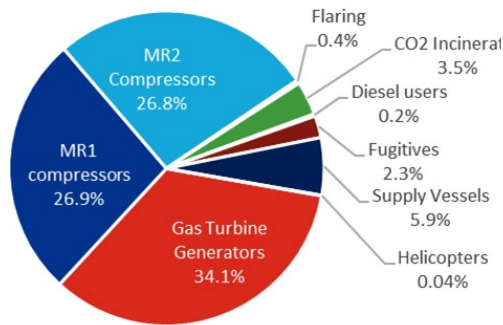
*Note a) Lifetime estimate assumes annual maintenance is not needed on year 1, nor years with TAR i.e., 16 occurrences of annual maintenance over 25 years.*

### AIII.2.2.3.3. Annual Operational Emissions

Emissions during normal operation (including Holding, Offloading, Maintenance, Fugitives and supply/support vessels and flights) is estimated to be 992 ktCO<sub>2e</sub>/y which increases to 1,037 ktCO<sub>2e</sub>/y on years with scheduled TAR. The relative contribution from the emissions sources during operation are shown in the figures below for years without TAR (Figure AIII.2) and years with TAR (Figure AIII.3). Both are quite similar, with the main differences being an increased contribution from flaring and diesel use contribution during TAR.

The primary source of emissions is the Gas Turbine Generators and MR1 and MR2 Gas Turbine Compressors which account for greater than 90% of GHG emissions from the facility.

Operational GHG Emissions (no TAR)  
Relative Contribution



Operational GHG Emissions (with TAR)  
Relative Contribution

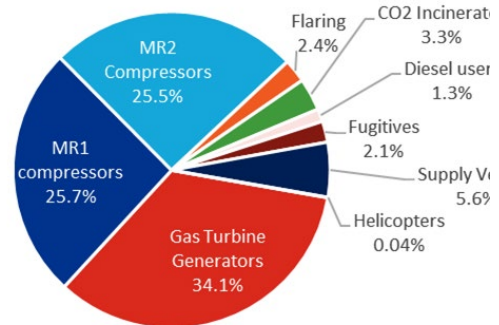


Figure AIII.1: Source Contribution – No TAR year

Figure AIII.2: Source Contribution – year with TAR

#### AIII.2.2.3.4. Carbon Intensity

The average carbon intensity metric in kgCO<sub>2e</sub>/tonne product and kgCO<sub>2e</sub>/BOE LNG across project operational life has been calculated as per table below. The evolution of the metric over time is shown in Figure AIII.4. The carbon intensity in year 1 is significantly higher as consequence of the start-up and commissioning activities. Through years 2-25 the intensity fluctuates slightly as response to changes in annual production and whether the year includes a TAR or not.

Table AIII.25: Carbon intensity

	CO2 Emissions (MMt)	LNG Production		Carbon Intensity (average)	
		MMt	MMBOE	kgCO <sub>2e</sub> /tonne LNG	kgCO <sub>2e</sub> /BOE <sup>(a)</sup>
Carbon Intensity	24.89	88.24	838.28	282.1	29.7

Note (a) based on conversion of 1 tonne LNG = ~9.5 BOE

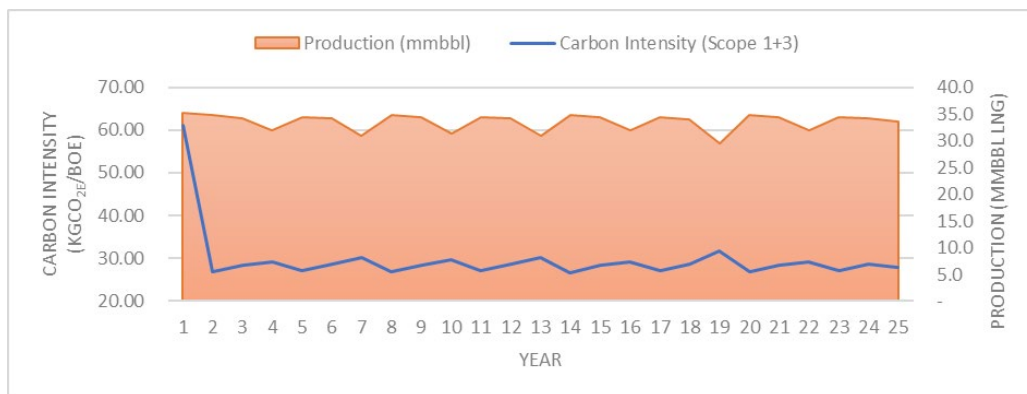


Figure AIII.4: Carbon intensity by year

## Annex III.A – Compositional Data

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The following compositions were used for the fuel gas flares. The compositional data was sourced from the Technical Note Sustainability KPIS Calculation<sup>10</sup>. Parameters of molar weight, heating value and CO<sub>2</sub> emission factor have been calculated here.

Due to the similarity of the flare compositions, Unit 360's flare composition has been used for all flare calculation emissions based on the slightly higher overall GHG emission (i.e., higher CH<sub>4</sub> emissions per kg flared) to produce a conservative estimation.

**Table III.A.1: Fuel gas composition and parameters**

Component	Mol %		
	Fuel Gas	Unit 360 Flare	Unit 335 Flare
Methane	96.21	96.68	95.74
Ethane	0.44	2.27	2.5
Propane	0.19	0.6	0.93
n-Butane	0.08	0.1	0.39
iso-pentane	0.02	0	0.1
n-Hexane	0.05	0	0
n-Heptane	0.01	0	0
n-Octane	0	0	0
n-Nonane	0.02	0	0
Carbon Dioxide	0	0.01	0.01
Nitrogen	2.99	0.34	0.34
Hydrogen Sulfide	0	0	0
Calculated Parameters			
Molar Weight (kg/kmol)	16.63	16.61	16.92
LHV (MJ/kg)	47.44	49.56	49.46
CO <sub>2</sub> Emission factor (kg/kg)	2.61	2.68	2.69
CH <sub>4</sub> Emission Factor (kg/kg)	Note a	0.019	0.018

Note a) Not calculated - API stoichiometric calculation approach assumes 100% combustion for non-flare sources (i.e., complete conversion to CO<sub>2</sub>). Therefore, CH<sub>4</sub> emission factor from guidance are applied.

<sup>10</sup> Technical Note Sustainability KPIS Calculation (000412\_DV\_EX.FAC.0682.000) Rev 05.

## Annex III.B – GHG Calculation Tables

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### AIII.B.1 - Operational Phase Calculation Tables

#### Operations: Holding

Source	Fuel	LHV (MJ/kg)	Loading (%)	Loading (kW)	Efficiency (%)	Heat Intake (MJ/h)	Fuel Consumpti on (kg/h)	Annual Uptime (h/y)	Emission Factors			Hourly Emissions (kg/h)				Annual Emissions (ktonnes)				
									CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>	
Gas Turbine Generator	Fuel Gas	47.44	70%	20,960	32.5%	232,172	4,894	6,934	33,938	2.61	3.697	1.290	12,776.87	0.86	0.30	12,880.2	88.59	0.01	0.00	89.31
Gas Turbine Generator	Fuel Gas	47.44	70%	20,960	32.5%	232,172	4,894	6,934	33,938	2.61	3.697	1.290	12,776.87	0.86	0.30	12,880.2	88.59	0.01	0.00	89.31
Gas Turbine Generator	Fuel Gas	47.44	70%	20,960	32.5%	232,172	4,894	6,934	33,938	2.61	3.697	1.290	12,776.87	0.86	0.30	12,880.2	88.59	0.01	0.00	89.31
MR1 Compressor	Fuel Gas	47.44	100%	30,225	37.3%	291,716	6,150	6,934	42,642	2.61	3.697	1.290	16,053.66	1.08	0.38	16,183.5	111.32	0.01	0.00	112.22
MR1 Compressor	Fuel Gas	47.44	100%	30,225	37.3%	291,716	6,150	6,934	42,642	2.61	3.697	1.290	16,053.66	1.08	0.38	16,183.5	111.32	0.01	0.00	112.22
MR2 Compressor	Fuel Gas	47.44	100%	30,195	37.3%	291,426	6,144	6,934	42,599	2.61	3.697	1.290	16,037.73	1.08	0.38	16,167.5	111.21	0.01	0.00	112.11
MR2 Compressor	Fuel Gas	47.44	100%	30,195	37.3%	291,426	6,144	6,934	42,599	2.61	3.697	1.290	16,037.73	1.08	0.38	16,167.5	111.21	0.01	0.00	112.11
HP Flare	Flare	49.56				1,780	36	6,934	249	2.68	376.67	-	96.45	0.67	-	115.2	0.67	0.00	-	0.80
HP Flare	Flare	49.56				2,907	59	6,934	407	2.68	376.67	-	157.48	1.09	-	188.1	1.09	0.01	-	1.30
LP Flare	Flare	49.56				127	3	6,934	18	2.68	376.67	-	6.86	0.05	-	8.2	0.05	0.00	-	0.06
LP Flare	Flare	49.56				751	15	6,934	105	2.68	376.67	-	40.69	0.28	-	48.6	0.28	0.00	-	0.34
LLP Flare	Flare	49.56				1,033	21	6,934	144	2.68	376.67	-	55.95	0.39	-	66.8	0.39	0.00	-	0.46
CO2 Incinerator	Fuel Gas	47.44	100%			22,682	478.2	6,934	3,316				4,238.07			4,238.1	29.39			29.39
	Waste Streams								0											
<b>TOTAL</b>													107,108.88	9.37	2.40	108,007.83	742.69	0.06	0.02	748.93

	Emission Factors			
	LHV (MJ/kg)	CO <sub>2</sub> (kg/kg)	CH <sub>4</sub> (kg/TJ)	N <sub>2</sub> O (kg/TJ)
Fuel Gas (Turbines)	47.44	2.61	3.7	1.3
Diesel	45.60	3.19	3.0	0.6
Flare	49.56	2.68	376.67	0.0

CH<sub>4</sub> and N<sub>2</sub>O from US-EPA AP42  
CH<sub>4</sub> and N<sub>2</sub>O from IPCC  
N<sub>2</sub>O from IPCC

	Flare Rate Conversions		
	Vol flow (Nm <sup>3</sup> /h)	Density (kg/Nm <sup>3</sup> )	Flow (kg/h)
HP	51.2	0.70	35.92
HP	83.6	0.70	58.65
LP	3.64	0.70	2.55
LLP	29.7	0.70	20.84
LP	21.6	0.70	15.15

Startup

Source	Fuel	LHV (MJ/kg)	Loading (%)	Loading (kW)	Efficiency	Heat Intake	Fuel Consumption	Annual Uptime	Fuel	Emission Factors			Hourly Emissions (kg/h)			Annual Emissions (ktonnes)				
										CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>
		MJ/kg	%	kW	%	MJ/h	kg/h	h/y	t/y	kg/kg	kg/TJ	kg/TJ								
Gas Turbine Generator A	Diesel	45.60	20%	6,000	20.0%	108,000	2,368	1,752	4,149	3.19	3.00	0.600	7,546.50	0.32	0.06	7,572.7	13.22	0.00	0.00	13.27
Gas Turbine Generator B	Diesel	45.60	20%	6,000	20.0%	108,000	2,368	1,704	4,036	3.19	3.00	0.600	7,546.50	0.32	0.06	7,572.7	12.86	0.00	0.00	12.90
Gas Turbine Generator A	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	1,848	9,496	2.61	3.70	1.290	13,414.71	0.90	0.31	13,523.2	24.79	0.00	0.00	24.99
Gas Turbine Generator B	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	1,728	8,880	2.61	3.70	1.290	13,414.71	0.90	0.31	13,523.2	23.18	0.00	0.00	23.37
Gas Turbine Generator C	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	1,584	8,140	2.61	3.70	1.290	13,414.71	0.90	0.31	13,523.2	21.25	0.00	0.00	21.42
MR1 Compressor	Fuel Gas	47.44	75%	22,650	33.3%	244,571	5,156	2,256	11,631	2.61	3.70	1.290	13,459.20	0.90	0.32	13,568.1	30.36	0.00	0.00	30.61
MR2 Compressor	Fuel Gas	47.44	75%	22,650	33.3%	244,571	5,156	2,112	10,889	2.61	3.70	1.290	13,459.20	0.90	0.32	13,568.1	28.43	0.00	0.00	28.66
EDG-1	Diesel	45.60	100%	8,000	44.0%	65,455	1,435	1,920	2,756	3.19	3.00	0.600	4,573.64	0.20	0.04	4,589.5	8.78	0.00	0.00	8.81
EDG-2	Diesel	45.60	100%	8,000	44.0%	65,455	1,435	2,088	2,997	3.19	3.00	0.600	4,573.64	0.20	0.04	4,589.5	9.55	0.00	0.00	9.58
CO2 Incinerator	Fuel Gas	47.44	50%			11,341	239.1	2,568	614	N/A - Aligned with Air Emissions Estimation Summary 4404GGBFEZ4003T			2,119.04			2,119.0	5.44			5.44
Flaring Startup (80 MMSCFD)	Waste Streams							24		N/A - Aligned with Air Emissions Estimation Summary 4404GGBFEZ4003T			179,579.00	319.69	-	188,530.4	4.31	0.01	-	4.52
Flaring Startup (120 MMSCFD)								120		N/A - Aligned with Air Emissions Estimation Summary 4404GGBFEZ4003T			269,361.00	479.00		282,773.0	32.32	0.06	-	33.93
<b>Flaring - Scenario 1</b>																				
Raw Gas Flaring (20% flow rate capacity of 1 well)								768		N/A - Aligned with flaring estimate provided in Air Emissions Summary 4404GGBFEZ4003T			258,948.00	461.00		271,856.0	198.87	0.35	-	208.79
Dry gas Flaring (40% of flow rate capacity of 1 well)								1,008		N/A - Aligned with flaring estimate provided in Air Emissions Summary 4404GGBFEZ4003T			519,365.77	461.50		532,287.8	523.52	0.47	-	536.55
<b>Flaring - Scenario 2</b>																				
Raw Gas Flaring (40% flow rate capacity of 1 well)								768		N/A - Aligned with flaring estimate provided in Air Emissions Summary 4404GGBFEZ4003T			569,305.00	1,013.50		597,683.0	437.23	0.78	-	459.02
Dry gas Flaring (40% of flow rate capacity of 1 well)								1,008		N/A - Aligned with flaring estimate provided in Air Emissions Summary 4404GGBFEZ4003T			519,365.77	461.50		532,287.8	523.52	0.47	-	536.55

TOTAL (with Scen1 Flaring)	1,320,775.62	1,726.75	1.78	1,369,596.72	936.89	0.89	0.00	962.84
TOTAL (with Scen2 flaring)	1,631,132.62	2,279.25	1.78	1,695,423.72	1,175.24	1.32	0.00	1,213.08

	LHV	Emission Factors			
		CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	
	MJ/kg	kg/kg	kg/TJ	kg/TJ	
Fuel Gas (Turbines)	47.44	2.61	3.7	1.3	CH <sub>4</sub> and N <sub>2</sub> O from US-EPA AP42
Diesel	45.60	3.19	3.0	0.6	CH <sub>4</sub> and N <sub>2</sub> O from IPCC
Flare	49.56	2.68	376.669	0.0	N <sub>2</sub> O from IPCC

### Operations: Annual Maintenance

Source	Fuel	LHV (MJ/kg)	Loading (%)	Loading (kW)	Efficiency (%)	Heat Intake (MJ/h)	Fuel Consumption (kg/h)	Annual Uptime (h/y)	Fuel (t/y)	Emission Factors			Hourly Emissions (kg/h)				Annual Emissions (ktonnes)			
										CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>
										kg/kg	kg/TJ	kg/TJ								
Essential Diesel Gen.	Diesel	45.60	100%	2,600	44.0%	21,273	467	26	12.1	3.19	3.000	0.600	1,486.43	0.06	0.01	1,491.6	0.04	0.00	0.00	0.04
EDG 1	Diesel	45.60	100%	8,000	44.0%	65,455	1,435	26	37.3	3.19	3.000	0.600	4,573.64	0.20	0.04	4,589.5	0.12	0.00	0.00	0.12
EDG 2	Diesel	45.60	100%	8,000	44.0%	65,455	1,435	26	37.3	3.19	3.000	0.600	4,573.64	0.20	0.04	4,589.5	0.12	0.00	0.00	0.12
EDG 3	Diesel	45.60	100%	8,000	44.0%	65,455	1,435	26	37.3	3.19	3.000	0.600	4,573.64	0.20	0.04	4,589.5	0.12	0.00	0.00	0.12
Firewater Pump 1	Diesel	45.60	100%	1,765	40.0%	15,885	348	26	9.1	3.19	3.000	0.600	1,109.96	0.05	0.01	1,113.8	0.03	0.00	0.00	0.03
Firewater Pump 2	Diesel	45.60	100%	1,765	40.0%	15,885	348	26	9.1	3.19	3.000	0.600	1,109.96	0.05	0.01	1,113.8	0.03	0.00	0.00	0.03
Firewater Pump 3	Diesel	45.60	100%	1,765	40.0%	15,885	348	26	9.1	3.19	3.000	0.600	1,109.96	0.05	0.01	1,113.8	0.03	0.00	0.00	0.03
<b>TOTAL</b>													18,537.23	0.80	0.16	18,601.70	0.48	0.00	0.00	0.48

	Emission Factors				
	LHV	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	
	MJ/kg	kg/kg	kg/TJ	kg/TJ	
Fuel Gas (Turbines)	47.44	2.61	3.7	1.3	CH <sub>4</sub> and N <sub>2</sub> O from US-EPA AP42
Diesel	45.60	3.19	3.0	0.6	CH <sub>4</sub> and N <sub>2</sub> O from IPCC
Flare	49.56	2.68	376.669	0.0	N <sub>2</sub> O from IPCC

**Operations: Turnaround - 1-per 3 year**

Source	Fuel	LHV (MJ/kg)	Loading (%)	Loading (kW)	Efficiency (%)	Heat Intake (MJ/h)	Fuel Consumption (kg/h)	Annual Uptime (h/y)	Fuel (t/y)	Emission Factors			Hourly Emissions (kg/h)				Annual Emissions (ktonnes)			
										CO <sub>2</sub> (kg/kg)	CH <sub>4</sub> (kg/TJ)	N <sub>2</sub> O (kg/TJ)	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>
Gas Turbine Generator 1	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	672	3,453	2.61	3.697	1.290	13,414.71	0.90	0.31	13,523.2	9.01	0.00	0.00	9.09
Gas Turbine Generator 2	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	672	3,453	2.61	3.697	1.290	13,414.71	0.90	0.31	13,523.2	9.01	0.00	0.00	9.09
MR1 Compressor 1	Fuel Gas	47.44	75%	22,670	33.3%	245,081	5,167	48	248	2.61	3.697	1.290	13,487.27	0.91	0.32	13,596.4	0.65	0.00	0.00	0.65
MR1 Compressor 2	Fuel Gas	47.44	75%	22,670	33.3%	245,081	5,167	48	248	2.61	3.697	1.290	13,487.27	0.91	0.32	13,596.4	0.65	0.00	0.00	0.65
MR1 Compressor 3	Fuel Gas	47.44	75%	22,670	33.3%	245,081	5,167	48	248	2.61	3.697	1.290	13,487.27	0.91	0.32	13,596.4	0.65	0.00	0.00	0.65
MR1 Compressor 4	Fuel Gas	47.44	75%	22,671	33.3%	245,092	5,167	48	248	2.61	3.697	1.290	13,487.86	0.91	0.32	13,597.0	0.65	0.00	0.00	0.65
EDG	Diesel	45.60	100%	8,000	44.0%	65,455	1,435	672	965	3.19	3.000	0.600	4,573.64	0.20	0.04	4,589.5	3.07	0.00	0.00	3.08
HP Flare (20% well capacity)	Flare	49.56				1,166,656	23,541	48	1,130	2.68	376.7	0.0000	63,205.80	439.44	-	75,510.2	3.03	0.02	-	3.62
HP Flare (10% well capacity)	Flare	49.56				583,328	11,771	48	565	2.68	376.7	0.0000	31,602.90	219.72	-	37,755.1	1.52	0.01	-	1.61
HP Flare (80% well capacity)	Flare	49.56				4,666,588	94,164	48	4,520	2.68	376.7	0.0000	252,821.30	1,757.76	-	302,038.6	12.14	0.08	-	14.50
CO2 Incinerator	Fuel Gas	47.44	50%			11,341	239.1	48	11				2,119.04			2,119.0	0.10	-	-	0.10
	Waste Streams																			
<b>Other Items</b>																				
Process Unit Gas Flaring	Flare							72					24,298.41	6.84		24,490.0	1.75	0.00	-	1.76
<b>TOTAL</b>											459,400.17	2,429.39	1.93	527,935.12	42.23	0.12	0.00	45.67		

**Operations: Offloading**

Source	Fuel	LHV (MJ/kg)	Loading (%)	Loading (kW)	Efficiency (%)	Heat Intake (MJ/h)	Fuel Consumption (kg/h)	Annual Uptime (h/y)	Fuel (t/y)	Emission Factors			Hourly Emissions (kg/h)				Annual Emissions (ktonnes)			
										CO <sub>2</sub> (kg/kg)	CH <sub>4</sub> (kg/TJ)	N <sub>2</sub> O (kg/TJ)	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO <sub>2e</sub>
Gas Turbine Generator 1	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	1,300	6,680	2.61	3.697	1.290	13,414.71	0.90	0.31	13,523.2	17.44	0.00	0.00	17.58
Gas Turbine Generator 2	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	1,300	6,680	2.61	3.697	1.290	13,414.71	0.90	0.31	13,523.2	17.44	0.00	0.00	17.58
Gas Turbine Generator 3	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	1,300	6,680	2.61	3.697	1.290	13,414.71	0.90	0.31	13,523.2	17.44	0.00	0.00	17.58
Gas Turbine Generator 4	Fuel Gas	47.44	80%	23,970	35.4%	243,763	5,139	1,300	6,680	2.61	3.697	1.290	13,414.71	0.90	0.31	13,523.2	17.44	0.00	0.00	17.58
MR1 Compressor1	Fuel Gas	47.44	100%	30,225	37.3%	291,716	6,150	1,300	7,995	2.61	3.697	1.290	16,053.66	1.08	0.38	16,183.5	20.87	0.00	0.00	21.04
MR1 Compressor2	Fuel Gas	47.44	100%	30,225	37.3%	291,716	6,150	1,300	7,995	2.61	3.697	1.290	16,053.66	1.08	0.38	16,183.5	20.87	0.00	0.00	21.04
MR2 Compressor 1	Fuel Gas	47.44	100%	30,225	37.3%	291,716	6,150	1,300	7,995	2.61	3.697	1.290	16,053.66	1.08	0.38	16,183.5	20.87	0.00	0.00	21.04
MR2 Compressor 2	Fuel Gas	47.44	100%	30,225	37.3%	291,716	6,150	1,300	7,995	2.61	3.697	1.290	16,053.66	1.08	0.38	16,183.5	20.87	0.00	0.00	21.04
HP Flare	Flare	49.56				1,780	36	1,300	47	2.68	376.67	0.0000	96.45	0.67	-	115.2	0.13	0.00	-	0.15
HP Flare	Flare	49.56				2,907	59	1,300	76	2.68	376.67	0.0000	157.48	1.09	-	188.1	0.20	0.00	-	0.24
LP Flare	Flare	49.56				127	3	1,300	3	2.68	376.67	0.0000	6.86	0.05	-	8.2	0.01	0.00	-	0.01
LP Flare	Flare	49.56				751	15	1,300	20	2.68	376.67	0.0000	40.69	0.28	-	48.6	0.05	0.00	-	0.06
LLP Flare	Flare	49.56				1,033	21	1,300	27	2.68	376.67	0.0000	55.95	0.39	-	66.8	0.07	0.00	-	0.09
CO2 Incinerator	Fuel Gas	47.44				22,682	478.2	1,300	622				4,238.07			4,238.1	5.51	-	-	5.51
	Waste Streams		100%																	
<b>TOTAL</b>											122,468.98	10.40	2.76	123,492.20	159.21	0.01	0.00	160.54		

## AIII.B.2 – Installation and Decommissioning Estimate

### Sea Vessel Fuel Estimation

Phase	Activity		Duty	No. Vessels	Duration	Combined Work Days	Vessel Fuel Rate	Fuel Usage	CO2 Factor	CO2	Comment
					Days/each vessel		tonnes/day	tonnes	t/ftuel	tonnes	
Drilling and Installation	Transfer of FLNG to Mozambique	Tug	Transit	5	45.0	225.0	14	3,150	3.16	9,954	based on ~8690 nautical mile distance (South Korea to Mozambique) and towing speed of 8 knots
	Onsite Drilling and Installation works	Drill Ship	Working	1	200	200	18	3,600	3.16	11,376	
		Installation Vessel	Working	2	400	800	5	4,000	4.16	16,640	
		Multi-Purpose Vessel	Working	1	400	400	25	10,000	3.16	31,600	
	FLNG onsite, awaiting Mooring	Tug	Working	5	35.0	175.0	25	4,375	3.16	13,825	Tugs stationkeeping during mooring of FLNG
Supply Runs	Platform Supply Vessel	Transit	3	57	171	15	2,571	3.16	8,126	Assume 1 supply run per vessel per week, with 1 day round trip	
<b>TOTAL</b>								<b>27,696</b>		<b>91,521</b>	

Commissioning and Operation	Commissioning	Floater	Working	1	228	228.0	30	6,840	3.16	21,614	Assumed required for full commissioning phase
	Standard Operation	Tug	Transit	3	9125	27375	14	383,250	3.16	1,211,070	Assume "transit" rate as not hauling - noted 6 tugs shared between Coral South/North, therefore assumed 3 each FLNG on average
		Platform Supply Vessel	transit	3	1300	3900	15	58,500	4.16	243,360	Assume weekly sailings
<b>TOTAL</b>								<b>448,590</b>		<b>1,476,044</b>	

Decommissioning	Unhooking Activities Assumed 6 weeks total including subsea work	Installation Vessel	Working	2	42	84	5	420	3.16	1,327	
		Floater	Working	1	42	42	30	1,260	4.16	5,242	
		Multi-Purpose Vessel	Working	3	42	126	25	3,150	3.16	9,954	
		Tug	Working	5	14	70	25	1,750	3.16	5,530	used for station keeping before removal
	Supply Runs	Platform Supply Vessel	Transit	1	5	5	15	75	3.16	237	Assume 1 supply run per week
	Transport FLNG to local harbor	Tug	Transit	5	2.0	10.0	14.0	140	3.16	442	Assumed Facility will end up in nearby major port prior to deconstruction. 2 x tug towing FLNG to Pemba
<b>TOTAL</b>								<b>6,795</b>		<b>22,732</b>	

### Helicopter Fuel Estimation

Fuel	Aviation Jet Fuel	
Fuel Rate	620	ltr/h
Fuel Density	0.84	kg/ltr
Fuel Mass Rate	0.5208	t/h

Data From IoP Guidance

Note - Sikorsky taken as represents worst-case in terms of speed and fuel usage

Helicopter Speed	138.1	mph
------------------	-------	-----

Data From IoP Guidance

Mobilisation point	Pemba	
Distance	256	km
	159.1	miles
Round Trip	318.1	miles

assumed

Flight Duration	2.304	hrs
-----------------	-------	-----

Assumes top speed

Phase	Basis	Duration (wks)	No. Shifts (2 wk)	Flights per shift	Total Flights	Cumulative Flight time (hr)	Fuel Use (t)	CO <sub>2</sub> Factor (t/fuel)	CO <sub>2</sub> (tonnes)	Notes
Drilling and Installation	60 POB. 4 Flights Per shift	57	28	4	112	258.02	134.4	3.18	427.4	assumes capacity of 16
Commissioning & Operation	4 Flights per shift	1300	650	4	2600	5989.64	3119.4	3.18	9,922.8	
Decommissioning	60 POB. 4 Flights Per shift	6	3	4	12	27.64	14.4	3.18	45.8	assumes capacity of 16

## Annex IV – Air Dispersion Modelling

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## AIV.1. Modelling Methodology

### AIV.1.1. Air Dispersion Model

CALPUFF is a multi-layer, multi-species non-steady state Gaussian puff dispersion model that simulates the effects of time and space-varying meteorological conditions on pollution transport, transformation, and removal<sup>11</sup>. This integrated modelling system comprises three main components, CALMET, CALPUFF, and CALPOST, and a set of pre-processing and post-processing programs.

CALMET is a diagnostic meteorological model that produces 3-D wind fields based on parameterized treatments of terrain effects, such as slope flows and terrain blocking effects. Meteorological data are used to determine the wind field in areas of the domain within which the observations are representative. Fine scale terrain effects are determined by the diagnostic wind module in CALMET.

CALPUFF allows simulating the effects of weather spatial and temporal condition variations in pollutant transport, transformation, and removal. CALPUFF can be used on different space scales, from a few metres to hundreds of kilometres. It includes algorithms that consider the small-scale grid resolution effects as well as long distance effects (such as pollutant removal due to wet deposition and dry deposition effects, chemical transformation, and particulate matter effects on visibility). CALPUFF also includes algorithms for Plume Rise Model Enhancements (PRIME), making the tool suitable for modelling the dispersion of air pollutants where neighbouring buildings can produce a downwash effect on the plume.

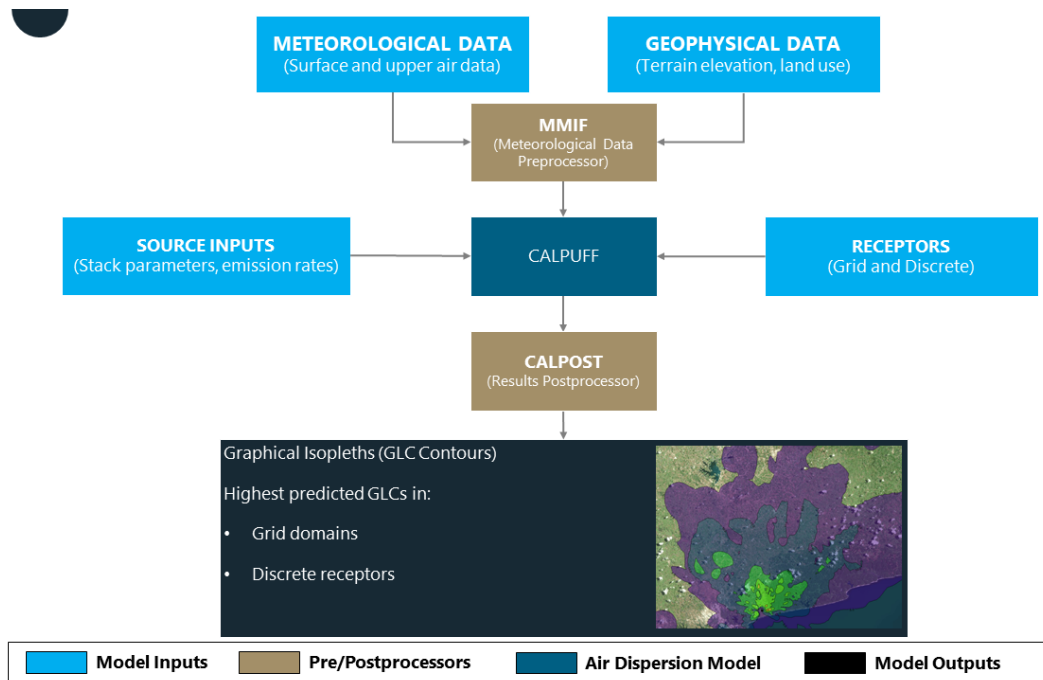
CALPOST is a post-processing program with options for the computation of time-averaged concentrations and deposition fluxes predicted by the CALPUFF model. Ground level concentrations (GLC) are calculated for each required averaging time-period (1-hour, 24-hour, or annual) over the full meteorological dataset at each grid receptor identified in the model domain. Maximum Contaminants of Concern (COC) concentrations can be then graphically mapped as contours across the grid or as discrete points at each sensitive receptor, and they represent the 'worst-case' meteorological conditions for atmospheric emissions.

The CALPUFF modelling methodology is shown schematically in Figure AVI.1.

CALPUFF simulates the dispersion of pollutants for every hour of the modelling period while incorporating 3D wind fields and calculates the GLCs of pollutants at every receptor on the modelling grid. Hourly results are stored and processed to provide maximum or average values at each receptor. Maximum predicted GLCs of pollutants over the entire modelling domain are presented as part of the results for each averaging period modelled (1-hour, 24-hour, and annual).

CALPUFF is internationally accepted as a regulatory model and is widely used to estimate air quality impacts as part of environmental impact assessments. The model can incorporate the effects of complex terrain, coastal effects, plume rise, buildings, and hills.

<sup>11</sup> Scire, J.S., Strimaitis, D.G. and Yamartino, R.J. A User's Guide for the CALPUFF Dispersion Model (Version 5). Earth Tech, Inc., January 2000.



**Figure AIV.1: Schematic of the CALPUFF Model**

CALPUFF View (version 9.0.1), the software tool selected for this assessment, is the commercial version of the model CALPUFF, which is developed and distributed by Lakes Environmental. CALPUFF View provides a complete graphical representation of the CALPUFF modelling results.

### AIV.1.2. Model Assumptions and Limitations

- The model is based on meteorological information collected from the nearest meteorological stations and prepared with the prognostic meteorological model WRF (Weather Research and Forecasting Model). As such, the meteorological data are not measured on-site or obtained from the proposed FLNG location;
- Continuous emissions over the entire modelling period (3 years) are considered for the four (4) scenarios modelled, although some are expected to last only for a few hours and/or days (i.e., first (1<sup>st</sup>) start-up phase and emergency flaring events). The purpose of this assumption is to obtain the worst (highest) air quality impacts, which are predicted by CALPUFF at specific meteorological conditions over the entire 3-year modelling period. This is a conservative assumption, since the flaring activities will most likely not coincide with the specific meteorological conditions that produce the maximum air GLCs predicted by CALPUFF;
- Dry and wet depositions of pollutants are not considered by the model, resulting in conservative GLC predictions;
- Photochemical formation of secondary pollutants in the atmosphere, such as ozone, is not considered by CALPUFF.

### AIV.1.3. Modelling Scenarios

The following four scenarios were modelled for this assessment:

- Scenario 1 – air quality impact from Coral North FLNG during the 1st start-up phase;
- Scenario 2 – air quality impact from Coral North FLNG during operational phase of the project;
- Scenario 3 – air quality impact from Coral North FLNG during an emergency flaring event in the FLNG;
- Scenario 4 – cumulative air quality impact during the operational phase of the project (Coral North plus Coral South).

### AIV.1.4. Modelling Inputs

#### AIV.1.4.1. Emission Sources

Emission data for the emitting sources involved in each of the modelling scenarios were obtained from the Air Emissions Estimate Summary prepared for the Coral South Development Project (Doc No. 4404GGBFEZ4003T). These data are applicable for this study considering that the operational conditions and sources in Coral North are identical to those in Coral South.

The sources considered under each modelling scenario are detailed in the following sections.

##### AIV.1.4.1.1. Scenario 1 (1<sup>st</sup> Start-up Phase)

Emission sources in Scenario 1 are summarized in Table AIV.1.

**Table AIV.1: Scenario 1 (start-up phase) emission sources**

Emission Source	Equipment Name	Operation Mode
FLNG HP Flare	TM2300FC001	Low flaring scenario <sup>a</sup>
CO <sub>2</sub> thermal incinerator	TM3300XX003	50% load
Gas Turbine Generators (GTG) (x2)	TM4100HW001A TM4100HW001B	20% load (6 MW) fed with liquid fuel
Gas Turbine Compressors (GTC) (x2)	TM3701MT001 TM3701MT002	75% load (22.65 MW) fed with fuel gas
Essential Diesel Generators (EDG) (x2)	HH4801XX100 HH4802XX100	8 MW each, fed with liquid fuel

a) identified as the most impacting in terms of air quality

Although the operational duration of each source during start-up is different, all sources were assumed to operate at the same time to obtain a worst-case estimate of their potential impact on air quality during start-up operation. Additionally, the emission rates provided in the Air Emissions Estimate Summary for these sources were increased by 25% for contingency purposes, as requested by MRV.

##### AIV.1.4.1.2. Scenario 2 (Operational Phase)

Emission sources in Scenario 2 are summarized in Table AIV.2.

**Table AIV.2: Scenario 2 (operational phase) emission sources**

Emission Source	Equipment Name	Operation Mode
CO <sub>2</sub> thermal incinerator	TM3300XX003	100% load
Gas Turbine Generators (GTG) (x3)	TM4100HW001A TM4100HW001B TM4100HW001C	70% load (20.96 MW) fed with fuel gas
Gas Turbine Compressors (GTC) (x4)	TM3701MT001 TM3702MT001 TM3701MT002 TM3702MT002	operating at 100% load (30.22 MW) fed with fuel gas

Pilot flaring or fugitive emissions were not considered under Scenario 2. Planned discontinuous emissions were excluded as they represent a negligible fraction of the continuous emissions.

**AIV.1.4.1.3. Scenario 3 (Emergency and/or Unplanned Flaring)**

Emission sources in Scenario 3 are summarized in Table AIV.3.

**Table AIV.3: Scenario 3 (emergency and/or unplanned flaring) emission sources**

Emission Source	Equipment Name	Operation Mode
FLNG HP Flare	TM2300FC001	flare vent and blowdown scenario (U230) <sup>a</sup>

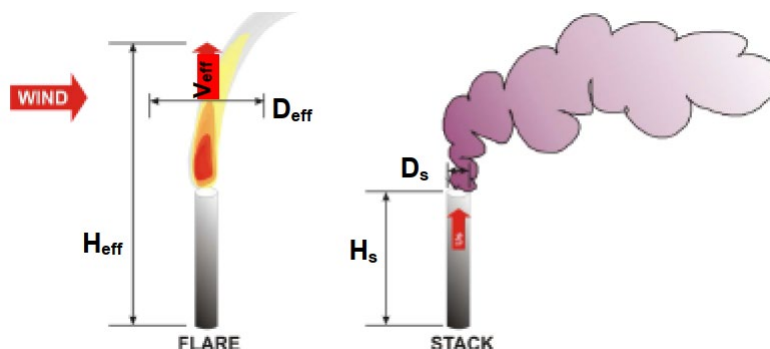
a) Identified as the worst-case of those described in the Air Emissions Estimate Summary due to its highest frequency (12 h/y) and highest NOX emissions (329.437 kg/h).

**AIV.1.4.1.4. Scenario 4 (Cumulative Air Quality Impact)**

The cumulative air quality impact was assessed considering the combined emissions from Coral North FLNG and Coral South FLNG during normal operations. Coral North is envisaged to replicate the existing Coral South project; therefore, the emission sources and their emissions for Coral South under normal operations are identical to those for Coral North under Scenario 2.

The air emission sources modelled under each scenario, as introduced into the CALPUFF model with the following considerations, are listed in Table AIV.4. The following must be considered when analysing input data in Table AIV.4.

- CALPUFF does not explicitly handle emissions from external combustion sources, such as flares. Consequently, emissions from the HP flare were converted into emissions from an internal combustion stack (point source) before being introduced into the model. The differences between an external combustion source (flare) and a typical point source (internal combustion stack) are illustrated in Figure AIV.2;



**Figure AIV.2: Differences between flares and point sources (stack)**

The flare to stack conversion relies on the calculation of pseudo-point or effective release parameters, accounting for the increased release height and diameter due to the external combustion (flame). While a typical point source (stack) is defined by its physical stack height ( $H_s$ ) and internal diameter ( $D_s$ ), the effective parameters that need to be calculated for modelling flares include the release height ( $H_{eff}$ ), diameter ( $D_{eff}$ ), and velocity ( $V_{eff}$ ). The US EPA procedure was followed in this assessment to estimate the effective release parameters of the flare<sup>1213</sup>. This procedure is based on the following:

- Heat release ( $H_R$ ) from the flare is estimated for each case based on the volumetric fuel gas to flare (provided by the Client) and its molar composition.
- Physical flare height ( $H_{PHYS}$ ), 177 m (provided by the Client for Coral South FLNG, assumed equal to Coral North FLNG).
- Effective release height ( $H_{EFF}$ ) calculated using the following equation:

$$H_{EFF} (m) = H_{PHYS}(m) + 4.56 \times 10^{-3} (H_R \left(\frac{cal}{s}\right))^{0.478}$$

- Effective release diameter ( $D_{EFF}$ ) calculated based on the flare buoyancy flux using the following equation:

$$D_{EFF} (m) = 9.88 \times 10^{-4} (0.45 \times H_R \left(\frac{cal}{s}\right))^{0.5}$$

This equation relies on the following assumptions:

- 55% of the total heat released from the flare is lost due to radiation
  - Effective release velocity and temperature are assumed as 20 m/s and 1273 K, respectively.
- Because of their equal emission parameters, the different GTGs, GTCs, and EDGs have been merged to generate a representative emission source under each scenario. This merging followed the US EPA procedure<sup>14</sup>, which indicates that merging can be done if 1) height, flow rates and exhaust gases temperatures from the stacks do not differ more than 20% each, and 2) if stacks are located within 100 m of each other. Under each scenario, the identical units merged into the representative emission source are provided in parentheses.

<sup>12</sup> US EPA. Workbook of Screening Techniques for Assessing Impacts of Toxic Air Pollutants (Revised). EPA-454/R-92-024. Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina. 1992

<sup>13</sup> US EPA. SCREEN3 Model User's Guide. Office of Air Quality Planning and Standards. Emissions, Monitoring and Analysis Division. Research Triangle Park, NC. EPA-454/B-95-004. 1995

<sup>14</sup> US EPA. Screening Procedures for Estimating the Air Quality Impact of Stationary Sources (Doc: EPA-454/R-92-019). 1992

**Table AIV.4: CALPUFF air emission sources**

Scenario 1 – 1 <sup>st</sup> Start-up phase										
Emission Source (Equipment Tag)	Coordinates (UTM 37 S)		Stack Height	Internal Diameter	Exhaust Temp	Exhaust Velocity	Emission rates (g/s)			
	E (m)	N (m)					CO	NO <sub>x</sub>	SO <sub>2</sub>	PM <sub>10</sub>
Warm and Wet HP Flare (TM2300FC001)	731508	8772185	242.6	14.8	1273	20	440.8	80.2	0	0
CO <sub>2</sub> Thermal Incinerator (TM3300XX003)	731488	8772185	74.7	1.9	1255	4.7	Traces	0.3	0.6	0.0
GTG (TM4100HW001A + TM4100HW001B)	731518	8772185	68.7	2.7	523	12.3	5.69	19.3	1.0	1.2
GTC (TM3701MT001 + TM3701MT002)	731520	8772185	59.2	2.8	809	24.0	12.4	6.2	0.1	6.2
EDG (HH4801XX100 + HH4802XX100)	731478	8772185	46.5	1	639	37.3	3.7	53.8	0.2	2.0
Scenario 2 – Normal operation										
Emission Source (Equipment Tag)	Coordinates (UTM 37 S)		Stack Height	Internal Diameter	Exhaust Temp	Exhaust Velocity	Emission rates (g/s)			
	E (m)	N (m)					CO	NO <sub>x</sub>	SO <sub>2</sub>	PM <sub>10</sub>
CO <sub>2</sub> Thermal Incinerator (TM3300XX003)	731488	8772185	74.7	1.9	1255	4.7	Traces	0.5	0.9	0
GTG (TM4100HW001A + TM4100HW001B + TM4100HW001C)	731518	8772185	68.7	2.7	493	18.4	5.6	8.3	0	1.7
GTC (TM3701MT001 + TM3702MT001 + TM3701MT002 + TM3702MT002)	731520	8772185	59.2	2.8	809	32.2	21.1	14.1	0	14.1
Scenario 3 – Emergency/unplanned flaring										
Emission Source (Equipment Tag)	Coordinates (UTM 37 S)		Stack Height	Internal Diameter	Exhaust Temp	Exhaust Velocity	Emission rates (g/s)			
	E (m)	N (m)					CO	NO <sub>x</sub>	SO <sub>2</sub>	PM <sub>10</sub>
Warm and Wet HP Flare (TM2300FC001)	731508	8772185	253.0	17.3	1273	20	503	91.5	0	0

Scenario 4 – Cumulative (Coral North FLNG + Coral South FLNG)										
Emission Source (Equipment Tag)	Coordinates (UTM 37 S)		Stack Height	Internal Diameter	Exhaust Temp	Exhaust Velocity	Emission rates (g/s)			
	E (m)	N (m)	m	m	K	m/s	CO	NO <sub>x</sub>	SO <sub>2</sub>	PM <sub>10</sub>
<b>Coral North FLNG</b>										
CO <sub>2</sub> Thermal Incinerator (TM3300XX003)	731488	8772185	74.7	1.9	1255	4.7	Traces	0.5	0.9	0
GTG (TM4100HW001A + TM4100HW001B + TM4100HW001C)	731518	8772185	68.7	2.7	493	18.4	5.6	8.3	0	1.7
GTC (TM3701MT001 + TM3702MT001 + TM3701MT002 + TM3702MT002)	731520	8772185	59.2	2.8	809	32.2	21.1	14.1	0	14.1
<b>Coral South FLNG</b>										
CO <sub>2</sub> Thermal Incinerator (TM3300XX003)	730067	8758571	74.7	1.9	1255	4.7	Traces	0.5	0.9	0
GTG (TM4100HW001A + TM4100HW001B + TM4100HW001C)	730097	8758571	68.7	2.7	493	18.4	5.6	8.3	0	1.7
GTC (TM3701MT001 + TM3702MT001 + TM3701MT002 + TM3702MT002)	730099	8758571	59.2	2.8	809	32.2	21.1	14.1	0	14.1

Notes:

[1] Coordinates are estimated from the Coral North FLNG location.

[2] Stack height and internal diameters of the HP flare represent effective release parameters calculated using the US EPA procedure to convert flares to pseudo-point sources.

[3] GTG, GTC and EDG sources represent merged emission parameters, estimated using the US EPA procedure. Under each scenario, the merged units in the representative emission source are provided in parentheses.

#### AIV.1.4.2. Meteorology

A meteorological file was prepared using the WRF prognostic model, which uses data provided by the National Centre for Environmental Prediction (NCEP) Global Reanalysis. The WRF Model is a next-generation mesoscale numerical weather prediction system designed to serve both atmospheric research and operational forecasting needs. The model serves a wide range of meteorological applications across scales from tens of metres to thousands of kilometres.

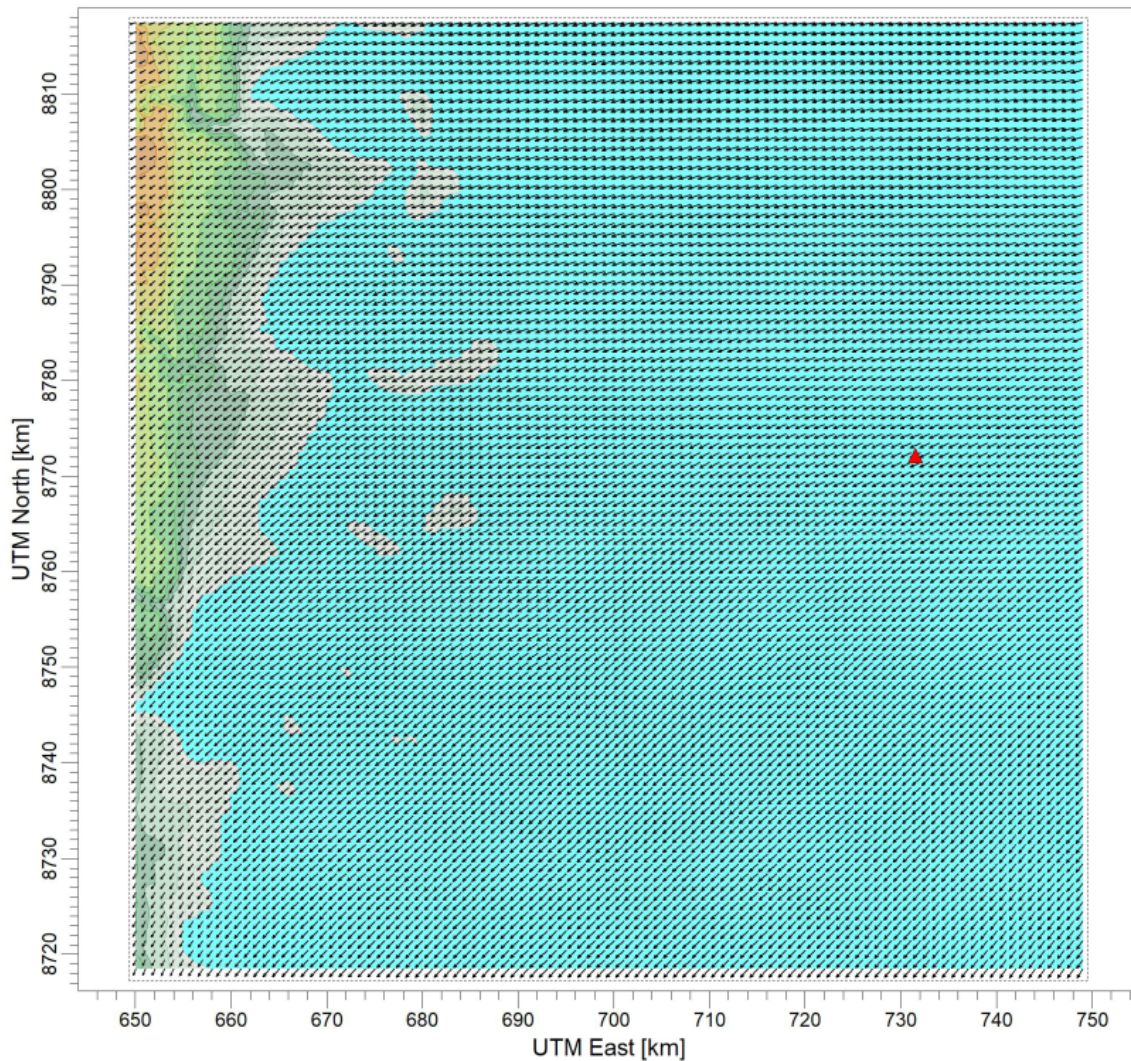
Running a regional model requires an initial condition as well as lateral boundary conditions. Obtaining meteorological data for a specific location requires the consideration of meteorological records from as many surface-level meteorological stations as possible and a large model run to set the boundary conditions.

The US EPA recommends the usage of meteorological data collected over a sufficiently long period to ensure that the worst-case meteorological conditions of the study area are adequately represented in the model results<sup>15</sup>. To meet this recommendation, the WRF meteorological file employed in this assessment covers a complete series of hourly values calculated from surface observations and upper soundings from the meteorological stations closest to the study area during a three (3) year period (2020-2022).

The surface dataset includes wind speed, wind direction, dry bulb temperature, cloud cover, and ceiling height. Upper soundings include wind speed, dew point, atmospheric pressure, and measurement height. The meteorological pre-processor CALMET uses the meteorological and geophysical data to create a spatially varying wind field for the study area for each hourly time step modelled. The complete set of hourly wind fields calculated by CALMET is used as input for the dispersion in CALPUFF. An example of this spatially varying wind field, calculated by CALMET for the time step 00:00-01:00 16 November 2021, is presented in Figure AIV.2, with the FLNG location indicated in red.

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<sup>15</sup> US EPA. Appendix W of 40 CFR Part 51. Revisions to the Guideline on Air Quality Models: Enhancements to the AERMOD Dispersion Modeling System and Incorporation of Approaches to Address Ozone and Fine Particulate Matter. Federal Register. 17 January 2017



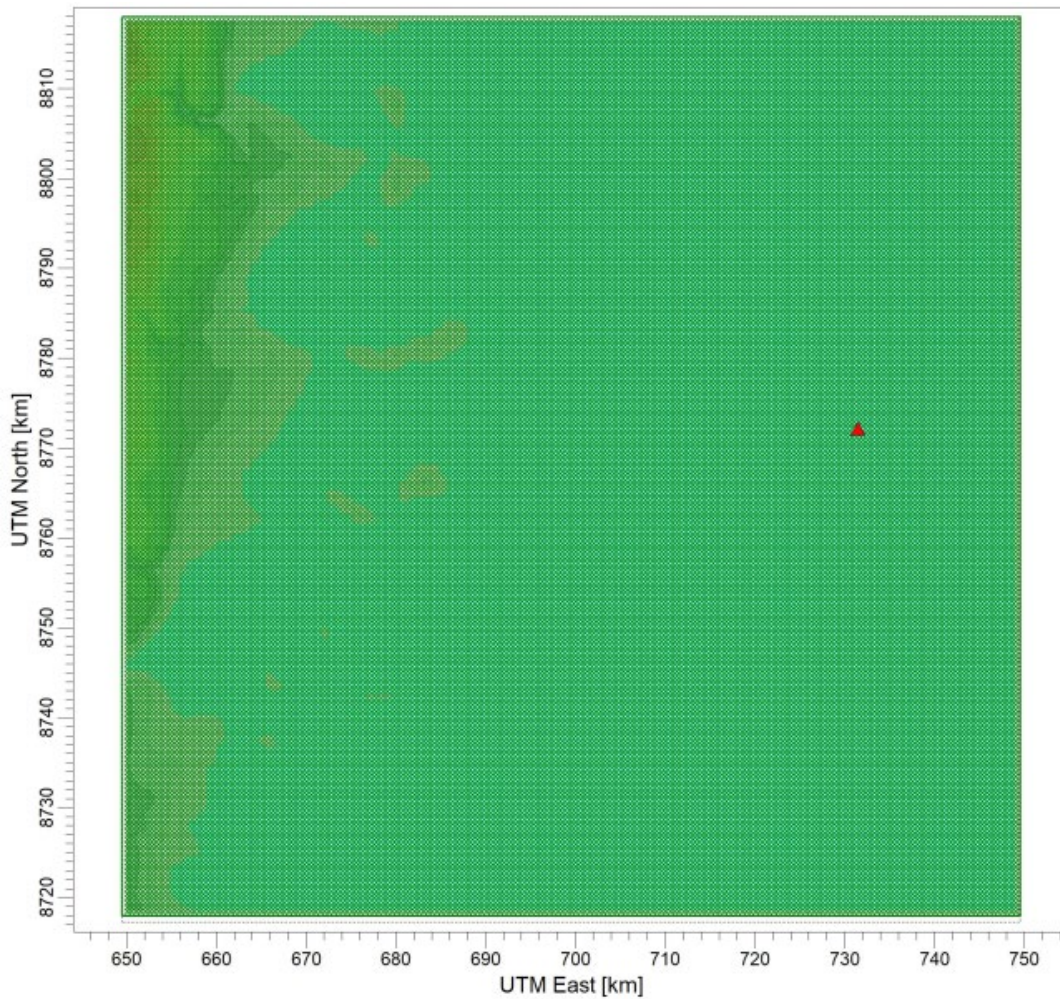
**Figure AIV.2: CALMET wind field output example (00:00-01:00, 16 November 2021)**

#### **AIV.1.4.3. Terrain Data**

Geophysical data used to characterize the terrain in the project area were obtained from SRTM (Shuttle Radar Topography Mission) terrain elevation data and GLCC (Global Land Cover Characterization) land use data. The topography of most of the modelling area is flat (offshore).

#### **AIV.1.4.4. Modelling Domain**

A modelling domain of 100 km x 100 km was defined for this assessment with a Cartesian grid of receptors with 500-m spacing to assess GLCs at each receptor (40,000 total) as predicted by CALPUFF. The modelling grid used for this assessment is shown in Figure AIV.3, with the FLNG location indicated in red.



**Figure AIV.3: Cartesian modelling grid**

The maximum COC GLCs, predicted at receptors using CALPUFF under four modelling scenarios across the entire Cartesian grid, were plotted as ground concentration contour maps, as provided in Annexes IV.A to IV.D. The modelling results are also presented and discussed in the impact assessment section for Air Quality (please see Volume II).

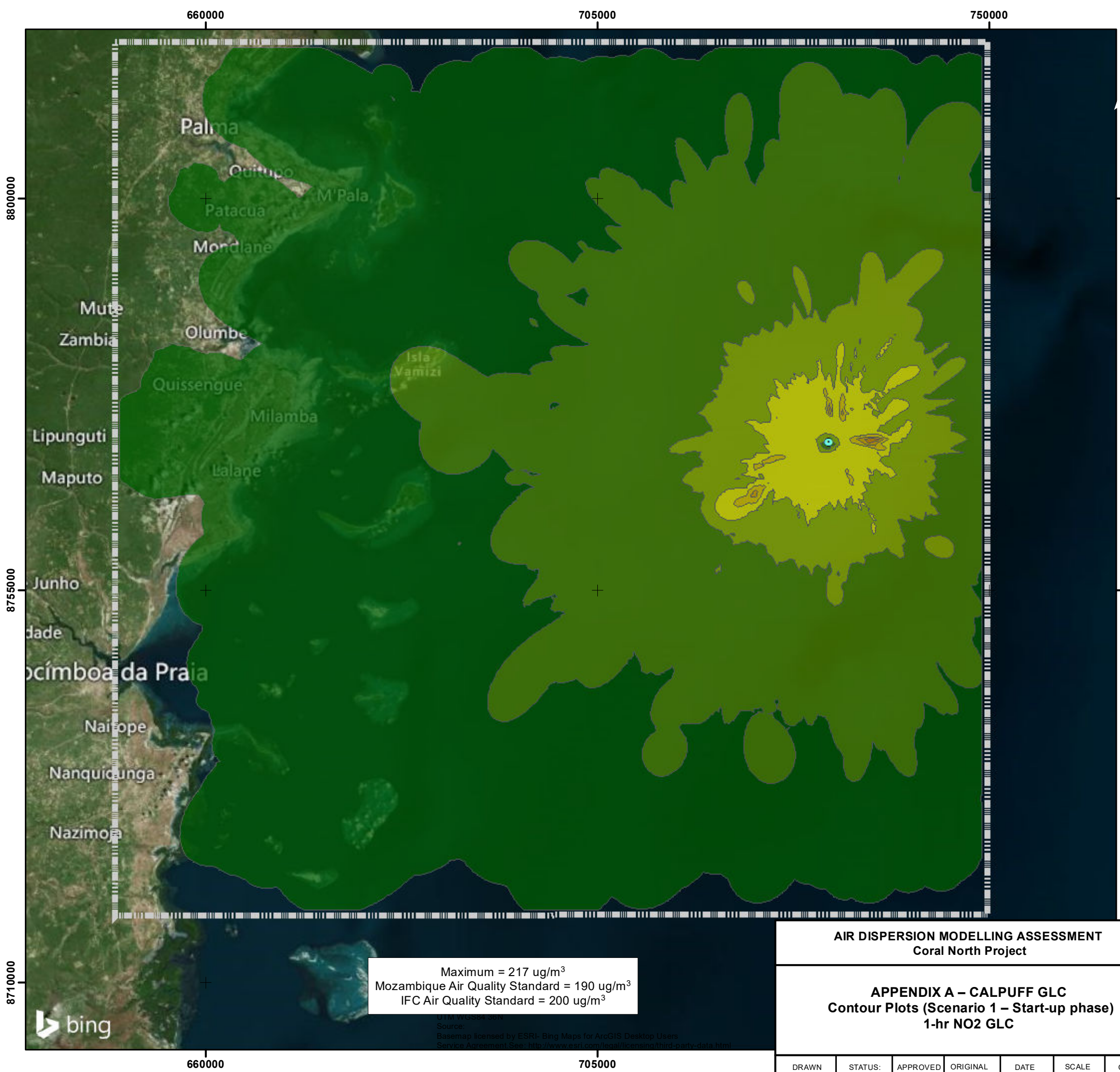
#### **AIV.1.4.5. NO<sub>x</sub> to NO<sub>2</sub> Conversion Ratio**

The modelled dispersion of NO<sub>x</sub> emitted by the flare is a mixture of NO<sub>2</sub> and NO. The GLCs of NO<sub>x</sub> predicted by the model cannot be directly compared with the Mozambique and WHO Ambient Air Quality Standards, which are established for NO<sub>2</sub>. As a conservative approach, it was assumed that all NO emitted in the NO<sub>x</sub> mixture is ultimately converted to NO<sub>2</sub> (i.e., full conversion). This assumption represents the Tier-1 approach recommended by the US EPA as a first screening method for NO<sub>2</sub> modelling<sup>16</sup>.

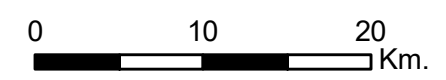
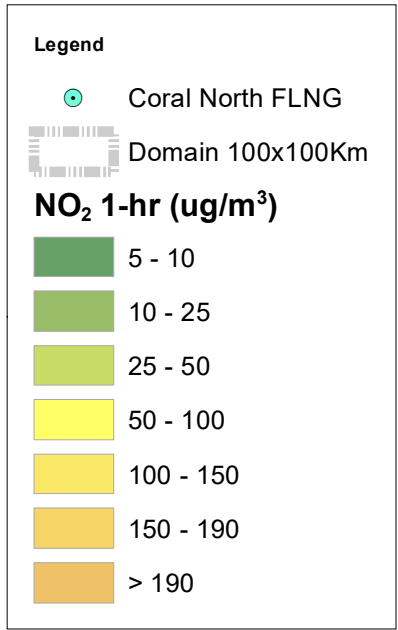
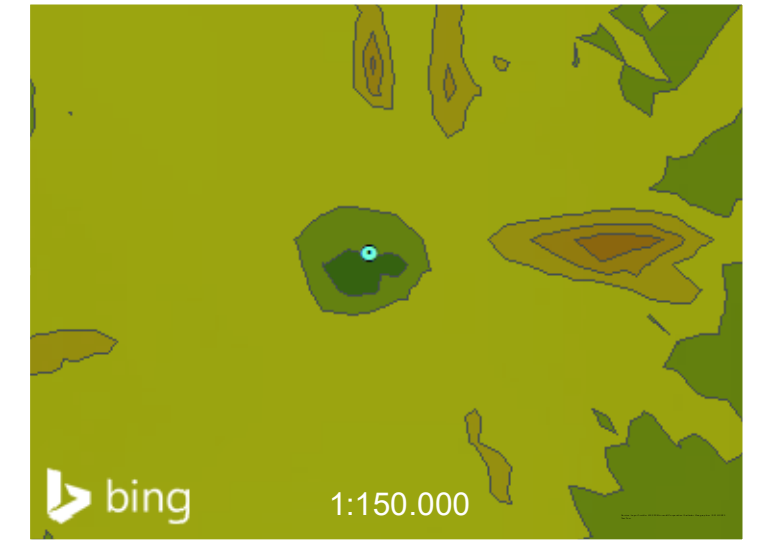
<sup>16</sup> US EPA. Appendix W of 40 CFR Part 51. Revisions to the Guideline on Air Quality Models: Enhancements to the AERMOD Dispersion Modeling System and Incorporation of Approaches to Address Ozone and Fine Particulate Matter. Federal Register. 17 January 2017

## **Annex IV.A – CALPUFF GLC Contour Plots (Scenario 1 – Start-up Phase)**

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Maximum = 217  $\mu\text{g}/\text{m}^3$   
 Mozambique Air Quality Standard = 190  $\mu\text{g}/\text{m}^3$   
 IFC Air Quality Standard = 200  $\mu\text{g}/\text{m}^3$



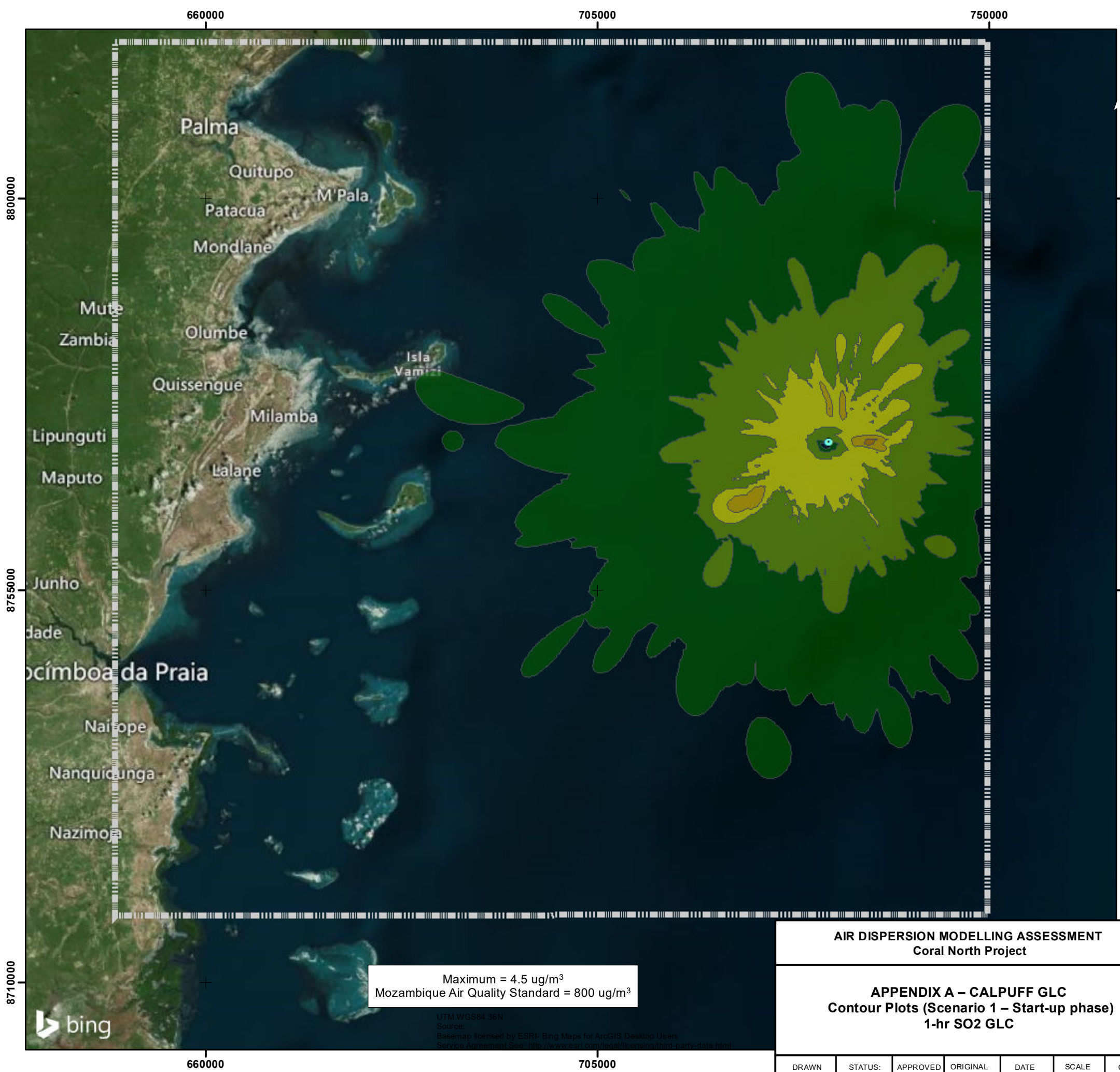
**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

**APPENDIX A – CALPUFF GLC**  
 Contour Plots (Scenario 1 – Start-up phase)  
 1-hr NO<sub>2</sub> GLC



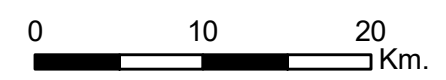
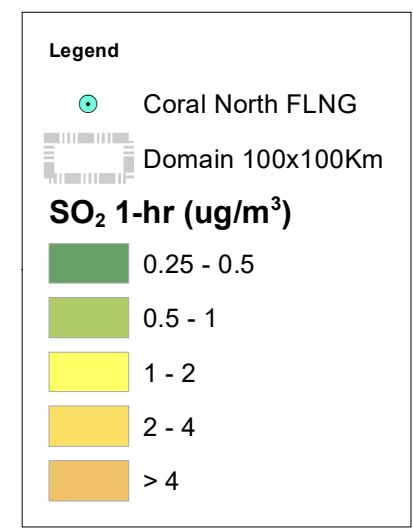
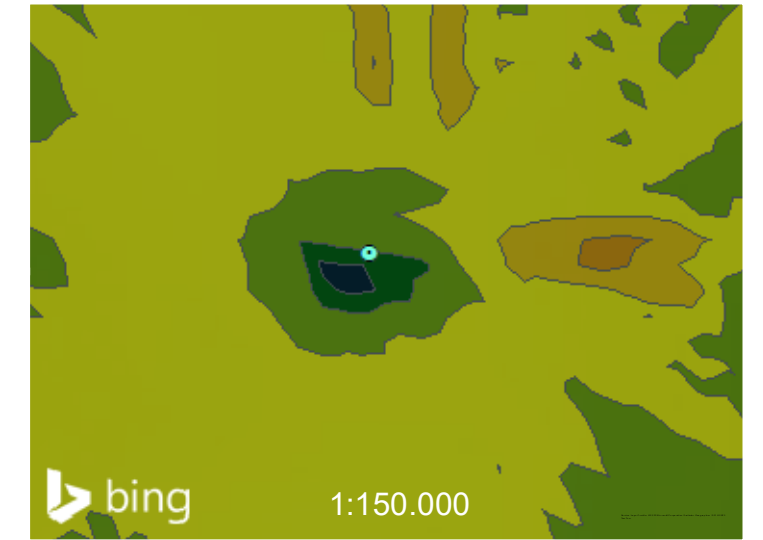
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450,000	OFFICE MADRID	CODE	<b>FIGURE A.1</b>	Rev.0
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NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\415000-00382 - Mozambique Coral North Air - A-1 - 1-hr NO2.mxd



Maximum = 4.5 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 800 ug/m<sup>3</sup>

UTM WGS84 36N  
 Source:  
 Basemap licensed by ESRI- Bing Maps for ArcGIS Desktop Users  
 Service Agreement See: <http://www.esri.com/legal/collaborating-partners-data.html>



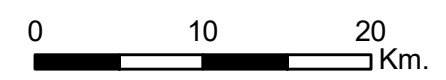
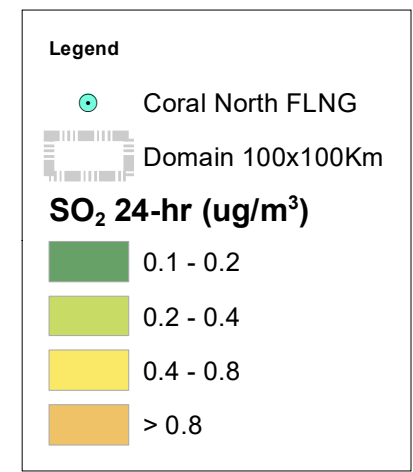
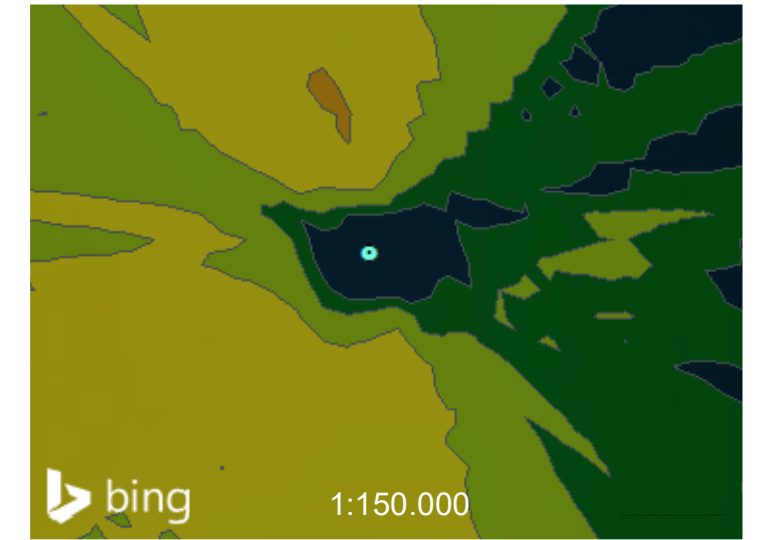
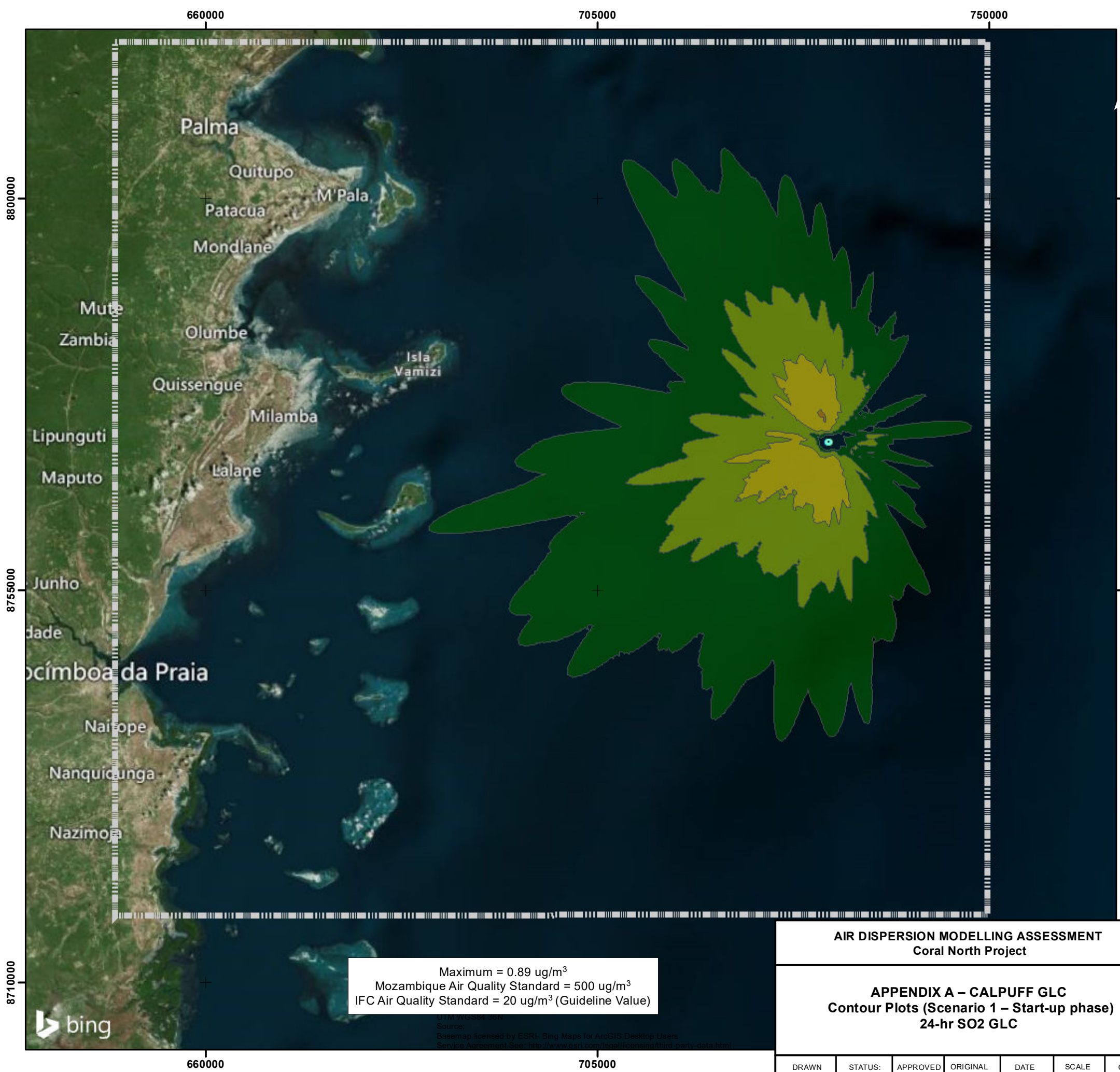
**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

**APPENDIX A – CALPUFF GLC**  
 Contour Plots (Scenario 1 – Start-up phase)  
 1-hr SO<sub>2</sub> GLC



DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450,000	OFFICE MADRID	CODE	<b>FIGURE A.2</b>	Rev.0
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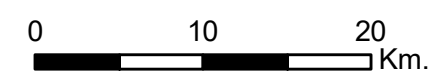
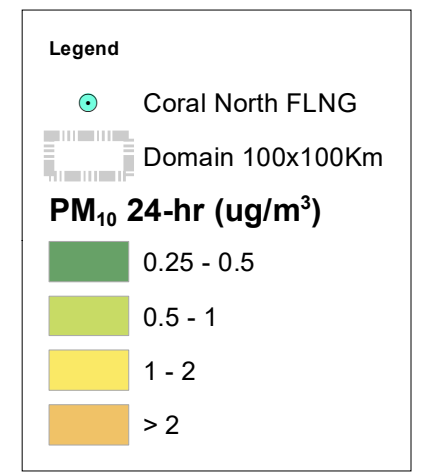
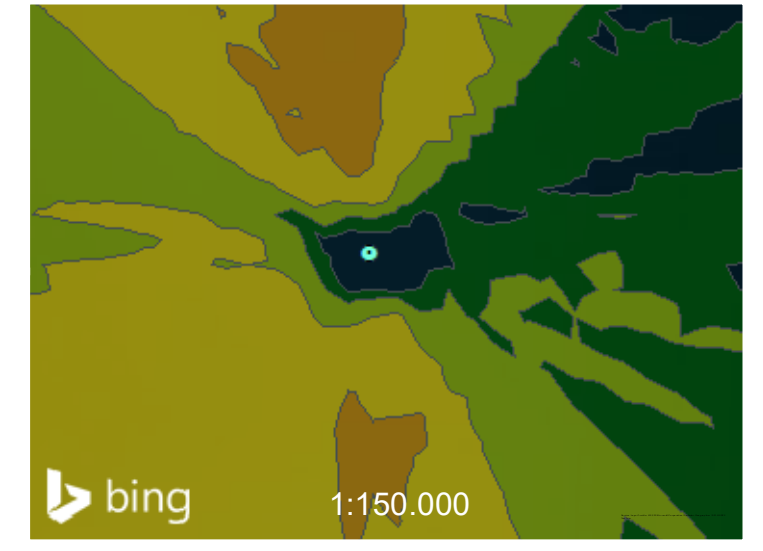
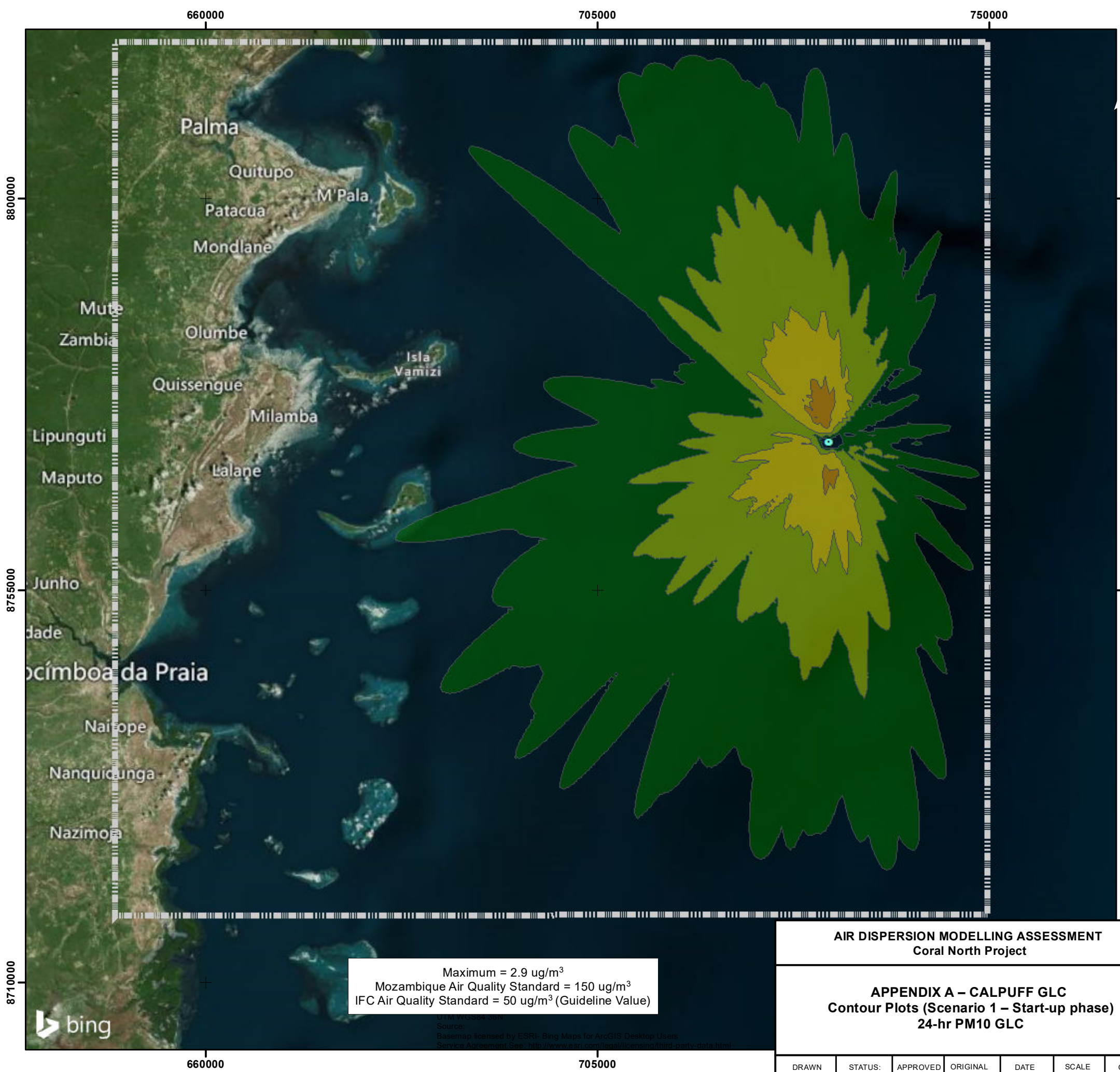
NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\415000-00382 - Mozambique Coral North Air - A-2 - 1-hr SO2.mxd



Maximum = 0.89 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 500 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 20 ug/m<sup>3</sup> (Guideline Value)

<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project								
<b>APPENDIX A – CALPUFF GLC</b> Contour Plots (Scenario 1 – Start-up phase) 24-hr SO <sub>2</sub> GLC								
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	<b>FIGURE A.3</b>
								Rev.0

NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
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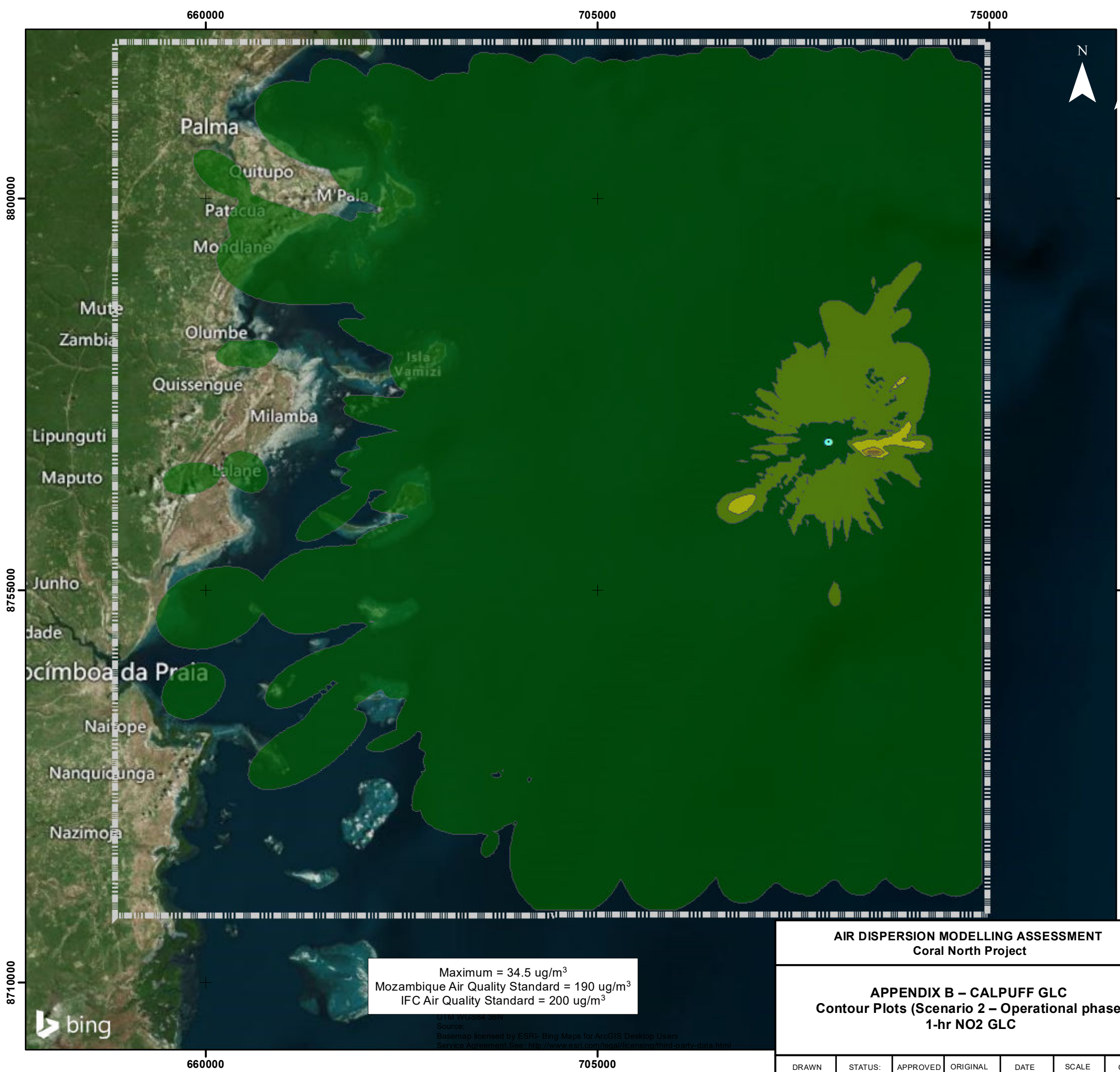
AIR DISPERSION MODELLING ASSESSMENT Coral North Project								
APPENDIX A – CALPUFF GLC Contour Plots (Scenario 1 – Start-up phase) 24-hr PM10 GLC								
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	<b>FIGURE A.4</b>
							Rev.0	



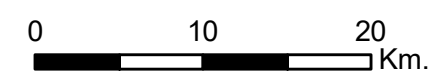
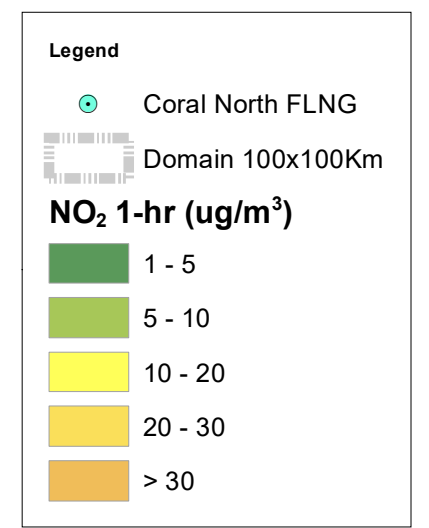
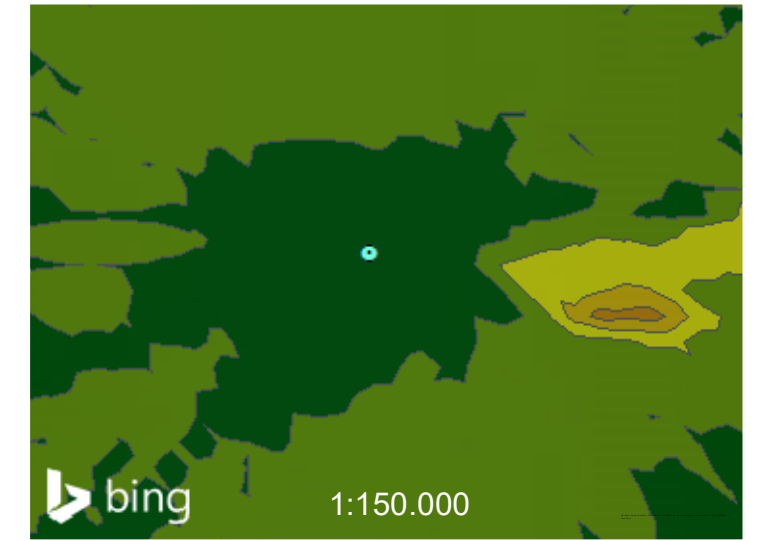
NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
Pathname: C:\TTCG\15000-00382 - GIS\MXD\415000-00382 - Mozambique Coral North Air - A-4 - 24-hr PM10.mxd

## **Annex IV.B – CALPUFF GLC Contour Plots (Scenario 2 – Operational Phase)**

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Maximum = 34.5 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 190 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 200 ug/m<sup>3</sup>



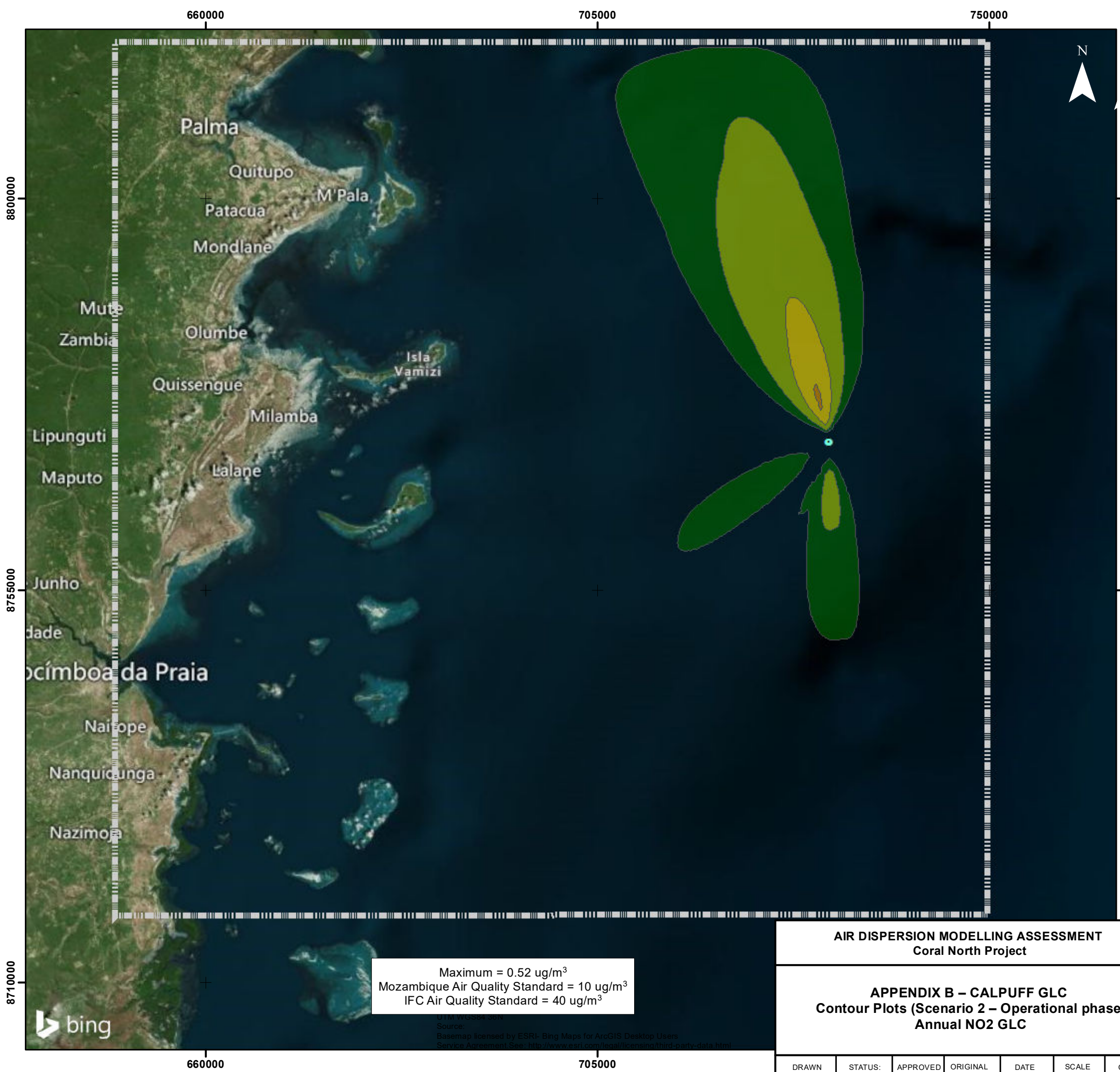
**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

**APPENDIX B – CALPUFF GLC**  
 Contour Plots (Scenario 2 – Operational phase)  
 1-hr NO<sub>2</sub> GLC

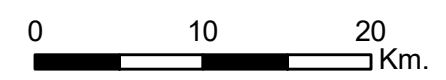
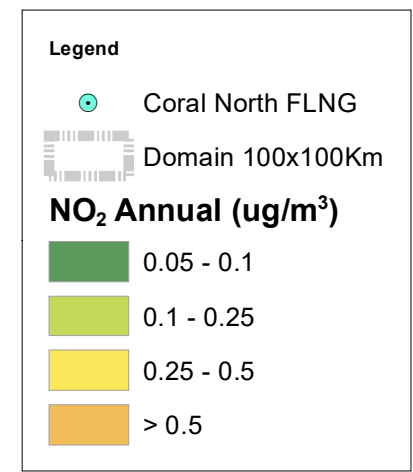
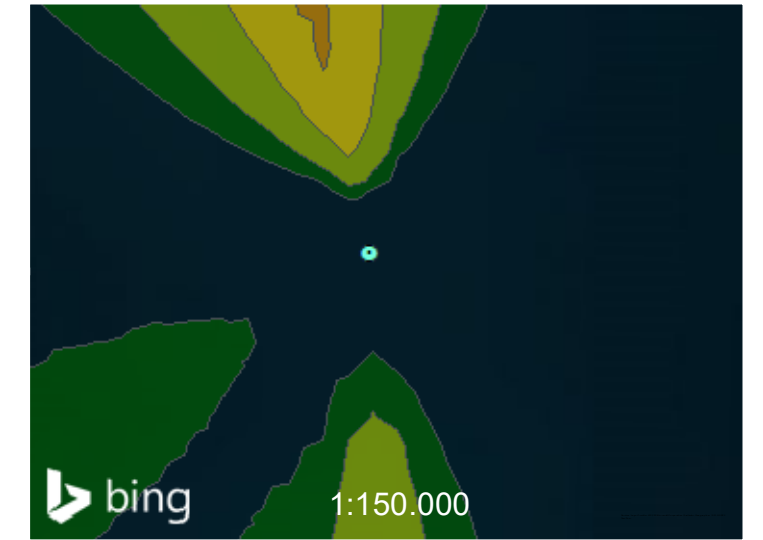
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID
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CODE	<b>FIGURE B.1</b>	Rev.0
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 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix B\15000-00382 - Mozambique Coral North Air - B-1\_1-hr NO2.mxd

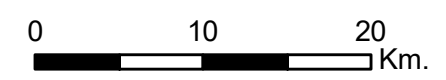
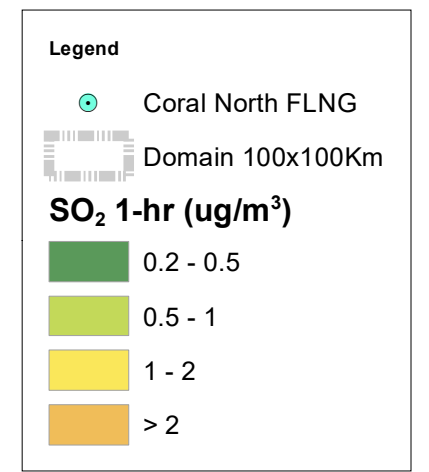
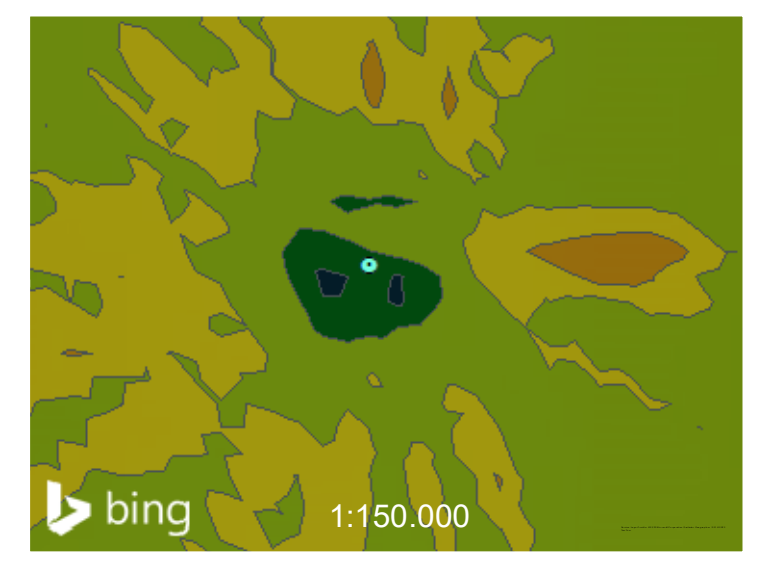
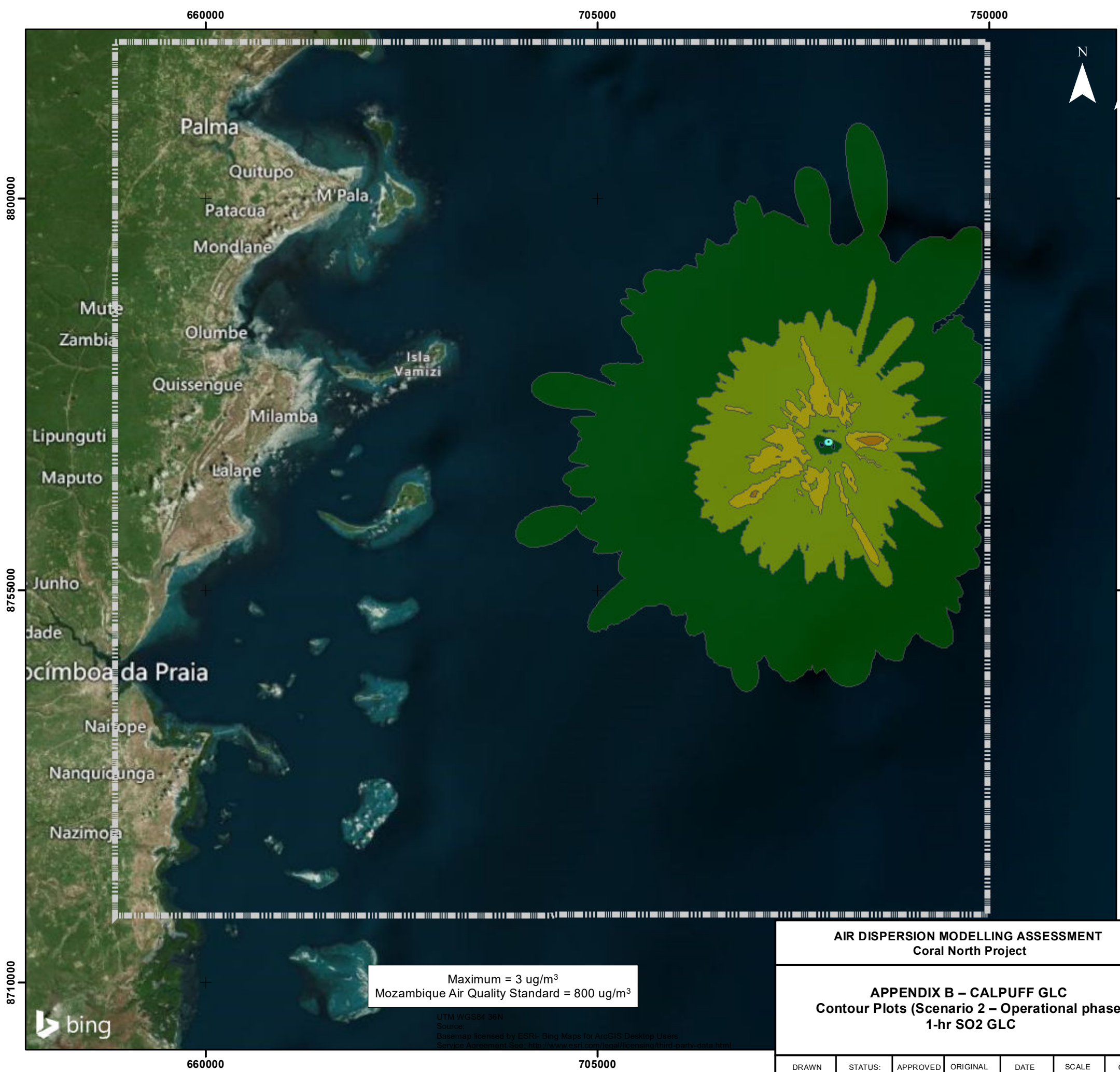


Maximum = 0.52 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 10 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 40 ug/m<sup>3</sup>



<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project									
<b>APPENDIX B – CALPUFF GLC</b> Contour Plots (Scenario 2 – Operational phase) Annual NO <sub>2</sub> GLC							  Worley Group		
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	<b>FIGURE B.2</b>	Rev.0

NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
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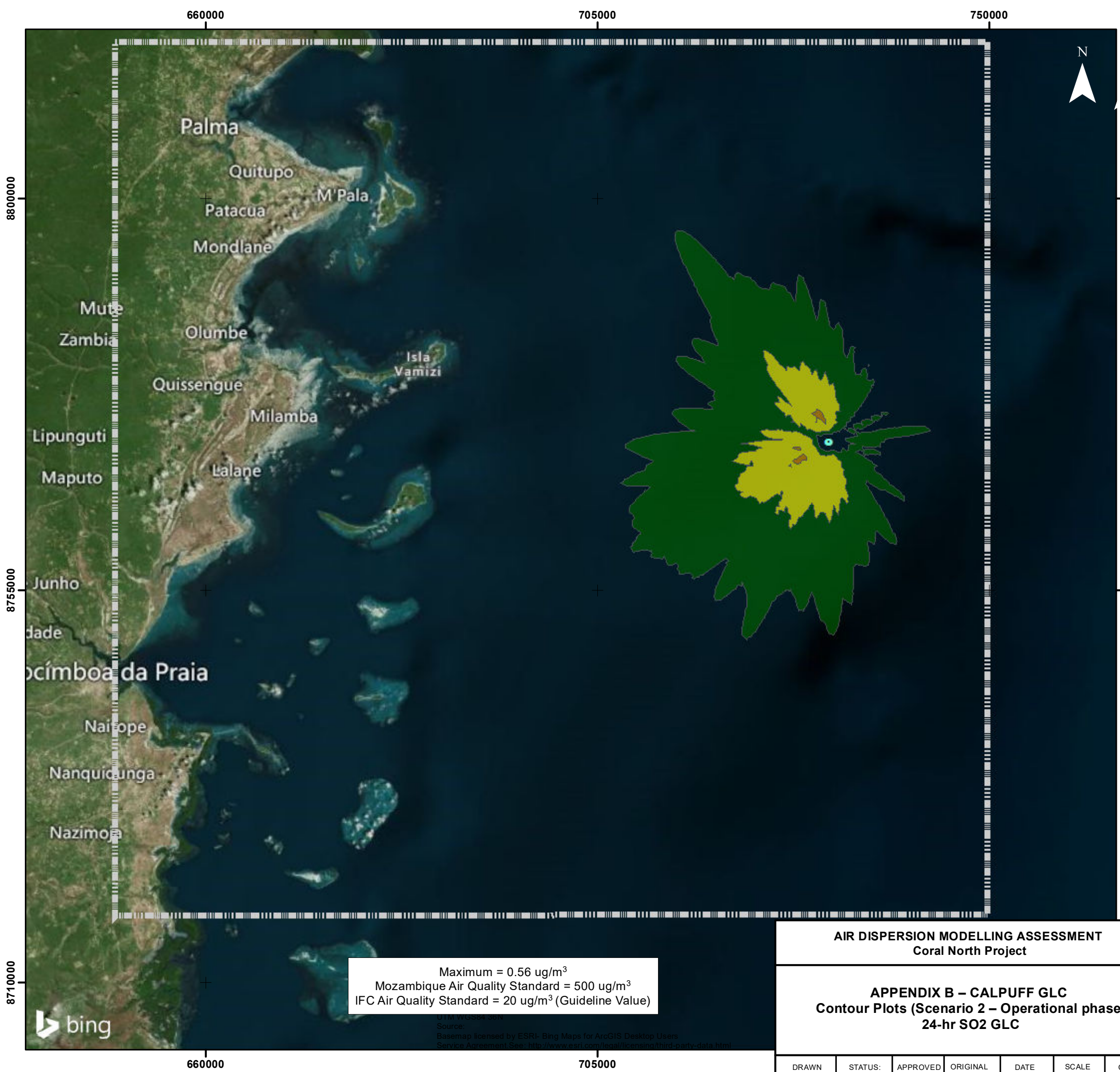
**AIR DISPERSION MODELLING ASSESSMENT**  
Coral North Project

**APPENDIX B – CALPUFF GLC**  
Contour Plots (Scenario 2 – Operational phase)  
1-hr SO<sub>2</sub> GLC

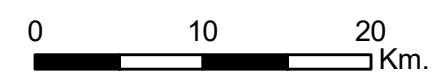
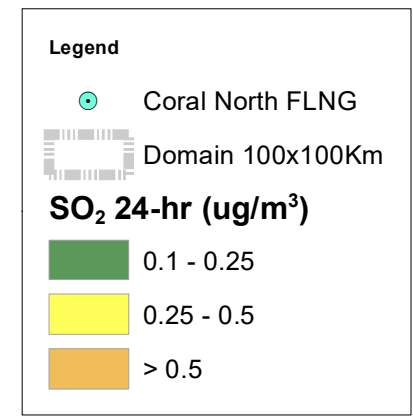
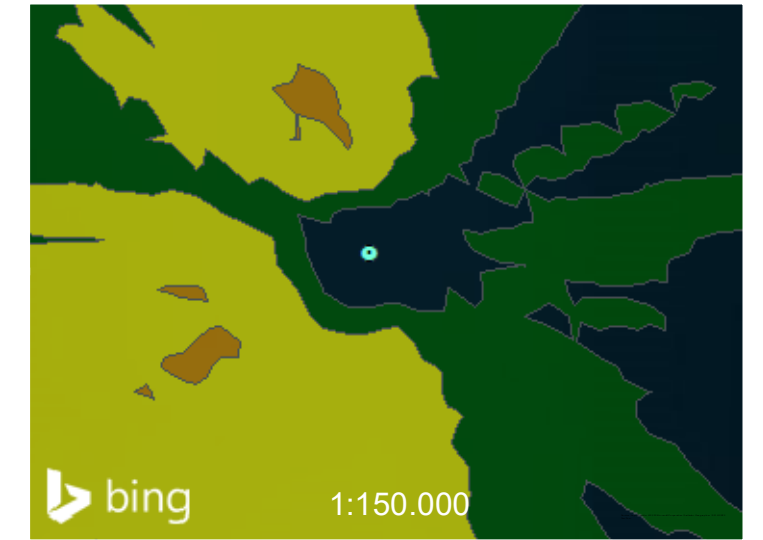


DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	<b>FIGURE B.3</b>	Rev.0
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NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
Pathname: C:\TTCG\15000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix B\15000-00-00382 - Mozambique Coral North Air - B-3 - 1-hr SO2.mxd

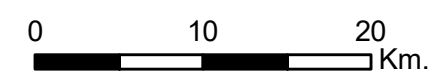
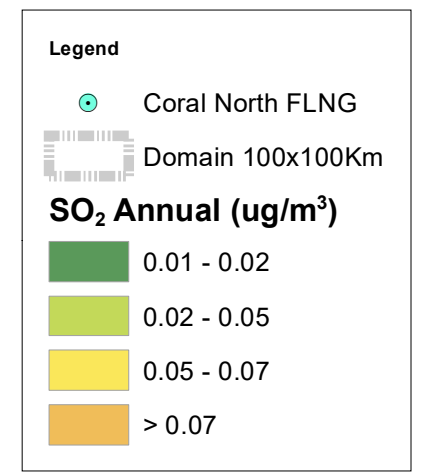
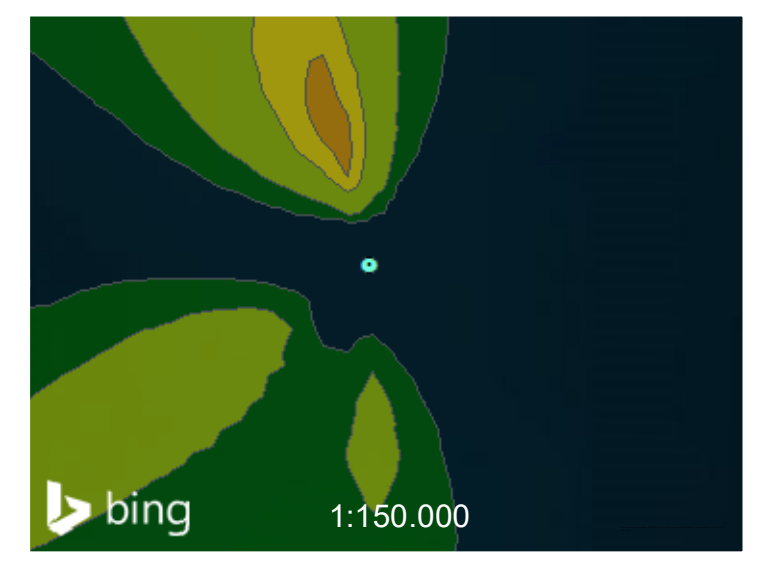
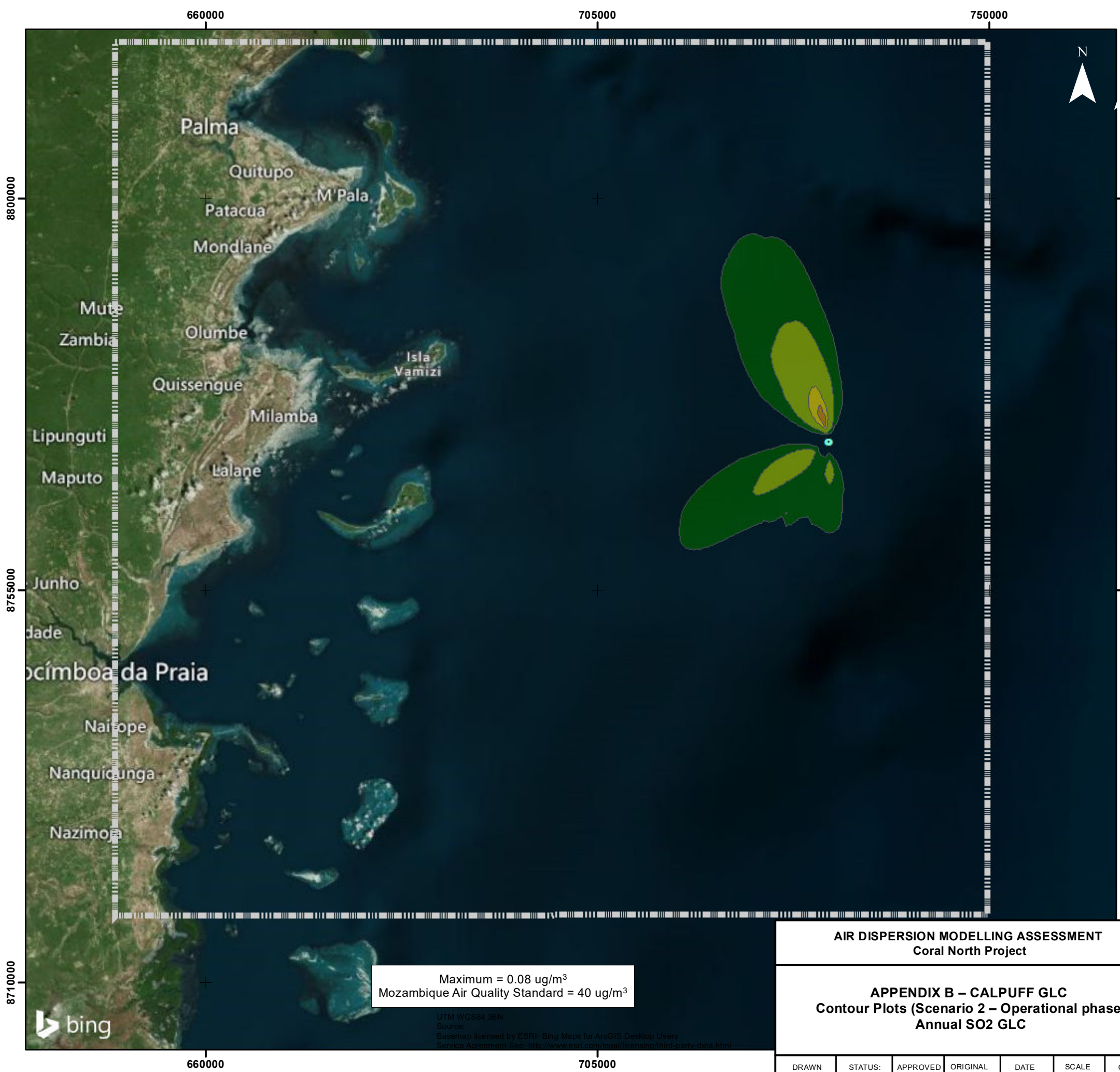


Maximum = 0.56 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 500 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 20 ug/m<sup>3</sup> (Guideline Value)



<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project									
<b>APPENDIX B – CALPUFF GLC</b> Contour Plots (Scenario 2 – Operational phase) 24-hr SO2 GLC									
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450,000	OFFICE MADRID	CODE	<b>FIGURE B.4</b>	Rev.0

NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix B\15000-00382 - Mozambique Coral North Air - B-4 - 24-hr SO2.mxd

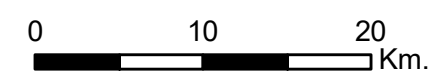
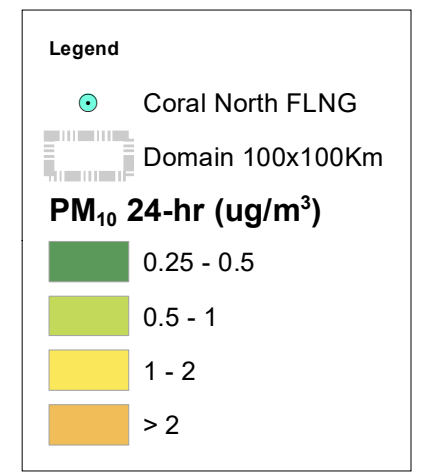
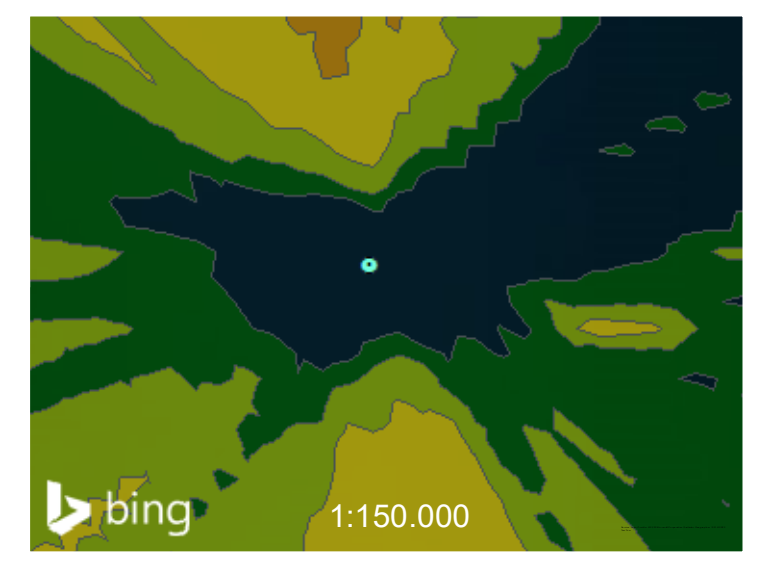
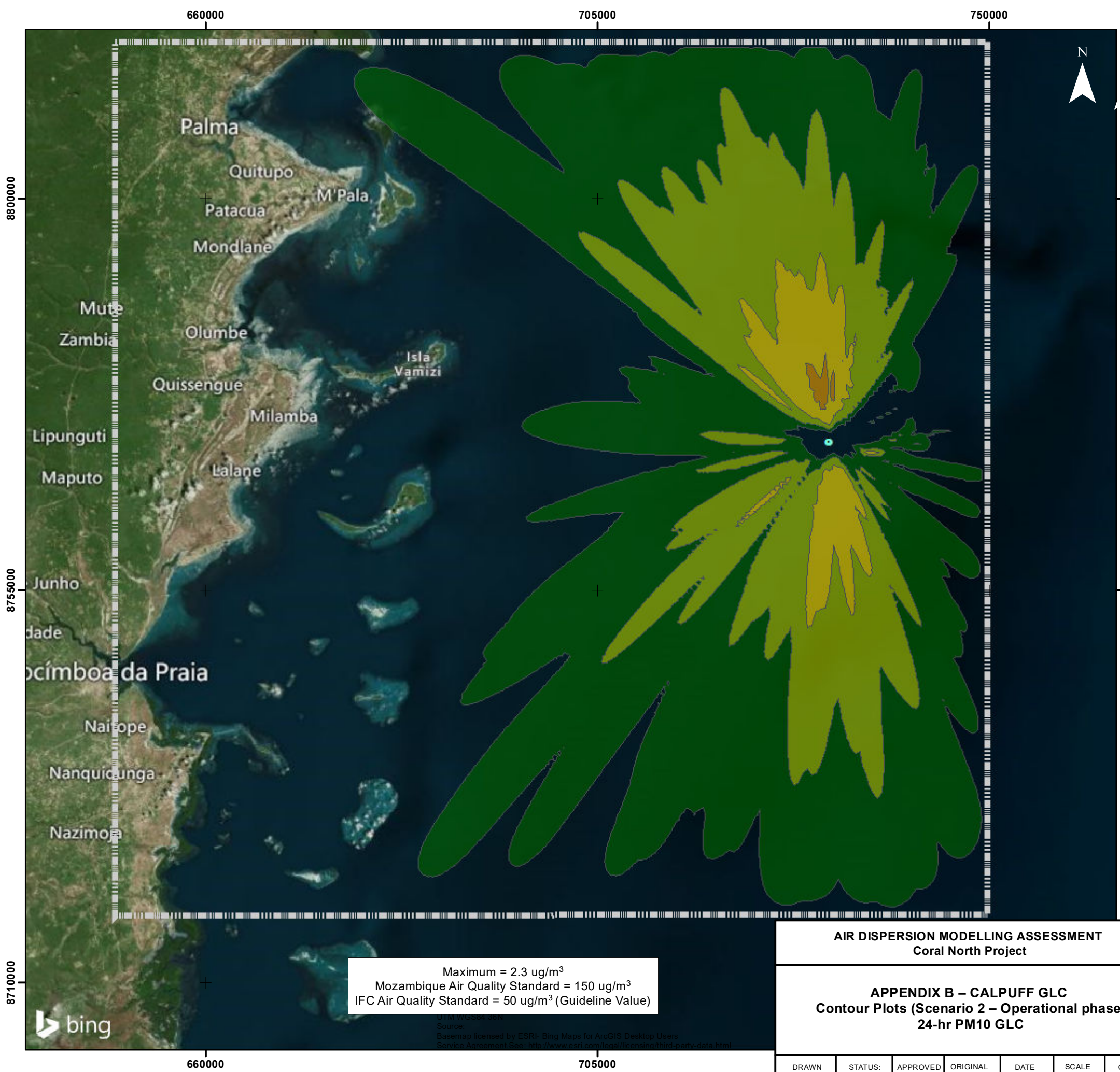


Maximum = 0.08 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 40 ug/m<sup>3</sup>

UTM WGS84 36N  
 Source:  
 Basemap licensed by ESRI- Bing Maps for ArcGIS Desktop Users  
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<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project							
<b>APPENDIX B – CALPUFF GLC</b> Contour Plots (Scenario 2 – Operational phase) Annual SO <sub>2</sub> GLC							
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE <b>FIGURE B.5</b>
						Rev.0	

NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC04\15000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix B\15000-00382 - Mozambique Coral North Air - B-5 - Annual SO2.mxd



Maximum = 2.3 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 150 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 50 ug/m<sup>3</sup> (Guideline Value)

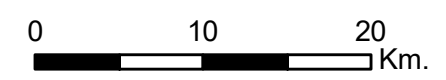
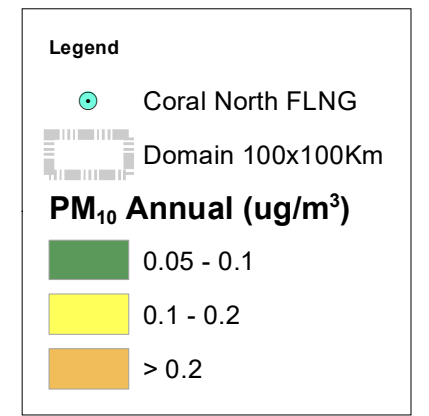
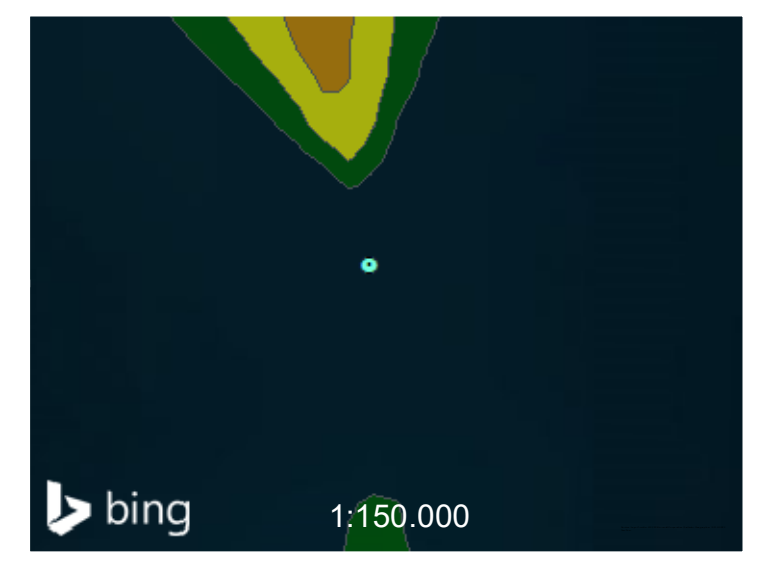
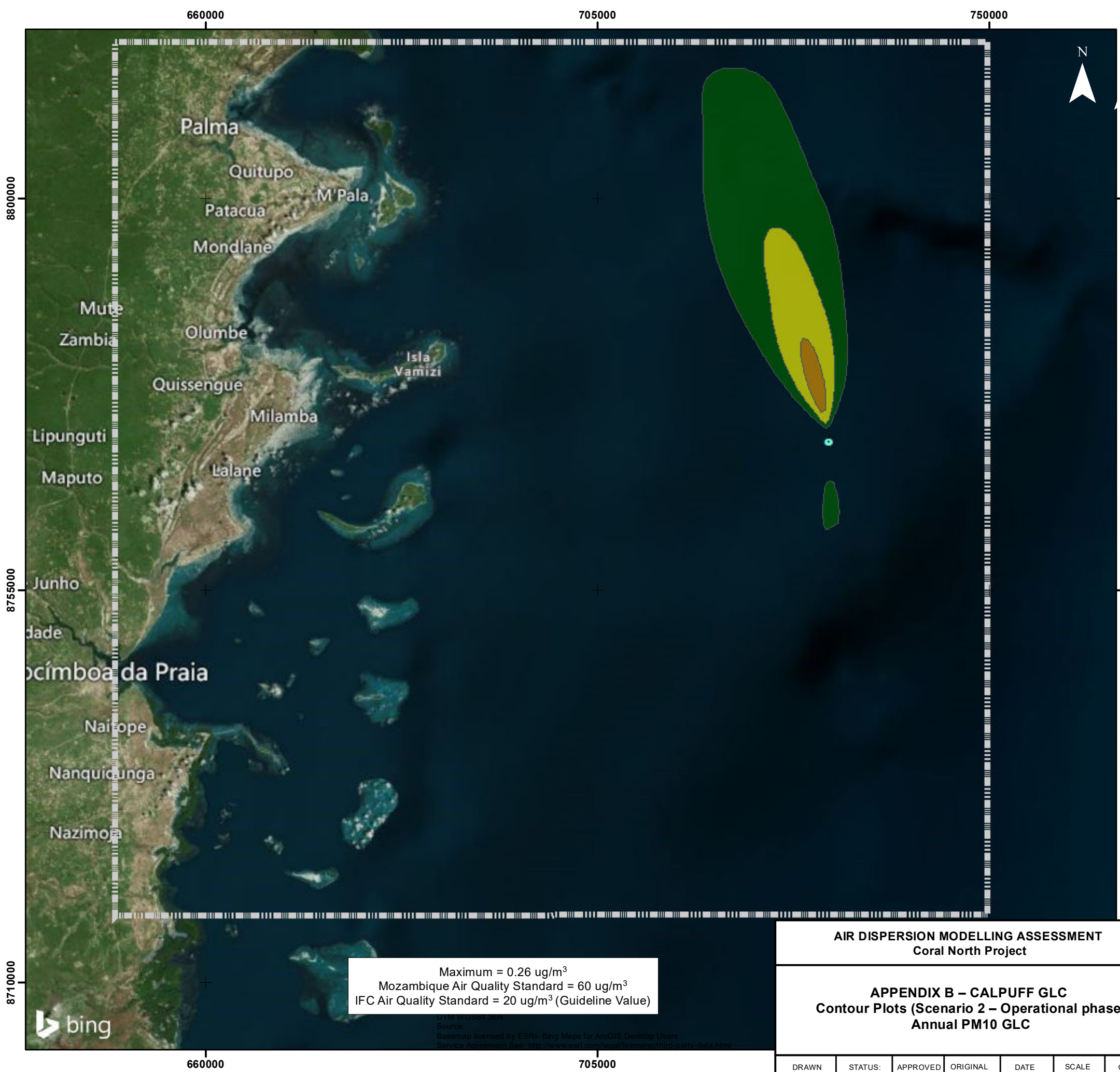
**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

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**APPENDIX B – CALPUFF GLC**  
 Contour Plots (Scenario 2 – Operational phase)  
 24-hr PM<sub>10</sub> GLC

DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450,000	OFFICE MADRID	CODE	<b>FIGURE B.6</b>	Rev.0
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NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix B\15000-00382 - Mozambique Coral North Air - B-6 - 24-hr PM10.mxd



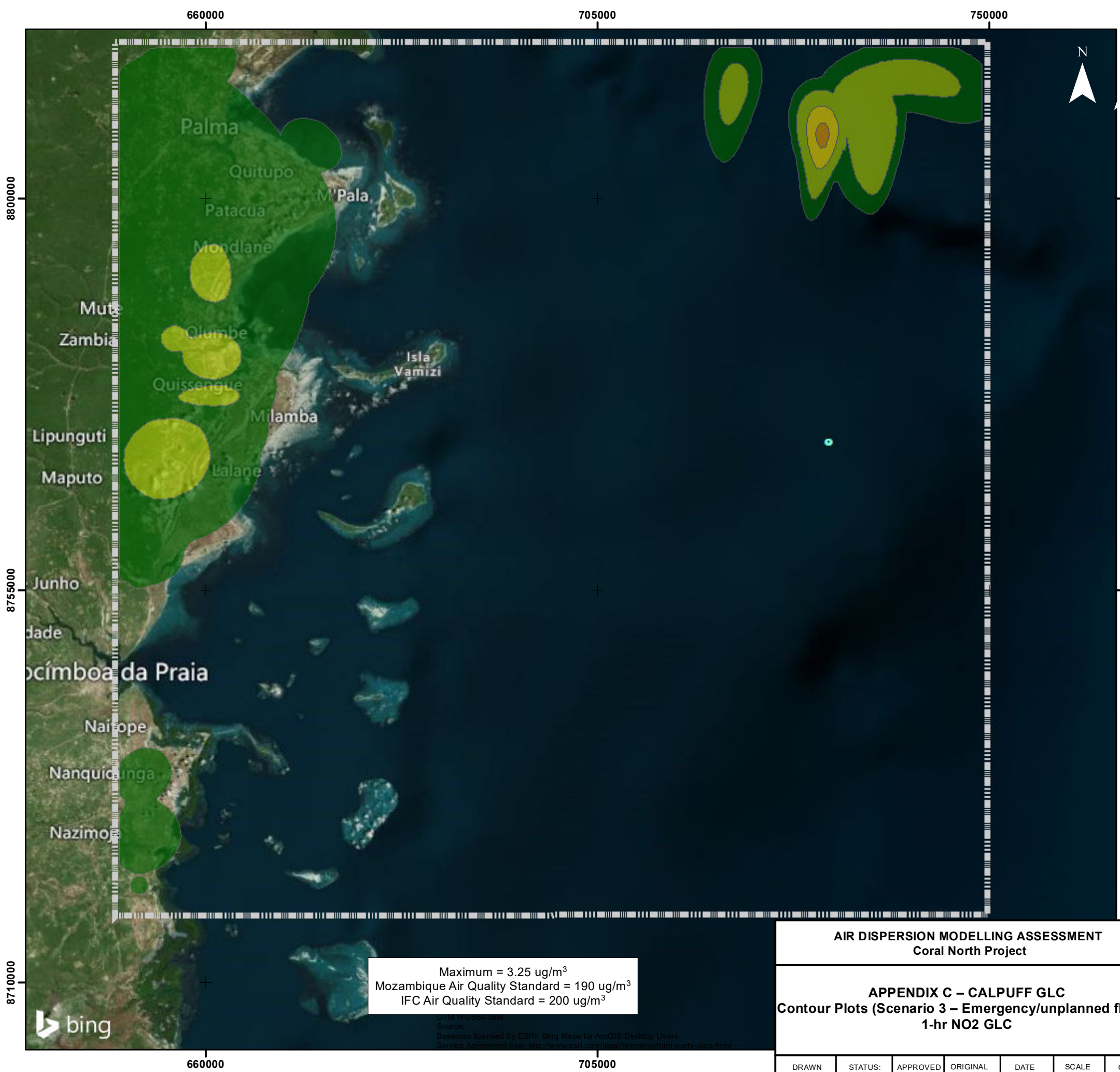
Maximum = 0.26 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 60 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 20 ug/m<sup>3</sup> (Guideline Value)

<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project									
<b>APPENDIX B – CALPUFF GLC</b> Contour Plots (Scenario 2 – Operational phase) Annual PM <sub>10</sub> GLC									
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	<b>FIGURE B.7</b>	Rev.0

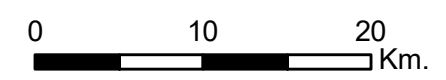
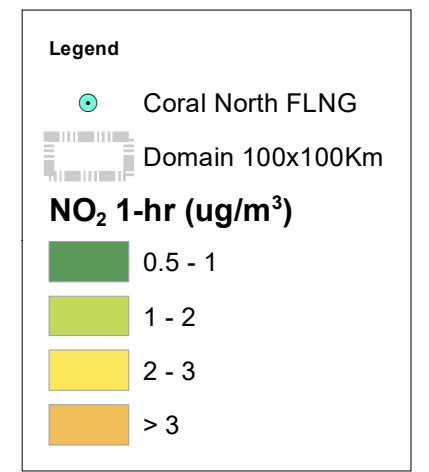
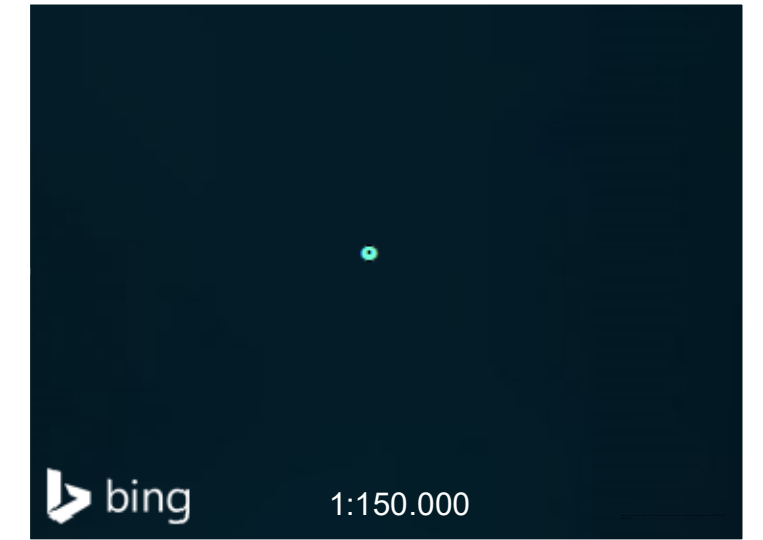
NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix B\15000-00382 - Mozambique Coral North Air - B-7 - Annual PM10.mxd

## **Annex IV.C – CALPUFF GLC Contour Plots (Scenario 3 – Emergency and/or Unplanned Flaring)**

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Maximum = 3.25 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 190 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 200 ug/m<sup>3</sup>

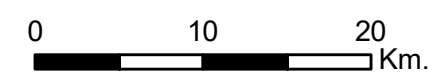
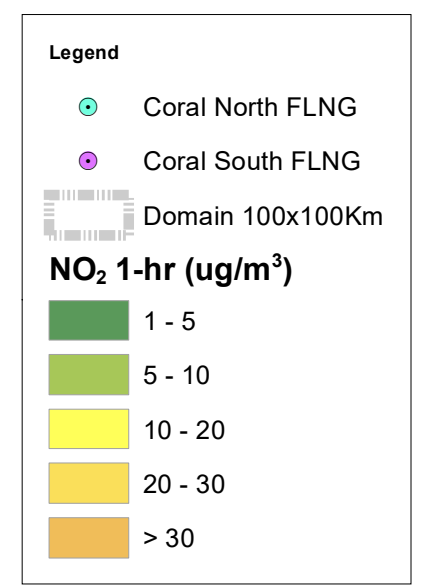
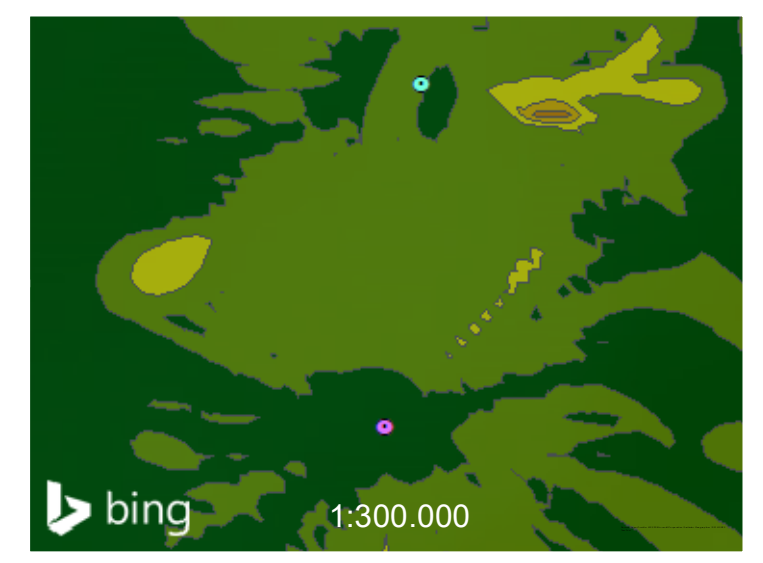
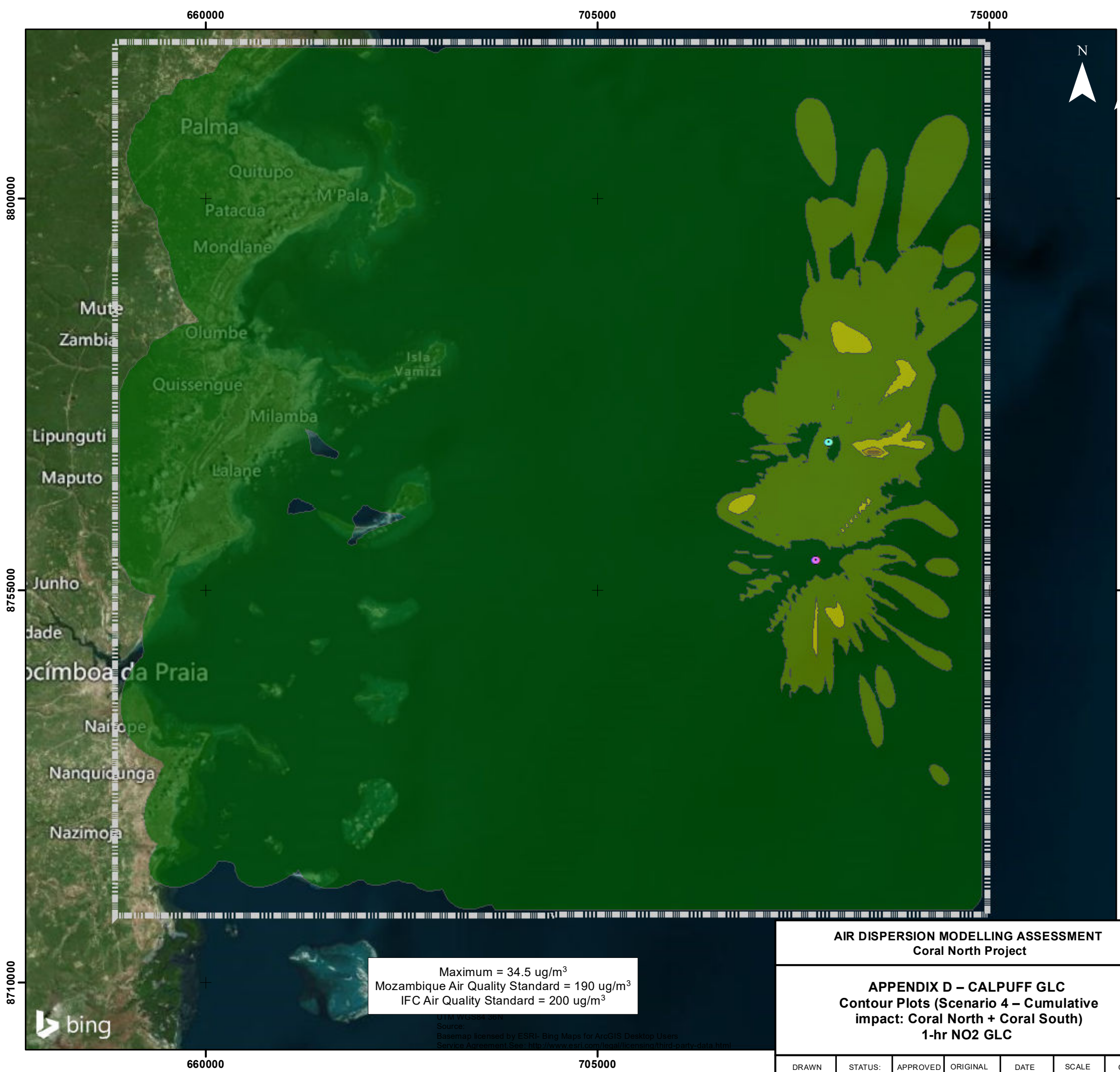


<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project									
<b>APPENDIX C – CALPUFF GLC</b> Contour Plots (Scenario 3 – Emergency/unplanned flaring) 1-hr NO <sub>2</sub> GLC									
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 24/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	FIGURE C.1	Rev.0

NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix C\415000-00382 - Mozambique Coral North Air - C-1\_1-hr-NO2.mxd

## **Annex IV.D – CALPUFF GLC Contour Plots (Scenario 4 – Cumulative Impact: Coral North plus Coral South)**

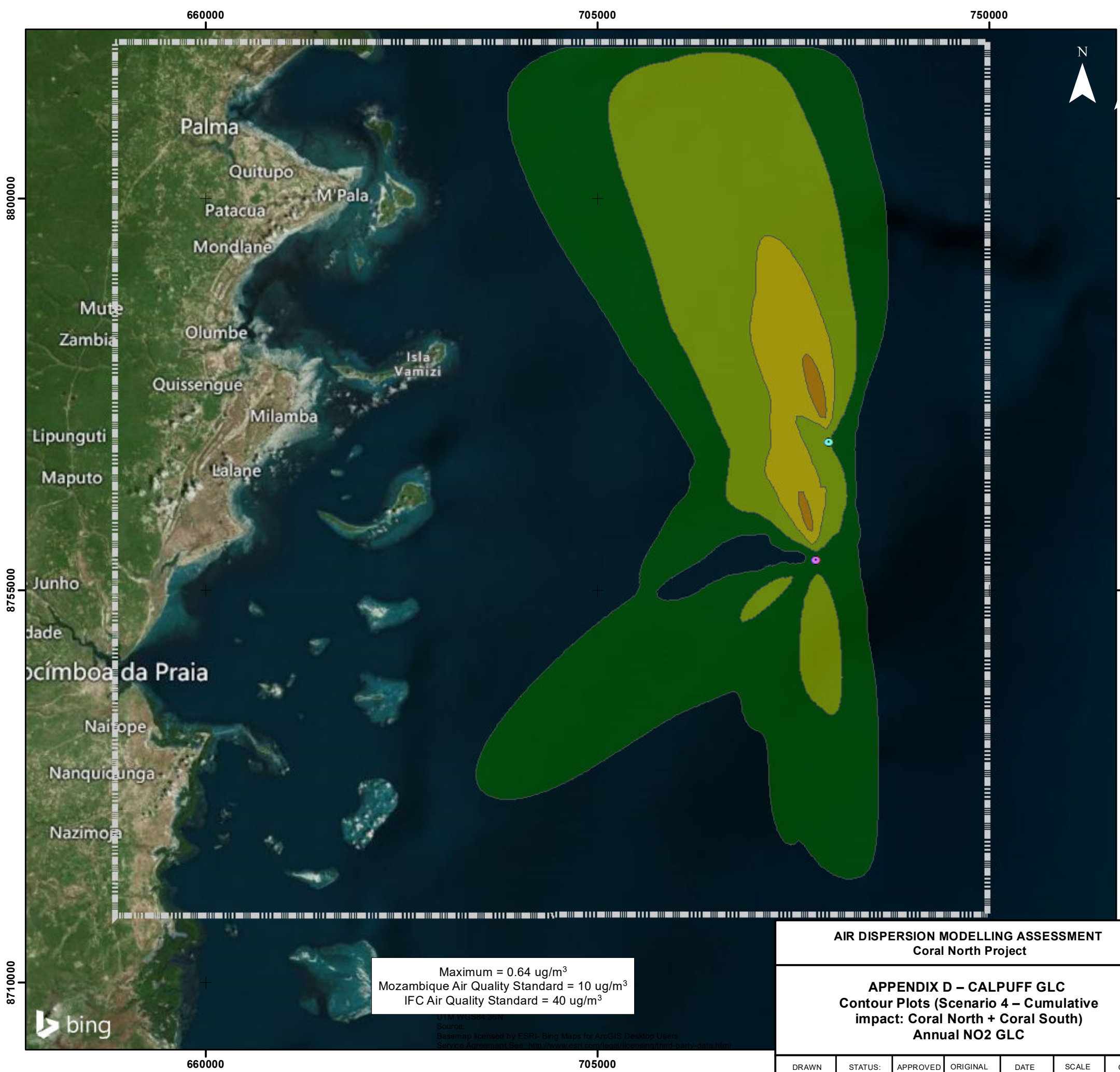
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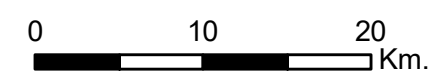
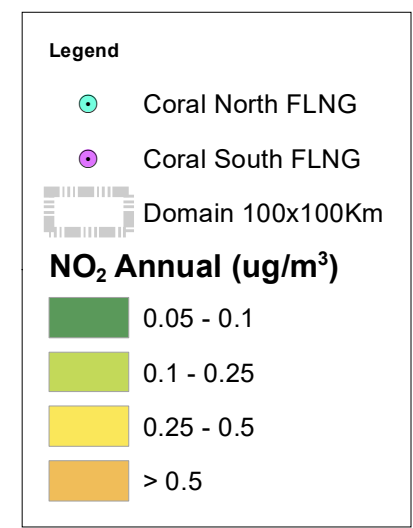
Maximum = 34.5 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 190 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 200 ug/m<sup>3</sup>

<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project									
<b>APPENDIX D – CALPUFF GLC</b> Contour Plots (Scenario 4 – Cumulative impact: Coral North + Coral South) 1-hr NO <sub>2</sub> GLC							 <b>Advisian</b> Worley Group		
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 25/08/2023	SCALE 1:450,000	OFFICE MADRID	CODE	<b>FIGURE D.1</b>	Rev.0

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 Pathname: C:\TTCG\415000-00382 - GISMXD\Appendix D\415000-00382 - Mozambique Coral North Air - D-1\_1-hr-NO2.mxd



Maximum = 0.64 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 10 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 40 ug/m<sup>3</sup>



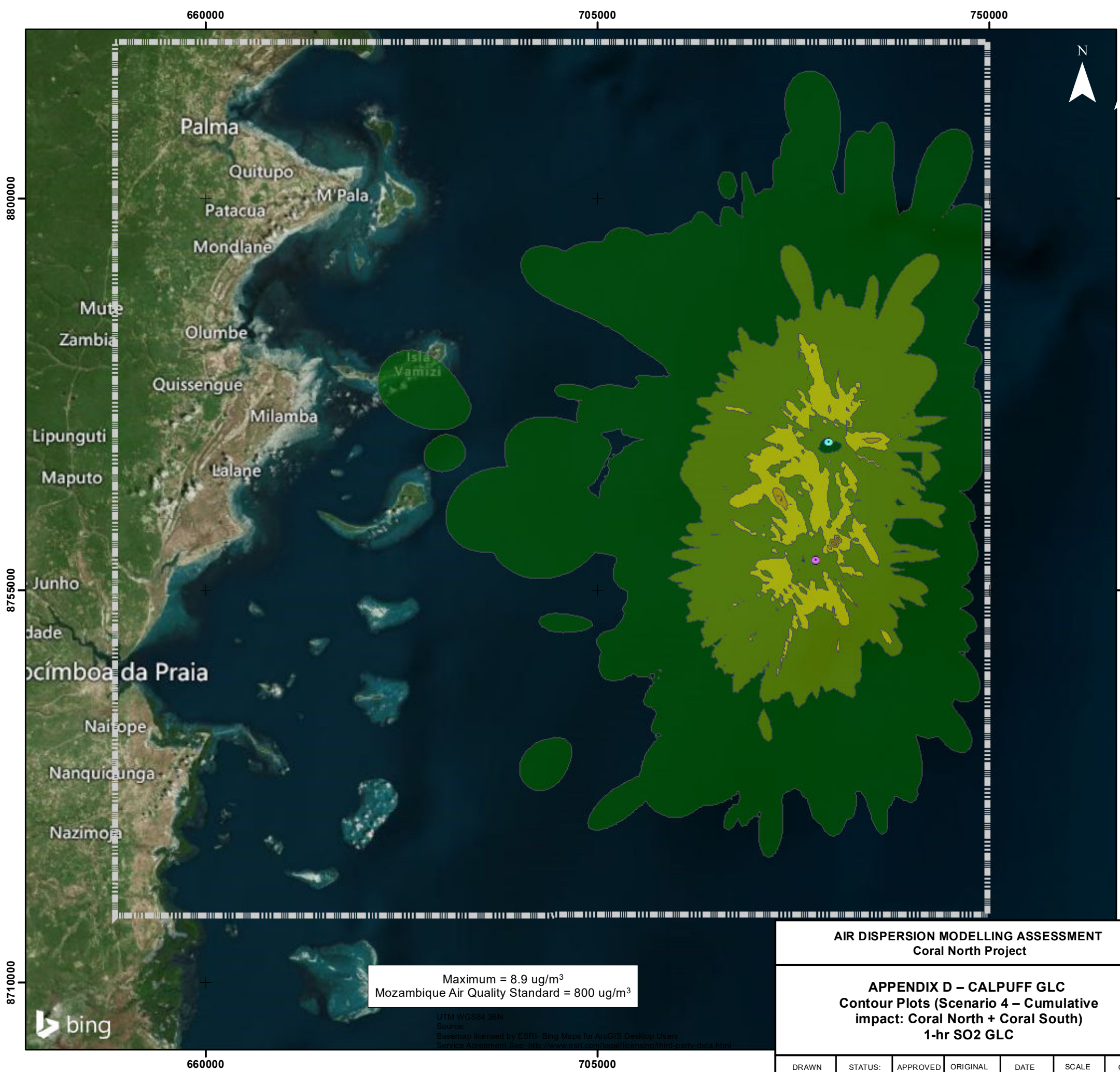
**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

**APPENDIX D – CALPUFF GLC**  
 Contour Plots (Scenario 4 – Cumulative  
 impact: Coral North + Coral South)  
 Annual NO<sub>2</sub> GLC



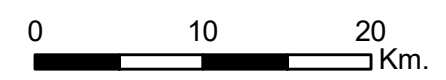
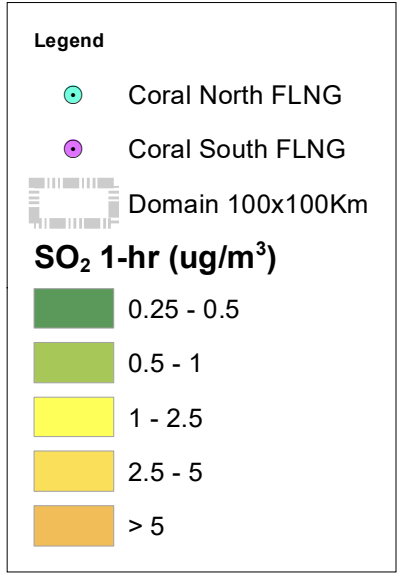
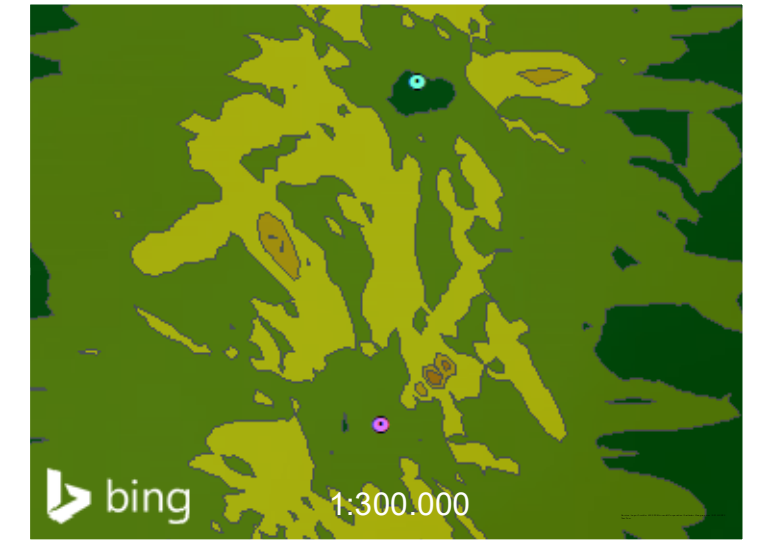
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Maximum = 8.9 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 800 ug/m<sup>3</sup>

UTM WGS84 36N  
 Source:  
 Basemap licensed by ESRI- Bing Maps for ArcGIS Desktop Users  
 Service Agreement See: [http://www.esri.com/legal/collateral/bing\\_maps\\_data.shtml](http://www.esri.com/legal/collateral/bing_maps_data.shtml)



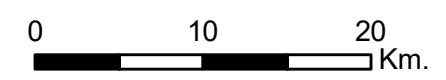
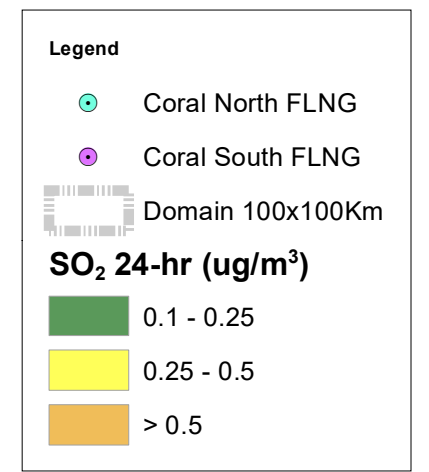
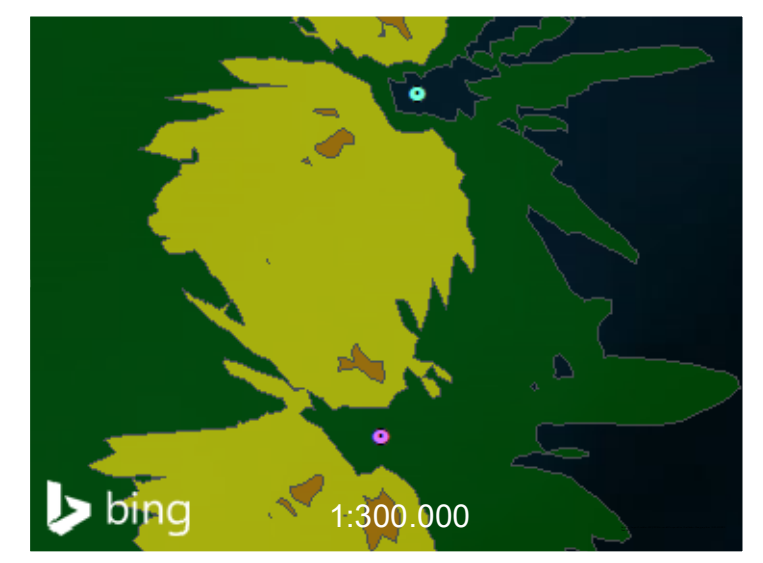
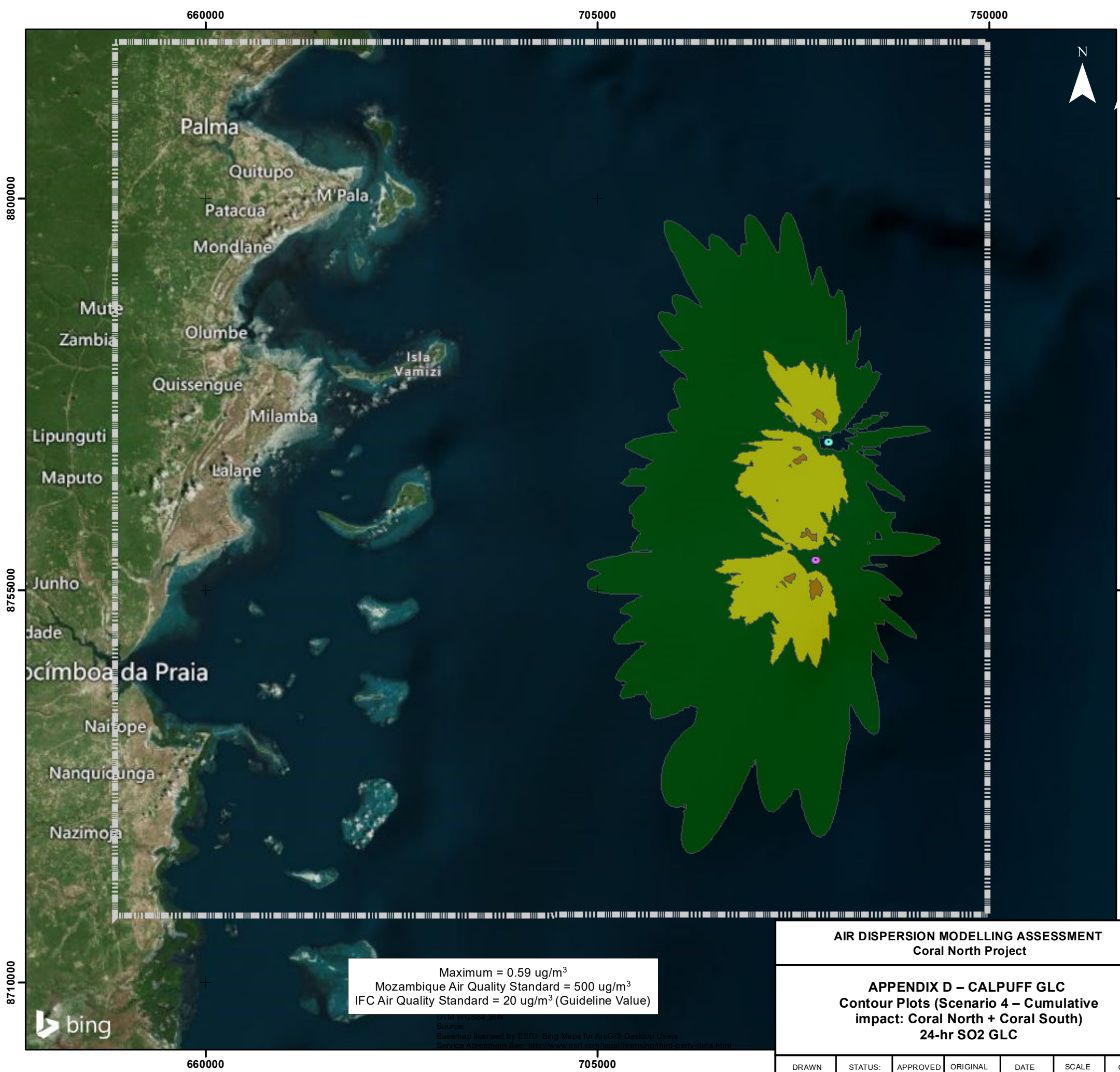
**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

**APPENDIX D – CALPUFF GLC**  
 Contour Plots (Scenario 4 – Cumulative  
 impact: Coral North + Coral South)  
 1-hr SO<sub>2</sub> GLC



DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 25/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	<b>FIGURE D.3</b>	Rev.0
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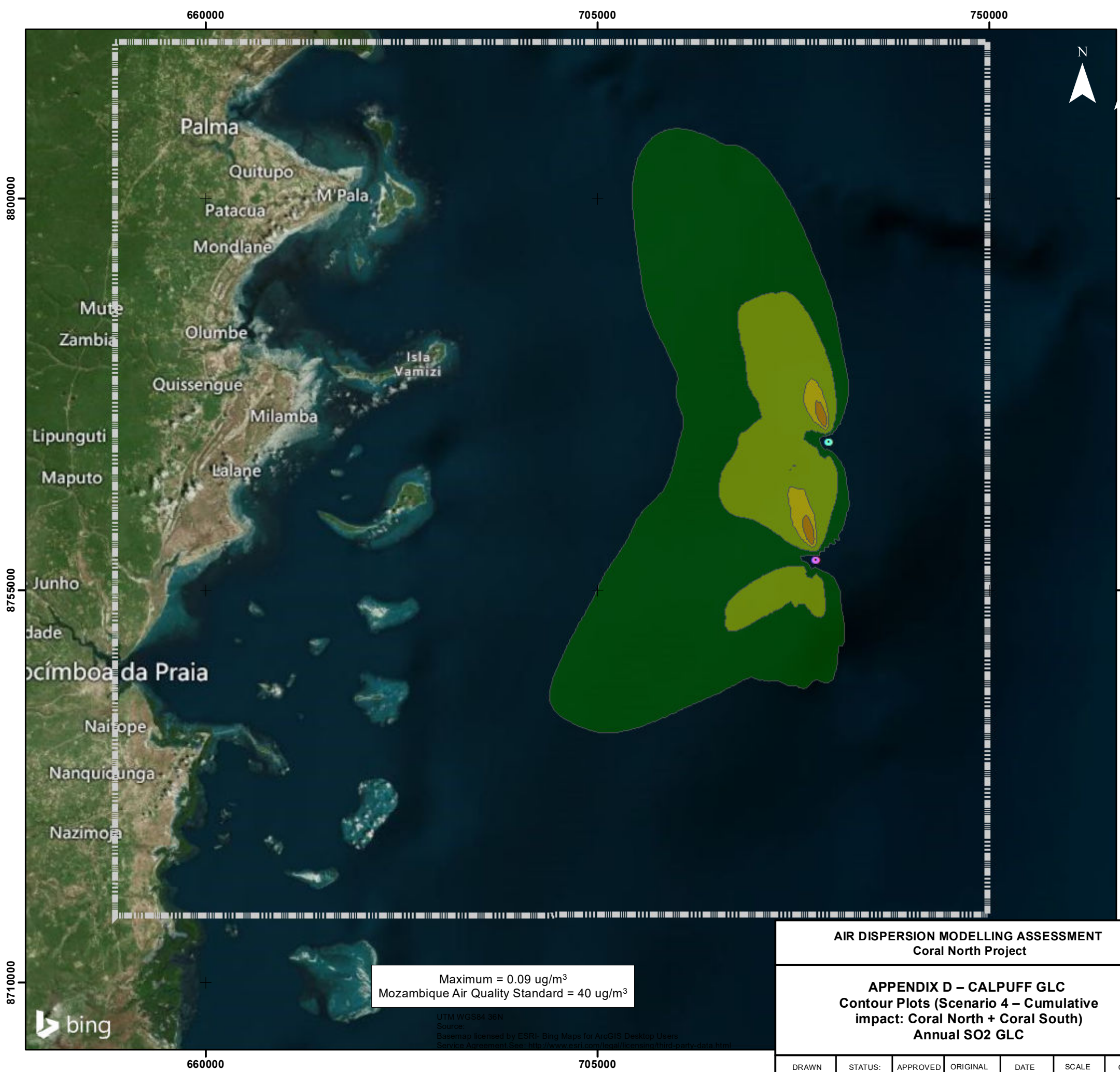


Maximum = 0.59 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 500 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 20 ug/m<sup>3</sup> (Guideline Value)

<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project							
<b>APPENDIX D – CALPUFF GLC</b> Contour Plots (Scenario 4 – Cumulative impact: Coral North + Coral South) 24-hr SO <sub>2</sub> GLC							
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 25/08/2023	SCALE 1:450,000	OFFICE MADRID	CODE
						<b>FIGURE D.4</b>	Rev.0

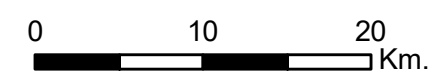
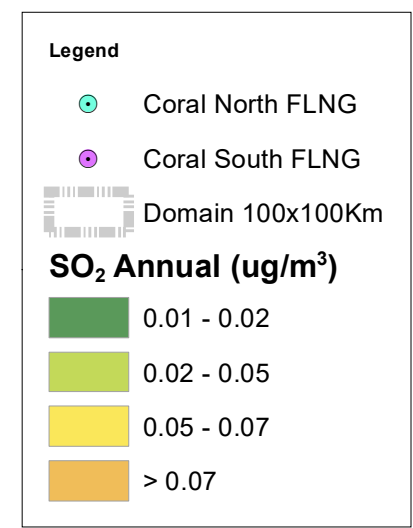
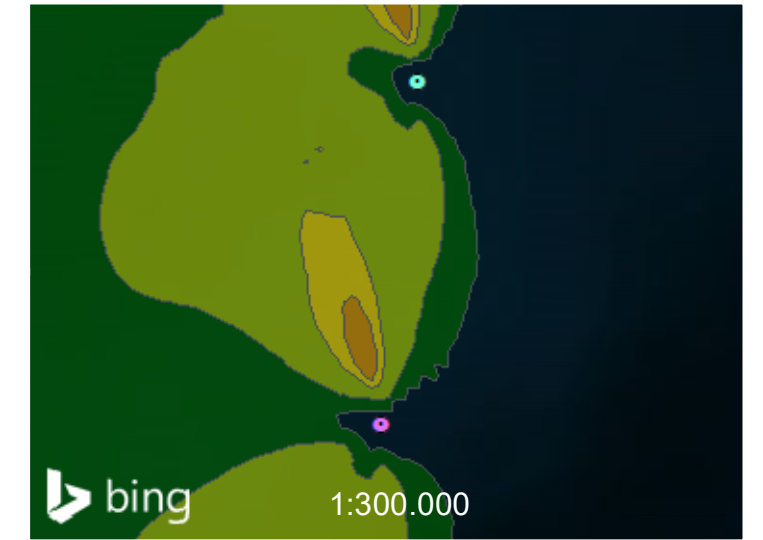
NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.

Pathname: C:\TTC\415000-00382 - GIS\MXD\Appendix D\4 15000-00382 - Mozambique Coral North Air - D-4 - 24-hr SO2.mxd



Maximum = 0.09 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 40 ug/m<sup>3</sup>

UTM WGS84 36N  
 Source:  
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 Service Agreement See: <http://www.esri.com/legal/collaborating-partners-data.html>



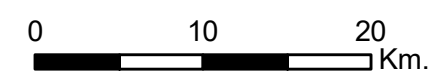
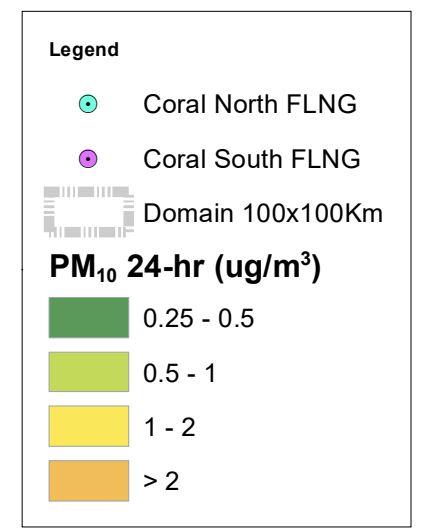
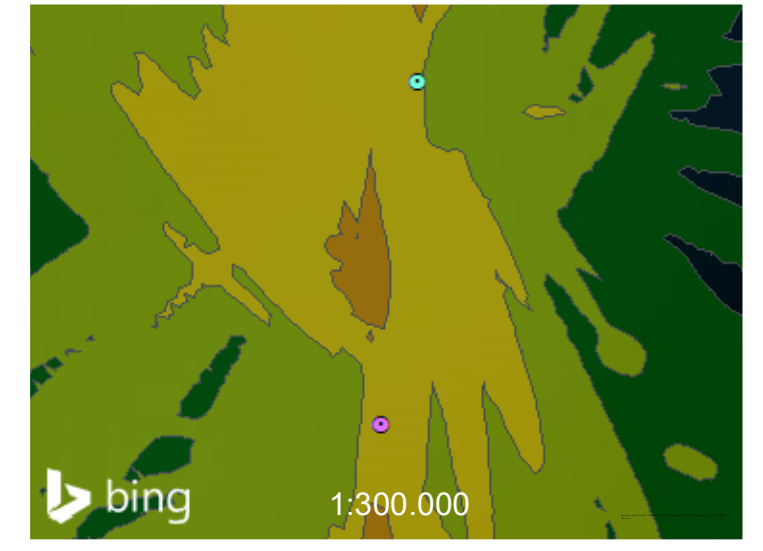
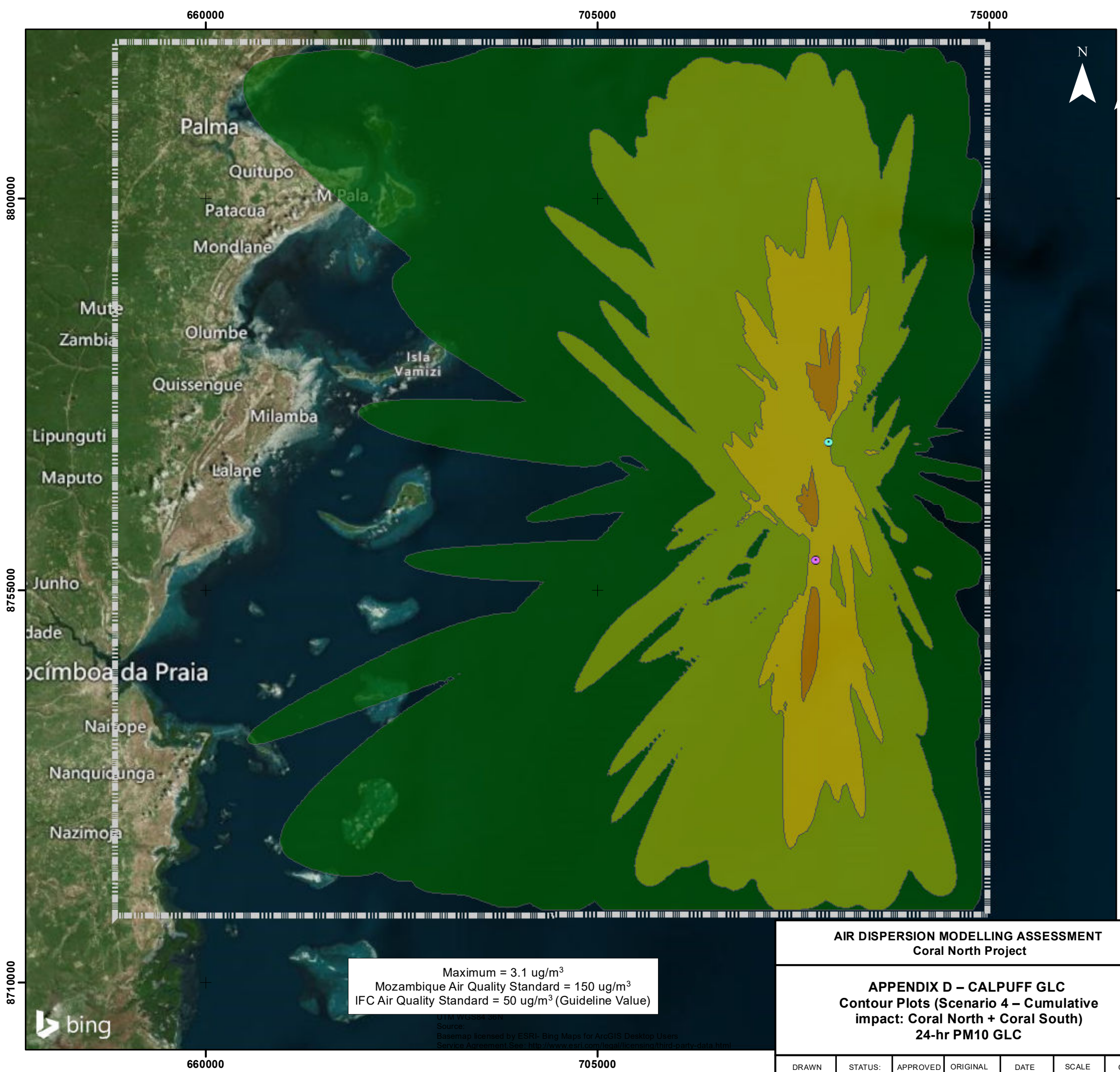
**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

**APPENDIX D – CALPUFF GLC**  
 Contour Plots (Scenario 4 – Cumulative  
 impact: Coral North + Coral South)  
 Annual SO<sub>2</sub> GLC



DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 25/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	<b>FIGURE D.5</b>	Rev.0
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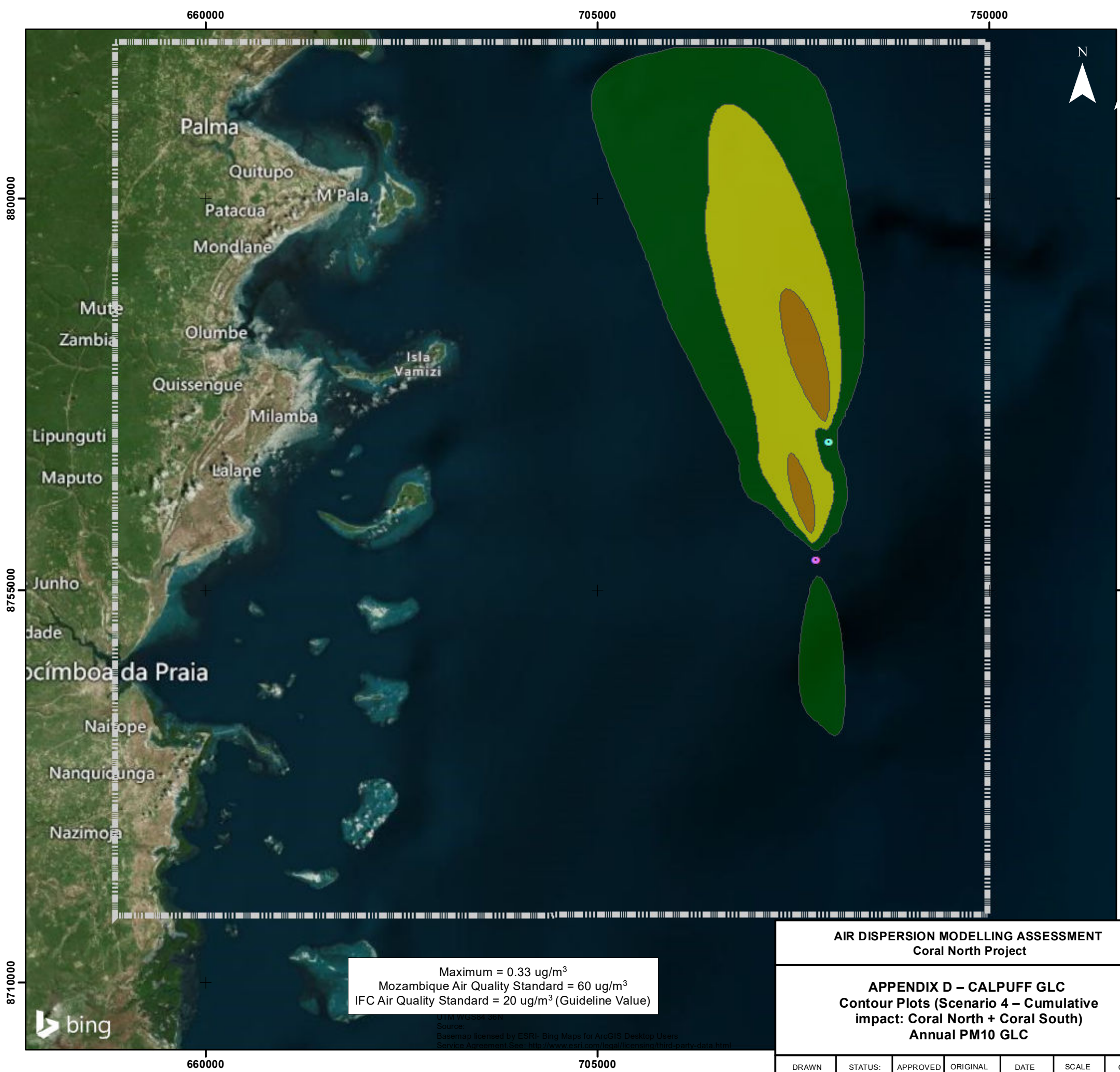
NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix D\415000-00382 - Mozambique Coral North Air - D-5 - Annual SO2.mxd



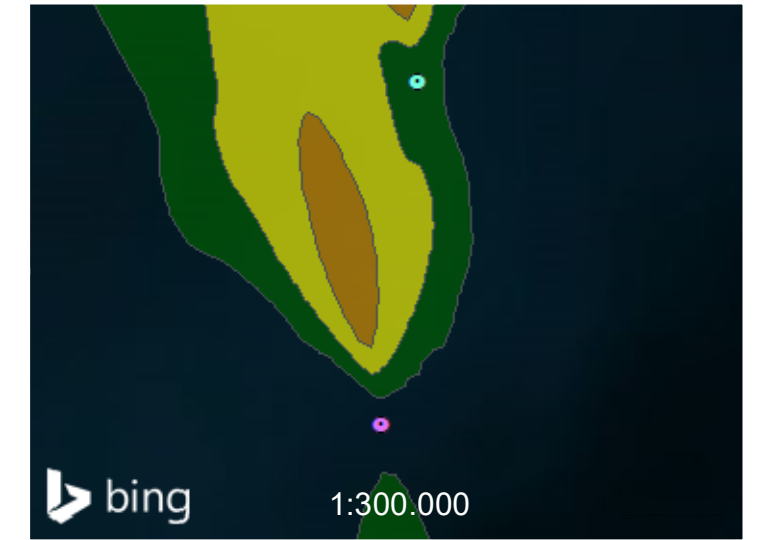
Maximum = 3.1 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 150 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 50 ug/m<sup>3</sup> (Guideline Value)

<b>AIR DISPERSION MODELLING ASSESSMENT</b> Coral North Project									
<b>APPENDIX D – CALPUFF GLC</b> Contour Plots (Scenario 4 – Cumulative impact: Coral North + Coral South) 24-hr PM <sub>10</sub> GLC									
DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 25/08/2023	SCALE 1:450.000	OFFICE MADRID	CODE	FIGURE D.6	Rev.0

NOTE: THE PROPERTY OF THIS DRAWING AND DESIGN IS VESTED IN WORLEYPARSONS AND MUST NOT BE COPIED OR REPRODUCED IN ANY WAY WITHOUT THEIR WRITTEN CONSENT.  
 Pathname: C:\TTC\415000-00382 - Mozambique Coral North FLNG Modelling\05 - GIS\MXD\Appendix D\415000-00382 - Mozambique Coral North Air - D.6 - 24-hr PM10.mxd



Maximum = 0.33 ug/m<sup>3</sup>  
 Mozambique Air Quality Standard = 60 ug/m<sup>3</sup>  
 IFC Air Quality Standard = 20 ug/m<sup>3</sup> (Guideline Value)

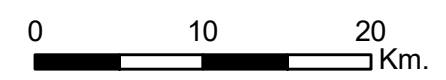


**Legend**

- Coral North FLNG
- Coral South FLNG
- Domain 100x100Km

**PM<sub>10</sub> Annual (ug/m<sup>3</sup>)**

- 0.05 - 0.1
- 0.1 - 0.2
- > 0.2



**AIR DISPERSION MODELLING ASSESSMENT**  
 Coral North Project

**APPENDIX D – CALPUFF GLC**  
 Contour Plots (Scenario 4 – Cumulative  
 impact: Coral North + Coral South)  
 Annual PM<sub>10</sub> GLC



DRAWN FJPA	STATUS: DRAFT	APPROVED MSA	ORIGINAL A3	DATE 25/08/2023	SCALE 1:450,000	OFFICE MADRID	CODE	<b>FIGURE D.7</b>	Rev.0
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 Pathname: C:\TTC\415000-00382 - GIS\MXD\Appendix D\15000-00382 - Mozambique Coral North Air - D-7 - Annual PM10.mxd

## Annex V – Biodiversity: Lists of Species

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**Table AV.1: Seabird species potentially present in the study area, and conservation status (Harrison *et al.*, 2021; IUCN, 2023)**

Family	Scientific Name	Common Name	Conservation Status As Per IUCN
Scolopacidae	<i>Actitis hypoleucos</i>	Common Sandpiper	LC
Ciconiidae	<i>Anastomus lamelligerus</i>	African Openbill	LC
Laridae	<i>Anous stolidus</i>	Brown Noddy	LC
Laridae	<i>Anous tenuirostris</i>	Lesser Noddy	LC
Procellariidae	<i>Ardenna carneipes</i>	Flesh-footed Shearwater	NT
Procellariidae	<i>Ardenna grisea</i>	Sooty Shearwater	NT
Procellariidae	<i>Ardenna pacifica</i>	Wedge-tailed Shearwater	LC
Ardeidae	<i>Ardeola idae</i>	Madagascar Pond-heron	EN
Scolopacidae	<i>Arenaria interpres</i>	Ruddy Turnstone	LC
Ardeidae	<i>Bubulcus ibis</i>	Cattle Egret	LC
Procellariidae	<i>Bulweria fallax</i>	Jouanin's Petrel	NT
Scolopacidae	<i>Calidris alba</i>	Sanderling	LC
Scolopacidae	<i>Calidris ferruginea</i>	Curlew Sandpiper	NT
Scolopacidae	<i>Calidris minuta</i>	Little Stint	LC
Cuculidae	<i>Ceuthmochares australis</i>	Whistling Yellowbill	LC
Charadriidae	<i>Charadrius hiaticula</i>	Common Ringed Plover	LC
Charadriidae	<i>Charadrius marginatus</i>	White-fronted Plover	LC
Charadriidae	<i>Charadrius mongolus</i>	Lesser Sandplover	LC
Charadriidae	<i>Charadrius pallidus</i>	Chestnut-banded Plover	LC
Laridae	<i>Chlidonias hybrida</i>	Whiskered Tern	LC
Laridae	<i>Chlidonias leucopterus</i>	White-winged Tern	LC
Ciconiidae	<i>Ciconia microscelis</i>	African Woollyneck	LC
Diomedeidae	<i>Diomedea exulans</i>	Wandering Albatross	VU
Dromadidae	<i>Dromas ardeola</i>	Crab-plover	LC
Ardeidae	<i>Egretta ardesiaca</i>	Black Heron	LC
Ardeidae	<i>Egretta garzetta</i>	Little Egret	LC
Ardeidae	<i>Egretta gularis</i>	Western Reef-egret	LC
Falconidae	<i>Falco concolor</i>	Sooty Falcon	VU
Fregatidae	<i>Fregata ariel</i>	Lesser Frigatebird	LC
Fregatidae	<i>Fregata minor</i>	Great Frigatebird	LC
Oceanitidae	<i>Fregatta tropica</i>	Black-bellied Storm-petrel	LC
Laridae	<i>Hydroprogne caspia</i>	Caspian Tern	LC
Laridae	<i>Larus cirrocephalus</i>	Grey-headed Gull	LC
Laridae	<i>Larus fuscus</i>	Lesser Black-backed Gull	LC
Laridae	<i>Larus hemprichii</i>	Sooty Gull	LC

Family	Scientific Name	Common Name	Conservation Status As Per IUCN
Scolopacidae	<i>Limosa lapponica</i>	Bar-tailed Godwit	NT
Phalacrocoracidae	<i>Microcarbo africanus</i>	Long-tailed Cormorant	LC
Sulidae	<i>Morus capensis</i>	Cape Gannet	EN
Scolopacidae	<i>Numenius arquata</i>	Eurasian curlew	NT
Scolopacidae	<i>Numenius phaeopus</i>	Whimbrel	LC
Oceanitidae	<i>Oceanites oceanicus</i>	Wilson's Storm-petrel	LC
Laridae	<i>Onychoprion anaethetus</i>	Bridled Tern	LC
Laridae	<i>Onychoprion fuscatus</i>	Sooty Tern	LC
Oceanitidae	<i>Pelagodroma marina</i>	White-faced Storm-petrel	LC
Pelecanidae	<i>Pelecanus onocrotalus</i>	Great White Pelican	LC
Pelecanidae	<i>Pelecanus rufescens</i>	Pink-backed Pelican	LC
Phaethontidae	<i>Phaethon lepturus</i>	White-tailed Tropicbird	LC
Phaethontidae	<i>Phaethon rubricauda</i>	Red-tailed Tropicbird	LC
Diomedeidae	<i>Phoebastria fusca</i>	Sooty Albatross	EN
Phoenicopteridae	<i>Phoeniconaias minor</i>	Lesser flamingo	NT
Phoenicopteridae	<i>Phoenicopterus roseus</i>	Greater flamingo	LC
Charadriidae	<i>Pluvialis squatarola</i>	Grey plover	LC
Procellariidae	<i>Procellaria aequinoctialis</i>	White-chinned petrel	VU
Procellariidae	<i>Procellaria cinerea</i>	Grey Petrel	NT
Procellariidae	<i>Pseudobulweria rostrata</i>	Tahiti Petrel	NT
Procellariidae	<i>Pterodroma mollis</i>	Soft-plumaged Petrel	LC
Procellariidae	<i>Puffinus bailloni ssp. nicolae</i>	Tropical Shearwater	LC
Procellariidae	<i>Puffinus persicus</i>	Persian Shearwater	LC
Laridae	<i>Rynchops flavirostris</i>	African Skimmer	LC
Spheniscidae	<i>Spheniscus demersus</i>	African Penguin	EN
Laridae	<i>Sterna dougallii</i>	Roseate Tern	LC
Laridae	<i>Sterna hirundo</i>	Common Tern	LC
Laridae	<i>Sterna sumatrana</i>	Black-naped Tern	LC
Laridae	<i>Sternula albifrons</i>	Little Tern	LC
Laridae	<i>Sternula saundersi</i>	Saunders's Tern	LC
Sulidae	<i>Sula dactylatra</i>	Masked Booby	LC
Sulidae	<i>Sula leucogaster</i>	Brown Booby	LC
Sulidae	<i>Sula sula</i>	Red-footed Booby	LC
Diomedeidae	<i>Thalassarche carteri</i>	Indian Yellow-nosed Albatross	EN
Diomedeidae	<i>Thalassarche cauta</i>	Shy Albatross	NT
Diomedeidae	<i>Thalassarche melanophrys</i>	Black-browed Albatross	LC

Family	Scientific Name	Common Name	Conservation Status As Per IUCN
Diomedidae	<i>Thalassarche steadi</i>	White-capped Albatross	NT
Laridae	<i>Thalasseus bengalensis</i>	Lesser Crested Tern	LC
Laridae	<i>Thalasseus bergii</i>	Greater Crested Tern	LC
Threskiornithidae	<i>Threskiornis aethiopicus</i>	African Sacred Ibis	LC

**Table AV.2: Species evaluated for CHA, percentage of DMU to EOO (see Critical Habitat Assessment section in Volume I) and conservation status (IUCN, 2023)**

Scientific Name	Taxonomic Group (Class)	Percent DMU/EOO	IUCN
<i>Ablennes hians</i>	Actinopterygii	0,02%	LC
<i>Abyssobrotula galathea</i>	Actinopterygii	> 0,01%	LC
<i>Accipiter badius</i>	Aves	-	LC
<i>Accipiter melanoleucus</i>	Aves	-	LC
<i>Aetomylaeus bovinus</i>	Chondrichthyes	> 0,01%	VU
<i>Alectis ciliaris</i>	Actinopterygii	> 0,01%	LC
<i>Alepisaurus ferox</i>	Actinopterygii	> 0,01%	LC
<i>Allocyttus verrucosus</i>	Actinopterygii	> 0,01%	LC
<i>Alopias superciliosus</i>	Chondrichthyes	> 0,01%	VU
<i>Aluterus monoceros</i>	Actinopterygii	-	LC
<i>Aluterus scriptus</i>	Actinopterygii	-	LC
<i>Amphilius uranoscopus</i>	Actinopterygii	> 0,01%	LC
<i>Anhinga rufa</i>	Aves	-	LC
<i>Anoplogaster cornuta</i>	Actinopterygii	-	LC
<i>Antennarius striatus</i>	Actinopterygii	0,05%	LC
<i>Anthus trivialis</i>	Aves	> 0,01%	LC
<i>Antigonia capros</i>	Actinopterygii	0,03%	LC
<i>Antimora rostrata</i>	Actinopterygii	> 0,01%	LC
<i>Aquila nipalensis</i>	Aves	> 0,01%	EN
<i>Aquila rapax</i>	Aves	> 0,01%	VU
<i>Arctozenus risso</i>	Actinopterygii	> 0,01%	LC
<i>Argyropelecus aculeatus</i>	Actinopterygii	> 0,01%	LC
<i>Argyropelecus gigas</i>	Actinopterygii	0,01%	LC
<i>Argyropelecus hemigymnus</i>	Actinopterygii	> 0,01%	LC
<i>Argyropelecus olfersii</i>	Actinopterygii	> 0,01%	LC
<i>Argyropelecus sladeni</i>	Actinopterygii	> 0,01%	LC
<i>Aristostomias lunifer</i>	Actinopterygii	0,01%	LC
<i>Asquamiceps caeruleus</i>	Actinopterygii	0,02%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EEO	IUCN
<i>Astronesthes niger</i>	Actinopterygii	0,01%	LC
<i>Auxis rochei</i>	Actinopterygii	0,02%	LC
<i>Auxis thazard</i>	Actinopterygii	0,02%	LC
<i>Avocettina acuticeps</i>	Actinopterygii	0,03%	LC
<i>Avocettina infans</i>	Actinopterygii	> 0,01%	LC
<i>Bajacalifornia calcarata</i>	Actinopterygii	0,03%	LC
<i>Balaenoptera acutorostrata</i>	Mammalia	0,01%	LC
<i>Balaenoptera borealis</i>	Mammalia	> 0,01%	EN
<i>Balaenoptera edeni</i>	Mammalia	> 0,01%	LC
<i>Balaenoptera musculus</i>	Mammalia	> 0,01%	EN
<i>Barbourisia rufa</i>	Actinopterygii	0,02%	LC
<i>Bathylaco nigricans</i>	Actinopterygii	0,02%	LC
<i>Benthosema suborbitale</i>	Actinopterygii	0,01%	LC
<i>Beryx splendens</i>	Actinopterygii	0,02%	LC
<i>Bolinichthys photothorax</i>	Actinopterygii	-	LC
<i>Bonapartia pedaliota</i>	Actinopterygii	0,01%	LC
<i>Brama brama</i>	Actinopterygii	0,01%	LC
<i>Brama dussumieri</i>	Actinopterygii	0,01%	LC
<i>Bregmaceros nectabanus</i>	Actinopterygii	0,04%	LC
<i>Brycinus imberi</i>	Actinopterygii	-	LC
<i>Canthidermis maculata</i>	Actinopterygii	0,03%	LC
<i>Carcharhinus falciformis</i>	Chondrichthyes	> 0,01%	NT
<i>Carcharhinus leucas</i>	Chondrichthyes	> 0,01%	VU
<i>Carcharhinus limbatus</i>	Chondrichthyes	> 0,01%	VU
<i>Carcharhinus longimanus</i>	Chondrichthyes	> 0,01%	CR
<i>Carcharias taurus</i>	Chondrichthyes	> 0,01%	NT
<i>Carcharodon carcharias</i>	Chondrichthyes	> 0,01%	NT
<i>Caretta caretta</i>	Reptilia	> 0,01%	NT
<i>Caulophryne jordani</i>	Actinopterygii	0,01%	LC
<i>Centrophorus uyato</i>	Chondrichthyes	> 0,01%	EN
<i>Ceratias holboelli</i>	Actinopterygii	> 0,01%	LC
<i>Ceratoscopelus townsendi</i>	Actinopterygii	> 0,01%	LC
<i>Ceratoscopelus warmingii</i>	Actinopterygii	> 0,01%	LC
<i>Chaenophryne draco</i>	Actinopterygii	0,01%	LC
<i>Chaenophryne longiceps</i>	Actinopterygii	> 0,01%	LC
<i>Chaenophryne ramifera</i>	Actinopterygii	0,02%	LC
<i>Chascanopsetta lugubris</i>	Actinopterygii	0,05%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EEO	IUCN
<i>Chauliodus sloani</i>	Actinopterygii	> 0,01%	LC
<i>Chaunax pictus</i>	Actinopterygii	0,05%	LC
<i>Cheilopogon nigricans</i>	Actinopterygii	0,01%	LC
<i>Chelon melinopterus</i>	Actinopterygii	> 0,01%	LC
<i>Chelonia mydas</i>	Reptilia	> 0,01%	EN
<i>Chiasmodon niger</i>	Actinopterygii	> 0,01%	LC
<i>Chiasmodon pluriradiatus</i>	Actinopterygii	0,02%	LC
<i>Chilomycterus reticulatus</i>	Actinopterygii	0,04%	LC
<i>Chlorophthalmus agassizi</i>	Actinopterygii	0,01%	LC
<i>Chondrodactylus laevigatus</i>	Reptilia	> 0,01%	LC
<i>Ciconia ciconia</i>	Aves	-	LC
<i>Circus pygargus</i>	Aves	> 0,01%	LC
<i>Clamator levaillantii</i>	Aves	> 0,01%	LC
<i>Clanga pomarina</i>	Aves	-	LC
<i>Clarias gariepinus</i>	Actinopterygii	> 0,01%	LC
<i>Coptodon rendalli</i>	Actinopterygii	-	LC
<i>Coracias garrulus</i>	Aves	> 0,01%	LC
<i>Coryphaena equiselis</i>	Actinopterygii	> 0,01%	LC
<i>Coryphaena hippurus</i>	Actinopterygii	> 0,01%	LC
<i>Cryptopsaras couesii</i>	Actinopterygii	> 0,01%	LC
<i>Cubiceps capensis</i>	Actinopterygii	-	LC
<i>Cubiceps pauciradiatus</i>	Actinopterygii	-	LC
<i>Cyanomitra olivacea</i>	Aves	-	LC
<i>Cyclothone acclinidens</i>	Actinopterygii	> 0,01%	LC
<i>Cyclothone alba</i>	Actinopterygii	> 0,01%	LC
<i>Cyclothone braueri</i>	Actinopterygii	> 0,01%	LC
<i>Cyclothone microdon</i>	Actinopterygii	> 0,01%	LC
<i>Cyclothone pallida</i>	Actinopterygii	> 0,01%	LC
<i>Cyclothone pseudopallida</i>	Actinopterygii	> 0,01%	LC
<i>Cynoglossus zanzibarensis</i>	Actinopterygii	> 0,01%	LC
<i>Dermodochelys coriacea</i>	Reptilia	> 0,01%	NT
<i>Diaphus lucidus</i>	Actinopterygii	-	LC
<i>Diaphus luetkeni</i>	Actinopterygii	-	LC
<i>Diaphus metopoclampus</i>	Actinopterygii	-	LC
<i>Diogenichthys atlanticus</i>	Actinopterygii	> 0,01%	LC
<i>Diplophos taenia</i>	Actinopterygii	> 0,01%	LC
<i>Diretmichthys parini</i>	Actinopterygii	> 0,01%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EEO	IUCN
<i>Diretmoides pauciradiatus</i>	Actinopterygii	> 0,01%	LC
<i>Diretmus argenteus</i>	Actinopterygii	> 0,01%	LC
<i>Dysalotus alcocki</i>	Actinopterygii	> 0,01%	LC
<i>Echeneis naucrates</i>	Actinopterygii	> 0,01%	LC
<i>Elapsoidea boulengeri</i>	Reptilia	-	LC
<i>Electrona risso</i>	Actinopterygii	-	LC
<i>Enteromius paludinosus</i>	Actinopterygii	> 0,01%	LC
<i>Enteromius radiatus</i>	Actinopterygii	> 0,01%	LC
<i>Eremomela scotops</i>	Aves	> 0,01%	LC
<i>Eretmochelys imbricata</i>	Reptilia	> 0,01%	CR
<i>Eumecichthys fiski</i>	Actinopterygii	-	LC
<i>Euplectes hordeaceus</i>	Aves	-	LC
<i>Euprotomicrus bispinatus</i>	Chondrichthyes	> 0,01%	LC
<i>Eurypharynx pelecanoides</i>	Actinopterygii	> 0,01%	LC
<i>Eustomias cryptobulbus</i>	Actinopterygii	-	LC
<i>Eustomias furcifer</i>	Actinopterygii	-	LC
<i>Eustomias macronema</i>	Actinopterygii	-	LC
<i>Eustomias macrurus</i>	Actinopterygii	-	LC
<i>Eustomias schmidtii</i>	Actinopterygii	-	LC
<i>Eustomias simplex</i>	Actinopterygii	-	LC
<i>Eutaeniophorus festivus</i>	Actinopterygii	> 0,01%	LC
<i>Evermannella indica</i>	Actinopterygii	> 0,01%	LC
<i>Falco amurensis</i>	Aves	> 0,01%	LC
<i>Falco peregrinus</i>	Aves	> 0,01%	LC
<i>Falco subbuteo</i>	Aves	> 0,01%	LC
<i>Falco tinnunculus</i>	Aves	> 0,01%	LC
<i>Feresa attenuata</i>	Mammalia	> 0,01%	LC
<i>Fistularia petimba</i>	Actinopterygii	> 0,01%	LC
<i>Flagellostomias boureei</i>	Actinopterygii	> 0,01%	LC
<i>Fregetta tropica</i>	Aves	> 0,01%	LC
<i>Globicephala macrorhynchus</i>	Mammalia	> 0,01%	LC
<i>Gonostoma atlanticum</i>	Actinopterygii	> 0,01%	LC
<i>Gonostoma elongatum</i>	Actinopterygii	> 0,01%	LC
<i>Grampus griseus</i>	Mammalia	> 0,01%	LC
<i>Hemidactylus mabouia</i>	Reptilia	-	LC
<i>Hieraaetus pennatus</i>	Aves	> 0,01%	LC
<i>Himantolophus groenlandicus</i>	Actinopterygii	> 0,01%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EOO	IUCN
<i>Hippolais olivetorum</i>	Aves	> 0,01%	LC
<i>Hoplostethus melanopus</i>	Actinopterygii	> 0,01%	LC
<i>Hygophum reinhardtii</i>	Actinopterygii	> 0,01%	LC
<i>Hymenocephalus italicus</i>	Actinopterygii	> 0,01%	LC
<i>Ilyophis brunneus</i>	Actinopterygii	> 0,01%	LC
<i>Istiophorus platypterus</i>	Actinopterygii	-	LC
<i>Isurus oxyrinchus</i>	Chondrichthyes	> 0,01%	EN
<i>Isurus paucus</i>	Chondrichthyes	> 0,01%	EN
<i>Kali colubrina</i>	Actinopterygii	-	LC
<i>Kali indica</i>	Actinopterygii	-	LC
<i>Kali kerberti</i>	Actinopterygii	-	LC
<i>Katsuwonus pelamis</i>	Actinopterygii	> 0,01%	LC
<i>Kogia breviceps</i>	Mammalia	> 0,01%	VU
<i>Kogia sima</i>	Mammalia	> 0,01%	VU
<i>Kyphosus bigibbus</i>	Actinopterygii	> 0,01%	LC
<i>Labeo cylindricus</i>	Actinopterygii	> 0,01%	LC
<i>Lagenodelphis hosei</i>	Mammalia	> 0,01%	LC
<i>Lagocephalus lagocephalus</i>	Actinopterygii	> 0,01%	LC
<i>Lampadena luminosa</i>	Actinopterygii	> 0,01%	LC
<i>Lampanyctus alatus</i>	Actinopterygii	> 0,01%	LC
<i>Lamprogrammus brunswigi</i>	Actinopterygii	> 0,01%	LC
<i>Lamprogrammus niger</i>	Actinopterygii	> 0,01%	LC
<i>Larus cirrocephalus</i>	Aves	> 0,01%	LC
<i>Lepidochelys olivacea</i>	Reptilia	> 0,01%	NT
<i>Lepus victoriae</i>	Mammalia	-	LC
<i>Lestidiops jayakari</i>	Actinopterygii	> 0,01%	LC
<i>Lestidium atlanticum</i>	Actinopterygii	> 0,01%	LC
<i>Lestrolepis intermedia</i>	Actinopterygii	> 0,01%	LC
<i>Limaformosa capensis</i>	Reptilia	> 0,01%	LC
<i>Linophryne densiramus</i>	Actinopterygii	-	LC
<i>Lobianchia gemellarii</i>	Actinopterygii	-	LC
<i>Locustella fluviatilis</i>	Aves	> 0,01%	LC
<i>Loweina rara</i>	Actinopterygii	-	LC
<i>Malacocephalus laevis</i>	Actinopterygii	> 0,01%	LC
<i>Masturus lanceolatus</i>	Actinopterygii	-	LC
<i>Megachasma pelagios</i>	Chondrichthyes	> 0,01%	LC
<i>Megaptera novaeangliae</i>	Mammalia	> 0,01%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EEO	IUCN
<i>Melanocetus johnsonii</i>	Actinopterygii	-	LC
<i>Melanocetus murrayi</i>	Actinopterygii	-	LC
<i>Melanolagus bercooides</i>	Actinopterygii	> 0,01%	LC
<i>Melanonus zugmayeri</i>	Actinopterygii	> 0,01%	LC
<i>Melanostomias bartonbeani</i>	Actinopterygii	> 0,01%	LC
<i>Melanostomias paucilaternatus</i>	Actinopterygii	> 0,01%	LC
<i>Melanostomias valdiviae</i>	Actinopterygii	> 0,01%	LC
<i>Meroles squamulosus</i>	Reptilia	> 0,01%	LC
<i>Mesoplodon densirostris</i>	Mammalia	> 0,01%	VU
<i>Micralestes acutidens</i>	Actinopterygii	-	LC
<i>Microlophichthys microlophus</i>	Actinopterygii	> 0,01%	LC
<i>Mobula birostris</i>	Chondrichthyes	> 0,01%	NT
<i>Mobula mobular</i>	Chondrichthyes	> 0,01%	EN
<i>Mobula tarapacana</i>	Chondrichthyes	> 0,01%	EN
<i>Mobula thurstoni</i>	Chondrichthyes	> 0,01%	EN
<i>Mola mola</i>	Actinopterygii	> 0,01%	VU
<i>Morus capensis</i>	Aves	0,38 %	EN
<i>Mugil cephalus</i>	Actinopterygii	> 0,01%	LC
<i>Myctophum asperum</i>	Actinopterygii	0,01%	LC
<i>Myctophum nitidulum</i>	Actinopterygii	> 0,01%	LC
<i>Myctophum spinosum</i>	Actinopterygii	> 0,01%	LC
<i>Myliobatis aquila</i>	Chondrichthyes	> 0,01%	DD
<i>Nannobranchium atrum</i>	Actinopterygii	0,01%	LC
<i>Nannobranchium lineatum</i>	Actinopterygii	0,01%	LC
<i>Natriciteres olivacea</i>	Reptilia	> 0,01%	LC
<i>Naucrates ductor</i>	Actinopterygii	0,02%	LC
<i>Nemichthys curvirostris</i>	Actinopterygii	0,01%	LC
<i>Nemichthys scolopaceus</i>	Actinopterygii	> 0,01%	LC
<i>Neoceratias spinifer</i>	Actinopterygii	> 0,01%	LC
<i>Neonesthes capensis</i>	Actinopterygii	0,01%	LC
<i>Neoscopelus microchir</i>	Actinopterygii	> 0,01%	LC
<i>Notolychnus valdiviae</i>	Actinopterygii	> 0,01%	LC
<i>Oceanites oceanicus</i>	Aves	> 0,01%	LC
<i>Odontomacurus murrayi</i>	Actinopterygii	0,01%	LC
<i>Odontostomops normalops</i>	Actinopterygii	> 0,01%	LC
<i>Oneiroides eschrichtii</i>	Actinopterygii	> 0,01%	LC
<i>Onychoprion fuscatus</i>	Aves	> 0,01%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EEO	IUCN
<i>Ophisurus serpens</i>	Actinopterygii	0,12%	LC
<i>Opisthoproctus soleatus</i>	Actinopterygii	0,01%	LC
<i>Pachydactylus punctatus</i>	Reptilia	-	LC
<i>Peponocephala electra</i>	Mammalia	> 0,01%	LC
<i>Photonectes braueri</i>	Actinopterygii	0,05%	LC
<i>Photonectes margarita</i>	Actinopterygii	0,02%	LC
<i>Photonectes mirabilis</i>	Actinopterygii	0,05%	LC
<i>Phtheichthys lineatus</i>	Actinopterygii	> 0,01%	LC
<i>Physeter macrocephalus</i>	Mammalia	> 0,01%	NT
<i>Planiliza macrolepis</i>	Actinopterygii	> 0,01%	LC
<i>Platybelone argalus</i>	Actinopterygii	0,03%	LC
<i>Porogadus miles</i>	Actinopterygii	0,01%	LC
<i>Pristis pristis</i>	Chondrichthyes	> 0,01%	CR
<i>Promethichthys prometheus</i>	Actinopterygii	0,03%	LC
<i>Psammophis angolensis</i>	Reptilia	-	LC
<i>Psammophis mossambicus</i>	Reptilia	-	LC
<i>Psenes arafurensis</i>	Actinopterygii	-	LC
<i>Psenes cyanophrys</i>	Actinopterygii	-	LC
<i>Psenes pellucidus</i>	Actinopterygii	-	LC
<i>Pseudocarcharias kamoharai</i>	Chondrichthyes	0,01%	LC
<i>Pseudocrenilabrus philander</i>	Actinopterygii	> 0,01%	LC
<i>Pseudoscopelus altipinnis</i>	Actinopterygii	> 0,01%	LC
<i>Python natalensis</i>	Reptilia	-	LC
<i>Rachycentron canadum</i>	Actinopterygii	0,03%	LC
<i>Ranzania laevis</i>	Actinopterygii	> 0,01%	LC
<i>Regalecus glesne</i>	Actinopterygii	0,01%	LC
<i>Remora australis</i>	Actinopterygii	> 0,01%	LC
<i>Remora brachyptera</i>	Actinopterygii	> 0,01%	LC
<i>Remora osteochir</i>	Actinopterygii	> 0,01%	LC
<i>Remora remora</i>	Actinopterygii	> 0,01%	LC
<i>Rhincodon typus</i>	Chondrichthyes	> 0,01%	EN
<i>Rhizoprionodon acutus</i>	Chondrichthyes	> 0,01%	LC
<i>Rondeletia loricata</i>	Actinopterygii	> 0,01%	LC
<i>Rouleina attrita</i>	Actinopterygii	> 0,01%	LC
<i>Ruvettus pretiosus</i>	Actinopterygii	0,03%	LC
<i>Saurenhelys stylura</i>	Actinopterygii	0,03%	LC
<i>Schilbe intermedius</i>	Actinopterygii	> 0,01%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EOO	IUCN
<i>Scopelarchus analis</i>	Actinopterygii	> 0,01%	LC
<i>Scopelarchus guentheri</i>	Actinopterygii	0,01%	LC
<i>Scopelengys tristis</i>	Actinopterygii	0,01%	LC
<i>Scopeloberyx opisthopterus</i>	Actinopterygii	> 0,01%	LC
<i>Scopelogadus mizolepis</i>	Actinopterygii	0,01%	LC
<i>Scorpaena scrofa</i>	Actinopterygii	0,20%	LC
<i>Selar crumenophthalmus</i>	Actinopterygii	0,03%	LC
<i>Seriola dumerili</i>	Actinopterygii	0,03%	LC
<i>Serrivomer beanii</i>	Actinopterygii	0,01%	LC
<i>Setarches guentheri</i>	Actinopterygii	0,02%	LC
<i>Sphoeroides pachygaster</i>	Actinopterygii	0,03%	LC
<i>Sphyrna lewini</i>	Chondrichthyes	> 0,01%	CR
<i>Sphyrna mokarran</i>	Chondrichthyes	> 0,01%	CR
<i>Stenella attenuata</i>	Mammalia	> 0,01%	LC
<i>Stenella coeruleoalba</i>	Mammalia	> 0,01%	LC
<i>Stenella longirostris</i>	Mammalia	> 0,01%	DD
<i>Steno bredanensis</i>	Mammalia	> 0,01%	LC
<i>Sterna hirundo</i>	Aves	0,01%	LC
<i>Sterna paradisaea</i>	Aves	> 0,01%	LC
<i>Sterna dougallii</i>	Aves	> 0,01%	LC
<i>Sternoptyx diaphana</i>	Actinopterygii	> 0,01%	LC
<i>Sternoptyx pseudobscura</i>	Actinopterygii	> 0,01%	LC
<i>Stigmochelys pardalis</i>	Reptilia	> 0,01%	LC
<i>Stomias affinis</i>	Actinopterygii	0,01%	LC
<i>Stomias boa</i>	Actinopterygii	0,01%	LC
<i>Stomias danae</i>	Actinopterygii	> 0,01%	LC
<i>Stylephorus chordatus</i>	Actinopterygii	0,02%	LC
<i>Sudis atrox</i>	Actinopterygii	> 0,01%	LC
<i>Synagrops japonicus</i>	Actinopterygii	0,03%	LC
<i>Synoicus adansonii</i>	Aves	-	LC
<i>Taaningichthys bathyphilus</i>	Actinopterygii	> 0,01%	LC
<i>Talismania antillarum</i>	Actinopterygii	> 0,01%	LC
<i>Telacanthura ussheri</i>	Aves	-	LC
<i>Telescopus semiannulatus</i>	Reptilia	-	LC
<i>Thalasseus bengalensis</i>	Aves	> 0,01%	LC
<i>Thalasseus bergii</i>	Aves	0,01%	LC
<i>Thunnus alalunga</i>	Actinopterygii	> 0,01%	LC

Scientific Name	Taxonomic Group (Class)	Percent DMU/EOO	IUCN
<i>Thunnus albacares</i>	Actinopterygii	> 0,01%	LC
<i>Thunnus obesus</i>	Actinopterygii	> 0,01%	NT
<i>Threskiornis aethiopicus</i>	Aves	> 0,01%	LC
<i>Trachylepis maculilabris</i>	Reptilia	-	LC
<i>Trachylepis striata</i>	Reptilia	-	LC
<i>Trichiurus lepturus</i>	Actinopterygii	0,03%	LC
<i>Trigonolampa miriceps</i>	Actinopterygii	0,01%	LC
<i>Turdoides jardineii</i>	Aves	-	LC
<i>Tursiops truncatus</i>	Mammalia	> 0,01%	LC
<i>Umbrina canariensis</i>	Actinopterygii	0,35%	LC
<i>Uraspis secunda</i>	Actinopterygii	0,10%	LC
<i>Valenciennellus tripunctulatus</i>	Actinopterygii	> 0,01%	LC
<i>Venefica proboscidea</i>	Actinopterygii	0,04%	LC
<i>Vinciguerria attenuata</i>	Actinopterygii	0,01%	LC
<i>Vinciguerria nimbaria</i>	Actinopterygii	0,01%	LC
<i>Xenodermichthys copei</i>	Actinopterygii	0,01%	LC
<i>Zenopsis conchifer</i>	Actinopterygii	0,09%	LC
<i>Zeus capensis</i>	Actinopterygii	0,32%	LC
<i>Ziphius cavirostris</i>	Mammalia	> 0,01%	LC
<i>Zu cristatus</i>	Actinopterygii	0,01%	LC

## Annex VI – Underwater Noise Modelling

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## AVI.1. Description of Underwater Noise and Assessment Units

### AVI.1.1. Introduction

Studies by Thomsen *et al.*<sup>17</sup> and Southall *et al.*<sup>18</sup>, amongst others, provide detailed reviews of the metrics used to measure and assess the impact of underwater noise in the marine environment. A detailed discussion has not therefore been provided here, although a brief overview is provided to assist the reader. It is noted that a number of these definitions and parameters draw on the advice given in American National Standards Institute (ANSI) S12.7-1986<sup>19</sup>.

Sound may be defined as the periodic disturbance in pressure from some equilibrium value. The unit of pressure is given in Pascals (Pa) or Newton per square metre (N/m<sup>2</sup>). The measurements however cover a very wide range of pressure values, typically from 1 x 10<sup>-3</sup> Pa for the hearing threshold value of a human diver at 1 kHz to 1 x 10<sup>7</sup> Pa for the sound of a lightning strike on the sea surface. For convenience therefore, sound levels are expressed in decibels (dB) relative to a fixed reference pressure commonly 1 µPa for measurements made underwater. The decibel is therefore a logarithmic way of describing a ratio of sound relative to a specified reference value. Further elucidation on this, often misunderstood concept, is provided by Chapman and Ellis in their short but seminal paper "*The Elusive Decibel*"<sup>20</sup>.

### AVI.1.2. Peak Sound Level

For transient pressure pulses such as an explosion or a single strike from a piledriving hammer, the peak sound level is the maximum absolute value of the instantaneous sound pressure recorded over a given time interval. Hence:

$$\text{Peak Level (zero-to-peak)} = 20 \times \log_{10} (|P_{\text{peak}}| / P_{\text{ref}}) \quad \text{Equation AVI.1}$$

where  $P_{\text{peak}}$  is the maximum zero-to-peak positive or negative acoustic pressure in Pascals and  $P_{\text{ref}}$  is the reference pressure of 1 microPascal (µPa).

When the pulse has approximately equal positive and negative parts to the waveform (see for instance Figure AVI.1), the peak-to-peak level is often quoted and this is equal to twice the peak level or 6 dB higher.

<sup>17</sup> Thomsen F., Luedemann K., Kafemann R. and Piper W., (2006). "Effects of wind farm noise on marine mammals and fish". Biola, Hamburg, Germany on behalf of COWRIE Ltd. (Coll. Offshore Wind Res. Environ.) Ltd.

<sup>18</sup> Southall, B.L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, P. L. Tyack, "Marine mammal noise exposure criteria: initial scientific recommendations." *Aquatic Mammals* 2007, 33, 411–521.

<sup>19</sup> ANSI S12.7-1986, "Methods for measurement of impulse noise", Issued by the American National Standards Institute, 20 February 1986.

<sup>20</sup> Chapman D. M. F., and D. D. Ellis, *The Elusive Decibel: Thoughts on Sonars and Marine Mammals*, Technical Note, *Canadian Acoustics* 26(2) 29-31 (1998).

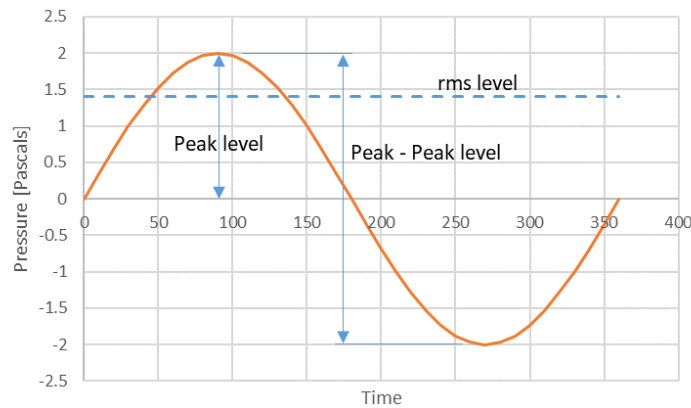
Accessed at [http://misclab.umeoce.maine.edu/boss/classes/SMS\\_598\\_2005/PDFs/AnnexD%5B1%5D.pdf](http://misclab.umeoce.maine.edu/boss/classes/SMS_598_2005/PDFs/AnnexD%5B1%5D.pdf)

### AVI.1.3. RMS Sound Pressure Level

The Root-Mean-Square (RMS or rms) Sound Pressure Level (SPL) is used to quantify noise of a continuous nature. Underwater sound sources of this type include shipping, sonar transmissions, drilling or cutting operations, and background sea noise. The RMS SPL is the mean square pressure level measured over a given time interval (t) (illustrated in Figure AVI.1), and hence represents a measure of the average sound pressure level over that time. It is expressed as:

$$\text{RMS Sound Pressure Level} = 20 \times \log_{10} (P_{\text{RMS}}/P_{\text{ref}}) \quad \text{Equation AVI.2}$$

When RMS SPLs are used to quantify the transient noise arising from an impact piling strike, the time period over which the measurements are averaged must be quoted as the RMS value will vary with the averaging time period. When the noise is continuous, as in the examples given above, the time period over which measurements are taken is not relevant as the measurement will give the same result regardless of the period over which the measurements are averaged.



**Figure AVI.1: Comparison of three metrics used to characterise the loudness of a sinusoidal sound wave**

Peak SPLs may be converted to equivalent RMS SPL following consideration of the nature of the signal. For a sinusoidal signal, the relationship between peak level signal and the RMS equivalent is given by peak level – 3 dB. For signals having non-equal positive and negative parts of the waveform such as those from impact piledriving or from seismic airguns, this conversion is not valid. Furthermore, during propagation the outgoing source signal stretches out in time (see e.g., Urick<sup>21</sup>) and this is attributed to the sound travelling along multiple paths and each arriving at a given location at a slightly different time. As a result, the difference between peak level and RMS varies with distance. Strictly, a conversion factor at any given distance from the piling site can only be determined following analysis of the pressure-time waveforms recorded during the piledriving activity. Without access to such data, it is necessary to obtain a best-estimate from available data. Various

<sup>21</sup> Urick, Robert J. (1983), Principles of Underwater Sound, 3rd Edition. New York. McGraw-Hill.

studies<sup>22,23,24</sup> suggest a range of values between 2 dB and 20 dB. The lower the conversion factor, the greater the overestimation of RMS SPL for any given non-sinusoidal signal. For the purpose of the subsequent analysis discussed herein and considering that all the noise types are non-impulsive, it is recommended that, based on the range of values above, a distance-invariant value of 3 dB be used to convert all peak level metrics to RMS metrics.

### AVI.1.4. Sound Exposure Level

The problems associated with the time period over which the Sound Pressure Levels are averaged, as highlighted above, can be overcome by describing a transient pressure wave in terms of its Sound Exposure Level (SEL). The SEL is the time integral of the square pressure over a time window long enough to include the entire pressure-time history. Greene<sup>23</sup> gives a practical definition of the duration of the time window based on the interval over which 90% of the sound energy arrives at the receptor location and this seems now to be a widely accepted approach<sup>18,22</sup>. The SEL is therefore the sum of the acoustic energy over a measurement period, and effectively takes account of both the level of the sound, and the duration over which the sound is present in the acoustic environment. Sound Exposure (SE) is defined by the equation:

$$SE = \int_0^T p^2(t) dt \quad \text{Equation AVI.3}$$

where T is the overall duration of the sound in seconds and t is time. The SE is a measure of the acoustic energy and therefore has units of Pascal squared seconds (Pa<sup>2</sup>.sec).

To express the Sound Exposure as a logarithmic decibel, it is compared with a reference acoustic energy level of 1 µPa<sup>2</sup>.sec. The SEL is then defined by:

$$SEL = 10 \log_{10} \int_0^T \frac{p^2(t) dt}{p_{ref}^2} \quad \text{Equation AVI.4}$$

When the time period is less than 1 second, the SPL is greater than the SEL. When the time period is 1 second, SPL is equal to SEL. For signals of more than 1 second duration, the SEL will be greater than the SPL where:

$$SEL = SPL_{90\%} + 10 \times \log_{10}(T) \quad \text{Equation AVI.5}$$

### AVI.1.5. Cumulative Sound Exposure Level

Where multiple noise events occur, the total or cumulative SEL can be calculated by summing the SEL from the individual events. The events themselves may be separated in time or space or both.

<sup>22</sup> Madsen P.T., (2005), "Marine mammals and noise: Problems with root mean square sound pressure levels for transients", J. Acoust. Soc. Am. 117(6), 3952.

<sup>23</sup> Greene Jnr C.R., "Physical acoustics measurements". In: W.J. Richardson (ed.) Northstar Marine Mammal Monitoring Program 1996: Marine Mammal and Acoustical Monitoring of a Seismic Program in the Alaskan Beaufort Sea. LGL Rep 2121-2, LGL Ltd, Canada and Greeneridge Sciences Inc. USA for BP (Alaska) Inc. and Nat. Mar. Fish Serv. Alaska. 245 pp.

<sup>24</sup> McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K. (2000). Marine seismic surveys – a study of environmental implications. APPEA Journal 2000:692-708.

For instance, the events could be either consecutive in time from seismic airgun array emissions at a given location or else concurrent from two drilling operations taking place in close physical proximity at the same time.

For multiple events, the cumulative SEL is computed by summing the SEL (in linear units) of N individual events thus:

$$SEL_{cum} = 10 \log_{10} \sum_{i=1}^N 10^{\frac{SEL}{10}} \quad \text{Equation AVI.6}$$

### AVI.1.6. Source Level

The source level (SL) is the apparent strength of a noise source at a reference distance, usually 1 m, from the source. For example, a noise source may be quoted as having e.g., a source SPL of 180 dB re 1 $\mu$ Pa at 1 m. In practice, the parameters of the source are rarely measured at such a close range and the source level is inferred by back-propagating the noise from a number of far-field measurements. Back-propagation in this way is most effective when the noise source is compact i.e., where the dimensions of the noise source are small compared with the wavelength of the emitted noise. For this scenario, the noise source is described as a point-source. The process falls down for the opposite case where the sound source is dimensionally large compared with the wavelength. For instance, vessel noise cannot be approximated as a point source hence the source level thus obtained may only be considered as a notional source level. Hence under these circumstances, back-propagation can lead to an over-estimate of source level.

### AVI.1.7. Propagation Loss and Transmission Loss

The propagation loss (PL) represents the loss in intensity or pressure of the acoustic field strength as the noise propagates from source to a receptor. In general terms, the propagation loss is given by:

$$PL = N \log(r) + \alpha r \quad \text{Equation AVI.7}$$

where r is the distance in metres from the source to the receptor, N is a factor representing attenuation due to geometric spreading, and  $\alpha$  (in dB.km<sup>-1</sup>) is a factor for the absorption of sound in water.

It is noted that the terms propagation loss and transmission loss (TL) have previously been declared synonymous<sup>25</sup> and are often used as such. However, the ISO Standard on underwater acoustic terminology<sup>26</sup> defines transmission loss as being the difference in sound pressure level at two different locations:

$$TL(r_2, r_1) = SPL(r_2) - SPL(r_1) \quad \text{Equation AVI.8}$$

<sup>25</sup> Ainslie M. A., "Transmission loss" and "propagation loss" in undersea acoustics", Journal of the Acoustical Society of America 118, 603 (2005).

<sup>26</sup> ISO 18405:2017 Underwater Acoustics – Terminology (International Organization for Standardization, Geneva, 2017).

where  $r_2$  and  $r_1$  are the distances from a source location and that  $r_2$  is larger than  $r_1$  so that the resulting TL is usually a positive number.

## AVI.1.8. Received Level

The Received level (RL) is the strength of the acoustic field at a given depth and range relative to the source. At a range  $r$  from a source, this is given by:

$$RL = SL - PL \quad \text{Equation AVI.9}$$

From Equation AVI.7, this can be written in the form:

$$RL = SL - N \log(r) - \alpha r \quad \text{Equation AVI.10}$$

As the received level varies with range, it is important to state the range at which the measurement has been taken or the estimate has been made.

## AVI.2. Sound Source Characterization

### AVI.2.1. Introduction

The development of an offshore field is a complex task involving a number of separate construction activities, including drilling of the production wells, installation of subsea infrastructure, and any number of vessel movements, involving a range of vessel types from bulk carriers through to tugs, will be undertaken in order to provide logistical support. Once complete, the field is commissioned and the FLNG finally becomes operational.

The Project activities will replicate those carried out earlier at the Coral South development, hence are well known. The type, function and numbers of vessels required are thus identified even if the specific vessels planned for deployment at Coral North remain unknown. In general, very few vessels have been noise-ranged whereby the noise levels emitted by the vessel during any specified activity are recorded and published. As a result, it is not possible to assign unambiguous acoustic characterisation data such as source sound levels and frequency spectra to each task to be undertaken at the Coral North development. In order to address this shortcoming, a review of the international published literature was undertaken. From this, each task was discussed in terms of the acoustic characteristics of the noise likely to arise. Representative sound levels for each operation were established and these are discussed below.

### AVI.2.2. Vessel Movements

#### AVI.2.2.1. Introduction

Noise from vessels is a major contributor to the overall noise in a given sea area due principally to the large numbers of ships present, their wide distribution and their mobility. Vessel noise is a

combination of broadband sound superimposed with tonals at specific frequencies corresponding to propeller blade rate, engine cylinder firing, and crankshaft rotation. Southall *et al.*<sup>18</sup> classifies vessel noise as being non-impulsive in nature.

A number of vessel types are planned for deployment at the Coral North Project Area. These include:

- Platform supply vessels (PSV) – These are for logistical support and transportation of goods, tools, equipment, and personnel to and from their destination. The vessels are typically 50 to 100 metres in length;
- Installation vessel – These are often vessels designed to lift heavy infrastructure into place. The cranes may have lifting capacities of 800 tonne to over 3,000 tonne. Typically, this class of vessels are 60-150 m long, 40-50 m breadth, 6–12 m depth, and 1600-30000 Deadweight tonnage (DWT)<sup>27</sup>;
- Multi-purpose vessel (MPV) – These are designed for carrying cargo. This is assumed to be large infrastructure components that will be craned off the vessel when it is in position in the Project Area. The vessels may be up to 200 m length and 30 m breadth with a capacity of 23,000 DWT;
- Flotel – This is a semi-submersible accommodation and construction support vessel. As a typical example, the *Flotel Triumph*<sup>28</sup> has an overall length of 200 m and a breadth of 78m. It is towed to site using a number of tug vessels;
- Anchor handling tug supply (AHTS) vessel – This is a marine vessel that manoeuvres other vessels by pushing or pulling them, with direct contact or a tow line. They tend to be smaller than other vessels but with powerful engines. A representative example is the *Lewek Leopard*<sup>29</sup> at 59 m length, 15 m breadth, and 1218 tonne DWT.

The breakdown of the numbers of vessel present during each stage of Project activity is given as follows:

- During drilling operations at Coral North, there will be 1 x drill ship and 3 x PSVs;
- During installation, there are planned to be 2 x installation vessels, 3 x PSVs and 1 x MPV;
- At the operational stage, there will be 1 x FLNG, 1 x Flotel [temporary], 3 x PSVs and 6 x AHTSs.

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<sup>27</sup> <https://www.deme-group.com/technology>

<sup>28</sup> <https://floatel.no/fleet/floatel-triumph>

<sup>29</sup> <https://directory.marinelink.com/ships/ship/lewek-leopard-10080>

### AVI.2.2.2. Acoustic Source Levels and Frequency Spectra

A limited set of acoustic data for noise-ranged vessels<sup>30,31,32,33,34</sup> are available, none of which are likely to include the vessels planned for the Coral North project. It is assumed that vessel noise is proportional to vessel power and overall vessel size<sup>35</sup>. It is necessary therefore to use acoustic characterisation data from other similarly sized (where possible) vessels as proxy data.

Wales and Heitmeyer<sup>36</sup> proposed a source spectra model for merchant ship-radiated noise, based on the Research Ambient Noise Directionality (RANDI) 3.1 model<sup>37</sup>. As part of the Joint Monitoring Programme for Ambient Noise in the North Sea (JOMOPANS) project, RANDI 3.1 was validated using acoustic data from a hydrophone located in Haro Strait, British Columbia, Canada together with Automated Information System (AIS) broadcasts from passing vessels<sup>38</sup>. Subsequent analysis was necessary in order to determine vessel source levels and frequency content. The ensuing model, drawing on vessel type, approximate length, breadth and depth; and a representative transit speed, was used in order to derive representative acoustic source level data for various classes of vessel proposed for use in the Coral North Project and these are given in Table AVI.1.

**Table AVI.1: Representative acoustic source levels for various classes of vessel proposed for deployment on Coral North project**

Class of vessel	Dimension Length x breadth x depth	SPL <sub>peak</sub>
AHTS	60 x 15 x 5	166.2 dB re 1 µPa @ 1 m
Installation	150 x 50 x 10	181.3 dB re 1 µPa @ 1 m
MPV	200 x 30 x 12	183.8 dB re 1 µPa @ 1 m
PSV	100 x 30 x 8	177.8 dB re 1 µPa @ 1 m

The shape of the frequency spectrum across the bandwidth of the noise emitted by each class of vessel is key to determining the significance of any ensuing acoustic impacts. Frequency spectra are given in Figure AVI.2.

<sup>30</sup> Richardson, W. J., Green Jr, C. R., Malme, C. I., Thomson, D. H., (1995), Marine Mammals and Noise. Academic Press, New York.

<sup>31</sup> Hannay, D.E. 2004. Noise. In Comparative Environmental Analysis (CEA), Chapter 4. Sakhalin Energy Investment Corporation. Available at: [http://www.sakhalinenergy.com/documents/doc\\_33\\_cea\\_chp4.pdf](http://www.sakhalinenergy.com/documents/doc_33_cea_chp4.pdf)

<sup>32</sup> Kiggavik Tug and Barge Noise Modelling, JASCO Applied Sciences, June 2011.

<sup>33</sup> A. Torbjörn Johansson and Mathias H. Andersson, "Ambient Underwater Noise Levels at Norra Midsjöbanken during Construction of the Nord Stream Pipeline", Report for Nord Stream AG and Naturvårdsverket, 2012.

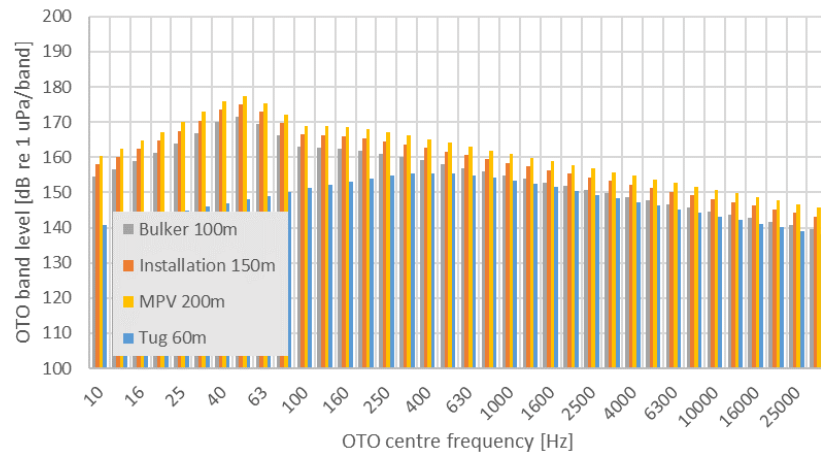
<sup>34</sup> Götz T., G. Hastie, L. T. Hatch, O. Raustein, B. L. Southall, M. Tasker, F. Thomsen, "Overview of the impacts of anthropogenic underwater sound in the marine environment", OSPAR Commission, 2009. Accessed from: [https://qsr2010.ospar.org/media/assessments/p00441\\_Noise\\_background\\_document.pdf](https://qsr2010.ospar.org/media/assessments/p00441_Noise_background_document.pdf)

<sup>35</sup> Li, Z., MacGillivray, A., and Wladichuk, J. (2011). Underwater Acoustic Modelling of Tug and Barge Noise for Estimating Effects on Marine Animals. Version 1.0. Technical report prepared for AREVA Resources Canada by JASCO Applied Sciences.

<sup>36</sup> Wales, S.C.; Heitmeyer, R.M. An ensemble source spectra model for merchant ship-radiated noise. Journal of the Acoustical Society of America. 2002, 111, 1211–1231.

<sup>37</sup> Breeding, J. & Pflug, Lisa & Bradley, Marshall & Hebert, Melanie & Wooten, Michael. (1994). RANDI 3.1 User's Guide. 86.

<sup>38</sup> MacGillivray, A.; de Jong, C. A., Reference Spectrum Model for Estimating Source Levels of Marine Shipping Based on Automated Identification System Data. J. Mar. Sci. Eng. 2021, 9, 369. <https://doi.org/10.3390/jmse9040369>



**Figure AVI.2: One third octave (OTO) band level spectra for vessels proposed for use on the Coral North Project**

No data are available on the directionality of vessel noise. It is assumed therefore that the sound radiates equally in all directions.

## AVI.2.3. Drilling

### AVI.2.3.1. Introduction

During drilling, noise is generated principally through the action of the drill bit on the surrounding rocks. The level of noise created is dependent therefore not only on the size of the drill bit but also on the degree to which the seabed rock is consolidated; a soft clay will produce lower levels of sound compared to that generated by a granite layer.

Specifically in relation to the seabed conditions at the Coral North Project site, the Eni drilling engineers<sup>39</sup> note that the first 700 m below seabed, and especially the topmost 100 m, comprise a loose shale formation which slowly gains density with increasing depth. Below around 700 m, higher density rock formation may be encountered however, due to the significant distance from the seabed it is unlikely that noise shall be recorded at seabed.

Noise generated at the drill head is likely to be transmitted into the water through two mechanisms. The first is where the noise is transmitted from the drill bit-sediment interface and into the surrounding seabed layers before becoming refracted back into the water column while the second is where vibrations travel up the drill shaft and then become transmitted into the water.

### AVI.2.3.2. Acoustic Source Levels and Frequency Spectra

A review of the literature on underwater drill noise revealed that there is little useful data that has been released into the public domain: invariably the noise measurement units are ambiguous; the drill diameter is not quoted; or there is no information on sediment or seabed rock type. A number of

<sup>39</sup> ENI drilling engineers. Pers. Comm. September 2023.

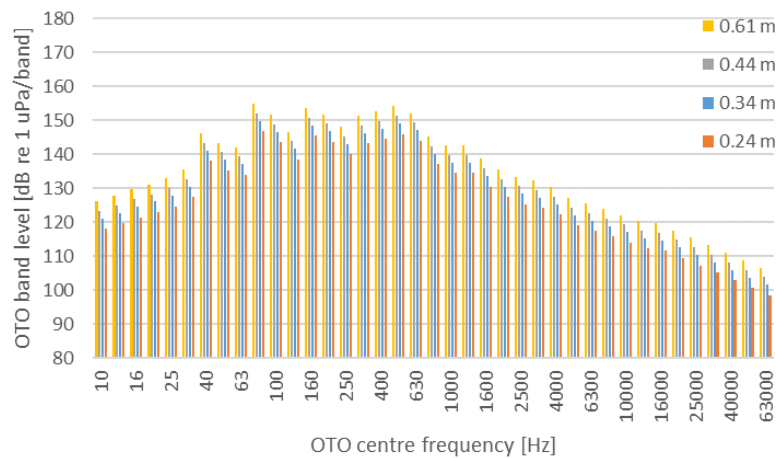
reports<sup>40,41,42</sup> were identified where the drill diameter was either smaller or larger than those proposed for Coral North by a factor of 10 or more. When drilling a 63.5 mm borehole under ice at a diamond exploration site in Canada, Mann *et al.*<sup>43</sup> determined an acoustic source level of 143 dB<sub>rms</sub> re 1 μPa at 1 m. In order to estimate a source level for the noise generated by a 1.5 m drill, Schlesinger *et al.*<sup>44</sup> suggested an uplift based on the notion that the weight applied to a drill-head is proportional to the cross-sectional area of its diameter. A scaling factor of  $10 \cdot \log_{10}(r^2/r_0^2)$  where  $r$  is the diameter of the proposed drill in millimetres (mm), and  $r_0$  is 63.5 mm, was thus proposed.

Accordingly, for the drill bit diameters proposed for deployment on the Coral North Project, acoustic source levels are summarised in Table AVI.2.

**Table AVI.2: Estimated acoustic source level for noise generated by drilling**

Drill bit diameter	Drill bit diameter	SPL <sub>peak</sub>
9.5 inch	0.24 m	154.5 dB re 1 μPa @ 1 m
12.25 – 13.5 inch	0.34 m	157.6 dB re 1 μPa @ 1 m
17.5 inch	0.44 m	159.8 dB re 1 μPa @ 1 m
24 inch	0.61 m	162.6 dB re 1 μPa @ 1 m

The source frequency spectrum shown in Figure AVI.3 is based on the data given by Mann *et al.*<sup>43</sup> with spectral levels adjusted to give the requisite source levels as given in Table AVI.2.



**Figure AVI.3: One third octave (OTO) band level source spectra for drilling at Coral North**

<sup>40</sup> Ward P. D., Needham K., "Modelling the vertical directivity of noise from underwater drilling". Proceedings of the 11th European Conference on Underwater Acoustics (ECUA 2012) and Acoustical Society of America Proceedings of Meetings on Acoustics (POMA), Vol 17, 070068, December 2012.

<sup>41</sup> Willis M. R., Broudic M., Bhurosah M., Masters I., "Noise Associated with Small Scale Drilling Operations", Proceedings of the 3rd International Conference on Ocean Energy, 6 October, Bilbao, 2010.

<sup>42</sup> Erbe C. and McPherson C., " Underwater noise from geotechnical drilling and standard penetration testing", J. Acoust. Soc. Am. 142 (3), September 2017.

<sup>43</sup> Mann, D., P. Cott, and B. Horne. 2009. Under-ice noise generated from diamond exploration in a Canadian sub-arctic lake and potential impacts on fishes. Journal of the Acoustical Society of America 126(5): 2215-2222.

<sup>44</sup> Schlesinger A., M-N. R. Matthews, Z. Li, J. Quijano, and D. Hannay. 2016. Aurora LNG Acoustic Study: Modelling of Underwater Sounds from Pile Driving, Rock Socket Drilling, and LNG Carrier Berthing and Transiting. Document 01134, Version 3.0. Technical report by JASCO Applied Sciences for Stantec Consulting Ltd.

## AVI.2.4. Suction Piling

Koschinski and Lüdemann<sup>45</sup> explain that the principle of suction piling is achieved through there being a pressure difference between the inside of an upside-down positioned foundation tube or similar feature and the hydrostatic pressure at the seabed. This leads to the structure being installed without any use of mechanical force.

In shallow waters, the adhesion between the feature and the seabed may be enhanced by deploying suction pumps to lower the pressure in the tube. Noise measurements made at the Borkum Riffgrund 2 OWF<sup>45</sup> indicate that the noise of the suction pumps could not be measured at distances beyond 500 m from the source. It is uncertain whether suction pumps could be deployed over water depths prevailing at the Coral North project site, being as they are in the range 1500-2000 m. It may be concluded that suction bucket foundations are low-noise foundations.

## AVI.2.5. FLNG

### AVI.2.5.1. Introduction

An FLNG is a specialised vessel containing production, storage and offloading systems that conduct liquified natural gas (LNG) operations for developing offshore natural gas resources. A number of pipelines from individual installations within a project area terminate at a subsea manifold from which a riser pipeline meets the FLNG at the sea surface. The FLNG is moored onsite with the aid of thrusters or propulsion systems fitted to the bow, stern, and along the hull - both port and starboard. Once in position, the Coral South FLNG, however, maintains its position through mooring lines with the thrusters being used during the LNG offloading operation. The thruster running time varies according to the weather and sea conditions. In most situations thrusters are only used during berthing and unberthing of the LNG Carrier (LNGC) although at times during a long swell or adverse weather, the thrusters may be used continuously during berthing and offloading operations; for example, during the winter months and also during normal days to mitigate the adverse condition and maintain the heading. The thrusters will be in operation as the LNGC makes the approach to FLNG approximately an hour before the berthing operation. Two of the three thrusters on Coral South FLNG are used during LNG offloading which equates to one cargo per six to seven days with the thrusters running for an approximate average of 15 hours. The FLNG thrusters are also engaged during helicopter operations. The Coral North Project will use the same strategy.

In general, vessel noise is a combination of broadband sound superimposed with tonals at specific frequencies corresponding to propeller blade rate, engine cylinder firing and crankshaft rotation<sup>46</sup> and it is considered likely that thruster noise will be broadly similar in characteristic. In addition, the onboard machinery and the power units that drive them, generate noise and vibration which is

<sup>45</sup> Koschinski S. & K. Lüdemann, Noise mitigation for the construction of increasingly large offshore wind turbines: Technical options for complying with noise limits. Technical Report for the Federal Agency for Nature Conservation, Germany, March 2020. Accessed September 2023 at <https://www.bfn.de/>

<sup>46</sup> Ross D., *Mechanics of Underwater Noise*, Pergamon Press, New York, 1976.

transmitted through the hull and into the ocean. Salgado-Kent *et al.*<sup>47</sup> consider that this noise component is likely to have substantially lower levels than that generated by the thrusters. As the processes are likely to run for extended periods of time and hence the FLNG facility is likely to remain on site similarly for extended periods<sup>48</sup>, FLNG noise, being predominantly due to the thrusters, as well as any noise not attributed to the thrusters, is classified as being continuous or non-impulsive in nature<sup>18</sup>.

### AVI.2.5.2. Acoustic Source Levels and Frequency Spectra

At the time of writing this report, acoustic data representing operational noise levels generated by Coral FLNG are not available. It is therefore necessary to use, as far as possible, proxy data from other facilities carrying out a similar function.

A literature search has revealed that there is a limited set of acoustic data for FLNG facilities. The Prelude FLNG Project<sup>49</sup> used an acoustic source level of 189 dB re 1  $\mu$ Pa at 1 m. This was based on measurements made over the frequency range of 10 Hz to 2 kHz of thruster noise generated by a much smaller vessel<sup>50</sup>, but then uplifted to take into account the difference in size and power output of the two platforms<sup>46</sup>. The Prelude FLNG is a double-hulled floating facility, approximately 480 m in length x 70-80 m width and weighing approximately 600,000 tonnes deadweight when fully ballasted. It has a production capability of 3.6 million tonnes per annum (MTPA) of LNG, LPG, and condensate. By comparison, the Coral FLNG is 439 m length x 65 m width with a weight of 210,000 tonnes (unballasted weight). It has a liquefaction capacity of 3.4 million tons. Thus, it will be seen that the Coral FLNG is slightly smaller overall than the Prelude FLNG. However, from a review of noise data generated by moored Floating Production Storage and Offloading (FPSO) platforms<sup>51</sup>, Erbe *et al.*<sup>52</sup> notes that noise levels do not appear to scale with FPSO size or power and it is assumed that this conclusion is equally applicable to FLNGs.

Underwater noise generated by an FPSO platform moored using thrusters was recorded from a hydrophone located in Haro Strait, British Columbia, Canada<sup>53</sup>. Noise data was recorded over the frequency range 10 Hz to 60 kHz and this yielded a notional acoustic source level of 182.5 dB re 1  $\mu$ Pa at 1 m. The data was processed in order to give a frequency spectrum over 1/3rd octave bands. For the current study, band levels were uplifted in order to yield an overall acoustic source level of 189 dB re 1  $\mu$ Pa at 1 m and the resulting spectrum is shown in Figure AIV.4.

<sup>47</sup> Salgado-Kent C., R. D. McCauley, A. Duncan, C. Erbe, A. Gavrilov, K. Lucke and I. Pamum, "Underwater Sound and Vibration from Offshore Petroleum Activities and their Potential Effects on Marine Fauna: An Australian Perspective", CMST Report 2015-13, April 2016.

<sup>48</sup> It is expected that the Coral North FLNG will be permanently moored onsite for the duration of the project; i.e., 25 years.

<sup>49</sup> Prelude Floating LNG Project: Draft Environmental Impact Statement produced for Shell Development (Australia) Pty Ltd by ERM Ltd, October 2009.

<sup>50</sup> McCauley, R. D., "Radiated underwater noise measured from the drilling rig *Ocean General*, rig tenders *Pacific Ariki* and *Pacific Frontier*, fishing vessel *Reef Venture* and natural sources in the Timor Sea", CMST Report C98-20 to Shell Australia. 1998.

<sup>51</sup> An FPSO is a floating vessel located near an offshore oil field, where oil is processed and stored until it can be transferred to a tanker for transporting and additional refining. Functionally, it is broadly similar to an FLNG where any differences between the two platforms are largely down to the industrial processes undertaken on board.

<sup>52</sup> Erbe C., R. McCauley, C. McPherson, A. Gavrilov, "Underwater noise from offshore oil production vessels", J. Acoust. Soc. Am. 133 (6), June 2013.

<sup>53</sup> MacGillivray, A.O., Li, Z.; Yurk, H. (2018a). Modelling of Cumulative Vessel Noise for Haro Strait Slowdown Trial: Final Report. Document Number 01577. Version 2.0. Technical report by JASCO Applied Sciences for Vancouver Fraser Port Authority ECHO Program. <https://www.flipsnack.com/portvancouver/echo-haro-strait-slowdown-trial-summary/fullview.html>.

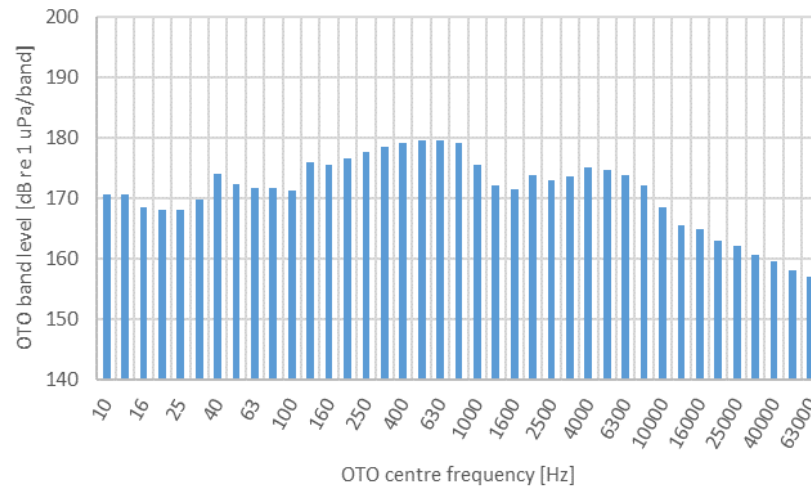


Figure AIV.4: Assumed band level spectra for the Coral North FLNG

## AVI.3. Acoustic Impact Thresholds for Marine Fauna

### AVI.3.1. Introduction

The derivation of appropriate threshold levels of noise on marine life exposed to man-made noise draws on the methodologies developed by Southall *et al.*<sup>18,54</sup> for cetaceans and pinnipeds; and Popper *et al.*<sup>55</sup> for fish and sea turtles. An overview of the salient points is given below.

### AVI.3.2. Marine Mammals

#### AVI.3.2.1. Physiological Impacts

Southall *et al.*<sup>18</sup> commenced by reviewing work undertaken over previous decades on animal audiology and noted that marine mammals could be assigned to one of a number of functional hearing groups where each group depended on differences and similarities in the animal's audiological physiology and behavioural psychophysics. To illustrate this, it was noted that although marine mammals possess the typical mammalian 3-stage ear, there are subtle differences that indicate specific adaptations to pressure, hydrodynamics, and sound reception in water. For instance, the outer ear, denoted by the pinna, has been eliminated in all cetacean species and some pinniped species, while gas spaces in the middle ear of some marine mammals have been reduced substantially thus indicating that bone conduction may be an important means by which sound is transferred to the inner ear. In addition, cetaceans were further subdivided on the basis of their

<sup>54</sup> Southall, B.L., Finneran, J.J., Reichmuth, C., Nachtigall, P.E., Ketten, D.R., Bowles, A.E., Ellison, W.T., Nowacek, D.P., & Tyack, P.L. Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. *Aquatic Mammals* 45(2), 2019.

<sup>55</sup> Popper, A. N., Hawkins, A. D., Fay, R. R., Mann, D., Bartol, S., Carlson, T., Coombs, S., Ellison, W. T., Gentry, R., Halvorsen, M. B., Løkkeborg, S., Rogers, P., Southall, B. L., Zeddis, D., and Tavolga, W. N. (2014). "Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report," ASA S3/SC1.4 TR-2014 prepared by ANSI Accredited Standards Committee S3/SC1 and registered with ANSI. Springer and ASA Press, Cham, Switzerland.

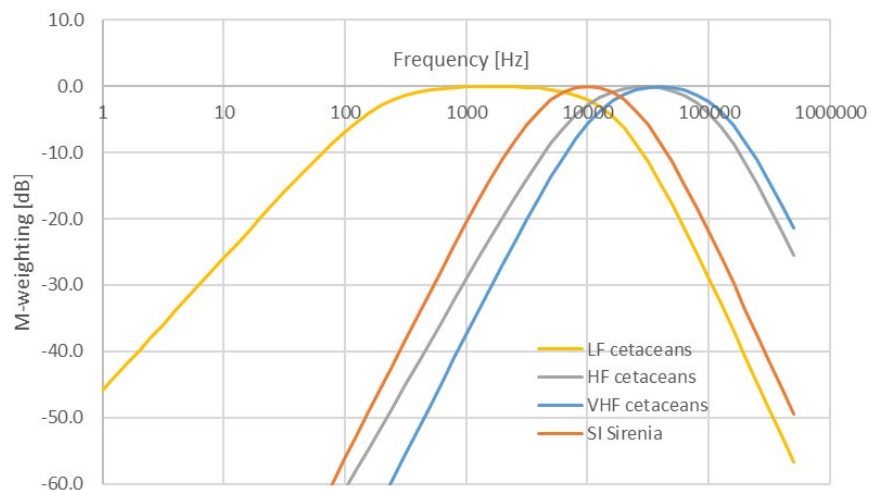
hearing sensitivity. Accordingly, low-frequency (LF) cetaceans (predominantly baleen whales) are most sensitive to low frequencies in the range 7 Hz to 35 kHz; high-frequency (HF) cetaceans have optimum sensitivity over the range 150 Hz to 160 kHz; while very high frequency (VHF) cetaceans are sensitive to high frequencies across the range 275 Hz to 160 kHz.

The latest functional hearing group (FHG) classification<sup>54</sup> for species relevant to Area 4 are given in Table AVI.4.

**Table AVI.4: Functional hearing groups for marine mammal species known or likely to be present within Area 4 or its surroundings**

Functional hearing group	Representative species in Area 4
Low-frequency cetaceans (LF)	Pygmy blue whale; humpback whale
High-frequency cetaceans (HF)	Sperm whale; Cuvier’s beaked whale; Risso’s dolphin; Indian Ocean humpback dolphin; common bottlenose dolphin; Indo-Pacific bottlenose dolphin; Pantropical spotted dolphin; spinner dolphin; striped dolphin; Pygmy killer whale; short-finned pilot whale.
Very high-frequency cetaceans (VHF)	Pygmy sperm whale; dwarf sperm whale
Sirenia (SI)	Dugong

It is acknowledged that, like humans, marine mammals do not hear equally well across all frequencies. In order to account for this, Southall *et al.*<sup>18</sup> proposed a series of frequency-dependent weightings that were derived from the hearing sensitivity curves for animals in each functional hearing group. These have the effect of emphasising the frequencies over which the animals are most sensitive and de-emphasising the remaining frequencies. For each FHG (species of which are listed in Table AVI.4), passband functions with specified roll-offs were developed by Southall *et al.*<sup>18</sup> and have been subsequently refined a number of times since<sup>54</sup>. The frequency-weighting curves, (collectively known as M-weightings), for each functional hearing group representing marine mammals found in and around Area 4 are shown in Figure AVI.5.



**Figure AVI.5: M-weighting curves for low-, high- and very high-frequency cetaceans and for sirenia**

The M-weighting curves are used to modify the frequency spectrum of the impacting noise so that it more closely represents the noise as perceived by the target species. From these data, weighting values are extracted for each functional hearing group and applied to the frequency band levels for the sound source given in Section AIV.2.

Given the frequency dependent M-weightings, it is possible to determine the apparent source levels of the underwater noise type as perceived by each of the FHGs following the technique demonstrated by Houser *et al.*<sup>56</sup>. The M-weighting curves are applied to the noise spectra as given in Section AIV.2 and the results are summarised in Table AVI.5 using SPL<sub>rms</sub> metrics. For reference, the column headed “Un” provides the unweighted noise source level. It is seen that LF cetaceans are likely to be most sensitive to the noises generated during the construction activities at the Coral North Project site due to the relatively high levels of low-frequency noise in the noise emitted by each activity. By comparison, VHF cetaceans are much less sensitive to the various noise types as the higher frequency components of the noise generated contain much less energy than those at lower frequencies.

**Table AVI.5: Apparent source levels perceived by each marine mammal functional hearing group**

Impacting noise type	Far-field apparent source level dB <sub>rms</sub> re 1 µPa				
	Un	LF	HF	VHF	SI
AHTS vessel	166.2	164.6	150.0	148.1	153.2
Installation vessel	181.4	173.6	155.1	153.2	158.3
MPV	183.8	176.1	157.6	155.7	160.8
PSV	177.8	170.1	151.6	149.7	154.8
Drilling	162.6	160.0	130.1	126.4	136.2
FLNG thruster	189.9	188.3	175.3	172.5	179.7

From reviewing available data derived from extensive tests involving marine mammals, Southall *et al.*<sup>18</sup> proposed thresholds representing the onset of permanent threshold shift (PTS) for marine mammals (based on measurements relating to the onset of temporary threshold shift (TTS)) which were expressed in terms of SPL and SEL, where the latter metric (expressed as dB re 1 µPa<sup>2</sup>.s) takes note not only of the period of time over which the receptor is exposed but also the sensitivity of the animal to the impacting sound. For continuous type noise such as that generated by vessel activity or drilling, the thresholds are given using only SEL metrics. The resulting impact thresholds, subsequently refined by Southall *et al.*<sup>54</sup>, for both PTS and TTS, are given in Table AVI.6.

<sup>56</sup> Houser D. S., W. Yost, R. Burkard, J. J. Finneran, C. Reichmuth and J. Mulsow, "A review of the history, development and application of auditory weighting functions in humans and marine mammals", J. Acoust. Soc. Am. 141 (3), March 2017.

**Table AVI.6: Summary of acoustic impact threshold criteria for PTS and TTS in SPL<sub>peak</sub> and M-weighted SEL metrics for each functional hearing group when exposed to non-impulsive noise<sup>54</sup>**

Functional hearing group	M-weighted SEL thresholds dB re 1 $\mu$ Pa <sup>2</sup> .sec	
	PTS	TTS
LF cetacean	199	179
HF cetacean	198	178
VHF cetacean	173	153
SI sirenia	206	186

### AVI.3.2.2. Behavioural Impacts

To arrive at threshold levels of noise giving rise to behavioural effects in animals when exposed to man-made underwater sound, Southall *et al.*<sup>18</sup> noted that the responses varied according to the sound level on the animal as well as the frequency and duration of the perturbing noise. Observations of the resulting behavioural response were standardised by being quantified on a Behavioural Response Severity Scale (BRSS) ranging from 0 (No observable response) through to 9 (Outright panic, flight, stampede, stranding). On such a scale, responses referred to herein as "Weak Responses" have a BRSS rating of 1-3 indicating brief and/or minor changes in *e.g.*, vocal behaviour, respiration, and locomotion. By contrast, responses referred to herein as "Strong Responses" are represented by extensive and/or prolonged changes in the behavioural traits mentioned above as well as aggressive behaviour amongst individuals and brief or minor separations of females and dependent offspring.

Having defined a BRSS, Southall *et al.*<sup>18</sup> provided a range of sound pressure levels on the animal over which each behavioural response had been observed. The ensuing data were categorized into 10-dB SPL bins and then ranked by the severity of the behavioural response observed over that SPL range. This tended to show that the higher the SPL on the animal the greater the BRSS score and the more severe the behavioural response.

It is noted that frequently, the data on which the BRSS is based is somewhat sparse, consisting as it does of relatively few observations of animal behaviour; behavioural responses being variable, context-dependent (*i.e.*, costs or benefits of fight or flight) and less predictable than physical and/or physiological effects; and there being a considerable overlap in the range of sound pressure levels over which a given mode of behaviour might be prevalent. Some degree of interpretation and extrapolation is thus required when applying the data in the manner required for the current study. For instance, Southall *et al.*<sup>18</sup> show that for a given severity response score the BRSS may indicate that more animals were observed giving a strong response to noises having low SPLs than at higher SPLs. This challenges the idea behind the continuum represented by the BRSS that low SPLs produce weak responses and high SPLs always lead to stronger responses. Digging deeper into the data reveals that some of the observations may relate to species of marine mammal not found in or around Area 4 hence these data can reasonably be overlooked.

Behavioural impacts are defined by a threshold which was set following observations of animals in each FHG when exposed to continuous-type noise - predominantly vessel noise (including that generated by thrusters) but also including drilling noise, acoustic deterrent devices (ADD), and oceanographic research sonar.

- For LF cetaceans, Southall *et al.*<sup>18</sup> noted that there was no (or very limited) response at received levels of 90-120 dB re 1  $\mu$ Pa rms and clearly defined avoidance behaviour at 120-160 dB re 1  $\mu$ Pa rms. However, it was seen that there was considerable variability in received levels for any given response type and this was attributed to contextual variables such as source proximity; the presence of vessels and/or humans close to subjects either for observation or during deployment of sound sources; animal activity at the time of exposure; and habituation or sensitisation to the sound;
- For MF cetaceans<sup>57</sup>, it was noted that high sensitivity to the noise was seen at received levels across the range 90-120 dB re 1  $\mu$ Pa rms while, often, no responses were seen at received levels of 120-150 dB re 1  $\mu$ Pa rms;
- For HF cetaceans<sup>57</sup>, only one species has been studied extensively thus far: namely harbour porpoise. These were seen to be relatively sensitive to sound levels across the range 90-120 dB re 1  $\mu$ Pa rms but when exposed to sounds above 140 dB re 1  $\mu$ Pa rms they exhibited profound behavioural responses. It is emphasised however that harbour porpoise is not a species extant to Area 4 and it is therefore not clear whether these results are relevant to other HF cetaceans such as dwarf and pygmy sperm whale;
- Thus far, no data is available at all on the behavioural responses of sirenia following exposure to continuous-type noise.

The latest work published by Southall *et al.*<sup>58</sup> identifies the inherent weaknesses in the approach discussed in the 2007 paper. A revised experimental protocol is recommended whereby the earlier anomalies are addressed with the objective of deriving probabilistic response functions for various modes of behaviour. It will likely take some years to collect sufficient data on which a rigorous analysis may be made. In the meantime, it is proposed to draw on guidance given by the US National Marine Fisheries Service (NMFS)<sup>59</sup> which sets a Level B Harassment threshold for exposure to continuous-type noise of 120 dB re 1  $\mu$ Pa (rms). NMFS define a Level B exposure as “*any act that disturbs or is likely to disturb a marine mammal or marine mammal stock in the wild by causing disruption of natural behavioural patterns, including, but not limited to, migration, surfacing, nursing, breeding, feeding, or sheltering, to a point where such behavioural patterns are abandoned or significantly altered.*” It is subject to interpretation as to how long a given behaviour (e.g., foraging) has to be interrupted before meeting the definition of being abandoned. Similarly, the phrase “*significantly altered*” could be interpreted in a statistically significant sense or in a biologically significant sense, i.e., are there a significant number of animals in a group displaying a given behavioural response; or are the responses amongst individuals themselves significant. The

<sup>57</sup> Note that MF and HF cetaceans in the Southall *et al.* (2007) report are now reassigned as HF and VHF cetaceans respectively in the Southall *et al.* (2019) report.

<sup>58</sup> Southall, B. L., Nowacek, D. P., Bowles, A. E., Senigaglia, V., Bejder L., Tyack P. L. Marine mammal noise exposure criteria: Assessing the severity of marine mammal behavioral responses to human noise. *Aquatic Mammals*. 47(5), 2021.

<sup>59</sup> Scoping Report for NMFS EIS for the National Acoustic Guidelines on Marine Mammals. National Marine Fisheries Service. 2005.

uncertainty surrounding the meaning of the term "*significantly altered*" is one of the reasons why behavioural impacts remain relatively undefined compared with physiological impacts. Furthermore, it must be emphasised that behavioural traits associated with the Level B threshold do not map exactly onto the BRSS scale. However, it may be suggested that Level B harassment behavioural responses probably correspond to a BRSS of 6 or thereabouts.

It is noted that the threshold level of 120 dB re 1  $\mu$ Pa (rms) lies close to the range of background noise levels. As a result, National Oceanic and Atmospheric Administration (NOAA) advice<sup>60</sup> suggest that the level may be "*slightly adjusted if background noise levels are at or above this level*" but gives no further guidance. Furthermore, Stocker<sup>61</sup> provides a qualitative critique of Level B thresholds and suggests that it is time that NOAA considers revising the threshold levels in the light of research that has been undertaken since the level was first established. Until the threshold levels are revised, it is impossible to determine what outcome, if any, any changes might have on the distances over which the corresponding impact criterion are met.

Despite these reservations and for the purpose of the current study, a threshold level of 120 dB<sub>rms</sub> re 1  $\mu$ Pa<sup>62</sup> is proposed as representing a noise which results in the onset of a strong behavioural reaction in marine mammals when exposed to non-impulsive type noise.

### AVI.3.3. Fish and Sea Turtles

#### AVI.3.3.1. Physiological Impacts

Popper *et al.*<sup>55</sup> conducted a similar process for fish as Southall *et al.*<sup>18</sup> had completed for marine mammals. They reviewed a number of studies and subsequently suggested various noise thresholds related to potential acoustic impacts that were a function of the hearing sensitivity of fish species and of the noise type. The functional hearing groups refer back to studies of either the internal physiology of the fish or else to their auditory sensitivity. The latest groupings<sup>63</sup> are summarised in Table AVI.7.

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<sup>60</sup> <https://www.fisheries.noaa.gov/west-coast/endangered-species-conservation/esa-section-7-consultation-tools-marine-mammals-west>. Accessed July 2023.

<sup>61</sup> Stocker M., "Best available science? Are NOAA Fisheries marine mammal noise exposure guidelines up to date?", Published by the Acoustical Society of America, Proceedings of Meetings on Acoustics, Vol. 36, 010001 (2019). Accessed <https://tethys.pnnl.gov/sites/default/files/publications/Stocker-2019-NOAA-Noise.pdf>, July 2023.

<sup>62</sup> [https://www.westcoast.fisheries.noaa.gov/protected\\_species/marine\\_mammals/threshold\\_guidance.html](https://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/threshold_guidance.html)

<sup>63</sup> Popper A. N., A. D. Hawkins, "An overview of fish bioacoustics and the impacts of anthropogenic sounds on fishes", J. Fish Biol. 2019;94:692–713.

**Table AVI.7: Fish and sea turtle hearing groups<sup>63</sup>**

Functional hearing group	Description	Characteristics
Group 1	Fish with no swim bladder	Generally, these fish have no swim bladder or other gas chamber. They are relatively unsusceptible to barotrauma <sup>64</sup> and are sensitive only to particle motion rather than sound pressure <sup>65</sup> . This class includes flatfish, sharks, and rays.
Group 2	Fish with swim bladders in which hearing does not involve the swim bladder	Although fish in this class have a swim bladder and thus the organ is able to respond to sound pressure, the swim bladder is not connected to the inner ear hence the hearing ability of fish depends only on particle motion. Fish in this class are relatively sensitive to only a narrow range of frequencies.
Group 3	Fishes with swim bladders that are close, but not intimately connected, to the ear	Fish in this class are sensitive to both particle motion and sound pressure. They are sensitive to a wider range of frequencies compared with Groups 1 and 2. This group includes members of the Gadidae, Anguillidae, and Sciaenidae families.
Group 4	Fish where hearing involves a swim bladder	Fish in this class have a connection between the swim bladder and the inner ear and are sensitive to both particle velocity and sound pressure. Species in this class are sensitive to sounds over a wide frequency range (~several kHz) and have a higher sensitivity than fish in the preceding groups. The group includes members of the Holocentridae, Sciaenidae, and Clupeidae families and the large group of otophysan fishes.
Group 5	Fish eggs and larvae	Studies show that the hearing abilities are similar to those of the adult of the species. Swim bladders may develop during the larval stage hence those species are particularly sensitive to barotrauma. Popper <i>et al.</i> <sup>55</sup> shows that there is very little data on the effects of sound or vibration on fish eggs.
Group 6	Sea turtles	There is relatively limited data on sea turtle hearing therefore the area is poorly understood. Studies of the auditory physiology of sea turtles indicate that the ear structure is closer to that found in fish than sea mammals but that they are adapted to detect sound pressure changes underwater. Popper <i>et al.</i> <sup>55</sup> maintains that until more data become available, fish hearing, rather than mammalian hearing, is the better model to use for sea turtles.

In attempting to provide a range of acoustic thresholds at which various impacts might occur, Popper *et al.*<sup>55</sup> reviewed data from tests where various fish species had been exposed to impulsive and non-impulsive sound and their resulting response observed. Impacts were described in terms of:

- Mortality and Potential Mortal Injury – where the acoustic-related injury is so severe that death follows either immediately or shortly very afterwards;
- Recoverable Injury – where the injury, including hair-cell damage, minor internal or external haematoma, is not likely to result in death;
- TTS – temporary hearing damage which is recoverable over time;
- Masking – where the man-made sound is sufficiently loud enough that it drowns out *e.g.*, vocalisations made by conspecifics or hunting noises made by predators;
- Behavioural effects – where there is a discernible change in behaviour of the animal when exposed to the sound. Such responses include large-scale and long-lasting movements away from feeding and breeding sites; or cessation of breeding or spawning activity.

<sup>64</sup> Barotrauma is tissue injury caused by a difference in pressure between a gas-filled space inside an organ and the surrounding tissues. Low levels of damage involve stretching of the tissue in tension or shear. Higher levels involve rupture of the tissues which can lead to fatalities.

<sup>65</sup> Hitherto, nearly all audiological investigations on fish have focused on sound pressure as a metric. Very little data have been acquired on the responses of fish to particle motion. Attempts are being made by the international research community to address this major knowledge shortfall, see *e.g.*, Popper A. N., and A. D. Hawkins, The importance of particle motion to fishes and invertebrates, *The Journal of the Acoustical Society of America* 143, 470 (2018); <https://doi.org/10.1121/1.5021594>.

Subsequently, Popper *et al.*<sup>55</sup> provides threshold levels of noise for fish of all functional hearing groups exposed to vessel and continuous noise and these are given in Table AVI.8 using, where relevant, SPL rms metrics.

It is noted that threshold levels representing the onset of Recoverable Injury; and TTS in fish eggs; and sea turtles do not currently exist due to insufficient data. Popper *et al.*<sup>55</sup> acknowledges the difficulty in ascribing specific distances or a range of distances to the risk of an impact given the number of variables that underpin such a decision. They suggest that “near” might be considered to be in the tens of metres from the source, “intermediate” in the hundreds of metres, and “far” in the thousands of metres”.

**Table AVI.8: Summary of acoustic impact threshold criteria in SPL<sub>peak</sub> and unweighted SEL metrics for fish functional hearing groups<sup>55</sup> exposed to vessel and continuous noise**

Functional hearing group	Mortality and Potential Mortal Injury	Recoverable Injury	TTS
Fish Group 1	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low
Fish Group 2	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low
Fish Group 3/4	(N) Low (I) Low (F) Low	170 dB rms for 48 h	158 dB rms for 12 h
Fish eggs and larvae Group 5	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low
Sea turtles Group 6	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low

Legend: N-Near distance; I-Intermediate distance; F-Far distance.

### AVI.3.3.2. Behavioural Impacts

Threshold levels may be assigned to the onset of behavioural response in fish species although current guidance appears somewhat ambiguous. The US Fish and Wildlife Service (USFWS) works with a level of 150 dB re 1 µPa as a threshold for behavioural responses in fish<sup>66</sup>. Popper *et al.*<sup>55</sup> state that it is not clear whether this is a peak or rms metric. They also affirm that the corresponding criterion does not specify a particular behavioural response or whether it merely assumes that at that sound level, there is the potential to experience a behavioural reaction. Furthermore, Hastings<sup>67</sup> declares that the scientific origin of this threshold is unknown and thus the validity of the criterion is uncertain. However, in the absence of any data in addition to the guidelines provided by USFWS and

<sup>66</sup> Stadler, J.H. and D.P. Woodbury. 2009. Assessing the effects to fishes from pile driving: Application of new hydroacoustic criteria. In: Inter-Noise 2009 Innovations in Practical Noise Control.

<sup>67</sup> Hastings M. C., (2008) “Coming to terms with the effects of ocean noise on marine animals”. *Acoustics Today* 4(2):22–34.

for the purpose of continuing the analysis contained in the current study, it is decided that a 150 dB<sub>rms</sub> re 1 µPa threshold be used to represent the onset of Low-Level Behavioural Responses in fish.

With regards to behavioural responses in sea turtles, Finneran and Jenkins<sup>68</sup> reviewed a number of studies reporting the responses of caged sea turtles when exposed to impulsive-type noises. They report that behavioural responses first become evident at received sound levels of 166 dB<sub>rms</sub> re 1 µPa. When sound levels are increased to lie in the range 175-179 dB<sub>rms</sub> re 1 µPa, the reactions are more erratic and avoidance behaviour becomes apparent. Accordingly, for the current study, a threshold of 175 dB<sub>rms</sub> re 1 µPa is used to represent the onset of avoidance behaviour in sea turtles.

## AVI.4. Underwater Acoustic Propagation Modelling

### AVI.4.1. Introduction

The following sections describe the acoustic propagation modelling undertaken in order to estimate received level variation with distance from the source, specifically the acoustic models used and the oceanographic and geo-acoustic<sup>69</sup> parameters required as input data for the models.

### AVI.4.2. Description of the Models

Numerous computer models are available to predict acoustic propagation in the marine environment. Each model has its own strengths and weaknesses in terms of input requirements and calculation methods, although all include some form of description of various environmental parameters, such as the water column sound speed profile<sup>70</sup> (SSP) and sediment acoustic properties.

Reviews of a number of acoustic propagation computer programs are given by Buckingham<sup>71</sup>, Jensen *et al.*<sup>72</sup> and Etter<sup>73</sup>. A number of these have been coded up and are included in the Acoustics Toolbox<sup>74</sup>. The computer programs are based on ray-trace, normal mode, parabolic equation, and fast field techniques. Not all programs are equally suitable for use: due consideration must be made to the nature of the problem to be addressed and this will guide the user to the most appropriate model<sup>75</sup>.

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<sup>68</sup> Finneran J. J., Jenkins A. K., "Criteria and Thresholds for U.S. Navy Acoustic and Explosive Effects Analysis", SSC Pacific Technical Report, April 2012.

<sup>69</sup> The term "geo-acoustic" alludes to the type and structure of the sediments that comprise the seabed but instead, described in acoustic terms. These include, amongst others, the speed of sound in the sediment layer, the density of the rock and its layer thickness.

<sup>70</sup> Defined from measurements of sound speed made in the water from the sea surface to the seabed.

<sup>71</sup> Buckingham M.J., "Ocean-acoustic propagation models". Journal d'Acoustique: 223-287 June 1992.

<sup>72</sup> Jensen Finn., Kuperman William., Porter Michael., and Schmidt Henrik., Computational Ocean Acoustics, Springer-Verlag (2000).

<sup>73</sup> Etter Paul C., Underwater Acoustic Modeling and Simulation , 5th Edition, CRC Press, 2018, DOI: <https://doi.org/10.1201/9781315166346>

<sup>74</sup> An online repository funded by the US Office of Naval Research and containing a number of underwater acoustic propagation loss computer programmes. Found at <http://oalib.hlsresearch.com/Modes/AcousticsToolbox/>

<sup>75</sup> Farcas, Adrian, Paul M. Thompson, and Nathan D. Merchant. 2016. "Underwater Noise Modelling for Environmental Impact Assessment." Environmental Impact Assessment Review 57: 114–22.

It is required to carry out a two-dimensional (2D) (in depth and distance) frequency-dependent analysis for a given sound speed profile in a varying-depth ocean waveguide which overlies a range-dependent, acoustically absorbent seabed sediment. In addition, the water depth is an important factor to be taken into account. The programs used for the analysis undertaken in this report are BELLHOP<sup>76</sup> – based on the ray-trace method; and RAM<sup>77,78</sup> – based on the parabolic equation. Both programs provide a solution that is valid over a limited frequency, water depth, and range regime: parabolic-equation models are optimised for use at lower frequencies while ray-trace models tend to be most suitable for high frequencies.

The noise sources discussed in Section AVI.2, each generate noise over a wide range of frequencies although the bulk of the acoustic energy tends to be carried at low frequencies, i.e., <~1 kHz, hence it is considered acceptable to use both the BELLHOP and RAM models such that the whole frequency range of interest is covered. The transition frequency at which it is appropriate to switch from one model to the other is related to the wavelength of the noise compared with the water depth. Buckingham<sup>71</sup> declares that ray modelling is satisfactory when the wavelength is very much less than any of the length scales in the problem. An appropriate length scale to be considered, is the water depth at the modelling origin. Etter<sup>73</sup> quantifies this by using a factor of 8-10 leading to a switchover frequency of around 8 Hz in the project area.

The two propagation models are classed as range-dependent which is to say they can deal with changes in water depth or SSP over increasing distance from the point of origin. The quality of the modelling results is therefore highly dependent on obtaining site- and time-specific data. The sources of data used as inputs to the propagation modelling process are discussed below.

### AVI.4.3. Transect Bathymetry

Water depth data was taken from the bathymetry database GEBCO 2023<sup>79</sup>. This is a database of water depths having global coverage and a resolution of 15 arc-seconds (corresponding to a spatial separation of around 0.45 km in the vicinity of the Area 4 Project Area).

Navigation charts<sup>80</sup> show that Area 4 is a deep-water region. Water depths are greatest towards the east of the Project Area while towards the west, they decrease gradually as the Quirimbas archipelago and Mozambique mainland is approached.

In order to capture the depth variation over the wider project area, a set of 12 equally spaced transects were used and these were centred at the nominal Coral North site. The transects themselves are approximately 40 km in length thus just spanning the distance between the Coral FLNG mooring site and the nearest coastline of the Quirimbas Islands to the west.

<sup>76</sup> Porter M. B., "The Bellhop Manual and User's Guide" 2011. Accessed at <http://oalib.hlsresearch.com>.

<sup>77</sup> Collins, M. D., "Applications and time-domain solution of higher-order parabolic equations in underwater acoustics", *Journal of the Acoustical Society of America*, 86(3), 1097–1102, 1989.

<sup>78</sup> Collins, M. D., "A split-step Padé solution for the parabolic equation method", *Journal of the Acoustical Society of America*, 93(4), 1736–1742, 1993.

<sup>79</sup> GEBCO Compilation Group (2023) GEBCO 2023 Grid (doi:10.5285/f98b053b-0cbc-6c23-e053-6c86abc0af7b). Accessed at [https://www.gebco.net/data\\_and\\_products/gridded\\_bathymetry\\_data/](https://www.gebco.net/data_and_products/gridded_bathymetry_data/)

<sup>80</sup> Admiralty Chart 2927 - Mozambique And Tanzania, Pemba To Mtwara, 1:300 000, ©Crown Copyright 2008 UK Hydrographic Office.

The modelling approach introduced above is termed Nx2D acoustic propagation modelling where 2D sound fields (in depth and range) are generated on each of N transects. Although this process gives the impression of a 3D sound field this is somewhat illusory as horizontal refraction is not permitted by the computer programs used in this task. Horizontal refraction could arise due to e.g., sound propagation through an ocean eddy or by sound being refracted around a seamount. In both examples, the curvature of the wavefront in the horizontal plane becomes non-negligible and the above-mentioned features located on one transect may subsequently influence the acoustic field on adjacent transects. To address these scenarios, full 3D acoustic propagation programmes should strictly be used<sup>81</sup>. However, those that exist are currently only suitable for research-type tasks and do not yet have the provenance that would justify their use in the current study. It is worth emphasising, that the resulting 2D sound fields are not themselves based on 2D geometrical spreading where acoustic wavefronts would be modelled as propagating over the perimeter of a circle<sup>82</sup>. For example, the ray-trace model BELLHOP is developed from a mathematical solution of the Helmholtz equation which itself is based on the 3D wave equation given in cylindrical coordinates<sup>72</sup>.

#### AVI.4.4. Oceanographic Data

Oceanographic data was obtained through the World Ocean Atlas (WOA, 2009<sup>83</sup>). This consists of gridded monthly samples of temperature, salinity, and depth and from which, sound speed profiles in the vicinity of the Project Area, may be reconstructed with the aid of the Chen-Millero<sup>84</sup> relationship.

Thus far in the Project timeline, dates have not been set over which any specific construction activity may take place. However, it is understood that the Coral FLNG will be operational all year round. It is considered impractical to undertake acoustic modelling for each month of the year given the sheer quantity of data that would need to be generated. To address this, the monthly sound speed profiles for the Project Area are reviewed in order to determine which profiles are most likely to give rise to maximum and minimum acoustic propagation conditions over the course of the year. Sound speed profiles extracted from the WOA for each month of the year are given in Figure AVI.6. It will be seen that only the topmost 500 m are plotted as, below the main thermocline from a depth of approximately 800 m, all the profiles converge.

The climate of coastal Mozambique is driven by the East African extension of the Indian Ocean monsoon. Metocean data<sup>85</sup> show that winds blow from the north-west through to the south while the predominant direction is from the southeast. As a result, the climate can be divided up into a number of distinct seasons: hot and rainy from November to March; dry from May to October; and cool from mid-May to mid-August. Figure AVI.6 shows that there is relatively little variation in the nature of the sound speed profile from month to month and where any differences arising are attributed to the

<sup>81</sup> <http://oalib.hlsresearch.com/ThreeD/index.html>

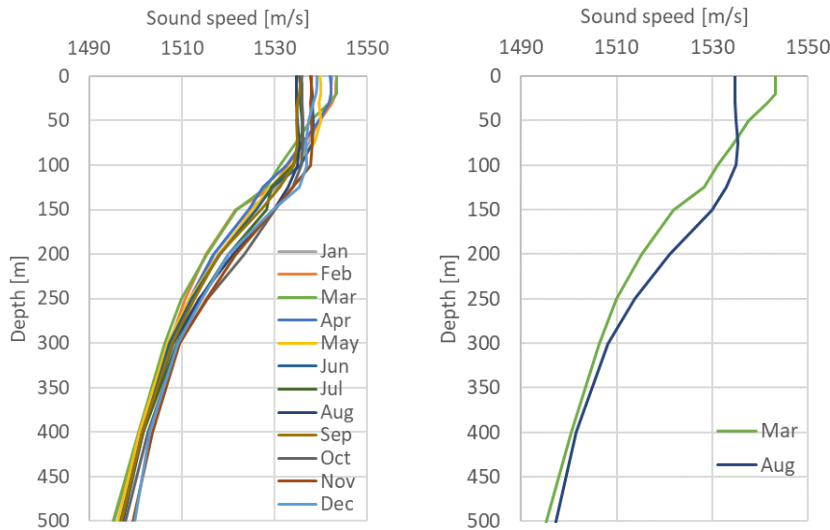
<sup>82</sup> Liner C. L., Elements of 3D Seismology, 3rd edition, SEG Books, 2016

<sup>83</sup> World Ocean Atlas dataset 2009, available for download at [www.nodc.noaa.gov/OC5/WOA09/pr\\_woa09.html](http://www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html)

<sup>84</sup> C-T. Chen and F. J. Millero, (1977), "Speed of Sound in Seawater at High Pressures". Journal of the Acoustical Society of America, 32(10), p 1357

<sup>85</sup> Metocean Design Basis For FLNG (CORAL) 440200FGRF02014

small fluctuations in temperature and rainfall. A high-level analysis of the sound speed profiles indicates that extremes of acoustic propagation are likely to arise during the months of March and August. Subsequently, SSPs for the months of March and August are taken forward for use in the propagation modelling discussed in this report.



**Figure AVI.6: (a) Monthly sound speed profiles for the Area 4 region; and (b) sound speed profiles for the months of March and August**

### AVI.4.5. Seabed Geoacoustics

Brownfield<sup>86</sup> undertook an assessment of the hydrocarbon resource potential off the coast of Mozambique including the region covered by Area 4. Stratigraphic data indicates that the Rovuma Delta Complex consists of sandstone traps contained in a marine shale/siltstone-sandstone horizon some 2000 m thick. Drawing on the Folk sediment classification<sup>87,88</sup>, a thick clay-silt layer is assumed to overlie a sandstone basement. Hamilton<sup>89,90,91</sup> provides advice on geoacoustic parameters and from this, corresponding sound speed, density and attenuation data were obtained and these are summarised in Table AVI.9 below. It is pointed out that both the sediment layer and the underlying semi-infinite bedrock are treated as elastic solids where both compressional (or primary (P)) waves and shear (or Secondary (S)) waves are supported. Given the thickness of the clay-silt layer, it is considered unlikely that the sandstone basement will contribute much to acoustic losses.

<sup>86</sup> Brownfield, M.E., 2016, Assessment of undiscovered oil and gas resources of the Mozambique Coastal Province, East Africa, in Brownfield, M.E., compiler, Geologic assessment of undiscovered hydrocarbon resources of Sub-Saharan Africa: U.S. Geological Survey Digital Data Series 69-GG, chap.10, 13 p., <http://dx.doi.org/10.3133/ds69GG>. ISSN 2327-638X (online)

<sup>87</sup> Folk, R.L., 1954. The distinction between grain size and mineral composition in sedimentary rock nomenclature. The Journal of Geology, 62, 344-359.

<sup>88</sup> Long, D., 2006. BGS detailed explanation of seabed sediment modified Folk classification. Available from: [http://www.emodnet-seabedhabitats.eu/PDF/GMHM3\\_Detailed\\_explanation\\_of\\_seabed\\_sediment\\_classification.pdf](http://www.emodnet-seabedhabitats.eu/PDF/GMHM3_Detailed_explanation_of_seabed_sediment_classification.pdf)

<sup>89</sup> E.L. Hamilton: Sediment Sound Velocity Measurements made In Situ from Bathyscaph TRIESTE, Journal of Geophysical Research 68 (1963) pp. 5991-5998.

<sup>90</sup> E.L. Hamilton: Sound velocity and related properties of marine sediments, North Pacific, Journal of Geophysical Research 75 (1970) pp. 4423-4446.

<sup>91</sup> E.L. Hamilton: Compressional-wave attenuation in marine sediments, Geophysics 37 (1972) pp. 620-646.

**Table AVI.9: Seabed sediment profile and bedrock properties for the Project Area**

Depth below seafloor m	Layer	P-wave velocity Vp m/s	S-wave velocity Vs m/s	Density kg/m <sup>3</sup>	P-wave attenuation dB/m/kHz	S-wave attenuation dB/m/kHz
0	Clayey silt	1528	185	1.454	1.032	3.196
100		1651	397	1.589	1.038	6.863
500		2027	619	2.111	0.879	10.714
1000		2348	869	2.672	0.540	15.041
2000		3228	1556	3.566	0.742	26.916
>2000	Sandstone	3913	2090	2.360	1.364	36.159

### AVI.4.6. Source Modelling Parameters

Sound emitted by the vessels, the FLNG thrusters, and from drilling activities, is characterised by a generally continuous noise covering a wide range of frequencies (see Section AVI.2). In order to model the underwater acoustic environment, the approach is to divide the source frequency bandwidth into 1/3<sup>rd</sup> octave bands<sup>92</sup> where each band has a given spectral level, centre frequency and bandwidth; and then to use a frequency-domain type program (such as those discussed above) for subsequent propagation modelling. The 1/3<sup>rd</sup> octave centre frequencies thus selected cover the frequency range of interest and are listed in Table AVI.10 while the corresponding 1/3<sup>rd</sup> octave band levels are obtained from Section AVI.2 for the noise created by vessel and drilling noise.

**Table AVI.10: Acoustic modelling parameters**

Parameter	Value	
Noise source	Vessel inc. FLNG	Drilling
Source depth [m]	5	At seabed
Frequency [Hz]	10, 12.5, 16, 20, 25, 31, 40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1k, 1.25k, 1.6k, 2k, 2.5k, 3.15k, 4k, 5k, 6.3k, 8k, 10k, 12.5k, 16k, 20k, 25k, 31.5k, 63k	
SSP - March	✓	✓
SSP - August	✓	✓

### AVI.4.7. Sound Propagation Modelling Scenarios

Using the bathymetric and geoaoustic data given in the preceding sections, propagation loss data was generated along a total of 12 transects radiating from the modelling centre using SSPs representing oceanography for the months of March and August.

The propagation loss data is generated at each of the 1/3<sup>rd</sup> octave band frequencies given in Table AVI.10. The frequency-dependent propagation loss is subtracted from the corresponding 1/3<sup>rd</sup> octave

<sup>92</sup> Kinsler, L.E., Frey, A.R., Coppens, A.B. & Sanders, J.V. (1999), *Fundamentals of Acoustics*, 4th edn. Wiley, NJ.

band source levels for each noise source (provided in Section AVI.2) in order to derive propagated SPL data as a function of distance from the activity site. A discussion of the results generated by this stage is given in the following section.

## AVI.5. Modelling Results

### AVI.5.1. Introduction

This section of the report describes the results of some of the acoustic propagation modelling undertaken in Section AVI.4. It discusses the physical aspects of acoustic propagation where the distribution of noise underwater is a function of the bathymetry, SSP, and seabed geoacoustics alone. As representative examples, the underwater noise propagation due to the FLNG and to drilling are examined where these have the highest and lowest source noise levels respectively (see Section AVI.2). For each noise source, unweighted sound levels as a function of depth and distance are discussed below.

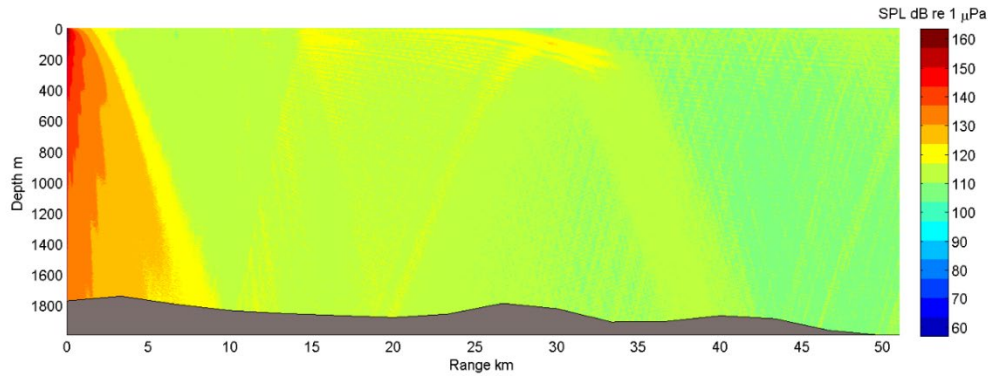
### AVI.5.2. FLNG Noise

The results from the acoustic propagation modelling indicate that sound pressure levels at any given depth and distance are dependent upon the nature of the SSP and, to a lesser extent given the large water depths, the underlying bathymetry. In order to illustrate this, the FLNG operational modelled over two representative transects and two seasons are discussed below.

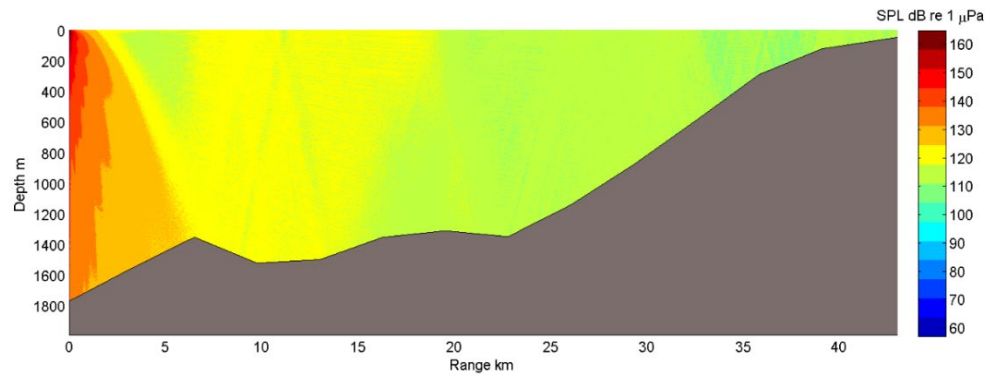
Figure AVI.7 shows contoured SPL for FLNG operational noise modelled using the March SSP along the 0° bearing transect radiating from the modelling site. The water depth undulates between around 1700 m and 2000 m over a transect length of 50 km. Although the noise source, predominantly the thrusters, are at a depth of 7 m thus lying in the surface duct of the SSP, the acoustic energy is directed largely towards the seabed and this is attributed to the downward refracting nature of the SSP below a depth of 500 m or so. Noise levels fall from 189 dB<sub>rms</sub> re 1 µPa at the point of origin to around 140 dB re 1 µPa at a distance of 2 km. From a distance of 10 km, some structure in the noise field becomes evident where seabed reflections return levels of acoustic energy back towards the sea surface. There appears a concentration of energy over the depth range 100 – 200 m at a distance of 30 km where noise levels are seen to be around 10-15 dB higher than outside the zone. At a distance of 50 km, noise levels are lying in the range 105-110 dB<sub>rms</sub> re 1 µPa and therefore lie close to the overall background noise levels recorded during the OEBS noise survey (ERM, 2016).

Figure AVI.8 shows the FLNG noise propagating along the 270° transect over a distance of approximately 42 km. This is one of the shortest modelling transects where it will be seen that water depths decrease from 1765 m at 0 km to less than 100 m at the end of the modelling transect which lies close to the Quirimbas Islands and the Mozambique mainland. Noise levels fall to around 140 dB re 1 µPa at a distance of 2 km. At a distance of 42 km, noise levels are down to 105 -110 dB re 1 µPa.

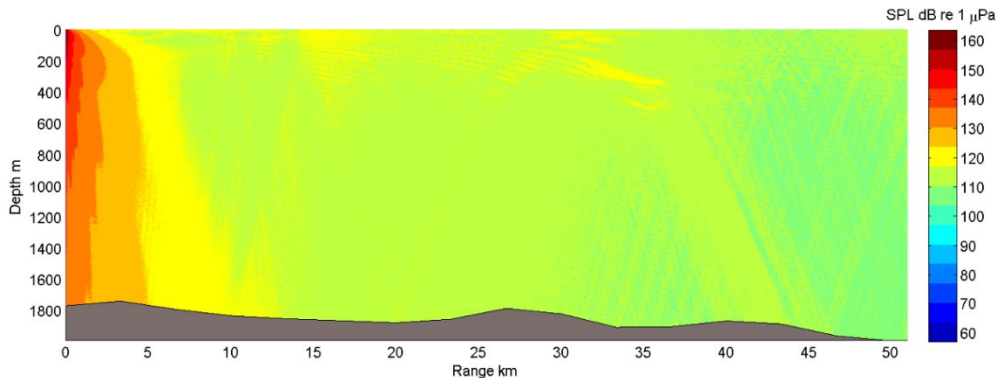
The oceanography discussed in Section AVI.4 indicates small differences in the nature of the SSP over the topmost 500 m of the water column. In order to demonstrate the practical effect of these differences, noise levels were modelled using the August SSP along the 0° transect, shown in Figure AVI.9, and along the 270° transect shown in Figure AVI.10. It will be seen that noise levels fall to 140 dB re 1  $\mu$ Pa over the range 1.5 – 2 km while at a distance of 50 km, noise levels lie in the range 100-105 dB re 1  $\mu$ Pa. Any differences attributed to the nature of the SSP are therefore considered minor.



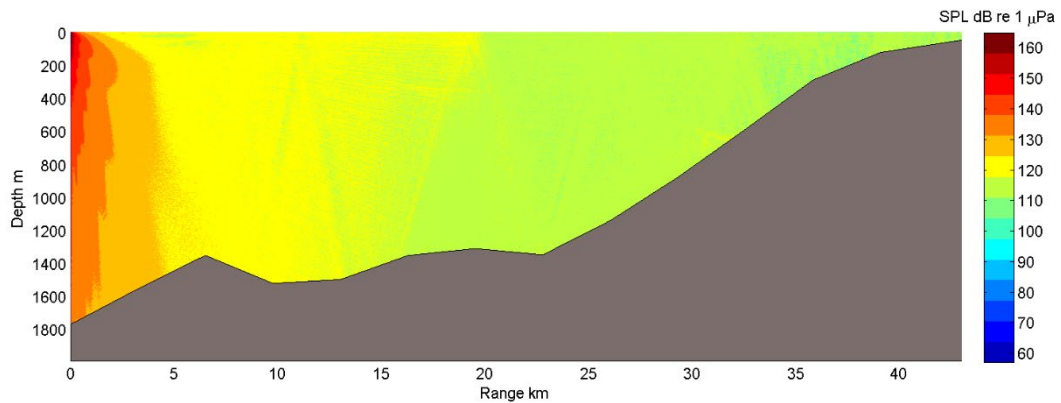
**Figure AVI.7: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North FLNG modelled along a bearing of 0° using March oceanographic conditions**



**Figure AVI.8: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North FLNG modelled along a bearing of 270° using March oceanographic conditions**



**Figure AVI.9: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North FLNG modelled along a bearing of 0° using August oceanographic conditions**



**Figure AVI.10: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North FLNG modelled along a bearing of 270° using August oceanographic conditions**

### AVI.5.3. Drilling Noise

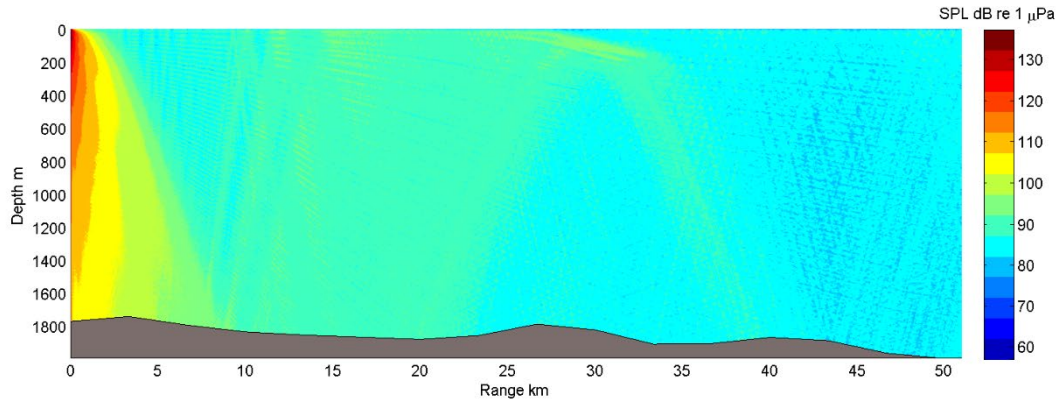
Figure AVI.11 shows the underwater noise propagating away from the drilling vessel modelled along the 0° transect using the March SSP. Propagated noise levels are substantially lower when compared with the results for FLNG noise seen above. At distances of <1km and within a depth of 400 m below the noise source, noise levels have fallen to 140 dB re 1 μPa. The structure of the noise field becomes evident at 30 km and over the depths 100-200 m where a small zone of intensity results in noise levels being around 20 dB higher compared with levels outside. At the end of the transect, noise levels are in the range 80-85 dB re 1 μPa and therefore probably below the background noise levels expected in this region.

Figure AVI.12 shows noise levels modelled along the 270° transect. A number of seabed reflections are noted from 10 km onwards and these contribute to there being several zones where resulting noise levels are around 10 dB higher than in surrounding regions. As the noise propagates upslope, energy is increasingly stripped out of the water column and becomes absorbed into the seabed. Subsequently, at a distance of 42 km, noise levels are down to 85 dB re 1 μPa.

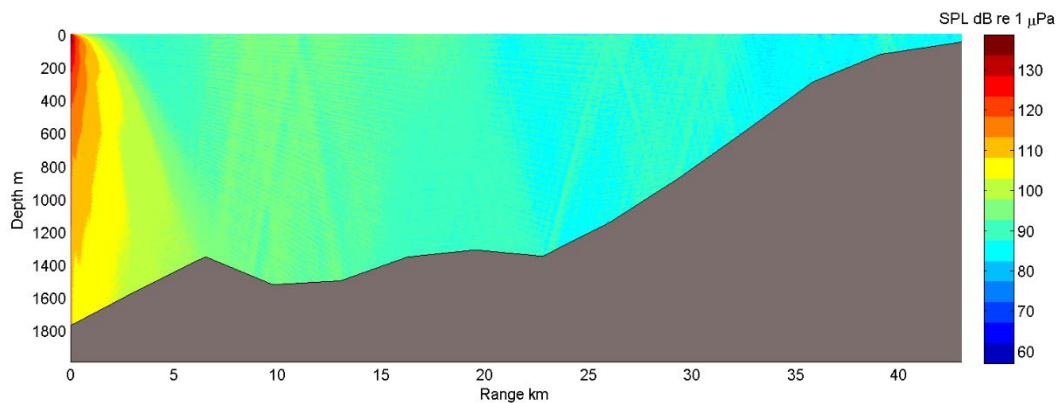
Figure AVI.13 and Figure AVI.14 show propagated noise levels modelled using the August SSP along the 0° and 270° transects respectively. There is seen to be little substantial difference between noise levels at any given location in the water column compared with those modelled using the March SSP and discussed above. For each scenario, modelled noise levels are down to around 85 dB re 1 μPa at distances of 40-50 km from the point of origin and are therefore likely to fall below background noise levels.

These eight figures indicate that the SPL at any given distance is largely dependent on the nature of the bathymetry and that differences in the SSP arising over the course of the year have relatively little effect on ensuing noise levels. In addition, it must be emphasised that the bathymetry sections as displayed in the figures above relate uniquely to the given modelling point and to the specific transects radiating therefrom. Along each transect, the nature of the bathymetry varies from location to location and this will subsequently affect to some extent, the propagation of noise through the

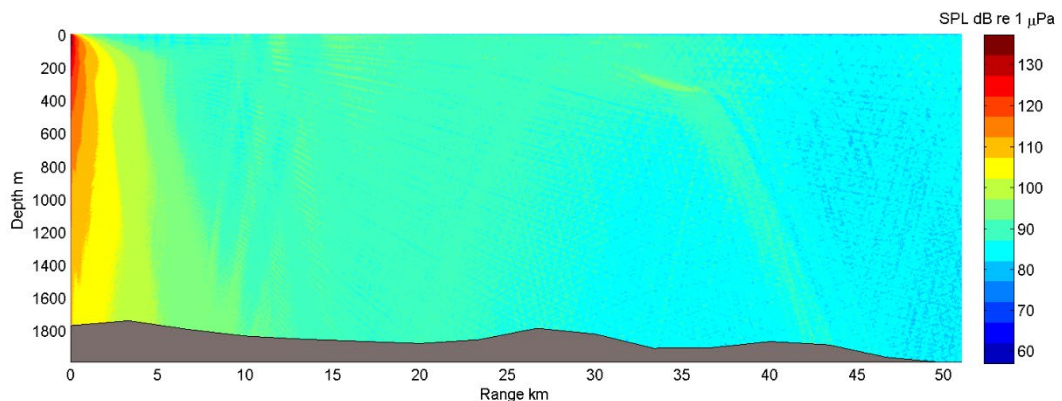
water. Accordingly, the distances over which each acoustic impact is met will vary along each modelled transect radiating from each modelled point. Impact distances are summarised in the next Section.



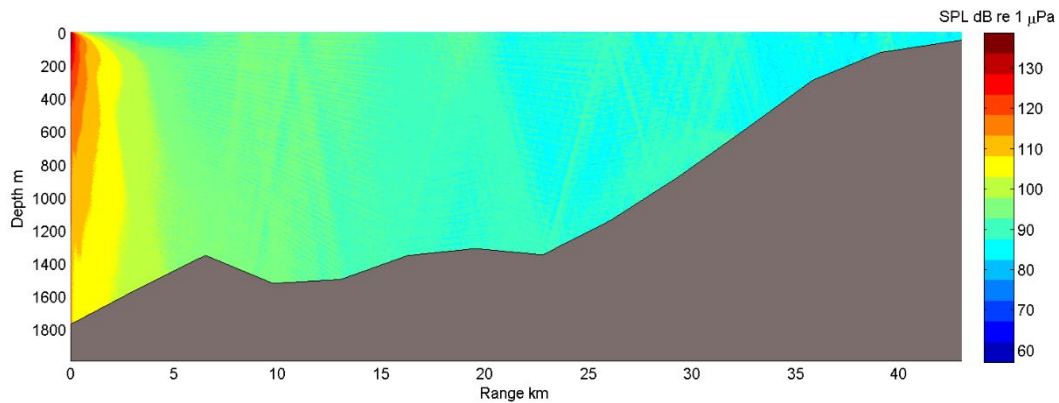
**Figure AVI.11: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North drilling vessel modelled along a bearing of 0° using March oceanographic conditions**



**Figure AVI.12: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North drilling vessel modelled along a bearing of 270° using March oceanographic conditions**



**Figure AVI.13: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North drilling vessel modelled along a bearing of 0° using August oceanographic conditions**



**Figure AVI.14: Contour plot of SPL as a function of depth and distance from mooring site generated by the Coral North drilling vessel modelled along a bearing of 270° using August oceanographic conditions**

## AVI.6. Acoustic Impact Modelling Results

### AVI.6.1. Introduction

The previous section discussed the propagation of noise through the marine environment that is generated by various project activities at the Coral North Project Site within Area 4. This section determines the distances at which noise levels fall to below the threshold levels associated with each of the potential impacts discussed in Section AVI.3.

The discussion commences on the assumption that the receptor is stationary. Distances over which each acoustic impact criterion are met are modelled using SPL and SEL metrics. In each case, a binary approach is followed with regards to quantifying the impact where the impact criterion corresponding to the onset of e.g., PTS, is either met or not met. This is followed by a discussion of the cumulative impacts arising on a receptor when exposed to the underwater noise generated by two FLNGs, one in each of the Coral North and Coral South fields. Each procedure is discussed below.

### AVI.6.2. Physiological and Behavioural Impacts

Acoustic impacts can arise on a receptor following a single exposure to a loud noise or following continued exposure to a lower-level of noise although over an extended period of time. For this latter consideration, NMFS guidance<sup>93</sup> recommends a baseline accumulation period of 24 hours for comparative purposes. However, the guidance also acknowledges that there may be situations where this accumulation period requires adjustment hence shorter or longer exposure durations may also be specified. Accordingly, a range of exposure durations are considered varying from 30 minutes up to 24-hours. The range of time exposures considered take into account the various periods over

<sup>93</sup> National Marine Fisheries Service. 2018. 2018 Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum NMFS-OPR-59, 167 p.

which an animal may be exposed to the impactful noise. The shorter exposure durations are appropriate for animals transiting rapidly through the Project Area while the longer periods are deemed more appropriate for slower moving animals and for those species which are habitat-constrained.

Impact distances modelled at the Project Site, using variously, SPL metrics and unweighted and M-weighted SEL metrics for a range of exposure durations, are given in Table AVI.11 through to Table AVI.17. A number of overarching conclusions are drawn from the results:

- Impact distances modelled using August oceanography tend (but not exclusively so) to be longer than those modelled using March oceanography;
- When exposed to vessel noise (viz. AHTS, Installation vessel, MPV and PSV), the VHF cetacean is the most sensitive marine mammal FHG. For an operational period of 24 hours, the PTS and TTS impact criteria extend over distances of 51 m and 561 m respectively. The least sensitive FHG are the HF cetacean and SI sirenia where both the PTS and TTS impact criteria are met at distances of <10 m;
- For all marine mammal FHG, the Level B Behavioural Response criterion covers a maximum distance of 3468 m;
- When exposed to noise from the drilling vessel, over an operational period of 24 hours, the LF cetacean is the most sensitive of marine mammal FHG. The modelling indicates that noise levels are insufficient to meet the threshold for PTS impact criterion except at distances <10 m while the TTS impact criterion extends to a maximum distance of 100 m. The Level B Behavioural Response criterion covers a maximum distance of 258 m;
- Although there are no recorded data against which suction piling noise can be assessed, the discussion in Section 4 indicates that this is a low-noise activity. As a result, it is suggested that the impact distances for drilling noise may also be applied to suction piling noise;
- When exposed to FLNG operational noise, the most sensitive FHG is the VHF cetacean. Over an operational period of 15 hours (representing the approximate maximum period of daily operations), the PTS impact criterion is met at a maximum distance of 258 m while the TTS impact criterion extends to 7.9 km. The least sensitive FHG is the SI sirenia where the PTS impact criterion is met at distances less than 10 m while that for TTS extends to 153 m. The Level B Behavioural response for all marine mammals is met over a distance out to 33 km;
- All fish groupings are insensitive to continuous type noise. Based on the modelling undertaken herein, the likelihood of physiological damage arising on all fish FHG exposed to continuous noise is low. However, it is noted that fish may still be killed if at very close proximity to the noise-generating activity;
- Fish and sea turtle species are assessed using SPL metrics. When exposed to vessel noise (viz. AHTS, Installation vessel, MPV and PSV), both the Recoverable Injury and the TTS impact criteria are met at distance of <10 m for Group 3 and Group 4 fish (being the most audiotically sensitive of fish groupings). The Low-Level Behavioural Response criterion is met over a maximum distance of 51 m for all fish groupings;

- Drilling noise is low level in intensity. Neither the Recoverable Injury, TTS nor the Low-Level Behavioural Response impact criteria are met for fish species at distances beyond 10 m. Given similar low noise levels, these impact distances may also be applied to suction piling noise;
- FLNG operational noise results for fish species in the Recoverable Injury impact criterion extending over less than 10 m while the TTS impact criterion extends to 51 m. The Low-Level Behavioural Response covers a maximum distance of 172 m;
- Sea turtles are insensitive to all the noise generating activities. The Aversive Response criterion is met at distances of <10 m from all noise sources.

Summaries of maximum impact distances for physiological and behavioural impacts on each marine mammal, fish, and sea turtle FHG assessed using SPL and SEL metrics are given in Annexes VI.A to VI.F for each of the noise-generating activities at the Coral North Project Site.

**Table AVI.11: Summary of maximum impact ranges in metres over all transects for marine mammals in the Area 4 region when exposed to AHTS vessel noise**

Functional hearing group	Impact	Threshold	Maximum impact range [metres]						
			0.5 hr	1 hr	2 hr	4 hr	8 hr	12 hr	24 hr
M <sub>lf</sub>	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	51	86	102	153
M <sub>hf</sub>	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
M <sub>vhf</sub>	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	43	51	86	129	153	215
M <sub>si</sub>	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
All	Level B	120 dB re 1 $\mu\text{Pa}$ rms	392						

**Table AVI.12: Summary of maximum impact ranges in metres over all transects for marine mammals in the Area 4 region when exposed to Installation Vessel noise**

Functional hearing group	Impact	Threshold	Maximum impact range [metres]						
			0.5 hr	1 hr	2 hr	4 hr	8 hr	12 hr	24 hr
M <sub>lf</sub>	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	51	51	102	153	215	258	392
M <sub>hf</sub>	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
M <sub>vhf</sub>	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	51	51	102	153	215	258	430
M <sub>si</sub>	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10
All	Level B	120 dB re 1 $\mu\text{Pa}$ rms	2346						

**Table AVI.13: Summary of maximum impact ranges in metres over all transects for marine mammals in the Area 4 region when exposed to Multi-Purpose Vessel noise**

Functional hearing group	Impact	Threshold	Maximum impact range [metres]								
			0.5 hr	1 hr	2 hr	4 hr	8 hr	12 hr	24 hr		
M <sub>lf</sub>	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	51	
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	51	102	153	215	301	357	516		
M <sub>hf</sub>	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
M <sub>vhf</sub>	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	51	
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	51	102	153	215	294	357	561		
M <sub>si</sub>	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
All	Level B	120 dB re 1 $\mu\text{Pa}$ rms	3468								

**Table AVI.14: Summary of maximum impact ranges in metres over all transects for marine mammals in the Area 4 region when exposed to Platform Supply Vessel noise**

Functional hearing group	Impact	Threshold	Maximum impact range [metres]								
			0.5 hr	1 hr	2 hr	4 hr	8 hr	12 hr	24 hr		
M <sub>lf</sub>	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	51	51	102	153	172	258		
M <sub>hf</sub>	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
M <sub>vhf</sub>	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	51	51	102	153	172	258		
M <sub>si</sub>	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
All	Level B	120 dB re 1 $\mu\text{Pa}$ rms	1326								

**Table AVI.15: Summary of maximum impact ranges in metres over all transects for marine mammals in the Area 4 region when exposed to Drilling noise and Suction Piling noise**

Functional hearing group	Impact	Threshold	Maximum impact range [metres]								
			0.5 hr	1 hr	2 hr	4 hr	8 hr	12 hr	24 hr		
M <sub>lf</sub>	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	51	51	100		
M <sub>hf</sub>	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
M <sub>vhf</sub>	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
M <sub>si</sub>	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	<10	<10	
All	Level B	120 dB re 1 $\mu\text{Pa}$ rms	258								

**Table AVI.16: Summary of maximum impact ranges in metres over all transects for marine mammals in the Area 4 region when exposed to FLNG operational noise**

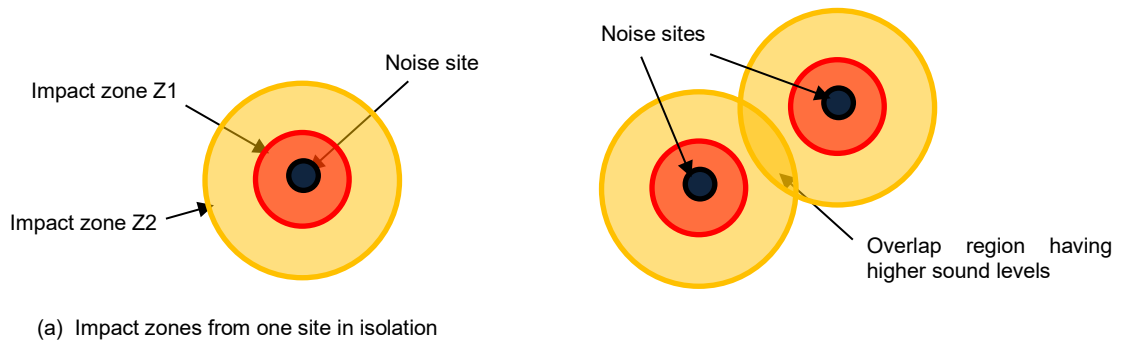
Functional hearing group	Impact	Threshold	Maximum impact range [metres]					
			0.5 hr	1 hr	2 hr	4 hr	8 hr	15 hr
M <sub>lf</sub>	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	43	51	100	129	200
	TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	357	510	750	1050	1500	2050
M <sub>hlf</sub>	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	86	102	172	215
M <sub>vhl</sub>	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	51	51	102	153	215	258
	TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	561	784	1950	2989	4730	7956
M <sub>si</sub>	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	51	51	102	153
All	Level B	120 dB re 1 $\mu$ Pa rms	33100					

**Table AVI.17: Summary of maximum distances in metres at which SPL has fallen to threshold level for Mortality, Recoverable Injury and Behavioural reactions for stationary fish groups exposed to noise generating activities in the Area 4 Project Area**

Activity	Impact	Gp 1	Gp 2	Gp 3	Gp 4	Sea turtle
AHTS vessel	Recov Inj	N/A	N/A	<10	N/A	
	TTS	N/A	N/A	N/A	<10	
	Behavioural	<10				<10
Installation vessel	Recov Inj	N/A	N/A	<10	N/A	
	TTS	N/A	N/A	N/A	<10	
	Behavioural	51				<10
Multi-Purpose Vessel	Recov Inj	N/A	N/A	<10	N/A	
	TTS	N/A	N/A	N/A	<10	
	Behavioural	51				<10
Project Supply Vessel	Recov Inj	N/A	N/A	<10	N/A	
	TTS	N/A	N/A	N/A	<10	
	Behavioural	<10				<10
Drilling & Suction piling	Recov Inj	N/A	N/A	<10	N/A	
	TTS	N/A	N/A	N/A	<10	
	Behavioural	<10				<10
FLNG operation	Recov Inj	N/A	N/A	<10	N/A	
	TTS	N/A	N/A	N/A	51	
	Behavioural	172				<10

### AVI.6.3. Cumulative Operational Noise from Coral North and Coral South FLNGs

The preceding sections have presented the results when a noise generating activity takes place at one site only. The resulting impact ranges can be thought of conceptually as an acoustic footprint centred on the noise site where the PTS and TTS impact criteria are met at increasingly greater distances. This is shown schematically in Figure AVI.15(a).



**Figure AVI.15: Schematic showing (a) single noise-generating site and impact zones; and (b) adjacent noise-generating sites with overlapping zones**

When a noise-generating activity takes place at a second site in relatively close proximity to the first, the individual acoustic footprint zones may overlap. In the overlap region, the SPLs (and consequently, the SELs) will be greater than would result if only one noise-generating site was active. This may be thought of as an example of an additive exposure and is shown schematically in Figure AVI.15(b).

It is understood that the Coral South development in the southern part of Area 4 was commissioned in late 2022 and the *Coral Sul* FLNG is now fully operational. It is expected that the Coral North development will become operational in 2027 when a new FLNG becomes available and is hooked-up to its mooring site which is located a distance of 12.9 km north north-west of the Coral South site. Consequently, the two FLNG's will be moored at their respective sites at the same time, and there may be occasions where the thrusters on the two FLNGs would be used at the same time for offloading and /or helicopter operations at the respective FLNG. The noise generated by each has the potential to generate acoustic zones which may overlap to a greater or lesser degree. Potential cumulative impacts arising from the FLNG operational noise generated simultaneously at the two sites are discussed below.

#### AVI.6.3.1. Cumulative SEL and Level B Impacts

Figure AVI.16 shows the variation in SPL generated at FLNG N (denoted by  $SPL_1$  in the figure) in isolation. Similarly, FLNG S (denoted by  $SPL_2$ ) is located at a separation of 12.9 km and the SPL variation with distance in isolation is also shown. At a distance of 10 km, FLNG S contributes relatively little energy to the acoustic field in the vicinity of FLNG N (and vice-versa). The combined SPL (denoted by  $SPL_{tot}$ ) is given by the linear sum of the SPLs. The  $SPL_{tot}$  is m-weighted to take into

account, in this case, the hearing sensitivity of LF cetaceans, and the cumulative SEL is determined for exposure durations of 1 hour, 2 hours, 4 hours, 8 hours, and 15 hours.

For an exposure duration of 1 hour, the cumulative SEL ( $SEL_{cum}$ ) falls from 223 dB re  $1 \mu Pa^2 \cdot sec$  at 0 km to 199 dB re  $1 \mu Pa^2 \cdot sec$  (corresponding to the threshold representing the onset of PTS for the LF cetacean FHG) at a distance of 50 m from FLNG N. The  $SEL_{cum}$  decreases further down to the threshold representing the onset of TTS (179 dB re  $1 \mu Pa^2 \cdot sec$ ) at a distance of 550 m from FLNG N. Similarly, from the perspective of FLNG S, the  $SEL_{cum}$  falls to the PTS threshold at a distance of  $(12900 - 50) = 12850$  m, and to the TTS threshold at a distance of  $(12900 - 550) = 12350$  m from FLNG N respectively. In the first case, this leaves a “sea corridor” of 12.85 km breadth in which the  $SEL_{cum}$  is below the PTS threshold while in the second case, the corridor is 12.35 km in extent. Consider now an exposure duration of 15 hours, the  $SEL_{cum}$  falls to the PTS and TTS thresholds at approximately 200 m and 2050 m from FLNG N respectively. This leads to a sub-PTS region between the two FLNGs of 12.5 km and to a sub-TTS region of 8.8 km.

Similarly, the variation of  $SEL_{cum}$  for a range of exposure durations are given in Figure AVI.17 for HF cetaceans, in Figure AVI.18 for VHF cetaceans and in Figure AVI.19 for SI sirenia.

For each marine mammal FHG, distances at which the  $SEL_{cum}$  falls to the PTS and TTS thresholds and the width of the sub-PTS and sub-TTS regions or “gap” between the two facilities, are given in Table AVI.18 through to Table AVI.21 for each marine mammal FHG.

The tabulated results indicate that, in general, the region between the two FLNG at which the  $SEL_{cum}$  meets neither the PTS nor TTS thresholds, decreases as the exposure duration increases. More specifically, for the LF cetacean (Table AVI.18), there is no region of sea where the  $SEL_{cum}$  remains above the thresholds representing the onset of either PTS or TTS for any of the exposure durations modelled.

The impact modelling discussed in Section AVI.4 indicates that the HF cetacean FHG is relatively insensitive to FLNG noise. As a result, Table AVI.19 shows that for an exposure duration of 24 hours, the gap between the FLNGs through which the animals can pass where the  $SEL_{cum}$  remains below the PTS and TTS thresholds, is no smaller in width than 12.8 km and 12.4 km respectively.

The VHF cetacean FHG is the most sensitive of marine mammal groupings to FLNG operational noise. The modelling results, given in Table AVI.20, show that for an operational period of 15 hours, the sub-PTS gap between the two FLNG platforms remains above 12.2 km. However, the modelling results show that during the month of August, for an exposure duration of 15 hours, the sub-TTS gap has closed entirely.

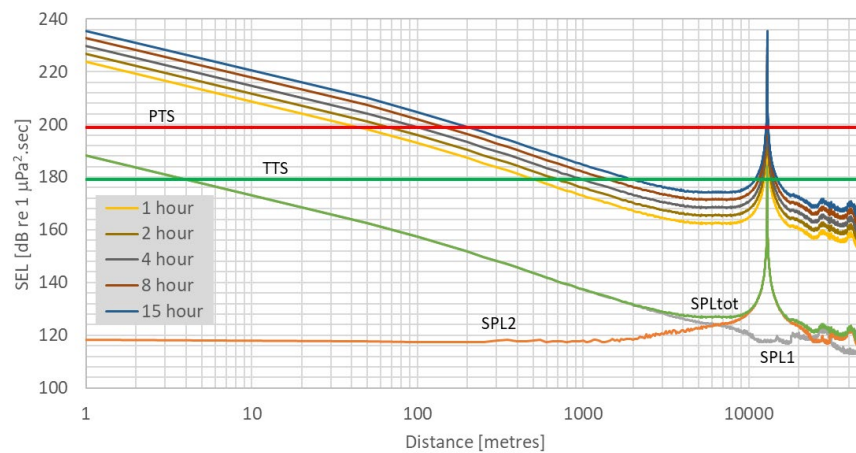
At an exposure duration of 15 hours, the  $SEL_{cum}$  breaches the TTS threshold frequently in the region between the two FLNG platforms. Over the ranges 5 km to 10 km, the  $SEL_{cum}$  fluctuates between 153 dB re  $1 \mu Pa^2 \cdot sec$  and 155 dB re  $1 \mu Pa^2 \cdot sec$ . The  $SEL_{cum}$  only falls permanently below the TTS threshold at a distance of 16.6 km from FLNG N (and hence 3.7 km from FLNG S).

The SI sirenia FHG is relatively insensitive to FLNG operational noise. Table AVI.21 shows that for an exposure duration of 24 hours, the gap between the two FLNG platforms through which the

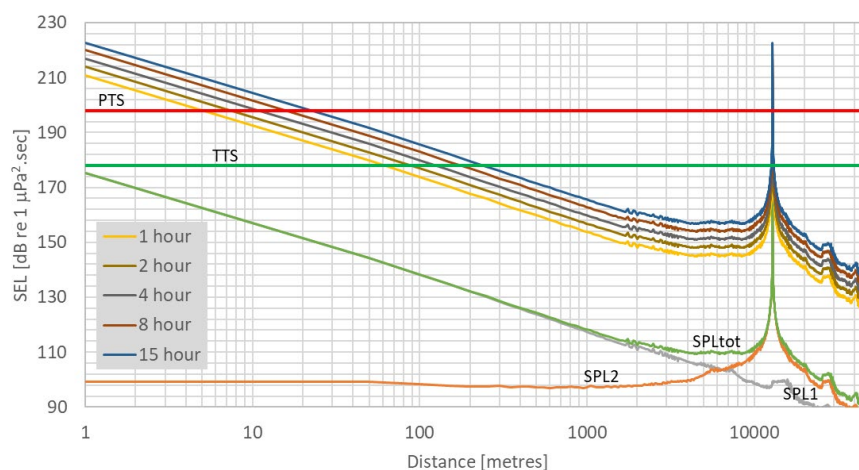
animals can pass where the SEL<sub>cum</sub> remains below the PTS and TTS thresholds, is no smaller in width than 12.8 km and 12.5 km respectively.

Cumulative SPLs may also give rise to behavioural impacts which are assessed using the Level B impact criterion. For continuous-type noise, the Level B threshold is 120 dB re 1  $\mu$ Pa rms and this is applied to all marine mammal groupings using unweighted SPLs. Taking into account the conversion factor given in Section AVI.3, the cumulative SPL arising from both FLNGs in operation simultaneously, is shown in Figure AVI.20.

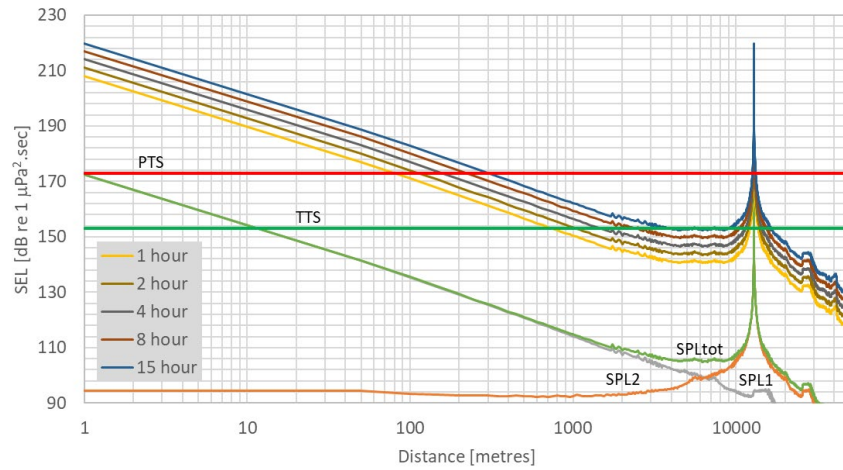
It will be seen that the minimum cumulative SPL in the region between the two facilities remains above the Level B threshold by 6-7 dB. The cumulative SPL eventually falls below the threshold 35.8 km in March while the corresponding distance for the month of August is 36 km.



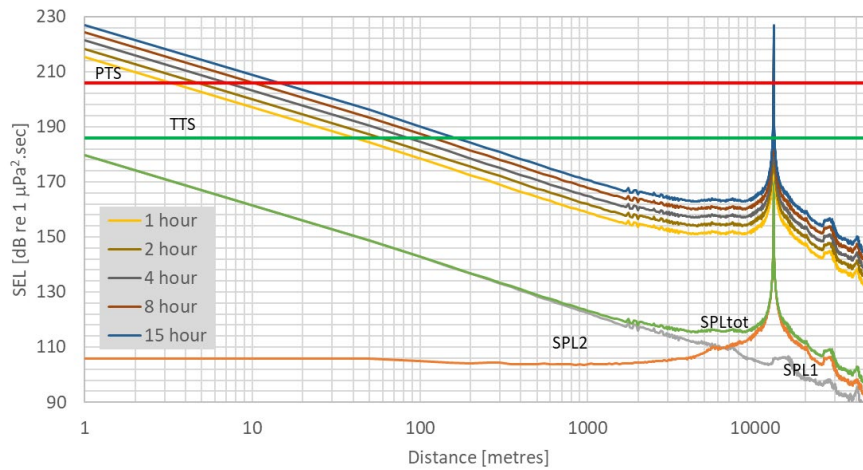
**Figure AVI.16: Cumulative SEL as a function of distance modelled for LF cetaceans exposed to noise generated during simultaneous operations from the Coral North and Coral South FLNGs**



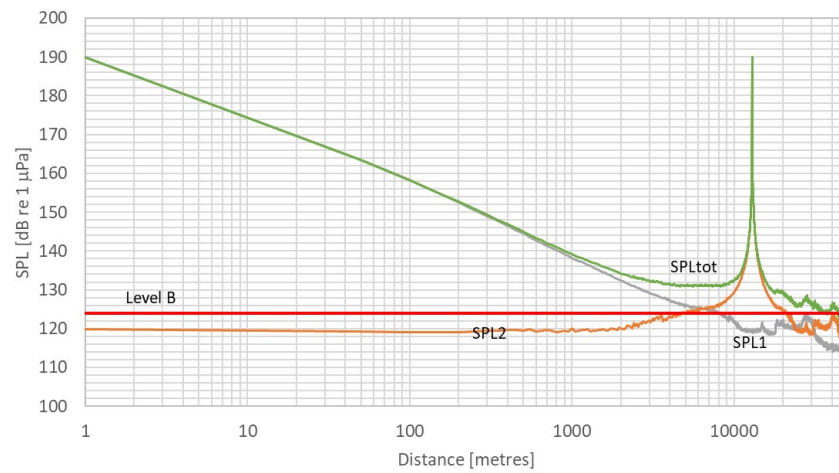
**Figure AVI.17: Cumulative SEL as a function of distance modelled for HF cetaceans exposed to noise generated during simultaneous operations from the Coral North and Coral South FLNGs**



**Figure AVI.18: Cumulative SEL as a function of distance modelled for VHF cetaceans exposed to noise generated during simultaneous operations from the Coral North and Coral South FLNGs**



**Figure AVI.19: Cumulative SEL as a function of distance modelled for SI sirenia exposed to noise generated during simultaneous operations from the Coral North and Coral South FLNGs**



**Figure AVI.20: Cumulative SPL as a function of distance modelled for all marine mammal groupings exposed to noise generated during simultaneous operations from the Coral North and Coral South FLNGs**

**Table AVI.18: Summary of impact distances in metres and width of sub-threshold “sea corridor” or gap between FLNG N and FLNG S for LF cetaceans**

Exposure duration	Impact	Threshold	March		August	
			Impact distance	Gap	Impact distance	Gap
1 hour	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	550	11800	600	11700
2 hours	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	100	12700	100	12700
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	750	11400	850	11200
4 hours	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	150	12600	150	12600
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	1050	10800	1200	10500
8 hours	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	150	12600	150	12600
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	1450	10000	1850	9200
15 hours	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	200	12500	250	12400
	TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	2050	8800	2750	7400

**Table AVI.19: Summary of impact distances in metres and width of sub-threshold “sea corridor” or gap between FLNG N and FLNG S for HF cetaceans**

Exposure duration	Impact	Threshold	March		August	
			Impact distance	Gap	Impact distance	Gap
1 hour	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	100	12700	100	12700
2 hours	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	100	12700	100	12700
4 hours	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	150	12600	150	12600
8 hours	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	200	12500	200	12500
15 hours	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	250	12400	250	12400

**Table AVI.20: Summary of impact distances in metres and width of sub-threshold “sea corridor” or gap between FLNG N and FLNG S for VHF cetaceans**

Exposure duration	Impact	Threshold	March		August	
			Impact distance	Gap	Impact distance	Gap
1 hour	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	100	12700	100	12700
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	750	11400	800	11300
2 hours	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	150	12600	150	12600
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	1100	10700	1150	10600
4 hours	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	200	12500	200	12500
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	1500	9900	2600	7700
8 hours	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	250	12400	250	12400
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	2400	8100	5100	2700
15 hours	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	300	12300	350	12200
	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	3500	5900	18000	0

**Table AVI.21: Summary of impact distances in metres and width of sub-threshold “sea corridor” or gap between FLNG N and FLNG S for SI sirenina**

Exposure duration	Impact	Threshold	March		August	
			Impact distance	Gap	Impact distance	Gap
1 hour	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
2 hours	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	100	12700	100	12700
4 hours	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	100	12700	100	12700
8 hours	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	150	12600	150	12600
15 hours	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	50	12800	50	12800
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	200	12500	200	12500

## Annex VI.A – Anchor Handling Tug Supply Vessel Noise

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**Table AVI.A.1: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to anchor handing tug supply vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
All MM	Level B	120 dB re 1 $\mu$ Pa rms	343	357	351	344	392	355

**Table AVI.A.2: Summary of impact ranges in metres at which M-weighted SEL has fallen to threshold level for marine mammals exposed to anchor handing tug supply vessel noise during the months of March and August**

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
0.5 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
1 hour	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	43	4	<10	43	4
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
2 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
4 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	86	53	<10	86	53
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
8 ours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	86	53	<10	86	53
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	129	103	<10	129	103
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
12 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	102	99	<10	102	99
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	153	149	<10	153	149
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
24 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	153	149	<10	153	149
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	215	202	<10	215	202
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10

**Table AVI.A.3: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish species exposed to anchor handing tug supply vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
Fish 3	Recoverable Injury	170 dB re 1 $\mu\text{Pa}$ rms for 48 hr exposure	<10	<10	<10	<10	<10	<10
Fish 4	TTS	158 dB re 1 $\mu\text{Pa}$ rms for 12 hr exposure	<10	<10	<10	<10	<10	<10
All Fish	Low Level Beh	150 dB re 1 $\mu\text{Pa}$ rms	<10	<10	<10	<10	<10	<10
Sea turtle	Aver. Beh	175 dB re 1 $\mu\text{Pa}$ rms	<10	<10	<10	<10	<10	<10

## Annex VI.B – Drilling Vessel Noise

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**Table AVI.B.1: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to drilling vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
All MM	Level B	120 dB re 1 $\mu$ Pa rms	245	258	252	245	258	252

**Table AVI.B.2: Summary of impact ranges in metres at which M-weighted SEL has fallen to threshold level for marine mammals exposed to drilling vessel noise during the months of March and August**

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
0.5 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
1 hour	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
2 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
4 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
8 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	51	45	<10	51	45
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
12 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	51	50	<10	51	50
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
24 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	100	74	<10	100	61
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10

**Table AVI.B.3: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish species exposed to drilling vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
Fish 3	Recoverable Injury	170 dB re 1 $\mu\text{Pa}$ rms for 48 hr exposure	<10	<10	<10	<10	<10	<10
Fish 4	TTS	158 dB re 1 $\mu\text{Pa}$ rms for 12 hr exposure	<10	<10	<10	<10	<10	<10
All Fish	Low Level Beh	150 dB re 1 $\mu\text{Pa}$ rms	<10	<10	<10	<10	<10	<10
Sea turtle	Aver. Beh	175 dB re 1 $\mu\text{Pa}$ rms	<10	<10	<10	<10	<10	<10

## Annex VI.C – Installation Vessel Noise

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**Table AVI.C.1: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to installation vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
All MM	Level B	120 dB re 1 $\mu$ Pa rms	2000	2346	2149	2000	2346	2151

**Table AVI.C.2: Summary of impact ranges in metres at which M-weighted SEL has fallen to threshold level for marine mammals exposed to installation vessel noise during the months of March and August**

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
0.5 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
1 hour	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
2 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	102	99	43	102	99
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	102	99	43	102	99
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
4 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	153	149	43	153	149
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	153	149	43	153	149
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
8 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	215	202	43	215	202
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	215	202	43	215	202
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
12 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	258	252	43	258	252
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	258	252	43	258	252
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
24 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	387	354	43	392	358
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	357	351	43	430	358
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10

**Table AVI.C.3: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish species exposed to installation vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
Fish 3	Recoverable Injury	170 dB re 1 $\mu$ Pa rms for 48 hr exposure	<10	<10	<10	<10	<10	<10
Fish 4	TTS	158 dB re 1 $\mu$ Pa rms for 12 hr exposure	<10	<10	<10	<10	<10	<10
All Fish	Low Level Beh	150 dB re 1 $\mu$ Pa rms	43	51	50	43	51	50
Sea turtle	Aver. Beh	175 dB re 1 $\mu$ Pa rms	<10	<10	<10	<10	<10	<10

## Annex VI.D – Multi-purpose Vessel Noise

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**Table AVI.D.1: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to multi-purpose vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
All MM	Level B	120 dB re 1 $\mu$ Pa rms	2907	3468	3188	2958	3440	3188

**Table AVI.D.2: Summary of impact ranges in metres at which M-weighted SEL has fallen to threshold level for marine mammals exposed to multi-purpose vessel noise during the months of March and August**

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
0.5 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	
1 hour	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	102	99	43	102	99
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	102	99	43	102	99
SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	
2 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	150	115	43	153	120
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	153	149	43	153	149
SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	
4 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	215	202	43	215	202
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	215	202	43	215	202
SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10	

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
8 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	301	280	43	301	288
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	294	256	43	294	256
SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
12 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	357	351	43	357	351
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	357	351	43	350	338
SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
24 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	51	33	<10	51	45
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	516	503	43	516	503
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	51	50	<10	51	50
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	490	458	43	561	479
SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	

**Table AVI.D.3: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish species exposed to multi-purpose vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
Fish 3	Recoverable Injury	170 dB re 1 $\mu\text{Pa}$ rms for 48 hr exposure	<10	<10	<10	<10	<10	<10
Fish 4	TTS	158 dB re 1 $\mu\text{Pa}$ rms for 12 hr exposure	<10	<10	<10	<10	<10	<10
All Fish	Low Level Beh	150 dB re 1 $\mu\text{Pa}$ rms	43	51	50	43	51	50
Sea turtle	Aver. Beh	175 dB re 1 $\mu\text{Pa}$ rms	<10	<10	<10	<10	<10	<10

## Annex VI.E – Platform Supply Vessel Noise

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**Table AVI.E.1: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to platform supply vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
All MM	Level B	120 dB re 1 $\mu$ Pa rms	1200	1326	1266	1200	1300	1266

**Table AVI E.2: Summary of impact ranges in metres at which M-weighted SEL has fallen to threshold level for marine mammals exposed to platform supply vessel noise during the months of March and August**

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
0.5 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
1 hour	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	45	<10	51	45
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
2 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
4 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	102	99	<10	102	99
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
	VHF	TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	SI	TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	102	99	<10	102	99
		PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
8 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	150	115	<10	153	120
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	153	149	<10	153	149
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
12 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	172	152	<10	172	152
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	172	152	<10	172	152
SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
24 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	258	252	<10	258	252
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	258	252	<10	258	252
SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	
	TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10	

**Table AVI.E.3: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish species exposed to platform supply vessel noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
Fish 3	Recoverable Injury	170 dB re 1 $\mu$ Pa rms for 48 hr exposure	<10	<10	<10	<10	<10	<10
Fish 4	TTS	158 dB re 1 $\mu$ Pa rms for 12 hr exposure	<10	<10	<10	<10	<10	<10
All Fish	Low Level Beh	150 dB re 1 $\mu$ Pa rms	<10	<10	<10	<10	<10	<10
Sea turtle	Aver. Beh	175 dB re 1 $\mu$ Pa rms	<10	<10	<10	<10	<10	<10

## Annex VI.F – FLNG Operational Noise

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**Table AVI.F.1: Summary of impact ranges in metres at which SPL has fallen to threshold level for marine mammals exposed to FLNG operational noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
All MM	Level B	120 dB re 1 $\mu$ Pa rms	8200	33100	19981	6783	27050	11271

**Table AVI.F.2: Summary of impact ranges in metres at which M-weighted SEL has fallen to threshold level for marine mammals exposed to FLNG operational noise during the months of March and August**

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
0.5 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	343	357	351	343	357	351
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	43	4	<10	43	4
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	473	510	499	473	561	512
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
1 hour	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	43	4	<10	43	4
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	343	510	491	343	510	499
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	51	50	43	51	50
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	473	700	689	473	784	730
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
2 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	343	714	680	343	750	718
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	86	53	<10	86	53
	VHF	PTS	173 dB re 1 $\mu$ Pa <sup>2</sup> .s	43	102	99	43	102	99
		TTS	153 dB re 1 $\mu$ Pa <sup>2</sup> .s	473	969	953	473	1950	1180
	SI	PTS	206 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	51	50	<10	51	50
4 hours	LF	PTS	199 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	100	74	<10	100	61
		TTS	179 dB re 1 $\mu$ Pa <sup>2</sup> .s	343	1000	969	343	1050	1031
	HF	PTS	198 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu$ Pa <sup>2</sup> .s	<10	102	99	<10	102	99

Operational period	FHG	Impact	Threshold	March			August		
				Min	Max	Mean	Min	Max	Mean
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	153	149	43	153	149
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	473	1323	1295	473	2989	2690
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	51	50	<10	51	50
8 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	129	103	<10	129	103
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	343	1428	1398	343	1500	1472
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	172	152	<10	172	152
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	215	202	43	215	202
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	473	2250	2050	473	4730	4354
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	<10	<10	<10	<10	<10
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	<10	102	99	<10	102	99
15 hours	LF	PTS	199 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	0	200	169	0	200	169
		TTS	179 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	343	2021	1937	343	2050	2021
	HF	PTS	198 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	0	0	0	0	0	0
		TTS	178 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	0	215	202	0	215	202
	VHF	PTS	173 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	43	258	252	43	258	252
		TTS	153 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	473	2924	2882	473	7956	7705
	SI	PTS	206 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	0	0	0	0	0	0
		TTS	186 dB re 1 $\mu\text{Pa}^2\cdot\text{s}$	0	153	149	0	153	149

**Table AVI.F.3: Summary of impact ranges in metres at which SPL has fallen to threshold level for fish species exposed to FLNG operational noise during the months of March and August**

FHG	Impact	Threshold	March			August		
			Min	Max	Mean	Min	Max	Mean
Fish 3	Recoverable Injury	170 dB re 1 $\mu\text{Pa}$ rms for 48 hr exposure	<10	<10	<10	<10	<10	<10
Fish 4	TTS	158 dB re 1 $\mu\text{Pa}$ rms for 12 hr exposure	43	51	50	43	51	50
All Fish	Low Level Beh	150 dB re 1 $\mu\text{Pa}$ rms	147	172	152	147	172	152
Sea turtle	Aver. Beh	175 dB re 1 $\mu\text{Pa}$ rms	<10	<10	<10	<10	<10	<10

## Annex VII – Marine Discharges Modelling

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## AVII.1. Site Conditions

### AVII.1.1. Bathymetric and Topographic Data

The following bathymetric data were considered in for the marine discharges modelling:

- Project specific bathymetry data (surveyed at 5 m depth contour intervals);
- General Bathymetric Chart of the Oceans (GEBCO) that provides digital bathymetric and topographic data (GEBCO Compilation Group, 2023) covering the study area.

Digital bathymetric data from GEBCO was used to supplement the project specific bathymetry data. All bathymetric data presented in this report is set relative to CD. Figure AVII.1 shows the coverage of the bathymetric data in the vicinity of the project site.

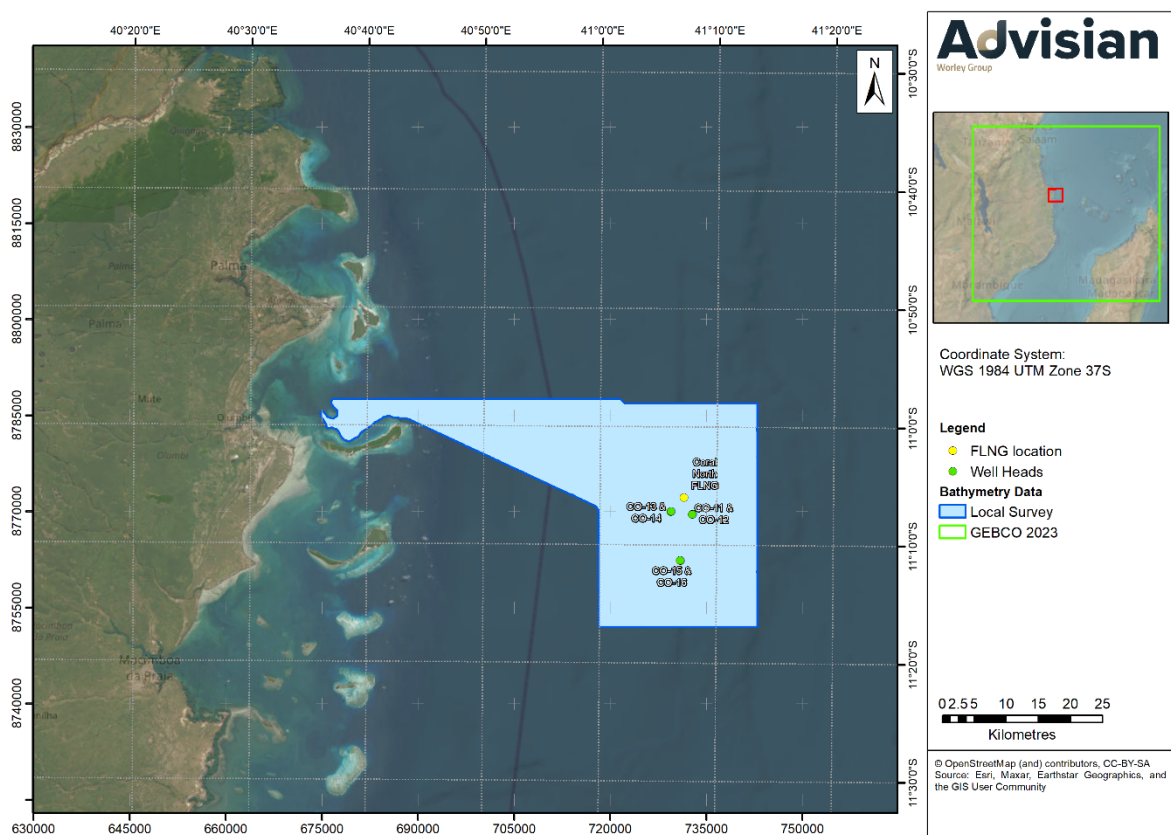


Figure AVII.1: Location and extents of bathymetric and topographic data sources

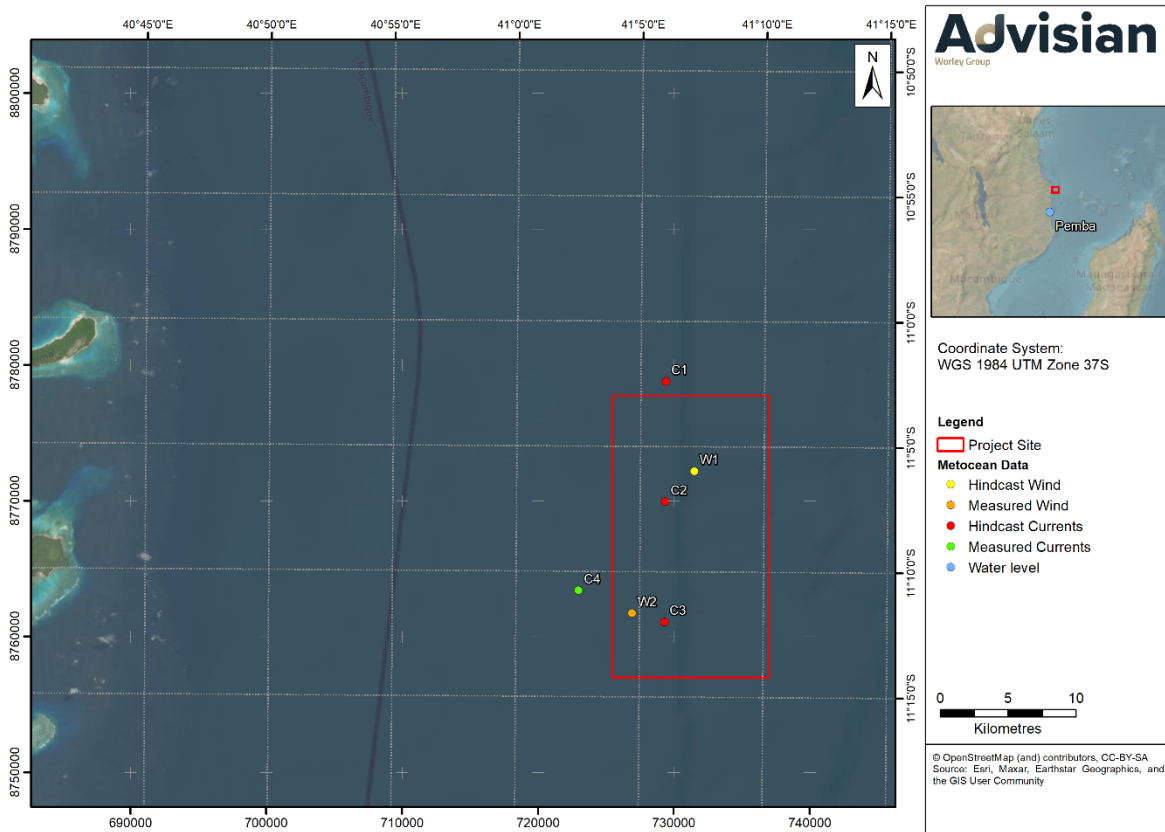
### AVII.1.2. Metocean Data

The relevant available metocean data locations, including wind, water level and current data are indicated in Figure AVII.2, whilst the details of these data sources are summarised in Table AVII.1.

**Table AVII.1: Metrocean data sources**

Data Type	Location ID	Easting (m UTM 37S)	Northing (m UTM 37S)	Data Period	Source
Hindcast Wind Data	W1	731 508	8 772 185	01/01/2011 – 01/01/2023	NOAA CFSv2
Measured Wind Data	W2	726 921	8 761 734	15/03/2013 – 17/01/2014	(Fugro, 2013)
Tidal Data	-(a)	-	-	-	(eni, 2014)
Measured Water Levels	Pemba	661 253	8 565 897	19/04/2007 – 28/06/2013	UHSLC
Hindcast Currents	C1	729 429	8 778 792	01/01/2013 – 31/12/2013	HYCOM
	C2	729 367	8 769 941		
	C3	729 304	8 761 089		
Measured Currents	C4	722 988	8 763 412	09/03/2013 – 02/02/2014	(Fugro, 2013)

Note a) Tidal plane data in project vicinity, without exact coordinates provided.



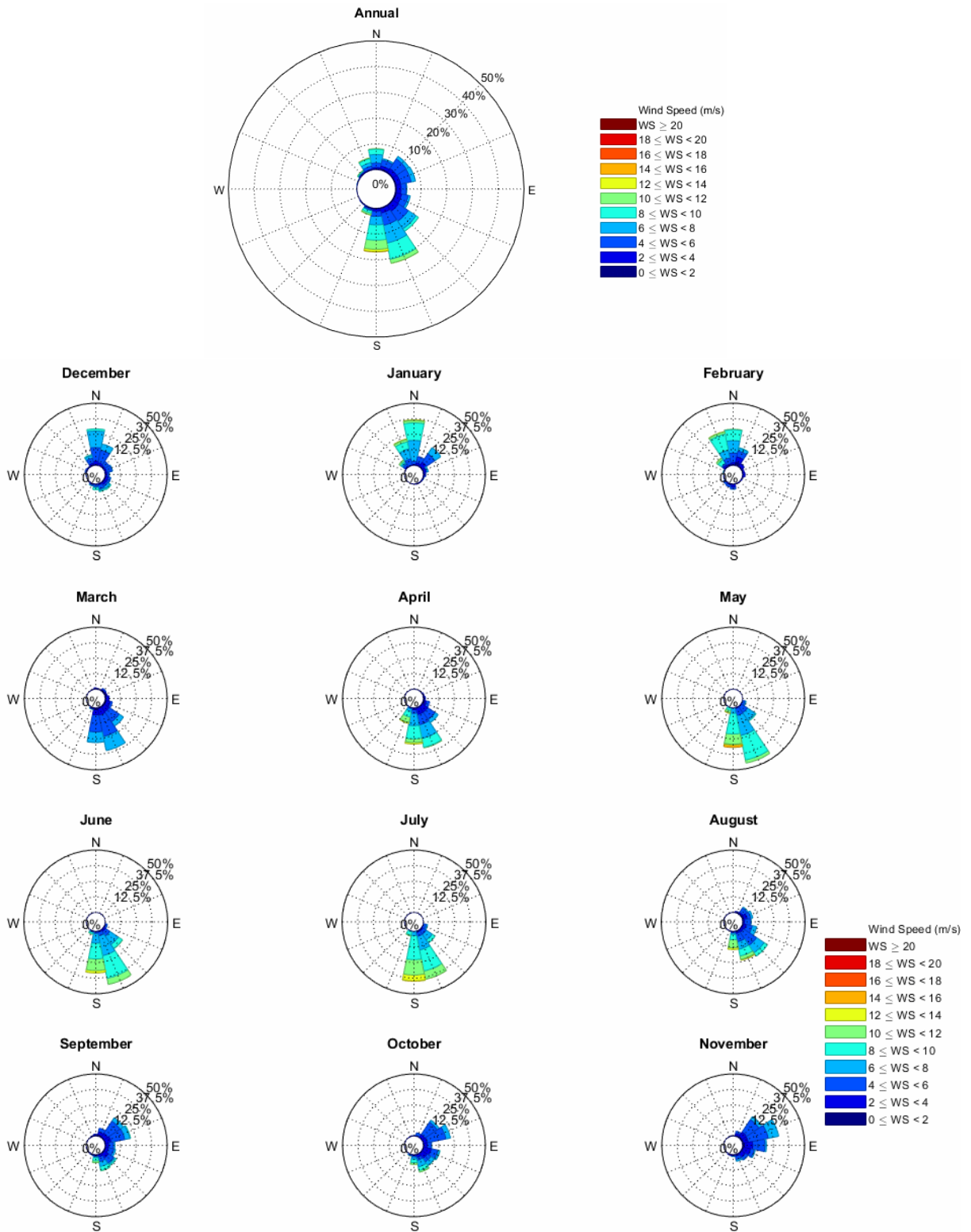
**Figure AVII.2: Metrocean data points (refer to Table AVII.1)**

## AVII.1.2.1. Offshore Wind Climate

### AVII.1.2.1.1. Hindcast CFSv2 Dataset

The long-term hindcast wind data at point W1 was extracted from the Climate Forecast System Version 2 (CFSv2) hindcast database, which is developed and administrated by the National Ocean and Atmospheric Administration (NOAA). The data consists of 13-year time series (2011-2023) of hourly wind components (i.e., wind speeds and wind directions).

The wind climate extracted at W1 point is represented in the form of wind roses with annual and monthly average breakdown (see Figure AVII.3). Table AVII.2 shows the joint annual frequency of occurrence of wind speed and wind direction; whilst the monthly frequency of occurrence of wind speeds is provided in Table AVII.3. The wind data extracted from W1 is referenced to a standard height of 10 m above ground. The shading in Table AVII.2 and Table AVII.3 represents low (white) to high (green) values to assist in interpretation of principal occurrence bins.



**Figure AVII.3: Wind roses based on the 1-hourly wind time-series extracted at W1 (annual and monthly breakdown)**

**Table AVII.2: Annual frequency of occurrence for 1-hourly averaged wind components (wind speed vs wind direction) at W1**

Annual		Wind Speed, WS (m/s)													All WS	Cum WS
		0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20	20 - 22	22 - 24	> 24		
Wind Direction, WD (°N)	N	0.19%	0.58%	1.77%	3.33%	2.02%	0.19%	0.05%	0%	0%	0%	0%	0%	0%	8.14%	8.14%
	NNE	0.39%	1.16%	2.34%	0.63%	0.02%	0%	0%	0%	0%	0%	0%	0%	0%	4.54%	12.68%
	NE	0.26%	1.76%	4.46%	1.28%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7.76%	20.44%
	ENE	0.34%	1.79%	4.20%	1.70%	0.06%	0%	0%	0%	0%	0%	0%	0%	0%	8.09%	28.54%
	E	0.35%	1.77%	2.03%	0.31%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4.46%	33.00%
	ESE	0.39%	2.16%	2.61%	0.86%	0.05%	0%	0%	0%	0%	0%	0%	0%	0%	6.06%	39.06%
	SE	0.27%	2.59%	4.65%	3.61%	1.16%	0.02%	0%	0%	0%	0%	0%	0%	0%	12.30%	51.36%
	SSE	0.24%	1.79%	4.81%	7.04%	6.39%	1.60%	0.08%	0%	0%	0%	0%	0%	0%	21.95%	73.31%
	S	0.27%	0.87%	1.99%	3.29%	5.97%	3.53%	0.87%	0.17%	0%	0%	0%	0%	0%	16.95%	90.26%
	SSW	0.16%	0.23%	0.43%	0.37%	0.96%	0.64%	0.10%	0.02%	0%	0%	0%	0%	0%	2.91%	93.17%
	SW	0.06%	0.11%	0.13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.30%	93.47%
	WSW	0.03%	0.02%	0.01%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.07%	93.54%
	W	0%	0%	0.05%	0.01%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.06%	93.60%
	WNW	0.07%	0.01%	0.08%	0.06%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.22%	93.81%
	NW	0.03%	0.26%	0.26%	0.15%	0.38%	0.25%	0%	0.01%	0%	0%	0%	0%	0%	1.35%	95.16%
	NNW	0.14%	0.27%	1.12%	1.37%	1.58%	0.30%	0.07%	0%	0%	0%	0%	0%	0%	4.84%	100.00%
All WD	3.21%	15.39%	30.93%	23.99%	18.58%	6.53%	1.16%	0.21%	0%	0%	0%	0%	0%			
Cum WD	3.21%	18.59%	49.53%	73.52%	92.10%	98.63%	99.79%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%			

**Table AVII.3: Monthly frequency of occurrence for 1-hourly averaged wind speeds at W1**

		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed, WS (m/s)	≤ 2	0.10%	0.41%	0.63%	0.29%	0%	0.03%	0.05%	0.40%	0.45%	0.10%	0.47%	0.29%
	2 - 4	1.08%	1.54%	2.00%	1.27%	0.11%	0.29%	0.15%	1.05%	1.97%	2.03%	2.41%	1.48%
	4 - 6	2.10%	1.84%	3.73%	1.80%	1.15%	0.84%	0.75%	3.12%	3.68%	3.97%	4.03%	3.92%
	6 - 8	2.88%	1.55%	2.13%	2.18%	2.47%	2.67%	1.84%	1.81%	1.32%	1.58%	1.31%	2.25%
	8 - 10	1.81%	1.99%	0%	1.86%	3.42%	2.99%	3.62%	1.13%	0.65%	0.55%	0%	0.56%
	10 - 12	0.43%	0.31%	0%	0.65%	1.06%	1.23%	1.67%	0.78%	0.15%	0.25%	0%	0%
	12 - 14	0.09%	0.02%	0%	0.17%	0.10%	0.16%	0.40%	0.21%	0%	0.01%	0%	0%
	14 - 16	0%	0.01%	0%	0%	0.17%	0%	0.02%	0%	0%	0%	0%	0%
	16 - 18	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	18 - 20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	20 - 22	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	22 - 24	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	> 24	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

**AVII.1.2.1.2. Measured Fugro Dataset**

Wind measurements were obtained at W2 location (see Figure AVII.2) in the vicinity of the project site during a measurement campaign conducted by Fugro (2013). The measurement period was taken from 15 March 2013 to 17 January 2014 and the data was reduced to standard conditions of 1 hour mean values at 10 m elevation. Accounting for gaps, the effective dataset length is 8.4 months (approx. 77%).

The wind climate at the measurement location is represented in the form of wind roses indicating wind speed and direction. Figure AVII.4 represent wind roses. The joint annual frequency of occurrence tables of the wind components (i.e. wind speed and direction) is provided in Table AVII.4; whilst the monthly frequency of occurrence of wind speeds is provided in Table AVII.5.

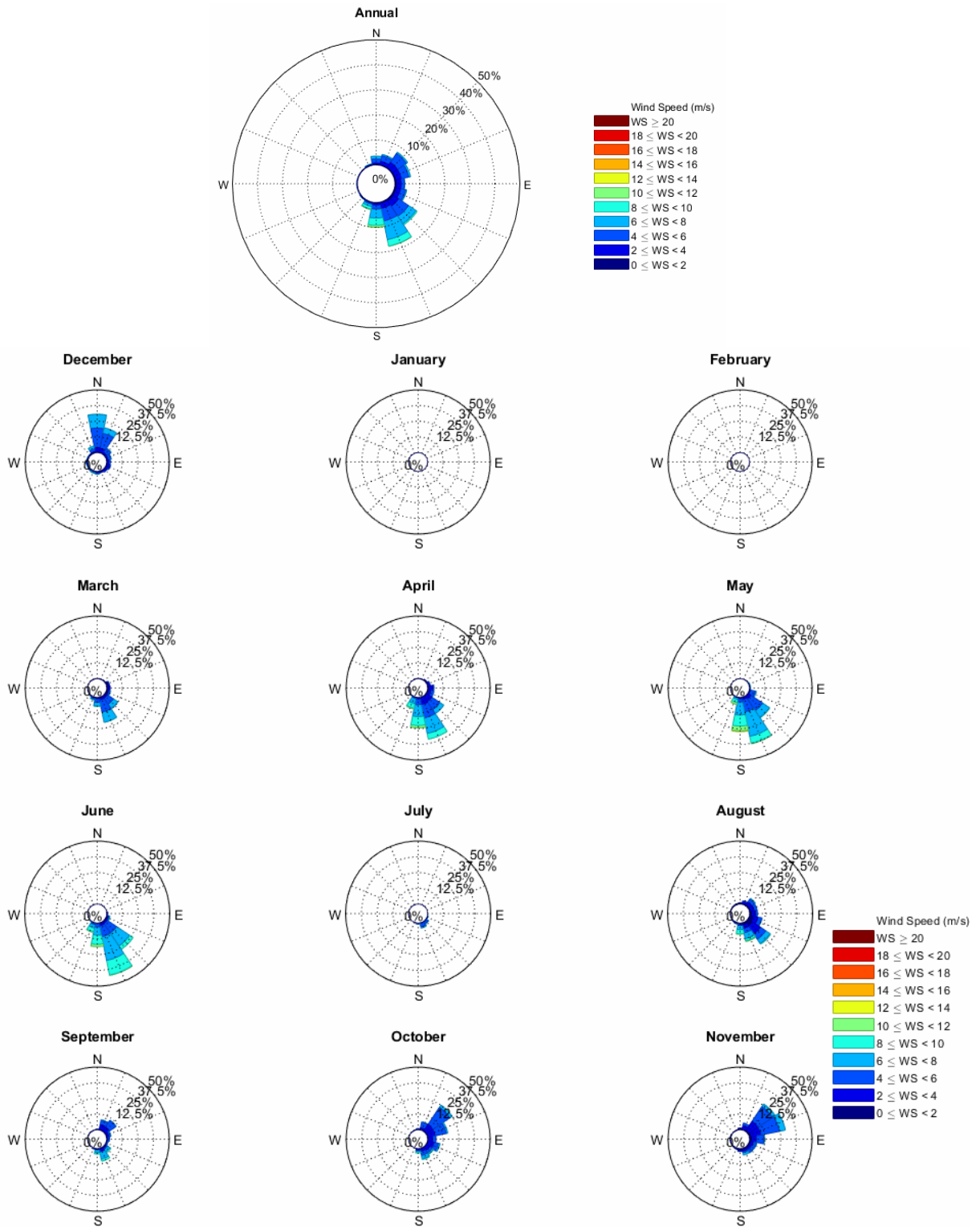


Figure AVII.4: Wind roses based on the wind time-series measured at W2 (annual and monthly breakdown)

**Table AVII.4: Annual frequency of occurrence for wind components (wind speed vs wind direction) at W2**

Annual		Wind Speed, WS (m/s)													All WS	Cum WS
		0 - 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	18 - 20	20 - 22	22 - 24	> 24		
Wind Direction, WD (°N)	N	0.24%	0.57%	1.61%	1.12%	0.02%	0%	0%	0%	0%	0%	0%	0%	0%	3.56%	3.56%
	NNE	0.21%	1.42%	2.24%	0.57%	0.00%	0%	0%	0%	0%	0%	0%	0%	0%	4.46%	8.02%
	NE	0.28%	2.49%	4.27%	0.66%	0.01%	0%	0%	0%	0%	0%	0%	0%	0%	7.70%	15.72%
	ENE	0.43%	2.30%	3.06%	0.74%	0.01%	0%	0%	0%	0%	0%	0%	0%	0%	6.54%	22.26%
	E	0.60%	1.88%	1.39%	0.11%	0.02%	0.00%	0%	0%	0%	0%	0%	0%	0%	4.00%	26.25%
	ESE	0.60%	1.87%	2.04%	0.44%	0.07%	0%	0%	0%	0%	0%	0%	0%	0%	5.02%	31.27%
	SE	0.70%	2.61%	4.77%	3.62%	0.56%	0.00%	0%	0%	0%	0%	0%	0%	0%	12.27%	43.54%
	SSE	0.42%	2.13%	5.12%	7.63%	2.58%	0.14%	0%	0%	0%	0%	0%	0%	0%	18.02%	61.55%
	S	0.27%	0.69%	1.64%	3.62%	2.88%	0.80%	0.06%	0%	0%	0%	0%	0%	0%	9.96%	71.52%
	SSW	0.16%	0.16%	0.48%	1.01%	0.99%	0.28%	0.00%	0%	0%	0%	0%	0%	0%	3.09%	74.61%
	SW	0.11%	0.17%	0.14%	0.07%	0.02%	0.01%	0%	0%	0%	0%	0%	0%	0%	0.51%	75.12%
	WSW	0.08%	0.11%	0.06%	0.02%	0.00%	0%	0%	0%	0%	0%	0%	0%	0%	0.27%	75.39%
	W	0.08%	0.12%	0.06%	0.02%	0.00%	0%	0%	0%	0%	0%	0%	0%	0%	0.29%	75.67%
	WNW	0.10%	0.07%	0.03%	0.01%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.21%	75.89%
NW	0.12%	0.05%	0.03%	0.01%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.21%	76.10%	
NNW	0.12%	0.11%	0.22%	0.23%	0.01%	0%	0%	0%	0%	0%	0%	0%	0%	0.69%	76.78%	
All WD	4.53%	16.76%	27.15%	19.89%	7.16%	1.23%	0.06%	0%	0%	0%	0%	0%	0%			
Cum WD	4.53%	21.28%	48.44%	68.33%	75.49%	76.72%	76.78%	76.78%	76.78%	76.78%	76.78%	76.78%	76.78%			

**Table AVII.5: Monthly frequency of occurrence for wind speeds at W2**

		Month											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Speed, WS (m/s)	≤ 2	0%	0%	0.61%	0.35%	0.08%	0.15%	0%	1.60%	0.29%	0.25%	0.99%	0.25%
	2 - 4	0%	0%	0.81%	1.95%	0.69%	0.47%	0.06%	2.90%	1.48%	3.02%	3.25%	2.14%
	4 - 6	0%	0%	2.22%	2.76%	2.90%	2.28%	0.59%	1.97%	1.51%	4.29%	4.35%	4.28%
	6 - 8	0%	0%	1.69%	2.98%	4.03%	4.11%	0.22%	1.43%	1.22%	1.06%	1.07%	2.09%
	8 - 10	0%	0%	0.10%	1.53%	1.77%	2.51%	0%	0.59%	0.36%	0.23%	0.01%	0.06%
	10 - 12	0%	0%	0.00%	0.24%	0.60%	0.28%	0%	0.09%	0%	0%	0.00%	0.01%
	12 - 14	0%	0%	0%	0.00%	0.06%	0%	0%	0%	0%	0%	0%	0%
	14 - 16	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	16 - 18	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	18 - 20	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	20 - 22	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	22 - 24	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	> 24	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

## AVII.1.2.2. Water Levels

### AVII.1.2.2.1. Astronomical Tidal Planes

The tides at the project site are predominantly semi-diurnal and the tidal planes are summarised in Table AVII.6. A tidal range of -2.12 to +2.24 m MSL is indicated between Lowest Astronomical Tide (LAT) and Highest Astronomical Tide (HAT).

**Table AVII.6: Tidal planes at the project site**

Tidal Plane	Abbrev.	m MSL	m CD (LAT)
Highest Astronomical Tide	HAT	2.24	4.36
Mean Higher Water Spring	MHWS	1.79	3.91
Mean Higher Water Neap	MHWN	0.46	2.58
Mean Sea Level	MSL	0.00	2.12
Mean Low Water Neap	MLWN	-0.52	1.60

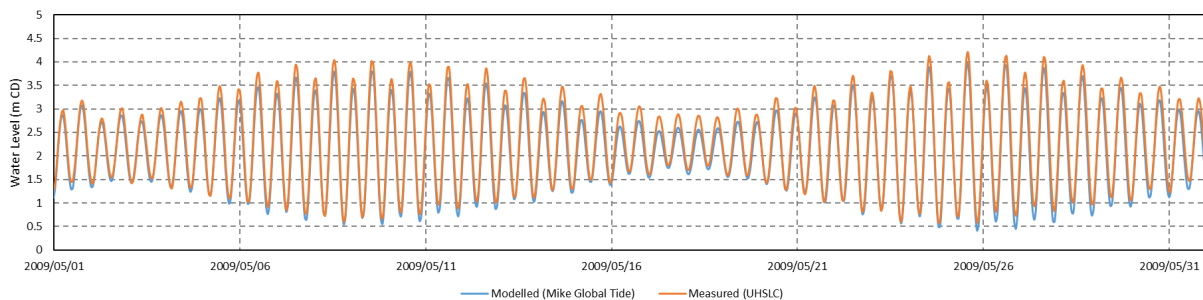
Tidal Plane	Abbrev.	m MSL	m CD (LAT)
Mean Low Water Spring	MLWS	-1.74	0.38
Lowest Astronomical Tide	LAT	-2.12	0.00

**AVII.1.2.2.2. Water Levels**

Tidal measurements taken at the Port of Pemba (Pemba point in Figure AVII.2) were obtained from the University of Hawaii Sea Level Centre (UHSLC). The available hourly average water level dataset covers the period of 19 April 2007 to 28 June 2013. The hourly water levels represent the average of fifteen-minute values taken at 7.5 minutes before and after the hour. Accounting for gaps, the effective dataset length is 3 years. The measured tidal range varies between 0.2 m CD (during neap tides) to 4.2 m CD (during spring tides).

Time-series of water levels required as boundary conditions for the hydrodynamic model were extracted from the Global Tide Model developed by DHI MIKE, which represents the major diurnal (K1, O1, P1 and Q1) and semidiurnal tidal constituents (M2, S2, N2 and K2) with a spatial resolution of 0.25° × 0.25° based on TOPEX/POSEIDON altimetry data.

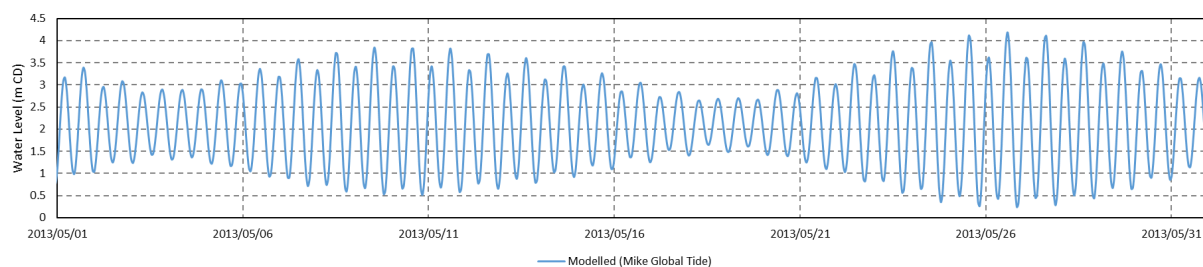
A comparison between the water levels extracted from the Global Tide Model and measured data from UHSLC at Pemba was undertaken, as depicted in Figure AVII.5, which confirms that the measured water levels are reasonably well reproduced by the model.



**Figure AVII.5: Comparison of measured and modelled water levels extracted from the Global Tide Model at the port of Pemba**

An example of the water level time-series extracted at the project site is provided.

Based on the water levels extracted from the Global Tide Model, the tides at the project site are classified as semi-diurnal as depicted in Figure AVII.6, with a maximum water level range of approximately 4 m.



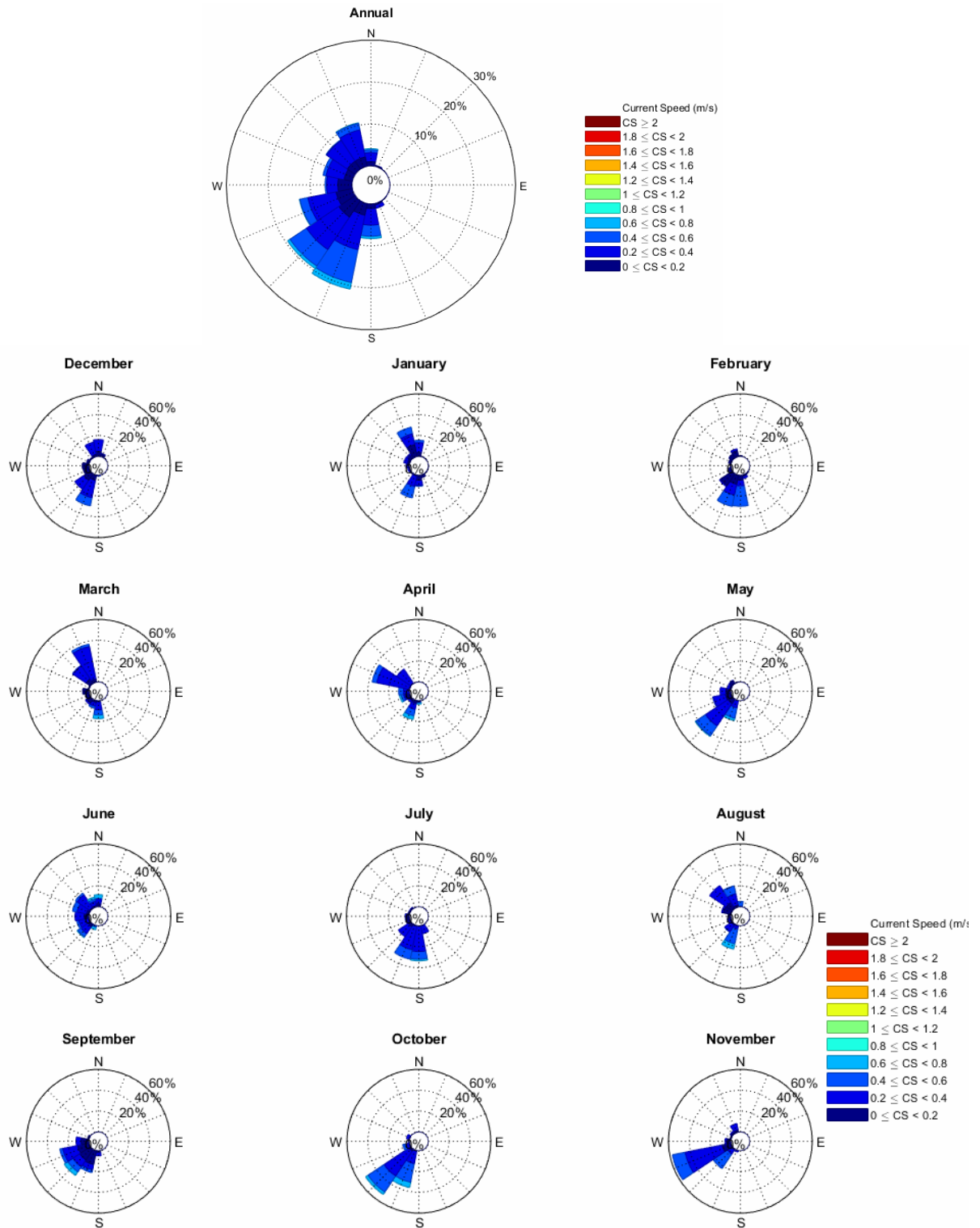
**Figure AVII.6: Example of water level variation in the vicinity of the project site as extracted from the Global Tide Model**

### **AVII.1.2.3. Currents**

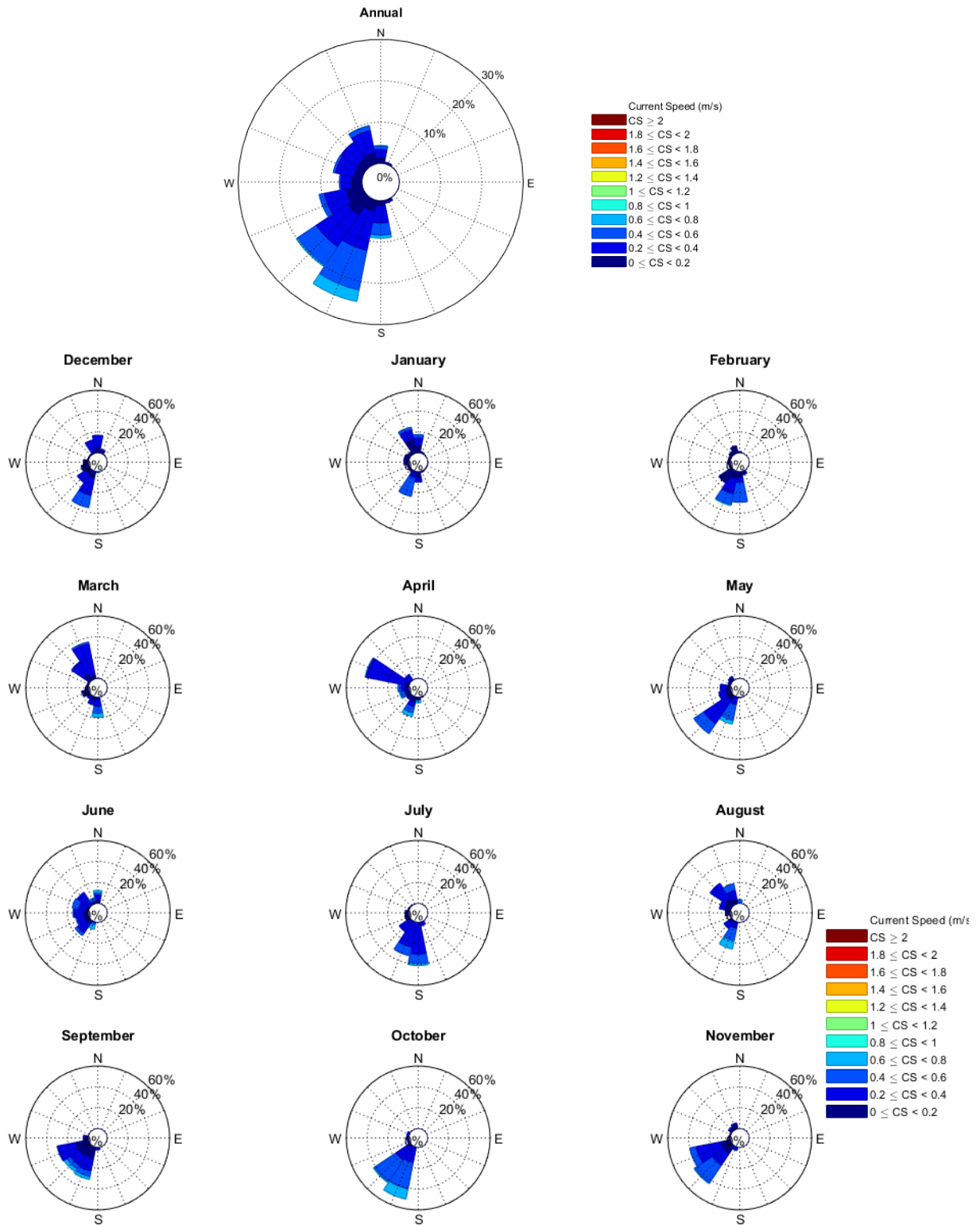
#### **AVII.1.2.3.1. Hindcast HYCOM Dataset**

Long-term hindcast current data was extracted from the Hybrid Coordinate Ocean Model (HYCOM) hindcast database, which is sponsored by the National Ocean Partnership Program (NOPP) as part of the U. S. Global Ocean Data Assimilation Experiment (GODAE). Only the period from January 2013 to December 2013 was extracted.

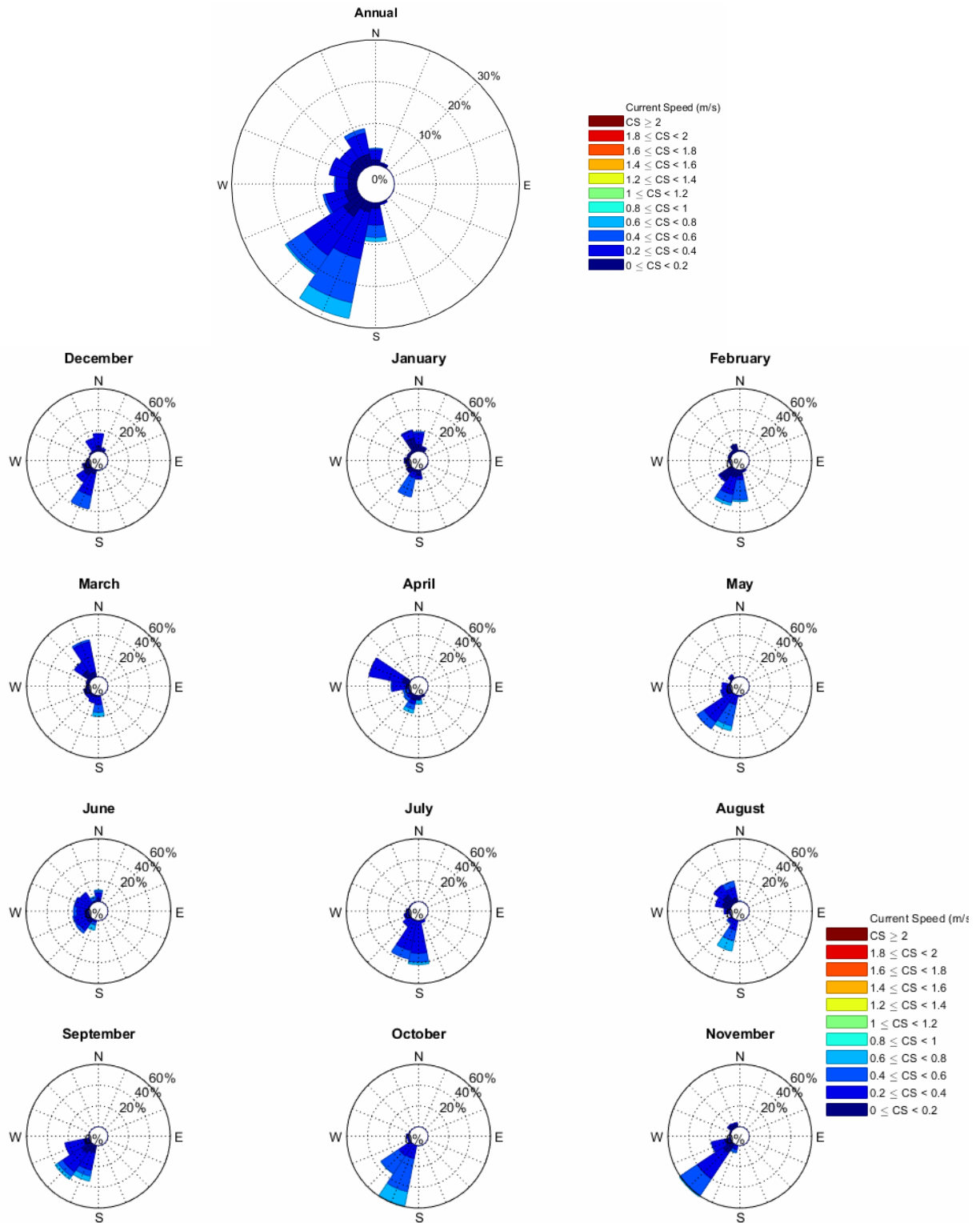
The current climate at the extracted locations (see Figure AVII.2) is represented in the form of current roses indicating current speed and direction for depth-averaged currents. Figure AVII.7, Figure AVII.8, and Figure AVII.9 represent current roses for locations C1, C2, and C3, respectively. The joint annual frequency of occurrence tables of the 3-hourly current components (i.e. current speed and direction) are provided in Table AVII.7, Table AVII.8, and Table AVII.9, for locations C1, C2, and C3, respectively.



**Figure AVII.7: Annual and monthly current roses based on the three-hourly current time-series extracted from HYCOM at location C1**



**Figure AVII.8: Annual and monthly current roses based on the three-hourly current time-series extracted from HYCOM at location C2**



**Figure AVII.9: Annual and monthly current roses based on the three-hourly current time-series extracted from HYCOM at location C3**

**Table AVII.7: Annual frequency of occurrence for 3-hourly averaged current components extracted from HYCOM at C1. Shading represents low (white) to high (green)**

Annual		Current Speed (m/s)										All CS	Cum CS
		0 - 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	> 0.9		
Current Direction, CD (°N)	N	0.34%	0.69%	1.68%	0.48%	0.31%	0.34%	0.31%	0%	0%	0%	4.15%	4.15%
	NNE	0.03%	0.21%	0.03%	0.03%	0%	0%	0%	0%	0%	0%	0.31%	4.46%
	NE	0.03%	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0.07%	4.53%
	ENE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.00%	4.53%
	E	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	4.56%
	ESE	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	4.60%
	SE	0.07%	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0.10%	4.70%
	SSE	0.17%	0.17%	0.24%	0.62%	0%	0%	0%	0%	0%	0%	1.20%	5.90%
	S	0.31%	0.82%	1.85%	2.09%	1.58%	1.06%	0.58%	0%	0%	0%	8.30%	14.20%
	SSW	0.38%	2.47%	4.63%	3.70%	5.49%	2.50%	1.51%	0.10%	0%	0%	20.78%	34.98%
	SW	1.03%	3.67%	6.21%	3.09%	3.53%	1.20%	0.72%	0%	0%	0%	19.44%	54.42%
	WSW	0.34%	3.64%	5.21%	1.65%	1.58%	0.38%	0.14%	0%	0%	0%	12.93%	67.35%
	W	0.62%	2.78%	2.19%	0.48%	0.10%	0.27%	0%	0%	0%	0%	6.45%	73.80%
	WNW	0.38%	1.65%	2.71%	1.68%	0.65%	0.10%	0%	0%	0%	0%	7.17%	80.97%
	NW	0.21%	2.06%	4.46%	1.51%	0.21%	0%	0%	0%	0%	0%	8.44%	89.40%
	NNW	0.24%	2.06%	3.74%	2.81%	1.23%	0.34%	0.17%	0%	0%	0%	10.60%	100.00%
All CD	4.22%	20.27%	32.96%	18.14%	14.68%	6.21%	3.43%	0.10%	0.00%	0.00%			
Cum CD	4.22%	24.49%	57.44%	75.58%	90.26%	96.47%	99.90%	100.00%	100.00%	100.00%			

**Table AVII.8: Annual frequency of occurrence for 3-hourly averaged current components extracted from HYCOM at C2. Shading represents low (white) to high (green)**

Annual		Current Speed (m/s)										All CS	Cum CS
		0 - 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	> 0.9		
Current Direction, CD (°N)	N	0.27%	1.10%	1.41%	0.62%	0.45%	0.34%	0.21%	0%	0%	0%	4.39%	4.39%
	NNE	0.03%	0.27%	0.10%	0.07%	0%	0%	0%	0%	0%	0%	0.48%	4.87%
	NE	0.03%	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0.07%	4.94%
	ENE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.00%	4.94%
	E	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	4.97%
	ESE	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	5.01%
	SE	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	5.04%
	SSE	0.21%	0.10%	0.14%	0.27%	0.03%	0%	0%	0%	0%	0%	0.75%	5.80%
	S	0.27%	0.93%	1.82%	2.40%	1.61%	1.30%	0.75%	0%	0%	0%	9.09%	14.88%
	SSW	0.38%	2.30%	6.07%	3.57%	6.24%	3.53%	2.61%	0.27%	0%	0%	24.97%	39.85%
	SW	0.93%	4.01%	6.34%	2.95%	3.84%	1.58%	0.41%	0.03%	0%	0%	20.10%	59.95%
	WSW	0.51%	3.50%	4.29%	1.13%	0.79%	0.41%	0.10%	0%	0%	0%	10.73%	70.68%
	W	0.72%	1.71%	2.26%	0.45%	0.27%	0.10%	0%	0%	0%	0%	5.52%	76.20%
	WNW	0.31%	1.65%	2.98%	1.68%	0.48%	0.14%	0%	0%	0%	0%	7.24%	83.44%
	NW	0.24%	2.06%	3.64%	1.17%	0.03%	0%	0%	0%	0%	0%	7.13%	90.57%
	NNW	0.34%	2.43%	3.70%	1.71%	0.89%	0.27%	0.07%	0%	0%	0%	9.43%	100.00%
All CD	4.36%	20.10%	32.75%	16.02%	14.64%	7.68%	4.15%	0.31%	0.00%	0.00%			
Cum CD	4.36%	24.45%	57.20%	73.22%	87.86%	95.54%	99.69%	100.00%	100.00%	100.00%			

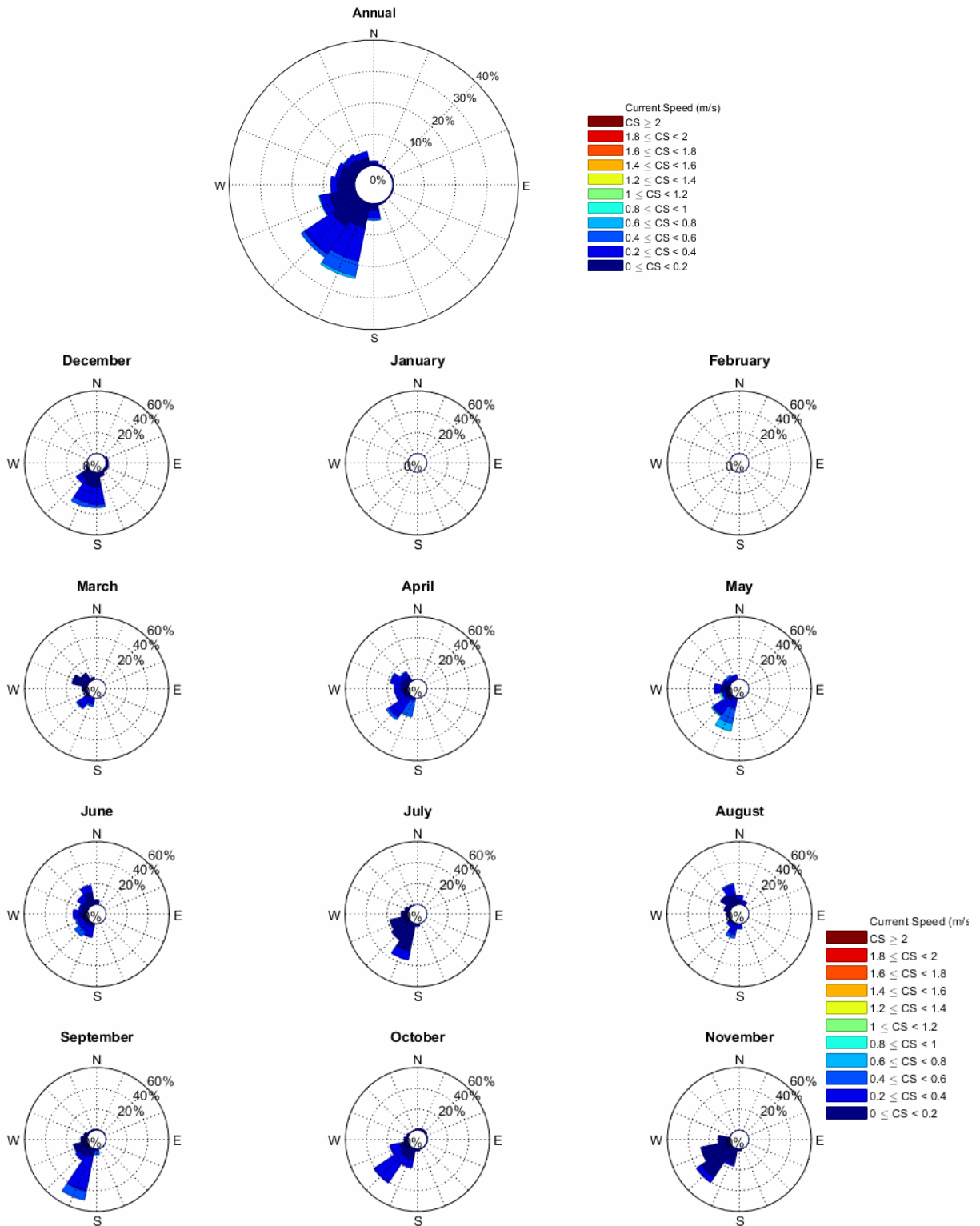
**Table AVII.9: Annual frequency of occurrence for 3-hourly averaged current components extracted from HYCOM at C3. Shading represents low (white) to high (green)**

Annual		Current Speed (m/s)										All CS	Cum CS
		0 - 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	> 0.9		
Current Direction, CD (°N)	N	0.34%	0.96%	1.37%	0.96%	0.21%	0.17%	0.07%	0%	0%	0%	4.08%	4.08%
	NNE	0.07%	0.48%	0.14%	0.10%	0%	0%	0%	0%	0%	0%	0.79%	4.87%
	NE	0%	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	4.90%
	ENE	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.00%	4.90%
	E	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.00%	4.90%
	ESE	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	4.94%
	SE	0.03%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0.03%	4.97%
	SSE	0.10%	0.17%	0.14%	0.17%	0%	0%	0%	0%	0%	0%	0.58%	5.56%
	S	0.38%	0.96%	1.71%	2.26%	1.58%	1.34%	0.89%	0.14%	0%	0%	9.26%	14.81%
	SSW	0.51%	1.78%	6.65%	4.73%	5.69%	5.04%	3.12%	0.72%	0%	0%	28.26%	43.07%
	SW	0.99%	3.81%	6.76%	4.46%	3.33%	1.75%	0.45%	0%	0%	0%	21.54%	64.61%
	WSW	0.62%	2.43%	4.05%	0.58%	0.58%	0.07%	0%	0%	0%	0%	8.33%	72.94%
	W	0.45%	1.58%	2.16%	0.82%	0.31%	0.07%	0%	0%	0%	0%	5.38%	78.33%
	WNW	0.34%	2.02%	2.74%	1.65%	0.07%	0%	0%	0%	0%	0%	6.82%	85.15%
	NW	0.34%	2.43%	2.09%	0.89%	0.07%	0%	0%	0%	0%	0%	5.83%	90.98%
	NNW	0.41%	2.40%	3.74%	1.41%	0.75%	0.24%	0.07%	0%	0%	0%	9.02%	100.00%
	All CD	4.63%	19.07%	31.55%	18.04%	12.59%	8.68%	4.60%	0.86%	0.00%	0.00%		
Cum CD	4.63%	23.70%	55.25%	73.29%	85.87%	94.55%	99.14%	100.00%	100.00%	100.00%			

**AVII.1.2.3.2. Measured Fugro Dataset**

Current measurements were obtained at C4 location (see Figure AVII.2) in the vicinity of the project site during a measurement campaign conducted by Fugro (2013). Currents were measured throughout the water column at ten different depths from surface to seabed. The measurement period for the meter was taken in intervals of 10-minute time steps from 09 March 2013 to 02 February 2014.

The current climate at the measurement location is represented in the form of current roses indicating current speed and direction for depth-averaged currents. Figure AVII.10 represent current roses, while the joint annual frequency of occurrence tables of the current components (i.e. current speed and direction) is provided in Table AVII.10.



**Figure AVII.10: Annual and monthly current roses based on the current time-series measured at location C4**

**Table AVII.10: Annual frequency of occurrence for current components measured at C4. Shading represents low (white) to high (green)**

Annual	Current Speed (m/s)										All CS	Cum CS	
	0 - 0.1	0.1 - 0.2	0.2 - 0.3	0.3 - 0.4	0.4 - 0.5	0.5 - 0.6	0.6 - 0.7	0.7 - 0.8	0.8 - 0.9	> 0.9			
Current Direction, CD (°N)	N	0.33%	0.74%	0.44%	0.13%	0.06%	0%	0%	0%	0%	0%	1.71%	1.71%
	NNE	0.27%	0.04%	0.23%	0.17%	0%	0%	0%	0%	0%	0%	0.71%	2.42%
	NE	0.28%	0.03%	0.02%	0.00%	0%	0%	0%	0%	0%	0%	0.33%	2.75%
	ENE	0.31%	0.06%	0.02%	0.00%	0%	0%	0%	0%	0%	0%	0.39%	3.14%
	E	0.27%	0.08%	0%	0%	0%	0%	0%	0%	0%	0%	0.34%	3.49%
	ESE	0.24%	0.12%	0%	0%	0%	0%	0%	0%	0%	0%	0.36%	3.85%
	SE	0.17%	0.15%	0%	0%	0%	0%	0%	0%	0%	0%	0.32%	4.17%
	SSE	0.20%	0.38%	0.03%	0%	0%	0%	0%	0%	0%	0%	0.62%	4.79%
	S	0.44%	1.87%	0.89%	1.66%	0.74%	0.13%	0.00%	0%	0%	0%	5.73%	10.51%
	SSW	0.63%	7.96%	6.56%	5.11%	2.91%	2.38%	0.86%	0.02%	0%	0%	26.43%	36.94%
	SW	1.11%	9.49%	6.72%	4.91%	1.21%	0.09%	0.03%	0.04%	0.04%	0%	23.63%	60.58%
	WSW	2.07%	7.11%	2.61%	0.56%	0.16%	0.03%	0.00%	0.06%	0.06%	0.13%	12.80%	73.37%
	W	1.61%	4.47%	2.12%	0.14%	0%	0%	0%	0%	0%	0%	8.35%	81.72%
	WNW	1.24%	4.04%	1.42%	0.18%	0.09%	0%	0%	0%	0%	0%	6.97%	88.69%
	NW	0.88%	3.03%	1.25%	0.57%	0.36%	0%	0%	0%	0%	0%	6.08%	94.77%
NNW	0.59%	2.30%	1.48%	0.67%	0.18%	0%	0%	0%	0%	0%	5.23%	100.00%	
All CD	10.64%	41.87%	23.79%	14.13%	5.71%	2.63%	0.89%	0.12%	0.10%	0.13%			
Cum CD	10.64%	52.51%	76.30%	90.42%	96.13%	98.76%	99.65%	99.78%	99.87%	100.00%			

### AVII.1.3. Seawater Properties

Sea water temperature, salinity, and density values were made available through a measurement campaign conducted by Fugro (2013). Sea water density have not been measured during the measurement campaign. Density has been calculated from temperature and salinity using the UNESCO formulation. Table AVII.11 summarizes the monthly variation of sea water temperature, salinity, and density at the surface.

**Table AVII.11: Monthly mean surface sea water temperature, salinity, and density values at the project site**

Month	Temperature (°C)	Salinity (PSU)	Density (kg/m <sup>3</sup> )
1	28.67	35.32	1022.42
2	29.09	35.25	1022.22
3	29.86	34.86	1021.67
4	29.02	34.83	1021.93
5	27.79	34.91	1022.40
6	26.46	35.02	1022.91
7	25.66	35.09	1023.21
8	25.25	35.05	1023.31
9	25.55	35.15	1023.29
10	26.72	35.15	1022.92
11	27.99	35.35	1022.66
12	29.23	35.36	1022.26

## AVII.1.4. Sediment Properties

The sediment properties of drill cuttings and adhered residual LTOBM (Low Toxic Oil Base Mud) to be used in the dispersion model are summarised in Table AVII.12. The information in Table AVII.12 is based on project-specific data as well as data gathered from the Coral South FLNG project (Consultec, 2015a) and assumptions made based on relevant previous experience of modelling drill cuttings and muds.

**Table AVII.12: Properties of drill cuttings and muds**

Parameter	Grain Diameter D <sub>50</sub> (mm)	Settling Velocity (m/s)*	Particle Density (kg/m <sup>3</sup> )
Drill cuttings	0.25	2.5051 x 10 <sup>-2</sup>	2 400
Drill Muds (LTOBM)	0.015	6.0122 x 10 <sup>-6</sup>	1 100

Note \*) Settling velocity formula according to Soulsby (1997).

## AVII.2. Description of Numerical Models

The computational modelling frameworks developed by the Danish Hydraulics Institute (DHI, [www.dhigroup.com](http://www.dhigroup.com)) MIKE were employed for this hydrodynamic study. DHI MIKE modelling framework allows for the simulation of flows, waves, sediment transport, water quality, morphological developments, oil spills and ecology.

MIKE 3 Flow Model (FM) is a modelling system for 3D free-surface flows. MIKE 3 FM is applicable to the simulation of hydraulic and environmental phenomena in oceans, coastal regions, estuaries, and lakes.

The Advection/Dispersion (AD) module simulates the spreading and fate of dissolved or suspended substances when provided with the flow field from the hydrodynamic module.

The following physical phenomena were included in the Hydrodynamic and Advection/Dispersion model developed as part of this study:

- Flood and drying;
- Bed resistance;
- Density variations;
- Transport of salinity and temperature;
- Turbulence modelling including buoyancy effects;
- Wind friction level and/or velocity boundaries;
- Isolated sources and sinks and/or connected source/sink pairs;
- Particle tracking;
- Discharge calculations;
- Dynamic nesting.

## AVII.3. Discharge Modelling Approach

### AVII.3.1. Overview

The Coral North FLNG Project is comprised of the following components (which are indicated in Figure AVII.11, Figure AVII.12, and Table AVII.13):

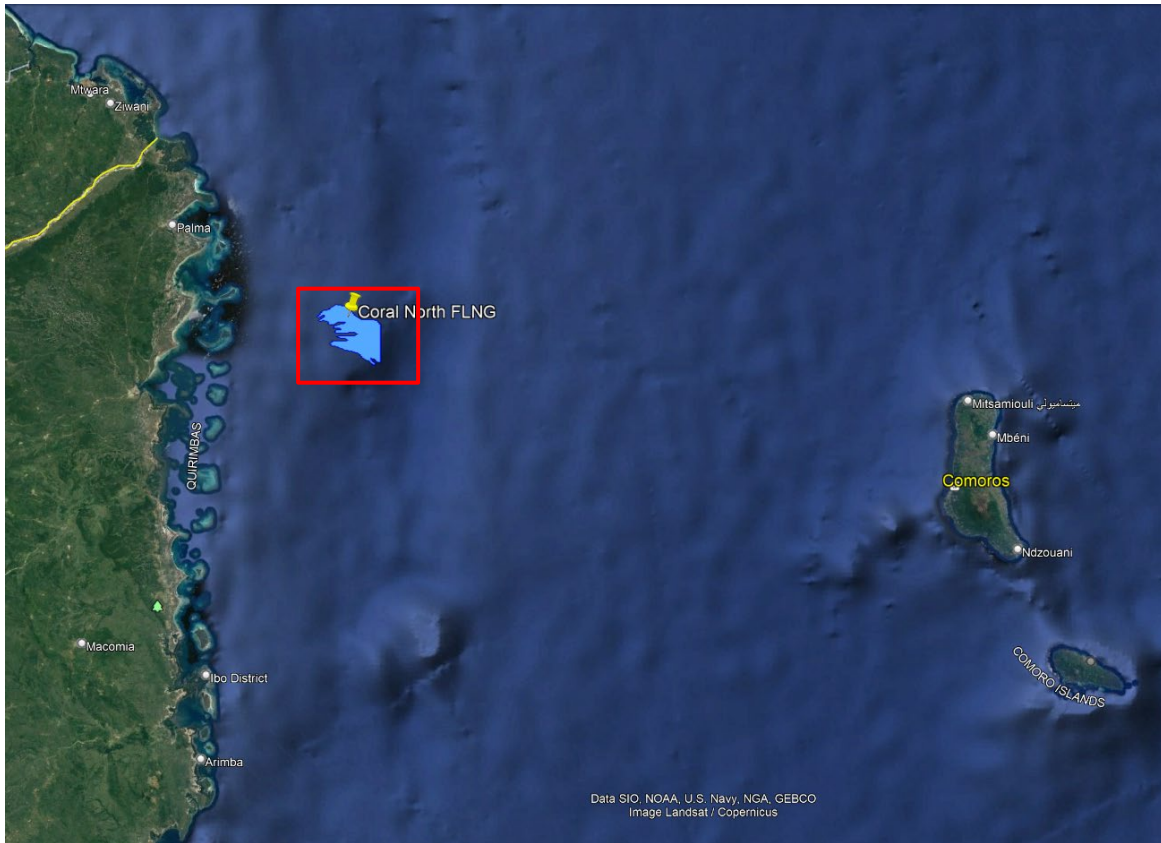
- An offshore floating gas treatment, liquefaction, storage and offloading vessel the same or similar to the Coral South FLNG;
- Subsea wells (CO-11 to CO-16), subsea production and control systems and risers to the FLNG.

The engineering scope of work related to discharge modelling studies includes:

- Hydrodynamic modelling;
- Thermal discharge modelling;
- Produced water discharge modelling;
- Drill cuttings discharge modelling;
- Oil spill modelling.



Figure AVII.11: Coral North project site



**Figure AVII.12: Coral North project site overview**

**Table AVII.13: FLNG and wellhead coordinates**

Name	Easting (m, UTM 37S)	Northing (m, UTM 37S)	Longitude (°E)	Latitude (°S)	Depth (m)
FLNG	731 508	8 772 185	41.119450	11.099583	1986
CO-11	732 843.1	8 769 590.7	41.131836	11.122949	2095
CO-12	732 802.9	8 769 533.3	41.131465	11.123467	2096
CO-13	729 466.9	8 769 959.3	41.100908	11.119832	2044
CO-14	729 507.1	8 770 016.7	41.101280	11.119314	2041
CO-15	730 973.7	8 762 341.6	41.115197	11.188585	1965
CO-16	730 904.3	8 762 350.4	41.114565	11.188508	1964

## AVII.3.2. Hydrodynamic Modelling

### AVII.3.2.1. Model Description

DHI MIKE is a multidimensional hydrodynamic simulation suite that compute non-steady flow patterns resulting from metoceanic forcing (mainly wind, pressure and tide) at their boundaries. This numerical tool is based on full Navier Stokes equations for shallow waters for different solving approaches and turbulence closure models.

This model can be used to simulate the tide propagation, including the effect of wind on the water surface, and to obtain outputs for flow velocities and water elevation fields. Both for littoral and offshore areas.

The integrated near-field and far-field approach included in latest versions (2016 or later) of the Danish Hydraulic Institute (DHI) MIKE 3 Hydrodynamic (HD) model coupled with the Advection-Dispersion (AD) can be used to simulate the transport of the various constituents in this project. MIKE 3 HD (including its modules) is one of the most widely used, recommended, and validated modelling suites available in the market.

### **AVII.3.2.2. Model Limitations**

The inherent limitations of the model are as follows:

- Any modelling technique can only provide a reasonable mathematical representation of complex reality based on appropriate simplifications and the isolation of the most important factors (variables). Analysis and interpretation of the modelling results require careful and experienced technical judgement in order to obtain proper conclusions. Some deviations from reality must be expected, and prudent safety margins should be considered. Models can be used to reduce (but not eliminate) uncertainty in decision-making;
- Model results are as good as the quality of the input data. Micro-topography under grid resolution cannot be solved;
- Due to the long times required for computing, the results cannot be extended over long periods. For example, wind conditions in nature do not persist over more than a few days, and the conclusions obtained from long-term simulations based on steady-state winds can be unrealistic.

### **AVII.3.2.3. Model Setup**

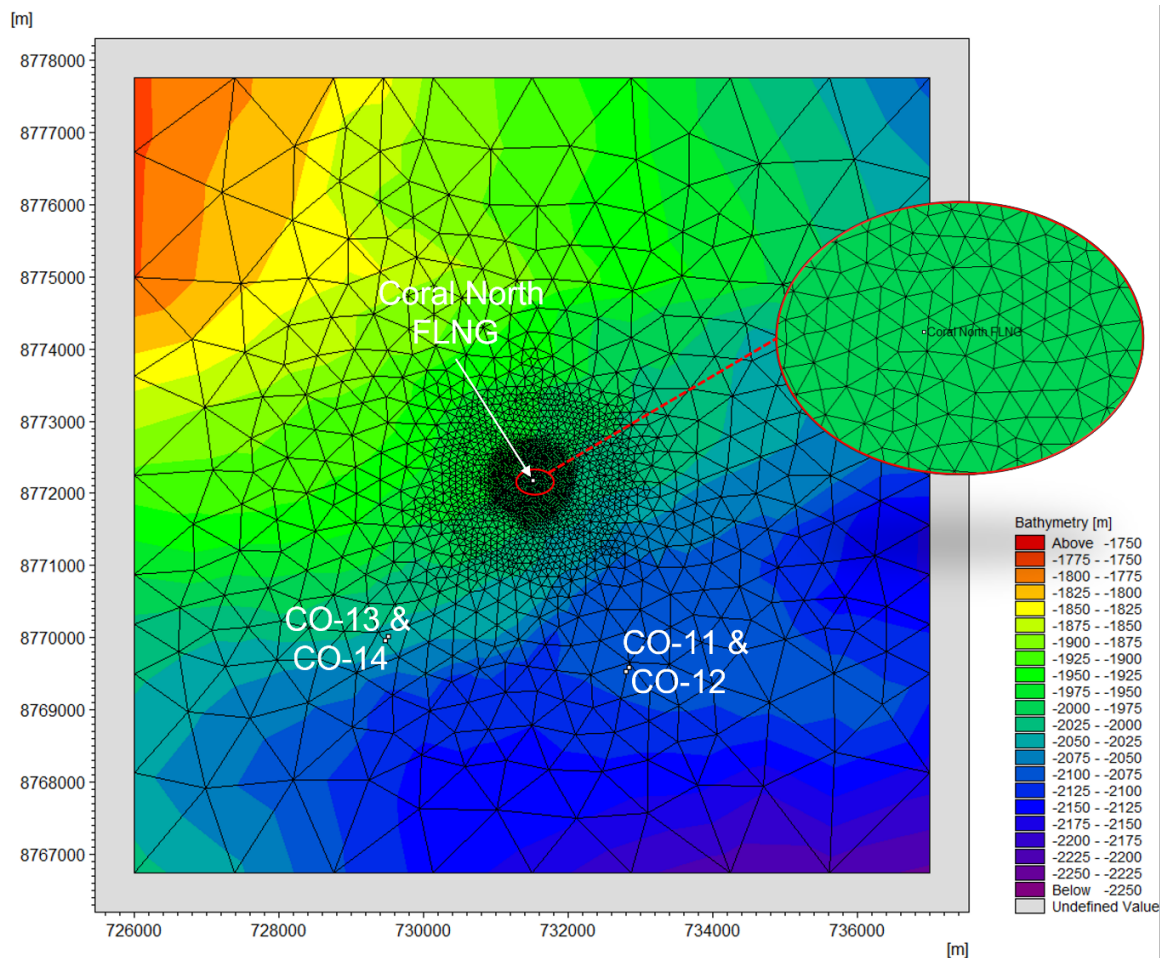
Environmental effects on surface waters from the operation of the FLNG vessel in the Mozambique Channel will be assessed using the comprehensive modelling approach embodied in DHI MIKE, described above. Given the complex three-dimensional current and temperature structure of the receiving water mass, it was necessary to select a model that can simulate three-dimensional hydrodynamics. It is also desirable that the transport of constituents also be handled in the same model. For this reason, DHI MIKE was selected to address these requirements.

A regional far-field model will be used to simulate the hydrodynamic patterns offshore, with the model grid covering an area spanning from 33 °E to 50 °E and 5 °S to 20 °S. The model grid consists of over 40 000 grid cells horizontally (including land, shoreline, and water) with up to 10 vertical layers and a uniform grid resolution of approx. 8 km cells.

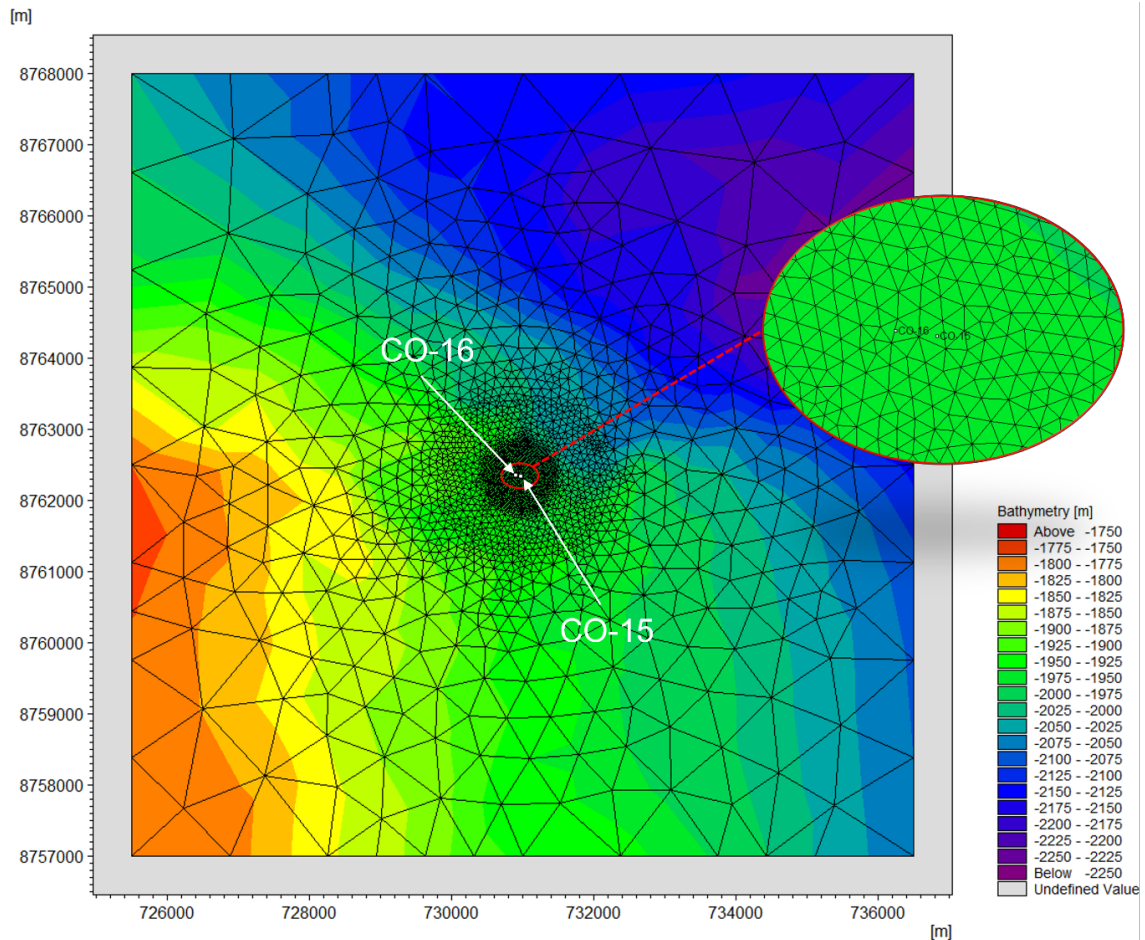
A near-field 3-D model nested within the far-field model will be used to simulate the transport of constituents on a finer scale with a model extent of approx. 30 km by 30 km centred at the respective discharge site and with a higher resolution of approx. 30 m.

Vertically, 10 sigma layers will be employed, with finer vertical resolution at the surface and seabed regions where the discharges are predicted.

The bathymetric data outlined in Section AVII.1.1 were interpolated onto the produced computational grids, giving preference to the highest resolution data, where data overlaps. Figure AVII.13 and Figure AVII.14 show the bathymetry and computational meshes for the surface discharge (FLNG location) and seabed discharge (well head CO-15) near-field models developed as part of this study.



**Figure AVII.13: Bathymetry and computational grid for FLNG near-field dispersion model domain**



**Figure AVII.14: Bathymetry and computational grid for CO-15 near-field dispersion model domain**

### AVII.3.2.4. Inputs

Data used for hydrodynamic model input include: tidal elevation at the boundaries, temperature and salinity profiles at the boundaries, and meteorological data. Boundary data were required for each of the three simulation periods. In order to simulate the hydrodynamic patterns as accurately as possible, elevation at all east, north and south boundaries were needed. The elevations consist of a tidal component as well as a non-tidal component. The tidal component is based on the Global Tide Model from DHI MIKE and the nontidal component is based on HYCOM. The total elevation was estimated by superposition of the two.

- Tidal elevation: the tidal elevation at the boundary was extracted from DHI MIKE’s Global Tide Model, which represents the major diurnal (K1, O1, P1 and Q1) and semidiurnal tidal constituents (M2, S2, N2 and K2) with a spatial resolution of 0.25° × 0.25° based on TOPEX/POSEIDON altimetry data. The tides here are semidiurnal with a pronounced spring–neap cycle;
- Non-tidal elevation: in order to capture the baroclinic features for the model domain, the non-tidal elevation record was extracted from HYCOM global model output;

- Meteorological properties: the meteorological properties used in the simulation are wind speed, wind direction, air temperature, solar radiation, and surface pressure. The meteorological data were obtained from CFSR and CFSv2. The time series of each meteorological property was extracted using the respective location closest to the FLNG;
- Temperature and salinity: daily temperature and salinity data off the coast of Mozambique are available from global HYCOM 1/12 degree analysis output. The thermocline is located at the top 200 m of the water column, while the salinity profile has very little variation (<1 psu) in this region.

### AVII.3.2.5. Scenarios

Three scenarios have been selected based on the annual and monthly average surface current from metocean observation at station C1 (Consultec, 2015a). Based on the annual and monthly average currents analysis, three scenarios are chosen to represent sea conditions of maximum, minimum, and typical surface current in that region. The three simulation periods which represent maximum (Scenario 01), minimum (Scenario 02) and typical (Scenario 03) current speeds at the FLNG project site are summarised in Table AVII.14.

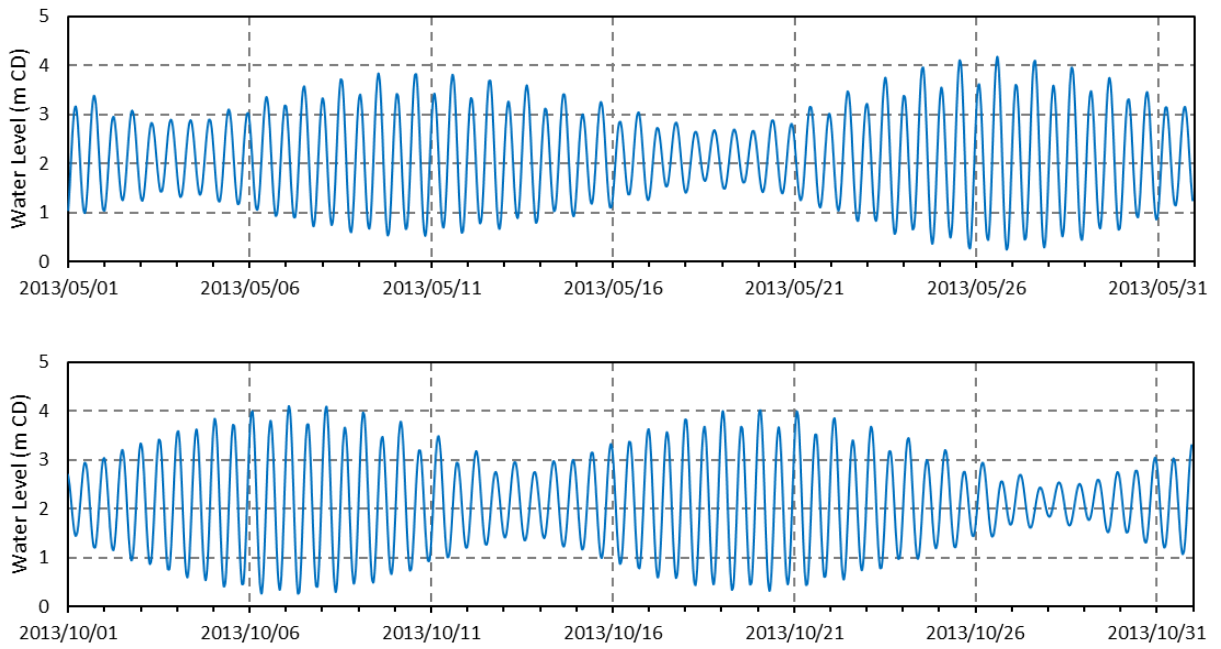
**Table AVII.14: Hydrodynamic simulation periods**

Scenario	Simulation Period	Hydrodynamic Condition (surface current)
Scenario 1	May 2013	Maximum current speed
Scenario 2	October 2013	Minimum current speed
Scenario 3	March 2013	Typical current speed

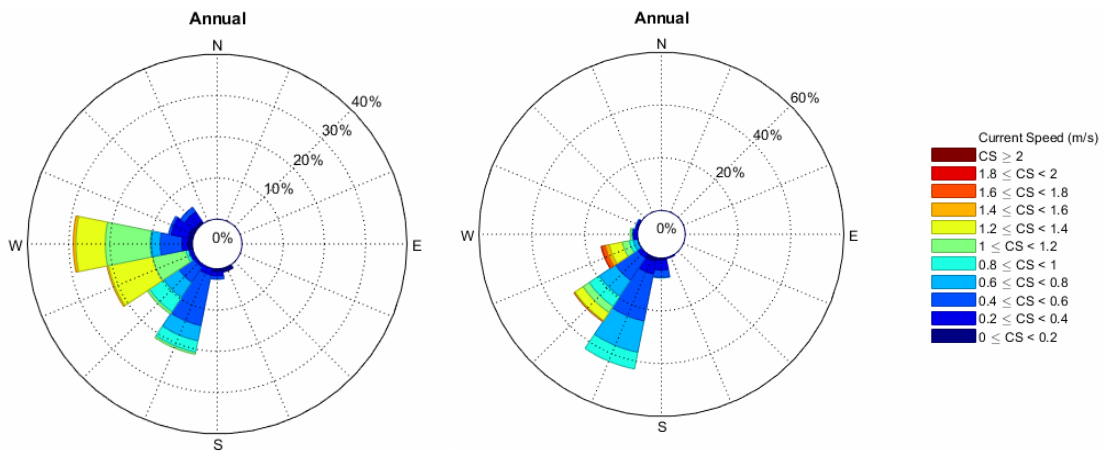
### AVII.3.2.6. Model Results

The typical water level time series extracted at the FLNG location for the months of May (maximum currents) and October (minimum currents) is presented in Figure AVII.15. The depth-averaged current speeds at the FLNG location during May (maximum currents) and October (minimum currents) are shown in Figure AVII.16.

Typical ebbing and flooding depth-averaged snapshots of water levels with current velocities during May (maximum currents) and October (minimum currents) at the FLNG site are illustrated in Figure AVII.17 to Figure AVII.18.



**Figure AVII.15: Time series of typical water levels at the site for the months of May (maximum currents) and October (minimum currents)**



**Figure AVII.16: Depth-averaged current speed at the FLNG site for the months of May (maximum currents) and October (minimum currents)**

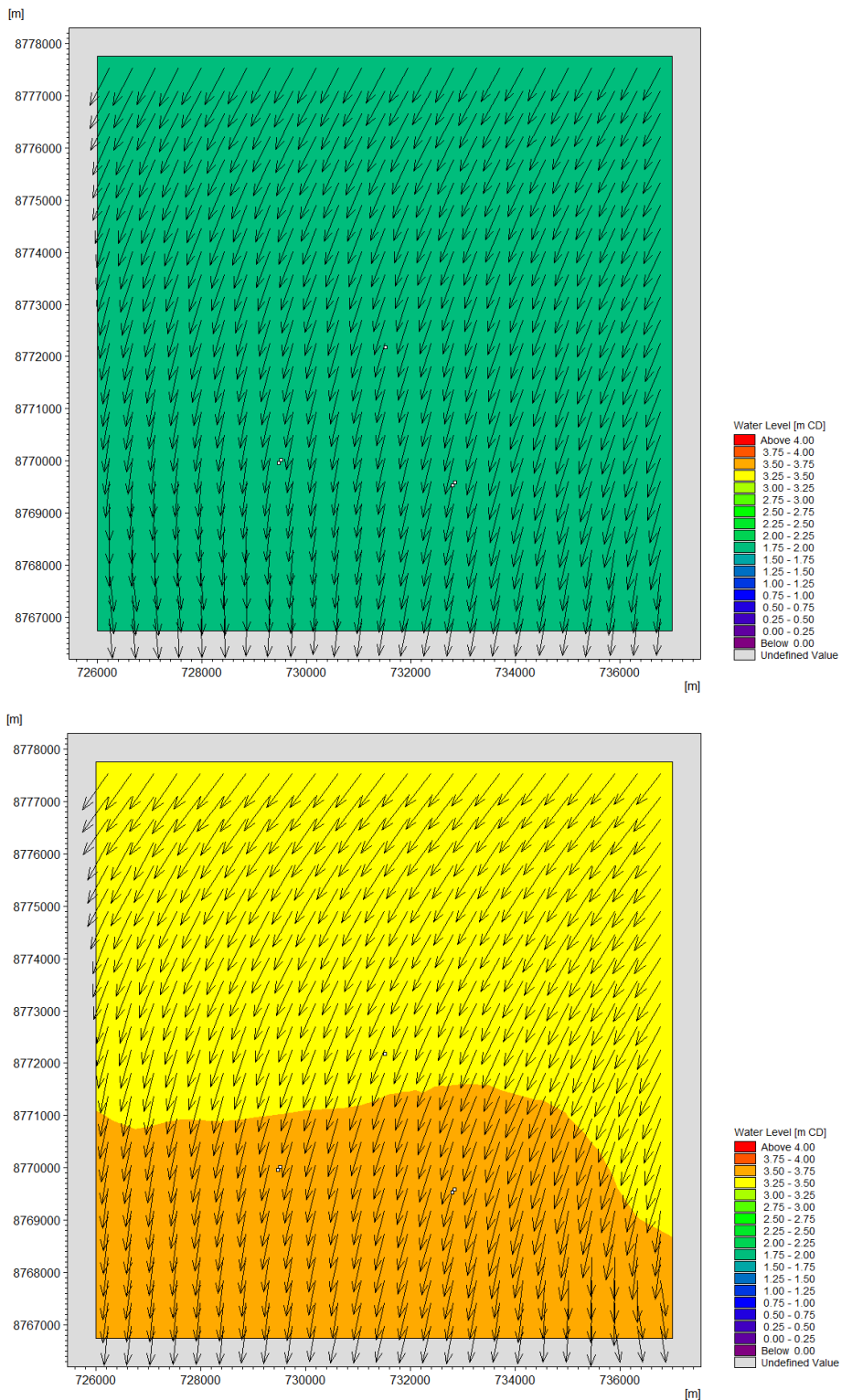
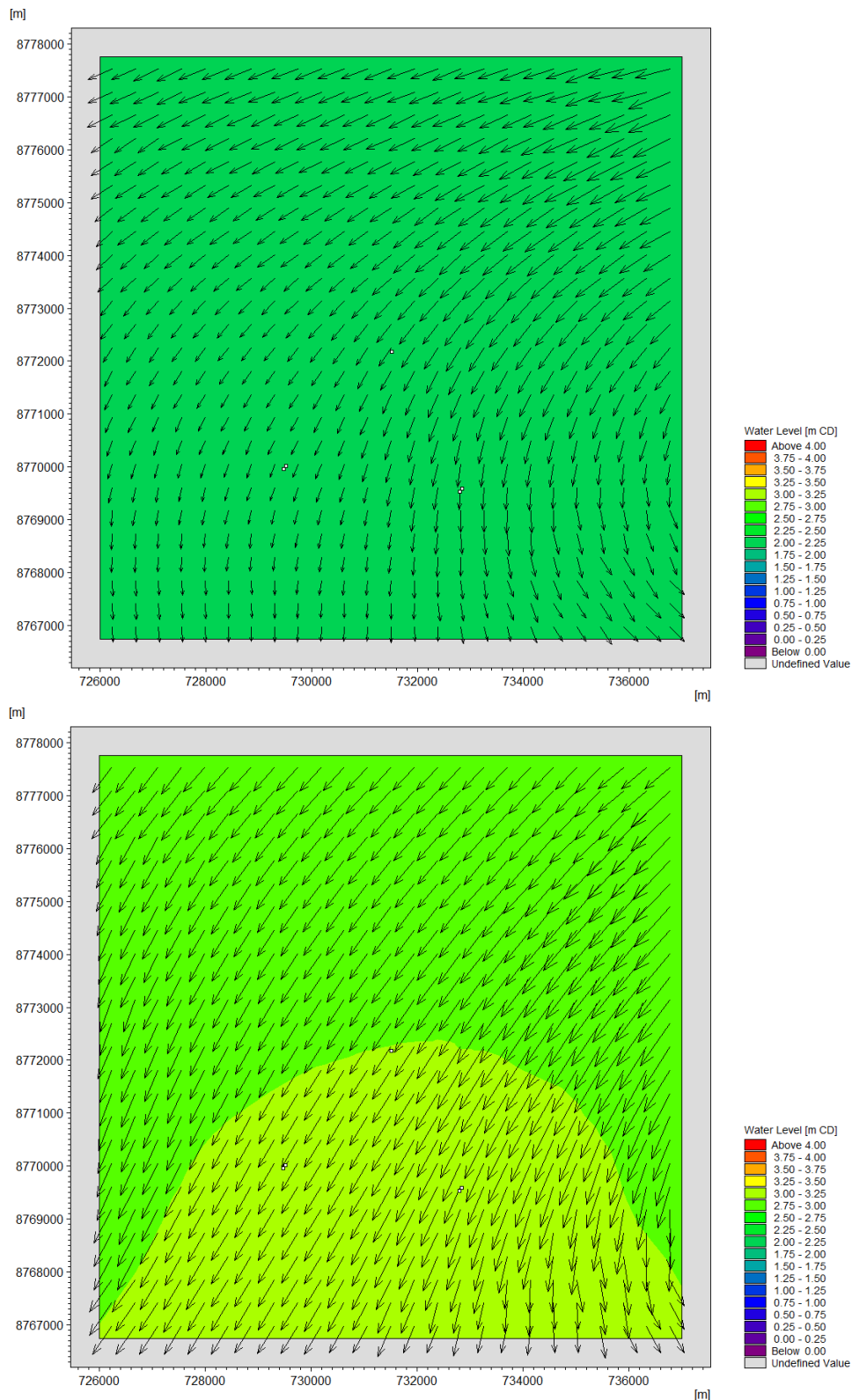


Figure AVII.17: Typical ebbing water levels during minimum currents in October (top) and maximum currents in May (bottom)



**Figure AVII.18: Typical flooding water levels during minimum currents in October (top) and maximum currents in May (bottom)**

## AVII.3.3. Thermal Discharge Model

### AVII.3.3.1. Model Setup

Two models will be used to assess the temperature impacts from cooling water discharge. One model (CORMIX) will predict the temperature rise from the point of discharge to the end of the mixing zone. The other model (DHI MIKE) will predict the temperature rise on a larger scale extending beyond the initial mixing zone, based on the established hydrodynamic modelling (see Section AVII.3.2 for the hydrodynamic methodology details).

In what regards the size of the mixing zone, the following recommendations have been tabled for South Africa (Anchor Environmental Consultants 2015): 300 m in an offshore environment, 100 m in a nearshore open coast environment, 30 m in sheltered coastal environments and special management areas, 0 m for outfalls in established or proposed MPAs, the surf zone and estuaries. These recommendations are applicable to Mozambican waters as well, and as such the recommended mixing zone would be 300 m. However, impacts of the thermal discharge were assessed for a stricter 100 m mixing zone, as a conservative approach.

As the standards applicable to marine thermal discharges include an end-of-mixing zone standard, modelling of the mixing zone was necessary. The model used for the mixing zone calculations is USEPA's CORMIX dilution model. This model is steady-state and was used in this modelling study to simulate various current conditions.

A nested 3-D model with extent of approx. 30 km by 30 km centred at the FLNG site will be created with a higher resolution of approx. 30 m.

### AVII.3.3.2. Inputs and Standards

#### Input Condition Data

- The boundary conditions for the nested near-field model (DHI MIKE) were derived from the regional far-field, low resolution hydrodynamic model output;
- Ambient hydrodynamic conditions (depth, velocity, temperature, and salinity) will be extracted from metocean field data (measurements) for use in the mixing zone model (CORMIX).

#### Ambient Seawater Temperature Standards

- The ambient temperature standards, in compliance with national regulations and IFC EHS guidelines are as follows: the increase of seawater temperature should not exceed 3°C at the edge of the recommended mixing zone (RMZ).

### AVII.3.3.3. Scenarios

Table AVII.15 summarizes the overview of modelling scenarios for both the CORMIX and DHI MIKE models, while Table AVII.16 and Table AVII.17 summarize the thermal discharge flow rates and

excess temperatures, respectively. In these simulations, the discharge will be assumed to be continuous throughout the monthly simulation periods, as described in Section AVII.3.2.5.

The discharge depth is at 11.5-17.5 m above base level of the vessel and the maximum draft of the FLNG is 18 m (Consultec, 2015a). Therefore, it is estimated that the seawater cooling discharge is a maximum of 0.5-7.5 m below sea level. For the modelling, it was estimated that discharge will be to the model segment that represents the top 5 m below sea level.

**Table AVII.15: Modelling scenarios**

Modelling Component	Model	Hydrodynamic Conditions	Discharge Condition
Temperature	DHI MIKE	High Current Speed (Scenario 1)	Average / Peak
		Low Current Speed (Scenario 2)	
		Typical Current Speed (Scenario 3)	
Temperature	CORMIX	High Current Speed (Scenario 1)	Average / Peak
		Low Current Speed (Scenario 2)	
		Typical Current Speed (Scenario 3)	

**Table AVII.16: Thermal discharge flow rates and temperatures**

Description	Average Discharge		Peak Discharge	
	MT/hr	m <sup>3</sup> /s	MT/hr	m <sup>3</sup> /s
Total Thermal Discharge <sup>1</sup> @ 30.64 °C	24 964	6.9344	27 445	7.6236

Note <sup>1</sup>) Total consists of combined Main Seawater, AFT Essential Seawater and FWD Essential Seawater.

**Table AVII.17: Ambient and excess temperatures**

Scenario	Average sea surface temperature (°C)	Excess discharge temperature (°C)
Scenario 1 – May 2013 (High current speed)	27.79	2.85
Scenario 2 – October 2013 (Low current speed)	26.72	3.92
Scenario 3 – March 2013 (Typical current speed)	29.86	0.78

### AVII.3.3.4. Nested Near-Field Model Results

The thermal dispersion model was run over three separate one-month simulation periods (see Table AVII.15). The simulations included a 7-day spin-up period prior to the start dates to allow for the water levels, and currents to stabilise (the spin-up period is however excluded in the post-processing of results). The relevant outputs of the model are temperature concentrations at hourly intervals over the duration of each simulation.

The thermal dispersion model results have been processed to provide the statistical maximum and high-percentile values of temperature rise as well as the percentage of exceedance above the

specified threshold of 3 °C. A mixing zone with radius of 100 m is shown as a dashed circle on each plot.

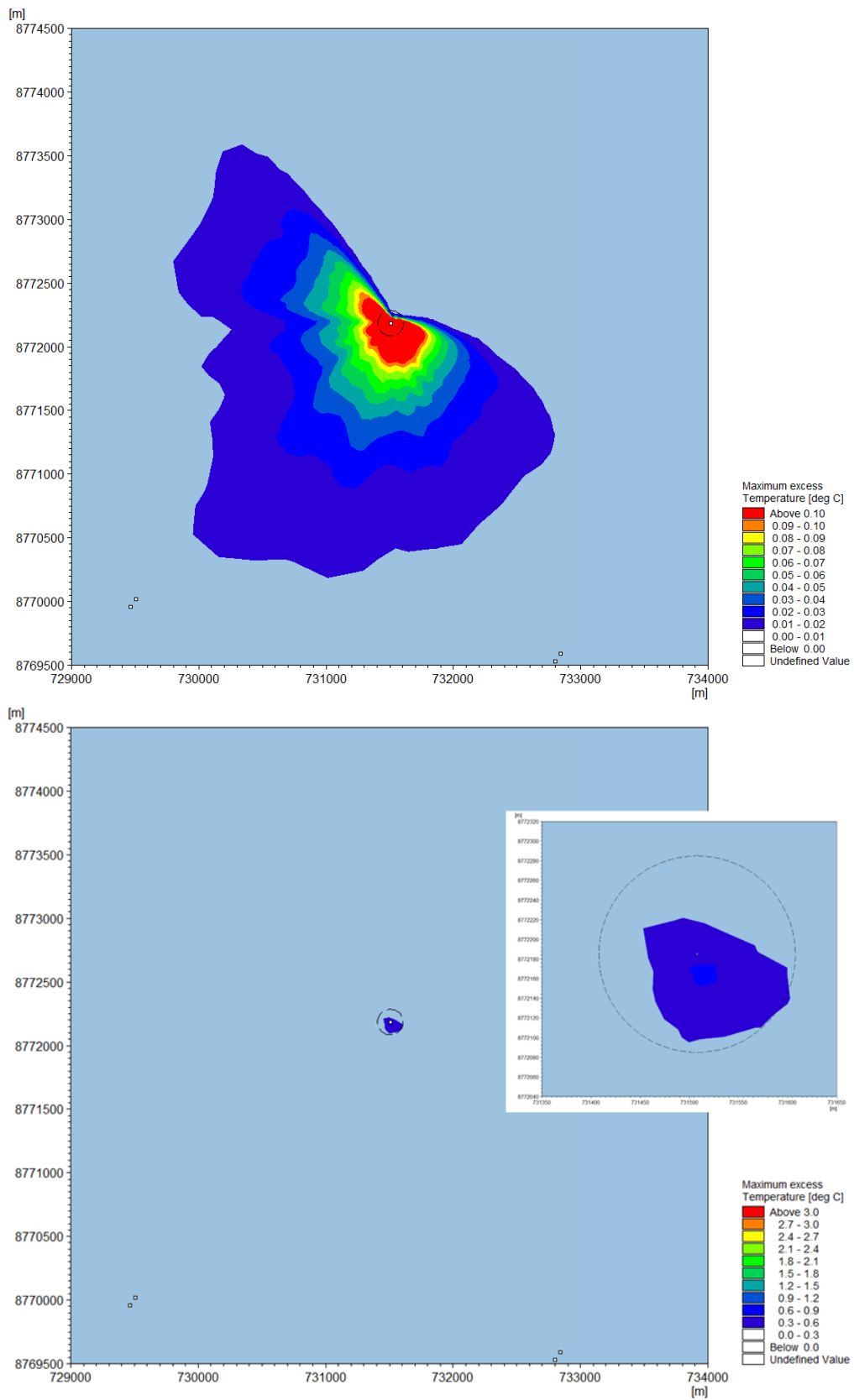
Percentiles are statistical terms used to describe how certain values compare to other values within the same dataset. A value at the 95<sup>th</sup> percentile mark indicates that 95% of the values in the dataset are smaller and 5% of the values are greater than that value. Therefore, the 95<sup>th</sup> and 99<sup>th</sup> percentile values are accurate representations of what can be expected as extreme high-percentile values and have been used here to produce extreme plume behaviours plots.

Percentage of exceedance plots show the duration as a percentage of the run time that excess concentrations exceed a specified threshold.

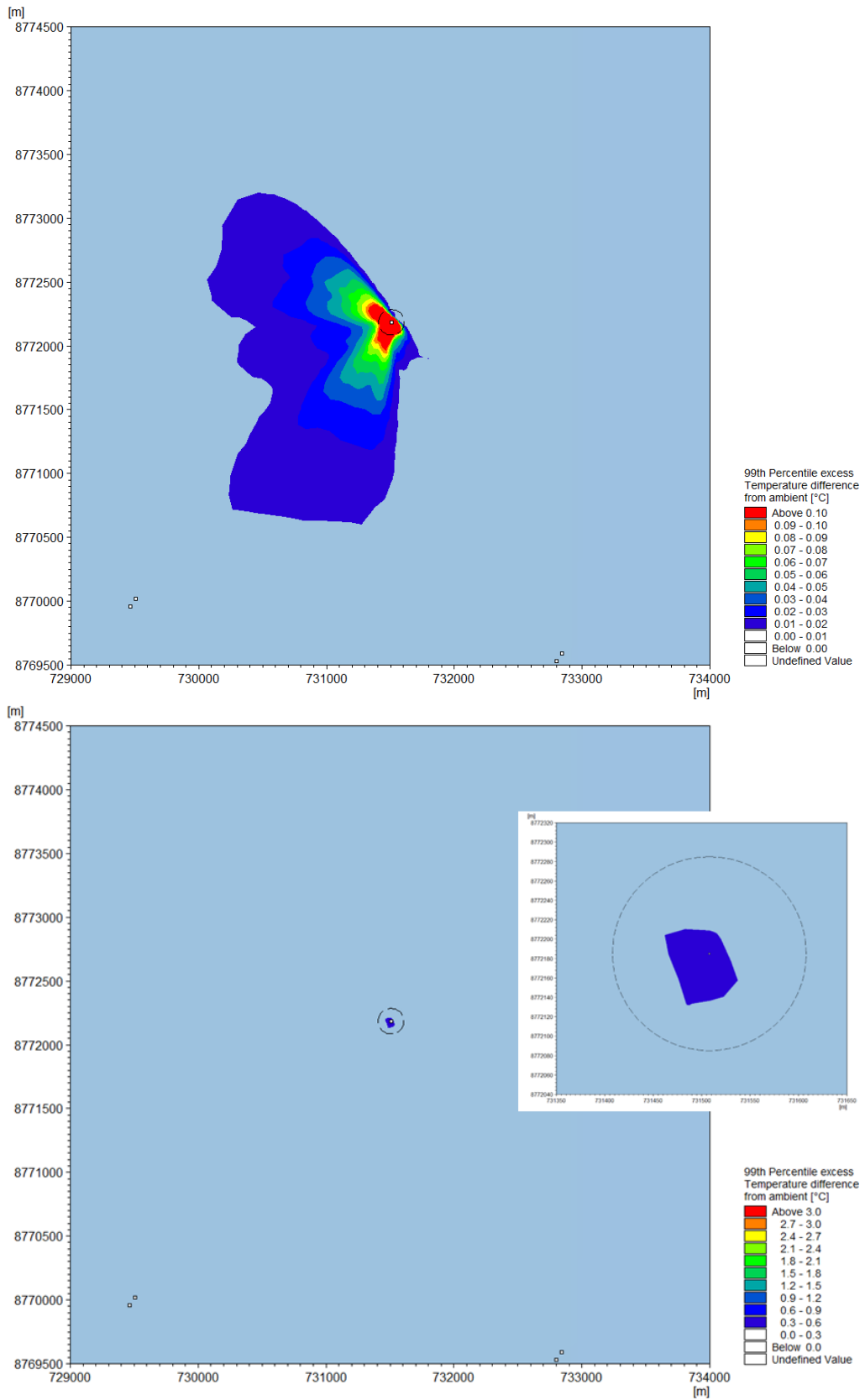
#### **AVII.3.3.4.1. Peak Discharge – Scenario 1 (May)**

Spatial plots for the statistical maximum, 99<sup>th</sup>-, and 95<sup>th</sup> percentile excess temperature values are provided in Figure AVII.19 to Figure AVII.21 for the high current speed scenario (May).

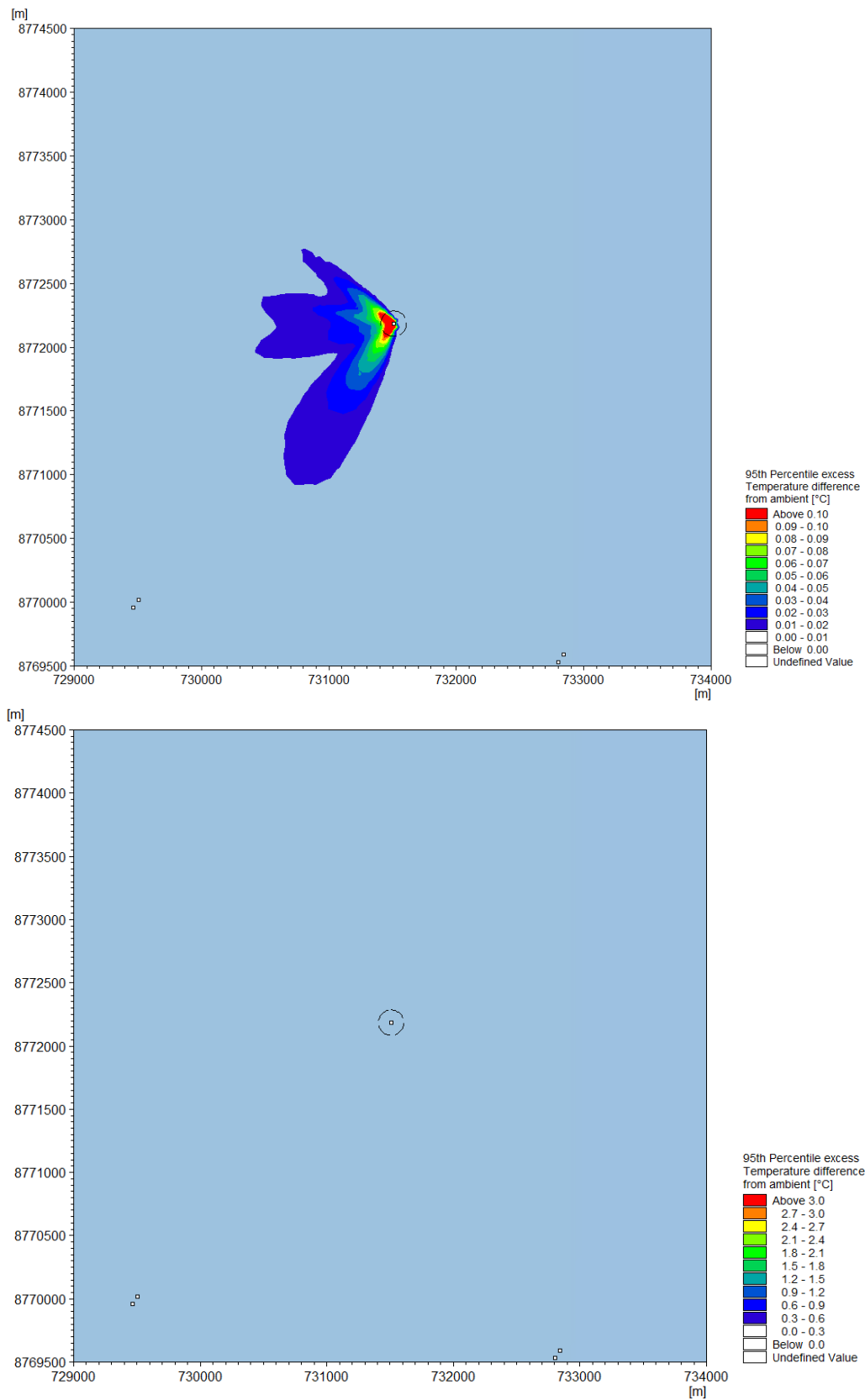
The percentage of exceedance plot for excess temperature is provided in Figure AVII.22.



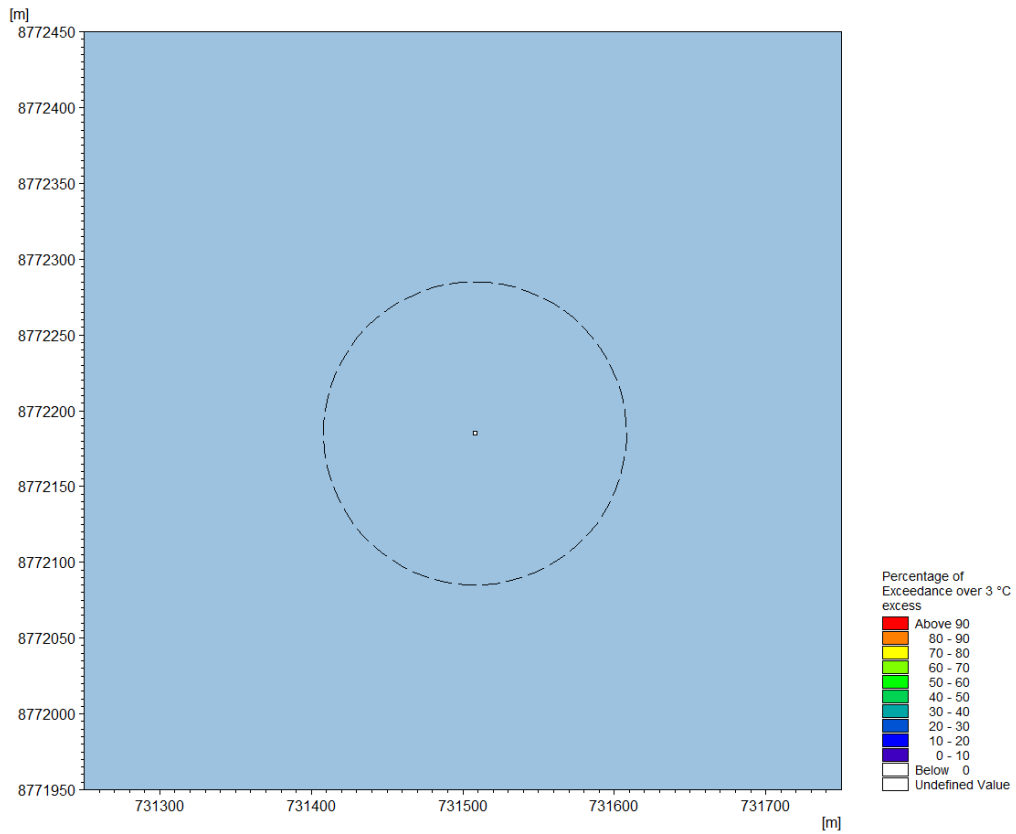
**Figure AVII.19: Maximum temperature rise during cooling water discharge simulation for Scenario 1. Thresholds of 0.1 °C (top) and 3 °C (bottom)**



**Figure AVII.20: 99<sup>th</sup> Percentile temperature rise during cooling water discharge simulation for Scenario 1. Thresholds of 0.1 °C (top) and 3 °C (bottom)**



**Figure AVII.21: 95<sup>th</sup> Percentile temperature rise during cooling water discharge simulation for Scenario 1. Thresholds of 0.1 °C (top) and 3 °C (bottom)**

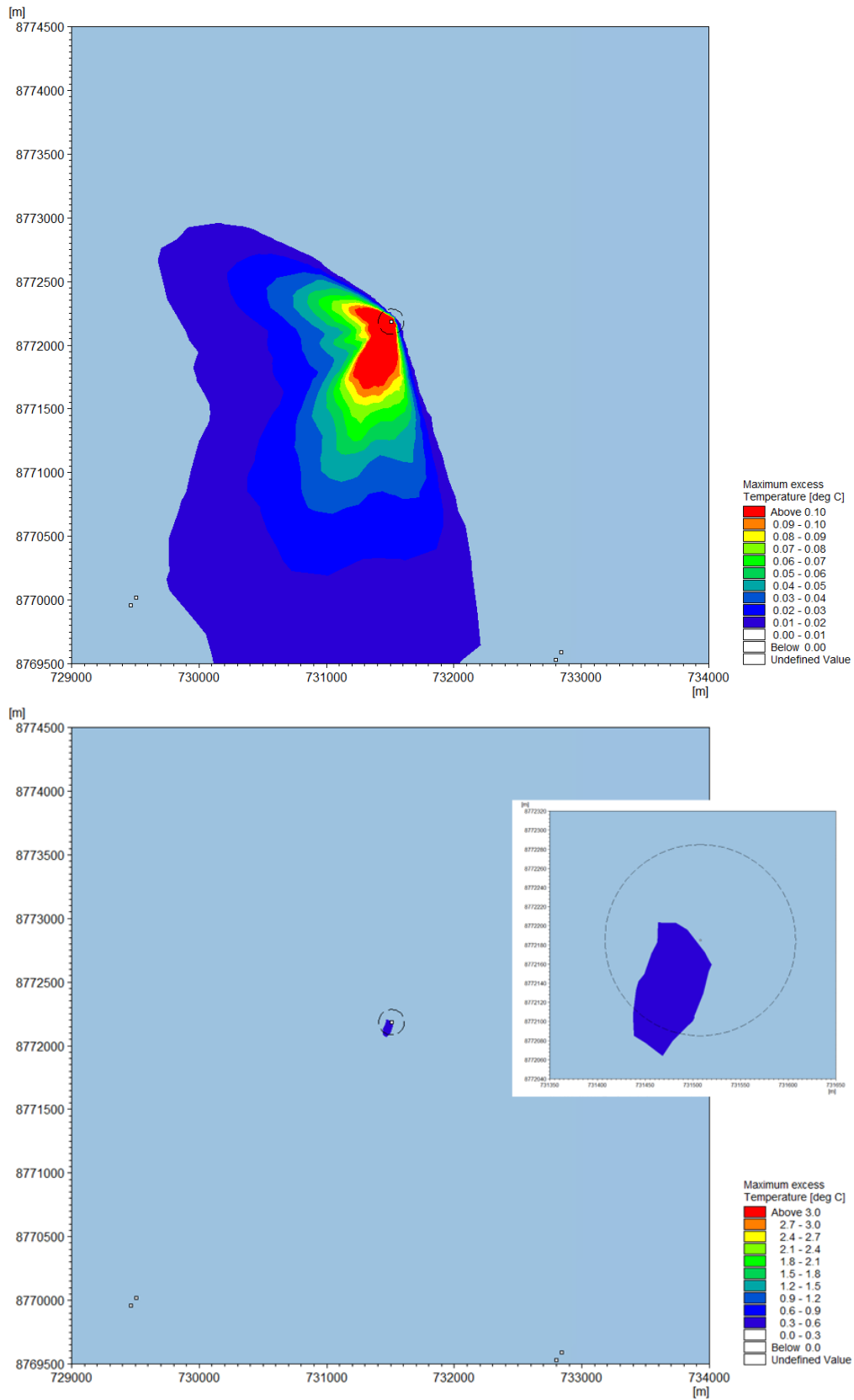


**Figure AVII.22: Percentage of exceedance of 3 °C threshold temperature rise during cooling water discharge simulation for Scenario 1**

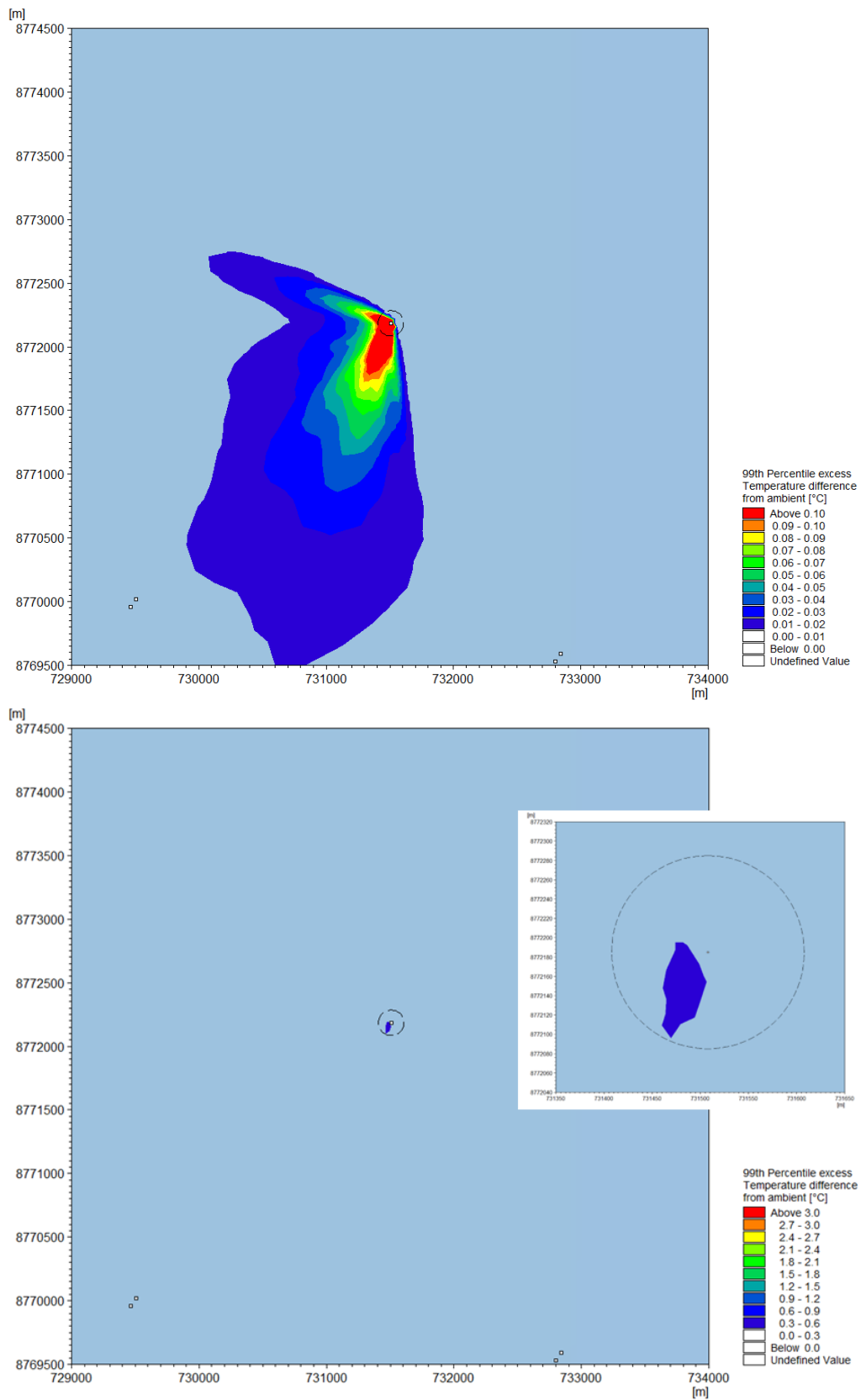
#### AVII.3.3.4.2. Peak Discharge – Scenario 2 (October)

Spatial plots for the statistical maximum, 99<sup>th</sup>-, and 95<sup>th</sup> percentile excess temperature values are provided in Figure AVII.23 to Figure AVII.25 for the low current speed scenario (October).

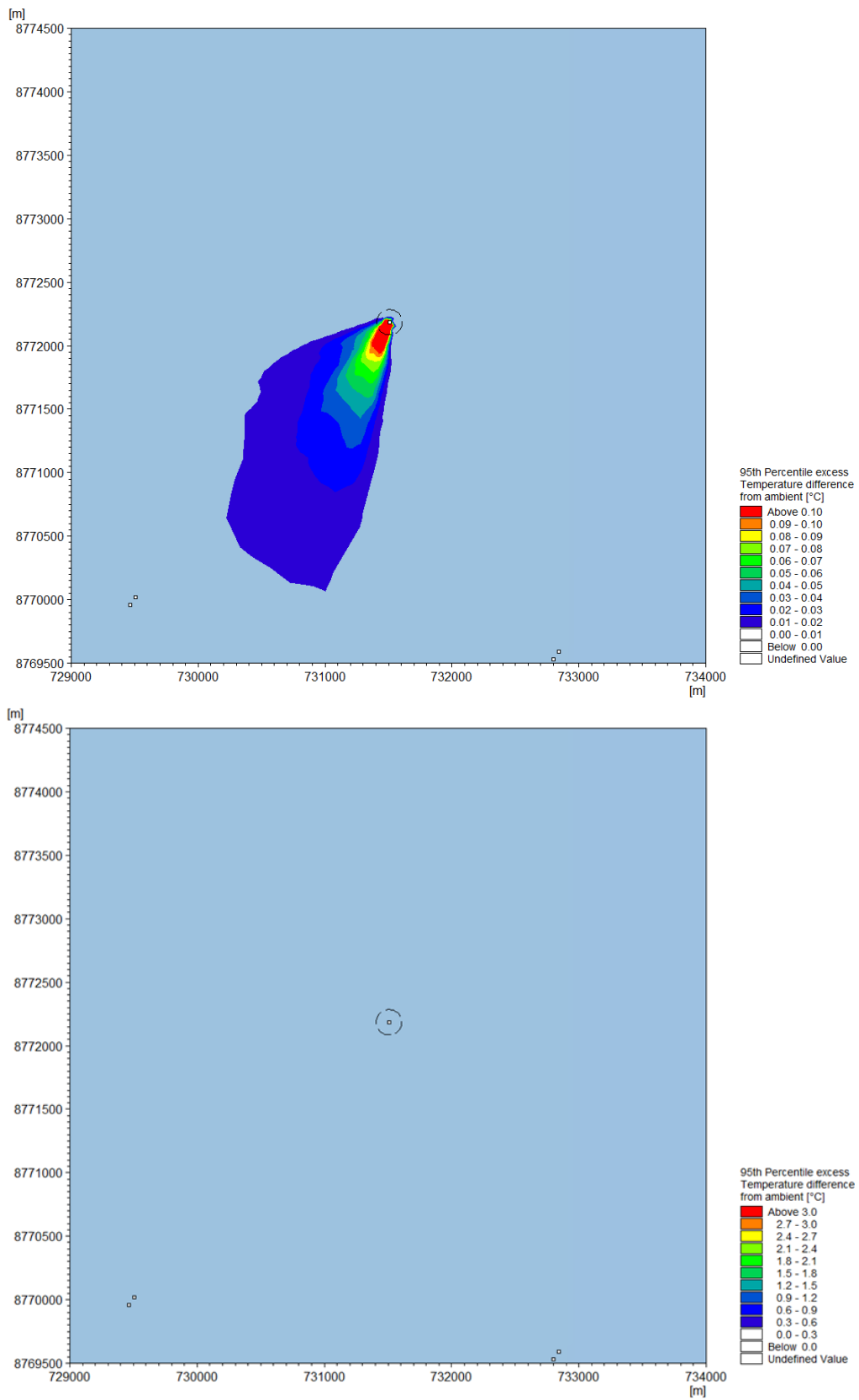
The percentage of exceedance plot for excess temperature is provided in Figure AVII.26.



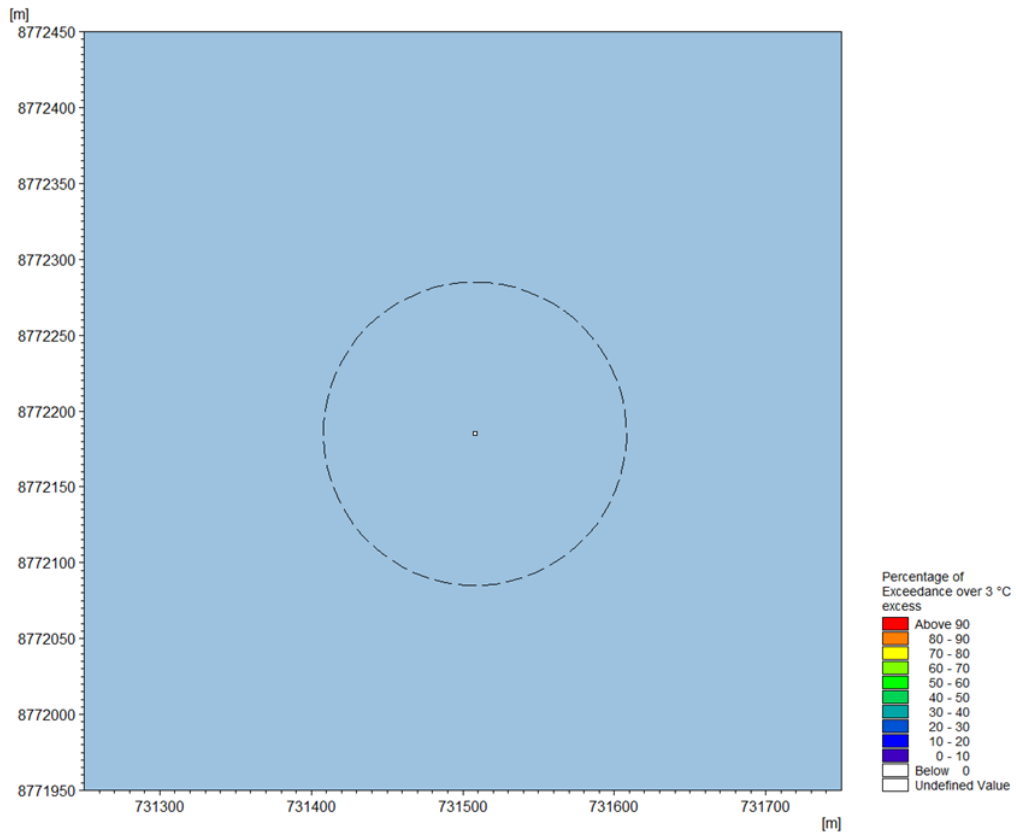
**Figure AVII.23: Maximum temperature rise during cooling water discharge simulation for Scenario 2. Thresholds of 0.1 °C (top) and 3 °C (bottom)**



**Figure AVII.24: 99<sup>th</sup> Percentile temperature rise during cooling water discharge simulation for Scenario 2. Thresholds of 0.1 °C (top) and 3 °C (bottom)**



**Figure AVII.25: 95<sup>th</sup> Percentile temperature rise during cooling water discharge simulation for Scenario 2. Thresholds of 0.1 °C (top) and 3 °C (bottom)**

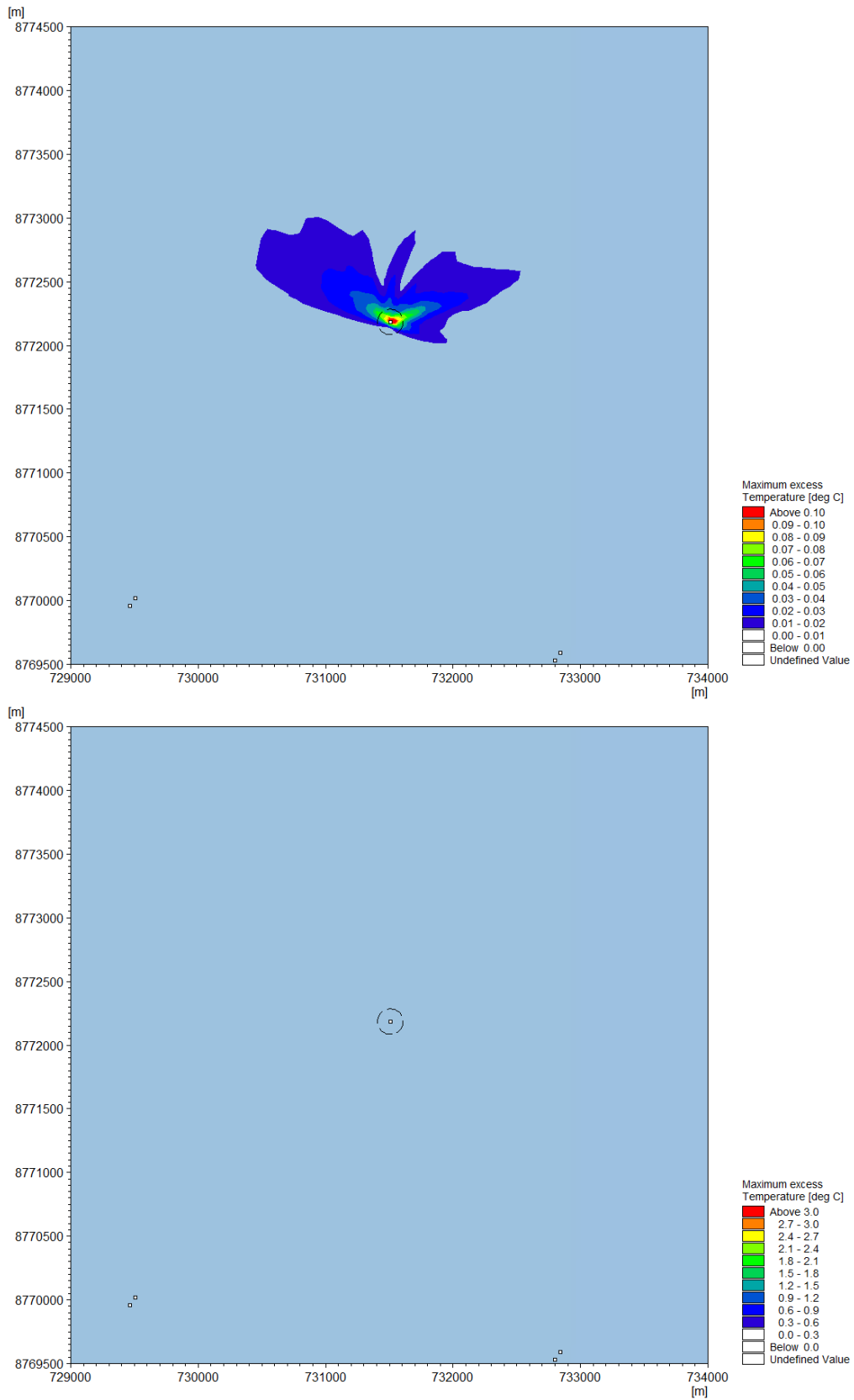


**Figure AVII.26: Percentage of exceedance of 3 °C threshold temperature rise during cooling water discharge simulation for Scenario 2**

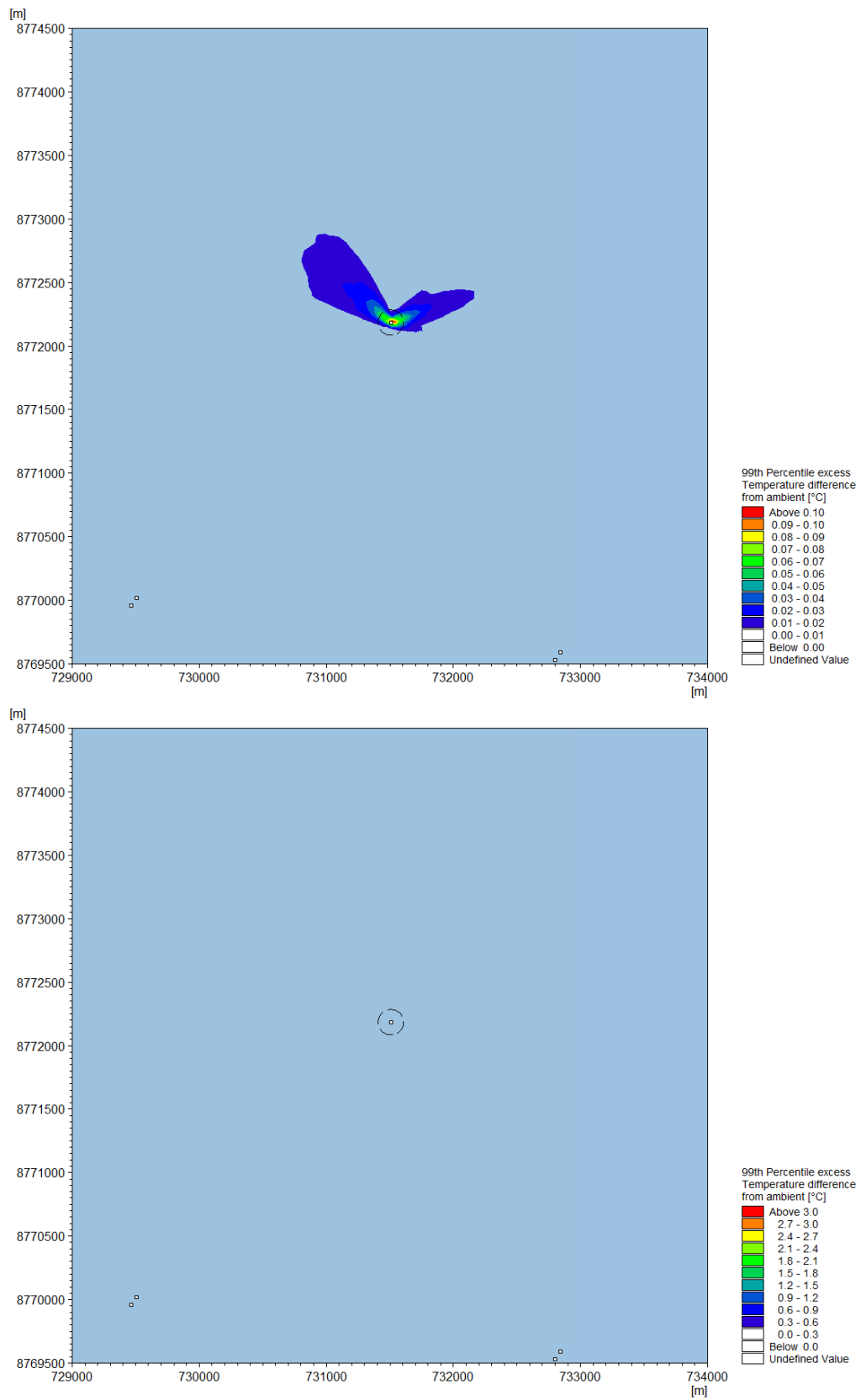
#### **AVII.3.3.4.3. Peak Discharge – Scenario 3 (March)**

Spatial plots for the statistical maximum, 99<sup>th</sup>-, and 95<sup>th</sup> percentile excess temperature values are provided in Figure AVII.27 to Figure AVII.29 for the typical current speed scenario (March).

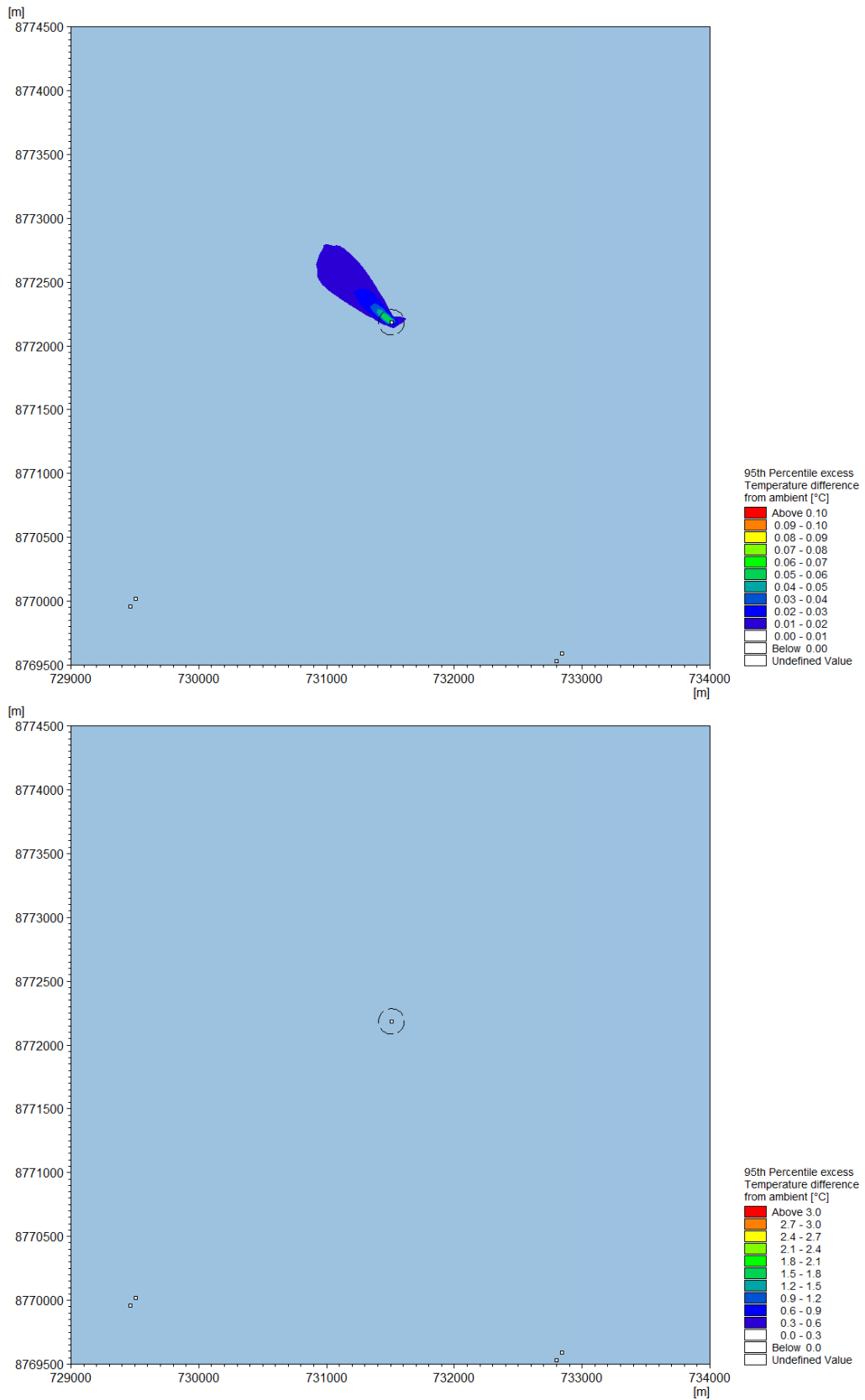
The percentage of exceedance plot for excess temperature is provided in Figure AVII.30.



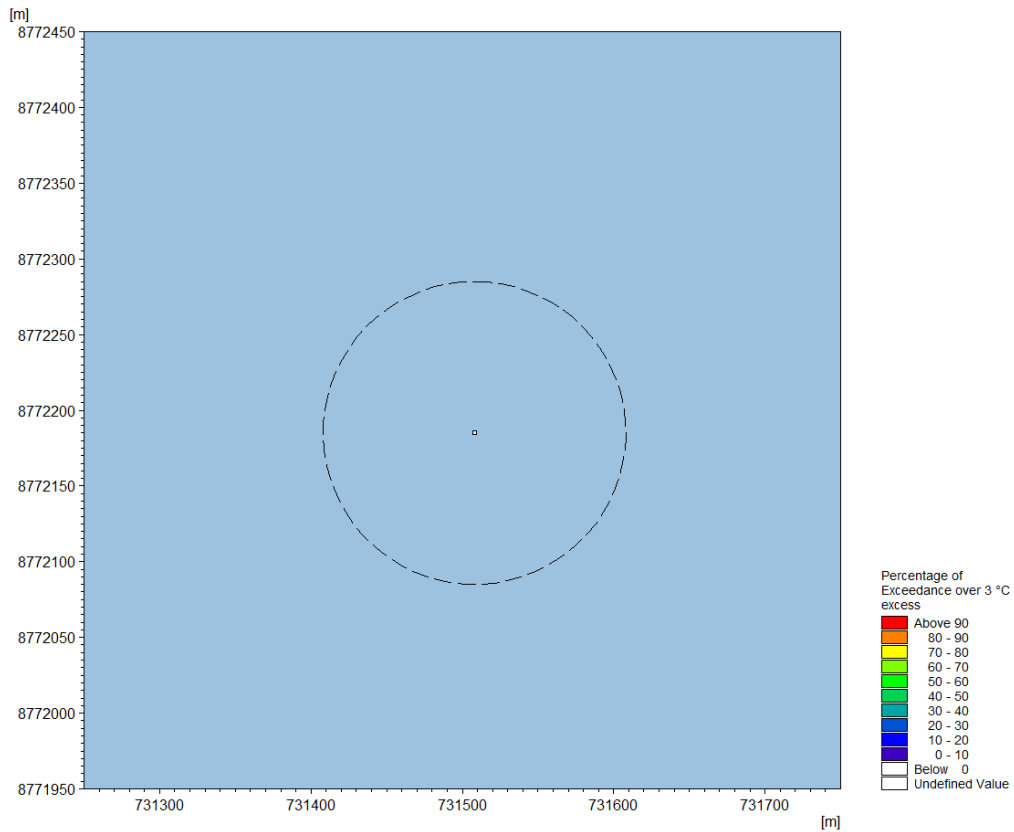
**Figure AVII.27: Maximum temperature rise during cooling water discharge simulation for Scenario 3. Thresholds of 0.1 °C (top) and 3 °C (bottom)**



**Figure AVII.28: 99<sup>th</sup> Percentile temperature rise during cooling water discharge simulation for Scenario 3. Thresholds of 0.1 °C (top) and 3 °C (bottom)**



**Figure AVII.29: 95<sup>th</sup> Percentile temperature rise during cooling water discharge simulation for Scenario 3. Thresholds of 0.1 °C (top) and 3 °C (bottom)**



**Figure AVII.30: Percentage of exceedance of 3 °C threshold temperature rise during cooling water discharge simulation for Scenario 3**

**AVII.3.3.4.4. Peak Discharge – Summary**

A summary of the maximum temperature rise for the three scenarios is shown in Table AVII.18. According to the standards for ambient seawater, the temperature rise should not exceed 3 °C at the 100 m edge of mixing zone. As seen from the summary below, the maximum temperature rise was predicted in Scenario 02 with a rise of 0.39 °C which is well below the 3 °C standard. Scenario 02 results in the highest temperature rise for the cooling water discharge, which is due to the fact that Scenario 02 represents the lowest ambient current conditions.

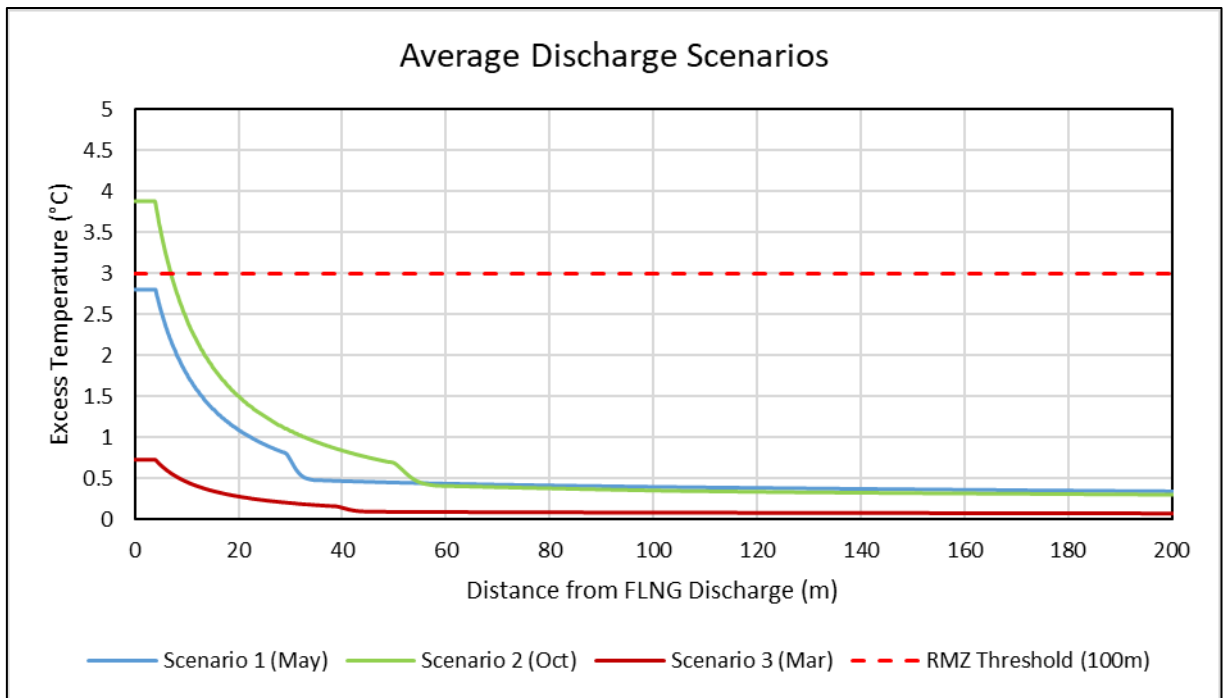
**Table AVII.18: Maximum temperature rise for the three scenarios under cooling water peak discharge**

Scenario	Maximum temperature rise (° C) at 100 m mixing zone
Scenario 1 (May)	0.33 (ESE direction)
Scenario 2 (October)	0.39 (SSW direction)
Scenario 3 (March)	0.11 (ENE direction)

### AVII.3.3.5. CORMIX Mixing Zone Model Results

#### AVII.3.3.5.1. Average Discharge

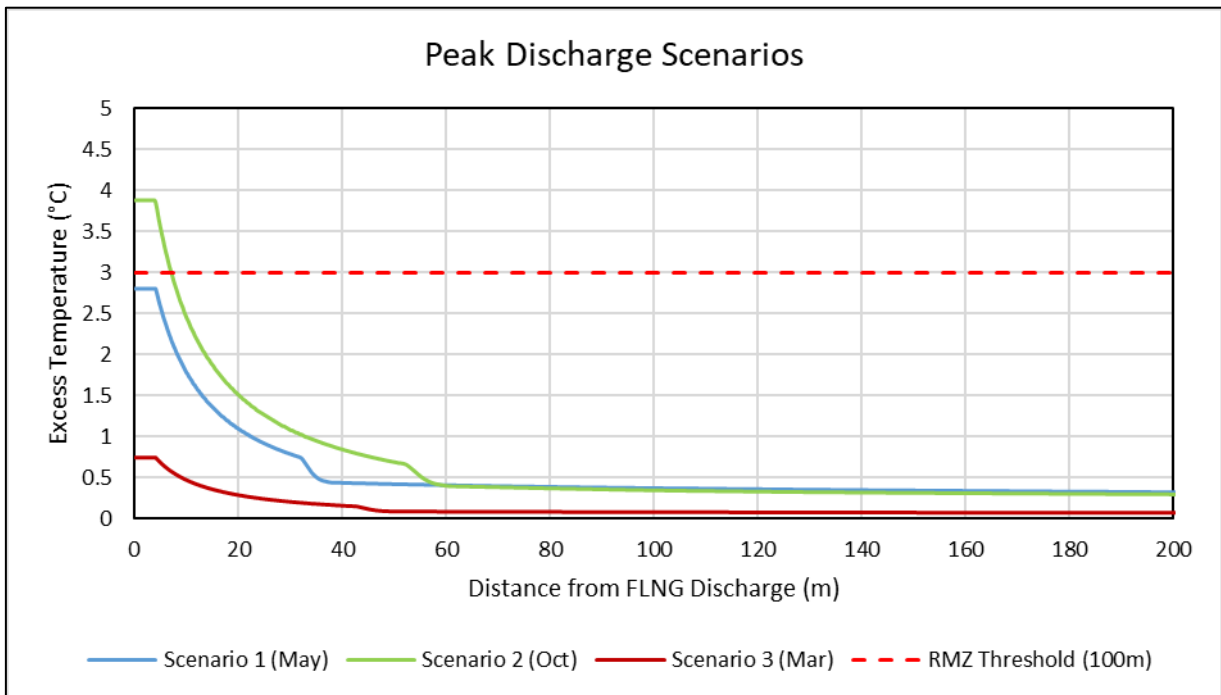
The steady state temperature rise results for the cooling water discharge under average discharge for the three scenarios are shown in Figure AVII.31. As can be seen, the temperature rise was predicted to be far below the 3 °C standard at distances of less than 10 m from the outfall. At the edge of the mixing zone the maximum increase is under 0.4°C.



**Figure AVII.31: Steady state temperature rise during cooling water discharge simulation for all average discharge scenarios**

#### AVII.3.3.5.2. Peak Discharge

The steady state temperature rise results for the cooling water discharge under peak discharge for the three scenarios are shown in Figure AVII.32. As can be seen, the temperature rise was predicted to be far below the 3 °C standard at distances of less than 10 m from the outfall. At the edge of the mixing zone the maximum increase is under 0.37°C.



**Figure AVII.32: Steady state temperature rise during cooling water discharge simulation for all peak discharge scenarios**

## AVII.3.4. Produced Water Discharge Model

### AVII.3.4.1. Model Setup

The effect of produced water discharge will be estimated by modelling the contribution of the discharge to the ambient water column concentrations. These concentrations will be calculated using the maximum surface constituent concentration (i.e., minimum dilution) computed by the model DHI MIKE, based on the established hydrodynamic modelling (see Section AVII.3.2 for the hydrodynamic methodology details).

The effluent data provided by MRV characterizes the treated produced water for three constituents with temperature also added due to its effects on marine life:

- Five-day biological oxygen demand (BOD<sub>5</sub>);
- Total suspended solids (TSS);
- Oil (assumed to represent oil and grease);
- Temperature

It should be noted that even though the abstracted produced water is known to have relevant concentrations of phenols, this constituent was not included in this assessment, as the FLNG's produced water treatment system is designed to reduce phenol concentrations in the discharged treated effluent up to 0.5 mg/l. This end-of-pipe concentration complies with the national ambient water quality standard, and as such no relevant effect is expected to result from this discharge.

A nested 3-D model with extent of approx. 30 km by 30 km centred at the FLNG site will be created with a higher resolution of approx. 30 m.

### AVII.3.4.2. Inputs and Standards

#### Input Condition Data

- The boundary conditions for the nested near-field model (DHI MIKE) were derived from the regional far-field, low resolution hydrodynamic model output.

#### Ambient Seawater Quality Standards

The ambient seawater quality standards used for the constituents are provided in Table AVII.19, with the treated effluent produced water limits provided in Table AVII.20.

**Table AVII.19: Ambient seawater quality standards for the constituents modelled for the produced water discharge**

Parameter	Unit	Ambient quality standard
Temperature	°C	<3 change 100 m from point of discharge <sup>a</sup>
BOD <sub>5</sub>	mg/L	5 <sup>b</sup>

References: <sup>a</sup> IFC EHS Guidelines for Offshore Oil and Gas Developments. <sup>b</sup> Annex V, Decree No. 18/2004 (as amended by Decree No. 67/2010).

**Table AVII.20: Treated produced water effluent limits**

Parameter	Project Standard <sup>a</sup>
Oil content	42 mg/L (daily maximum) 29 mg/L (monthly average)

Reference: <sup>a</sup> IFC EHS Guidelines for Offshore Oil and Gas Developments.

### AVII.3.4.3. Scenarios

Table AVII.21 summarizes the overview of modelling scenarios for the DHI MIKE model, while Table AVII.22 and Table AVII.23 summarize the produced water discharge flow rates and discharge concentrations, respectively. In these simulations, the discharge will be assumed to be continuous throughout the monthly simulation periods, as described in Section AVII.3.2.5.

Results indicate an assessment of incremental excess concentrations.

For the modelling, it was estimated that discharge will be to the model segment that represents the top 5 m below sea level. As the discharge depth is projected to be 10 m; due to the rapid dilution of solutes observed within the model domain at the initial discharge depth corresponding to the surface layer of the model ranging from 0 to 5 m below MSL, the model was not updated as the results indicate that discharging at 10 m depth would have an insignificant impact on dilution. In this case, this scenario is viewed as a conservative worst-case approach.

**Table AVII.21: Modelling scenarios**

Modelling Component	Hydrodynamic Conditions	Discharge Condition
Oil and Grease	High Current Speed (Scenario 1)	Average / Peak
	Low Current Speed (Scenario 2)	
	Typical Current Speed (Scenario 3)	
BOD <sub>5</sub>	High Current Speed (Scenario 1)	Average / Peak
	Low Current Speed (Scenario 2)	
	Typical Current Speed (Scenario 3)	
TSS	High Current Speed (Scenario 1)	Average / Peak
	Low Current Speed (Scenario 2)	
	Typical Current Speed (Scenario 3)	
Temperature	High Current Speed (Scenario 1)	Average / Peak
	Low Current Speed (Scenario 2)	
	Typical Current Speed (Scenario 3)	

**Table AVII.22: Produced water discharge flow rates**

Description	Average Discharge		Peak Discharge	
	m <sup>3</sup> /hr	m <sup>3</sup> /s	m <sup>3</sup> /hr	m <sup>3</sup> /s
Flow rate	32	0.00889	62	0.01722

**Table AVII.23: Effluent discharge concentrations**

Constituent	Unit	Discharge Concentration
Oil and Grease	mg/L	10
BOD <sub>5</sub>	mg/L	599
TSS	mg/L	35
Temperature	°C	38

#### AVII.3.4.4. Model Results

The produced water dispersion model was run over three separate one-month simulation periods (see Table AVII.21). The simulations included a 7-day spin-up period prior to the start dates to allow for the water levels, and currents to stabilise (the spin-up period is however excluded in the post-processing of results). The relevant outputs of the model are temperature and various solutes (oil and grease, BOD<sub>5</sub>, TSS), modelled as conservative tracers, concentrations at hourly intervals over the duration of each simulation.

The produced water dispersion model results have been processed to provide the statistical maximum and high-percentile values of temperature rise as well as the percentage of exceedance above the specified threshold of 3 °C. Only the statistical maximum values of rise in concentration

for the various solutes are provided. Mixing zones with radii of 100 m and 300 m are shown as dashed circles on the temperature and solutes plots, respectively. Plots are presented according to a scale of values with the maximum value representing the relevant threshold, if applicable. In cases where no plumes are visible for the relevant threshold value, an additional plot is provided according to a lower scale of values in order to present the behaviour of the plume, albeit with insignificantly low values.

Percentiles are statistical terms used to describe how certain values compare to other values within the same dataset. A value at the 95<sup>th</sup> percentile mark indicates that 95% of the values in the dataset are smaller and 5% of the values are greater than that value. Therefore, the 95<sup>th</sup> and 99<sup>th</sup> percentile values are accurate representations of what can be expected as extreme high-percentile values and have been used here to produce extreme plume behaviours plots.

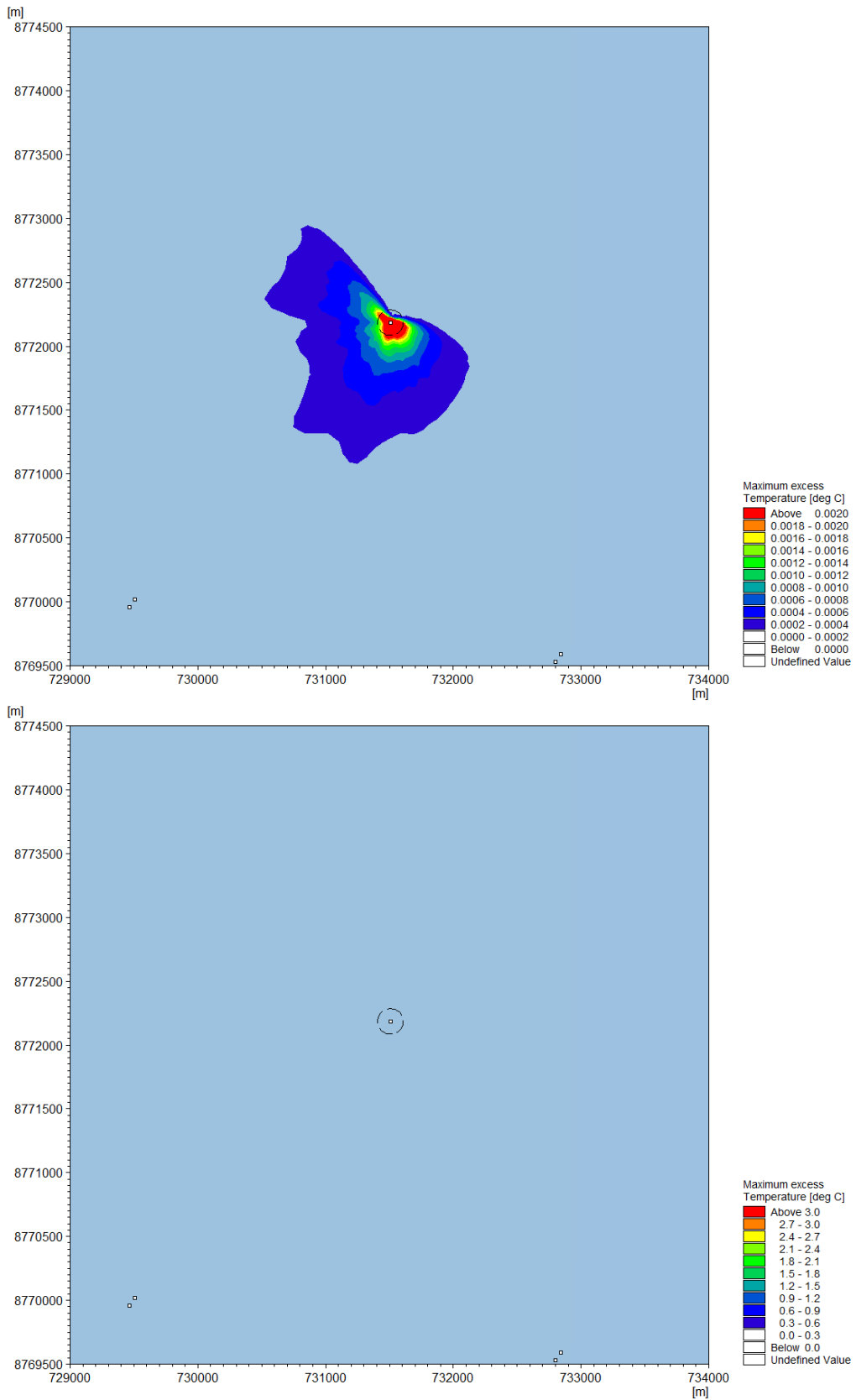
Percentage of exceedance plots show the duration as a percentage of the run time that excess concentrations exceed a specified threshold.

#### **AVII.3.4.4.1. Peak Discharge – Scenario 1 (May)**

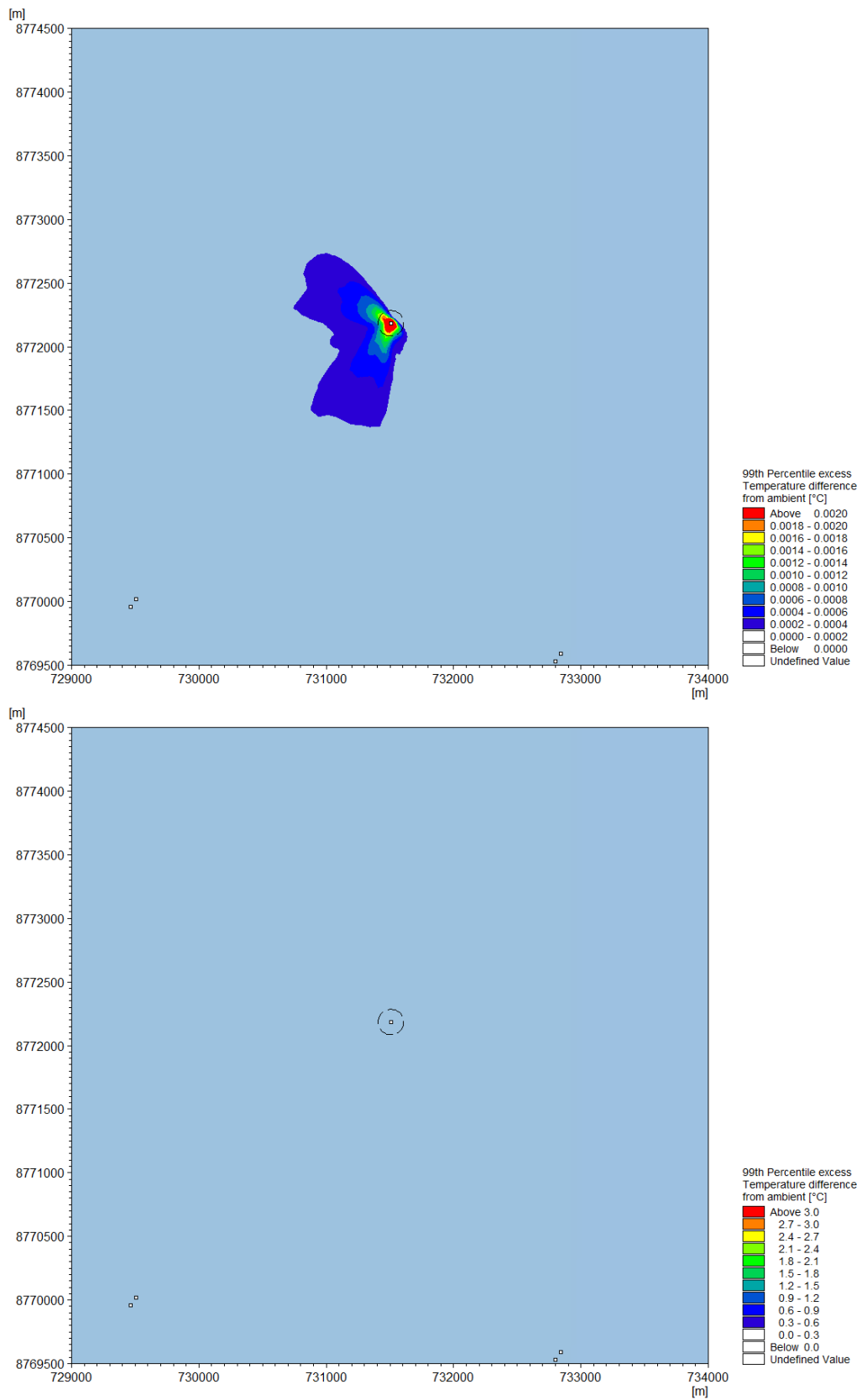
Spatial plots for the statistical maximum, 99<sup>th</sup>-, and 95<sup>th</sup> percentile excess temperature values are provided in Figure AVII.33 to Figure AVII.35 for the high current speed scenario (May).

The percentage of exceedance plot for excess temperature is provided in Figure AVII.36.

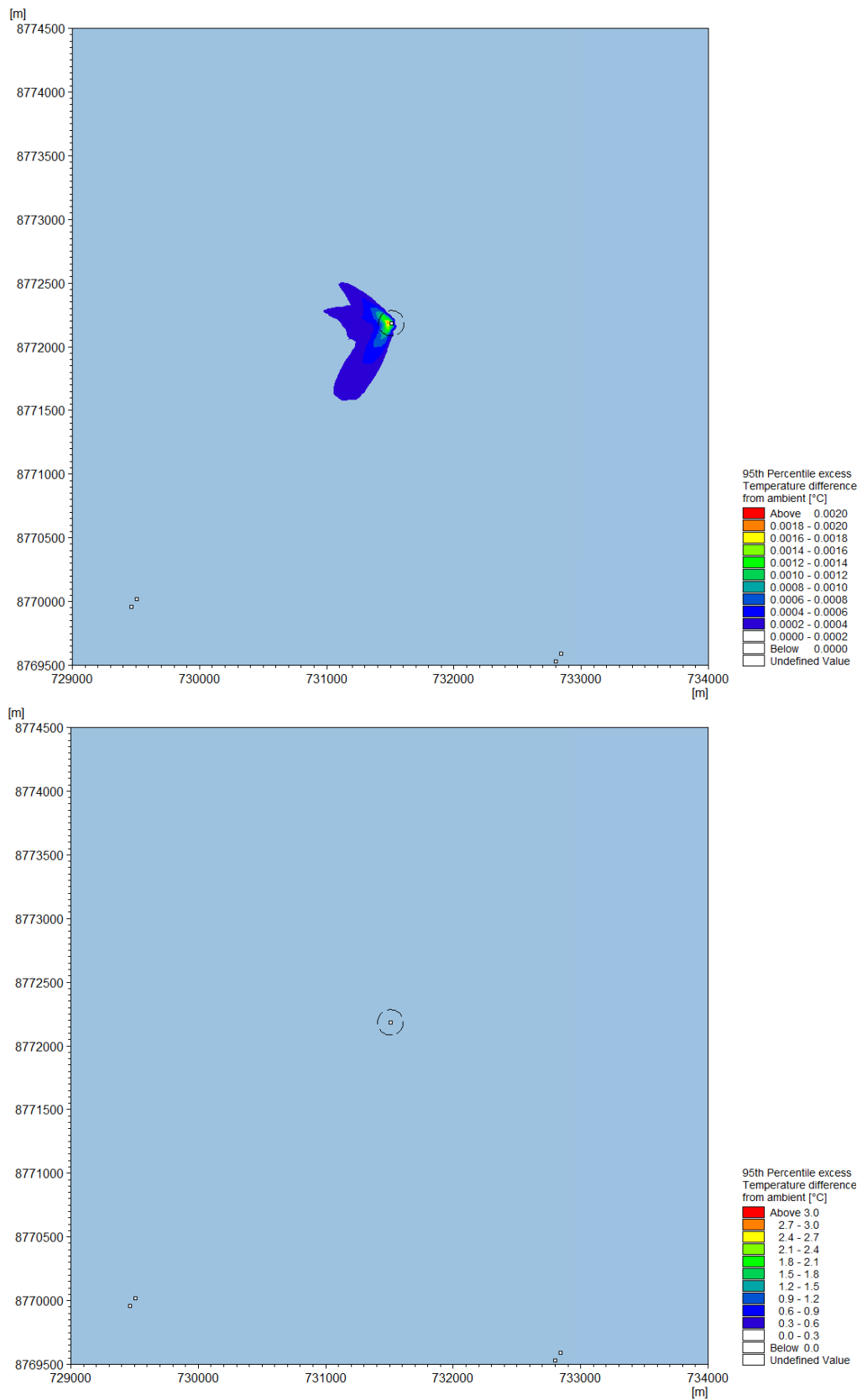
Spatial plots for the statistical maximum excess solutes (oil and grease, BOD<sub>5</sub>, TSS) concentration values are provided in Figure AVII.37 to Figure AVII.39.



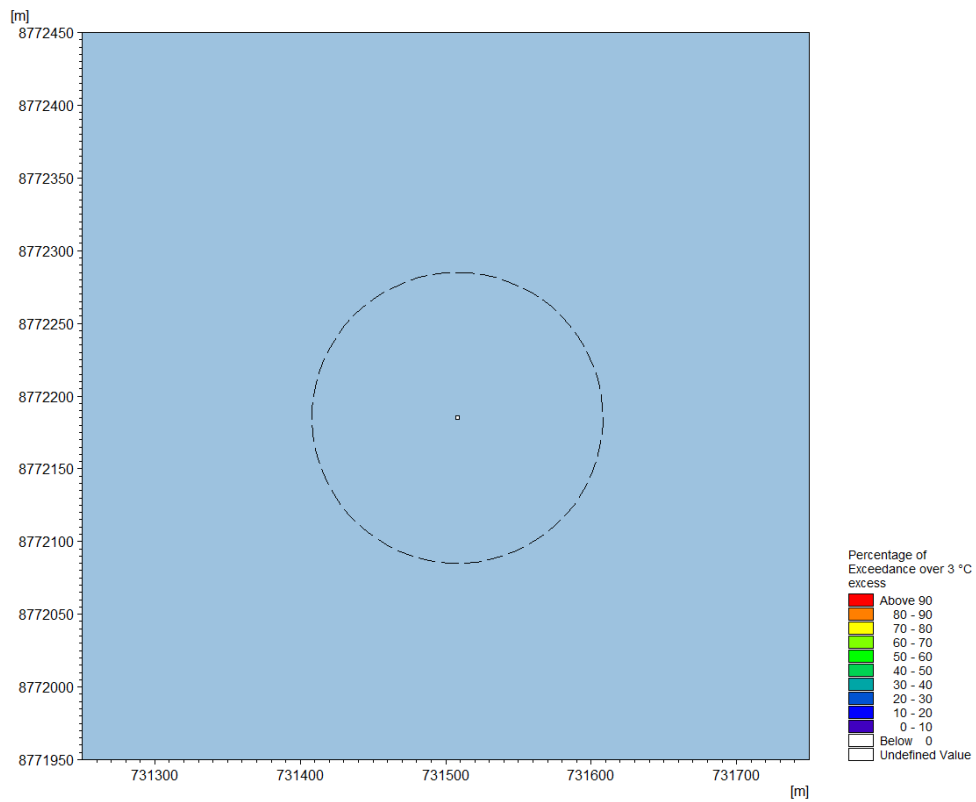
**Figure AVII.33: Maximum temperature rise during produced water discharge simulation for Scenario 1. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



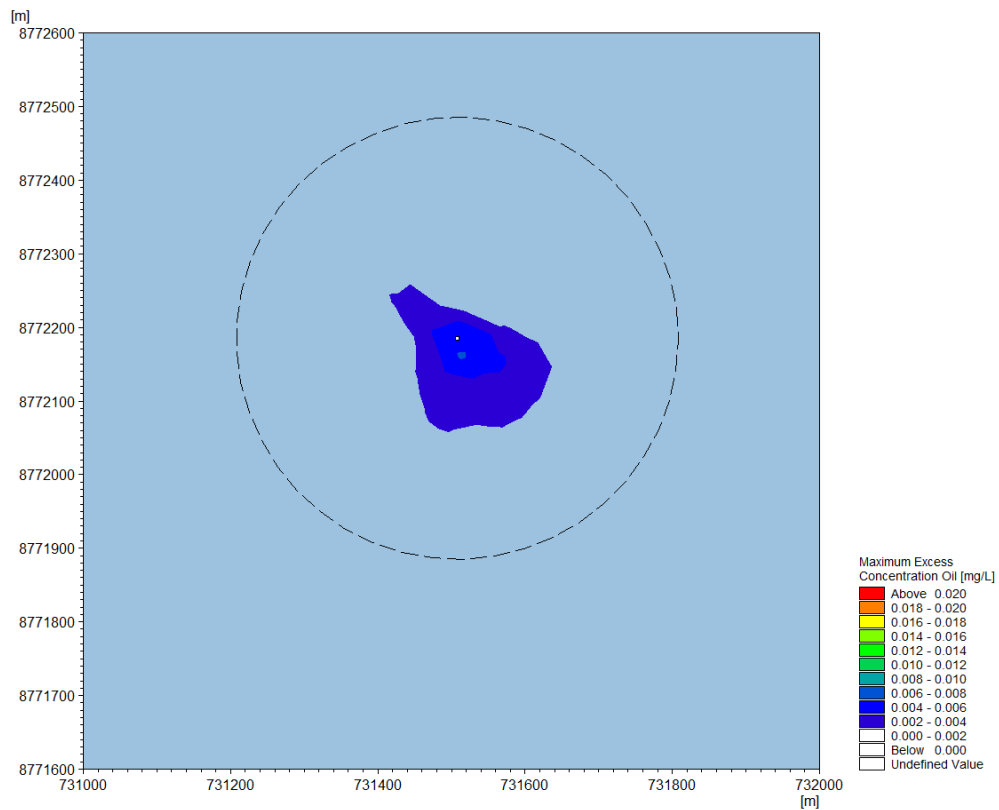
**Figure AVII.34: 99<sup>th</sup> Percentile temperature rise during produced water discharge simulation for Scenario 1. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



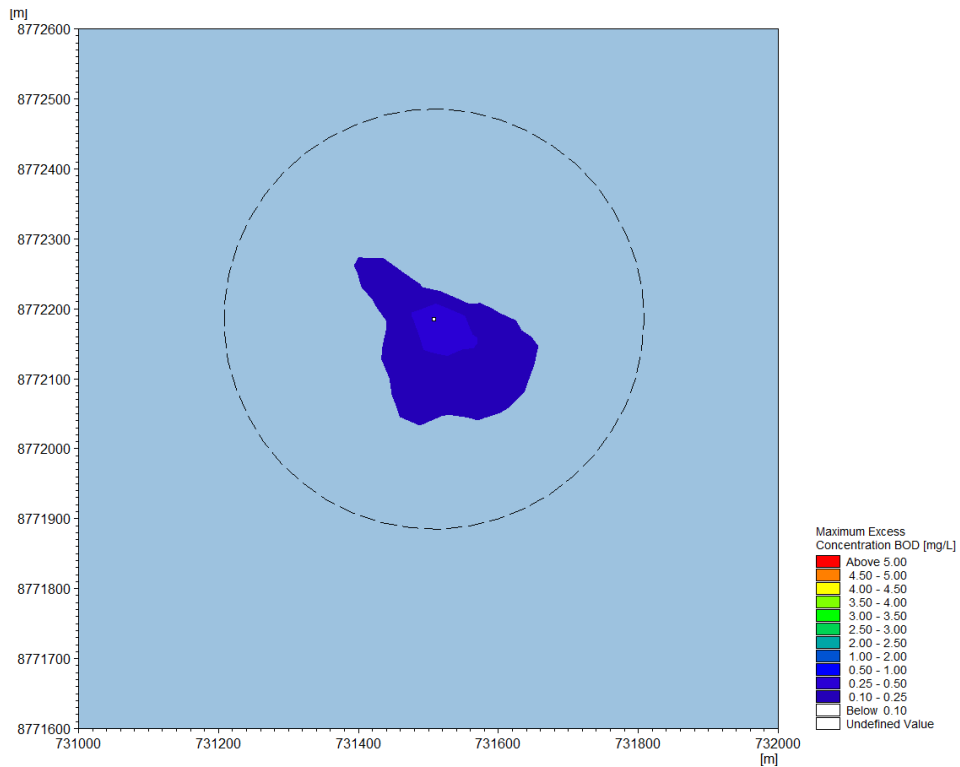
**Figure AVII.35: 95<sup>th</sup> Percentile temperature rise during produced water discharge simulation for Scenario 1. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



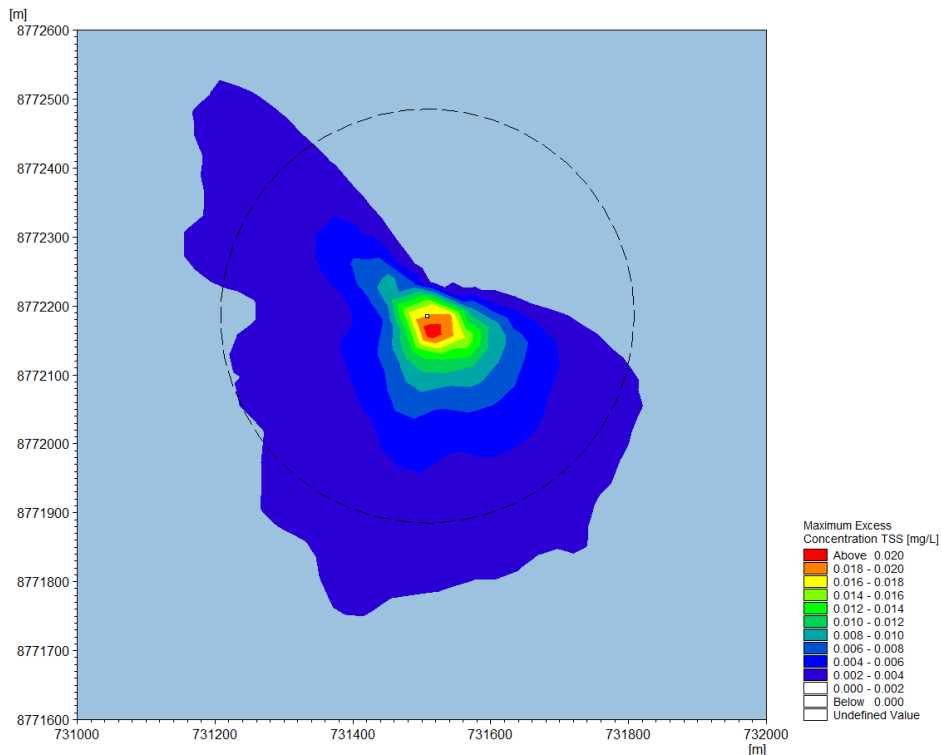
**Figure AVII.36: Percentage of exceedance of 3 °C threshold temperature rise during produced water discharge simulation for Scenario 1**



**Figure AVII.37: Maximum oil and grease concentration rise during produced water discharge simulation for Scenario 1 (thresholds of 0.02 mg/L)**



**Figure AVII.38: Maximum BOD<sub>5</sub> concentration rise during produced water discharge simulation for Scenario 1 (thresholds of 5 mg/L)**



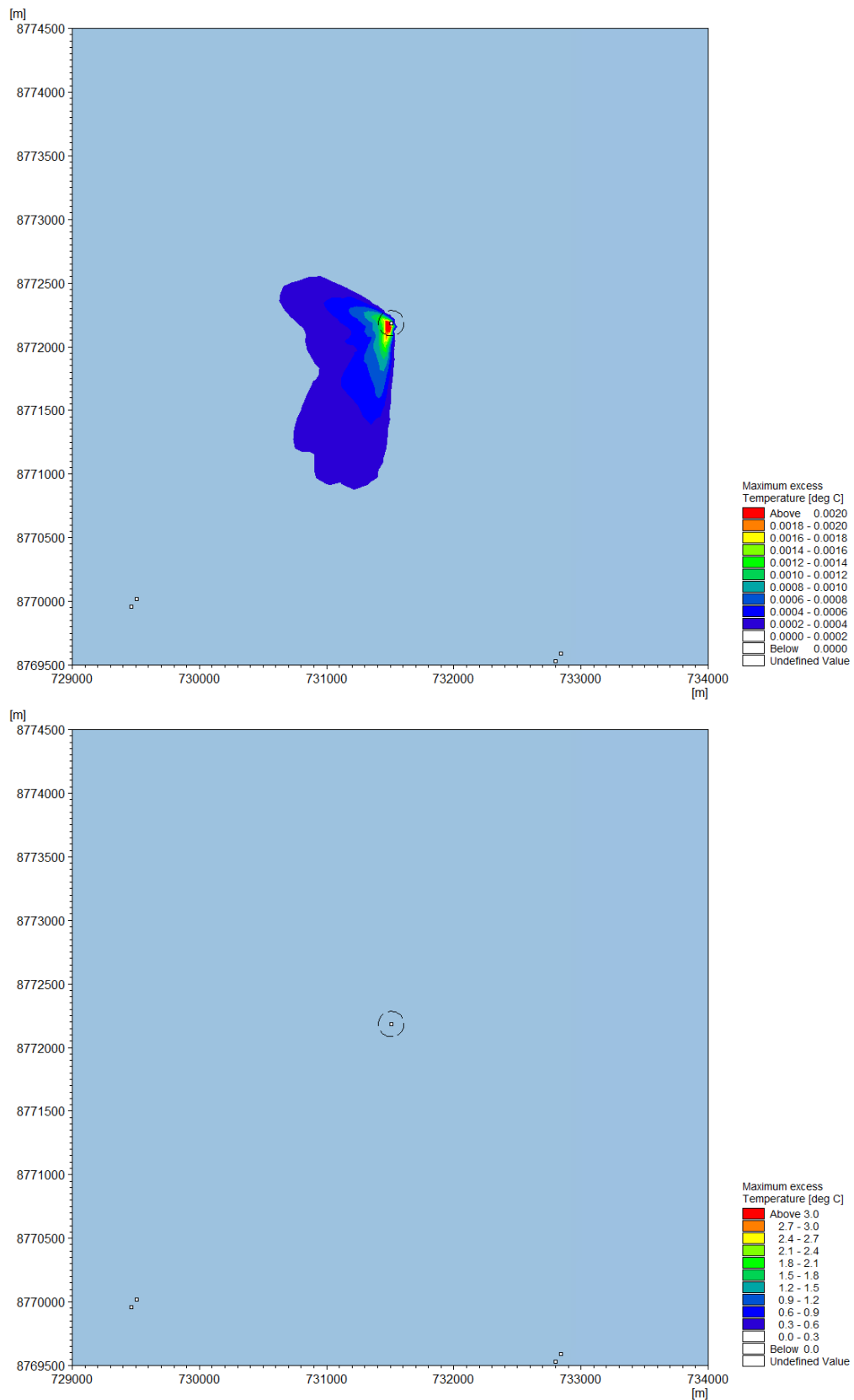
**Figure AVII.39: Maximum TSS concentration rise during produced water discharge simulation for Scenario 1 (thresholds of 0.02 mg/L)**

#### **AVII.3.4.4.2. Peak Discharge – Scenario 2 (October)**

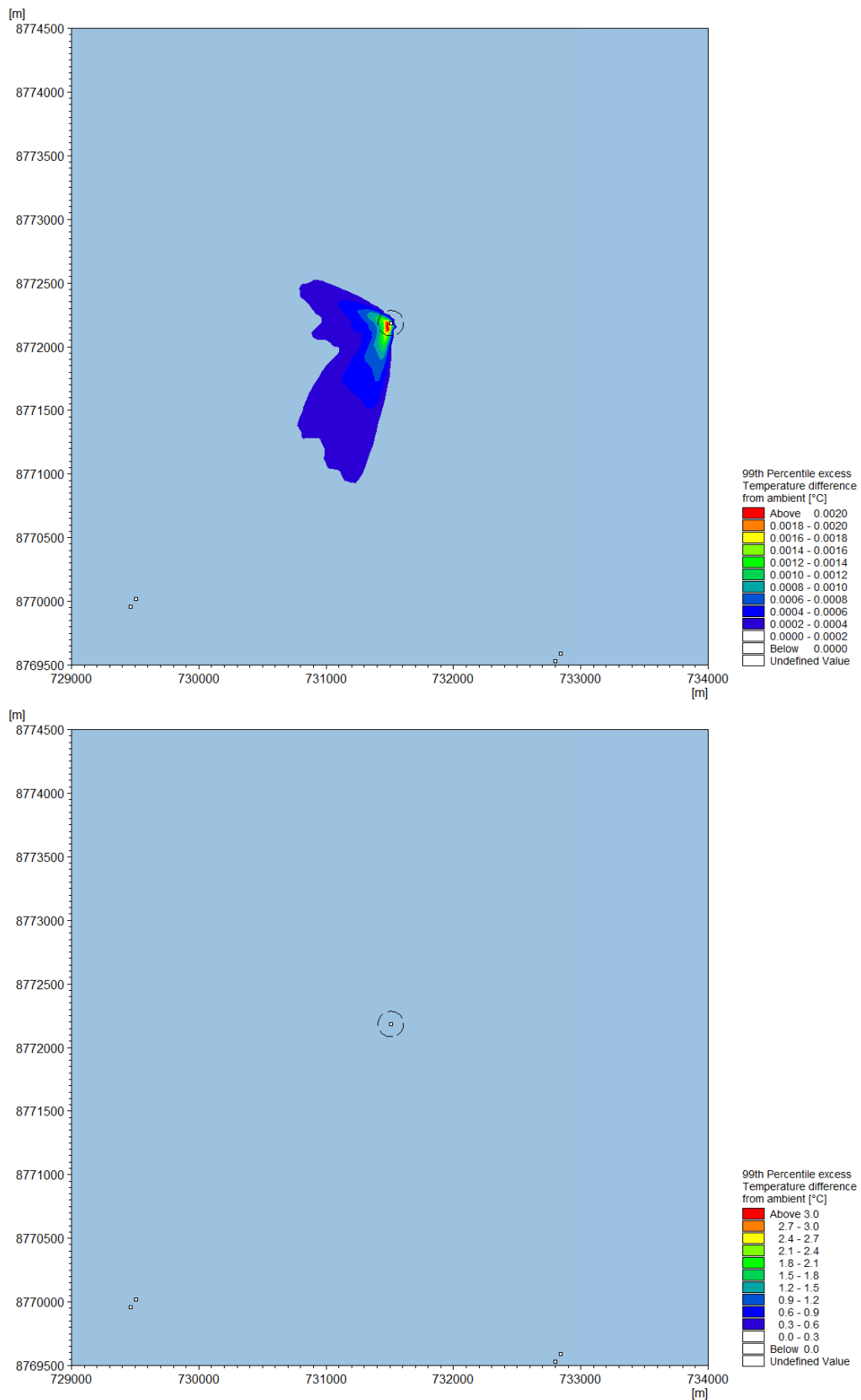
Spatial plots for the statistical maximum, 99<sup>th</sup>-, and 95<sup>th</sup> percentile excess temperature values are provided in Figure AVII.40 to Figure AVII.42 for the low current speed scenario (October).

The percentage of exceedance plot for excess temperature is provided in Figure AVII.43.

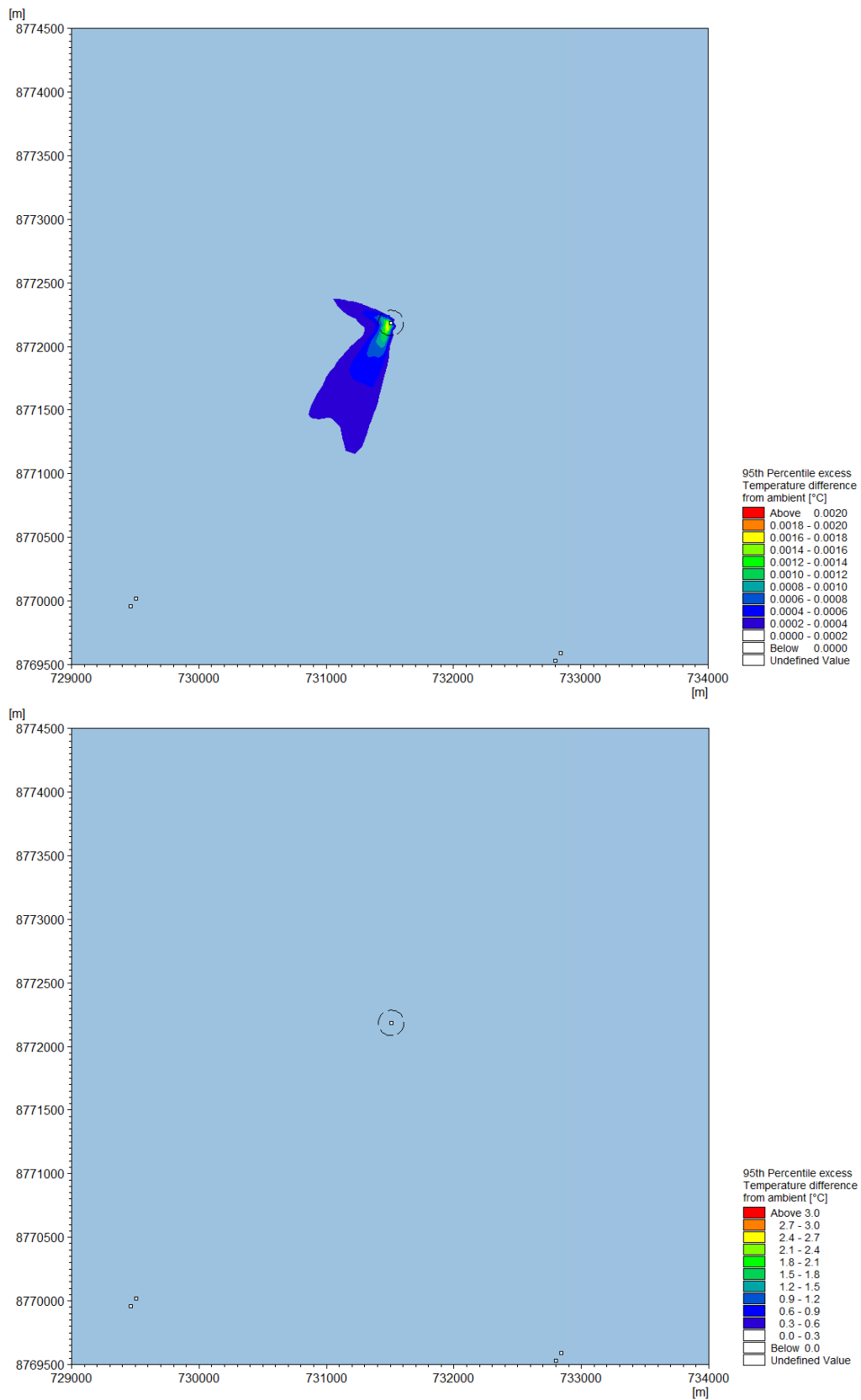
Spatial plots for the statistical maximum excess solutes (oil and grease, BOD<sub>5</sub>, TSS) concentration values are provided in Figure AVII.44 to Figure AVII.46.



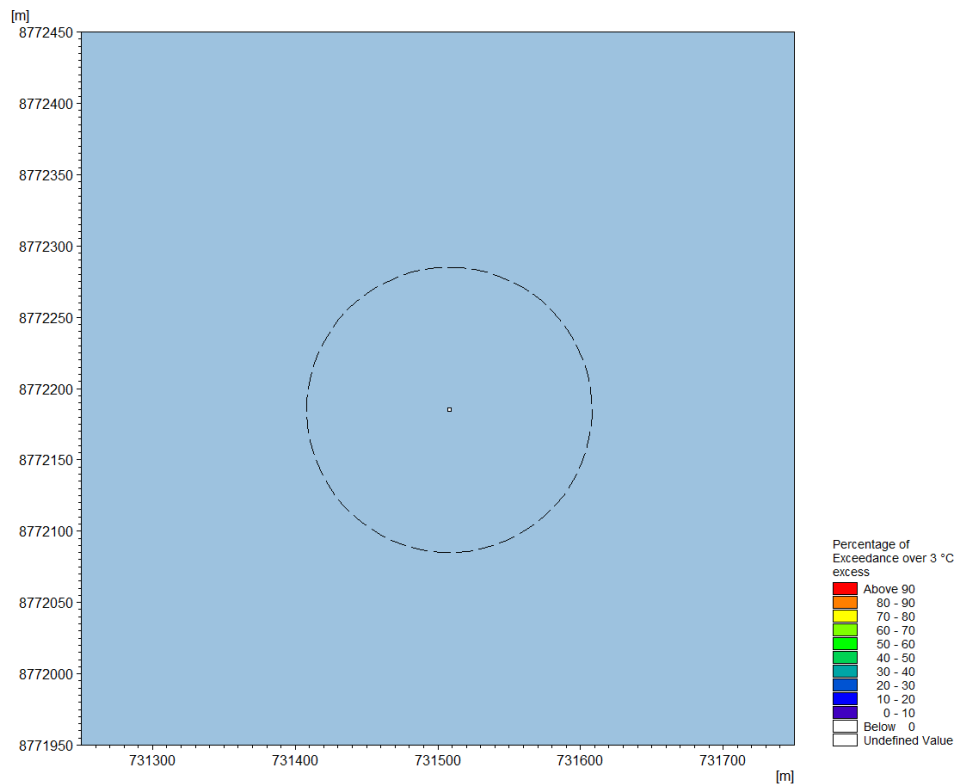
**Figure AVII.40: Maximum temperature rise during produced water discharge simulation for Scenario 2. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



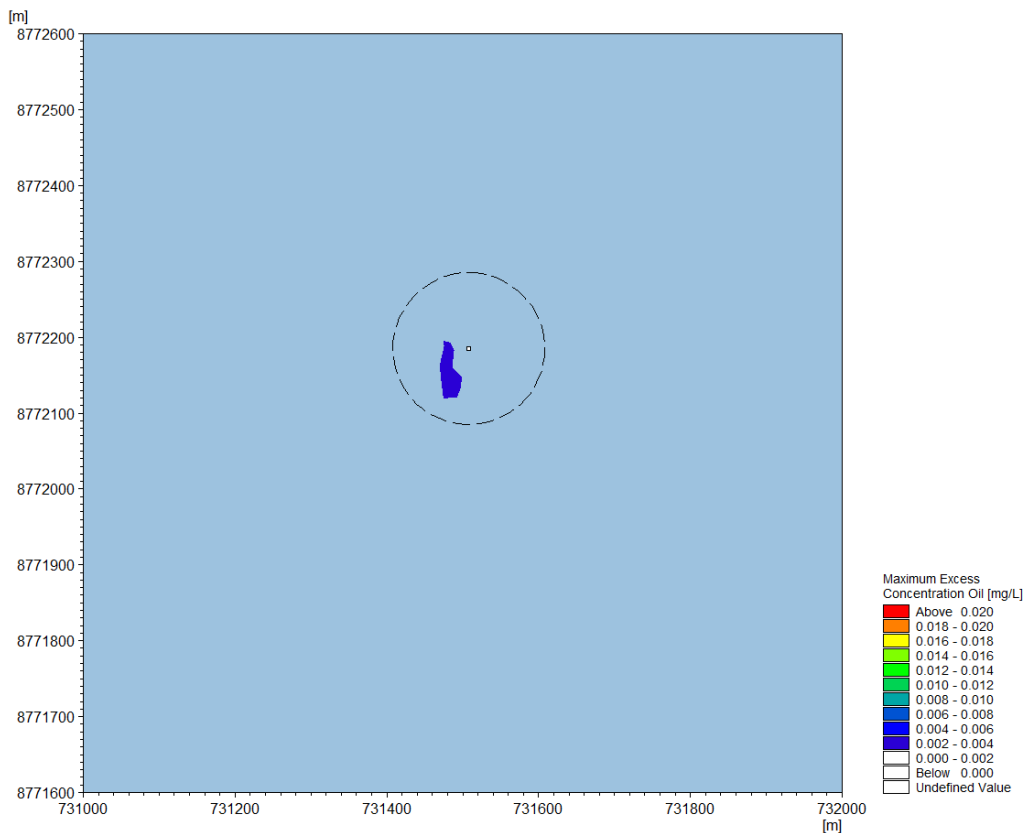
**Figure AVII.41: 99<sup>th</sup> Percentile temperature rise during produced water discharge simulation for Scenario 2. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



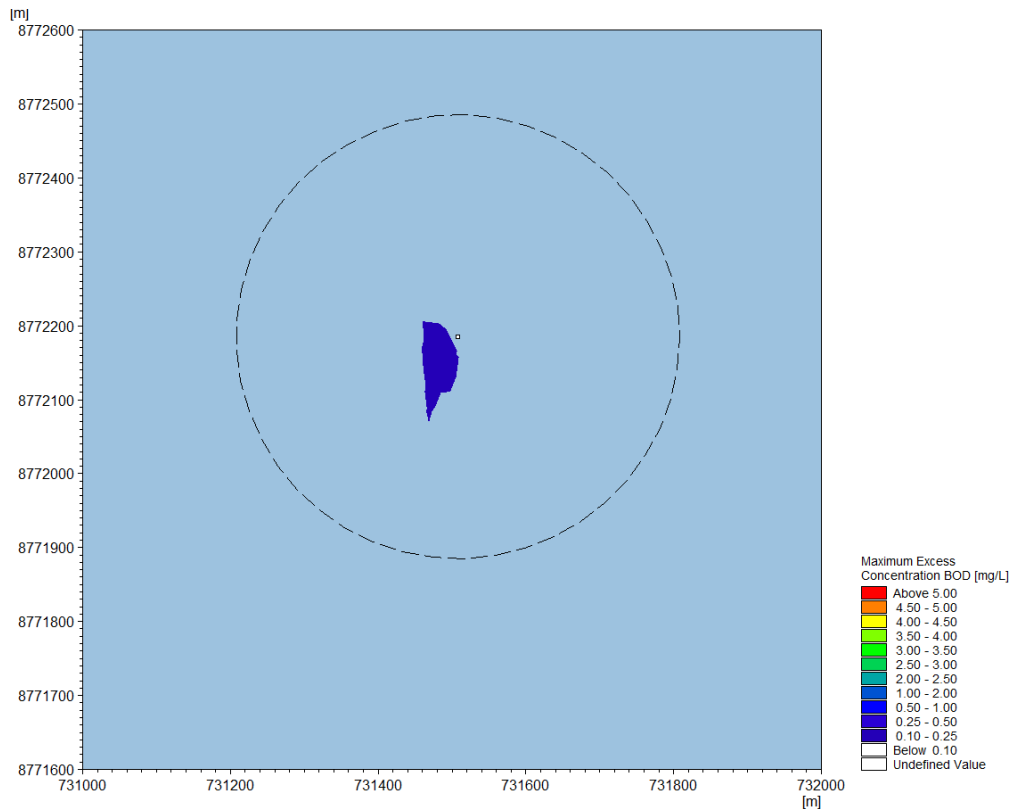
**Figure AVII.42: 95<sup>th</sup> Percentile temperature rise during produced water discharge simulation for Scenario 2. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



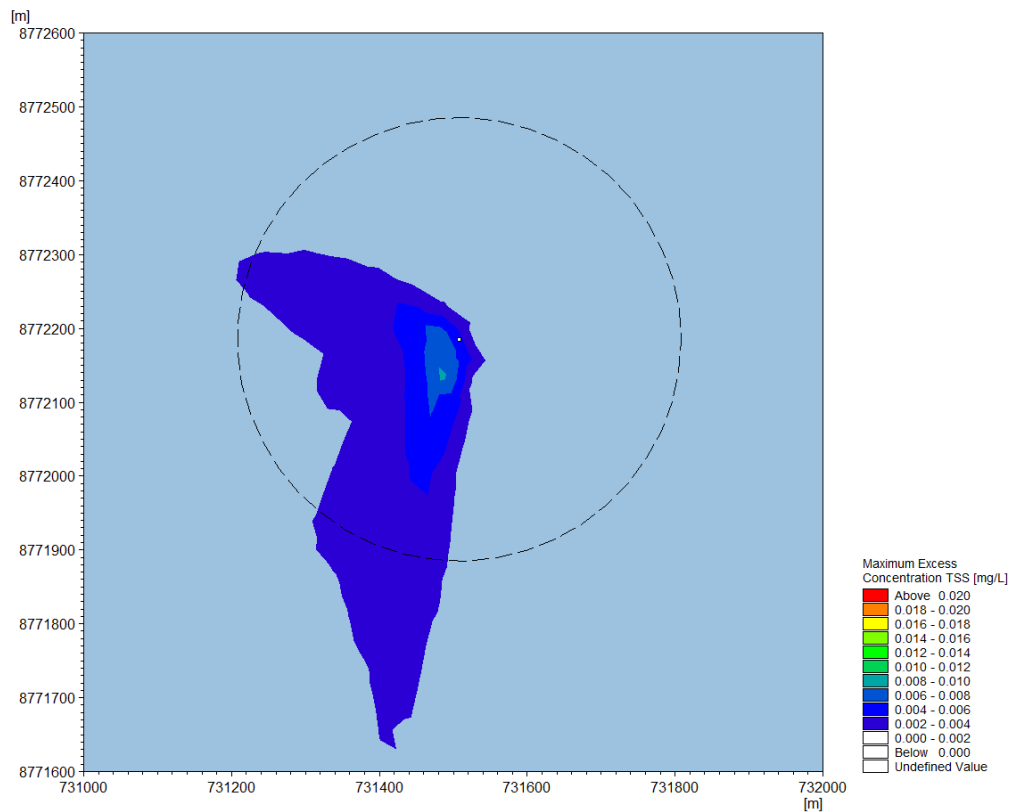
**Figure AVII.43: Percentage of exceedance of 3 °C threshold temperature rise during produced water discharge simulation for Scenario 2**



**Figure AVII.44: Maximum oil and grease concentration rise during produced water discharge simulation for Scenario 2 (thresholds of 0.02 mg/L)**



**Figure AVII.45: Maximum BOD<sub>5</sub> concentration rise during produced water discharge simulation for Scenario 2 (thresholds of 5 mg/L)**



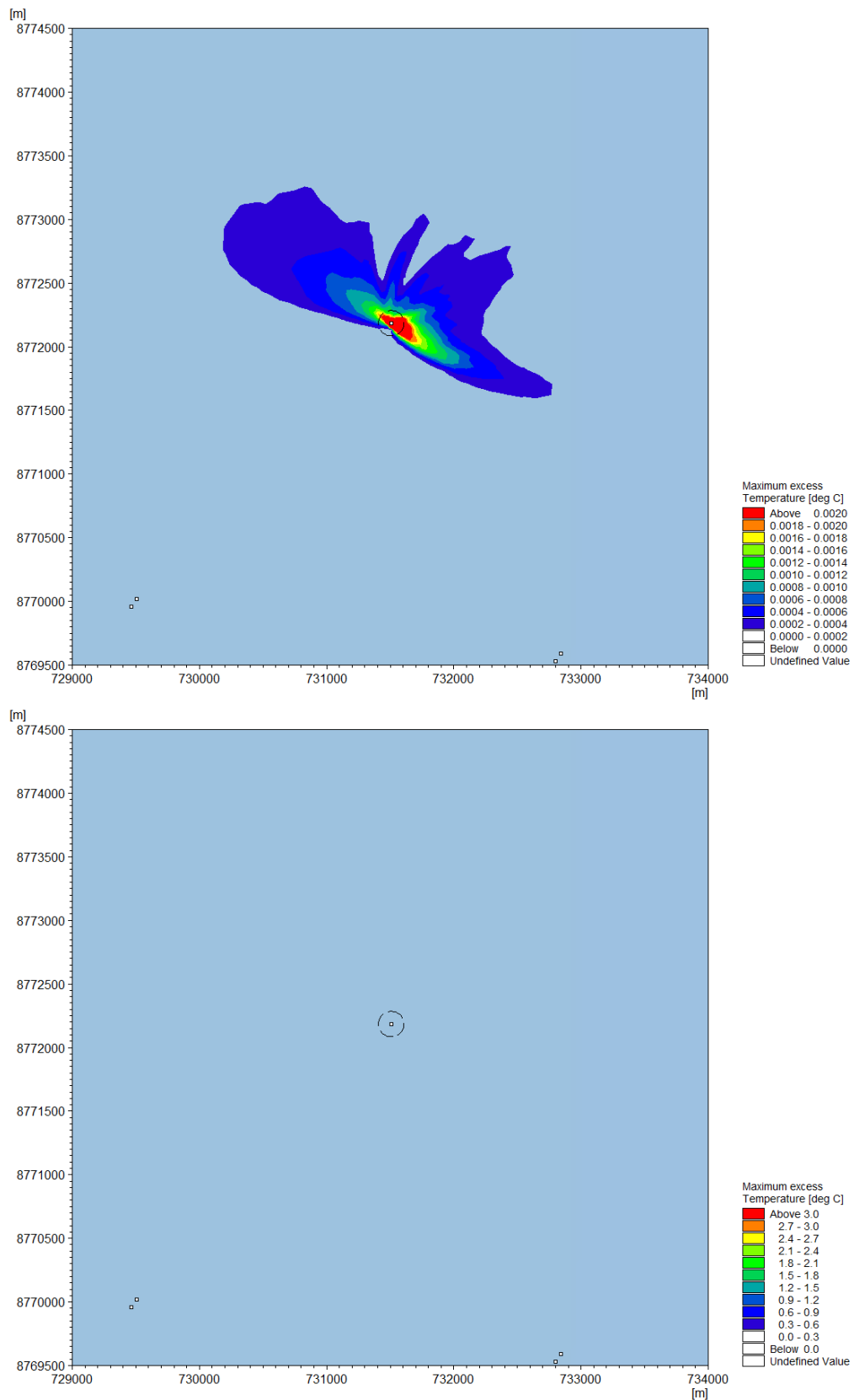
**Figure AVII.46: Maximum TSS concentration rise during produced water discharge simulation for Scenario 2 (thresholds of 0.02 mg/L)**

#### **AVII.3.4.4.3. Peak Discharge – Scenario 3 (March)**

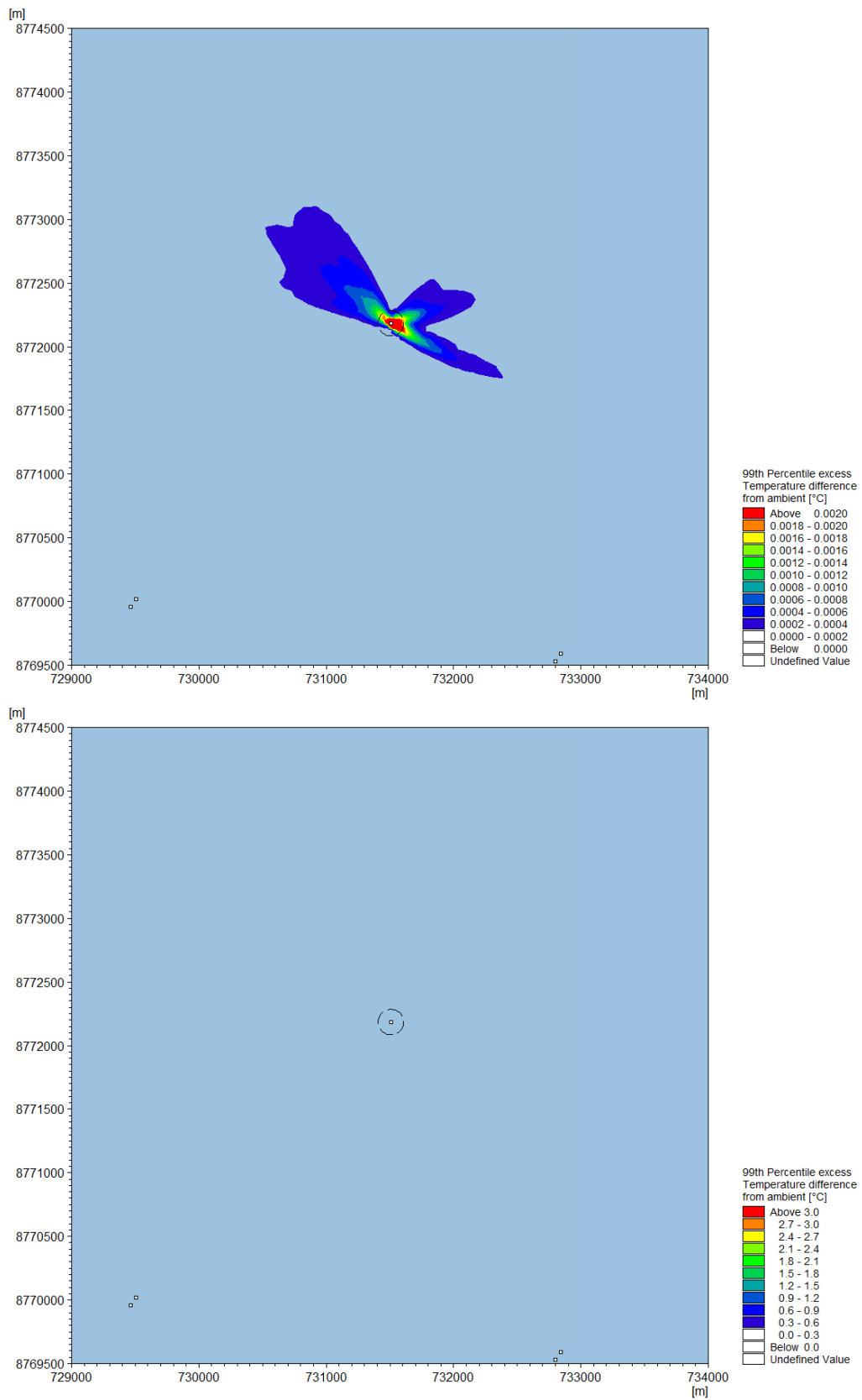
Spatial plots for the statistical maximum, 99<sup>th</sup>-, and 95<sup>th</sup> percentile excess temperature values are provided in Figure AVII.47 to Figure AVII.49 for the typical current speed scenario (March).

The percentage of exceedance plot for excess temperature is provided in Figure AVII.50.

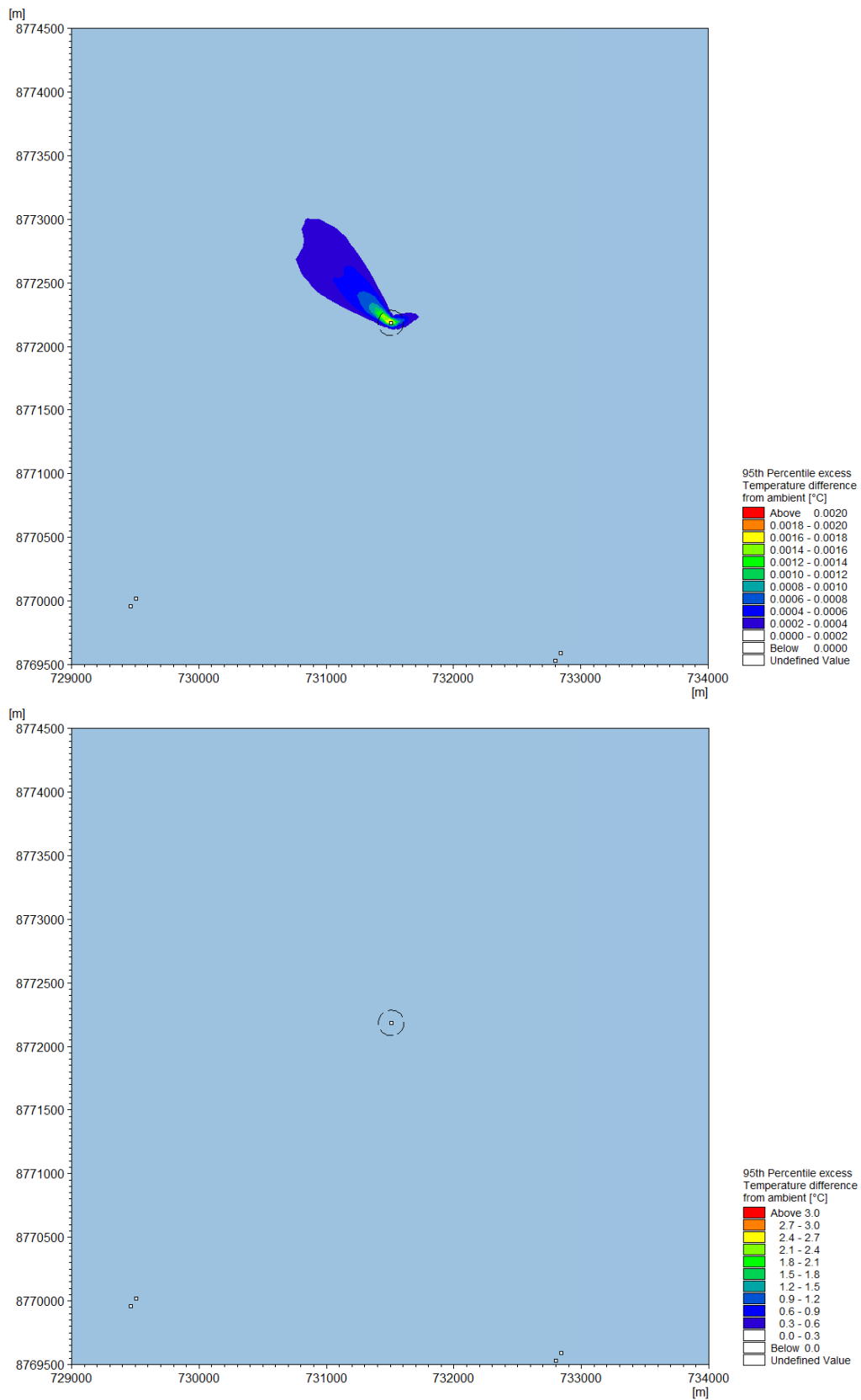
Spatial plots for the statistical maximum excess solutes (oil and grease, BOD<sub>5</sub>, TSS) concentration values are provided in Figure AVII.51 to Figure AVII.53.



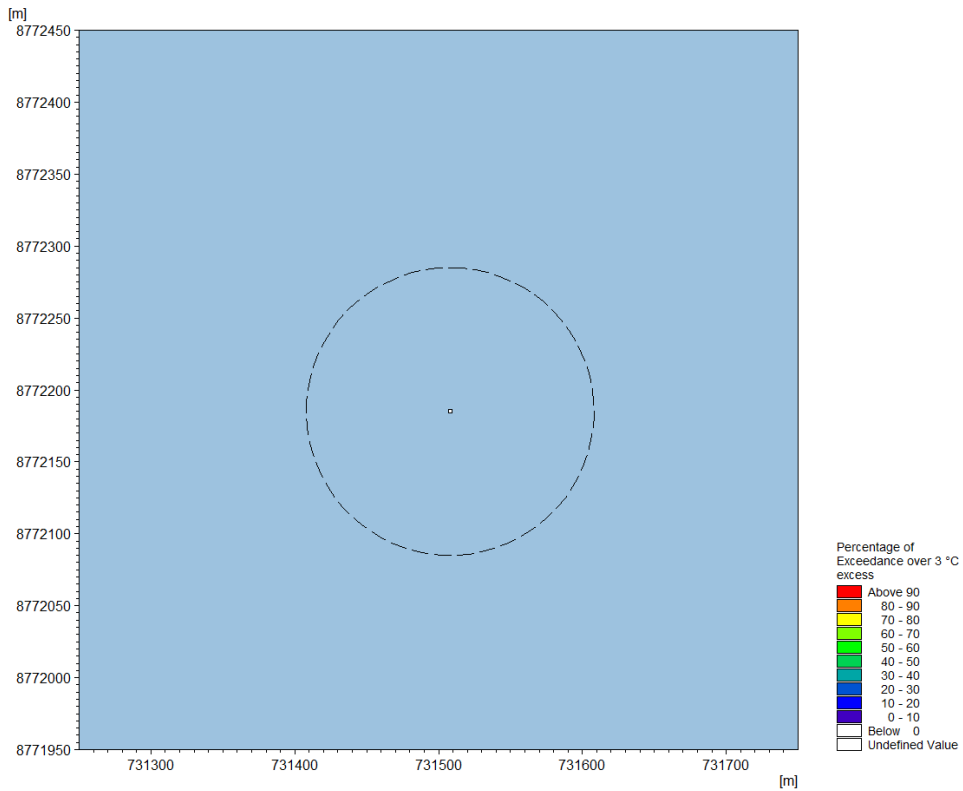
**Figure AVII.47: Maximum temperature rise during produced water discharge simulation for Scenario 3. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



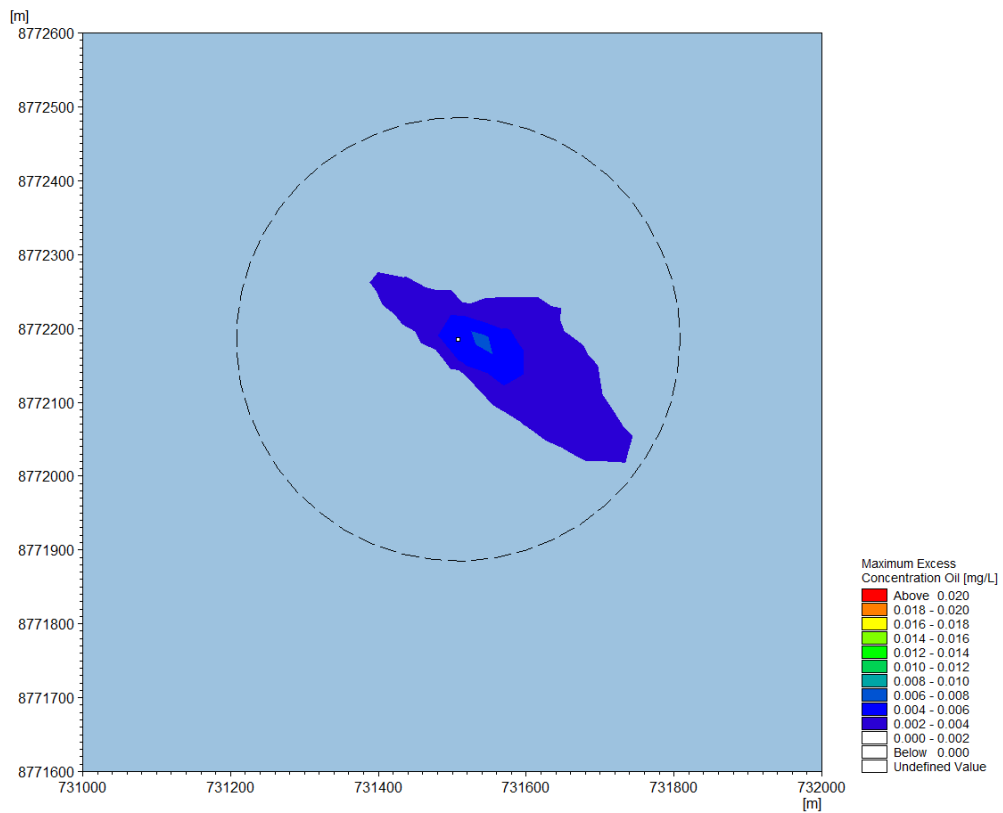
**Figure AVII.48: 99<sup>th</sup> Percentile temperature rise during produced water discharge simulation for Scenario 3. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



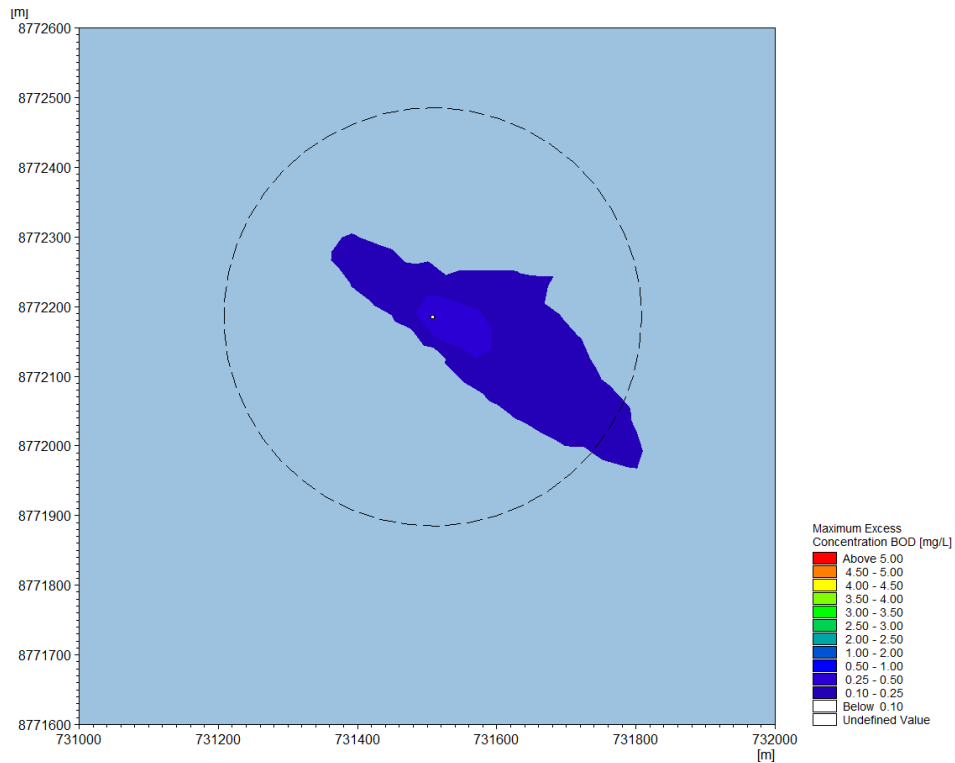
**Figure AVII.49: 95<sup>th</sup> Percentile temperature rise during produced water discharge simulation for Scenario 3. Thresholds of 0.002 °C (top) and 3 °C (bottom)**



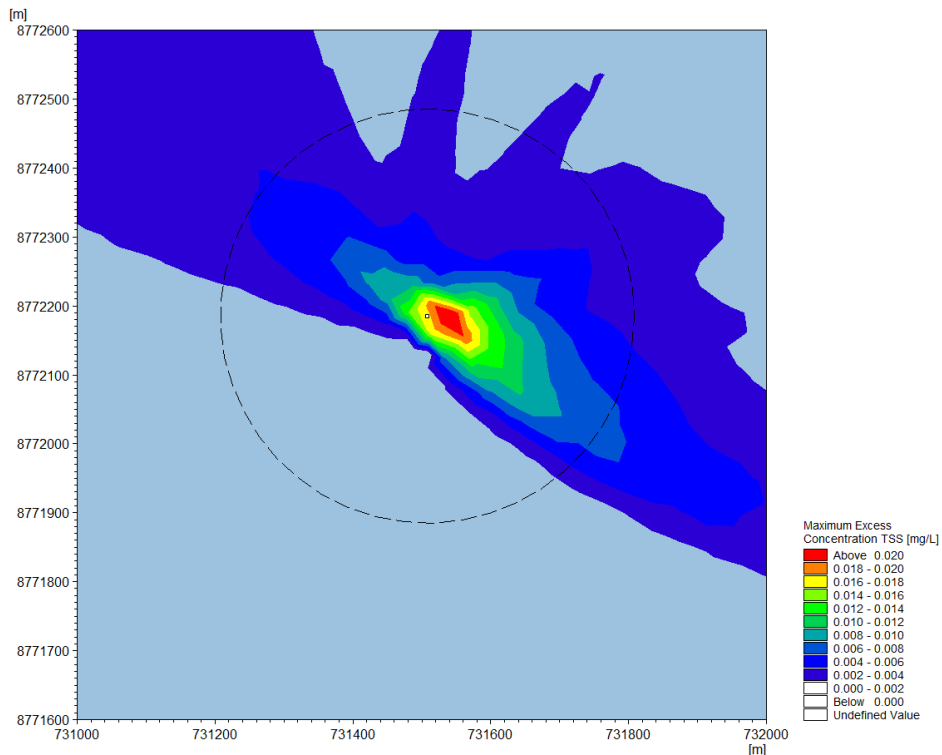
**Figure AVII.50: Percentage of exceedance of 3 °C threshold temperature rise during produced water discharge simulation for Scenario 3**



**Figure AVII.51: Maximum oil and grease concentration rise during produced water discharge simulation for Scenario 3 (thresholds of 0.02 mg/L)**



**Figure AVII.52: Maximum BOD<sub>5</sub> concentration rise during produced water discharge simulation for Scenario 3 (thresholds of 5 mg/L)**



**Figure AVII.53: Maximum TSS concentration rise during produced water discharge simulation for Scenario 3 (thresholds of 0.02 mg/L)**

#### AVII.3.4.4.4. Peak Discharge – Summary

A summary of the maximum temperature rise for the three scenarios is shown in Table AVII.24. According to the standards for ambient seawater, the temperature rise should not exceed 3 °C at the edge of the mixing zone. As seen from the summary below, a similar maximum temperature rise across all three scenarios of 0.003 °C was predicted at 100 m from the discharge, which is well below the 3 °C standard.

**Table AVII.24: Maximum temperature rise for the three scenarios under produced water peak discharge**

Scenario	Maximum temperature rise (° C) at 100 m from discharge
Scenario 1 (May)	0.003 (ESE direction)
Scenario 2 (October)	0.003 (SSW direction)
Scenario 3 (March)	0.003 (SE direction)

A summary of the maximum solute concentrations for the three scenarios is shown in Table AVII.25. The minimum dilution occurs at the grid cell containing the outfall. The discharge is diluted by a factor of 900, 3100, and 900 for Scenarios 01, 02, and 03 respectively.

As seen from Table AVII.19, the applicable standard for parameter BOD<sub>5</sub> is 5 mg/L. The model results show that the predicted BOD<sub>5</sub> concentrations are significantly lower than the standard, with the highest value being 0.67 mg/l. The highest predicted values for oil and grease and TSS are 0.011 mg/L and 0.039 mg/L, respectively.

**Table AVII.25: Maximum predicted solute concentrations resulting from produced water peak discharge for all three scenarios**

Scenario	Initial Concentration (mg/L)			Maximum Concentration (mg/L)			Minimum Dilution Factor
	Oil and Grease	BOD <sub>5</sub>	TSS	Oil and Grease	BOD <sub>5</sub>	TSS	
Scenario 1	10	599	35	1.1E-2	6.7E-1	3.9E-2	900
Scenario 2	10	599	35	3.2E-3	1.9E-1	1.1E-2	3100
Scenario 3	10	599	35	1.1E-2	6.7E-1	3.9E-2	900

### AVII.3.5. Drill Cuttings Model

#### AVII.3.5.1. Modelling Approach

The DHI MIKE Mud Transport Module will be used to simulate the fate, transport, potential deposition, and increased TSS concentration above ambient values due to the release of drill cuttings with residual adhered base oil from the LTOBM (low toxicity oil base mud).

Six production wells were selected for modelling, representing the range of locations that may be drilled to produce natural gas (see Table AVII.13 and Figure AVII.11).

The top sections jetted material is released at the seafloor. All remaining drilled sections and related drilling materials will be recovered to the vessel and transferred to shore for treatment and disposal.

While this is the design option, an alternative procedure that may be required, if transfer to shore becomes unavailable for some reason, is the release of the drill cuttings from mean sea level after treatment onboard the drilling rig.

If the first option is executed (transfer for onshore treatment and disposal) no impacts on water quality will be experienced. However, given the possibility of offshore disposal, a modelling study was conducted to investigate potential impacts associated with this procedure. Offshore disposal would include treatment aboard the drilling rig. This treatment process consists of mud separation first, followed by thermal treatment, in order to reduce the amount of adhered residual LTOBM as much as possible. After this treatment, drill cuttings would then be discharged to sea. Material released at mean sea level will pass vertically through the water column, because cuttings and the adhered residual LTOBM are denser than the receiving water. Cuttings and adhered residual LTOBM dispersion is fundamentally a three-dimensional (3-D) phenomenon.

### **AVII.3.5.2. Model Setup**

A nested 3-D model with extent of approx. 30 km by 30 km will be created with a resolution of approx. 30 m at the area of interest (FLNG and wellhead locations).

#### Input Condition Data

- The input and boundary conditions (consisting of currents, water temperature, and salinity) for the nested model were derived from the regional far-field, low resolution hydrodynamic model output (see Section AVII.3.2).

### **AVII.3.5.3. Scenarios**

An analysis of the effects of the currents is required to determine the simulation period. This analysis attempts to capture a drill cutting release period that represent the most localized and highest magnitude impacts possible. Therefore, October 2013 was chosen for having the lowest average current speed, thereby posing the highest risk to benthic and life surrounding the release sites.

Estimated quantities and material properties of potential anticipated drill cuttings (Fraction 1) and adhered residual LTOBM (Fraction 2) to be discharged during drilling from the various wellhead locations are provided in Table AVII.26.

It is anticipated that some particles of the drilling mud may be discharged together/adhered with the drill cuttings, which typically ranges between 5 and 25%. For this study, the total amount of drilling fluid lost together with the disposed cuttings was assumed to be 5% of the volume of disposed cuttings during the drilling operations.

**Table AVII.26: Cuttings and muds discharge properties**

Parameter	Discharge Volume (m <sup>3</sup> )	Grain Diameter D <sub>50</sub> (mm)	Settling Velocity (m/s)*	Particle Density (kg/m <sup>3</sup> )
Fraction 1 - Drill cuttings	1 350	0.25	2.5051 x 10 <sup>-2</sup>	2 400
Fraction 2 - Drill Muds (LTOBM)	67.5	0.015	6.0122 x 10 <sup>-6</sup>	1 100

Note: \* Settling velocity formula according to Soulsby (1997).

The drilling operation is anticipated to reach a well depth of 2 800 m below seabed surface. At a rate of 20 m per hour, the duration of drilling is approx. 140 hours or 5.83 days (assuming 24-hour operations). Therefore, the discharge rates are calculated and summarised in Table AVII.27.

**Table AVII.27: Cuttings and muds discharge rates**

Parameter	Discharge rate (m <sup>3</sup> /h)	Discharge rate (m <sup>3</sup> /s)
Fraction 1 - Drill cuttings	9.6429	0.0026786
Fraction 2 - Drill Muds (LTOBM)	0.4821	0.0001339

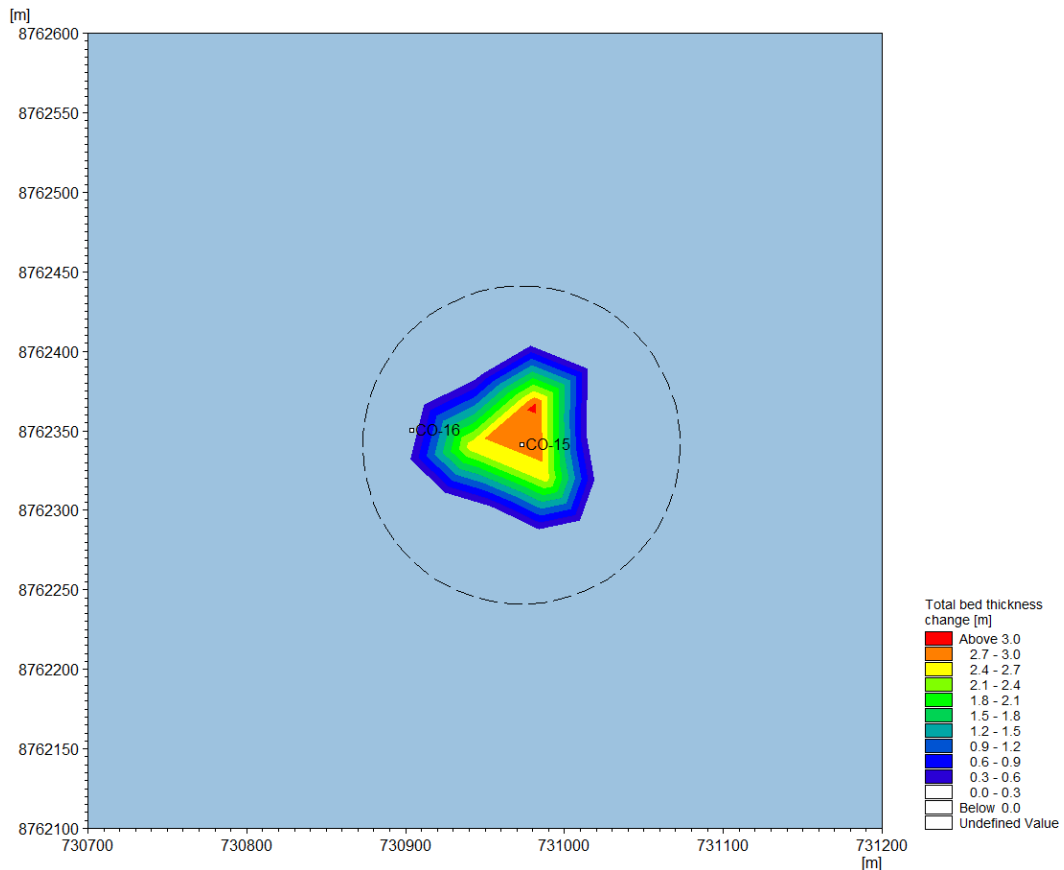
### AVII.3.5.4. Model Results

The sediment dispersion model was run over a two-week simulation period. The simulation included a 7-day spin-up period prior to the start date to allow for the water levels, and currents to stabilise (the spin-up period is however excluded in the post-processing of results). The relevant outputs of the model are depositional thickness and total suspended solids (TSS) at the end of the simulation period.

The sediment dispersion model results have been processed to provide the statistical maximum TSS concentration and total bed thickness change. A mixing zone with radius of 100 m is shown as a dashed circle on each plot.

#### AVII.3.5.4.1. Depositional Thickness

Figure AVII.54 shows the maximum particle deposition thickness for released cuttings and adhered residual LTOBM at the end of the drilling and discharges for well CO-15. Particles primarily settle within a 450 m<sup>2</sup> area, which represents the cell area at which discharge takes place and the maximum deposit is estimated to reach a peak of 3.03 m thick. Therefore, the deposition within this area exceeds the 50 mm maximum deposition threshold (Consultec, 2015a). This highly localized deposit is due to the large grain size and associated high settling velocity of the drill cuttings combined with low current velocities at the seabed.



**Figure AVII.54: Maximum depositional thickness at the end of all drilling and deposition**

**AVII.3.5.4.2. Total Suspended Solids**

Figure AVII.55 shows a plot of the maximum TSS concentration for released cuttings and adhered residual LTOBM from site CO-15. The national regulation does not establish an ambient water quality limit for TSS concentration on marine waters. In the absence of a national standard, best practice international standards were adopted, namely IFC’s guidelines for effluent discharges of hydrotest water at LNG Facilities (IFC, 2007), which lists a guidance limit of 35 mg/l. This guidance limit was adopted in this assessment as an ambient water quality threshold value for TSS.

A maximum TSS concentration of 0.23 mg/L was estimated, extending to 25 m from the discharge location, which is well below the reference threshold value of 35 mg/L. This increase of suspended solids is therefore very unlikely to cause impacts related to light inhabitation, especially at depths below 1,800 m, well below the photic zone where photosynthesis occurs in the ocean.

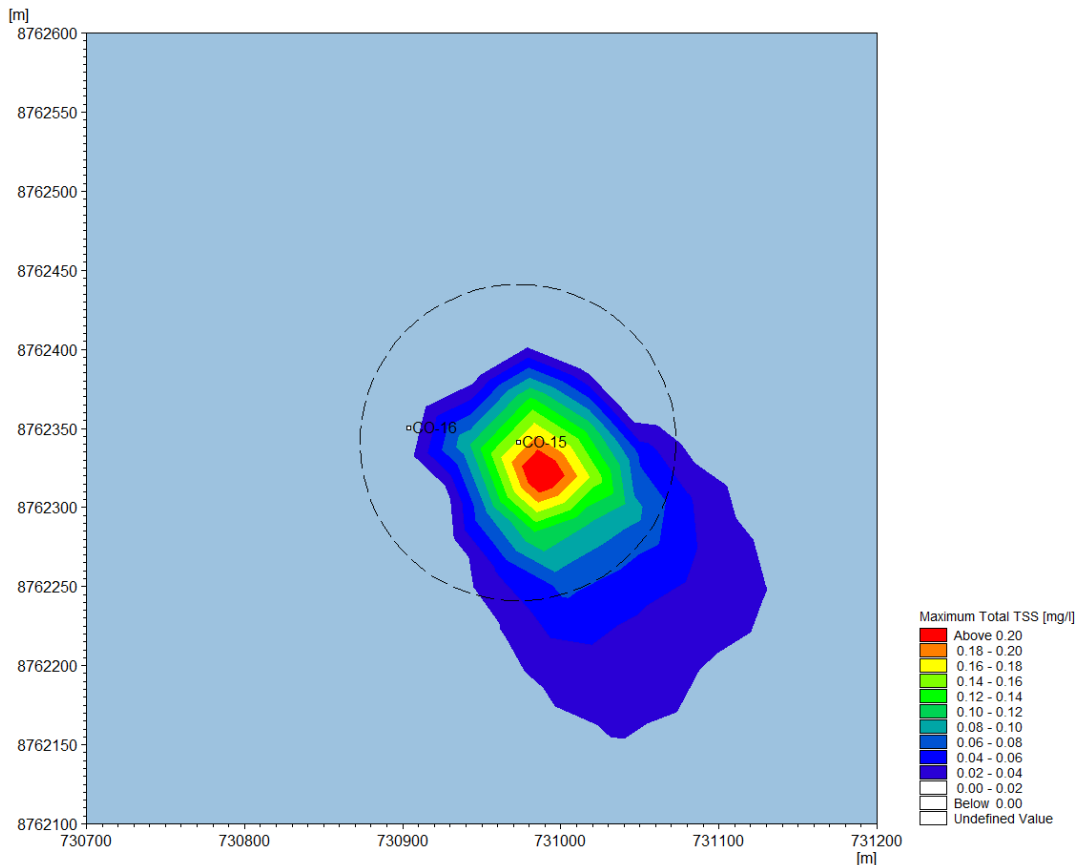


Figure AVII.55: Maximum concentration TSS

### AVII.3.5.4.3. Summary

A summary of the results for the drill cuttings model are provided in Table AVII.28.

Table AVII.28: Drill cuttings modelling results summary

Well head Location	Max deposition (m) (Recommended 50 mm threshold)	Max TSS (mg/L) (35 mg/L threshold)
CO-15	3.03	0.23

## AVII.3.6. Oil Spill Model

### AVII.3.6.1. Modelling Approach

The term “scenario” refers to the conditions that describe a specific spill event, including the type of oil spilled, as well as the volume, duration, location, and depth of the release. A “simulation” is a model run for a specific period of time (e.g., autumn condition). For stochastic analyses, each simulation is repeated multiple times within the specified time period but selecting from many start dates over a long period (example: one year) for a range of wind and current conditions. Each of these runs repeated within a stochastic simulation is called “iteration”. This stochastic (or probabilistic) mode will be used in this modelling. The results of each of these stochastic iterations are summarized as probability diagrams, which intend to represent the range of locations across a

grid of surface cells potentially affected by the presence of oil and therefor present the summary of all potential outcomes.

It is to be noted that the probabilistic summaries do not represent the outcome of a single spill; rather these summaries show the probability of presence of oil at various locations. A single iteration, representing an individual spill event, would cover only a portion of the area shown.

In addition to stochastic analysis, a deterministic modelling approach was also used to assess the fate and trajectory of single oil spill events. This approach is based on a single simulation based on an assessment of impacts from the stochastic analysis.

### AVII.3.6.2. Assessment Criteria for the Simulation of Spills

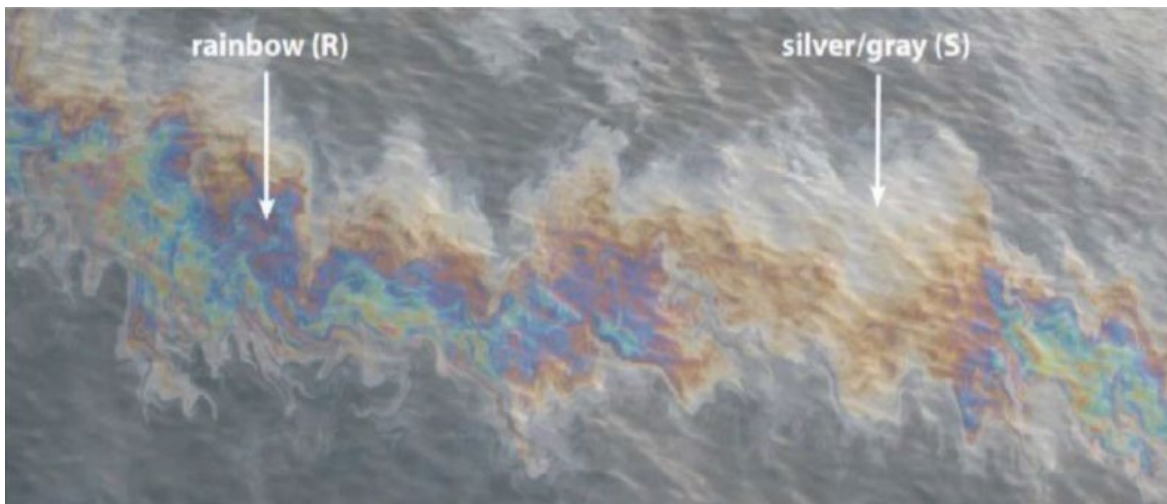
“Significant surface oiling” is defined as oil having a thickness above a minimum thickness threshold, which delineates where oil becomes visible and below which aquatic biota are at near zero risk of smothering from crude oil. The first clearly visible oil appears as a silvery sheen at thicknesses between 0.04 µm to 0.3 µm based on values catalogued in BAOAC (2017). Table AVII.29 summarizes the thickness descriptors represented by the BAOAC standard colour designations, while Figure AVII.56 gives an example of an aerial photograph of oil appearance.

**Table AVII.29: Oil thickness thresholds used in impacted areas**

Code	Description of appearance	Layer thickness (µm)	Litres per km <sup>2</sup>
1	Sheen (silvery/grey)	0.04 to 0.30	40 to 300
2	Rainbow	0.30 to 5.0	300 to 5,000
3	Metallic	5.0 to 50	5,000 to 50,000
4	Discontinuous true oil colour	50 to 200	50,000 to 200,000
5	Continuous true oil colour	200	> 200,000

Source: Adopted from BAOAC (2017).

Oil at a thickness of 0.1 µm may be visible and potentially wash upon the shore as a silver sheen but is not expected to cause physical injury (e.g., oiling, smothering) to wildlife contacting it. On this basis, simulations were performed until a minimum surface thickness threshold of 0.1 µm was reached. The analysis and presentation of results provided is based on a minimum threshold of 1 µm, the threshold below which exposure by seabirds is considered low risk.



Source: NOAA (2016).

**Figure AVII.56: Oil colour/appearance for silver-grey and rainbow sheen**

A summary of the significance of the oil spill modelling outputs is presented in Table AVII.30.

**Table AVII.30: Oil spill output assessments and significance**

Output component	Importance of information
Geographic distribution and probability of surface oiling (significant threshold range of 0.1 µm to 1 µm)	Understanding relative risk and extent of a spill event
Geographic distribution of oil slick thicknesses	Understanding extent of significant oil mass per area and the risk of smothering biota
Probability of shoreline oiling and arrival time	Understanding risk to coastal receptors and extent of shoreline oiling
Mass Balance Plots	Illustrate the fate of the oil as time-varying percentages of the total mass due to various weathering processes (e.g. spreading, evaporation, dispersion, and dissolution)

### AVII.3.6.3. Scenarios

Stochastic and deterministic simulations will be performed for the offshore oil spills at the CO-15 well location, as summarised in Table AVII.31.

**Table AVII.31: Details of the oil release scenarios**

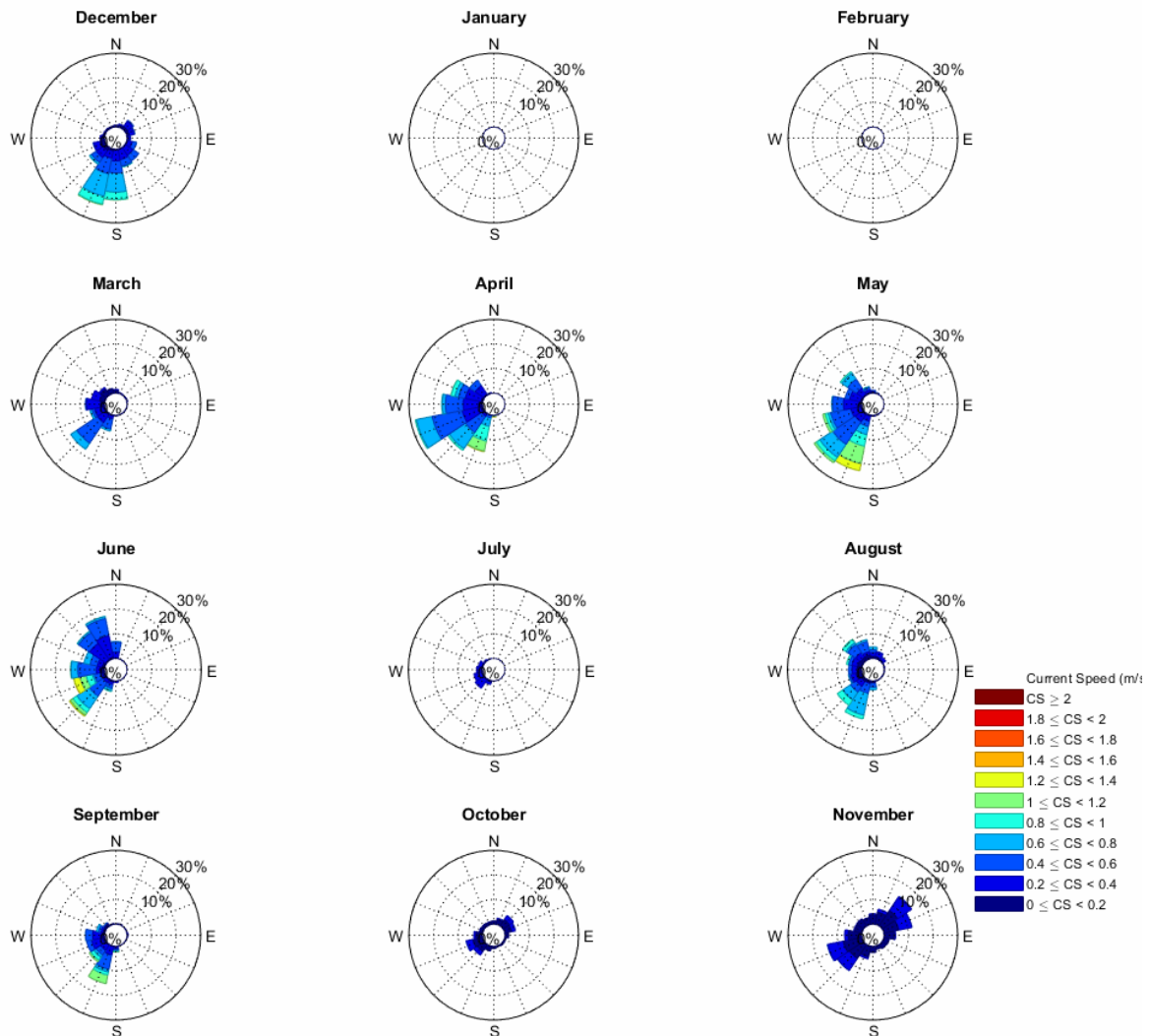
Scenario	Wellhead Location	Total release volume	Release duration	Release rate (bbl/d)
Diesel spill at MSL associated with vessel collision	CO-15	2,000 bbl	Instantaneous (1 hour)	Instantaneous (1 hour)
Blowout of the wellhead on the seabed (gas condensate)	CO-15	60,300 bbl	45 days	1,340
Riser disconnect LTOBM release	CO-15	1,650 bbl	Instantaneous (1 hour)	Instantaneous (1 hour)

Three separate simulation periods within a specific year were selected to be used in the deterministic oil spill modelling, whereas the stochastic simulations were performed covering the entire year of

2013. The year of 2013 was selected for modelling the oil spill dispersion taking into account the most conservative environmental forcing conditions (i.e., currents) to drive the oil spill processes at the project site (see Section AVII.3.2.3). Having selected the representative year, the representative seasons to be used in the model will be selected taking into account the estimates of shortest time for the oil to reach the shore (maximum westerly currents) and maximum oil extent at the sea surface (minimum current speeds).

The selection of these simulation periods (incl. starting month and modelling duration) was determined following an assessment of the measured monthly surface currents during 2013, as depicted in the current roses in Figure AVII.57.

The three simulation periods selected represent the maximum (May), minimum (October), and typical (March) current speeds at the CO-15/16 project site. Median simulations, representative of typical behaviour, were also identified and included with deterministic results.



**Figure AVII.57: Current roses based on surface current measurements conducted by Fugro (2013)**

#### **AVII.3.6.4. Model Setup**

A regional far-field hydrodynamic model for the oil spill modelling was built based on HYCOM data. A description of this model is provided in Section AVII.3.2.3. Hydrodynamic data for all simulations will be based on HYCOM currents extracted for the year of 2013.

#### **AVII.3.6.5. Model Results**

The relevant outputs of the stochastic model are average oil concentration, average oil thickness, minimum time to oiling, and probability of oiling. The relevant outputs of the deterministic model are the fate and trajectory of single oil spill events, specifically tracking the change in oil thickness due to weathering processes.

##### **AVII.3.6.5.1. Stochastic Model Results**

The extent of visible surface oil (average oil thickness > 0.1  $\mu\text{m}$ ) is shown in Figure AVII.58, Figure AVII.59, and Figure AVII.60 for diesel, gas condensate, and LTOBM, respectively. Oil thickness of 1  $\mu\text{m}$  is also shown as a yellow isolines on the plots.

The average oil concentration is shown in Figure AVII.61, Figure AVII.62, and Figure AVII.63 for diesel, gas condensate, and LTOBM, respectively, only for visible surface oil, i.e., thicker than 0.1  $\mu\text{m}$ .

The probability of oiling (exceeding average oil thickness > 0.1  $\mu\text{m}$ ) is shown in Figure AVII.64, Figure AVII.65, Figure AVII.66 for diesel, gas condensate, and LTOBM, respectively.

The minimum time to oiling (exceeding average oil thickness > 0.1  $\mu\text{m}$ ) is shown in Figure AVII.67, Figure AVII.68, and Figure AVII.69 for diesel, gas condensate, and LTOBM, respectively.

Figure AVII.70 shows the time to oiling over distance travelled from source as a scatter diagram. The condensate blowout dispersion occurs at an approximate rate of between 50 km to 60 km per day, while the diesel and LTOBM spill disperses at an approximate rate of between 110 km to 120 km per day. Figure AVII.71 and Table AVII.32 summarises the percentage probability of oiling that can occur at distance from the source during an unplanned event.

Mass balance plots for the averaged stochastic diesel, gas condensate, and LTOBM are included as Figure AVII.72, Figure AVII.73, and Figure AVII.74. As noted, the presence of oil particles in the seawater surface reduces over time due to the various weathering processes (e.g., spreading, evaporation, dispersion and dissolution) that transform the oil properties as the oils spends time in the environment. The disintegration rate of the oil is therefore affected by local conditions (i.e., winds, currents, and seawater characteristics) which can either enhance or reduce the presence of oil in the water surface.

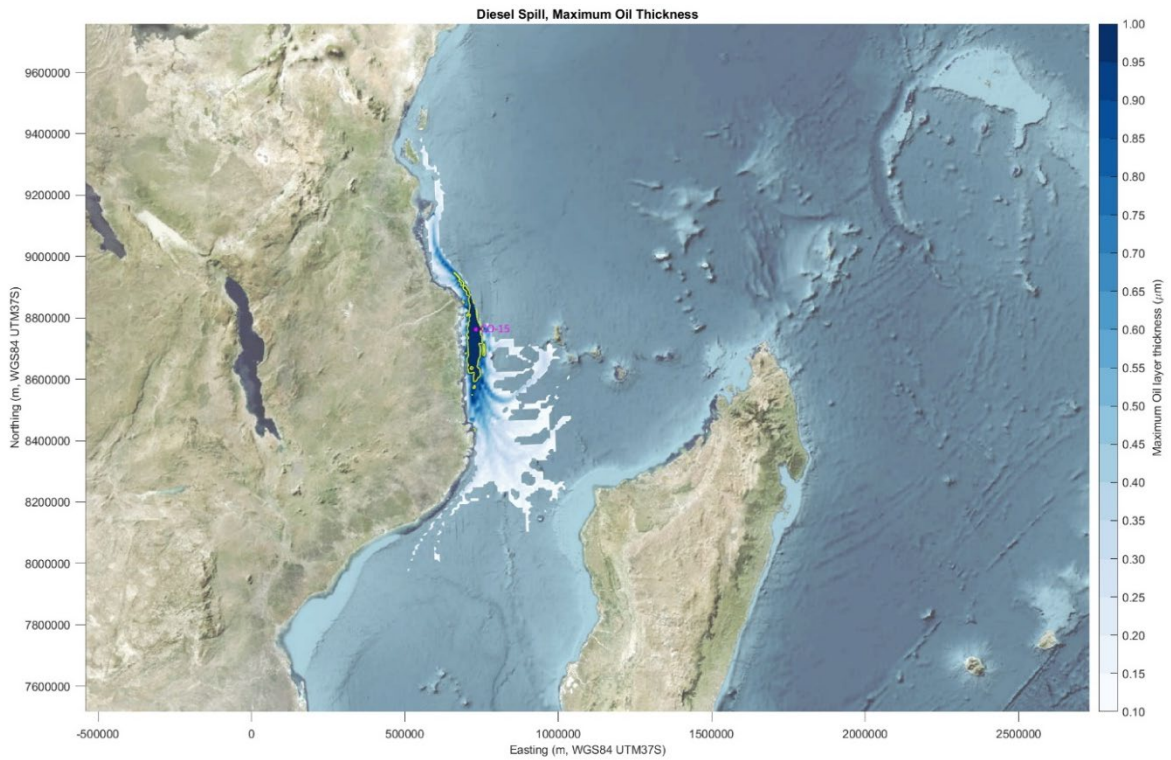
Summaries of the vessel collision diesel spill, the gas condensate blowout release, and the riser disconnect LTOBM release model results for the stochastic simulations are found in Table AVII.32.

**Table AVII.32: Stochastic modelling results for the year of 2013**

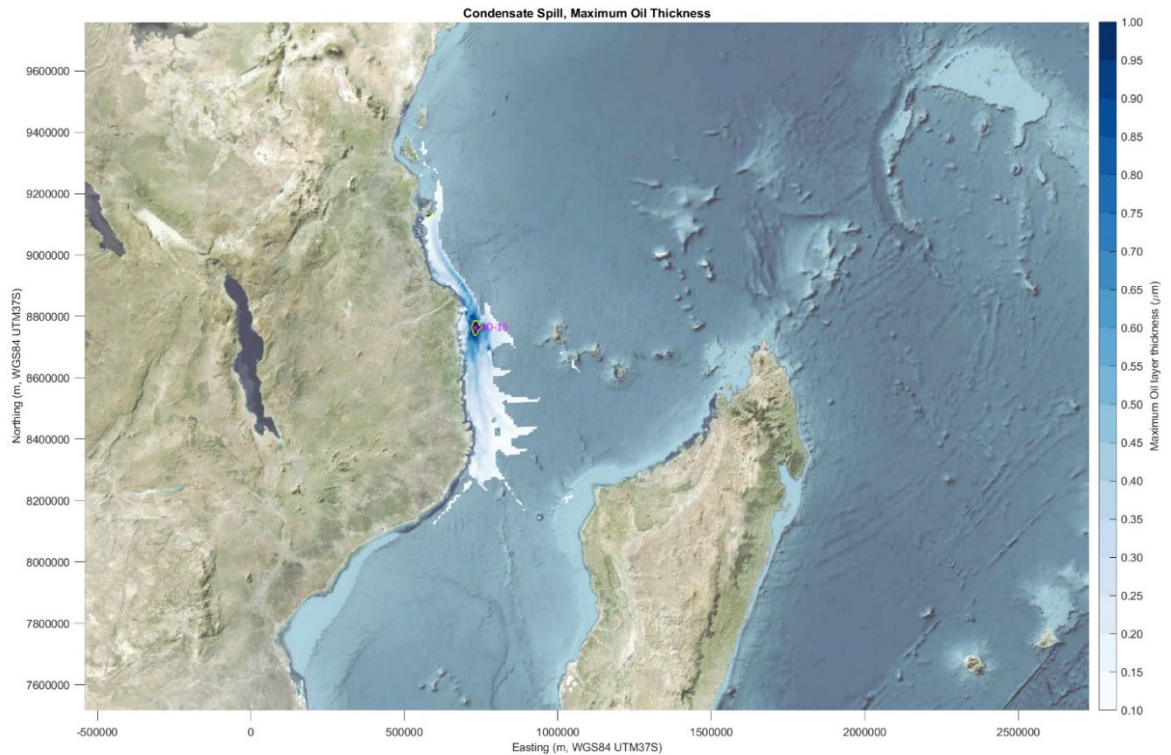
Scenario	Max concentration (L/km <sup>2</sup> )	Average Surface Area With Visible Oil (km <sup>2</sup> )	Average Surface Area >1µm (km <sup>2</sup> )	Typical Dispersion rate (km/day)
Averaged over 100 simulations diesel spill at MSL associated with vessel collision	3,791	172,552	9,298	110 to 120
Averaged over 100 simulations blowout of the wellhead on the seabed (gas condensate)	2,881	108,203	1,264	50 to 60
Averaged over 100 simulations for riser disconnect (LTOBM)	3,073	145,538	9,175	110 to 120
Each of the 100 simulations diesel spill at MSL associated with vessel collision	median = 3,686	median = 7,964		
Each of the 100 simulations blowout of the wellhead on the seabed (gas condensate)	(2,760 to 24,603)	median = 789		
Each of the 100 simulations for riser disconnect (LTOBM)	(237 to 1,971)	-		

**Table AVII.33: Probability of oiling at distance from source**

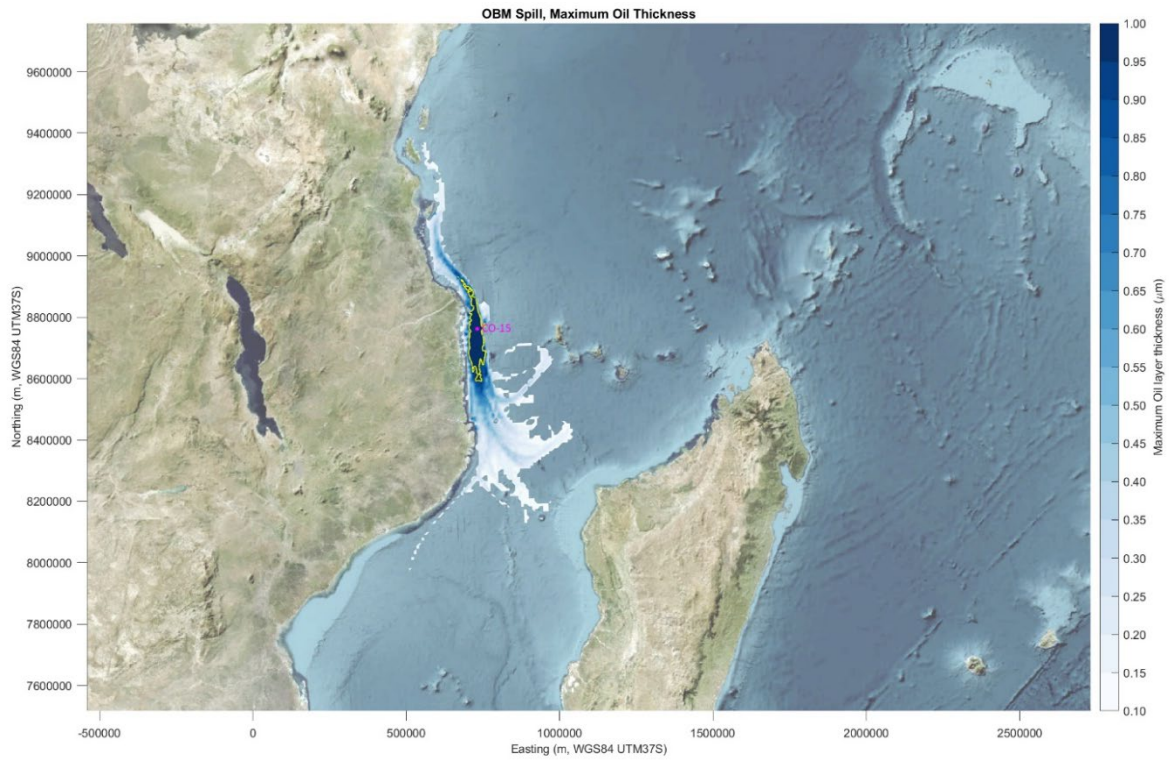
Probability (%)	Diesel spill Distance from source (km)	Condensate blowout Distance from source (km)	LTOBM Distance from source (km)
80 to 100	< 10	< 180	< 10
60 to 80	10 to 20	180 to 300	10 to 45
40 to 60	20 to 180	300 to 400	45 to 170
20 to 40	180 to 330	400 to 500	170 to 330
0 – 20	330 to 860	500 to 950	330 to 850



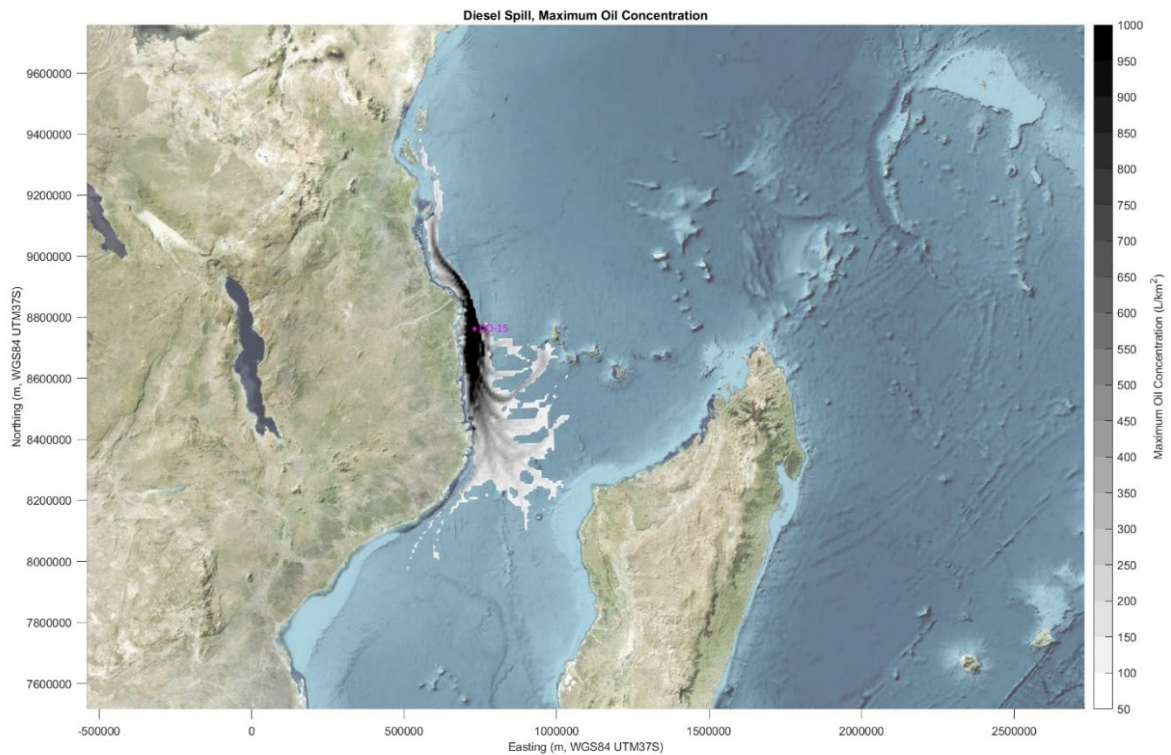
**Figure AVII.58: Maximum oil thickness for the diesel spill stochastic simulation**



**Figure AVII.59: Maximum oil thickness for the condensate spill stochastic simulation**



**Figure AVII.60: Maximum oil thickness for the LTOBM spill stochastic simulation**



**Figure AVII.61: Maximum concentration for the diesel spill stochastic simulation**

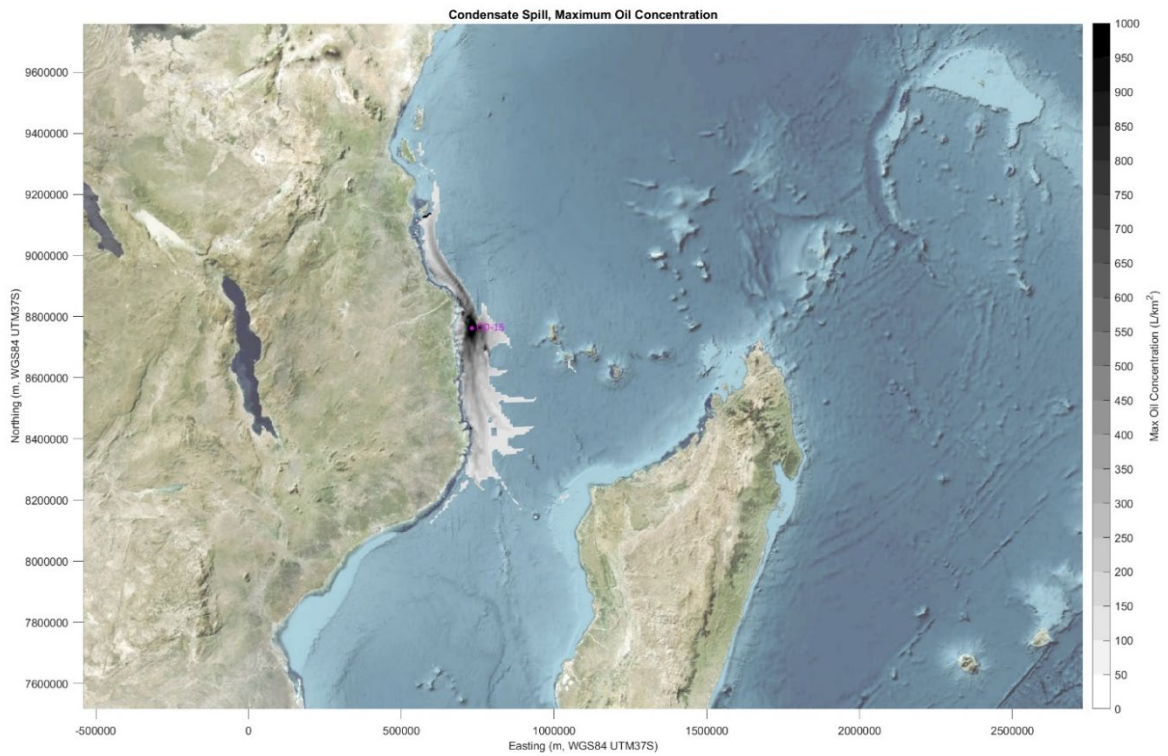


Figure AVII.62: Maximum concentration for the condensate spill stochastic simulation

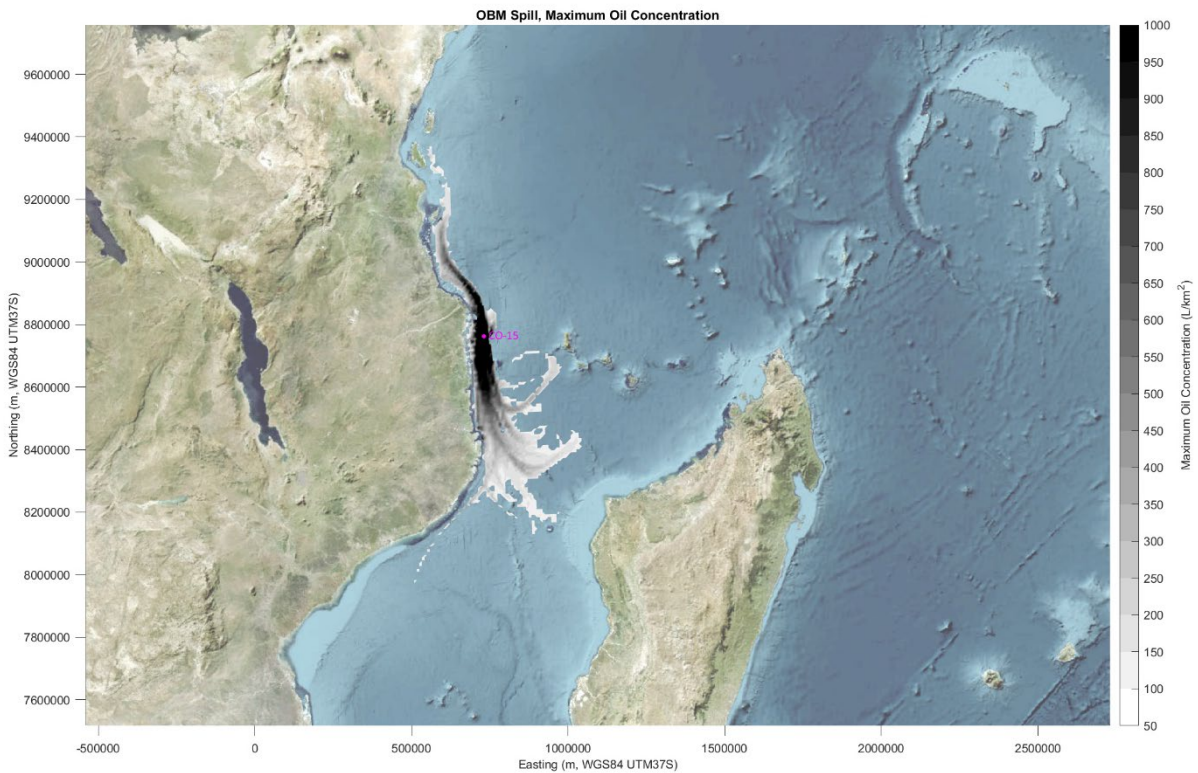
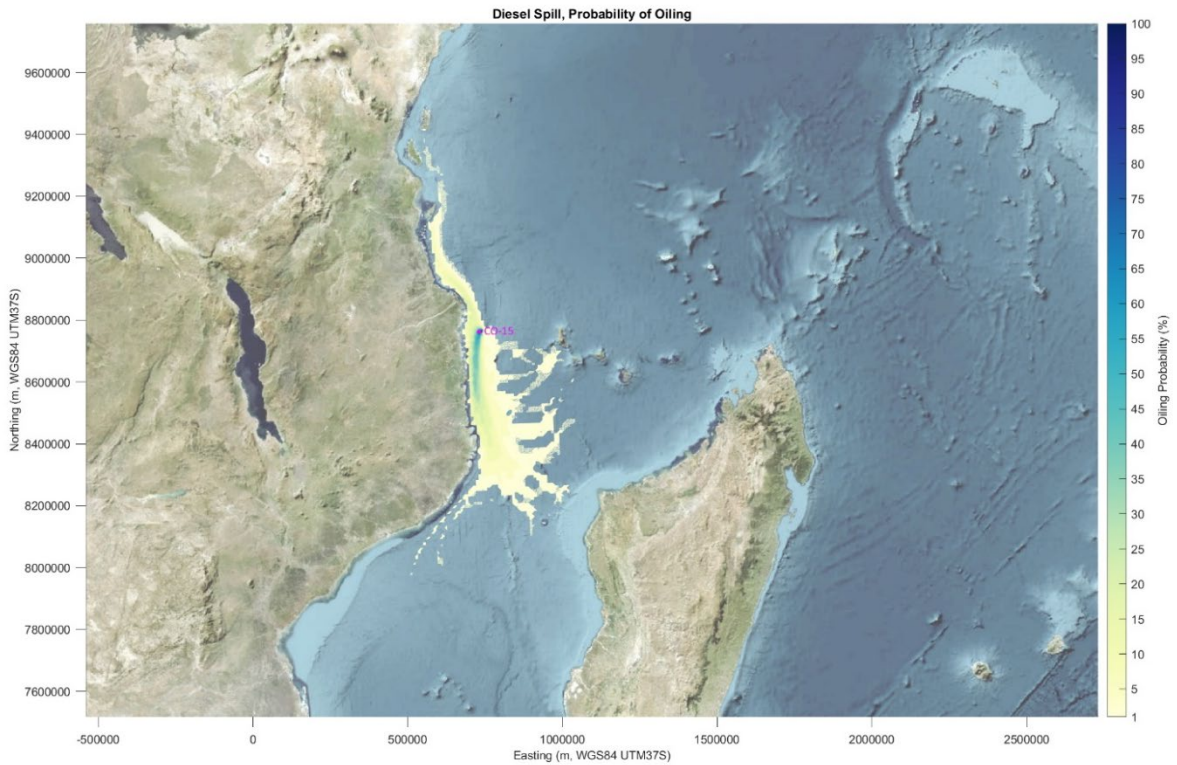
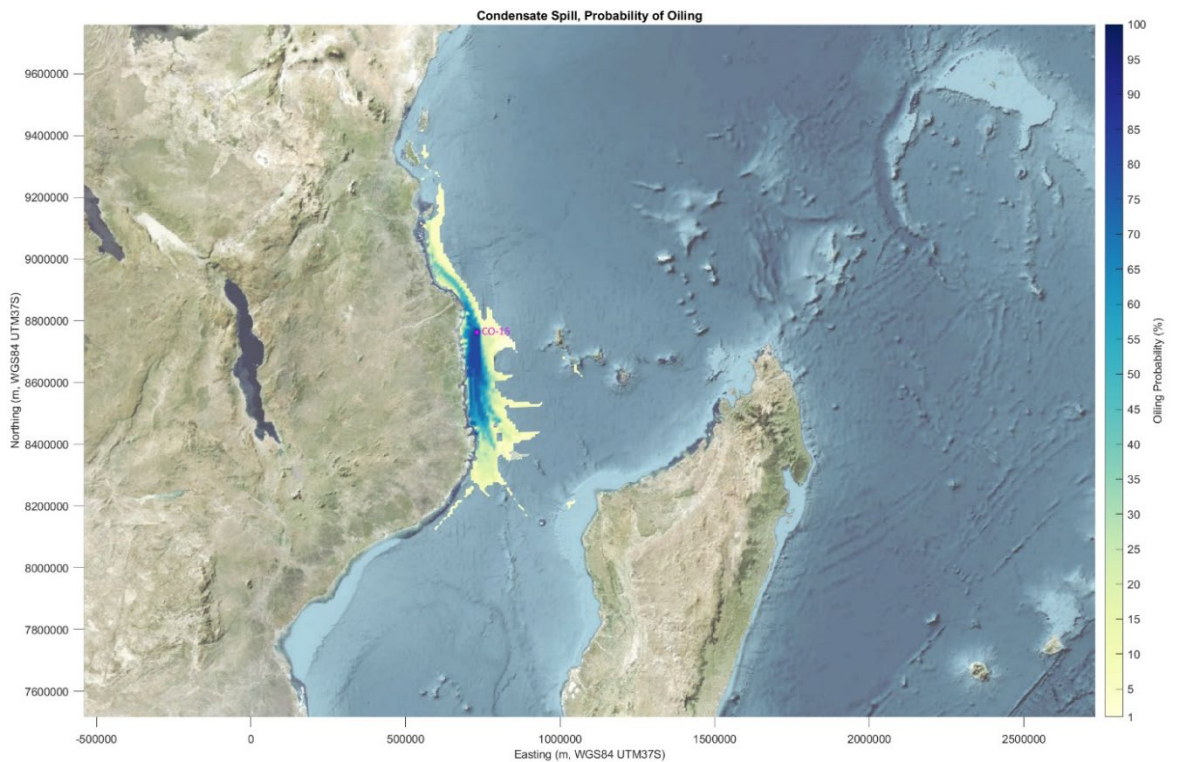


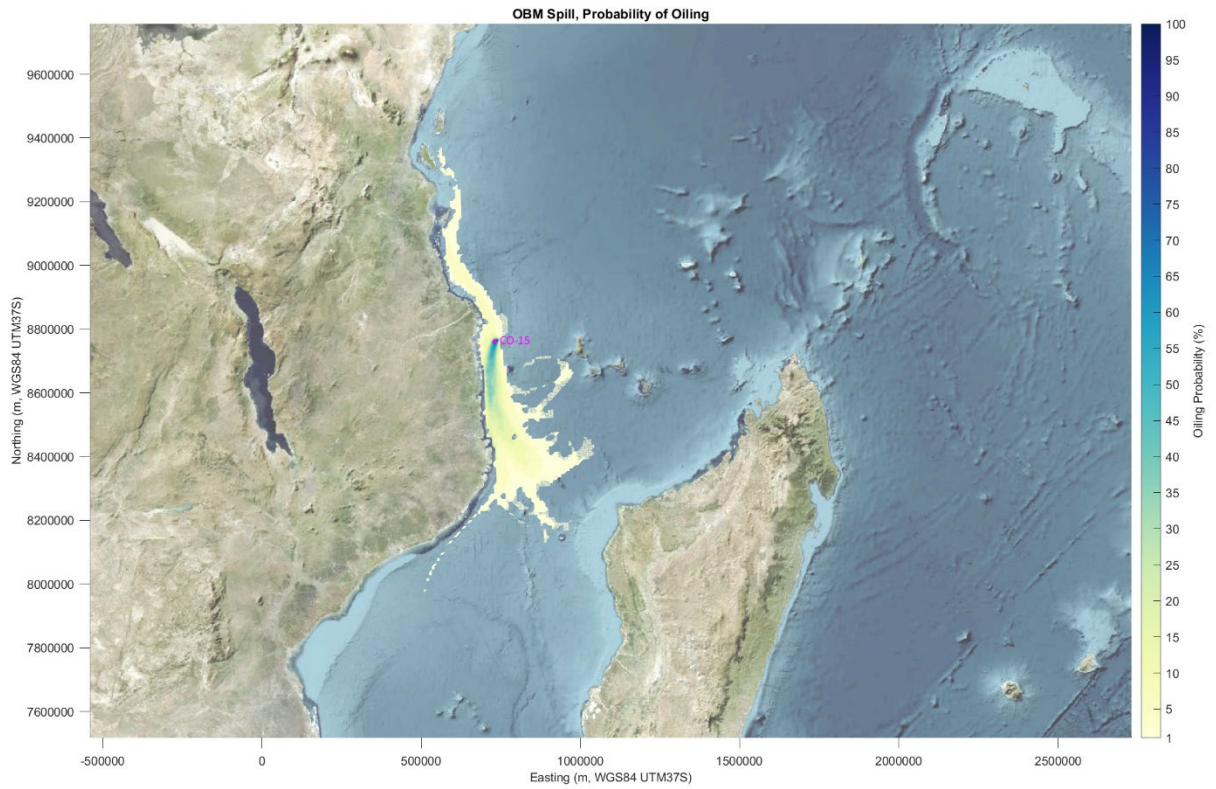
Figure AVII.63: Maximum concentration for the LTOBM spill stochastic simulation



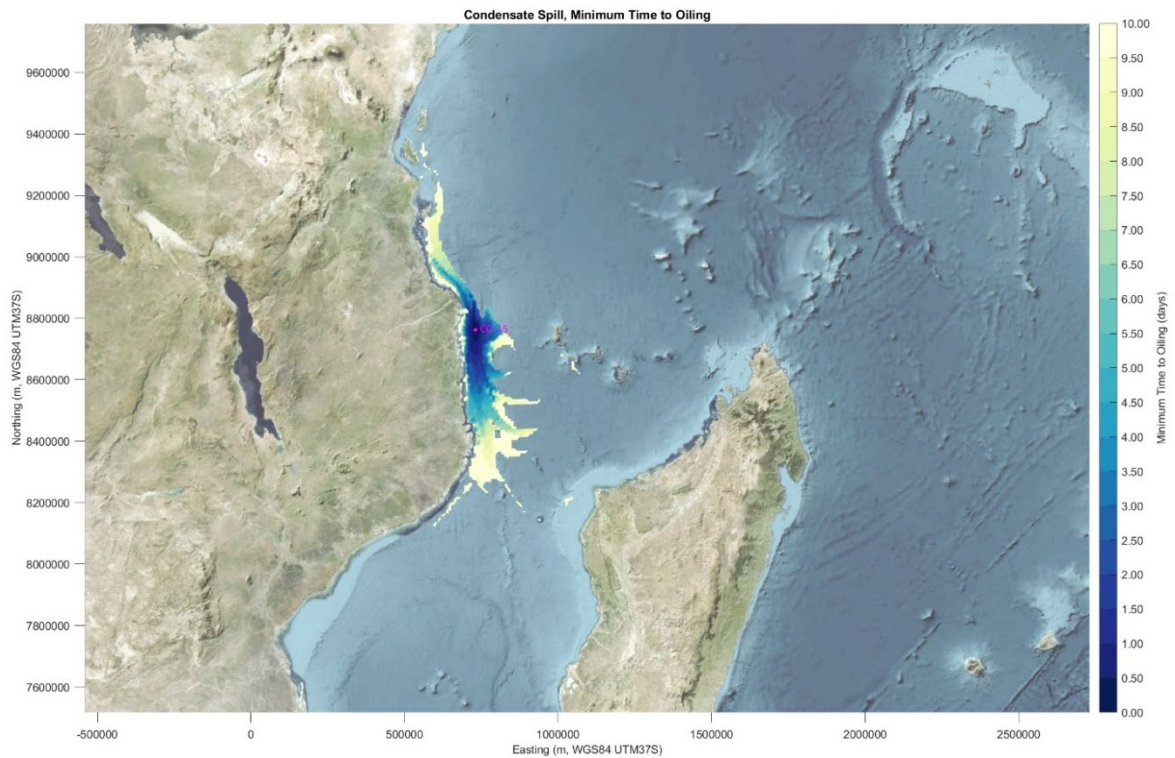
**Figure AVII.64: Probability of oiling for the diesel spill stochastic simulation**



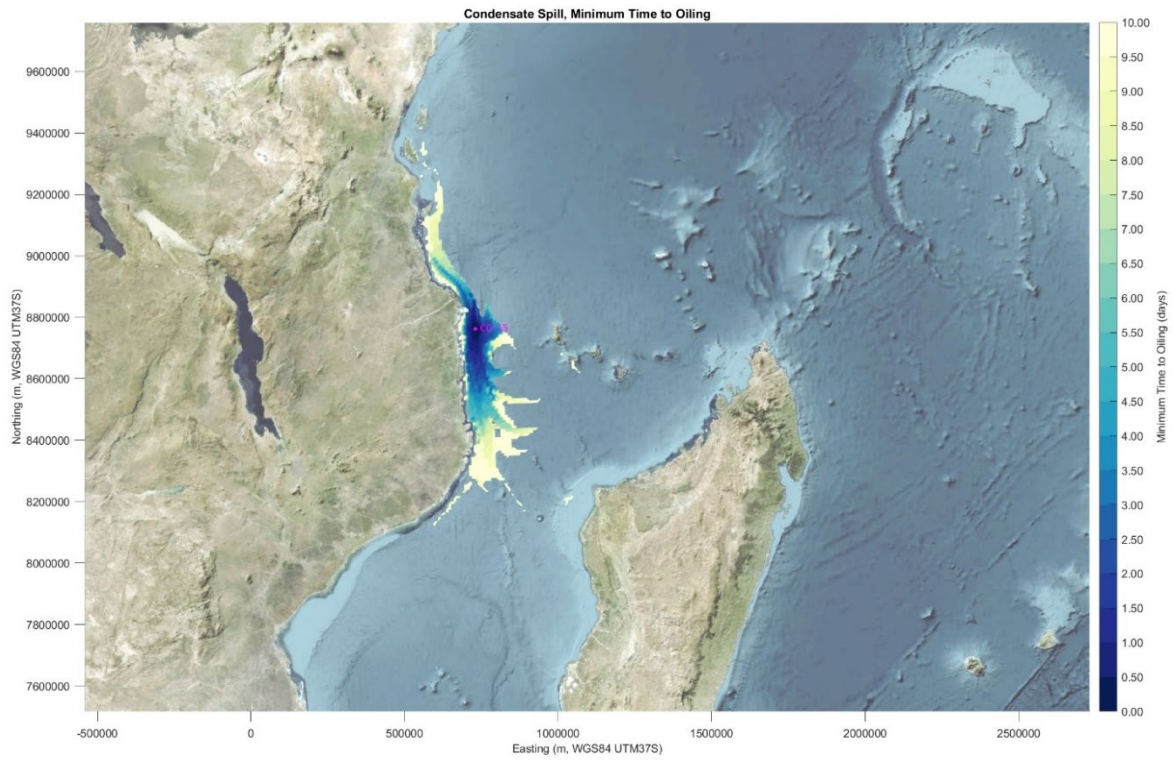
**Figure AVII.65: Probability of oiling for the condensate spill stochastic simulation**



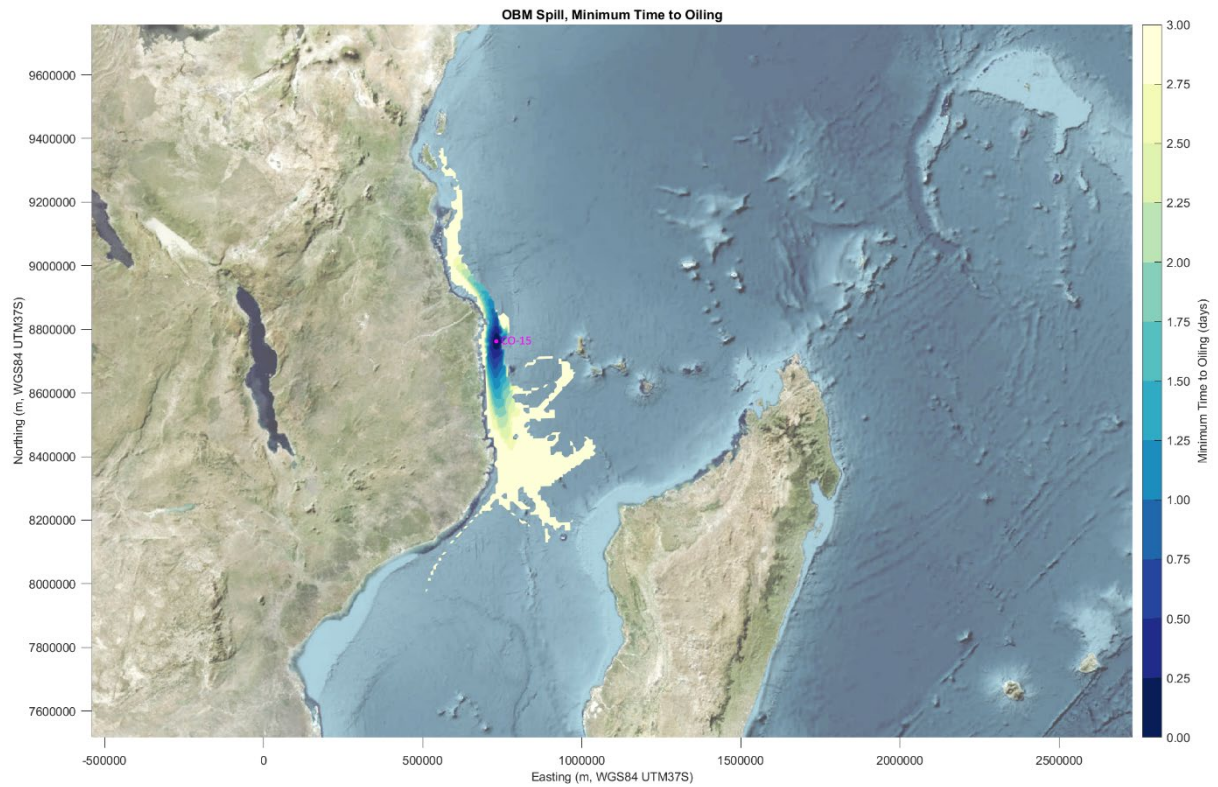
**Figure AVII.66: Probability of oiling for the LTOBM spill stochastic simulation**



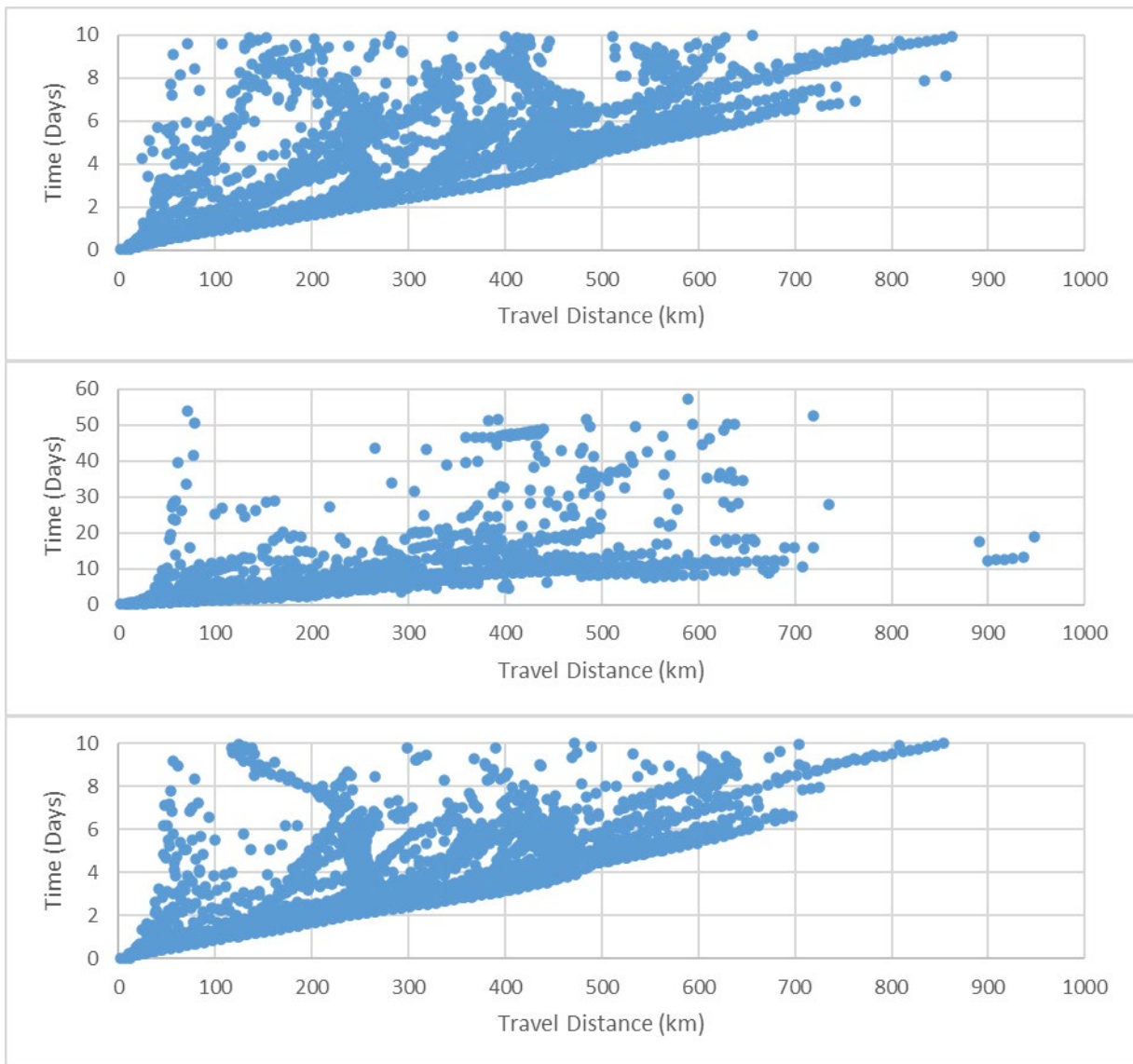
**Figure AVII.67: Minimum time to oiling for the diesel spill stochastic simulation**



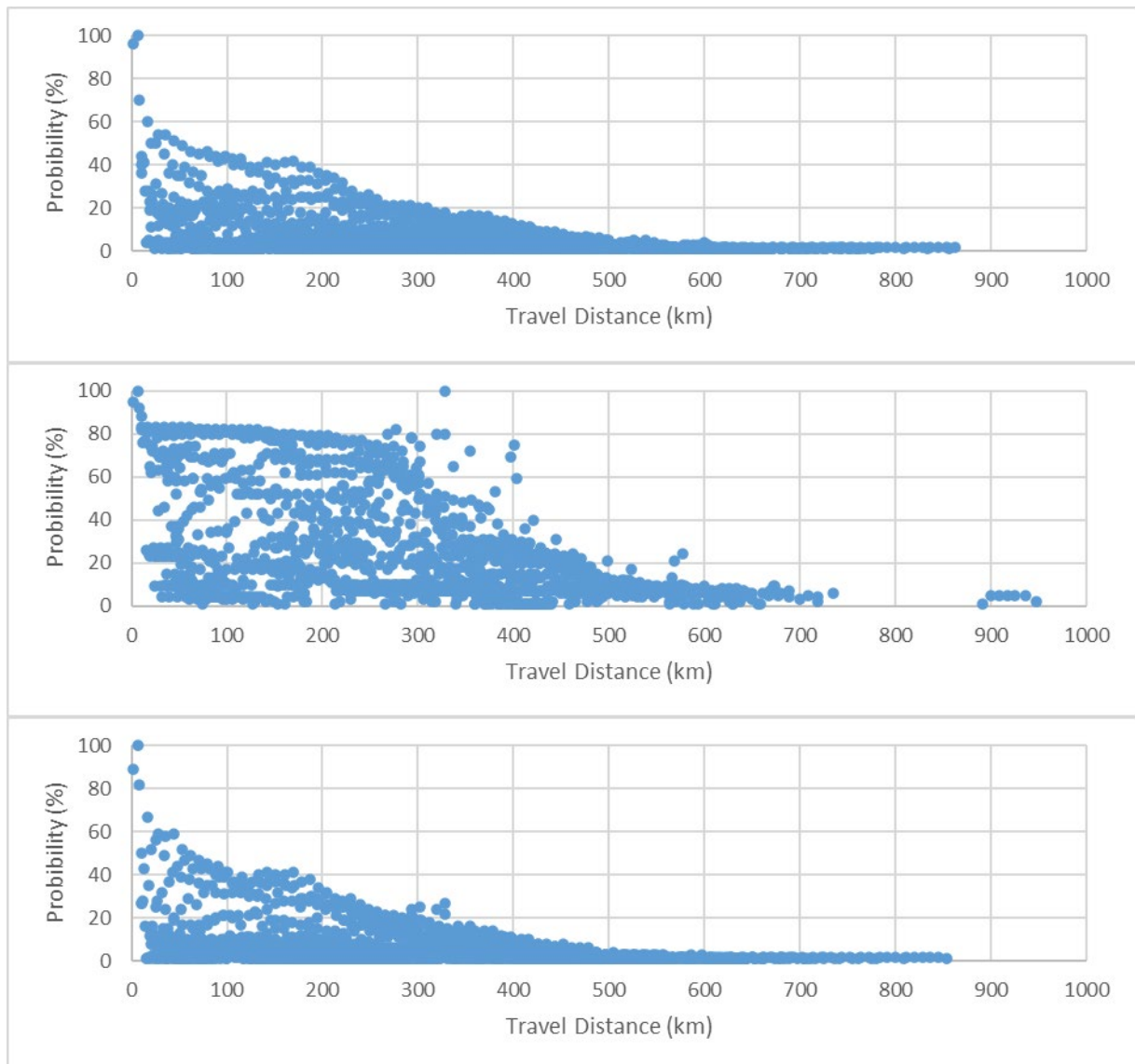
**Figure AVII.68: Minimum time to oiling for the condensate spill stochastic simulation**



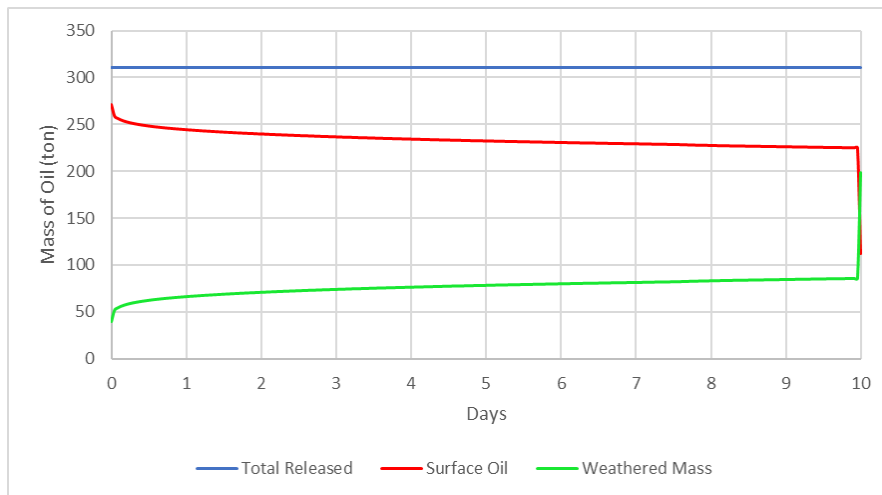
**Figure AVII.69: Minimum time to oiling for the LTOBM spill stochastic simulation**



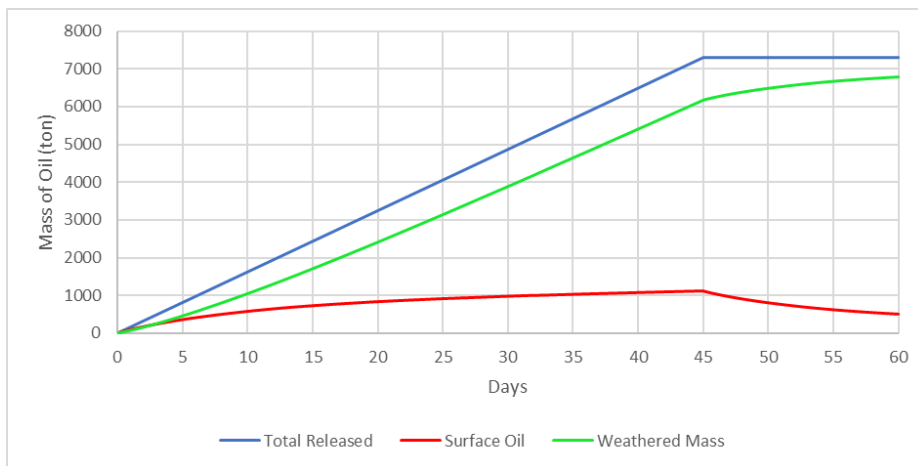
**Figure AVII.70: Time to oiling over travel distance for the diesel spill (top), the condensate blowout (middle), and LTOBM (bottom) stochastic simulations**



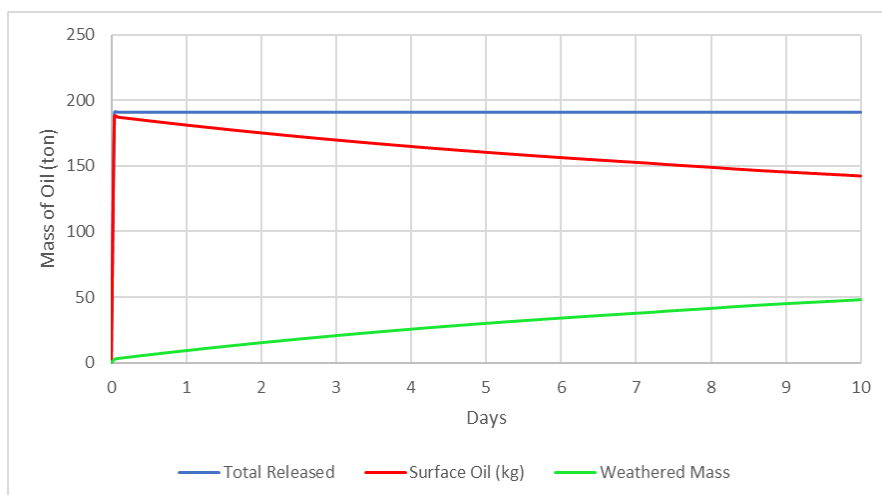
**Figure AVII.71: Probability of oiling over travel distance for the diesel spill (top), the condensate blowout (middle), and LTOBM (bottom) stochastic simulations**



**Figure AVII.72: Mass balance for the diesel spill stochastic simulations, based on affected surface area**



**Figure AVII.73: Mass balance for the condensate blowout spill stochastic simulations, based on affected surface area**



**Figure AVII.74: Mass balance for the LTOBM spill stochastic simulations, based on affected surface area**

### AVII.3.6.5.2. Deterministic Model Results

The deterministic model shows the fate and trajectory of single oil spill events, specifically tracking the change in oil thickness due to weathering processes.

The weathering process during the period starting in May of the discharged oil from the diesel vessel collision can be seen in Figure AVII.75 to Figure AVII.77, while the condensate blowout and LTOBM weathering can be seen in Figure AVII.78 to Figure AVII.83, and Figure AVII.84 to Figure AVII.86.

The weathering process during the period starting in October of the discharged oil from the diesel vessel collision can be seen in Figure AVII.87 to Figure AVII.89, while the condensate blowout and LTOBM weathering can be in from Figure AVII.90 to Figure AVII.95, and Figure AVII.96 to Figure AVII.98.

The weathering process during the period starting in March of the discharged oil from the diesel vessel collision can be seen in Figure AVII.99 to Figure AVII.101, while the condensate blowout and LTOBM weathering can be seen from Figure AVII.102 to Figure AVII.107, and Figure AVII.108 to Figure AVII.110.

Figure AVII.111 to Figure AVII.119 show the mass balance (total volumes in tons) plots for diesel, gas condensate and LTOBM simulations for each of the deterministic periods. As noted in the figures, the presence of oil particles in the seawater surface reduces over time due to the various weathering processes (e.g., spreading, evaporation, dispersion and dissolution) that transform the oil properties as the oils spends time in the environment. The disintegration rate of the oil is therefore affected by local conditions (i.e., winds, currents, and seawater characteristics) which can either enhance or reduce the presence of oil in the water surface. Figure AVII.120 to Figure AVII.128 shows the increasing area and decreasing oil thickness of the spill for each of the deterministic simulations.

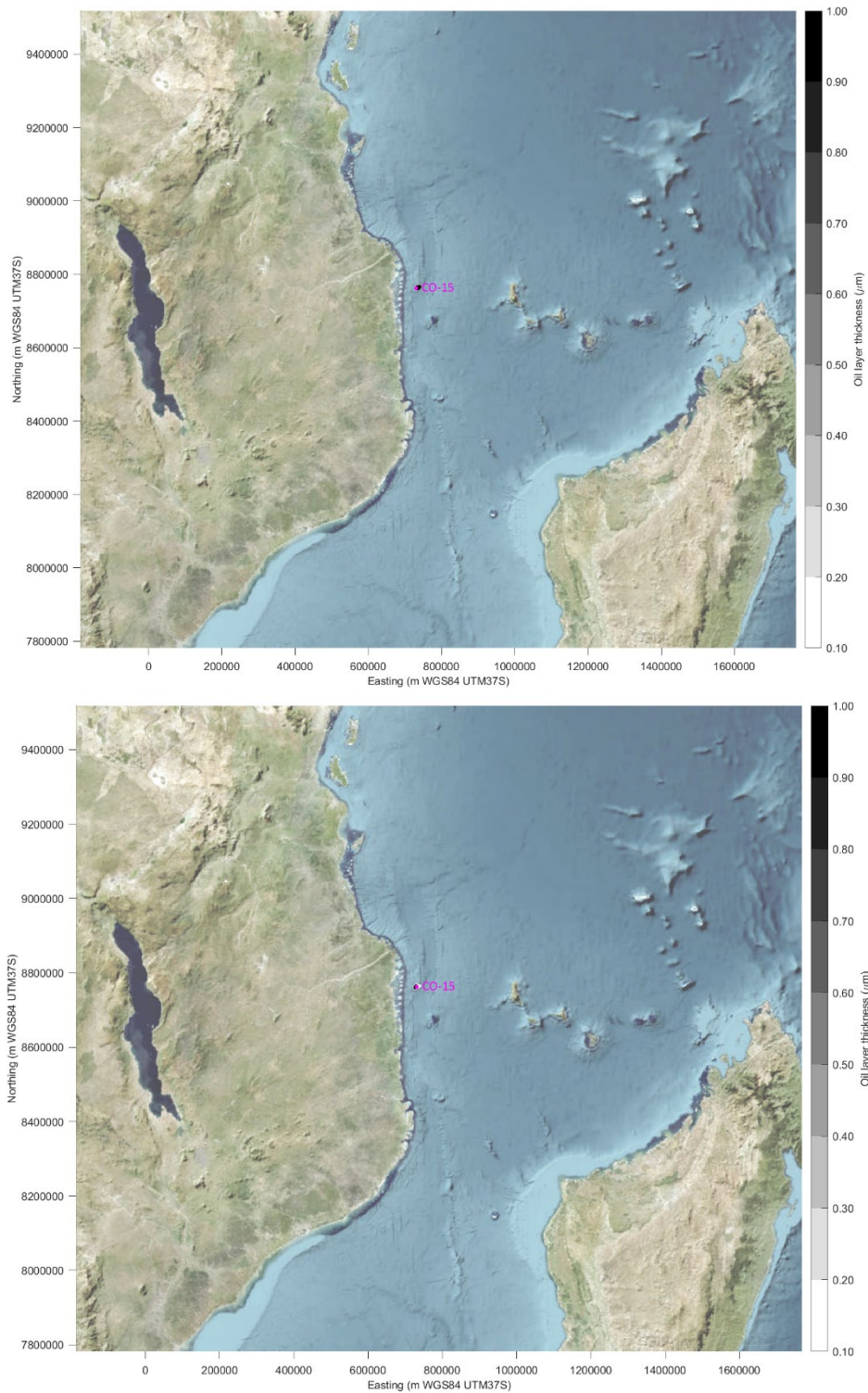
Figure AVII.129, Figure AVII.130, and Figure AVII.131 depict the maximum surface area for each of the 100 simulations exceeding an average oil thickness of greater than 0.1  $\mu\text{m}$  (visible oil) as executed for the stochastic for diesel spill, gas condensate, and LTOBM, respectively. It also shows the ranking on affected surface area for each of the individual runs, with the median highlighted with an orange fill.

The development movement and decay of the surface spill for the median simulations are represented in Figure AVII.132 to Figure AVII.134 for the diesel, Figure AVII.135 to Figure AVII.140 for the gas condensate, and Figure AVII.141 to Figure AVII.143 for the LTOBM. Figure AVII.144 and Figure AVII.145 show the mass balance for the identified median simulation of the diesel spill, condensate blowout, and LTOBM, while Figure AVII.147 to Figure AVII.149 show the increasing area and decreasing oil thickness over time for each of the median scenarios.

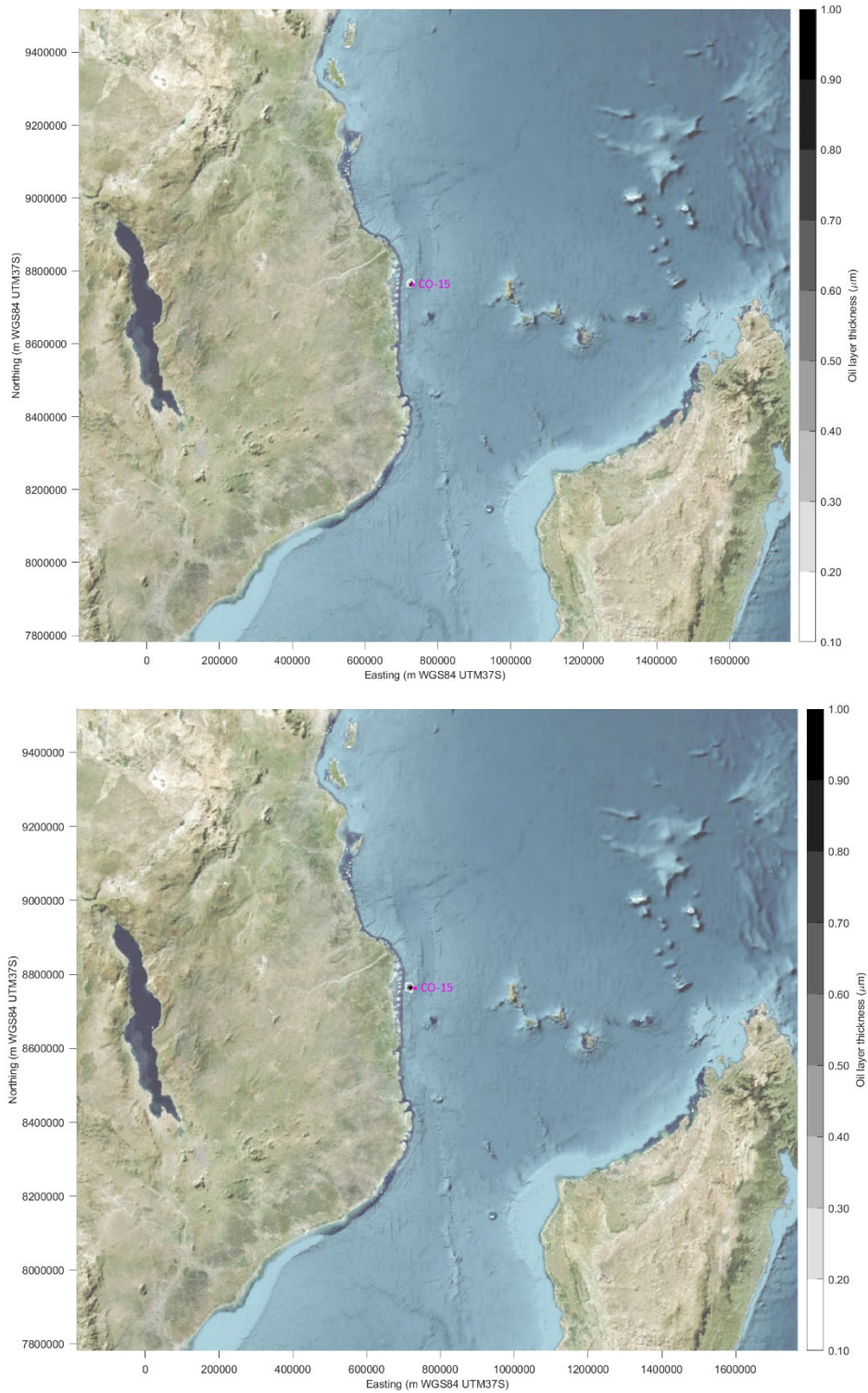
Summaries of the vessel collision diesel spill, the gas condensate blowout release, and the LTOBM model results for the each of the deterministic simulations are included in Table AVII.34.

**Table AVII.34: Deterministic modelling results**

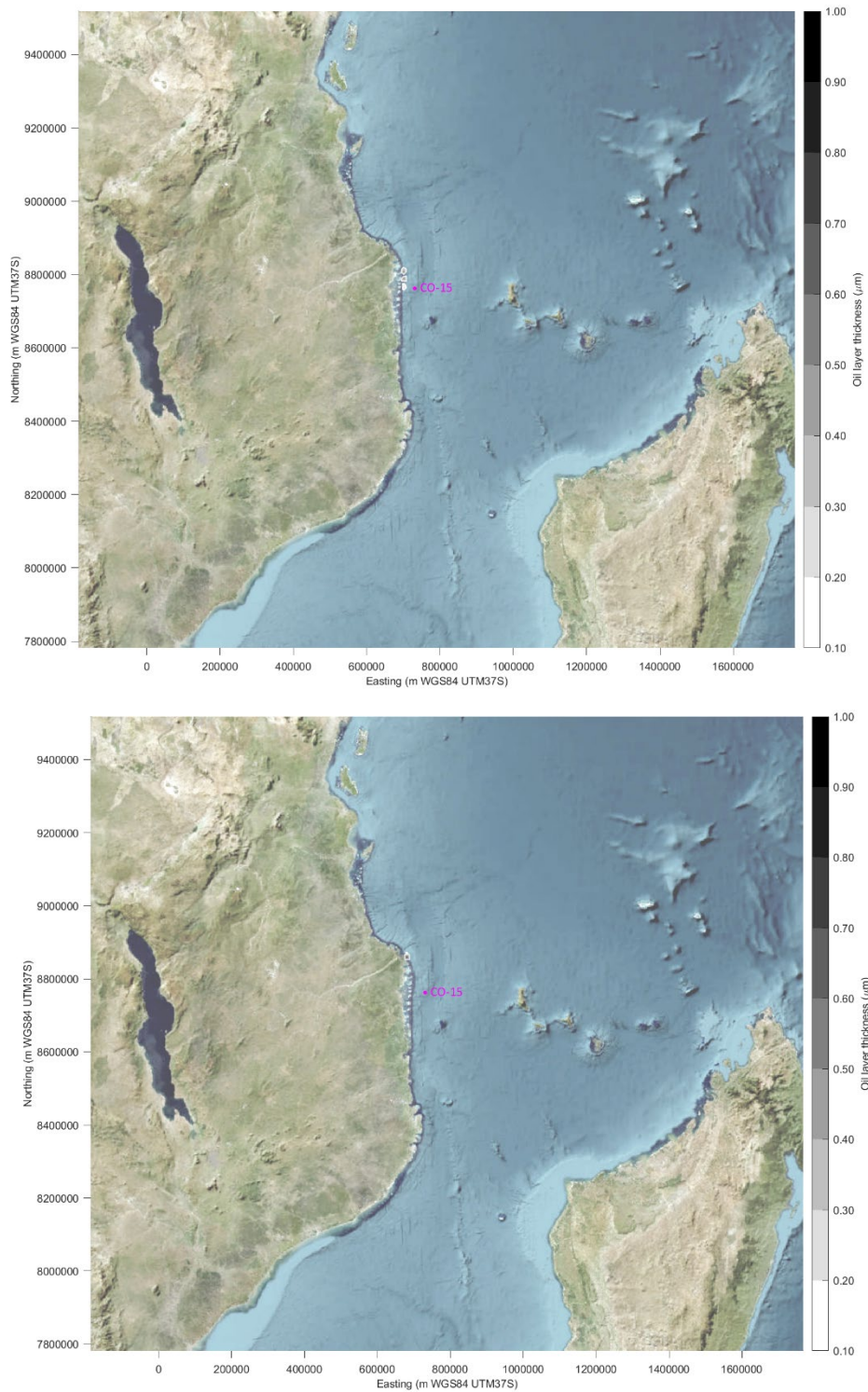
Scenario	Max Concentration (L/km <sup>2</sup> )	Maximum Cumulative Surface Area With Visible Oil (km <sup>2</sup> )	Maximum Cumulative Surface Area > 1µm (km <sup>2</sup> )
Diesel spill at MSL associated with vessel collision during May	3,002	3,548	315
Blowout of the wellhead on the seabed (gas condensate) during May	1,994	46,209	867
Riser disconnect associated with release of LTOBM during May	3,064	3,312	315
Diesel spill at MSL associated with vessel collision during March	3,730	3,706	473
Blowout of the wellhead on the seabed (gas condensate) during March	2,858	36,904	552
Riser disconnect associated with release of LTOBM during March	3,105	3,391	394
Diesel spill at MSL associated with vessel collision during October	3,031	4,652	473
Blowout of the wellhead on the seabed (gas condensate) during October	1,639	34,696	315
Riser disconnect associated with release of LTOBM during October	3,073	3,706	552
Diesel spill at MSL associated with vessel collision for median simulation	3,686	7,964	789
Blowout of the wellhead on the seabed (gas condensate) for median simulation	2,858	36,904	552
Riser disconnect associated with release of LTOBM for median simulation	3,077	8,280	631



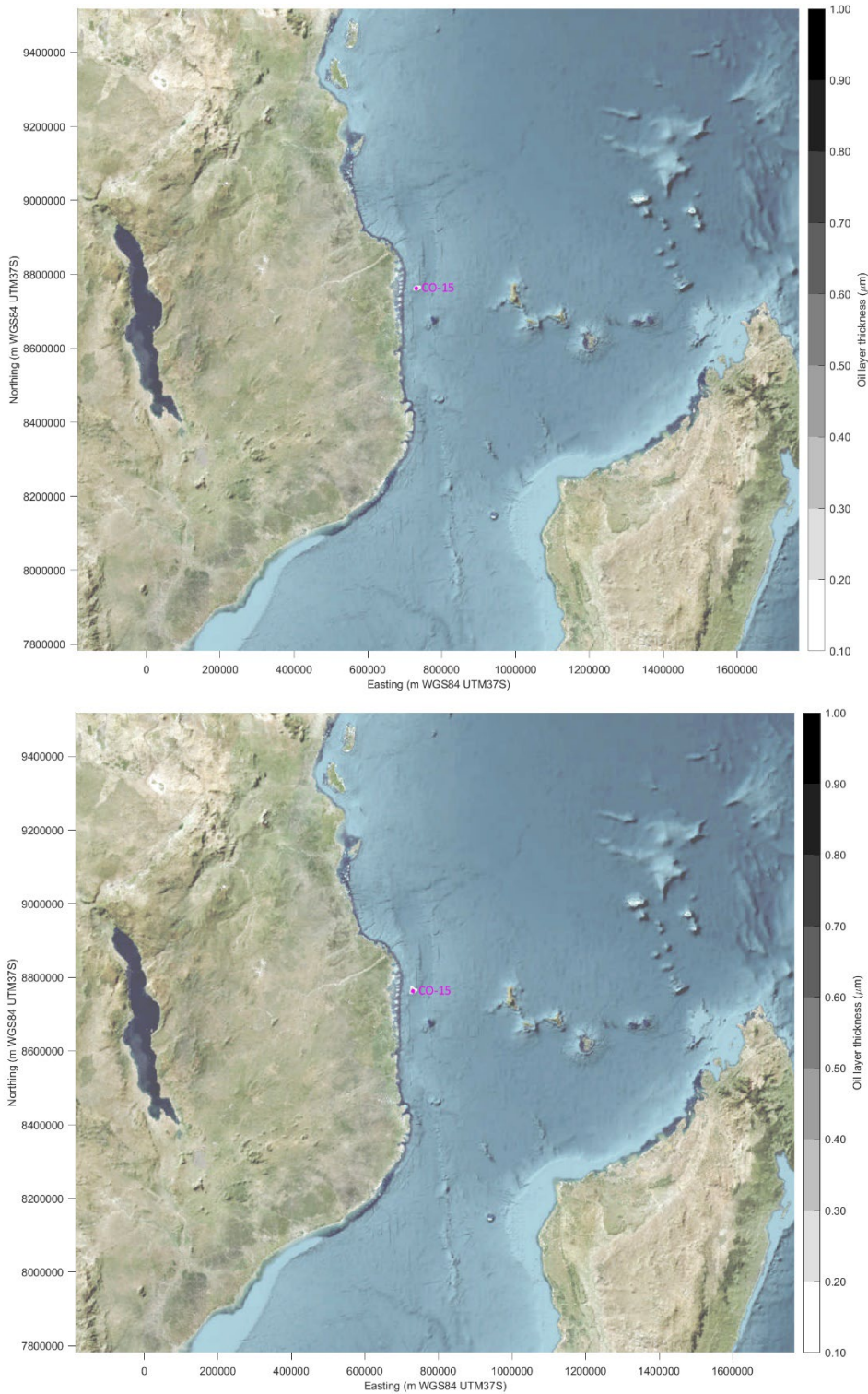
**Figure AVII.75: Weathering of diesel spill during May after 1 hour (top) and 6 hours (bottom)**



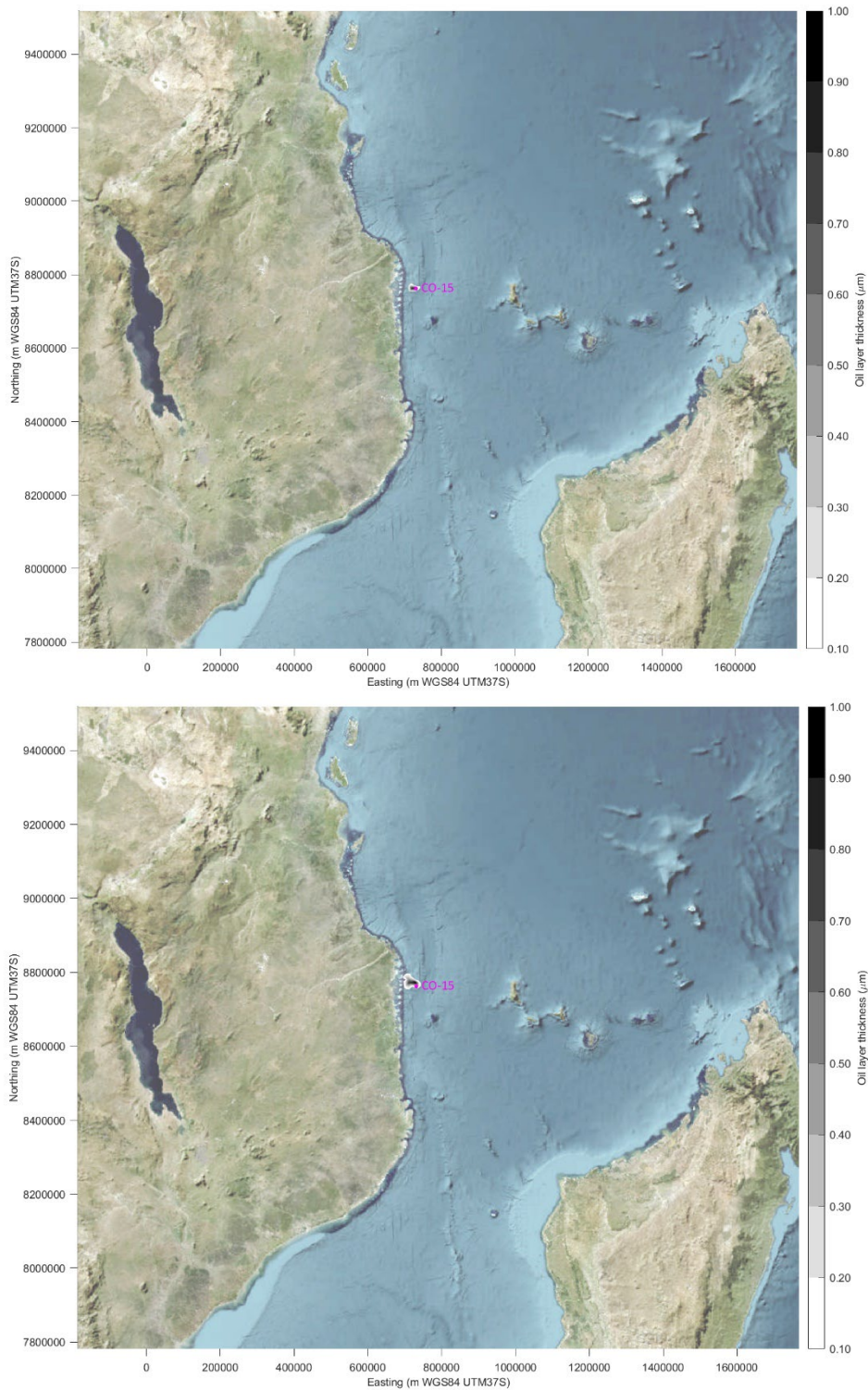
**Figure AVII.76: Weathering of diesel spill during May after 12 hours (top) and 24 hours (bottom)**



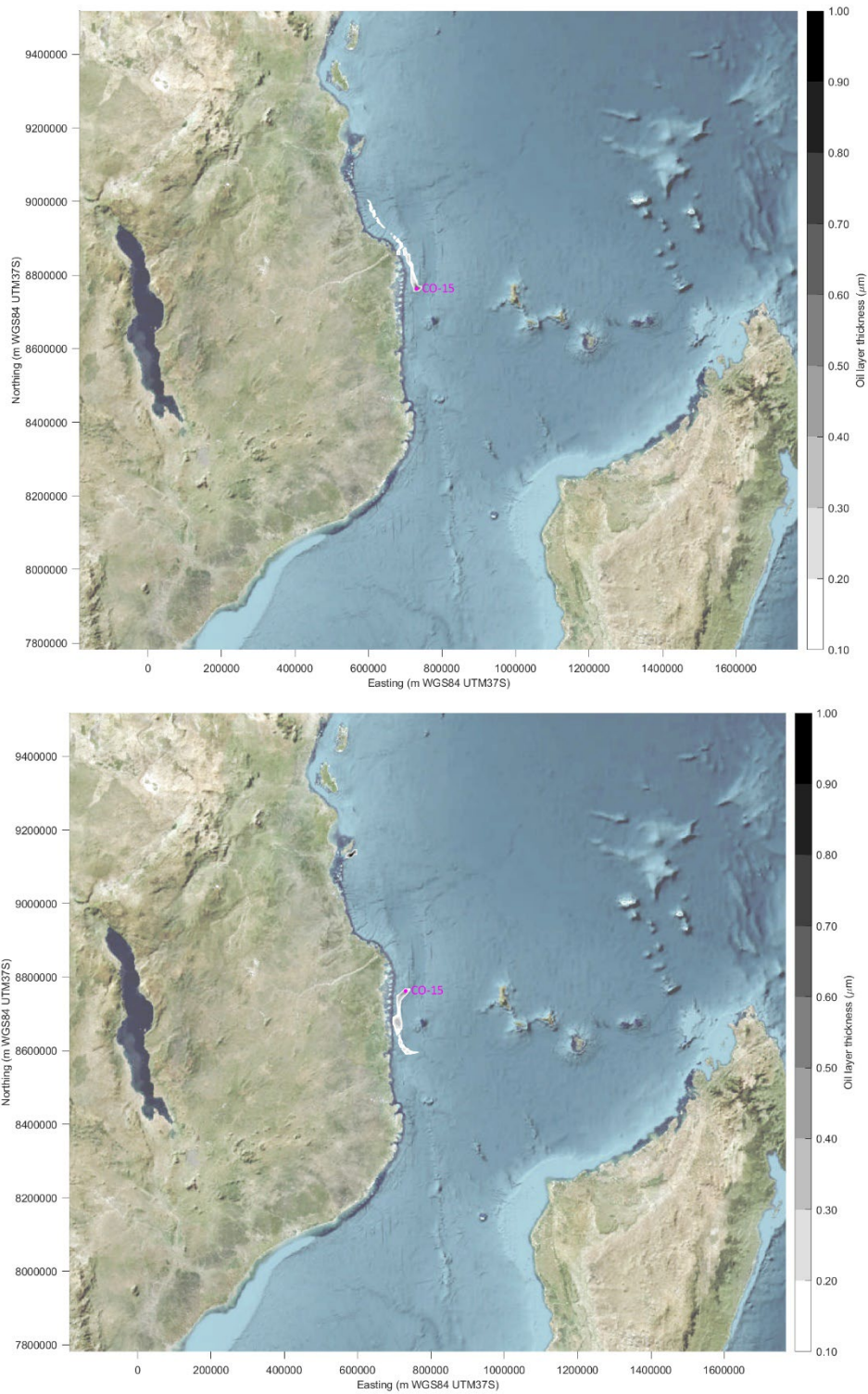
**Figure AVII.77: Weathering of diesel spill during May after 3 days (top) and 7 days (bottom)**



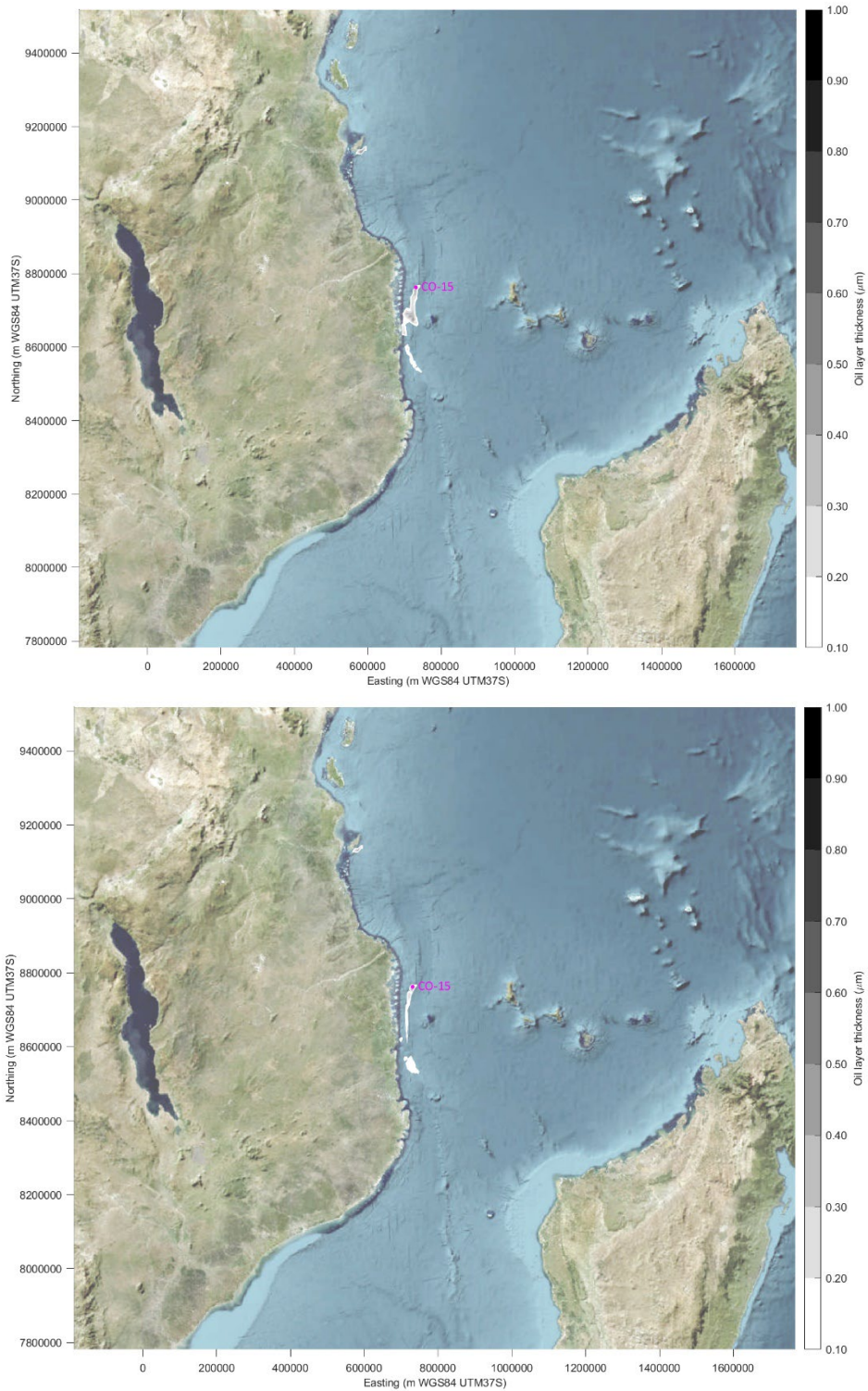
**Figure AVII.78: Weathering of condensate blowout during May after 6 hours (top) and 12 hours (bottom)**



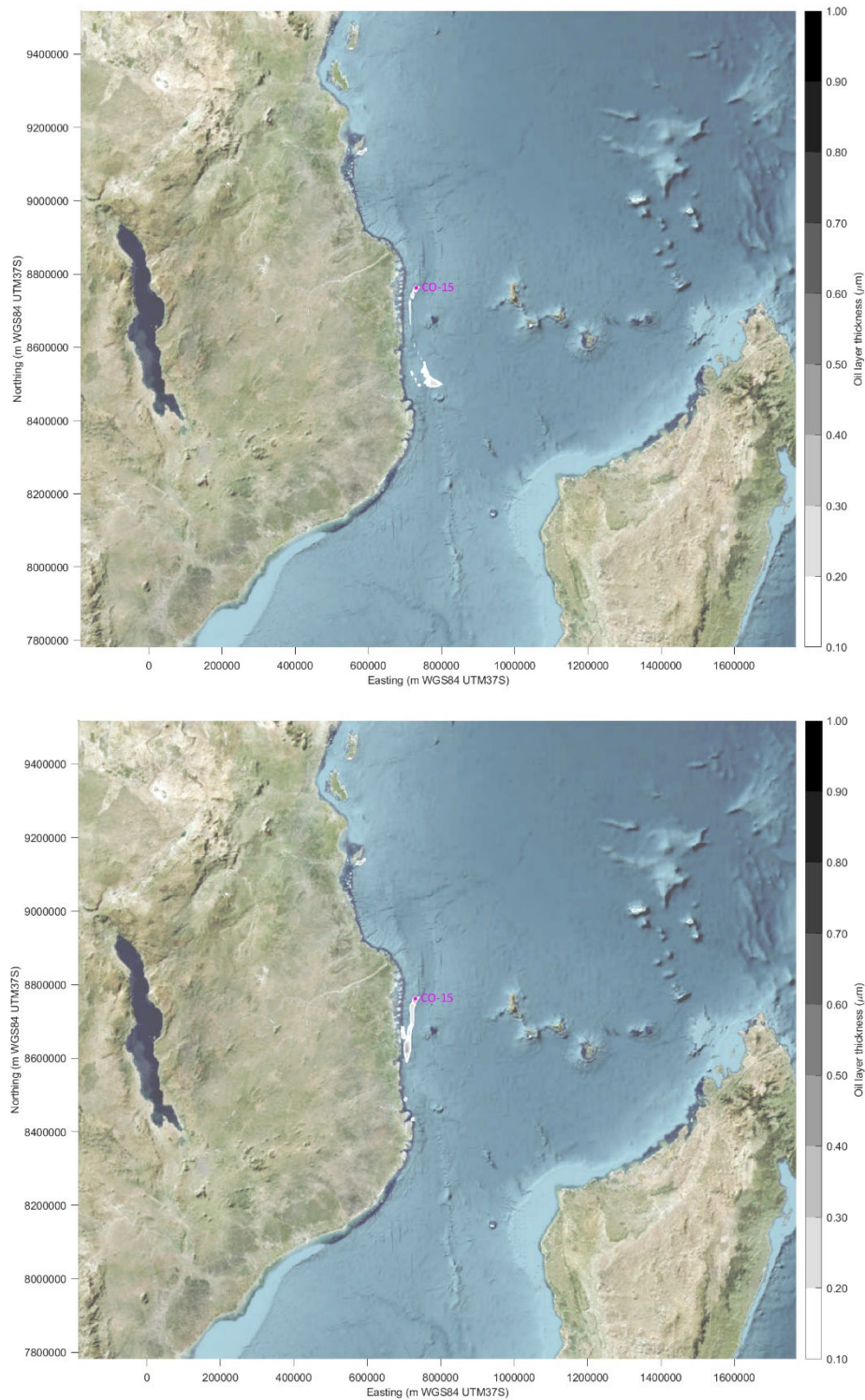
**Figure AVII.79: Weathering of condensate blowout during May after 24 hours (top) and 3 days (bottom)**



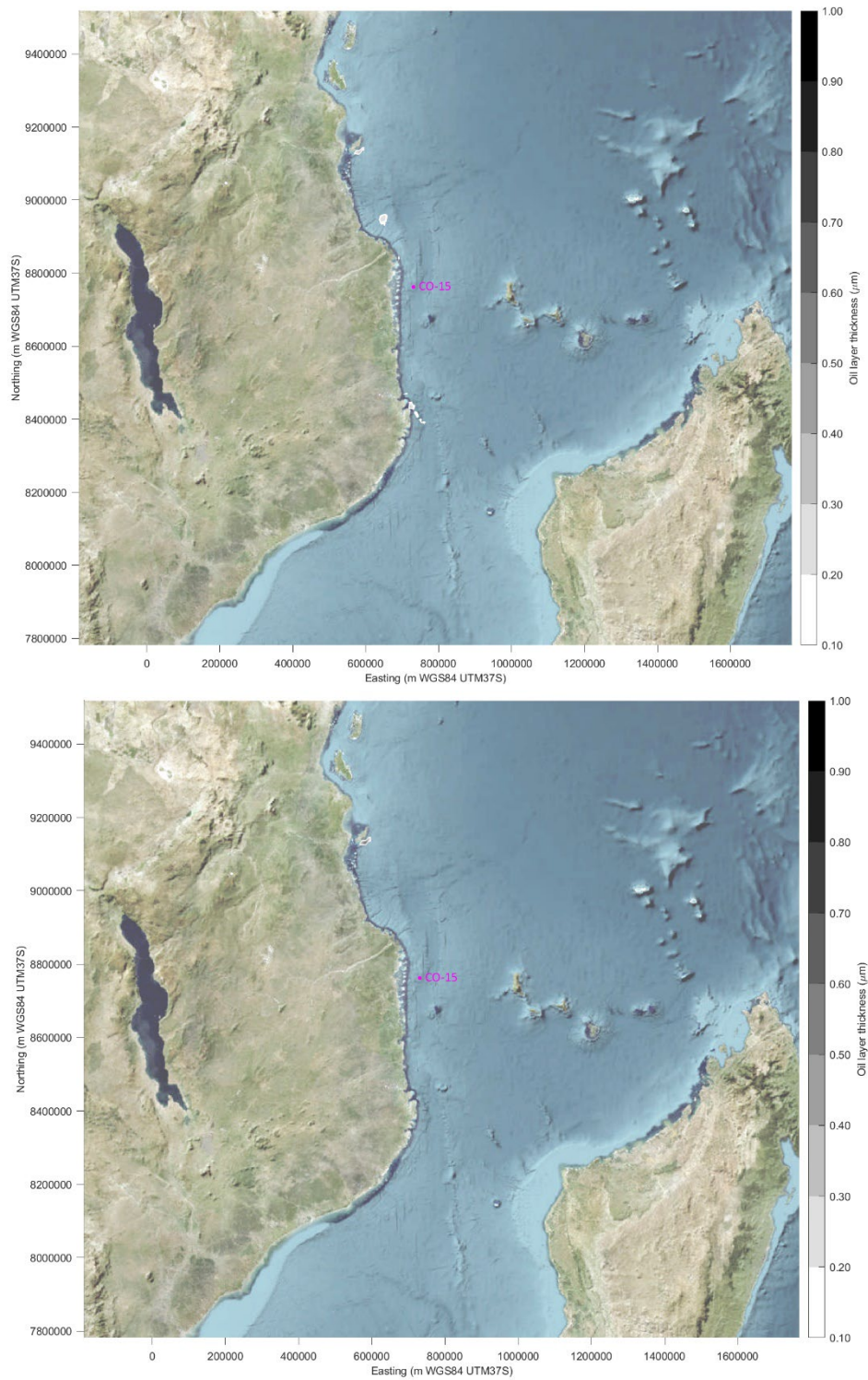
**Figure AVII.80: Weathering of condensate blowout during May after 7 days (top) and 2 weeks (bottom)**



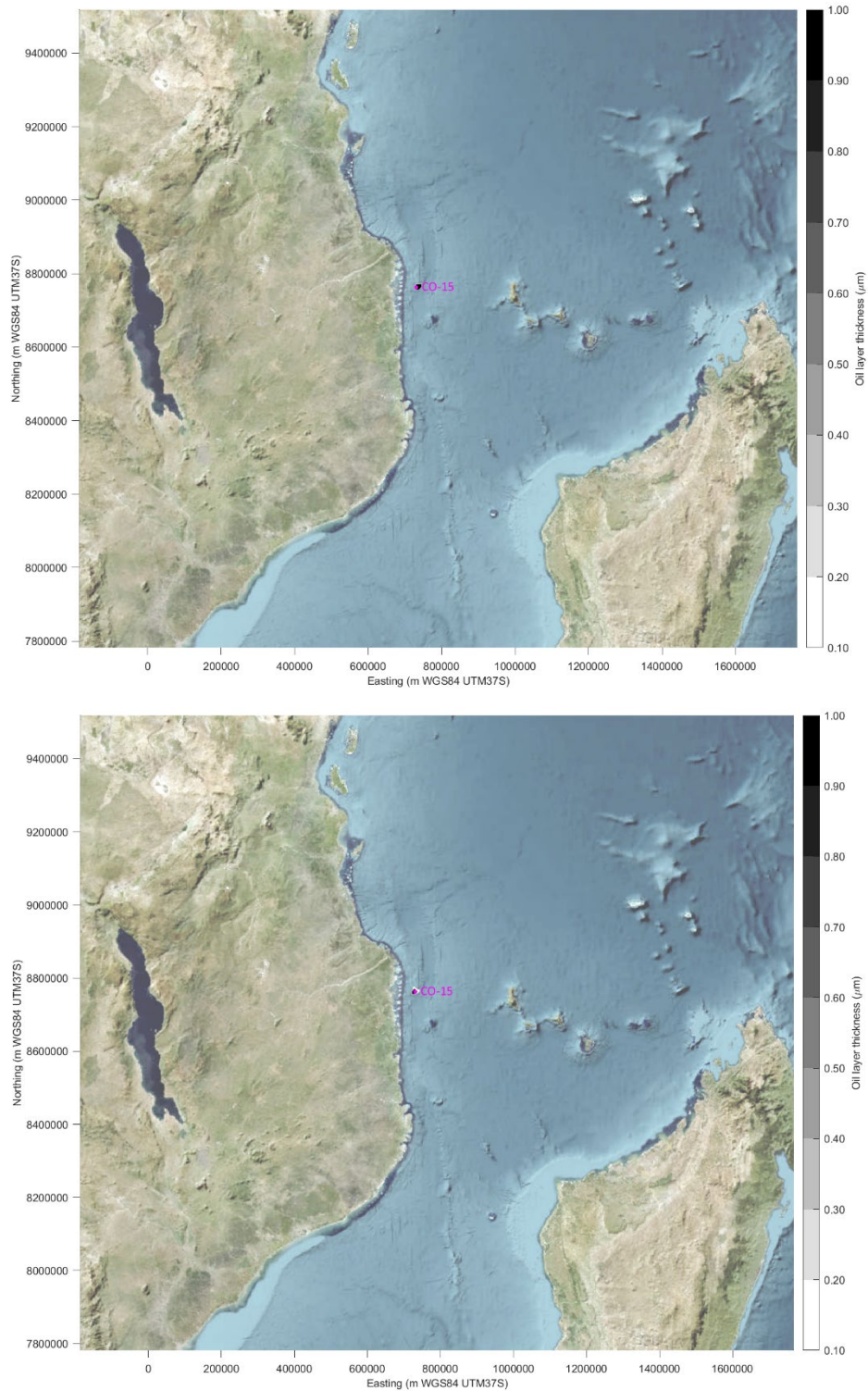
**Figure AVII.81: Weathering of condensate blowout during May after 3 weeks (top) and 4 weeks (bottom)**



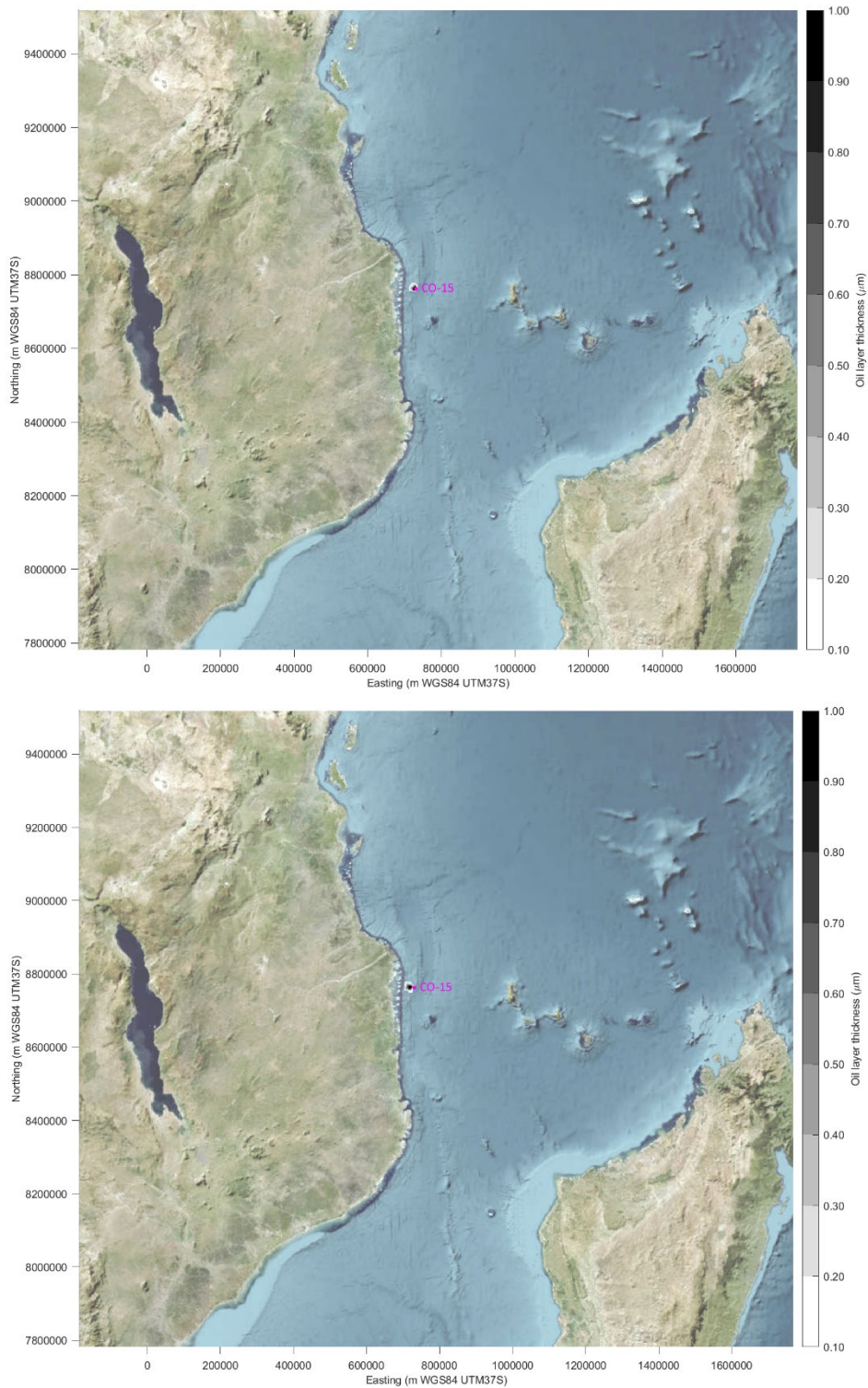
**Figure AVII.82: Weathering of condensate blowout during May after 5 weeks (top) and 6 weeks (bottom)**



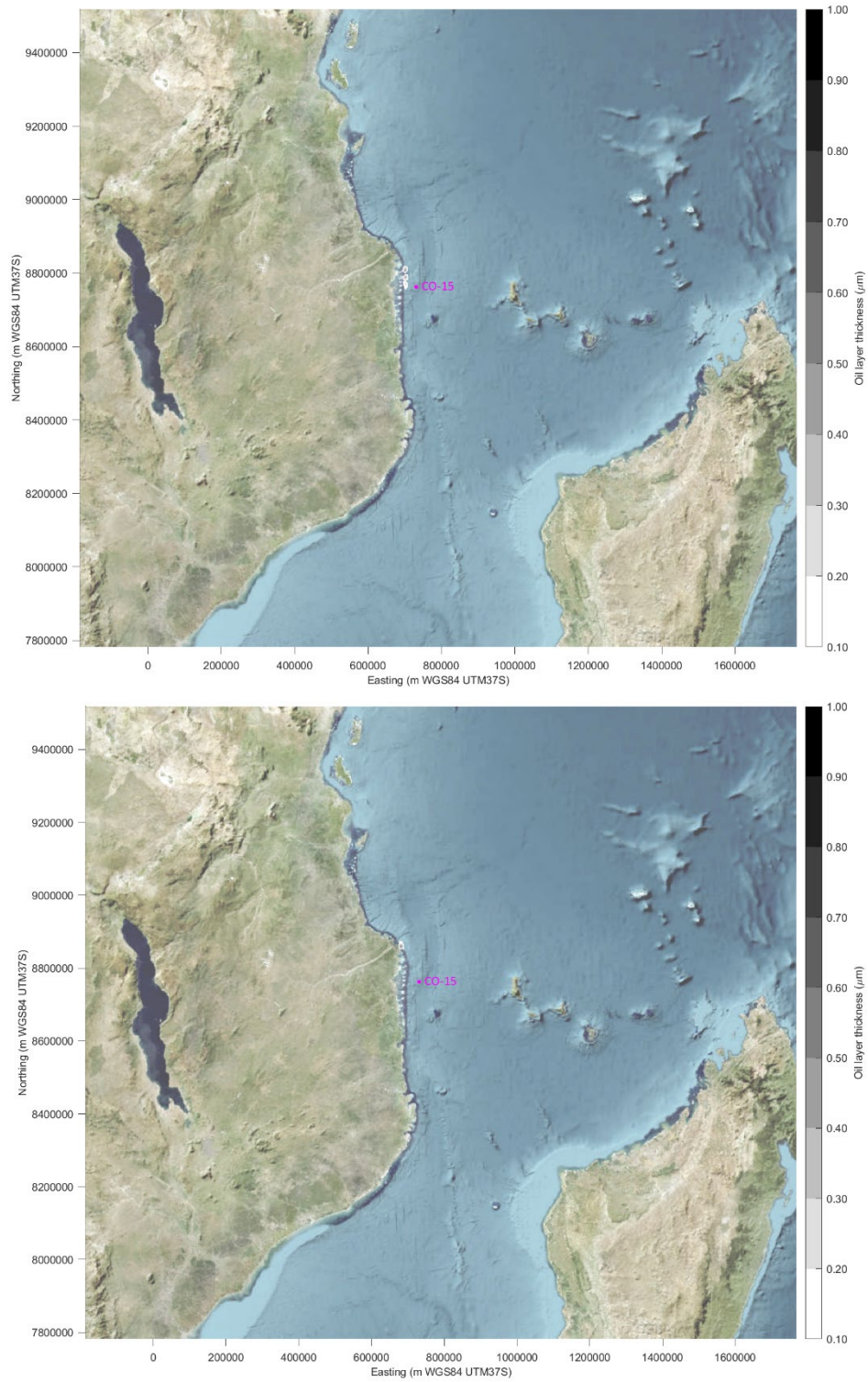
**Figure AVII.83: Weathering of condensate blowout during May after 7 weeks (top) and 8 weeks (bottom)**



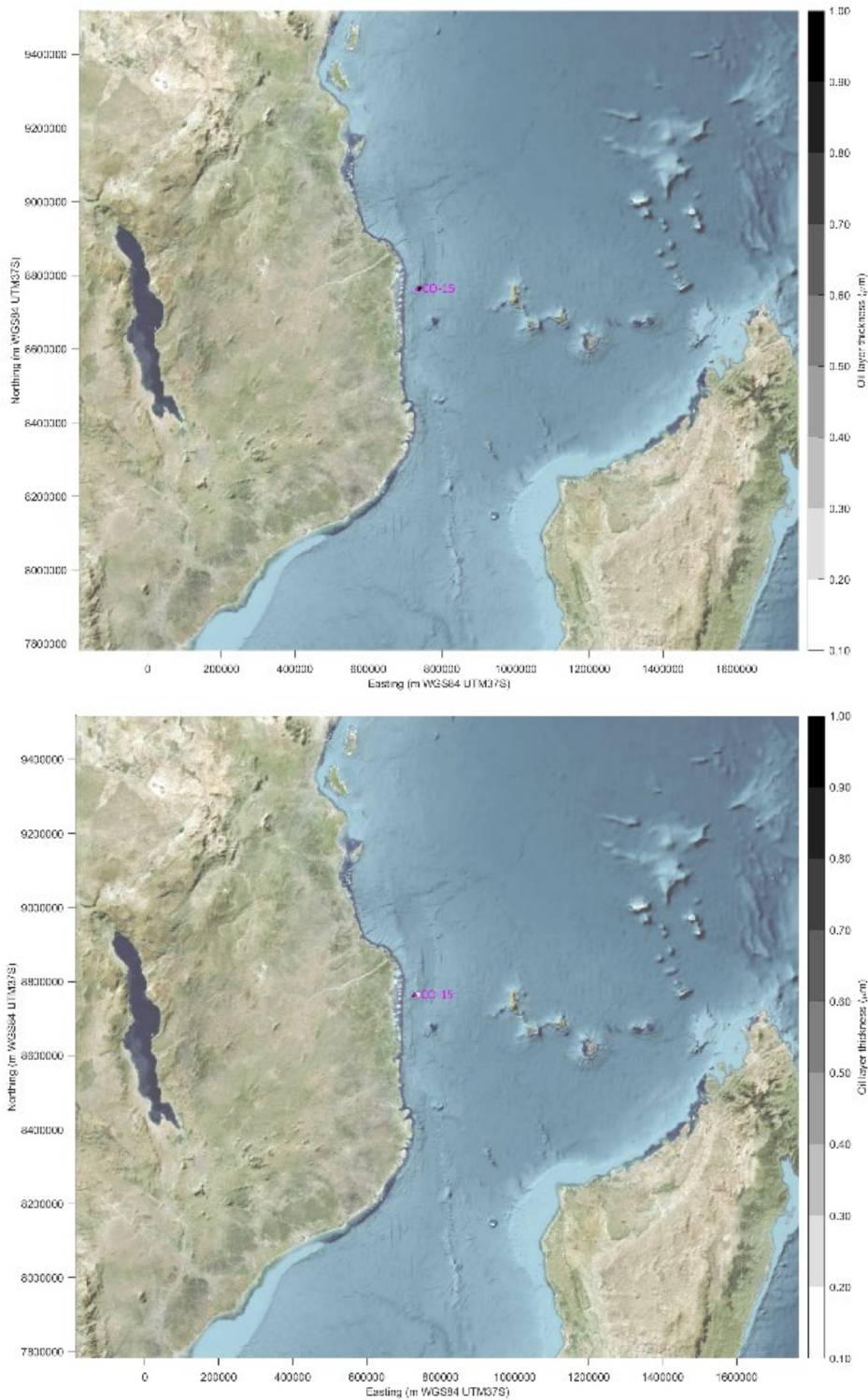
**Figure AVII.84: Weathering of LTOBM spill during May after 1 hour (top) and 6 hours (bottom)**



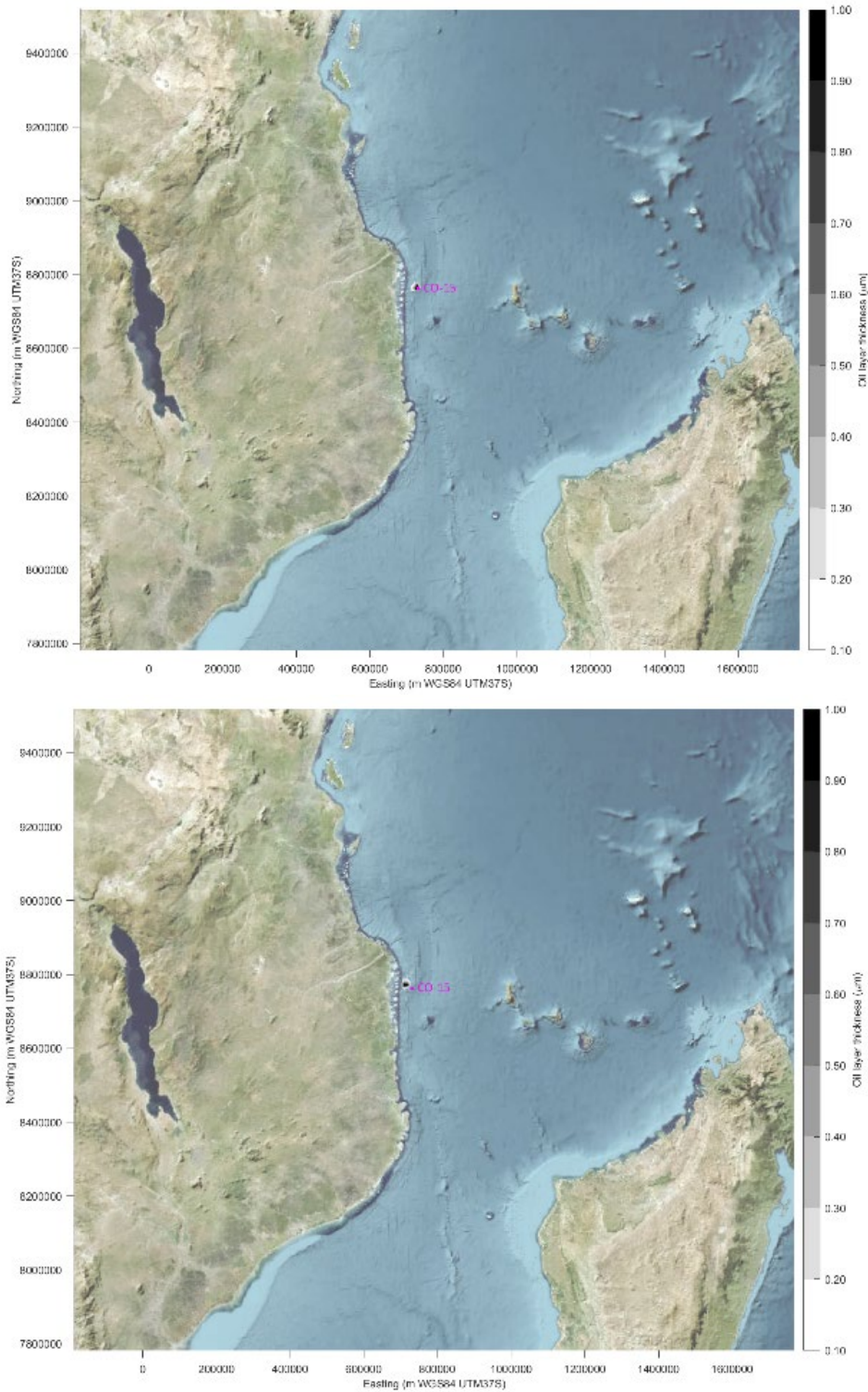
**Figure AVII.85: Weathering of LTOBM spill during May after 12 hours (top) and 24 hours (bottom)**



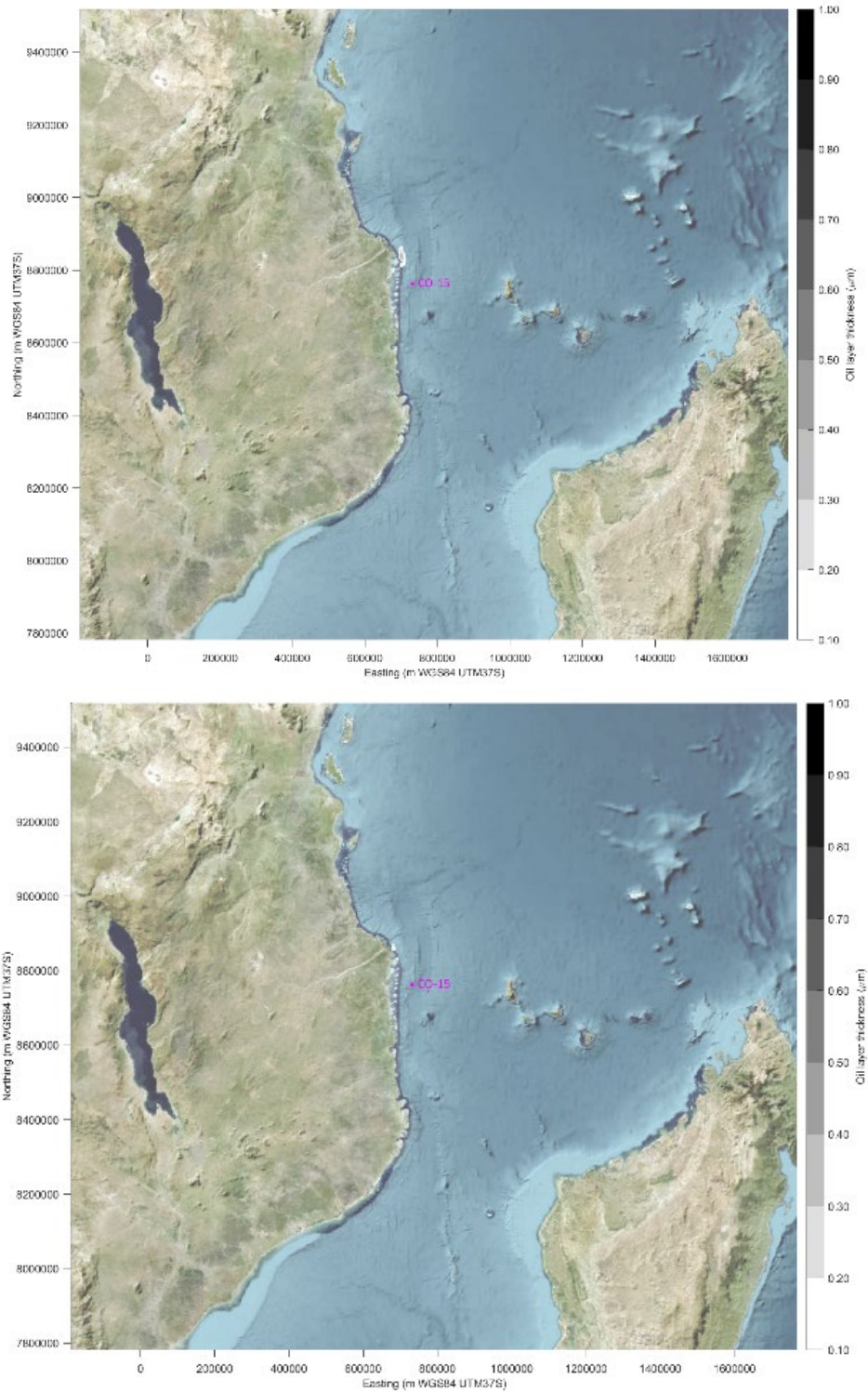
**Figure AVII.86: Weathering of LTOBM spill during May after 3 days (top) and 7 days (bottom)**



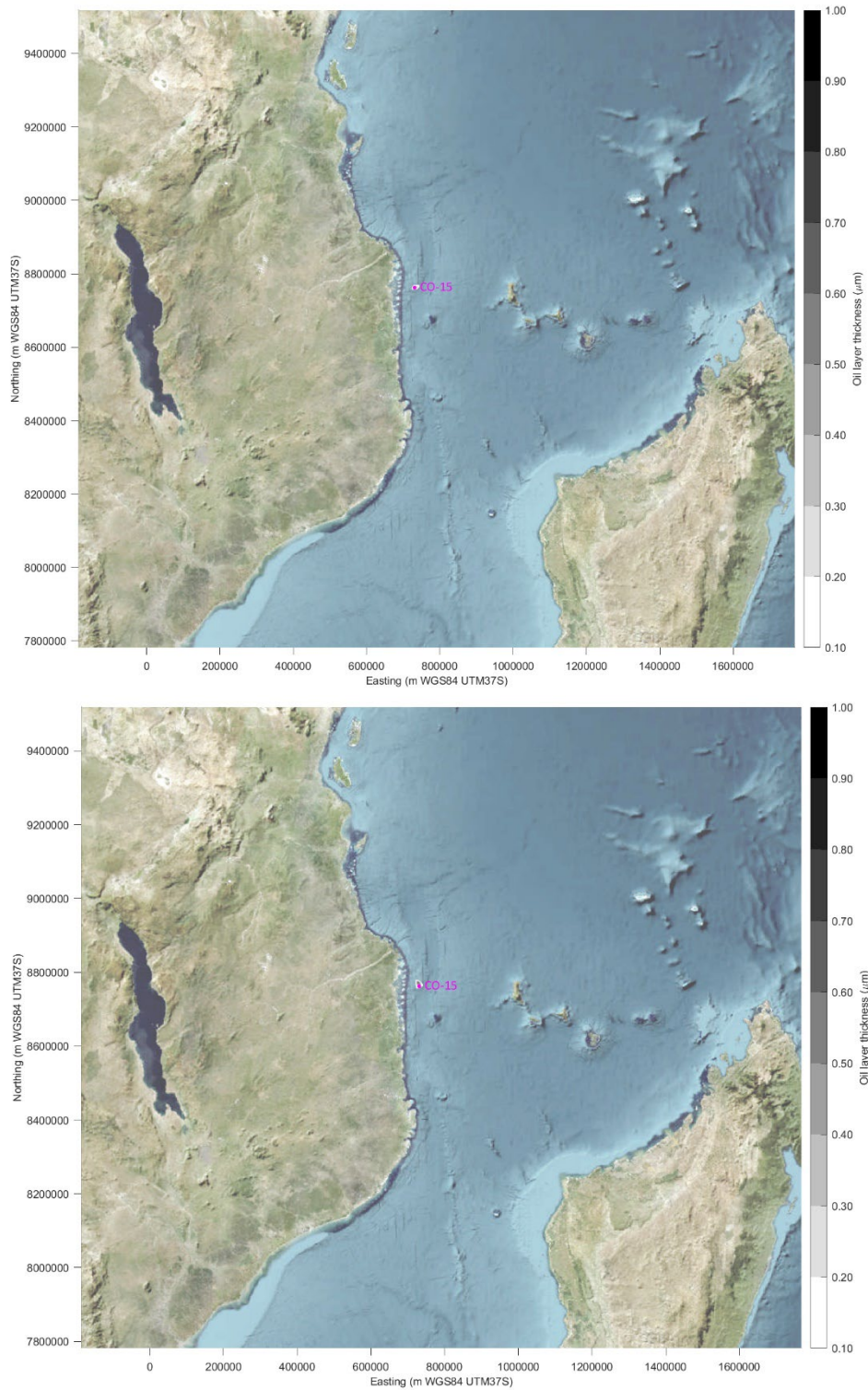
**Figure AVII.87: Weathering of diesel spill during October after 1 hour (top) and 6 hours (bottom)**



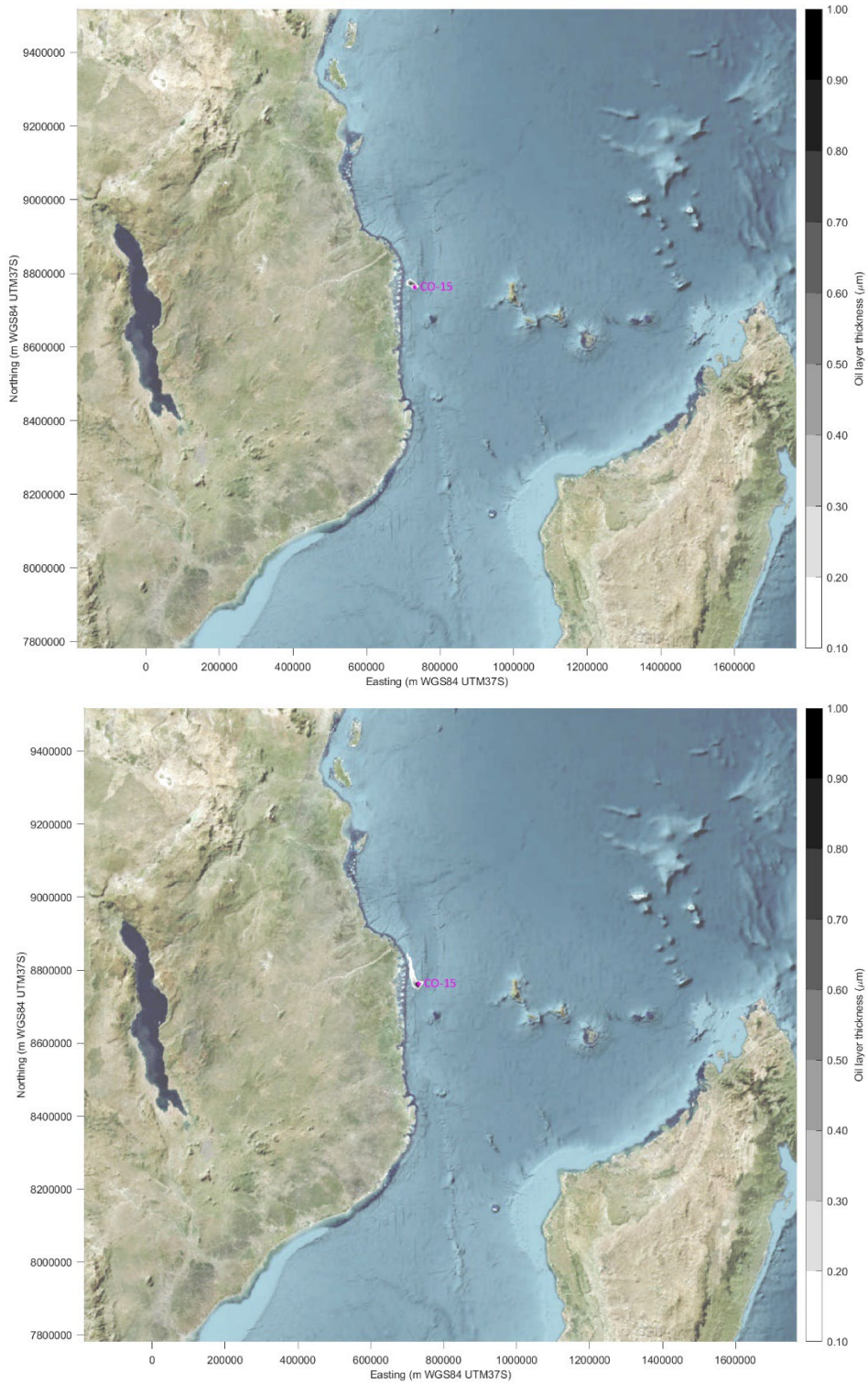
**Figure AVII.88: Weathering of diesel spill during October after 12 hours (top) and 24 hours (bottom)**



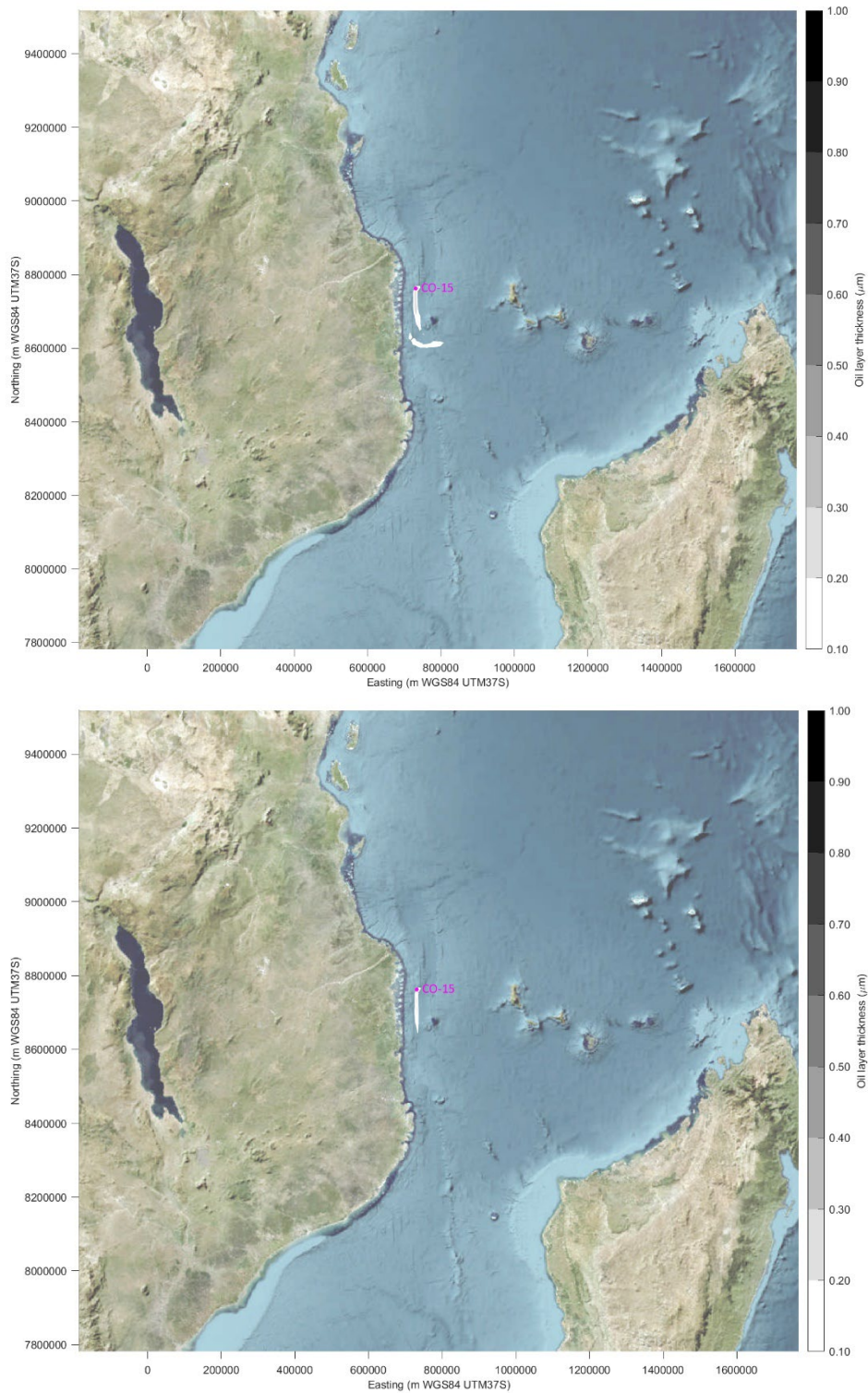
**Figure AVII.89: Weathering of diesel spill during October after 3 days (top) and 7 days (bottom)**



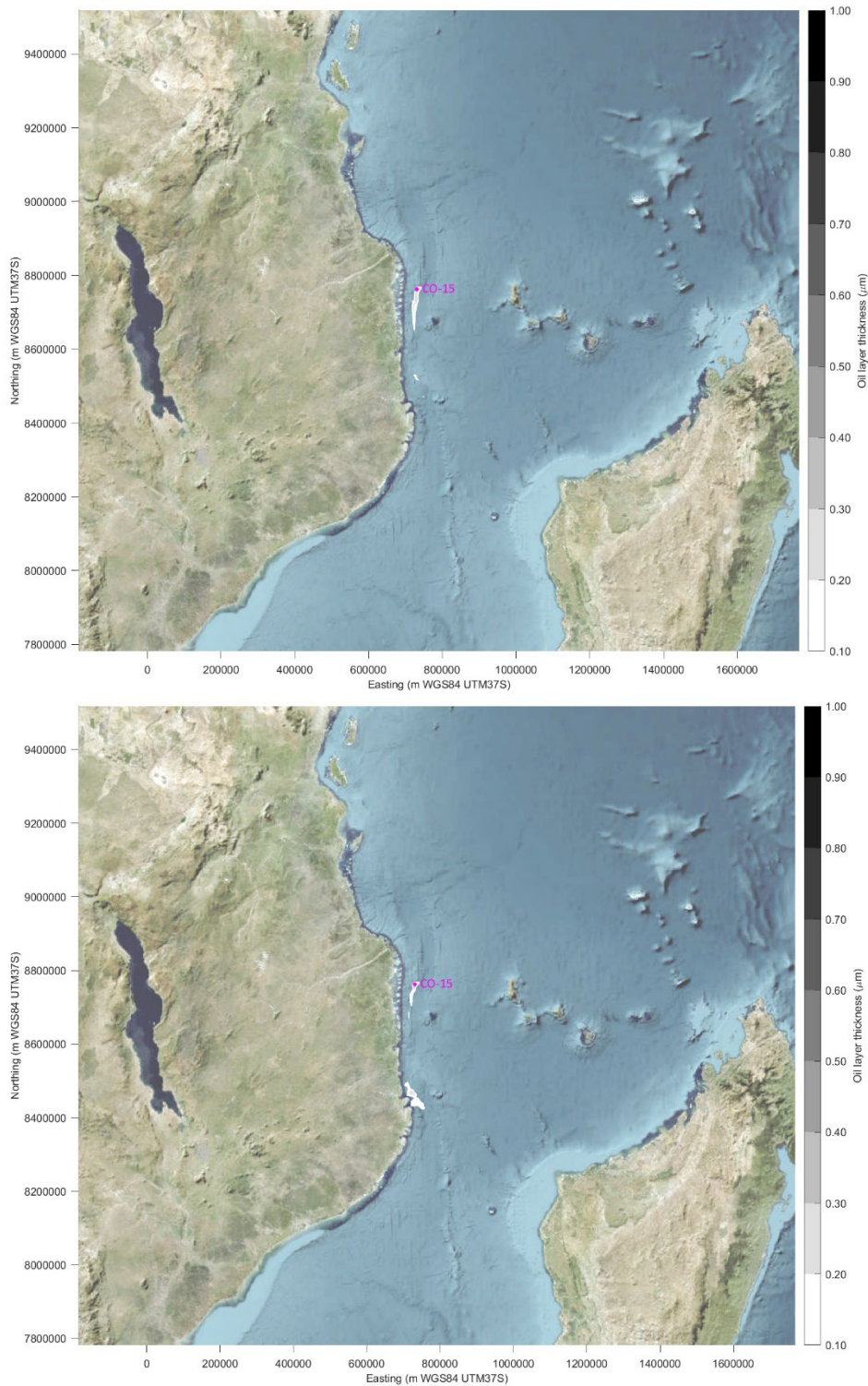
**Figure AVII.90: Weathering of condensate blowout during October after 6 hours (top) and 12 hours (bottom)**



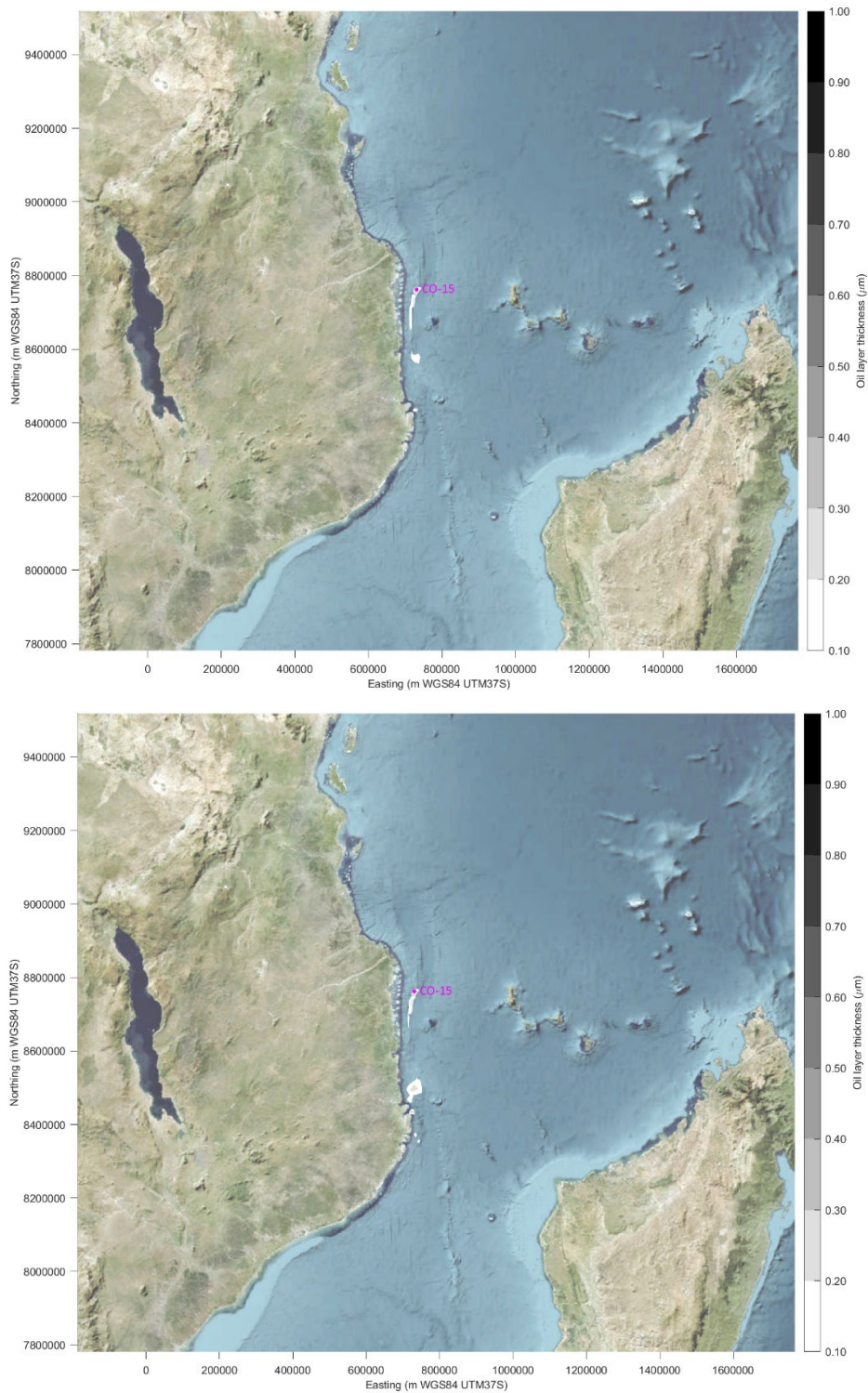
**Figure AVII.91: Weathering of condensate blowout during October after 24 hours (top) and 3 days (bottom)**



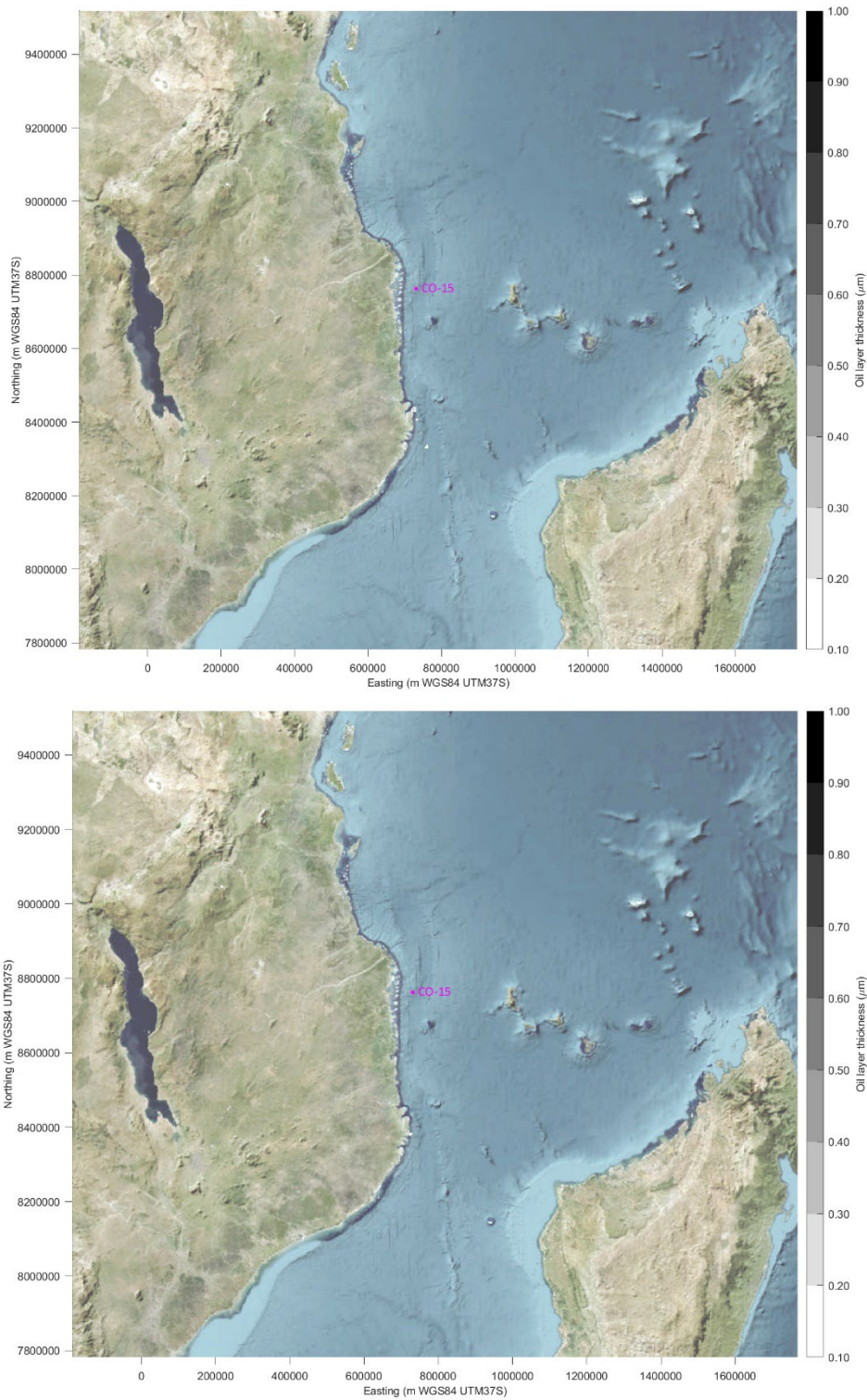
**Figure AVII.92: Weathering of condensate blowout during October after 7 days (top) and 2 weeks (bottom)**



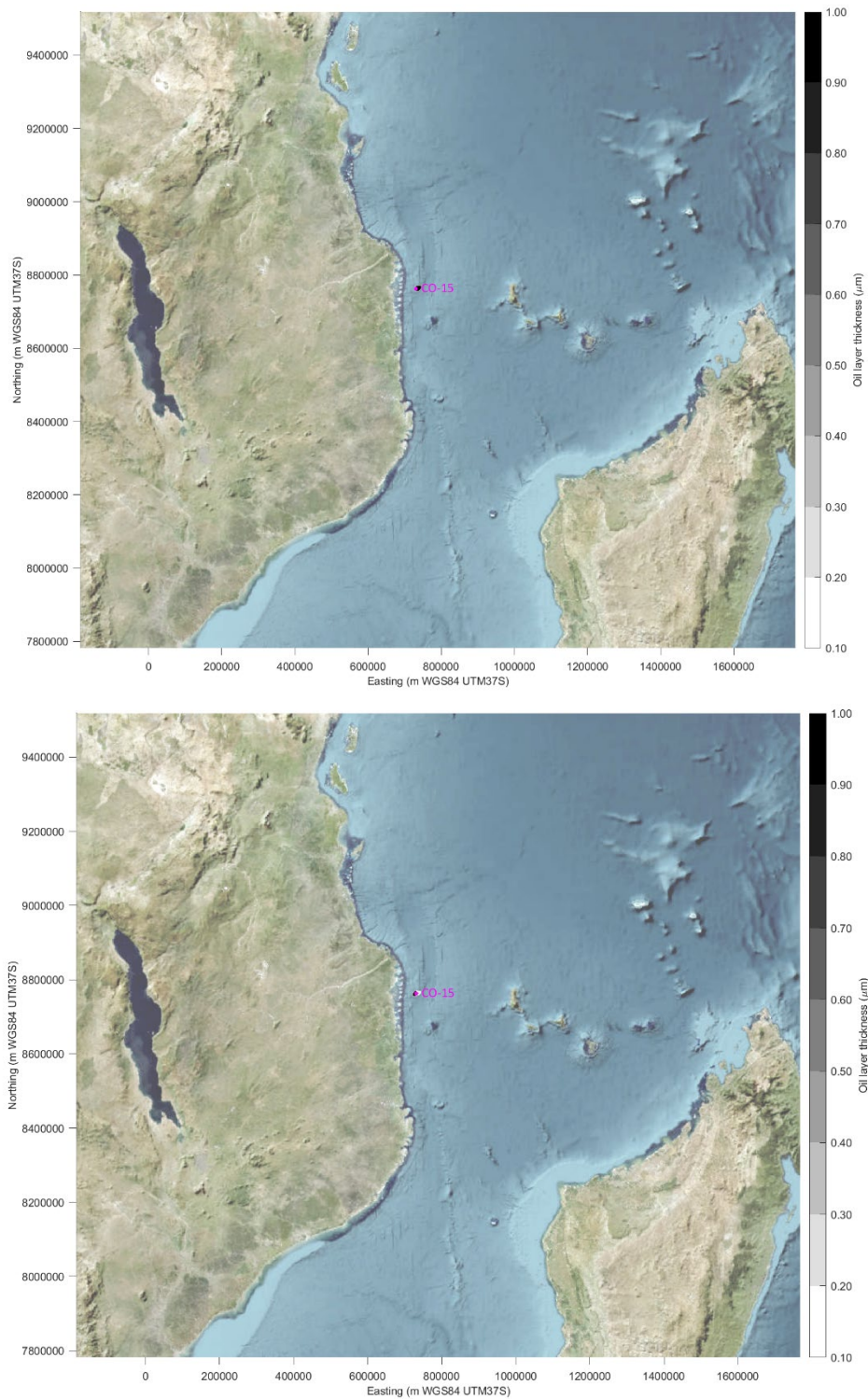
**Figure AVII.93: Weathering of condensate blowout during October after 3 weeks (top) and 4 weeks (bottom)**



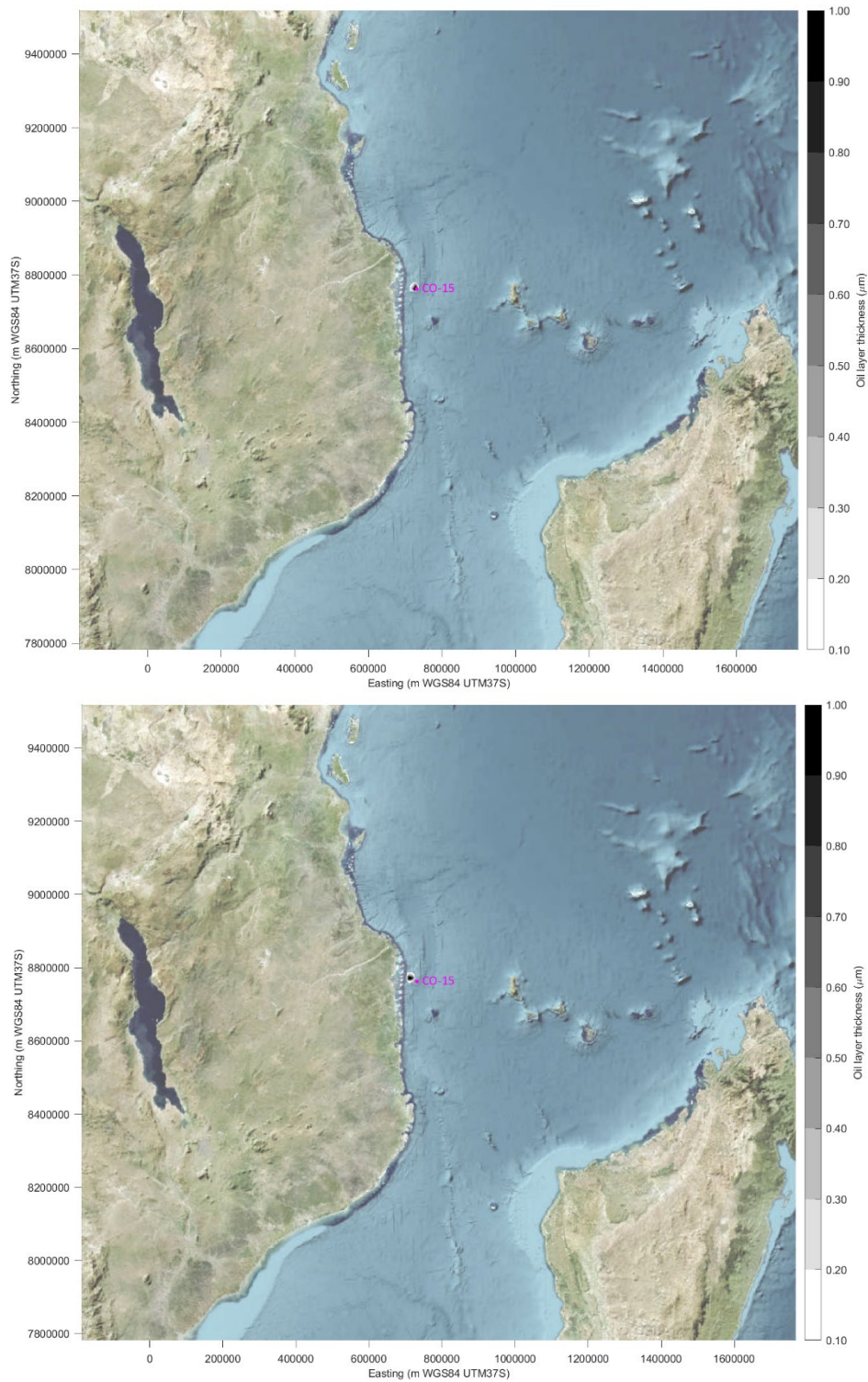
**Figure AVII.94: Weathering of condensate blowout during October after 5 weeks (top) and 6 weeks (bottom)**



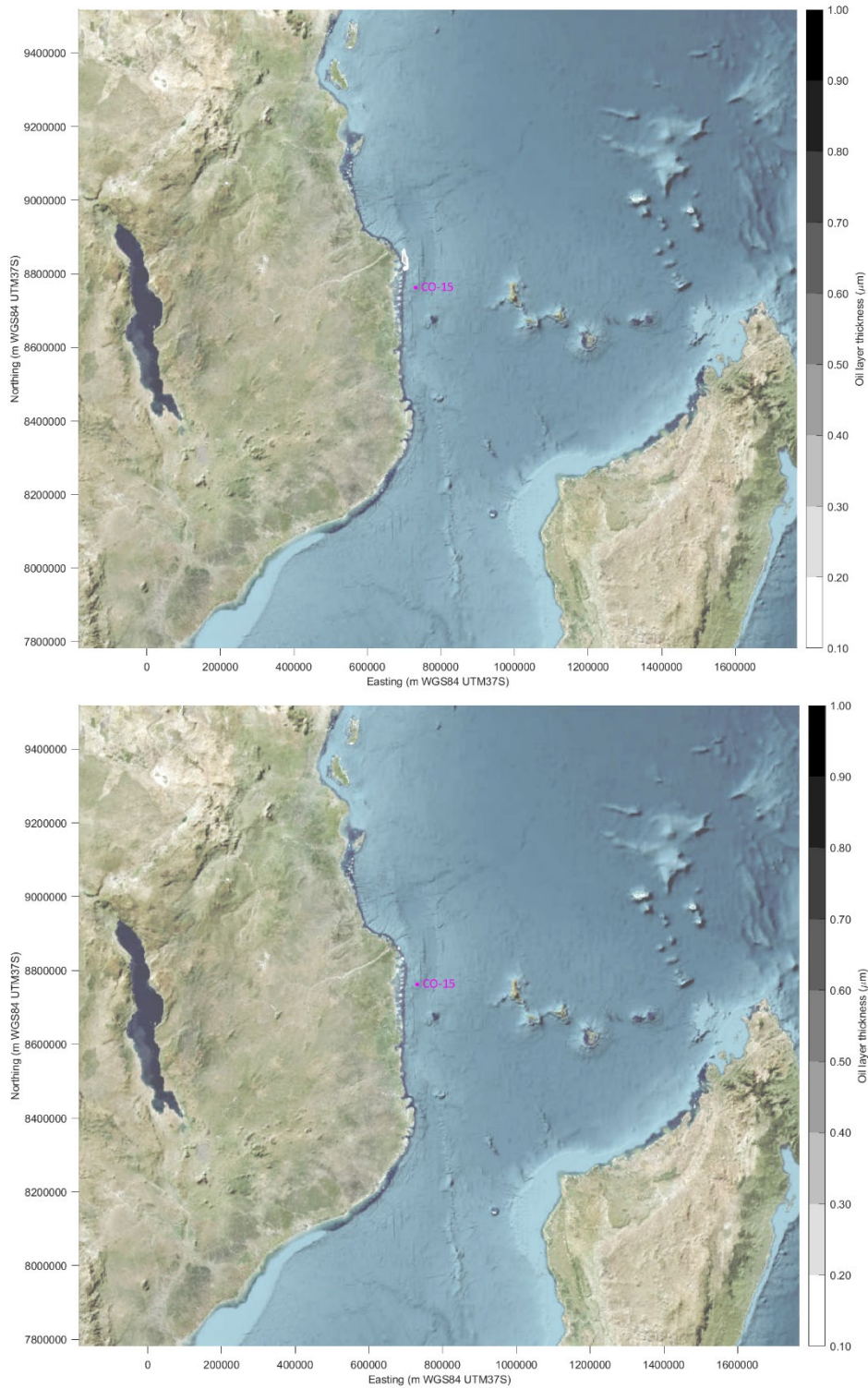
**Figure AVII.95: Weathering of condensate blowout during October after 7 weeks (top) and 8 weeks (bottom)**



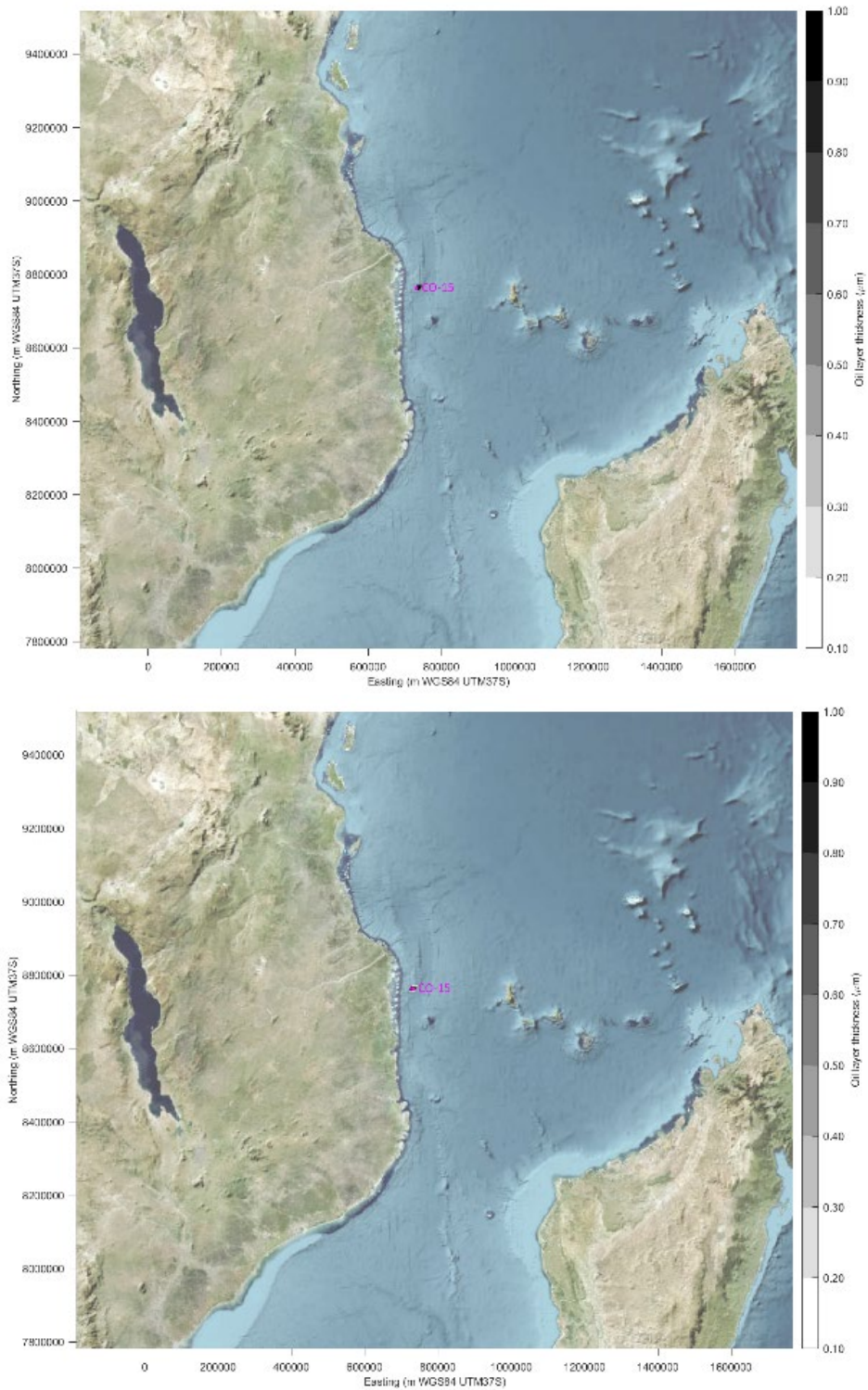
**Figure AVII.96: Weathering of LTOBM spill during October after 1 hour (top) and 6 hours (bottom)**



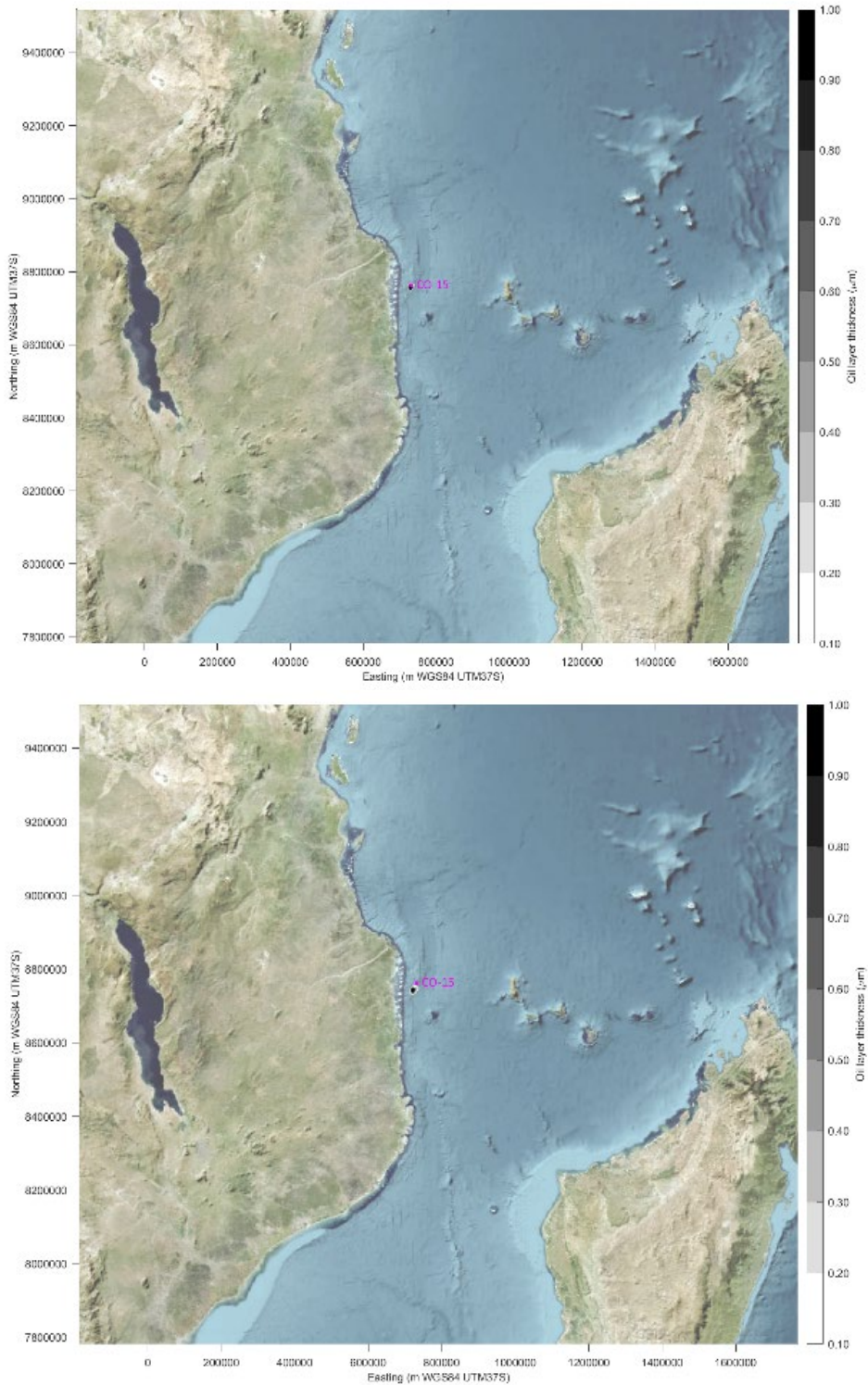
**Figure AVII.97: Weathering of LTOBM spill during October after 12 hours (top) and 24 hours (bottom)**



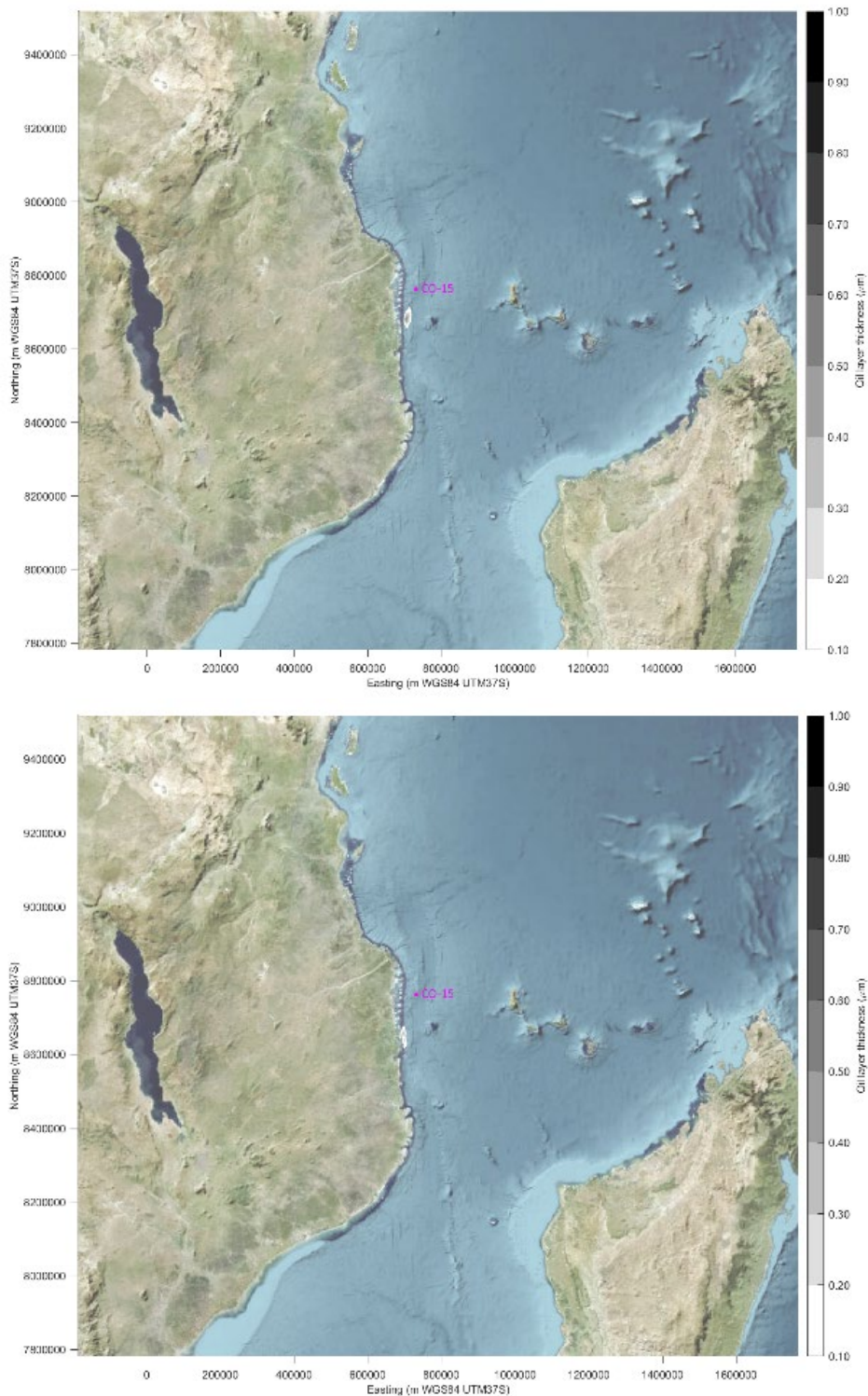
**Figure AVII.98: Weathering of LTOBM spill during October after 3 days (top) and 7 days (bottom)**



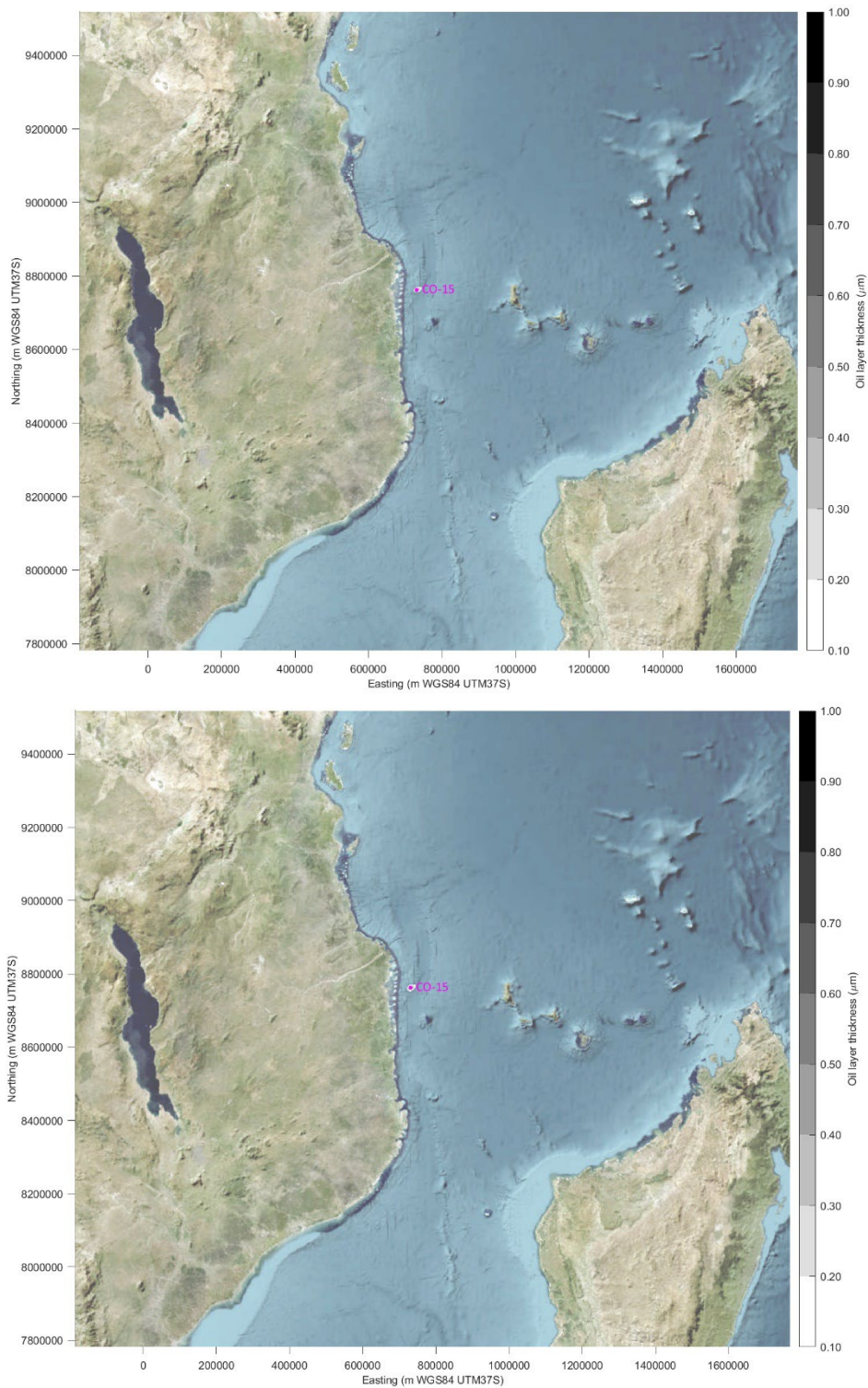
**Figure AVII.99: Weathering of diesel spill during March after 1 hour (top) and 6 hours (bottom)**



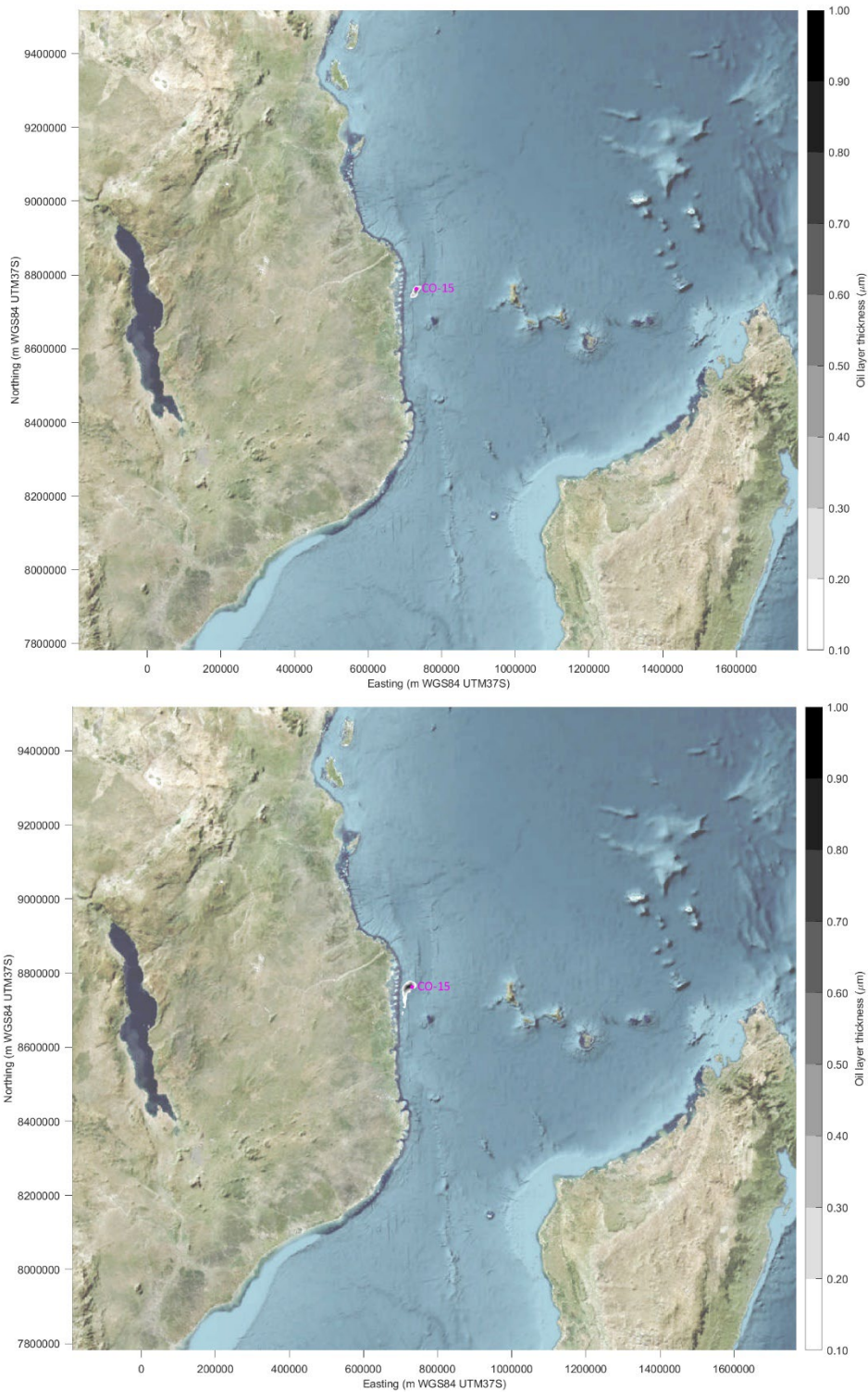
**Figure AVII.100: Weathering of diesel spill during March after 12 hours (top) and 24 hours (bottom)**



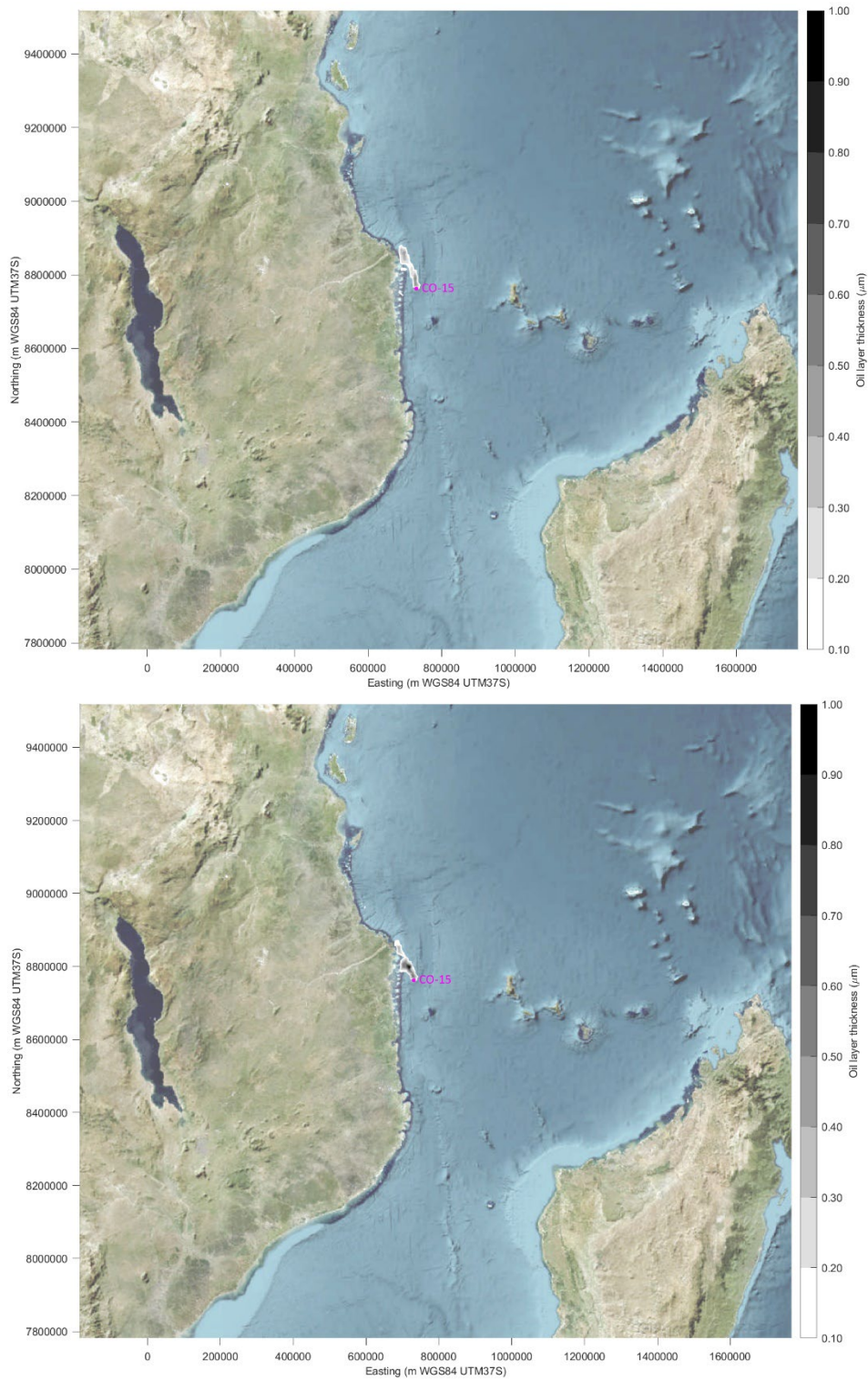
**Figure AVII.101: Weathering of diesel spill during March after 3 days (top) and 7 days (bottom)**



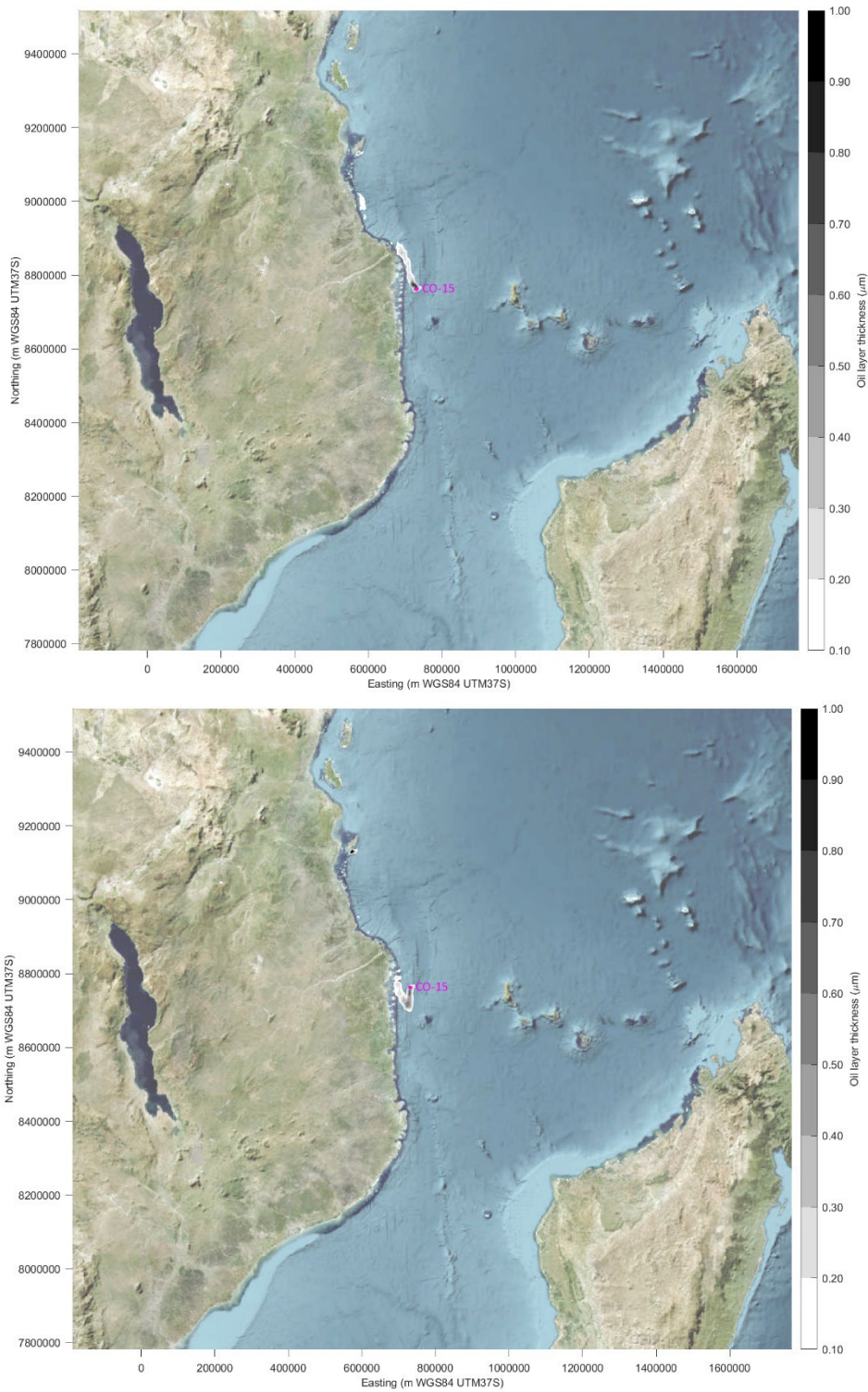
**Figure AVII.102: Weathering of condensate blowout during March after 6 hours (top) and 12 hours (bottom)**



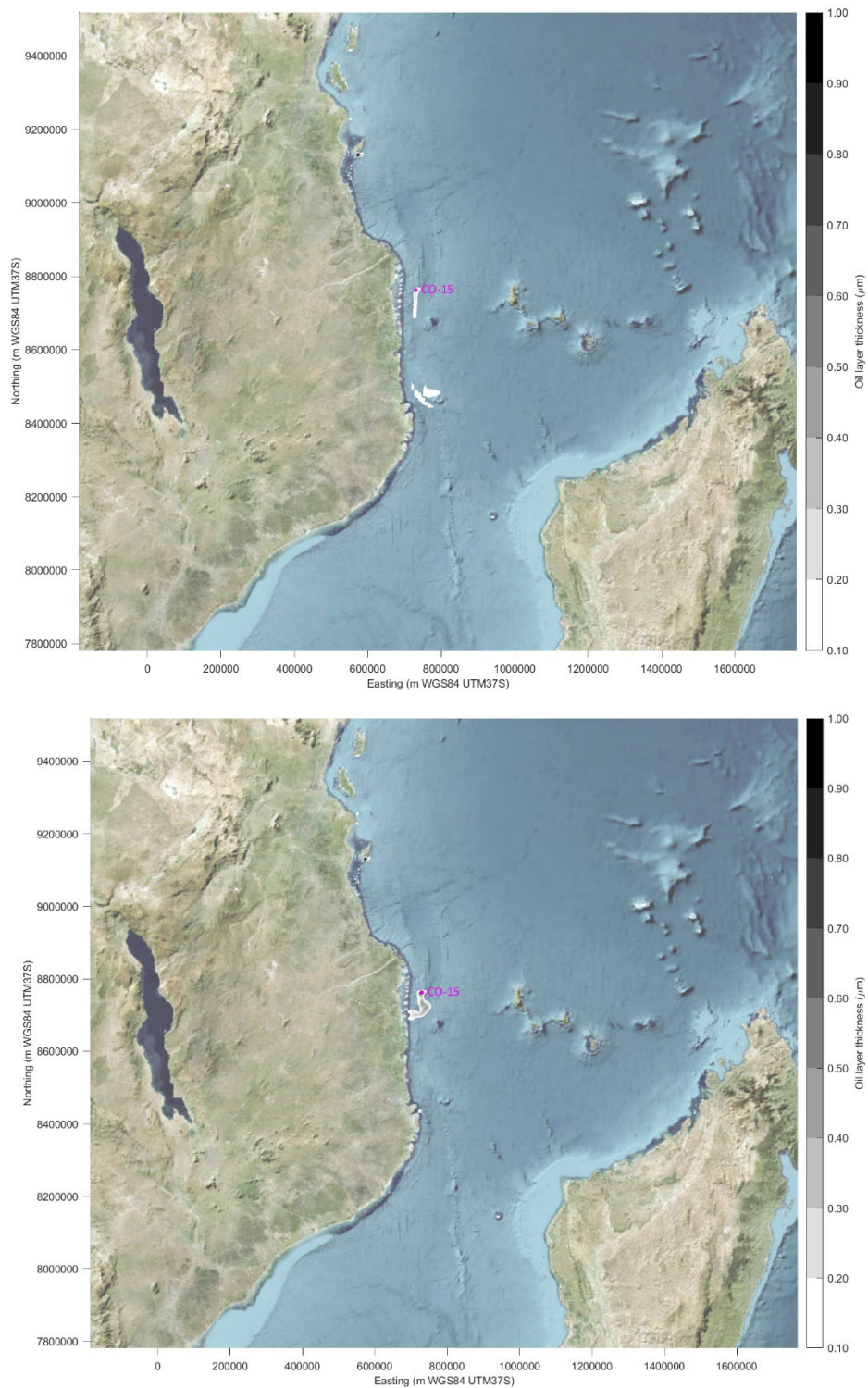
**Figure AVII.103: Weathering of condensate blowout during March after 24 hours (top) and 3 days (bottom)**



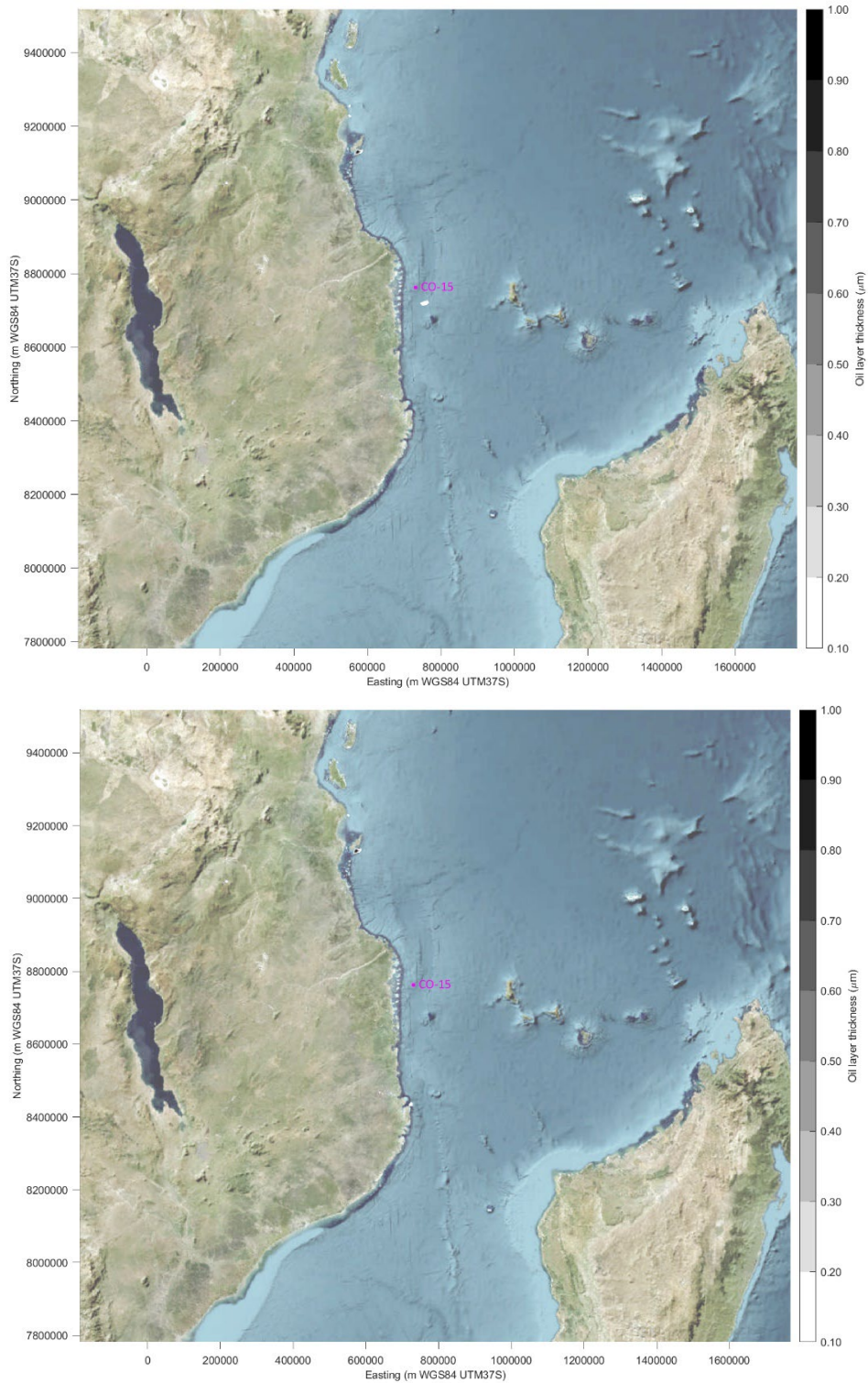
**Figure AVII.104: Weathering of condensate blowout during March after 7 days (top) and 2 weeks (bottom)**



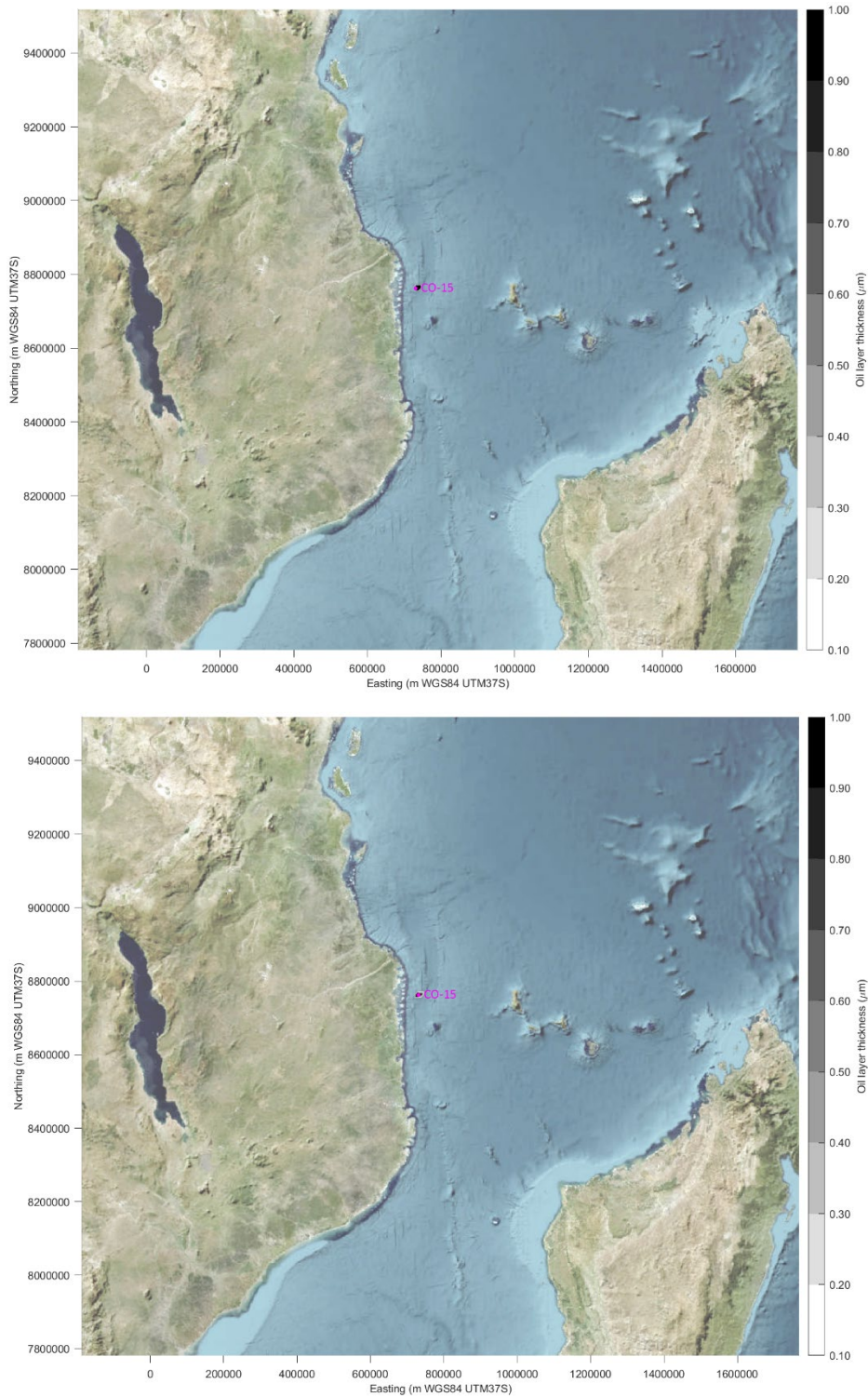
**Figure AVII.105: Weathering of condensate blowout during March after 3 weeks (top) and 4 weeks (bottom)**



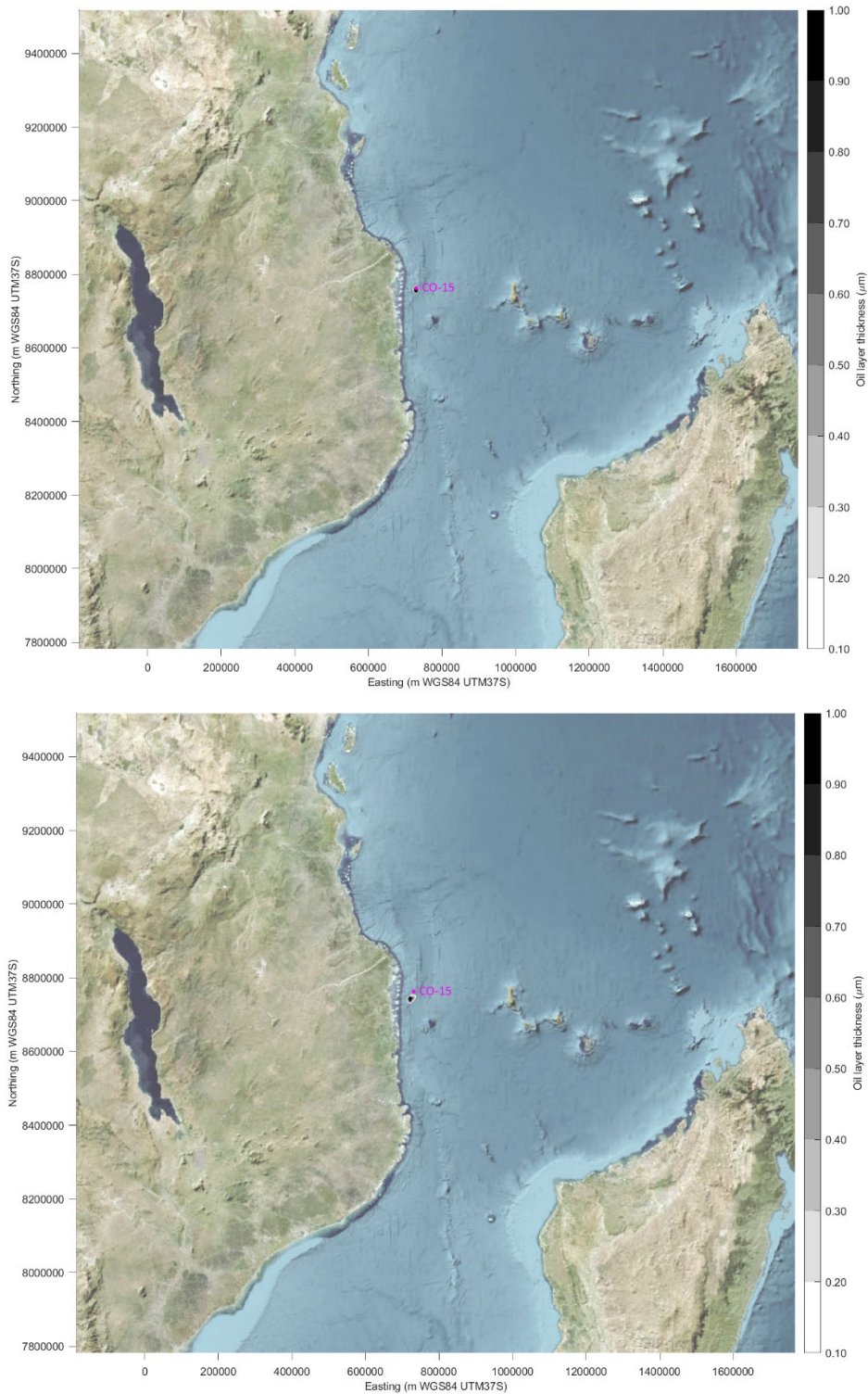
**Figure AVII.106: Weathering of condensate blowout during March after 5 weeks (top) and 6 weeks (bottom)**



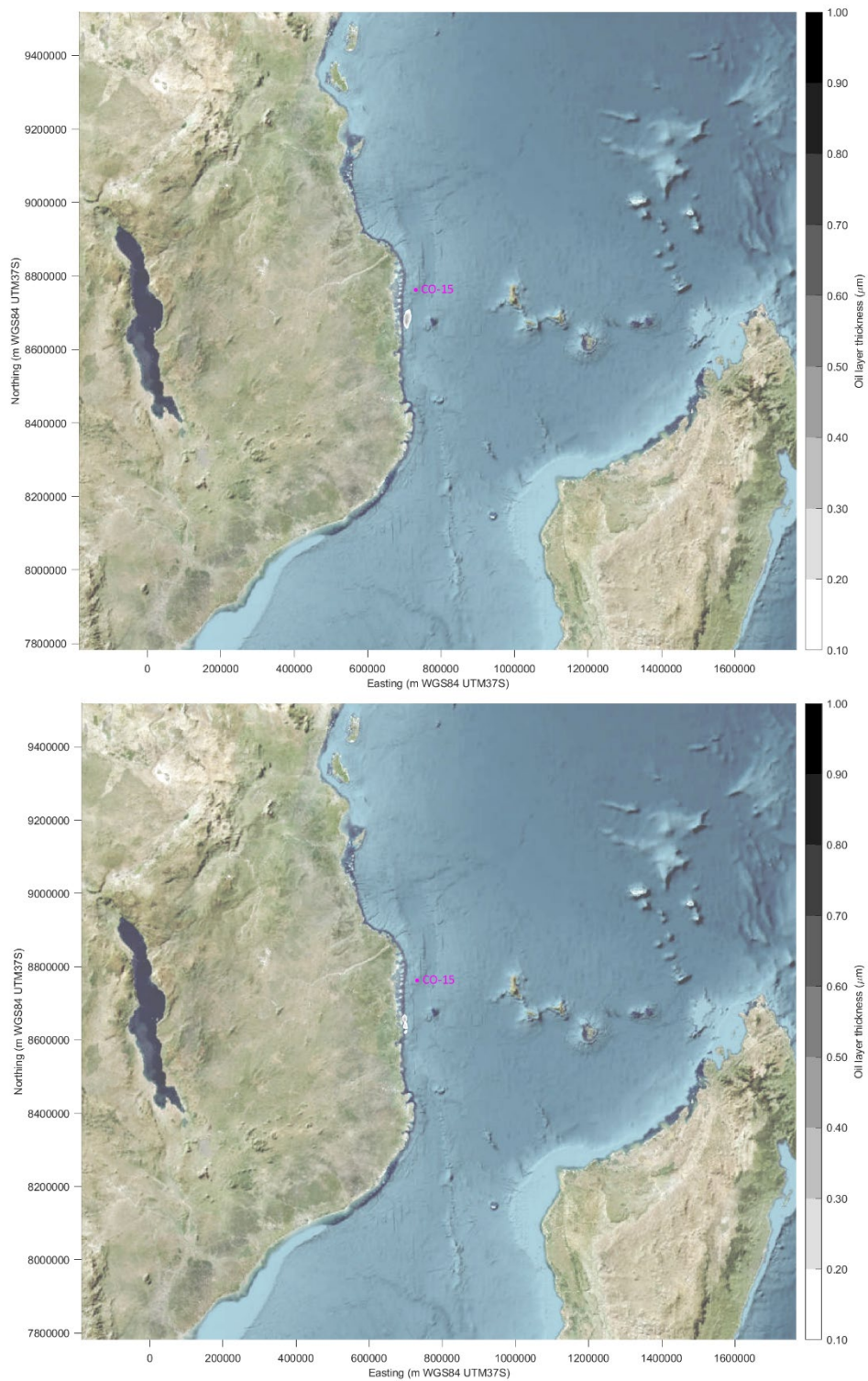
**Figure AVII.107: Weathering of condensate blowout during March after 7 weeks (top) and 8 weeks (bottom)**



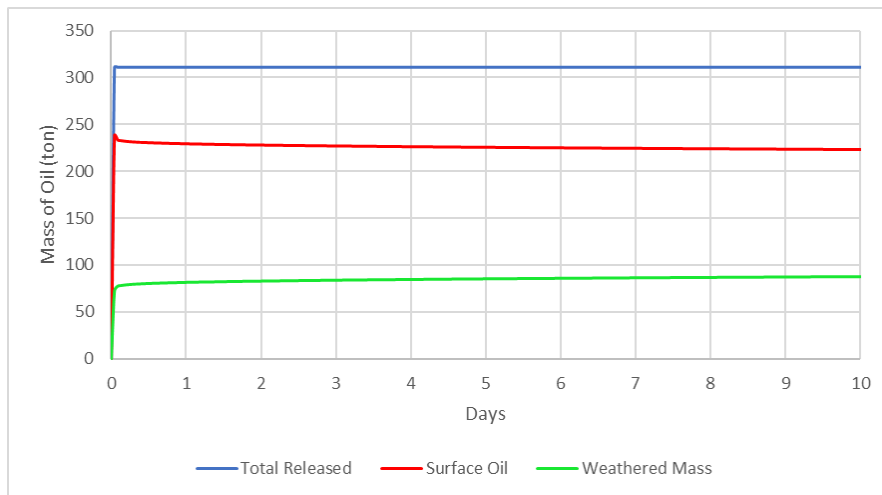
**Figure AVII.108: Weathering of LTOBM spill during March after 1 hour (top) and 6 hours (bottom)**



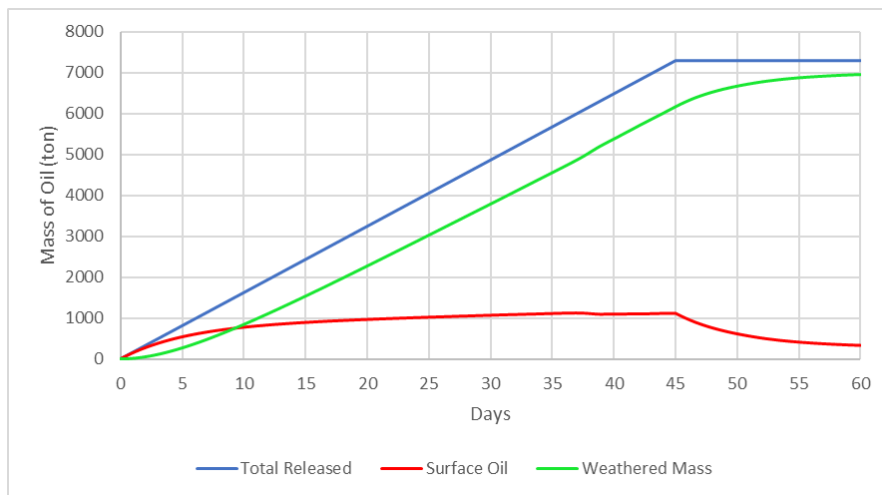
**Figure AVII.109: Weathering of LTOBM spill during March after 12 hours (top) and 24 hours (bottom)**



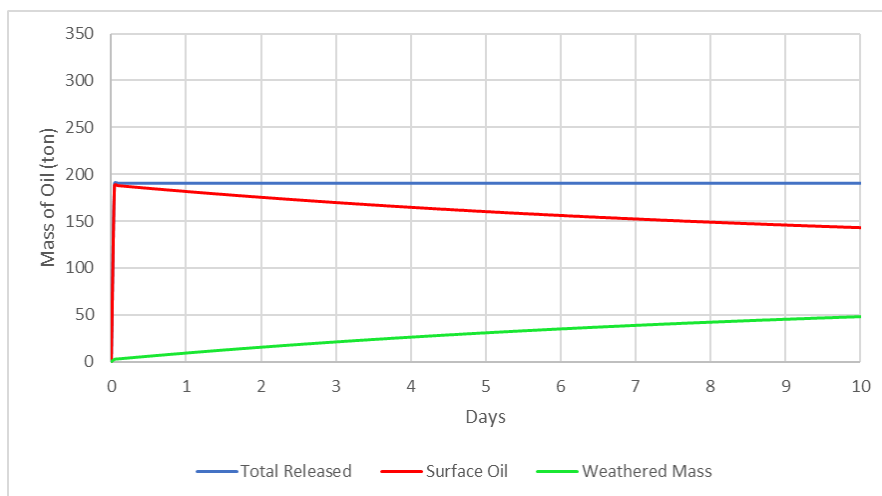
**Figure AVII.110: Weathering of LTOBM spill during March after 3 days (top) and 7 days (bottom)**



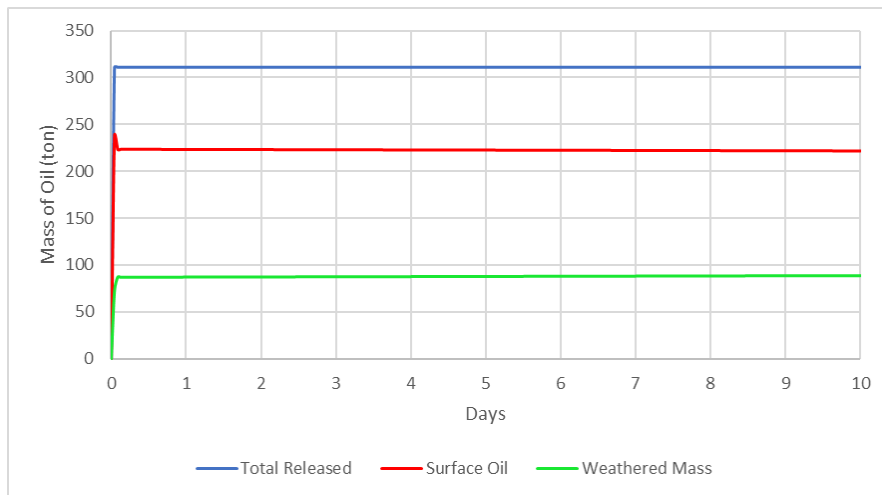
**Figure AVII.111: Mass balance for the diesel spill during October, based on affected surface area**



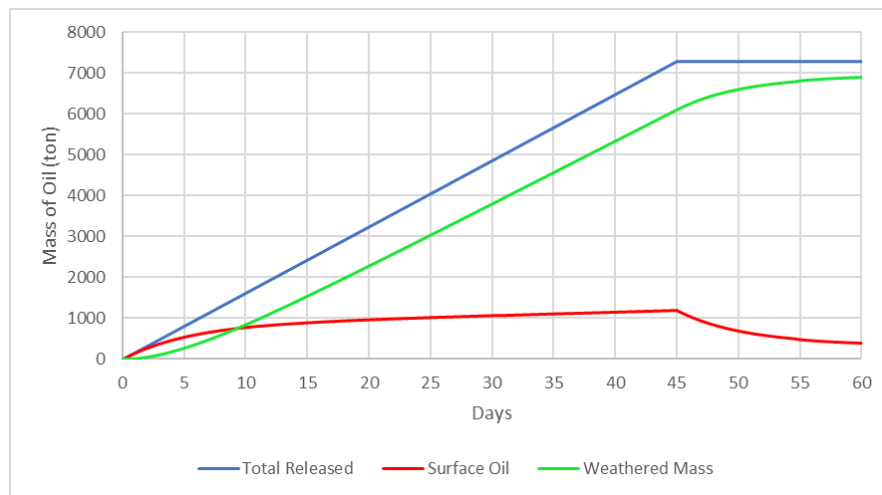
**Figure AVII.112: Mass balance for the condensate blowout spill during October, based on affected surface area**



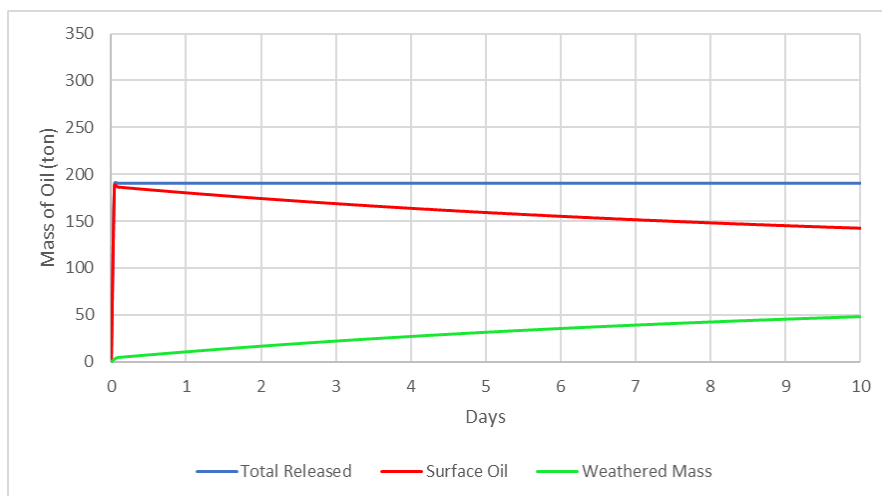
**Figure AVII.113: Mass balance for the LTOBM spill during October, based on affected surface area**



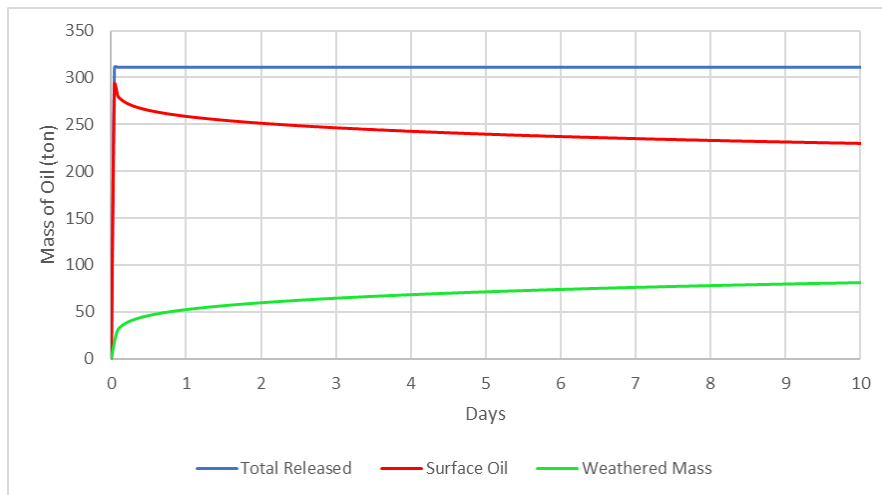
**Figure AVII.114: Mass balance for the diesel spill during May, based on affected surface area**



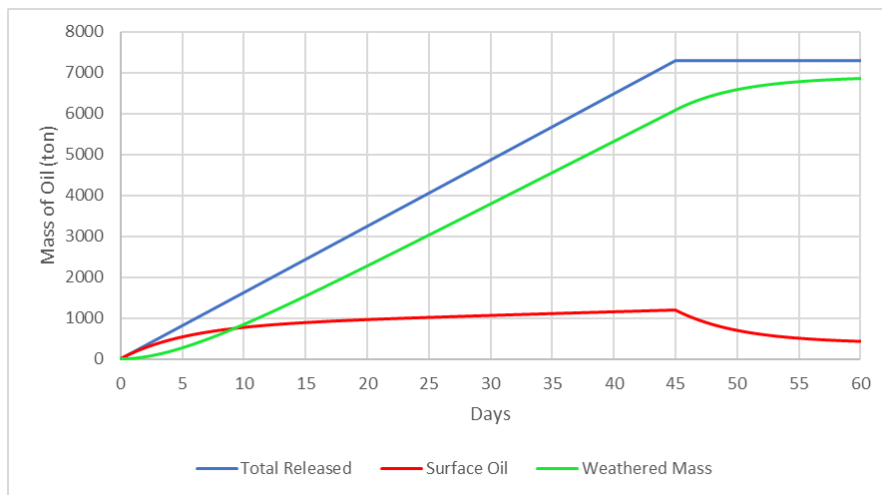
**Figure AVII.115: Mass balance for the condensate blowout spill during May, based on affected surface area**



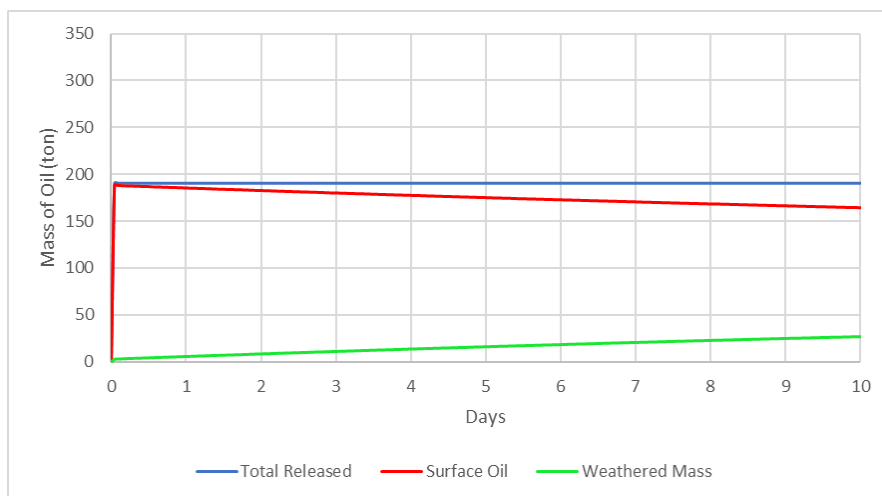
**Figure AVII.116: Mass balance for the LTOBM spill during May, based on affected surface area**



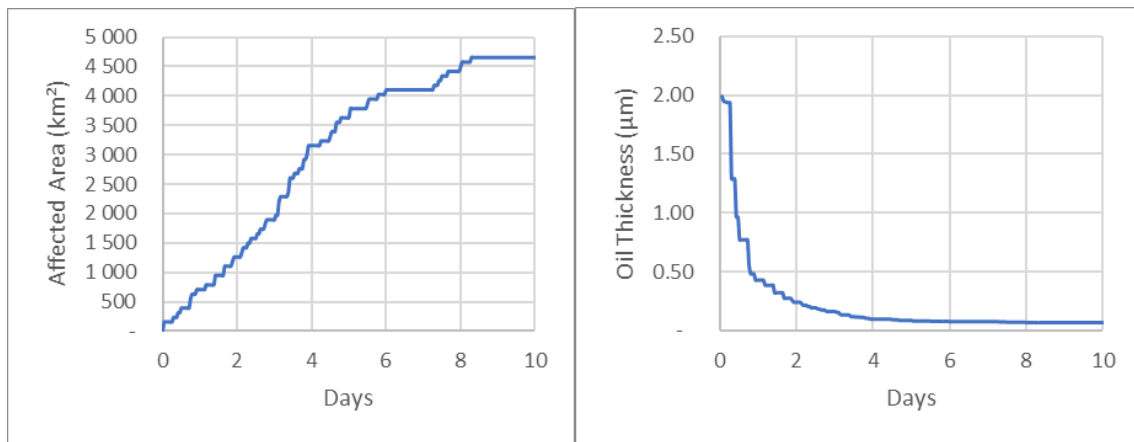
**Figure AVII.117: Mass balance for the diesel spill during March, based on affected surface area**



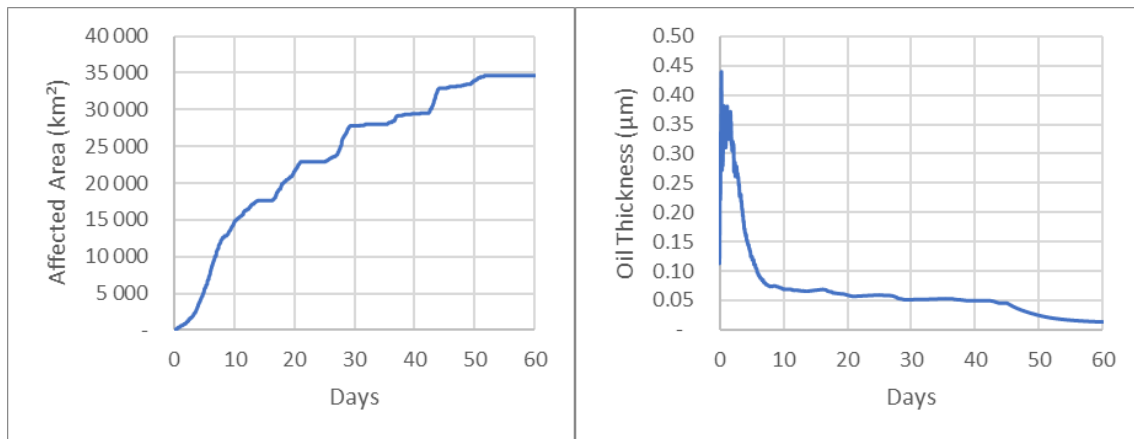
**Figure AVII.118: Mass balance for the condensate blowout spill during March, based on affected surface area**



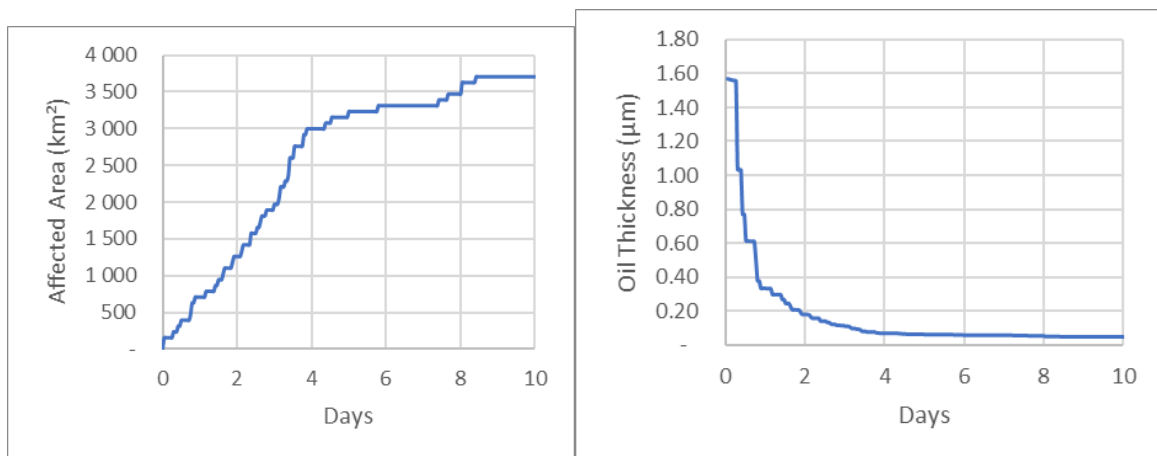
**Figure AVII.119: Mass balance for the LTOBM spill during March, based on affected surface area**



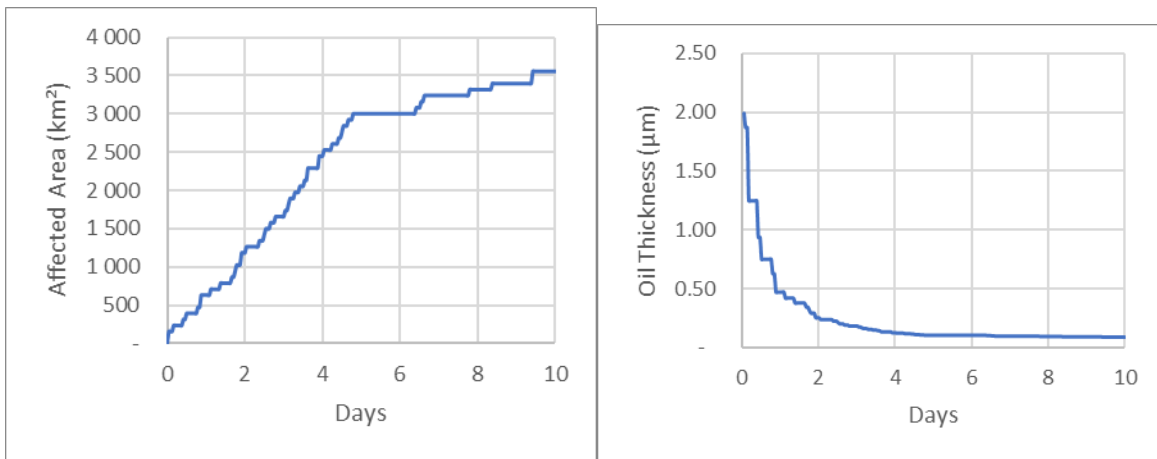
**Figure AVII.120: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the diesel spill during October**



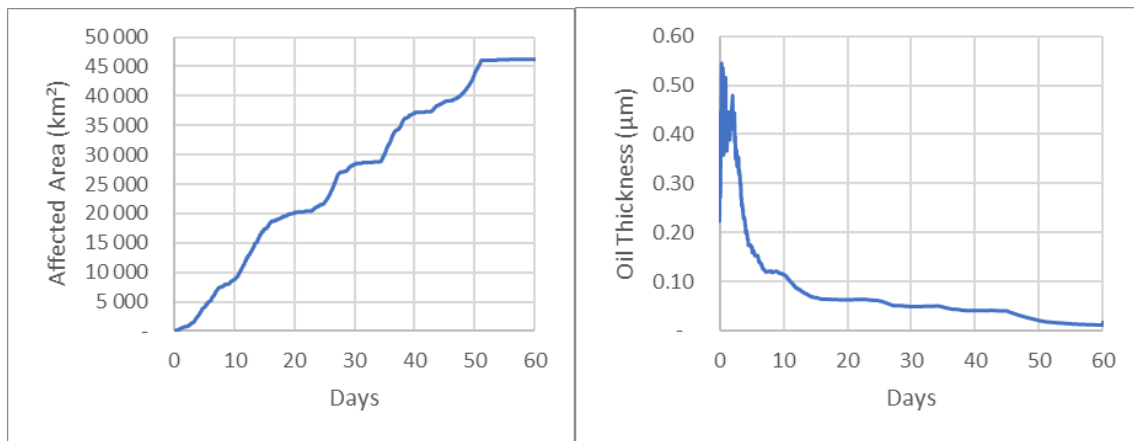
**Figure AVII.121: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the condensate blowout spill during October**



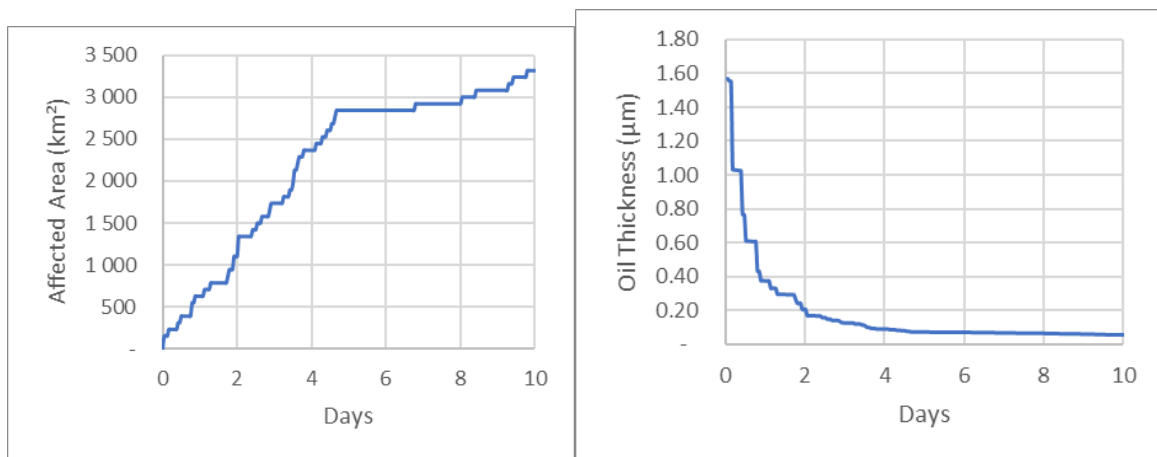
**Figure AVII.122: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the LTOBM spill during October**



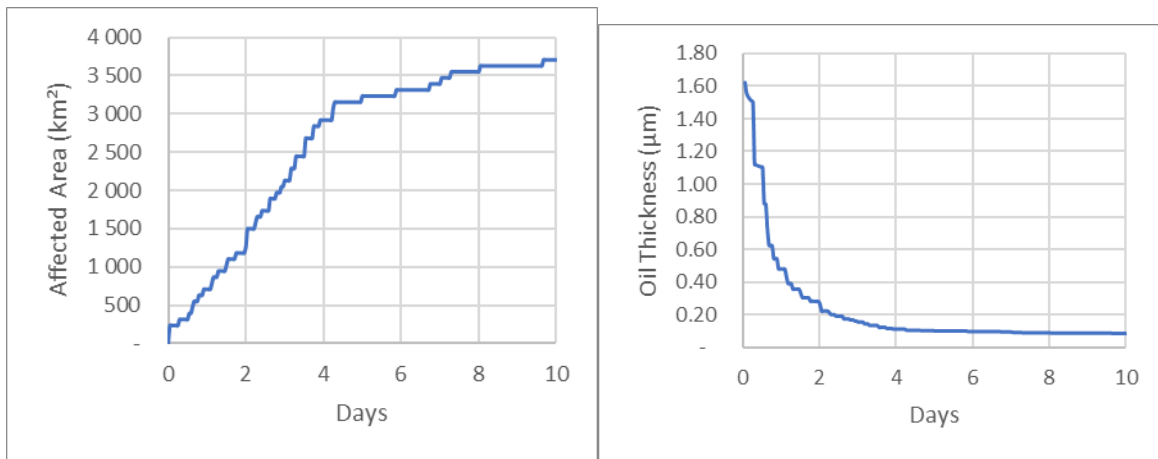
**Figure AVII.123: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the diesel spill during May**



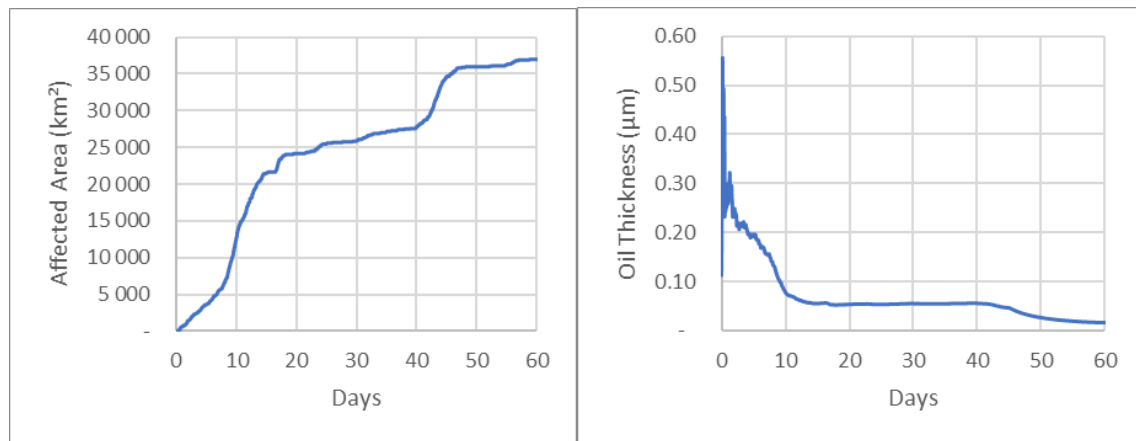
**Figure AVII.124: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the condensate blowout spill during May**



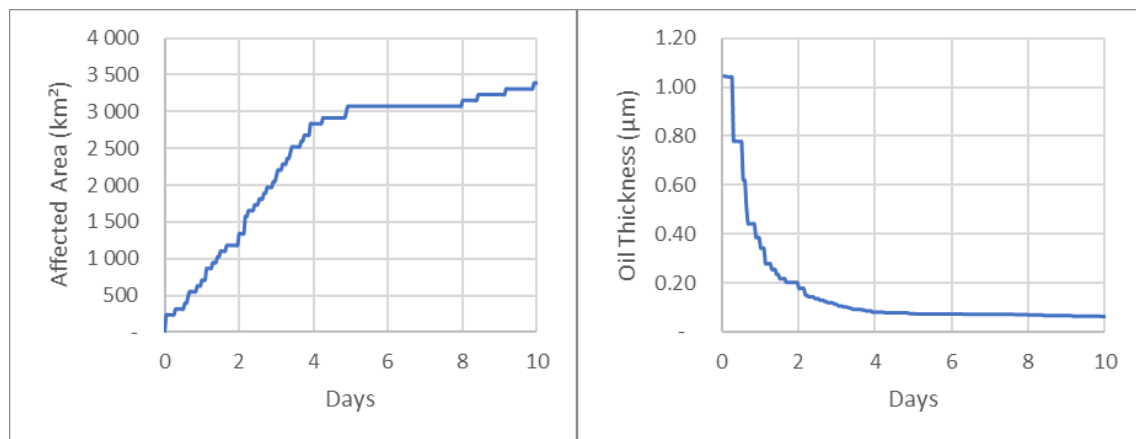
**Figure AVII.125: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the LTOBM spill during May**



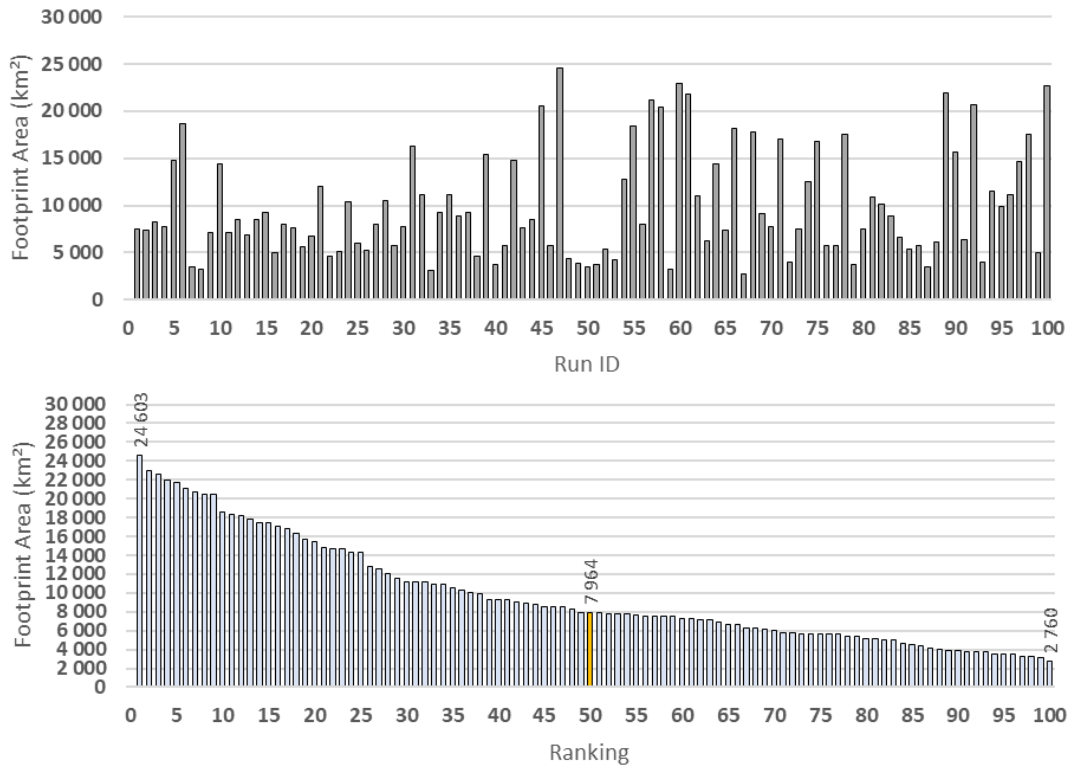
**Figure AVII.126: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the diesel spill during March**



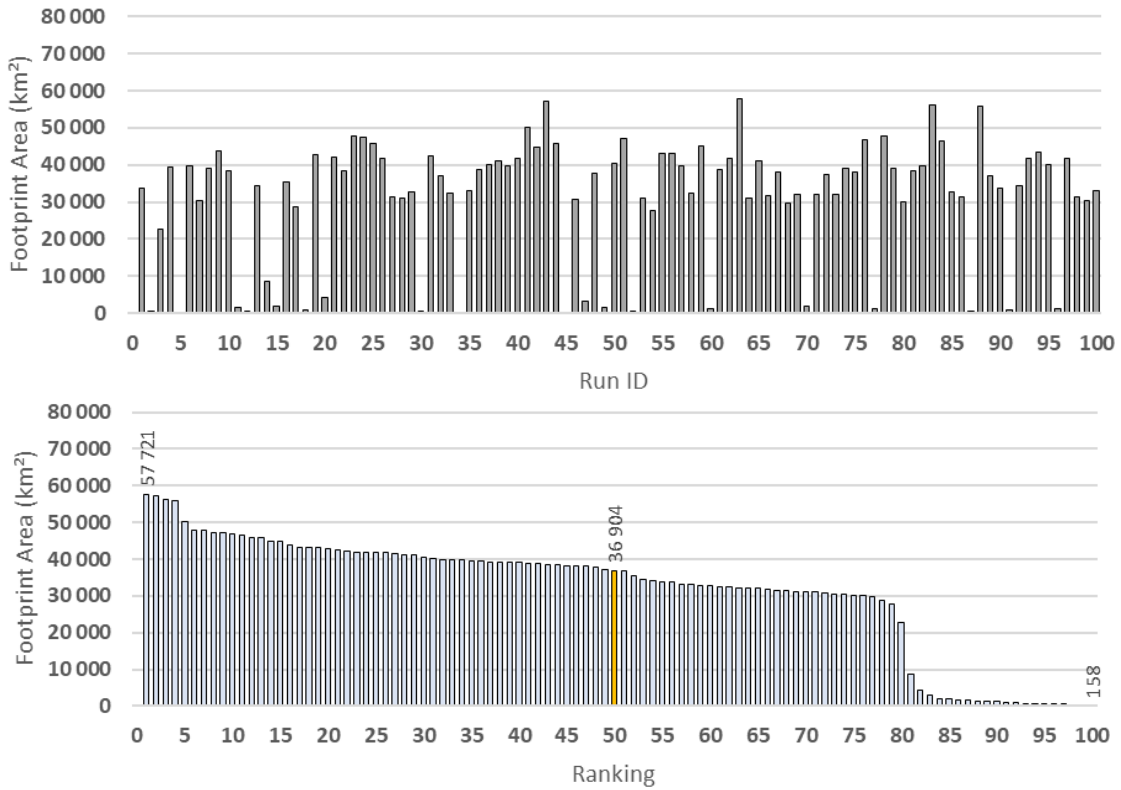
**Figure AVII.127: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the condensate blowout spill during March**



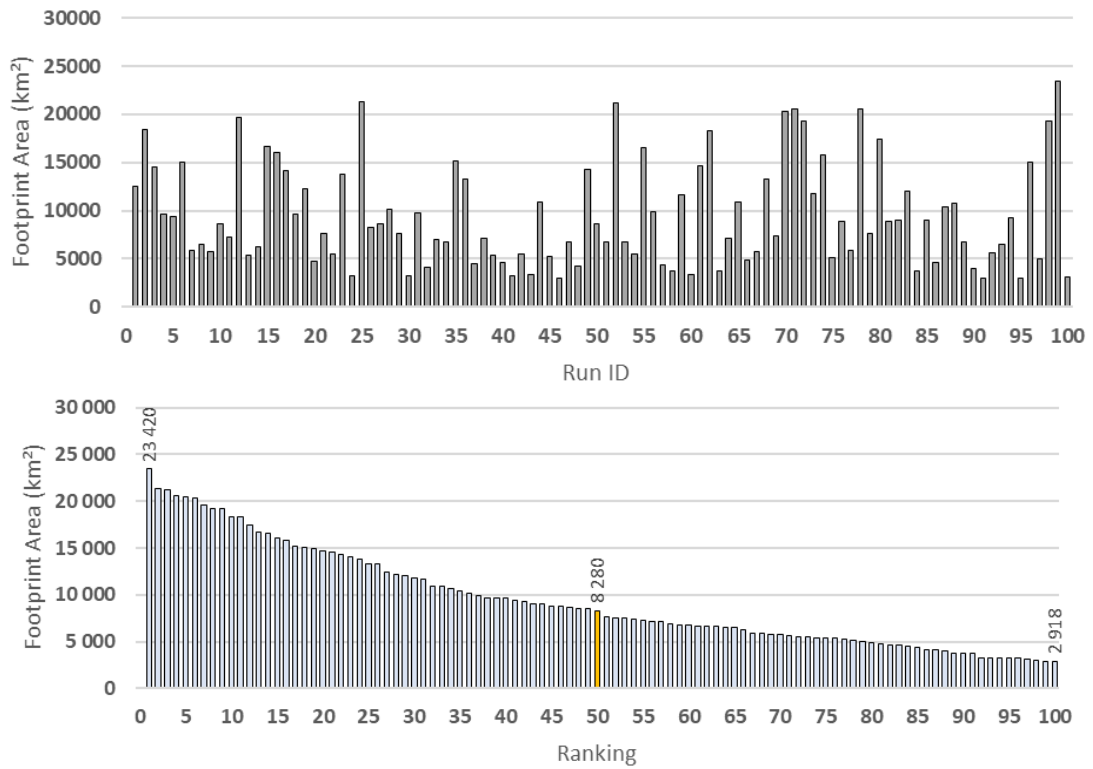
**Figure AVII.128: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the LTOBM spill during March**



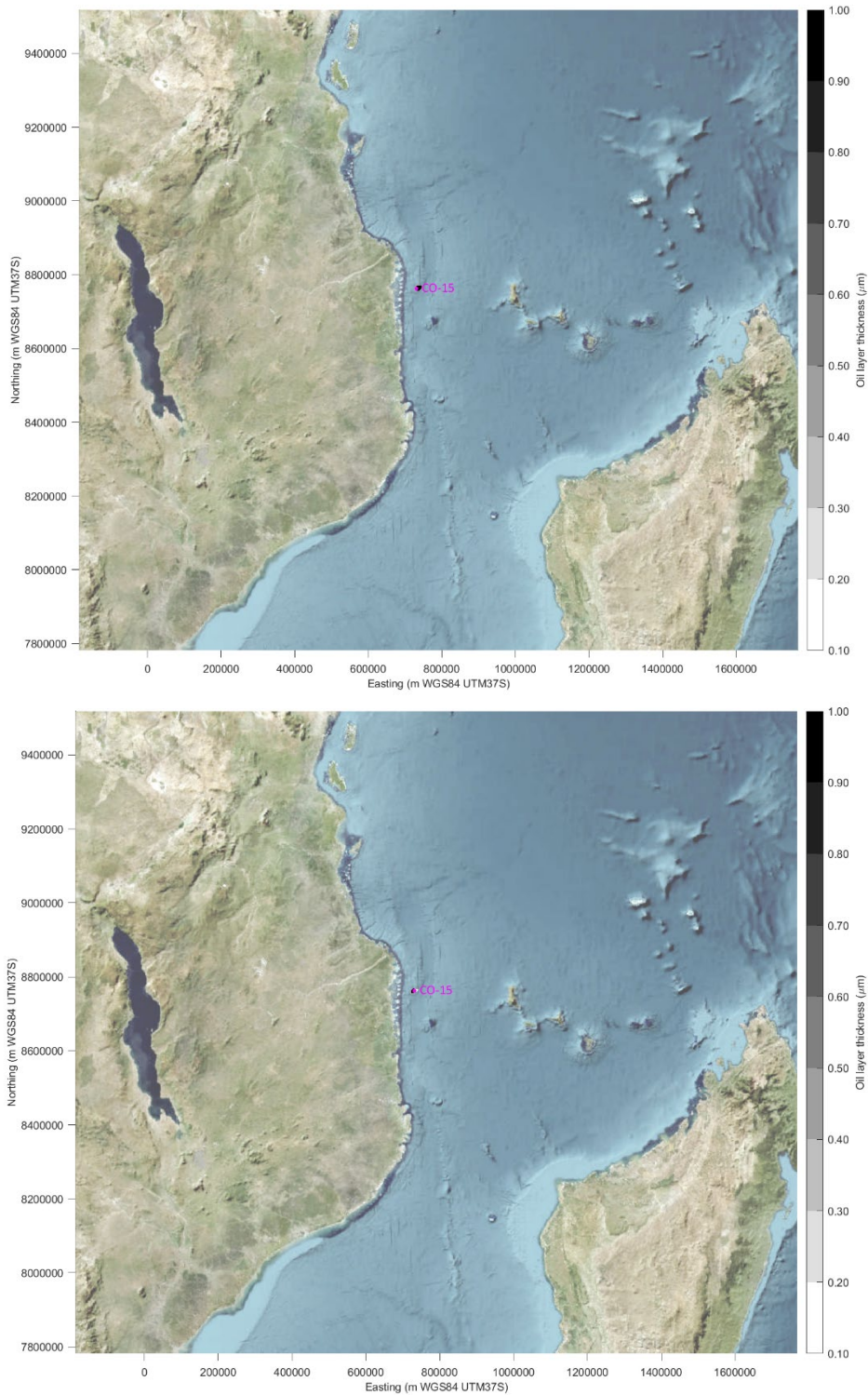
**Figure AVII.129: Affected surface area (top) and ranking of simulations with identified median with orange fill (bottom) for each of the diesel spill simulations**



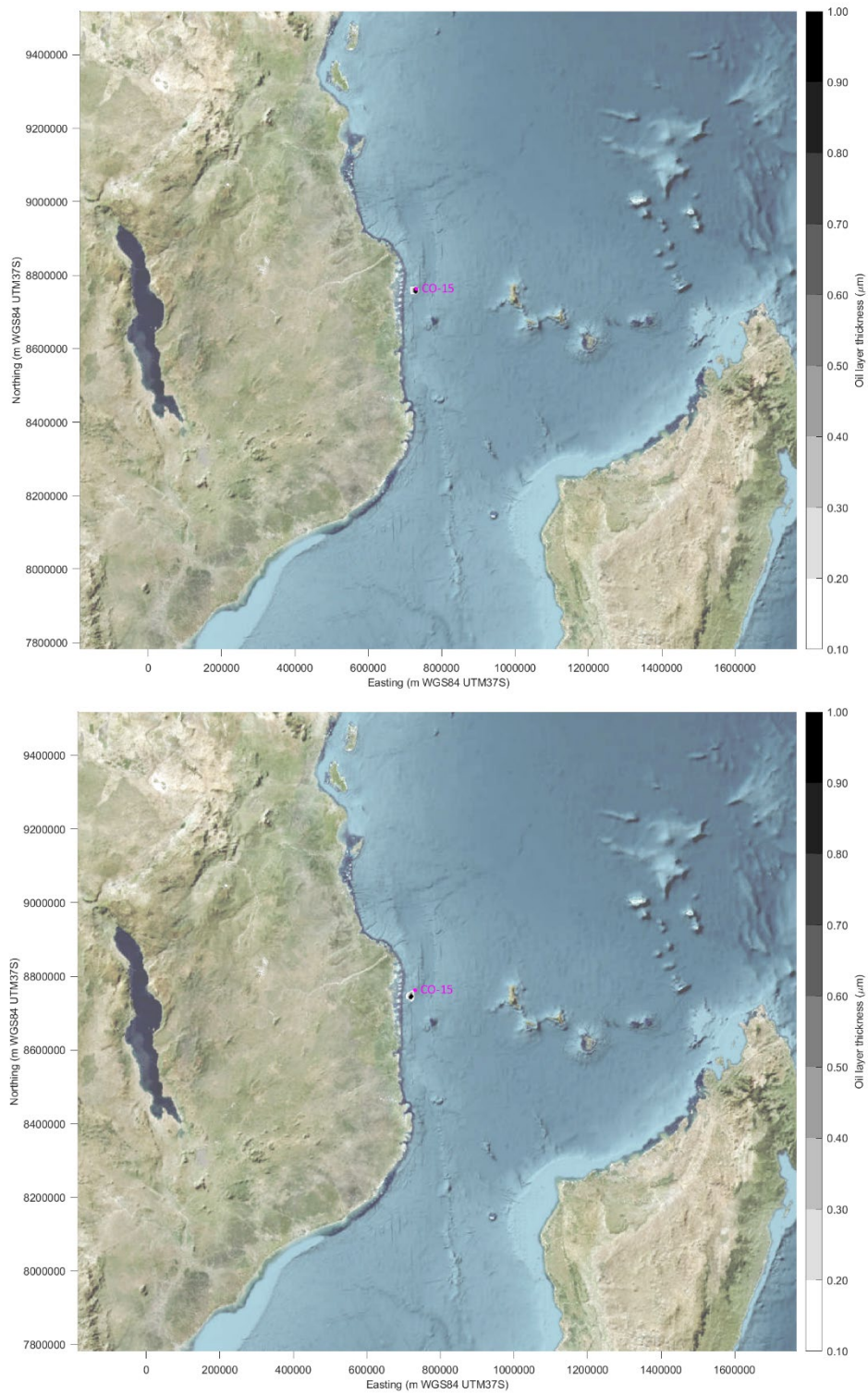
**Figure AVII.130: Affected surface area (top) and ranking of simulations with identified median with orange fill (bottom) for each of the condensate blowout spill simulations**



**Figure AVII.131: Affected surface area (top) and ranking of simulations with identified median with orange fill (bottom) for each of the LTOBM spill simulations**



**Figure AVII.132: Weathering of median diesel spill after 1 hour (top) and 6 hours (bottom)**



**Figure AVII.133: Weathering of median diesel spill 12 hours (top) and 24 hours (bottom)**

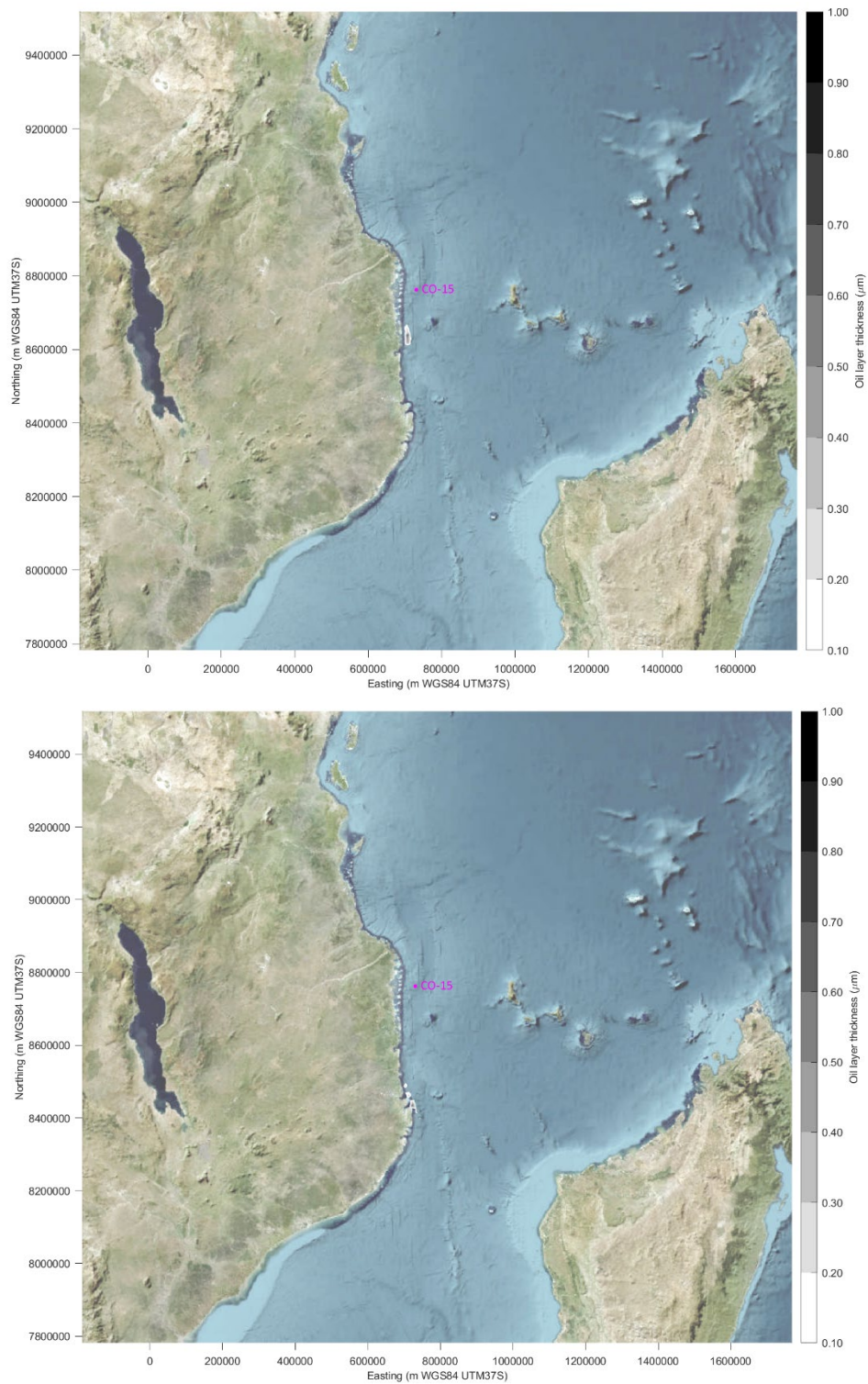
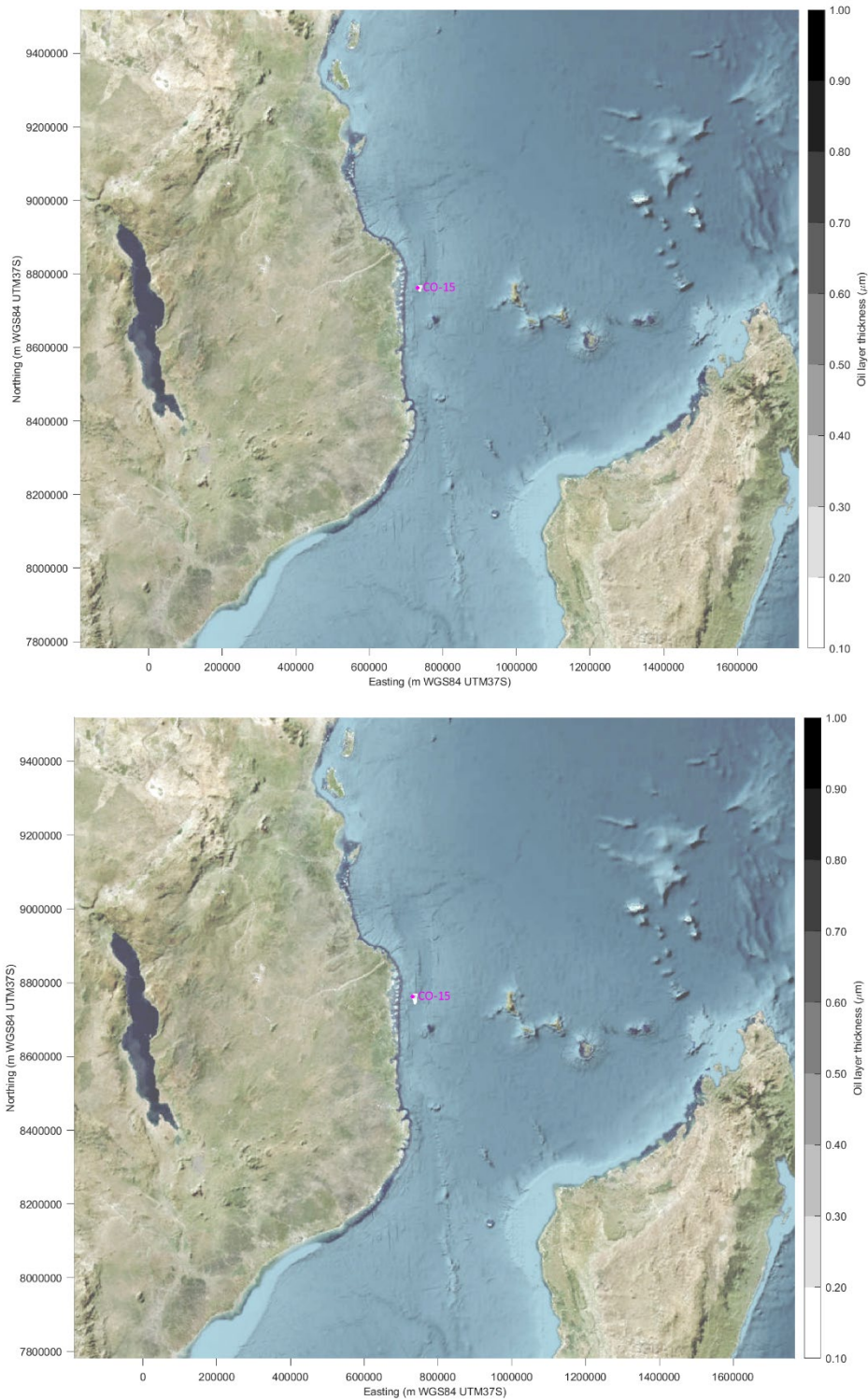
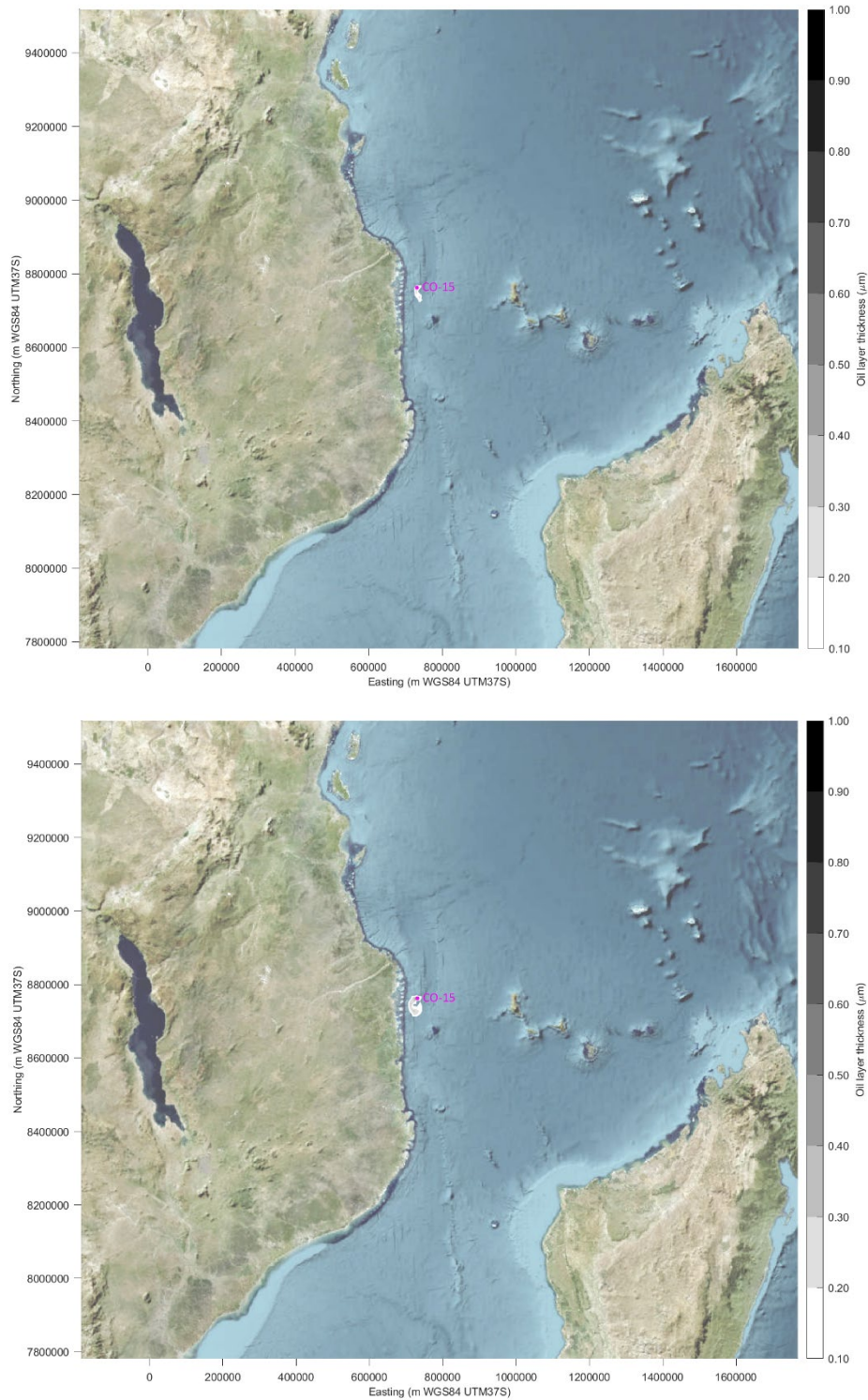


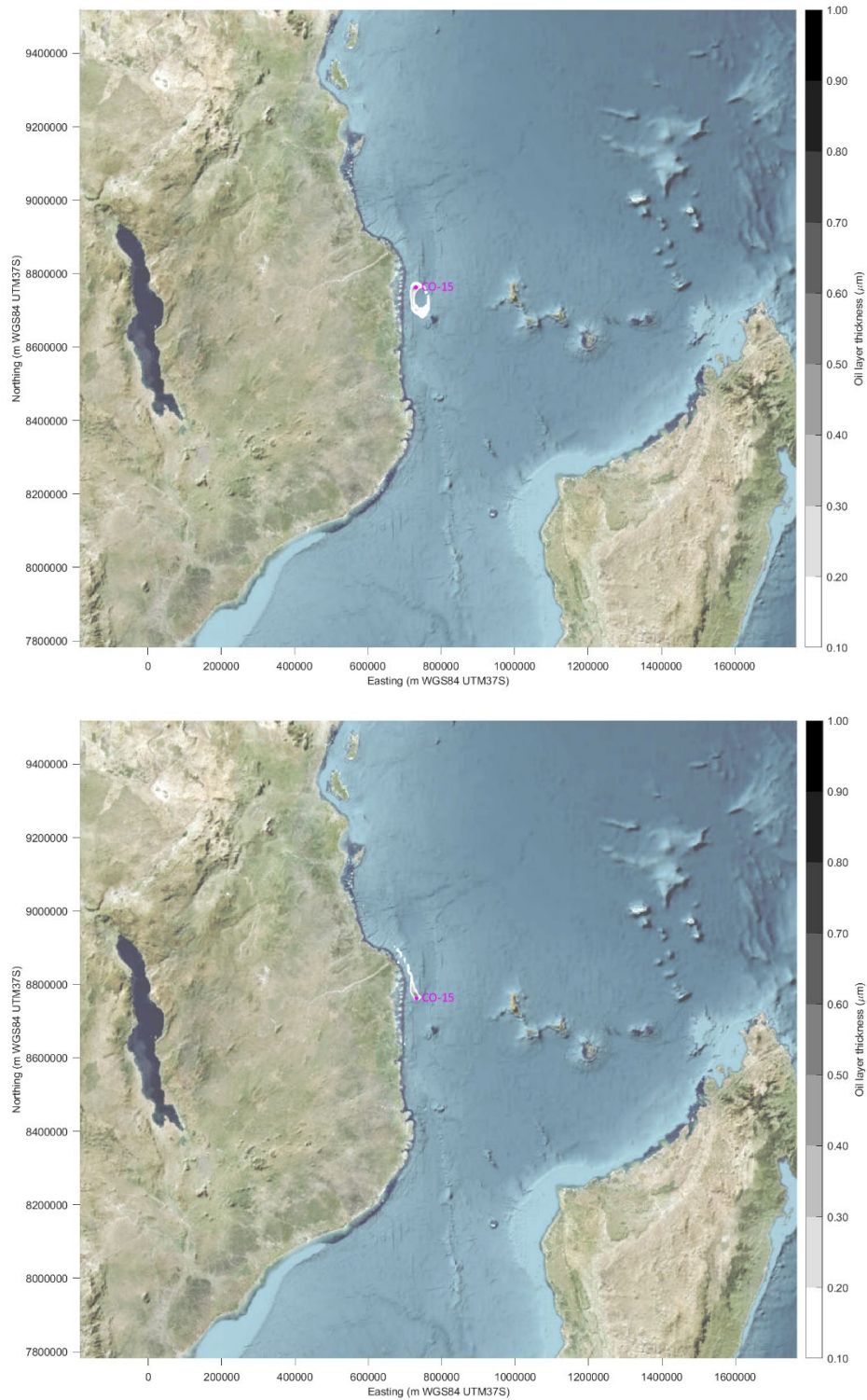
Figure AVII.134: Weathering of median diesel spill after 3 days (top) and 7 days (bottom)



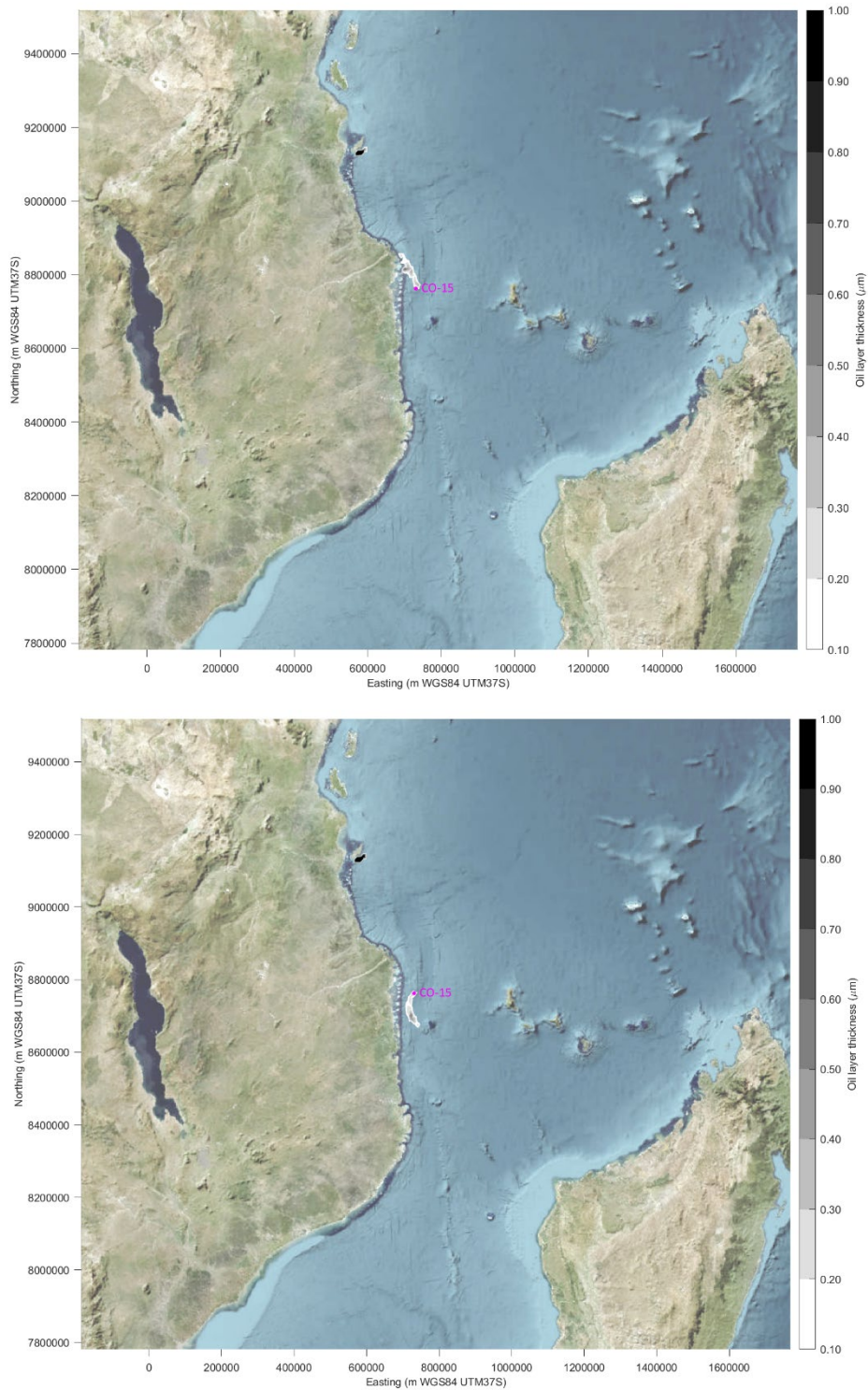
**Figure AVII.135: Weathering of median condensate blowout after 6 hours (top) and 12 hours (bottom)**



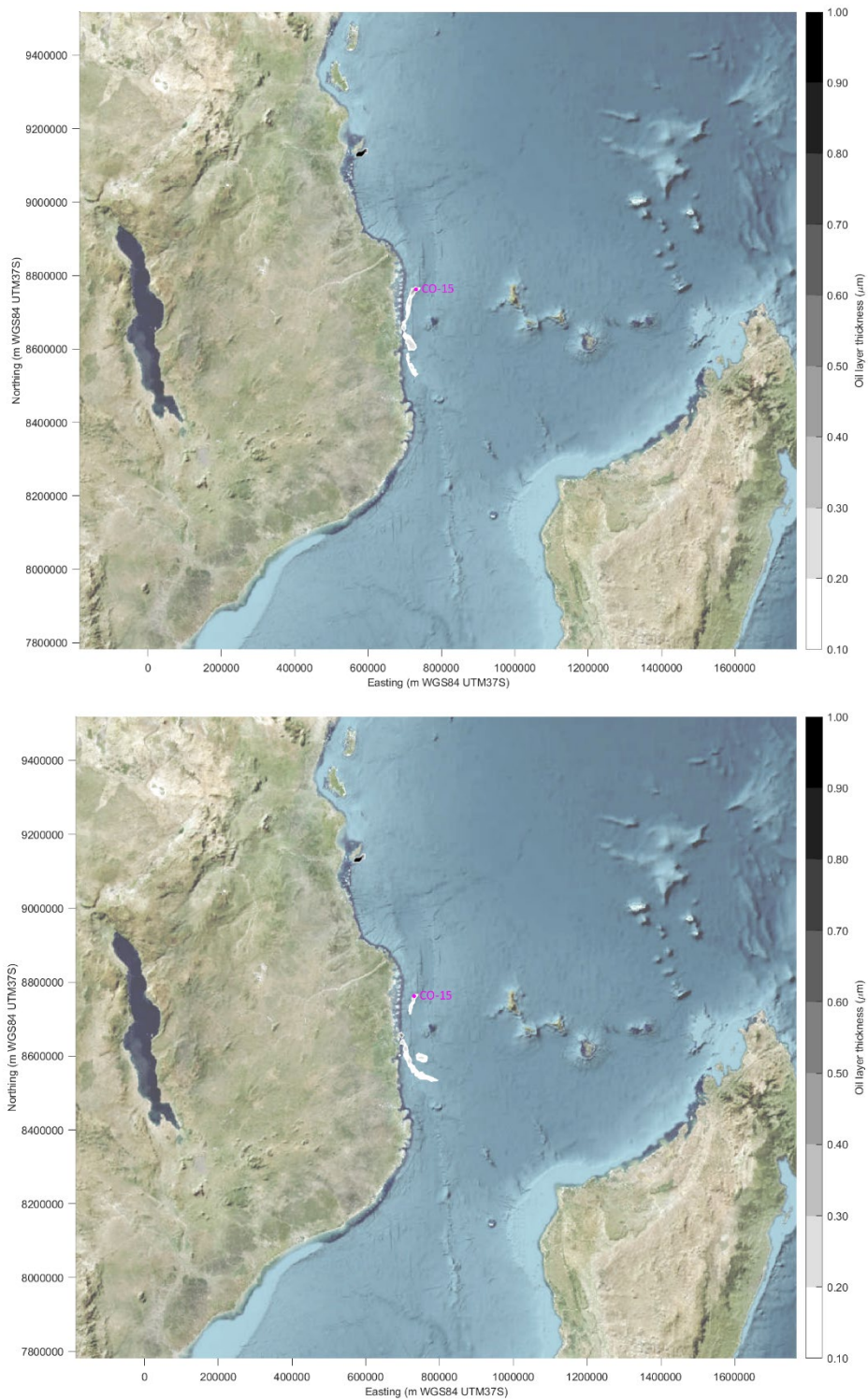
**Figure AVII.136: Weathering of median condensate blowout after 24 hours (top) and 3 days (bottom)**



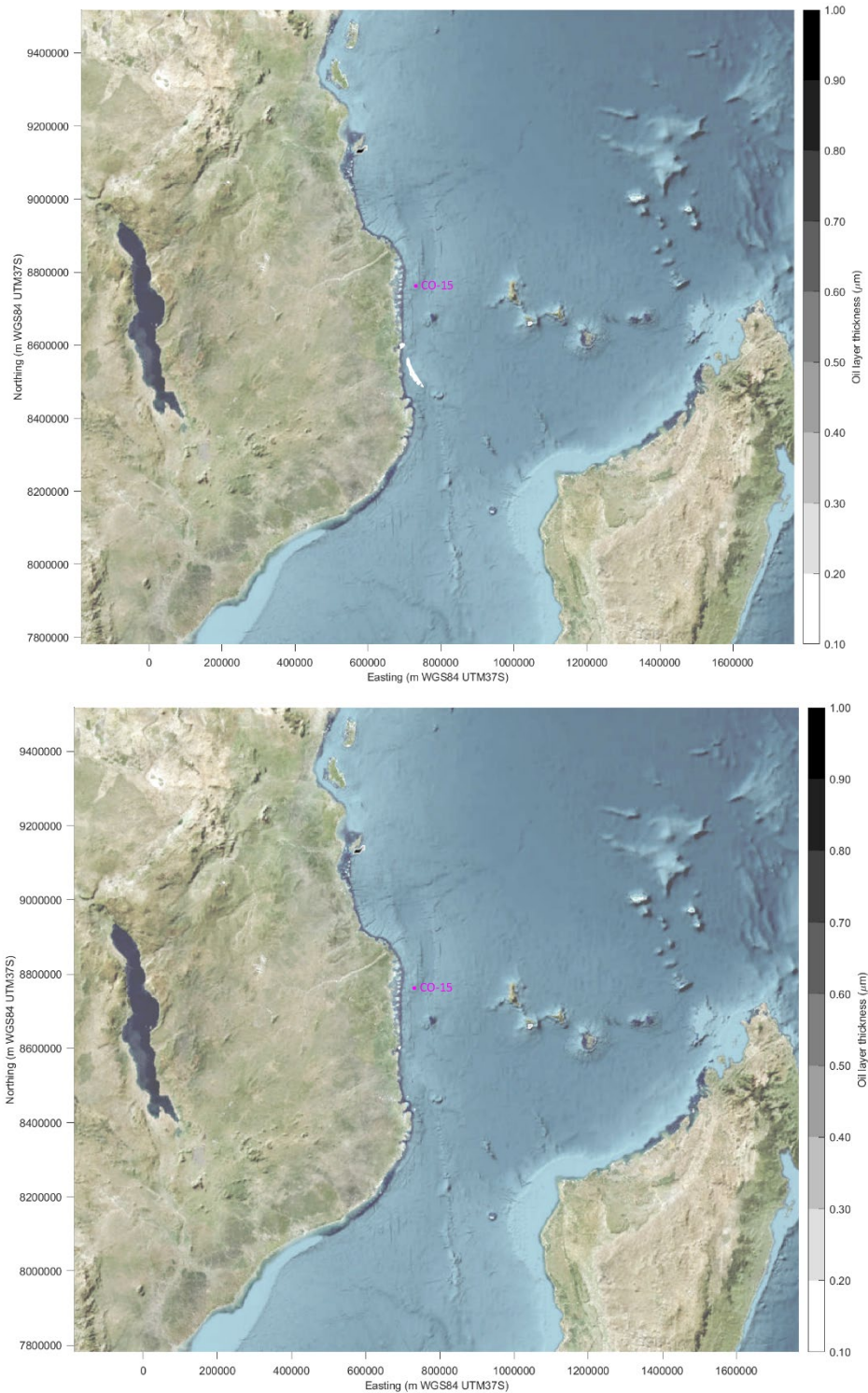
**Figure AVII.137: Weathering of median condensate blowout after 7 days (top) and 2 weeks (bottom)**



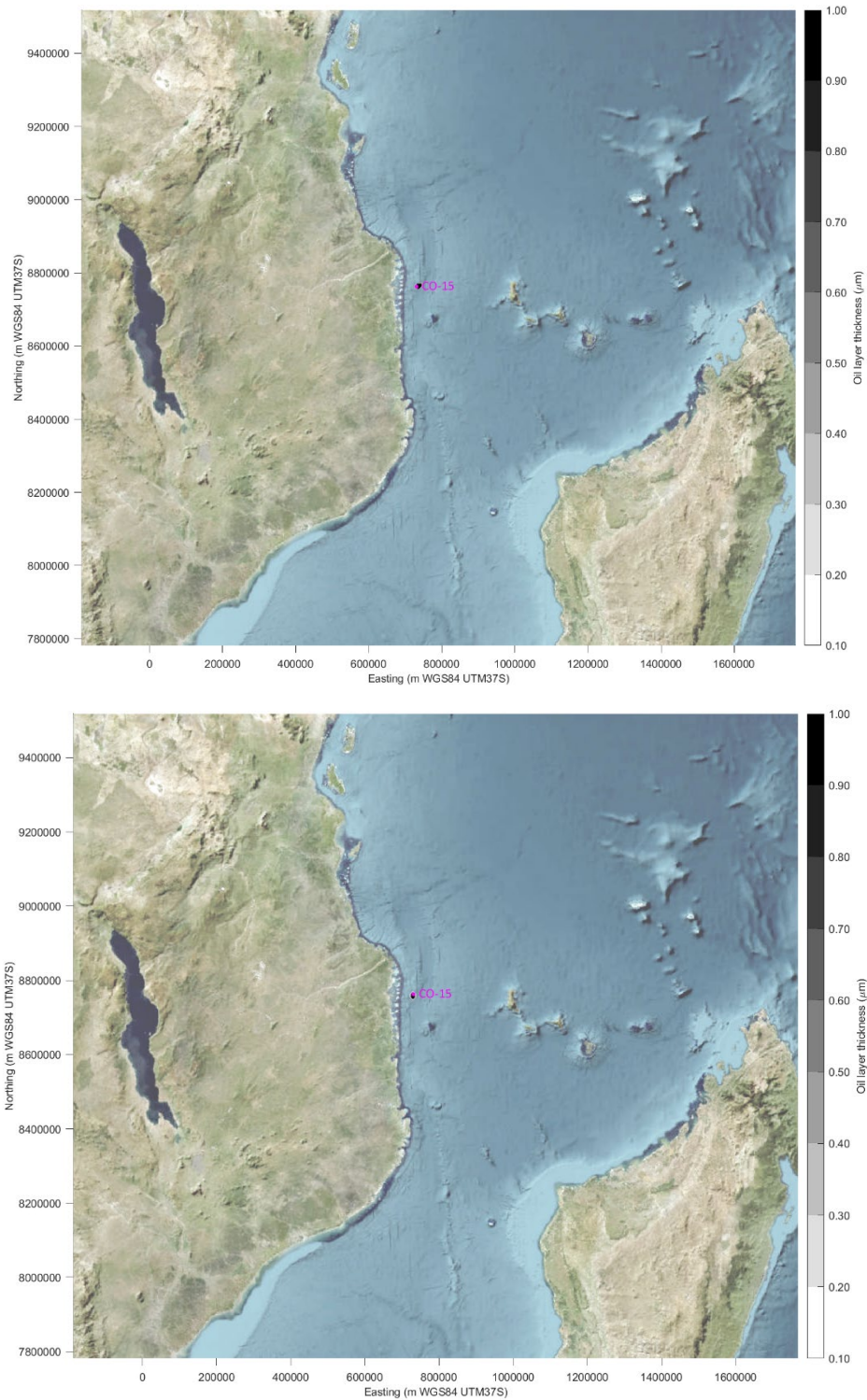
**Figure AVII.138: Weathering of median condensate blowout after 3 weeks (top) and 4 weeks (bottom)**



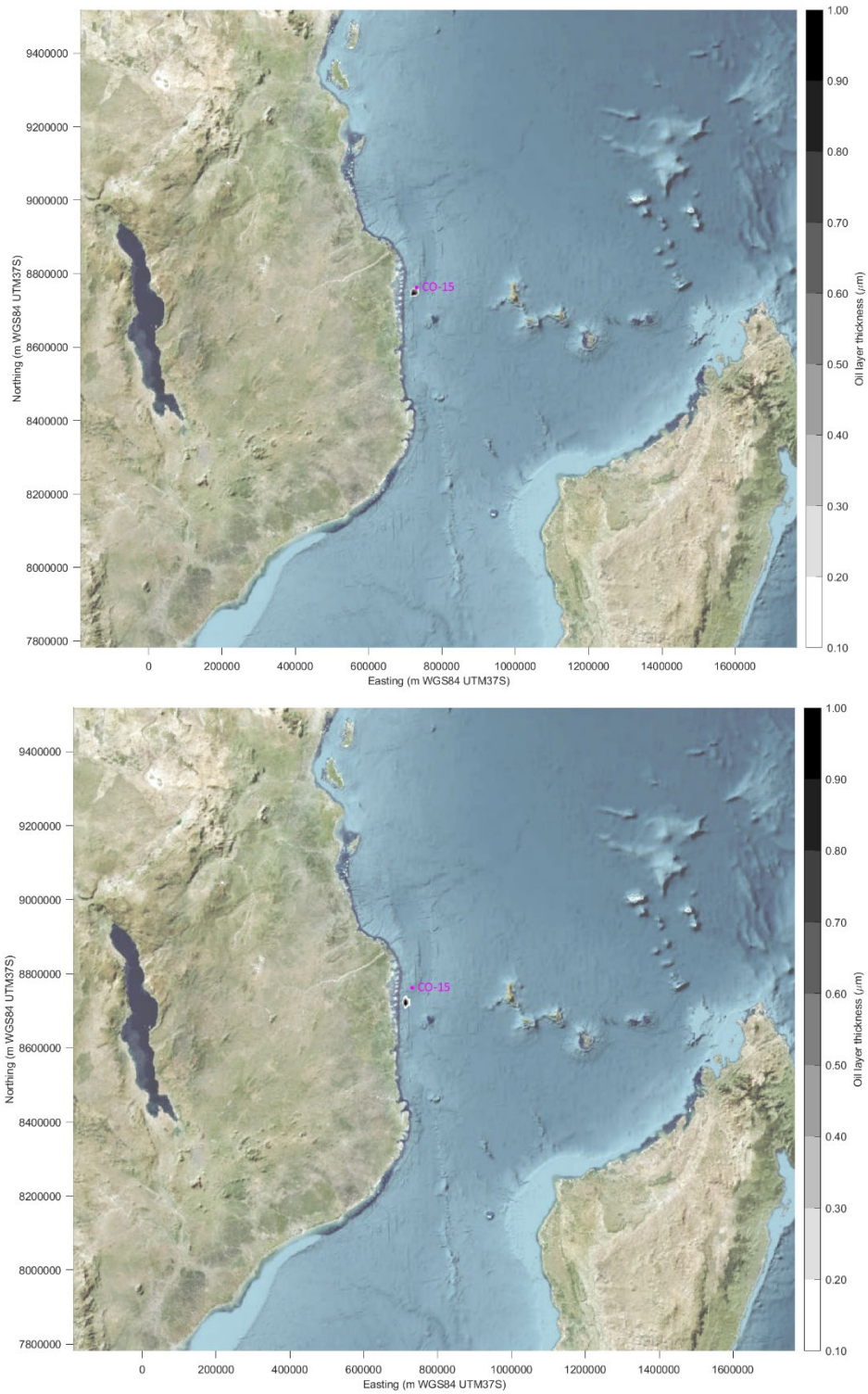
**Figure AVII.139: Weathering of median condensate blowout after 5 weeks (top) and 6 weeks (bottom)**



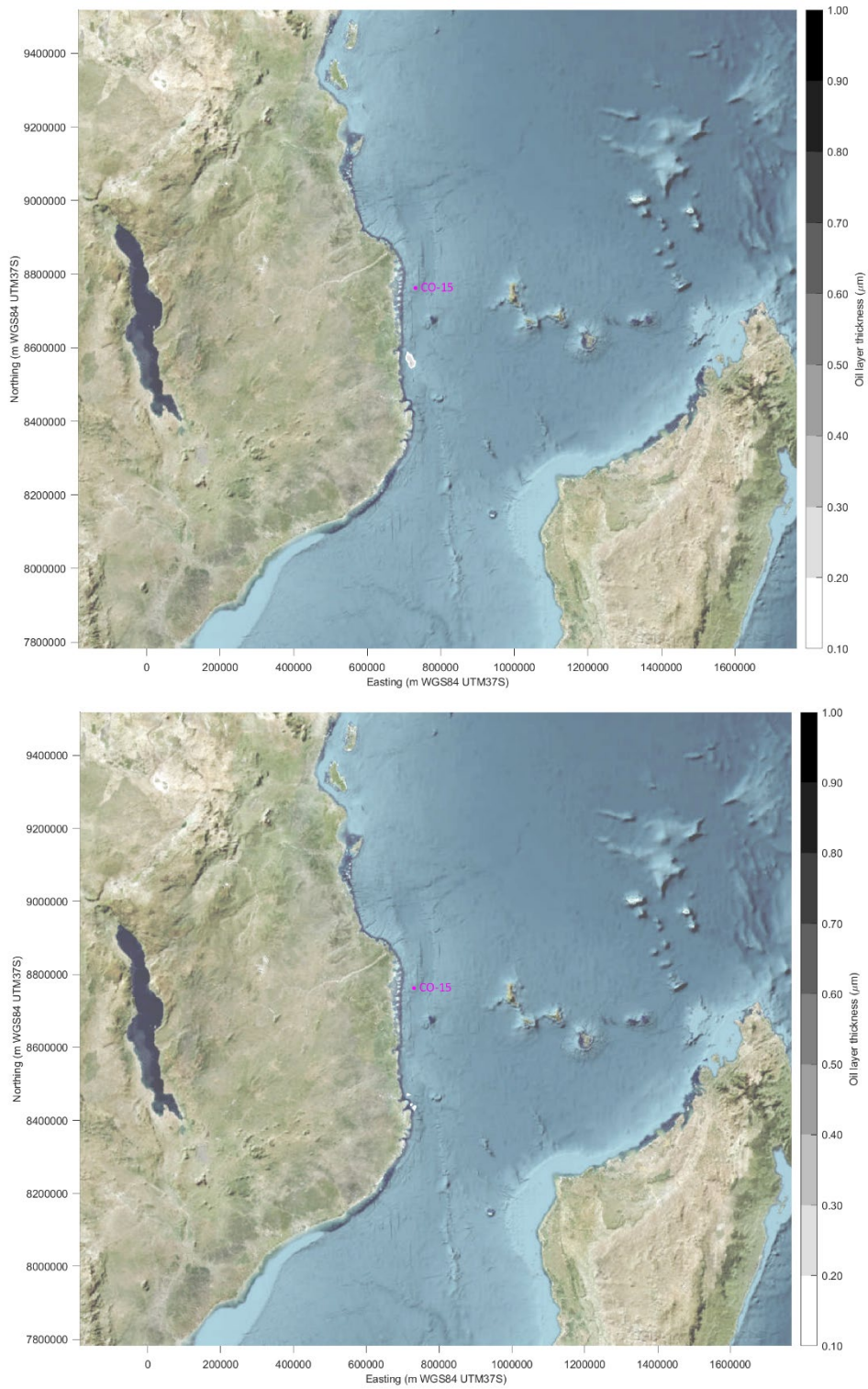
**Figure AVII.140: Weathering of median condensate blowout after 7 weeks (top) and 8 weeks (bottom)**



**Figure AVII.141: Weathering of median LTOBM spill after 1 hour (top) and 6 hours (bottom)**



**Figure AVII.142: Weathering of median LTOBM spill 12 hours (top) and 24 hours (bottom)**



**Figure AVII.143: Weathering of median LTOBM spill after 3 days (top) and 7 days (bottom)**

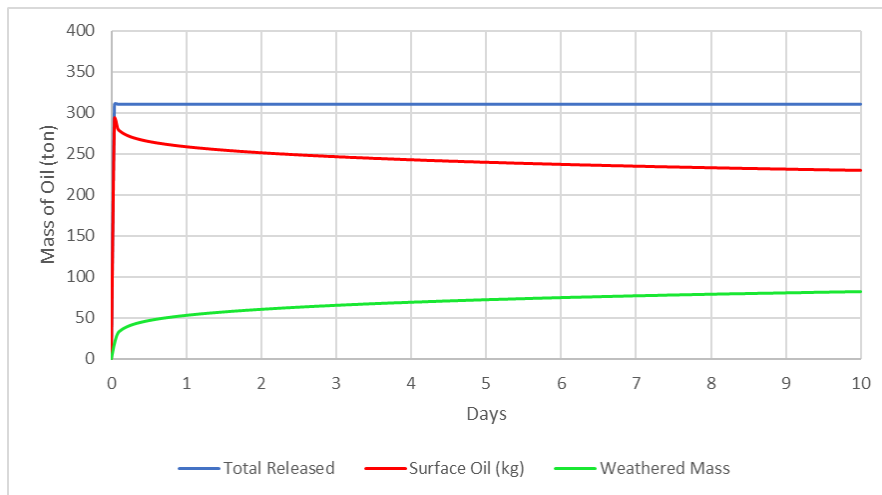


Figure AVII.144: Mass balance for the median diesel spill, based on affected surface area

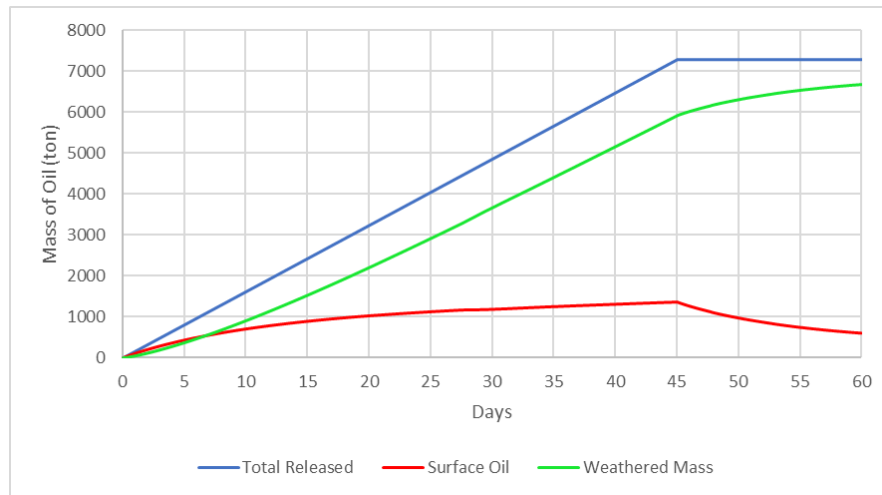


Figure AVII.145: Mass balance for the median condensate blowout spill, based on affected surface area

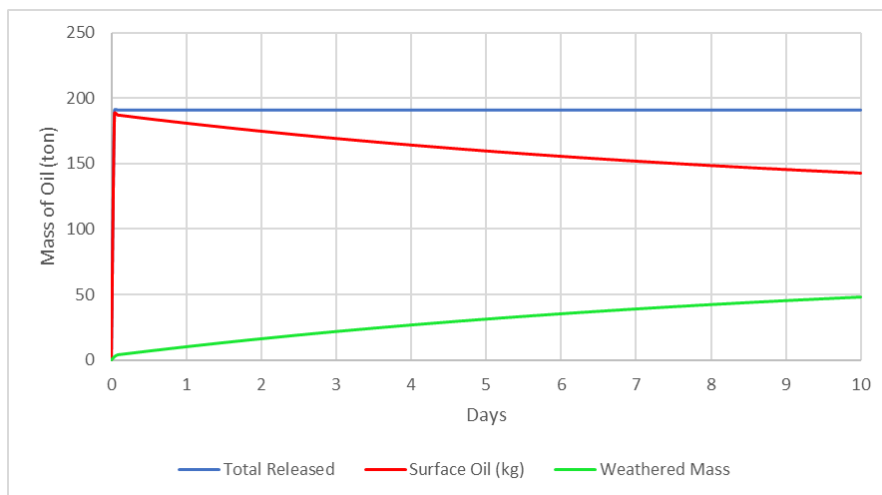
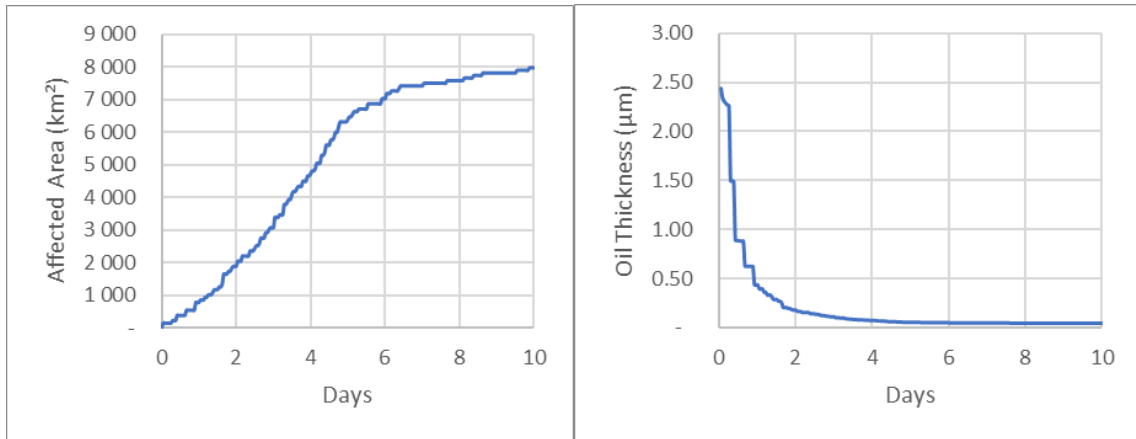
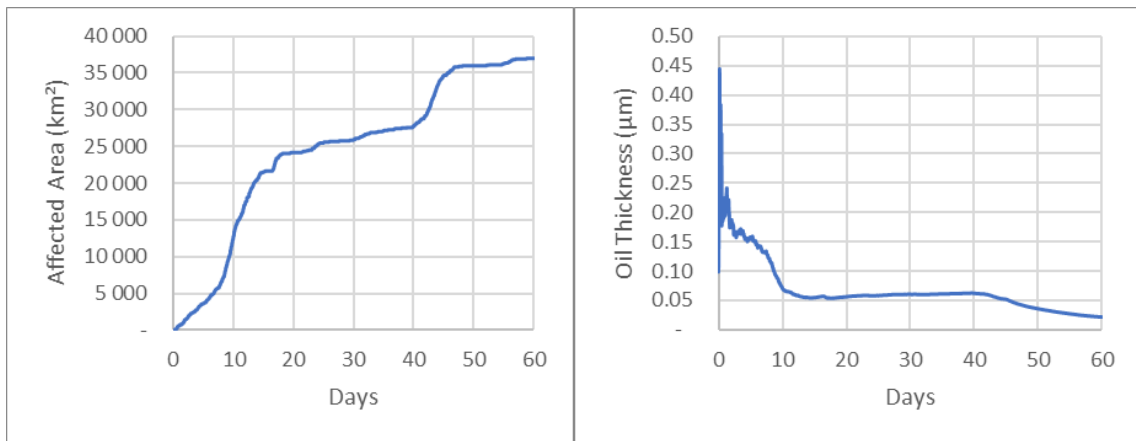


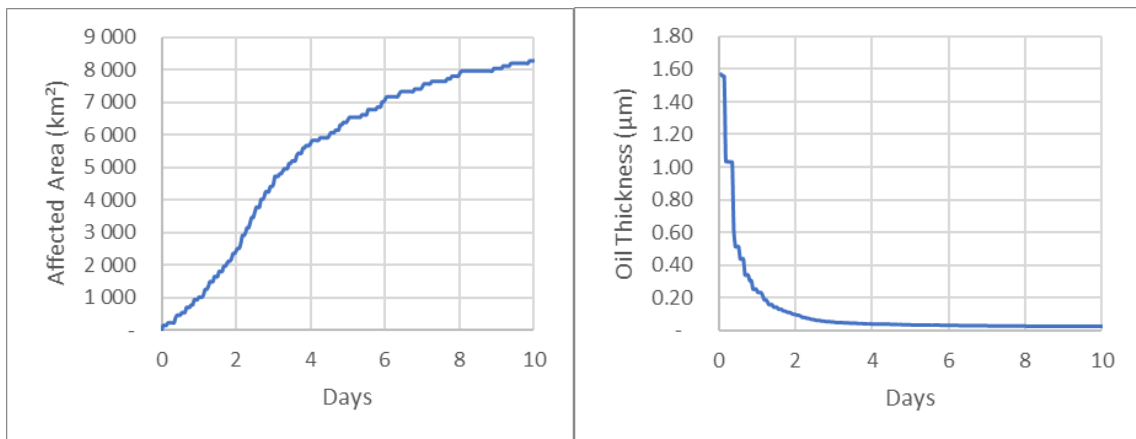
Figure AVII.146: Mass balance for the median LTOBM spill, based on affected surface area



**Figure AVII.147: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the median diesel spill**



**Figure AVII.148: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the median condensate blowout spill**



**Figure AVII.149: Increasing affected area (left) and decreasing approximate oil thickness (right) over time for the median LTOBM spill**

## Annex VIII – Climate Change Risk Assessment Tables

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**Table AVIII.1: Assessment of physical risks – 2028 (Project start) conditions**

Climate Variable	Risk to Project Site	Comments on Risk	Likelihood	Consequence	Risk classification
<b>TEMPERATURE</b>					
<b>Mean and maximum temperature</b>	Heat-related failure of above water equipment and infrastructure (PR1)	Periods of extreme temperature have the potential to damage and/or deteriorate equipment and supporting infrastructure, resulting in operational downtime and increased maintenance. This is exacerbated if materials and equipment are located outdoors with no protection from the sun and heat. Examples of impacts include damage from equipment operating beyond vendor thresholds and degradation of construction materials.	1	2	Negligible
	Heat-related deterioration of above water equipment and infrastructure (PR2)		1	2	Negligible
	Power generation and availability for process cooling (PR3)	Periods of extreme temperature may affect power-generating capacity of internal facilities. Examples of impacts include reduced power output and increased maintenance costs for systems not built to sufficient specifications. Costs associated with power for process and chilling of natural gas to reduce volume for storage are also temperature dependent.	1	2	Negligible
	Temperature effects on the health and productivity of workforce (PR4)	Extreme temperatures will affect the health and productivity of the workforce. Extended periods of extreme heat present a physical danger to workers and may limit working hours.	2	2	Low
	Energy demand for air conditioning (PR5)	Energy demands for air conditioning will be impacted by temperatures.	1	2	Negligible
<b>Sea water temperature</b>	Heat-related deterioration of below-water equipment and infrastructure (PR6)	Periods of increased temperature have the potential to deteriorate equipment and supporting infrastructure, resulting in operational downtime and increased maintenance. Examples of impacts include damage from equipment operating beyond vendor thresholds and degradation of construction materials.	1	2	Negligible
	Heat-sensitive environmental receptors (PR7)	The marine environment around Project site is typical of a tropical open ocean, well mixed deepwater environment. Changes to average and maximum temperatures may although unlikely to affect the functioning of the ecosystem.	1	1	Negligible
	Sea water for LNG cooling (PR8)	The temperature of inflows will impact the effectiveness of sea water for cooling	1	2	Negligible
<b>RAINFALL</b>					
<b>Frequency of intense rainfall events</b>	Water related failure of equipment and infrastructure (PR9)	Intense rainfall events may cause failures and/or degradation of equipment and infrastructure gradually resulting in operational downtime	1	3	Low
	Water-related deterioration of above water equipment and infrastructure (PR10)		2	2	Low
	Effect of extreme rainfall on health and productivity of workforce (PR11)	Health and safety risks are increased during heavy rainfall potentially resulting in more incidents.	2	3	Low
<b>STORM EVENTS Extreme Wind and Cyclones</b>					
<b>Frequency and strength of storm events</b>	Extreme winds-related failure of equipment and infrastructure (PR12)	Extreme cyclone strength winds have the potential to damage and degrade infrastructure and equipment, resulting in operational downtime and increased maintenance.	3	2	Low
	Extreme winds- related deterioration of infrastructure and equipment (PR13)		2	2	Low
	Effects of extreme winds on supply operations (PR14)	Extreme winds will affect supply operations e.g., ship loading/unloading, damage to cargos.	3	2	Low
	Effects of extreme winds on the health and productivity of workforce (PR15)	High winds increase risks to the health and safety of the workforce.	3	2	Low
	Extreme winds causing spills which impact the marine environment (PR16)	Extreme winds and wave action may increase the likelihood of spills	1	3	Low

**Table AVIII.2: Assessment of physical risks – low to intermediate emissions scenario (SSP2-4.5) for period 2041 to 2060**

Climate Variable	Risk to Project Site	Comments on Risk	Likelihood	Consequence	Risk classification
<b>TEMPERATURE</b>					
<b>Mean and maximum temperature</b>	Heat-related failure of above water equipment and infrastructure (PR1)	Periods of extreme temperature have the potential to damage and/or deteriorate equipment and supporting infrastructure, resulting in operational downtime and increased maintenance. This is exacerbated if materials and equipment are located outdoors with no protection from the sun and heat.	1	2	Negligible
	Heat-related deterioration of above water equipment and infrastructure (PR2)	Examples of impacts include damage from equipment operating beyond vendor thresholds and degradation of construction materials.	1	2	Negligible
	Power generation and availability for process cooling (PR3)	Periods of extreme temperature may affect power-generating capacity of internal facilities. Examples of impacts include reduced power output and increased maintenance costs for systems not built to sufficient specifications. Costs associated with power for process and chilling of natural gas to reduce volume for storage are also temperature dependent.	2	2	Low
	Temperature effects on the health and productivity of workforce (PR4)	Extreme temperatures will affect the health and productivity of the workforce. Extended periods of extreme heat present a physical danger to workers and may limit working hours.	2	2	Low
	Energy demand for air conditioning (PR5)	Energy demands for air conditioning will be impacted by temperatures.	2	2	Low
<b>Sea water temperature</b>	Heat-related deterioration of below-water equipment and infrastructure (PR6)	Periods of increased temperature have the potential to deteriorate equipment and supporting infrastructure, resulting in operational downtime and increased maintenance. Examples of impacts include damage from equipment operating beyond vendor thresholds and degradation of construction materials.	1	2	Negligible
	Heat-sensitive environmental receptors (PR7)	The marine environment around Project site is typical of a tropical open ocean, well mixed deepwater environment. Changes to average and maximum temperatures may although unlikely to affect the functioning of the ecosystem.	2	1	Negligible
	Sea water for LNG cooling (PR8)	The temperature of inflows will impact the effectiveness of sea water for cooling	2	2	Low
<b>RAINFALL</b>					
<b>Frequency of intense rainfall events</b>	Water related failure of equipment and infrastructure (PR9)	Intense rainfall events may cause failures and/or degradation of equipment and infrastructure gradually resulting in operational downtime	1	3	Low
	Water-related deterioration of above water equipment and infrastructure (PR10)		2	2	Low
	Effect of extreme rainfall on health and productivity of workforce (PR11)	Health and safety risks are increased during heavy rainfall potentially resulting in more incidents.	2	3	Low
<b>STORM EVENTS Extreme Wind and Cyclones</b>					
<b>Frequency and strength of storm events</b>	Extreme winds-related failure of equipment and infrastructure (PR12)	Extreme cyclone strength winds have the potential to damage and degrade infrastructure and equipment, resulting in operational downtime and increased maintenance.	3	2	Low
	Extreme winds-related deterioration of infrastructure and equipment (PR13)		2	2	Low
	Effects of extreme winds on supply operations (PR14)	Extreme winds will affect supply operations e.g., ship loading/unloading, damage to cargos.	3	2	Low
	Effects of extreme winds on the health and productivity of workforce (PR15)	High winds increase risks to the health and safety of the workforce.	3	2	Low
	Extreme winds causing spills which impact the marine environment (PR16)	Extreme winds and wave action may increase the likelihood of spills	2	3	Low

**Table AVIII.3: Assessment of physical risks – high emissions scenario (SSP5-8.5) for period 2041 to 2060**

Climate Variable	Risk to Project Site	Comments on Risk	Likelihood	Consequence	Risk classification
<b>TEMPERATURE</b>					
<b>Mean and maximum temperature</b>	Heat-related failure of above water equipment and infrastructure (PR1)	Periods of extreme temperature have the potential to damage and/or deteriorate equipment and supporting infrastructure, resulting in operational downtime and increased maintenance. This is exacerbated if materials and equipment are located outdoors with no protection from the sun and heat. Examples of impacts include damage from equipment operating beyond vendor thresholds and degradation of construction materials.	1	2	Negligible
	Heat-related deterioration of above water equipment and infrastructure (PR2)		1	2	Negligible
	Power generation and availability for process cooling (PR3)	Periods of extreme temperature may affect power-generating capacity of internal facilities. Examples of impacts include reduced power output and increased maintenance costs for systems not built to sufficient specifications. Costs associated with power for process and chilling of natural gas to reduce volume for storage are also temperature dependent.	2	2	Low
	Temperature effects on the health and productivity of workforce (PR4)	Extreme temperatures will affect the health and productivity of the workforce. Extended periods of extreme heat present a physical danger to workers and may limit working hours.	2	3	Low
	Energy demand for air conditioning (PR5)	Energy demands for air conditioning will be impacted by temperatures.	2	2	Low
<b>Sea water temperature</b>	Heat-related deterioration of below-water equipment and infrastructure (PR6)	Periods of increased temperature have the potential to deteriorate equipment and supporting infrastructure, resulting in operational downtime and increased maintenance. Examples of impacts include damage from equipment operating beyond vendor thresholds and degradation of construction materials.	1	2	Negligible
	Heat-sensitive environmental receptors (PR7)	The marine environment around Project site is typical of a tropical open ocean, well mixed deepwater environment. Changes to average and maximum temperatures may although unlikely to affect the functioning of the ecosystem.	2	1	Negligible
	Sea water for LNG cooling (PR8)	The temperature of inflows will impact the effectiveness of sea water for cooling	2	2	Low
<b>RAINFALL</b>					
<b>Frequency of intense rainfall events</b>	Water-related failure of equipment and infrastructure (PR9)	Intense rainfall events may cause failures and/or degradation of equipment and infrastructure gradually resulting in operational downtime	1	3	Low
	Water-related deterioration of above water equipment and infrastructure (PR10)		2	2	Low
	Effect of extreme rainfall on health and productivity of workforce (PR11)	Health and safety risks are increased during heavy rainfall potentially resulting in more incidents.	2	3	Low
<b>STORM EVENTS Extreme Wind and Cyclones</b>					
<b>Frequency and strength of storm events</b>	Extreme winds-related failure of equipment and infrastructure (PR12)	Extreme cyclone strength winds have the potential to damage and degrade infrastructure and equipment, resulting in operational downtime and increased maintenance.	3	2	Low
	Extreme winds-related deterioration of infrastructure and equipment (PR13)		2	2	Low
	Effects of extreme winds on supply operations (PR14)	Extreme winds will affect supply operations e.g., ship loading/unloading, damage to cargos.	3	2	Low
	Effects of extreme winds on the health and productivity of workforce (PR15)	High winds increase risks to the health and safety of the workforce.	3	2	Low
	Extreme winds causing spills which impact the marine environment (PR16)	Extreme winds and wave action may increase the likelihood of spills	2	3	Low