CAIRNS SHIPPING DEVELOPMENT PROJECT

Revised Draft Environmental Impact Statement

APPENDIX AX: CSDP Air Quality Impact Assessment

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Cairns Shipping Development Project Revised Draft EIS

TS11: Air Quality Impact Assessment

Report: 8483R03V05_TS11_Air Quality Impact Assessment.docx

Prepared for:

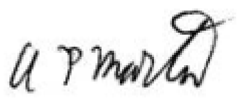
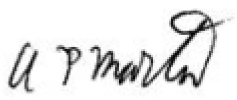
Ports North

4 July, 2017






Document Control				
*W:\8400\8483\ASKout\R03 Port Air\8483R03V05_TS11*_Air Quality Impact Assessment.docx				
Document Ref	**Date of Issue**	**Status**	**Author**	**Reviewer**
8483R03V01	8 June, 2017	Final	AM / MY	WM / MY / AM
8483R03V02	21 June, 2017	Clarifications	AM	MY
8483R03V03	21 June, 2017	Clarifications	AM	MY
8483R03V04	22 June, 2017	Clarifications	AM	MY
8483R03V05	4 July, 2017	Additional modelling	MY	AM

Document Approval			
Author Signature		Approver Signature	
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1. Introduction

1.1 Overview of this Assessment

ASK Consulting Engineers Pty Ltd (ASK) was commissioned by Flanagan Consulting Group to provide air quality consultancy services to describe the impacts of the revised Cairns Shipping Development Project (CSD Project) for the Revised Draft Environmental Impact Statement (EIS). The project revision relates to a reduction in the quantity of material to be dredged from 4,400,000 m3 to 1,000,000 m3 in-situ material, and relocation of the dredge material placement area (DMPA) to land instead of sea. ASK has previously provided the existing baseline air quality constraints assessment as part of initial environmental values assessments for the revised EIS. Revision of the EIS is also to address feedback received from the Office of the Coordinator General, including including assessment of the impact of ship exhausts and construction activities.

A brief overview of the elements of the overall CSD project which are relevant for the air quality assessment is as follows:

- Dredge material is to be transported to shore based Dredge Material Placement Areas (DMPAs) at the Northern Sands sand extraction operation on the Barron Delta and two sites on Tingira Street, Portsmith.
- The soft clays are to be dredged via a 5,600m^3 capacity Trailer Suction Hopper Dredge (TSHD) discharging at a location between approximately 2.6 and 3.6 km NE of Yorkeys Knob.
- Soft clay dredge material will be pumped from the pump out location via a submerged steel pipeline, which will make landfall near the Richters Creek mouth, thence to the Northern Sands DMPA via cane farm headlands and Captain Cook Highway culverts.
- Due to the 8 km pipeline distance from pump out to the NS DMPA, approximately three pipeline booster pumps will be required, depending on TSHD pumping capacity.
- Tailwater at the Northern Sands DMPA is proposed to be discharged adjacent to site or pumped to an outfall at the Barron River highway bridge.
- Stiff clays are to be dredged by a backhoe dredger to split hopper barges for transport to the Tingira Street DMPA. It is expected that both the stiff clay DMPA and the Northern Sands DMPA will operate 24 hours per day, although pumping equipment will only operate for shorter time periods.

The requirements of the air quality impact assessment include the following:

- Air dispersion modelling of shipping emissions is to include port entry, manoeuvring to berths and departures including worst case emission scenarios.
- Pollutants assessed are to include odour, particulates and visual impacts from dark smoke.
- Dust from construction is to be modelled.
- Dust and odour from spoil placement at the DMPA are to be assessed.
- The implication of fuel quality limits on ships such as established in NSW POEO Regulation 2015 (Part 6 A) is to be discussed.

The stiff clay DMPA is assessed separately in an additional report (ASK 2017).

The following scope of work has been undertaken for this report:

(1) Review air quality section (B11) of the draft EIS to reuse appropriate and current material.

(2) Review equipment and activity data.

(3) Summarise air quality values, existing air quality and sensitive receptors identified in existing situation (1B) study of this Revised EIS.

(4) Undertake additional Calmet meteorological modelling in the Northern Sands to Yorkeys Knob region for the DMPA modelling.

(5) Review air quality emission factors for the following sources and conduct additional literature research to determine the most appropriate factors:

  (a) particulates (TSP, PM_{10} and dust fallout) and odour from the Northern Sands DMPA placement area and pipeline construction

  (b) haul route dust generation and vehicle emissions

  (c) ship waste unloading odour at port

  (d) booster stations

  (e) dredgers, barge, tugs and off-loader emissions

  (f) ship exhaust emissions under different load conditions including particulates less than 2.5 microns ($PM_{2.5}$), particulates less than 10 microns (PM_{10}), total suspended particulates, dust deposition, carbon monoxide, nitrogen oxides, benzene (and other VOCs) and sulphur dioxide (SO_2). Emission limits referred to in the current Australian Maritime Safety Authority (AMSA) regulations are identified.

(6) Identify coordinates of emission sources using aerial photography.

(7) Undertake dispersion modelling using the Calpuff dispersion model for the Northern Sands domain at ground level and the wharf domain at ground and three additional heights. Calpuff has been chosen since the sources are wake-affected and near-calm wind conditions may be critical. Worst case emission scenarios have been modelled as required by the Terms of Reference.

(8) Prepare tables of predicted concentrations and depositions at key receptors.

(9) Process results using Calpost and prepare figures showing contours of critical predicted pollutants.

(10) Undertake qualitative discussion of dark smoke from ship exhaust, and discharge of tailwater at the DMPA.

(11) Complete risk assessment of impacts without any additional management measures.

(12) Make comment on the reduction in impacts due to the reduced dredging program associated with the revised scope of dredging works..

(13) Undertake hazard and risk assessment describing the factors that affect workforce health, community health, public safety and quality of life associated with odour, dust and other air pollutants.

(14) Determine ameliorative measures (both design changes and management measures) if required and practical. Update risk assessment with measures.

(15) The application of fuel quality limits on ships such as the 0.1% sulphur content cap for cruise ships at berth, established in NSW POEO Regulation 2015 (Part 6A) is to be discussed and an adopted approach for this project defined. The new International Maritime Organization (IMO) sulphur cap of 0.5% in 2020 (IMO 2008) is included as a future control.

(16) Prepare the air quality aspects of an EMP including objectives, strategies, performance indicators, specific control measures, monitoring and reporting, corrective actions and review mechanism.

(17) Provide report with input data, modelling methods and results, analysis and recommendations.

To aid in the understanding of the terms in this report a glossary is included in **Appendix A**.

1.2 Terms of Reference

The terms of reference issued by the Queensland Coordinator-General (November 2012) include those listed in **Table 1.1** which are relevant to air quality.

Table 1.1 Relevant Terms of Reference

ToR	Details Required	Relevant Section of Report
5.6.1	**Describe the existing air quality that may be affected by the project in the context of environmental values as defined by the EP Act and Environmental Protection (Air) Policy 2008 (EPP (Air)).**	
	Discuss the existing local and regional air shed environment, including:	
	• background levels and sources of particulates, gaseous and odorous compounds and any major constituent	Section 6
	• pollutants (including greenhouse gases)	Section 6 Greenhouse gases are addressed in TS16 and associated data report.
	• baseline monitoring results, sensitive receptors	Sections 6 & 2.2
	Data on local meteorology and ambient levels of pollutants should be gathered to provide a baseline for later studies or for the modelling of air quality environmental harms. Parameters should include air temperature, wind speed and direction, atmospheric stability, mixing depth and other parameters necessary for input to the models.	ASK (2016) Section 5
5.6.2	**Consider the following air quality issues and their mitigation:**	
	• an inventory of air emissions from the project expected during construction and operational activities (including source, nature and levels of emissions)	Section 7
	• 'worst case' emissions that may occur during operation. If these emissions are significantly higher than those for normal operations, it will be necessary to separately evaluate the worst-case impact to determine whether the planned buffer distance between the facility and neighbouring sensitive receptors will be adequate	Section 7
	• ground level predictions should be made at any site that includes the environmental values identified by the EPP (Air), including any sites that could be sensitive to the effects of predicted emissions	Section 9
	• dust and odour generation from construction activities, especially in areas where construction activities are adjacent to existing road networks or are in close proximity to sensitive receivers	Section 7
	• climatic patterns that could affect dust generation and movement	Section 7
	• vehicle emissions and dust generation along major haulage routes both internal and external to the project site	Section 7
	• human health risk associated with emissions from project activities of all hazardous or toxic pollutants	Section 11.1
	Detail the best practice mitigation measures together with proactive and predictive operational and maintenance strategies that could be used to prevent and mitigate impacts.	Section 10
	Discuss potential air quality impacts from emissions, with reference to the National Environmental Protection (Ambient Air Quality) Measure 2003 (Cwlth) and the EPP (Air). If an emission is not addressed in these legislative instruments, discuss the emission with reference to its risk to human health, including appropriate health-based guidelines/standards.	Section 9

1.3 Study Team Details

Table 1.2 Air Quality Study Team Details

Name	Experience / Qualifications	Role on EIS
Andrew Martin	Andrew Martin has 23 years experience in air quality assessment including air quality monitoring projects at RG Tanna, Hay Point, Dalrymple Bay and Townsville ports. He has expert knowledge of air emission inventories and dispersion modelling as well as air quality management and control strategies. • Bachelor of Science (Physics) • Master of Applied Science (Medical Physics) • Master of Science (Environmental Management) • Fellow of Clean Air Society of ANZ	Principal author of this air quality report and greenhouse gas emission calculations.
Michelle Yu	Michelle Yu has 6 years of experience in air quality assessment including emissions testing, air monitoring and dispersion modelling in mining, industrial, agricultural and utility sectors. • Bachelor of Engineering (Chemical) • Master of Engineering (Environmental) • Member of Clean Air Society of ANZ	Air quality emission inventory development, ship modelling and review of this air quality report.

2. Study Area Description

2.1 Overview

The sites under assessment in this report include the wharf, channel, Northern Sands DMPA and associated pipeline route. Descriptions of the environment at these locations are contained in the Baseline Air Quality Constraints Assessment (ASK 2016). The Tingira Street DMPA is assessed in a separate report (ASK 2017).

2.2 Identification of Existing Sensitive Receptors

Sensitive land uses are defined in the State Planning Policy (2014) as caretakers accommodation, child care centre, community care centre, community residence, detention facility, dual occupancy, dwelling house, dwelling unit, educational establishment, health care services, hospital, hotel, multiple dwelling, non-resident workforce accommodation, relocatable home park, residential care facility, resort complex, retirement facility, rooming accommodation, rural workers accommodation, short-term accommodation or tourist park.

Boat berths where permanent pylons are provided for mooring are considered sensitive locations under the definition of relocatable home park. It is understood that Ports North control the lease of these mooring pylons, and that during construction activity (including dredging), that Ports North may limit the use of boat moorings to prevent the potential for noise impacts to these receptors.

The nearest sensitive receptors are summarised in **Table 2.1** including their northing and easting locations and are shown in **Figure 2.1**. All of the receptors listed in **Table 2.1** are residences with the exception of receptor J which is an educational centre, receptor S which is a residential dwelling currently under construction, and receptor I which are boat moorings. Tall buildings such as sensitive receptors A to H were modelled at different receptor heights to represent the different levels of these receptors.

Table 2.1 List of Sensitive Receptors with UTM Coordinates (WGS84 Z55)

ID	Name / Address	Real Property Description	Approximate Distance and Direction from Site	Easting (m)	Northing (m)
Near wharf	**Cairns City**				
A	Park Regis City Quays Hotel, 6-8 Lake Street	N/A	Approximately 130 metres west of dockside.	369960	8128319
B	Park Regis Piermonde Apartments, 2-4 Lake Street	N/A	Approximately 130 metres west of dockside.	369999	8128255
C	Jack & Newel Apartments, 27-29 Wharf Street	N/A	Approximately 130 metres west of dockside.	370006	8128299
D	Madison on Abbott Apartments, 3 Abbott Street	N/A	Approximately 130 metres west of dockside.	370001	8128362
E	Pullman Reef Hotel & Casino, 6-8 Abbott Street	N/A	Approximately 100 metres west of dockside.	370054	8128412

ID	Name / Address	Real Property Description	Approximate Distance and Direction from Site	Easting (m)	Northing (m)
F	Cairns Hilton Hotel, 34 Esplanade	N/A	Approximately 80 metres west of shipping channel.	370141	8128578
G	Cairns Harbour Lights Managed Apartments, 101 Marlin Parade	N/A	Approximately 100 metres west of shipping channel.	370151	8128632
H	Shangri-La Hotel, Pier Point Road	N/A	Approximately 220 metres west of shipping channel.	370146	8128990
I	Boats used as residences, east side of Trinity Inlet	N/A	Variable	370558	8128061
Near Northern Sands Placement area					
J	Holloways Beach Environmental Education Centre, 46 Poinsettia Street, Holloways Beach	122/NR840892	Approximately 500m from pipeline.	365190	8138963
K	2-4 Deauville Close, Yorkeys Knob	0/BUP105844	Approximately 1km from pipeline.	364417	8140742
L	30 Acacia Street, Holloways Beach	328/H9082	Approximately 500m from pipeline.	365130	8138811
M	280 Yorkeys Knob Road, Yorkeys Knob	2/RP800898	Approximately 300m from pipeline.	363937	8138570
N	72 Baronia Crescent, Holloways Beach	40/RP742748	Approximately 500m from pipeline.	364972	8138264
O	108 Baronia Crescent, Holloways Beach	22/RP742750	Approximately 700m from pipeline.	364958	8137890
P	101-103 Wistaria Street, Holloways Beach	1/RP731885	Approximately 1km from pipeline.	365220	8137538
Q	78 Wistaria Street, Holloways Beach	21/RP741077	Approximately 1km from pipeline.	365265	8137228
R	613 Holloways Beach Access Road	5/RP857577	Approximately 400m from pipeline.	364512	8136716
S	Dwelling under construction, Holloways Beach Access Road	22/SP211748	Approximately 850 metres north of Northern Sands area.	364587	8136488
T	637 Captain Cook Highway, Barron	4/RP800591	Approximately 200 metres north-west of Northern Sands area.	363235	8136373
U	637 Captain Cook Highway, Barron	4/RP800591	Approximately 200 metres north-west of Northern Sands area.	363162	8136228

ID	Name / Address	Real Property Description	Approximate Distance and Direction from Site	Easting (m)	Northing (m)
V	Holloways Beach Access Road	1/RP804218	Approximately 400 metres east of Northern Sands area.	364663	8135785
W	Holloways Beach Access Road	1/RP804218	Approximately 300 metres east of Northern Sands area.	364566	8135742
X	Holloways Beach Access Road	1/RP804218	Approximately 300 metres east of Northern Sands area.	364561	8135676
Y	417-419 Captain Cook Highway	4/RP748713	Approximately 400 metres east of Northern Sands area.	364658	8135085

Figure 2.1 Location of Sensitive Receptors in Wharf Street Area (Image from Google Earth Pro)

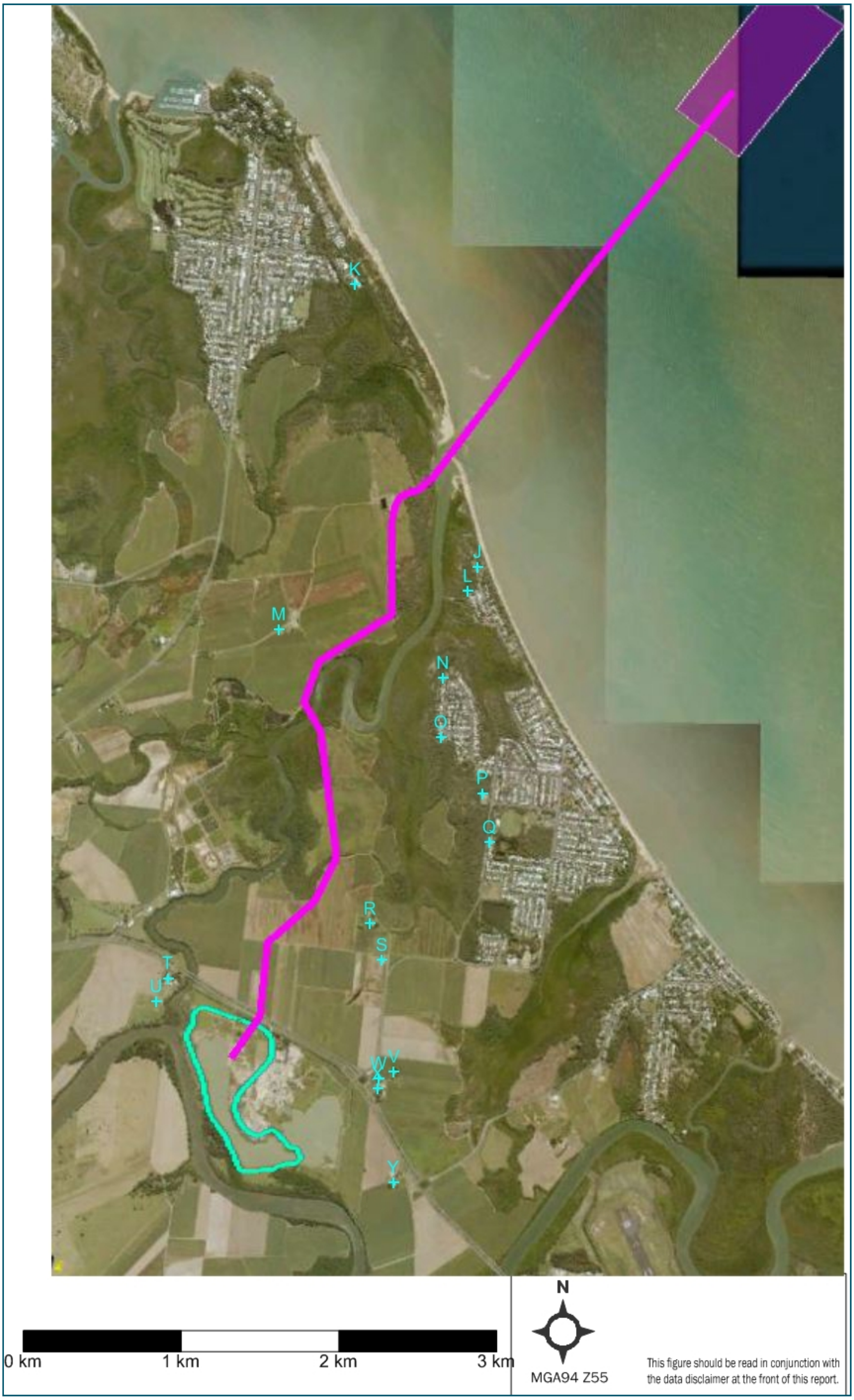

Figure 2.2 Location of Sensitive Receptors near Northern Sands Placement Area

3. Existing Operations and Proposed Development

3.1 Project Definition

The objective of the Cairns Shipping Development Project (CSDP) is to accommodate larger cruise ships and a potential expansion of HMAS Cairns Navy Base through widening and deepening of the Cairns Shipping Channel and improvement of navigation and wharf facilities.

The channel design to be assessed in the Revised Draft EIS will involve the following elements shown in **Figure 3.1** :

- -8.8m Declared Channel depth
- Expanded Crystal Swing Basin to 380m
- Smith's Creek Swing Basin to 310m
- Outer Channel width 90 -100m
- Inner Channel width generally to 110m (outer bend to 180m)
- Further optimisation may occur at dredging contract negotiation stage.

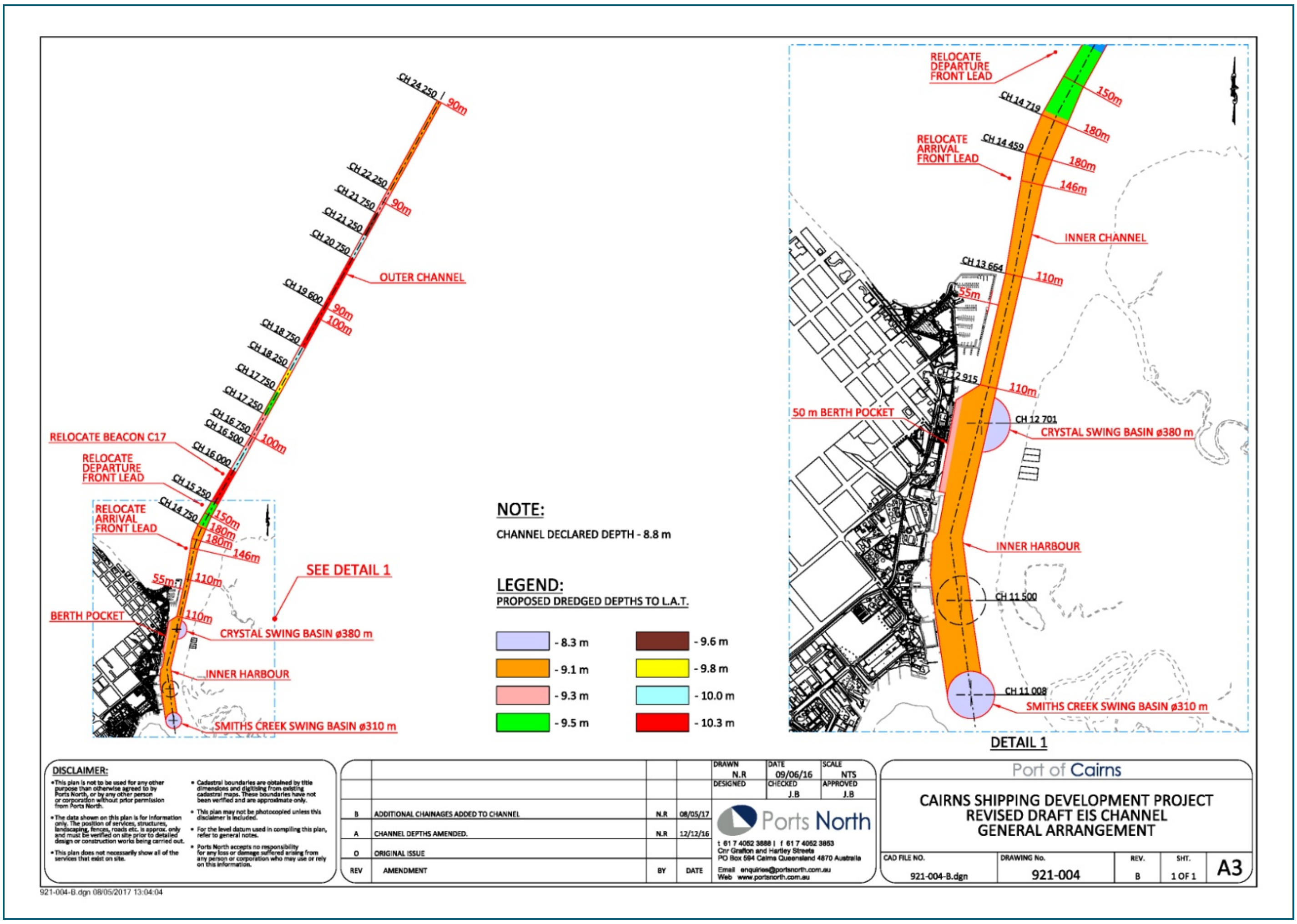

Figure 3.1 General Arrangement of Channel Design

Dredge material quantities include soft clays (900,000m^3, including 320,000m^3 Possible Acid Sulphate Soils PASS) and 580,000m^3 (self-neutralising clays) and stiff clays (100,000m^3). Dredge material is to be transported to shore based Dredge Material Placement Areas (DMPAs) at the Northern Sands sand extraction operation on the Barron Delta and reclamation areas at Tingira Street Portsmith.

The soft clays are to be dredged via a 5,600m^3 capacity Trailer Suction Hopper Dredge (TSHD) discharging to a temporary floating pump out facility between approximately 2.6 and 3.6 km NE of Yorkeys Knob.

Dredge material will be pumped from the pump out facility via a submerged steel pipeline, which will make landfall near the Richters Creek mouth, thence to the Northern Sands DMPA via cane farm headlands and Captain Cook Highway culverts (**Figure 3.2**). Due to the 8km pipeline distance from pump out to the NS DMPA, up to three pipeline booster pumps will be required, depending on TSHD pumping capacity. As the Terms of Reference require assessment of worst case scenarios, three land-based boosters and one off-shore booster have been modelled.

Stiff clays are to be dredged by a backhoe dredger to dumb barges for unloading at the barge ramp along Smiths Creek and heavy vehicle transport to the adjacent Tingira Street facility.

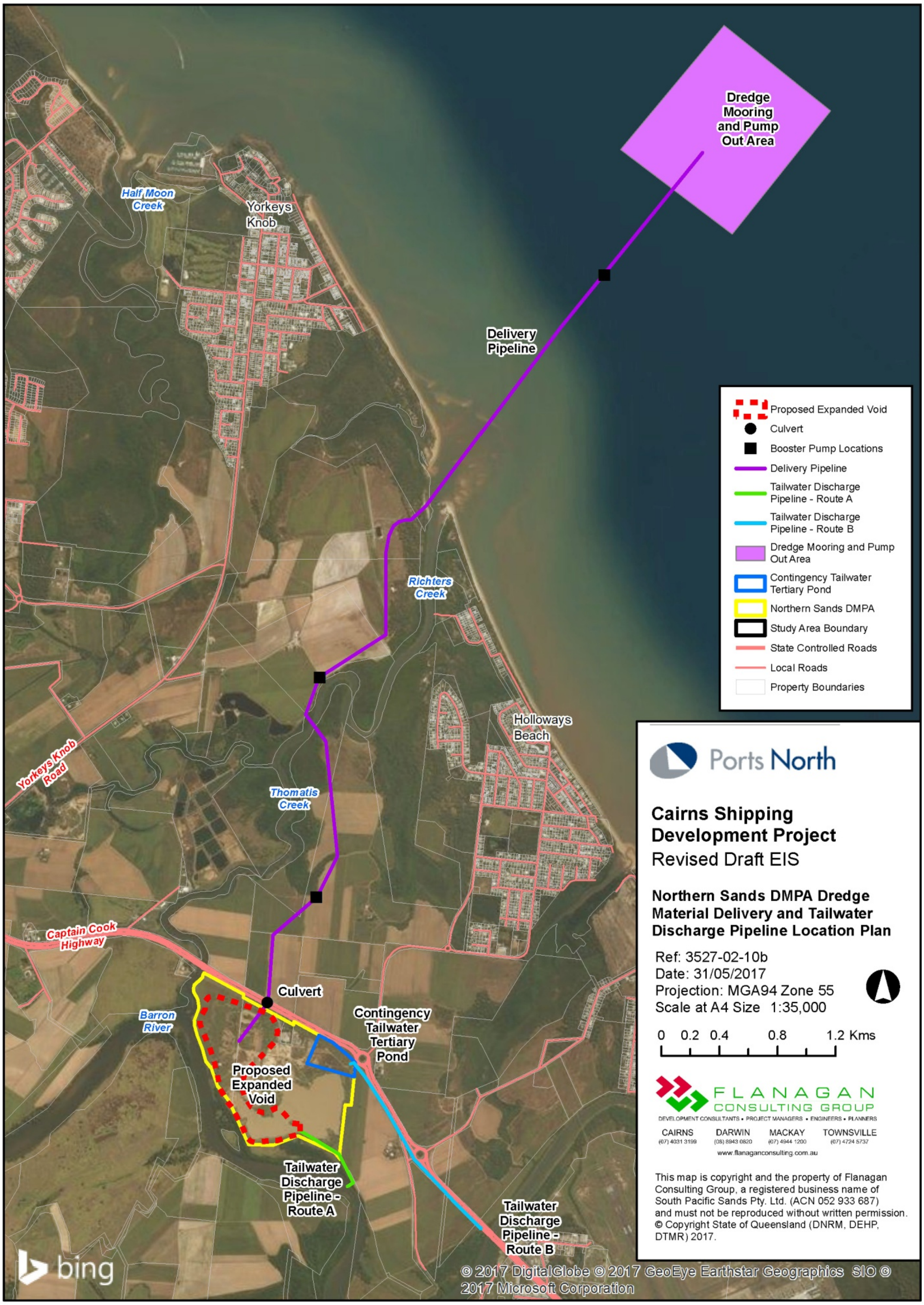

Figure 3.2 Northern Sands DMPA Location Plan

The Northern Sands DMPA will consist of the following elements illustrated in **Figure 3.3**:

- Facility capacity required during placement is 3,000,000m³. Material is expected to further consolidate with time to approximately 1,700,000m³ (with additional void shaping, assumed final settled bed level at approximately 3.0m AHD approx.).
- Temporary bunding to 7.5 m AHD (exceeds 100 year Flood immunity 5.8 m AHD), which will minimise risk of sediment remobilisation in the event of event exceedance.
- Water volume above RL 5.5 approx. 400,000m³ (allowing 500mm free board from top of bund).
- Clay sheeted rock wall at Reedy/Snake island to separate DMPA from southern sand pit.
- Tailwater is proposed to be discharged adjacent to site or pumped to an outfall at the Barron River highway bridge.

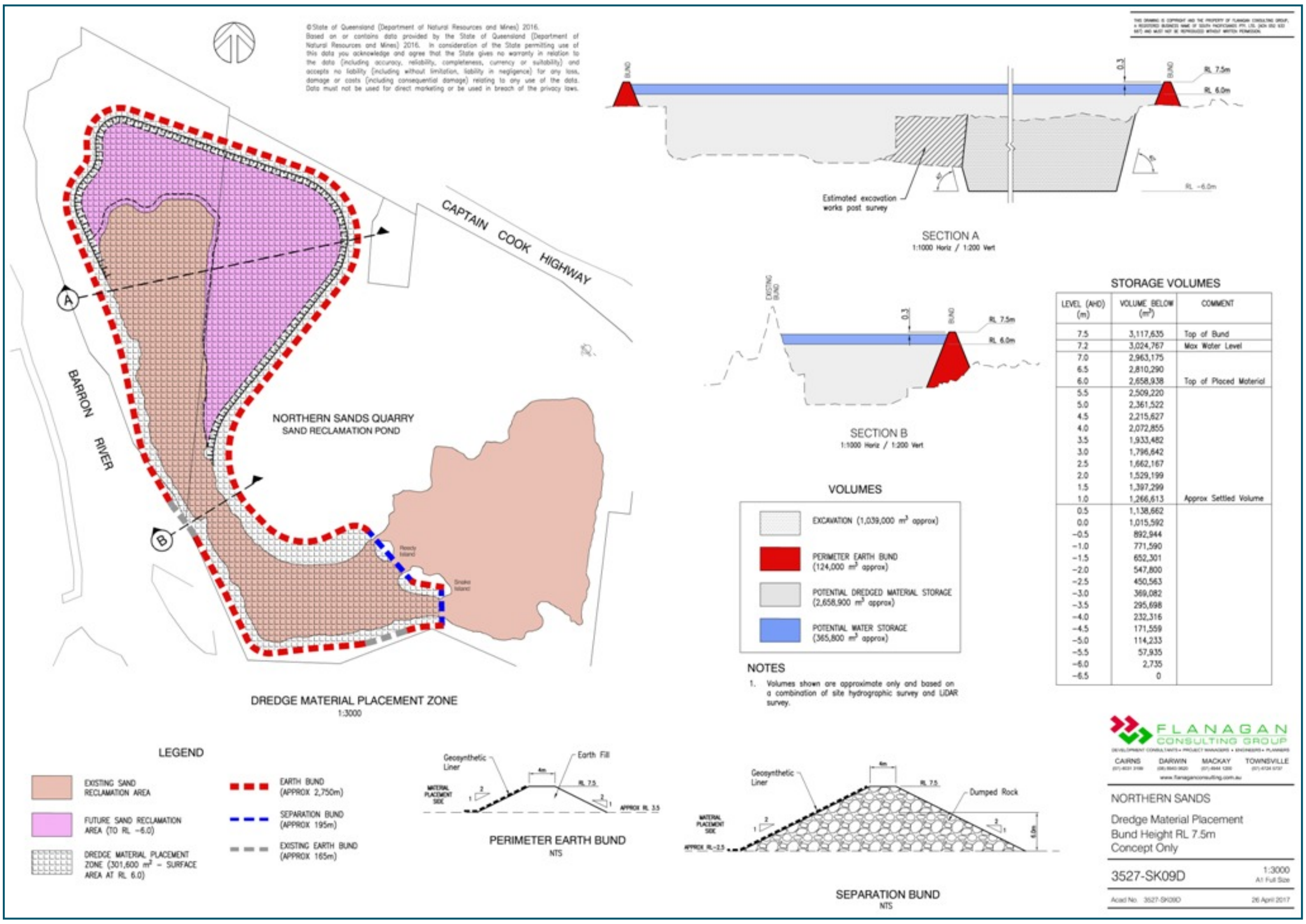

Figure 3.3 Northern Sands DMPA Concept Layout

3.2 Overview of Air Emission Sources of the Project

3.2.1 Overview

The CSD Project involves upgrading of existing infrastructure for the Port of Cairns to accommodate larger cruise ships, including expansion of the existing shipping channel and swing basin, and upgrades to the existing wharves and associated services. Associated with this is the construction of infrastructure for placing the dredge material on land.

3.2.2 Overview of Air Emission Sources of Construction

Construction sources include:

- the dredger itself moving up and down the channel, motoring to a pump-out point located offshore of Yorkeys Knob and pumping out load
- land-based wharf infrastructure construction
- dust from vehicle movement on unsealed surfaces
- exhaust emissions from plant and equipment for construction and dredging vessels
- exhaust emissions from on-road vehicles
- exhaust emissions from barge tugs
- construction, operation and decommissioning of the pipeline between the pump-out point and the Northern Sands DMPA and especially exhaust emissions from the three booster stations
- construction and placement activities at the Northern Sands DMPA, including discharge of tailwater.

Section B11.5.2 of the draft EIS described the substantial construction and operational sources. It is understood that no haulage or fill will be required for the project.

Wharf construction hours are likely to be 6:30am to 6:30pm Monday to Saturday. Dredging and DMPA operation are likely to be 24 hours per day seven days per week. The following timeframes are anticipated:

- For the Northern Sands placement option, the current time estimate is 12 weeks plus pipeline mobilisation and demobilisation. DMPA and pipeline construction (concurrent) for Northern Sands will be done during daylight hours only for a duration of six weeks, with demobilisation also taking up to six weeks.
- The wharf upgrade will take approximately seven to eight months intermittently over a year.
- The other land infrastructure will be concurrent with the wharf upgrade.

3.2.3 Overview of Air Emission Sources of Operation

Operational sources include:

- cruise ship wharf activities
- cruise ships traversing the channel and manoeuvring to the wharf
- maintenance dredging

The numbers of cruise ships berthing at the Port of Cairns is currently approximately 30 cruise ships, 76 bulk cargo ships (>100 metres in length) and 182 general cargo ships. In 2026 with the upgrade the number of cruise ships is projected to be up to a maximum of 177 cruise ships including 164 megaships per year. It is anticipated that only one cruise ship will be docked at any one time.

Other vehicles will include buses, taxis, private vehicles, delivery trucks, sewerage trucks and fuel tankers. The draft EIS traffic impact assessment concluded that road traffic volumes were not anticipated to change significantly, based on only one large cruise ship being berthed at any time, and it is understood that this is still the case. Traffic associated with the current largest vessel (Legend of the Seas), is typically 26 buses and 40 taxis in one day.

It is proposed that Intermediate Fuel Oil (IFO) will be stored and dispensed via pipeline from the nearby fuel farm to the wharf, depending on commercial negotiations between fuel suppliers and cruise companies.

3.3 Proposed Wharf Construction

An additional IFO storage tank, with a capacity of approximately 10,000 m^3 may be required within the existing fuel farm to store monthly deliveries from fuel ships via the existing fuel wharf 10. Fuel will be delivered from the storage tank to cruise ships via pump station and pipeline to wharf 3. According to the Draft EIS, construction of the fuel storage and transfer infrastructure is likely to require:

- 35 – 80 tonne mobile crane
- ~20 tonne Franna crane
- 20 tonne excavator
- rigid dump trucks
- power generators
- welding equipment.

New water, firefighting and sewerage services are required for wharves 1 to 5. These will include replacement / extension of existing water mains and installation of a sewage pump station, underground storage tank and odour control system. Equipment required for the construction of these services may include:

- ~20 tonne Franna crane
- 20 tonne excavator
- rigid dump trucks
- concrete pump truck
- concrete delivery trucks

Work for the wharf upgrade includes installation of new berthing structures including driving of piles and drilling of sockets into the seabed. In particular wharf #6 is to be demolished and re-constructed. The undertaking of this construction may require:

- 35 – 80 tonne mobile crane
- ~20 tonne Franna crane
- concrete pump truck
- power generators
- 7 dump/concrete deliveries per day intermittently.

The extent of the wharf and associated land works are shown in **Figure 3.4**. The anticipated duration of construction works for the wharf is seven to eight months.

Figure 3.4 Extent of Wharf and Associated Land Works Area and Proposed Channel

3.4 Wharf Operations

3.4.1 Existing Wharf

The existing wharf is shown in **Figure 3.5** and caters for cruise ships and a variety of smaller vessels.

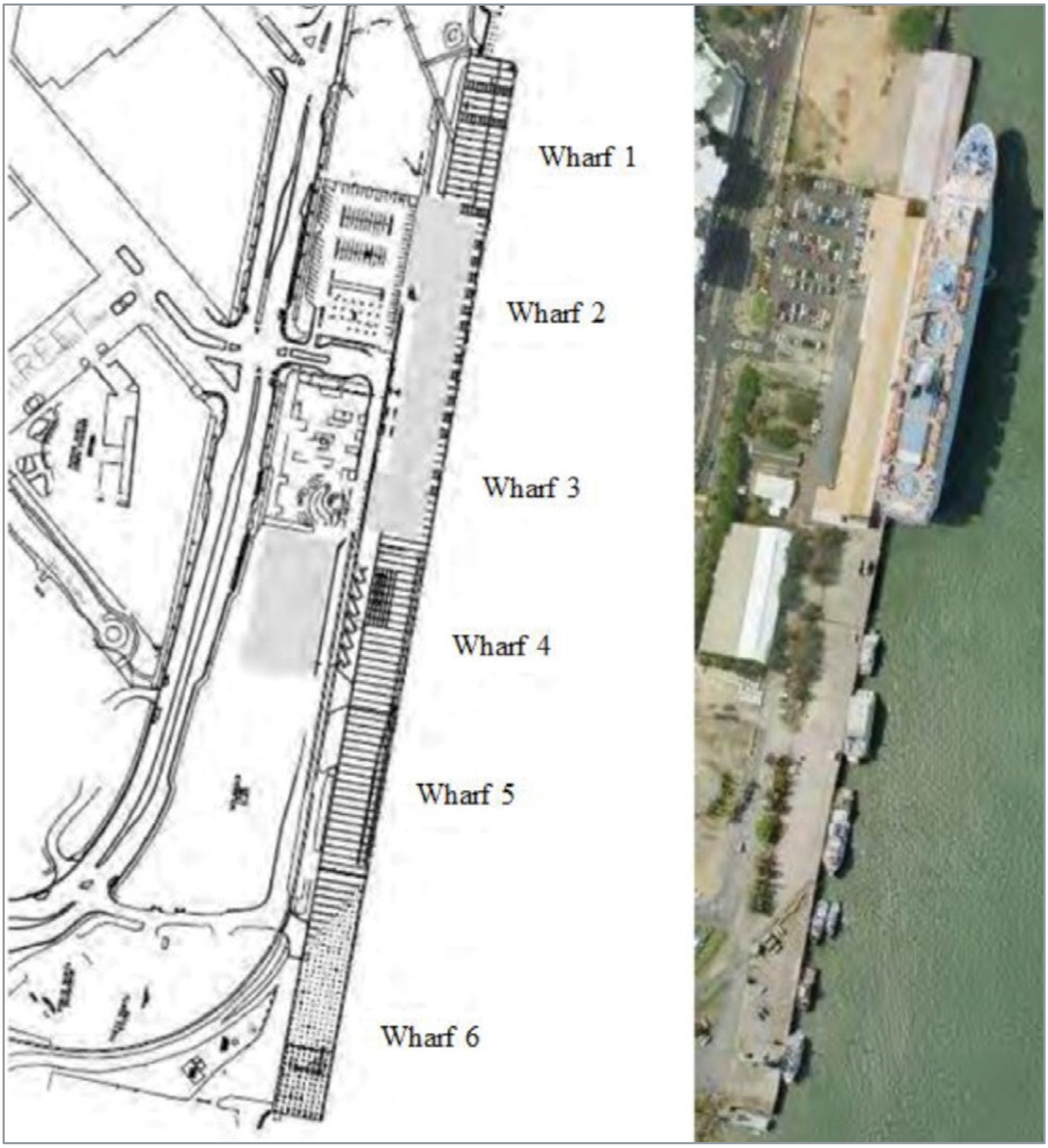

Figure 3.5 Plan and Aerial Photo of Port (from Draft EIS Chapter A4)

3.4.2 Existing Tank Farm

Quantities of marine diesel fuel over 30,000 litres can be supplied to vessels at Wharf 10. A bunkering service via road tankers, or on occasion, lighter barge service is available if required. There is no direct fuel line to the cruise shipping wharves. Data for each tank was estimated using aerial photography provided by the Queensland Globe layer on Google Earth Pro and are listed in **Table 3.1**. Heights were estimated from Google Earth Street View and the aerial photography shadow lengths of each tank. Capacity was calculated from height and diameter. The total estimated capacity would be approximately 100,000 m^3, but it is understood that some of these are decommissioned and awaiting removal.

Table 3.1 List of Existing Tanks

Model ID	Easting (m)	Northing (m)	Diameter (m)	Height (m)	Capacity (m^3)
t1	369685	8127339	23	20	8494
t2	369650	8127369	17	17	3927
t3	369631	8127352	8	9	474
t4	369607	8127333	22	13	4783
t5	369583	8127361	22	14	5380
t6	369611	8127385	23	22	9148
t7	369713	8127390	31	16	11870
t8	369675	8127424	36	16	16008
t9	369732	8127428	25	16	7720
t10	369708	8127459	21	16	5447
t11	369753	8127475	32	16	12648
t12	396921	8127518	12	8	889
t13	369635	8127528	15	8	1390
t14	369761	8127609	25	9	4632
t15	369741	8127642	27	9	5403
t16	369758	8127671	15	13	2223
t17	369756	8127703	16	13	2530
t18	369774	8127718	12	17	1956
t19	369756	8127728	13	9	1252

3.4.3 Proposed Tank Farm

Intermediate Fuel Oil (IFO) is used as another fuel in marine diesel engines. IFO is a blend of heavy fuel oil and distillate oil. IFO is not currently available and supplied in Cairns.

An additional IFO storage tank(s) will be required within the existing fuel farm area (see **Figure 3.6**). The exact design and size of the IFO supply will be finalised during detailed design. However, based on preliminary demand forecasts, it is anticipated that an additional IFO storage tank(s) with a capacity of approximately 10,000 m^3 will be required within the existing fuel farm area to store monthly fuel deliveries. The estimate easting and northing coordinates for the tank are 369738 metres, 8127321 metres.

The extent of the upgrades for the fuel storage works is shown in **Figure 3.6**.

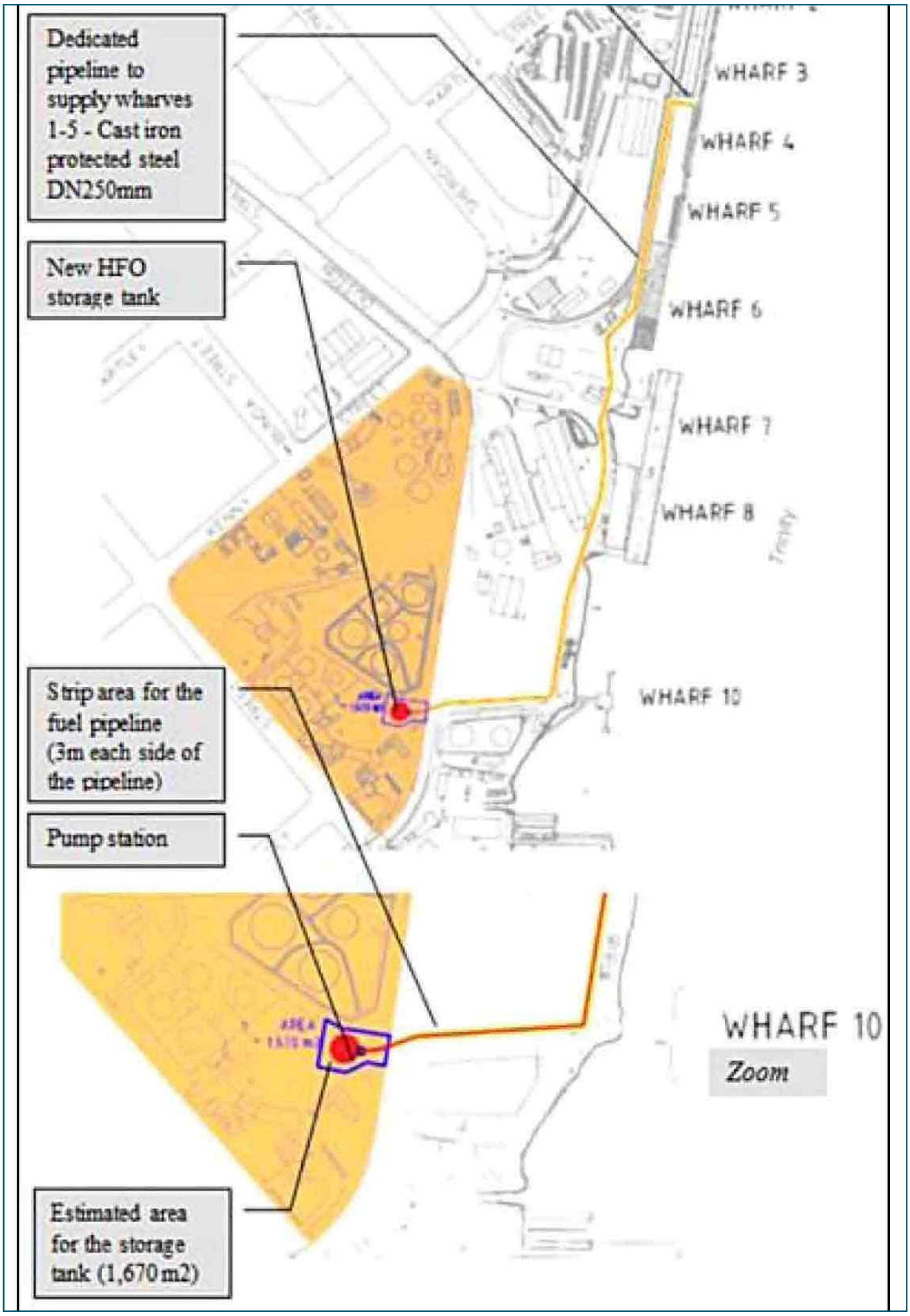

Figure 3.6 Fuel Storage Works

3.4.4 Proposed Cruise Shipping Movements

The information in this sub-section has been summarised from AEC (2016). **Table 3.2** provides the relevant details of each classification of cruise ship.

Table 3.2 Cruise Ship Classification by Length

Classification	Length (m)	Example	Gross registered mass (tonnes)	Overall Length (m)
Sub-regal	< 240	Pacific Aria	55,451	219
Regal	240 – 260	Pacific Dawn	70,285	245
Sun	260 – 290	Sun Princess	77,441	261
Vista	290 – 300	Queen Victoria	90,049	294
Grand	300 – 310	Emerald Princess	113,561	290
Voyager	> 310	Voyager of the Seas	137,276	312

Projections of ship visits are provided in **Table 3.3** for the lowest baseline (AEC scenario 1 without Brisbane Cruise Terminal and without home porting) and in **Table 3.4** the highest with the project (scenario 16 with Brisbane Cruise Terminal and home porting and bunkering). Voyager class will not be able to negotiate the inlet even with the proposed channel widening, and have been excluded from all calculations.

Table 3.5 shows the baseline ship visits to Yorkeys Knob. The project scenario ship visits to Yorkeys Knob will be zero (apart from the Voyager class).

AEC provided low, medium and high projections for the years 2016, 2021, 2026 and 2031. For this assessment, the medium baseline (of scenario 1) and high project (of scenario 16) projections have been used.

ASK has modelled a 10 year planning horizon being the year 2028 for both the baseline and the project scenario. Shipping numbers for 2028 were interpolated linearly from the AEC data.

Table 3.3 Projected Baseline (AEC Scenario 1) Ship Visits to Trinity Wharves

Classification	2016	2018	2021	2026	2028	2031
Sub-regal	29	27	25	33	37	42
Regal	-	1	3	2	2	2
Sun	15	15	16	14	12	10
Vista	-	-	-	-	-	-
Grand	-	-	-	-	-	-
TOTAL	**44**	**43**	**44**	**49**	**51**	**54**

Table 3.4 Projected Project (AEC Scenario 16) Ship Visits to Trinity Wharves

Classification	2016	2018	2021	2026	2028	2031
Sub-regal	29	31	33	43	48	55
Regal	-	3	7	4	5	6
Sun	15	25	40	31	27	20
Vista	-	27	67	77	69	57
Grand	-	3	7	22	31	45
TOTAL	**44**	**89**	**154**	**177**	**180**	**183**

Table 3.5 Projected Baseline (AEC Scenario 1) Ship Visits to Yorkeys Knob

Classification	2016	2018	2021	2026	2028	2031
Sub-regal	-	-	-	-	-	-
Regal	11	8	3	2	2	2
Sun	-	-	-	-	-	-
Vista	5	10	18	23	20	16
Grand	-	1	3	9	13	20
TOTAL	**16**	**19**	**24**	**34**	**35**	**38**

3.4.5 Ship Movement Scenario

Information in this sub-section was provided by Ports North. The location of beacons is shown in

Figure 3.7. Port of Cairns speed restrictions are:

- 10 knots seaward of beacon 15
- 8 knots inward of beacon 15.

The engine configuration is different for each ship however a typical scenario for the **Jewel class** (eg Vista class) vessel for arrival follows:

- Transit from Pilot Boarding Ground Alpha (Lat 16 degrees 47 minutes; Long 145 degrees 53 minutes, which is approximately 4 nautical miles NNE of channel entrance fairway beacons) to first lines on the wharf is with running of three diesel generators. Typically each generator is 20,000 HP. Time taken is 1 hour and 30 mins on average coming in, including swinging in swing basin. Transit speed in channel is 10-12 knots up to Beacon 15/16 (WGS84 UTM coordinates of 371952, 8132238) then slow to 8-10 knots beacon 15/16 to beacon 20 (WGS84 UTM coordinates of 370553, 8129245). Then 6-8 knots from Beacon 20 down to 4 knots at swing basin (WGS84 UTM coordinates of 370335, 8128172).
- Swing basin manoeuvre takes approximately 15-20 minutes including coming in parallel to berth with stern and bow thrusters (at very low speed).
- From first lines on wharf to all lines fast two generators are run. Time taken is approximately 15-20 minutes.
- Whilst alongside wharf continue to power ship services with one generator at about 40%-50% power. Alongside wharf fuel consumption is typically 10 – 15 tonnes per day.

A typical scenario for departure follows:

- Continue with one generator from first line off to last line off.
- From last line off for full departure to Pilot Boarding Ground using three generators. Time is approximately 1 hour (no swinging).

The Radiance class (Vista size) vessel use gas turbines in transit and one diesel generator at berth.

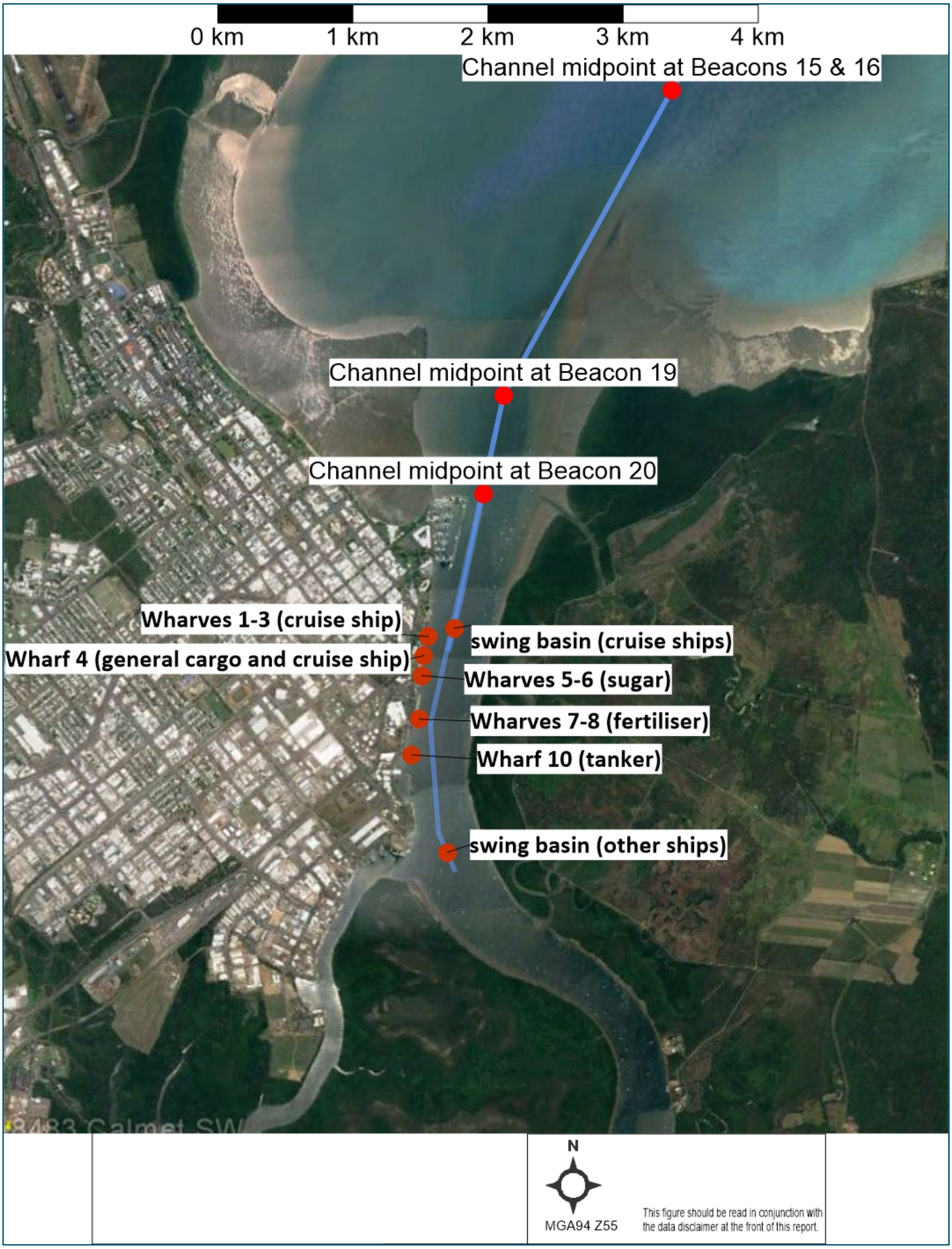

Figure 3.7 Locations Relevant to Ship Movements

3.4.6 Other Shipping Movements

The Port of Cairns has two types of cargo shipping that use its facilities. This includes:

- supply trade to northern communities in Gulf and Torres Strait
- bulk cargo – sugar, molasses, fuel products, fertilisers and general cargo.

The northern supply trade currently supplies the major Freeport McMoran mine in Papua, Indonesia and Seaswift and Toll supply to the Torres Strait and to Weipa. The existing channel is wide and deep enough to allow navigation of these vessels, and no upgrade is required for these purposes (Cummings Economics 2014).

The bulk cargo ships are of a size that cannot enter the port at low tide, even with restricted loads. This means they are subject to a six-to-eight hour wait for the tides (Cummings Economics 2014). This equates to approximately 12-to-16 hour turnaround, as vessels are required to wait for suitable tides while entering and leaving the Port of Cairns. Even at high tide, bulk cargo ships are unable to enter the port fully loaded and as such, they share loads with other ports, mainly with Townsville (45 ships per year).

The average number of bulk cargo ships per year estimated by Cummings Economics (2014) was 62 made up of:

- Fuel: 40 ships per year
- Sugar ships: 15 ships per year
- Fertiliser ships: 7 ships per year.

The total number has since been updated and included in this assessment but the breakdown proportion has been used in the modelling. The model assumes a total of 79 ships per year which is the highest of a range of values.

The Port of Cairns is also a base for the Royal Australian Navy patrol boats and a large fishing fleet. In addition, Cairns Marlin Marina was established as a key component of the Cityport precinct and caters for super yachts and a significant fleet of tourist vessels that provide daily tours to the Great Barrier Reef.

Naval ships have not been included in the baseline assessment due to the lack of emission factors and activity data, and their contribution is expected to be considerably less than the commercial fleet. Recreational marina craft have also not been included for the same reasons and since their engine sizes are relatively small.

3.4.7 Waste from Port Operations

Ports North have advised that there are no waste storage bins at the cruise liner facility. Putrescible waste is removed directly by contractors. Typically two small sized skips may be placed behind the cruise liner terminal for baggage waste and terminal staff domestic waste. Quarantine waste will continue to be disposed by licensed commercial waste contractor at a high temperature autoclave. Balance of putrescible waste will be taken by contractor directly off the ships to landfill.

Table 3.6 Predicted Non-Incinerated Waste Quantities (as provided by Golder Associates)

	Units	Boutique Class	Mid-size Class	Mega Class	Total
Total non-incinerable waste for removal at port per visit. (five days). (refer to assumptions in above table).	(kg/visit)	2,844	8,750	17,500	29,094
Baseline					
Total Visits per Passenger Class per annum in 2031		62	16	0	78

	Units	Boutique Class	Mid-size Class	Mega Class	Total
Total non-incinerable waste for removal at port per year in 2031 (recyclables - aluminium, glass, etc), project scenario.	(tonnes/ year)	176.3	140.0	0.0	316.3
Project					
Total Visits per Passenger Class per annum in 2031		50	64	38	152
Total non-incinerable waste for removal at port per year in 2031 (recyclables - aluminium, glass, etc), project scenario.	(tonnes/ year)	142.2	560.0	665.0	1367.2

3.5 Maintenance Dredging

The annual maintenance dredging volume of the outer channel will increase by approximately 2 to 6% up to a total of approximately 350,000 m^3 per year. This will be removed by a dredge similar to the currently used Port of Brisbane's TSHD and placed at the designated offshore DMPA. This is included in the operatonal modelling scenario as part of the background.

3.6 Construction Dredging of Soft Clay

3.6.1 Dredge material, dredging and Placement

The "soft" clay (900,000 m^3) will be removed by the TSHD prior to the dredging of the "stiff" clay by the backhoe dredger in order to avoid double mobilisation of the backhoe spread. The TSHD will take the material to Northern Sands DMPA which will be bunded to 7.5 metres AHD by the quarry operator prior to placement. It is understood that the material will settle at or above current ground level after dewatering, and form a crust. The area will be revegetated by the quary operator

The Dredge Placement Scope Study (Flanagan Consulting Group 2016) identifies that:

- the dredge material consists of approximately 10% sand and 90% silt
- approximately 320,000 m^3 has acid sulphate properties that will require lime treatment.

Akuna (2017) have reported two soil types with size fractions shown in **Table 3.7**. The majority of the material will comprise very soft silty clay which has an average density of 1.34 t/m^3. The remainder, soft silty clay has an average density of 1.54 t/m^3.

Table 3.7 Soft Clay Accumulative Size Fractions (Akuna 2017)

Particle type	Particle size definition (µm)	Very soft silty clay	Soft silty clay
Clay	<2	37%	61%
Medium silt	<20	70%	94%
Silt	<60	91%	98%
Fine sand	<200	98%	98%

Dredgers deepening the channel will operate 24 hours per day, seven days per week. A small spreader pontoon with four shore winches will be required at the DMPA (Akuna 2017).

The TSHD would typically dredge at 1 to 3 knots then steam to and from the pump-out location at 6 to 9 knots. It would then unload at the pump-out location to the discharge pipeline, with seawater pumped into the pipeline to dilute solid material to 10 to 15% by volume.

Location of possible (alternative) tailwater outfalls at Northern Sands are (1) adjacent to the site and (2) an alternative site along the Barron River and then discharging near the Captain Cook Highway bridge.

3.6.2 Acid Sulphate Material

As reported by Akuna (2017), the majority of potential acid sulphate material (PASS) is classified as self-neutralising (580,000 m^3). The total quantity of PASS material is estimated as 320,000 m^3. This material will be dredged as the first priority so that is can be covered with self-neutralising PASS. All material disposed at the Northern Sands DMPA is to remain under water.

3.6.3 Marine Equipment

It is expected that the equipment required at sea will be:

- small to medium sized TSHD (such as the 5,600 m^3 TSHD Marieke (Akuna 2017)) to dredge soft clays and transport to shore, operating 135 hrs /wk. The power ratings are:
  - 6776 kW total power
  - 4050kW pump shore power
  - 4050kW propulsion sailing
  - 3450kW propulsion dredging
  - 450kW bow thruster
- survey/crew change vessel, a 460kW launch working day shift and standby at night
- work boat, multicat, 45T Bollard Pull Shoalbuster type, for anchoring and coupling TSHD and bunkering the booster, day and night
- tug (25T Bollard Pull type) day time only for sweep bar/plough
- temporary mooring facility at the TSHD pump out location
- booster pump station, 4,475 kilowatts operating 40 hours per week when material being pumped from TSHD (Akuna 2017) approximately 800 metres offshore
- barge mounted crane to install pipeline.

The TSHD will be moored at the pump-ashore location without the need for propulsion power so engines are only powering the pump-out.

3.7 Details of the Northern Sand DMPA

The Northern Sands DMPA is located on flat land in the Barron Delta which is currently an operating sand quarry. A concept plan and visualisation are shown in **Figure 3.8** and **Figure 3.9** respectively. The operation will consist of underwater placement of soft clay dredge material within the existing water filled quarry void. The DMPA operations will be separated from ongoing sand extraction by a temporary clay lined rock wall.

A weir box will allow excess water from the top of the DMPA to be pumped out. This typically has boards that can be added or removed to set the height of the overflow to control tailwater quality.

A temporary 9 hectare tailwater treatment pond may also be constructed depending on the outcome of the site investigation and laboratory testing program to increase the flow path and detention time to ensure sufficient solids are removed from suspension prior to tailwater release.

Site activities at the Barron Delta site will be minimal as the pipeline will deliver slurry to an existing water-filled void. Bunds will be built during business as usual operations of the sand quarry and will be complete prior to commencement of DMPA operations. The tailwater volumes are to be approximately 4 million m^3 at a pump capacity of 100,000 m^3/day.

Tailwater is proposed to be discharged from the Northern Sands site (as per **Figure 3.10**) and pumped to one of the following sites:

- Site A on the Barron River immediately downstream of the Northern Sands site.
- Site B further downstream of the Northern Sands site at the location of the Captain Cook Highway bridge in the Barron River.

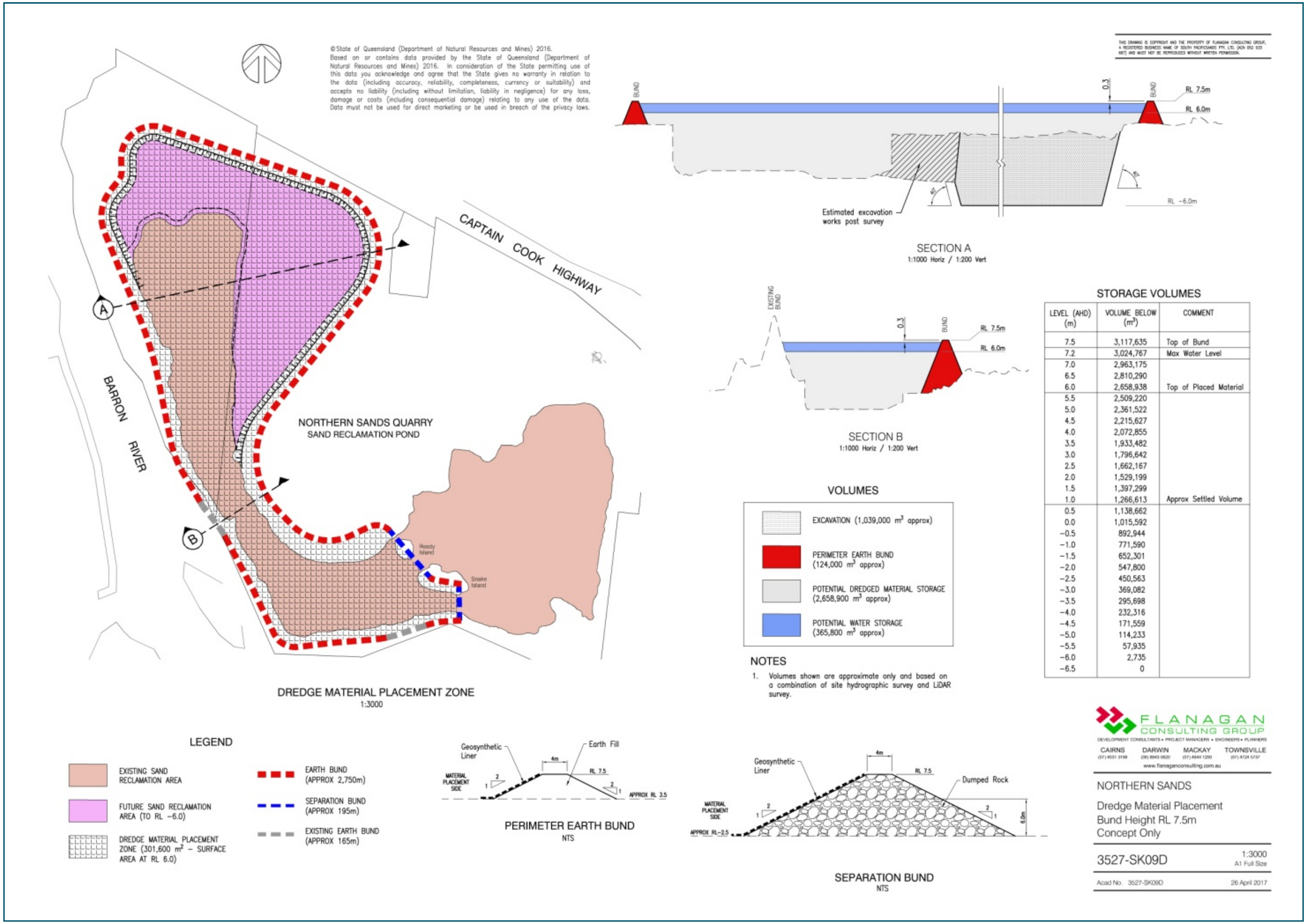

Figure 3.8 Northern Sands DMPA Concept Plan

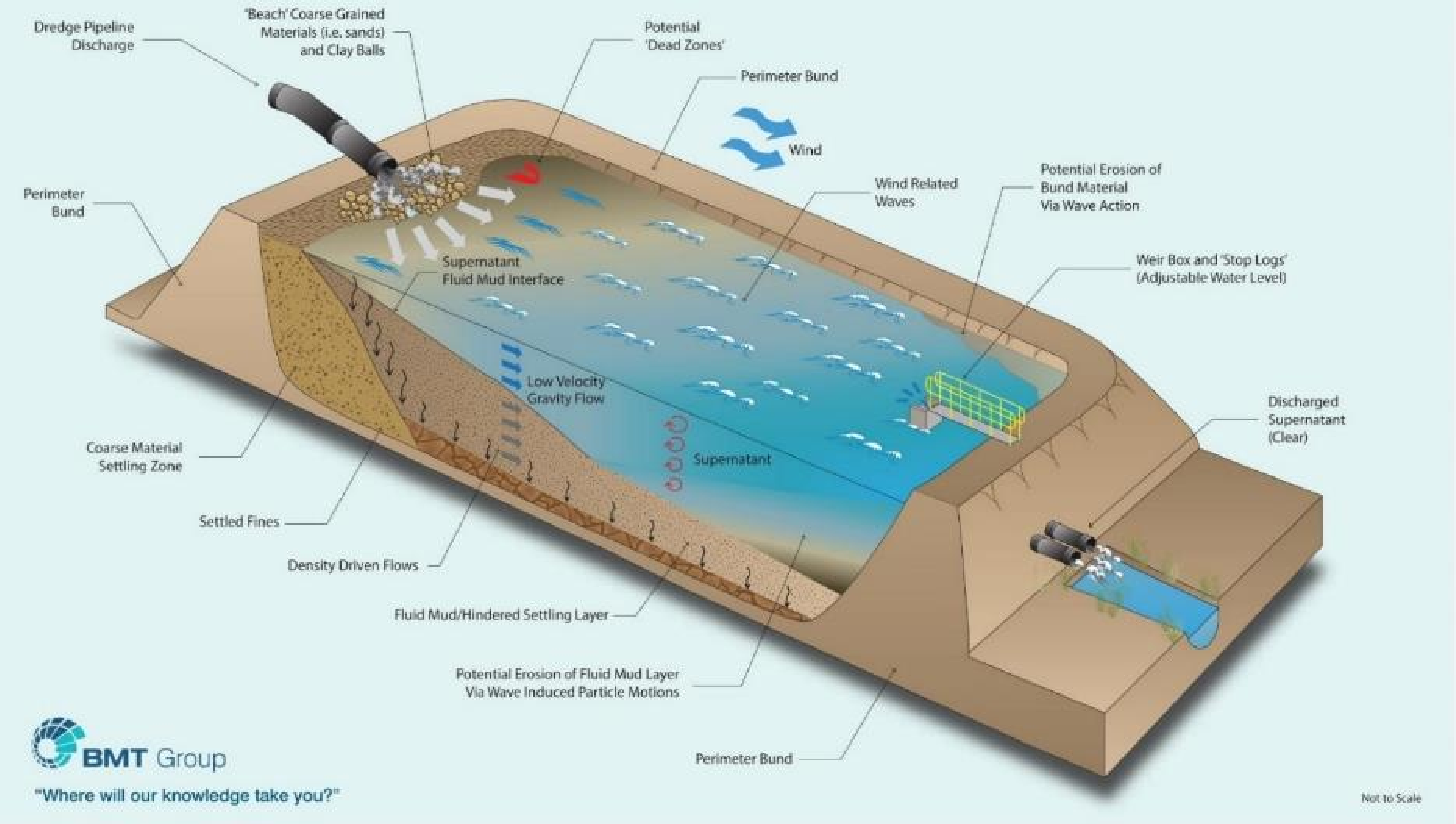

Figure 3.9 Northern Sands DMPA Concept Diagram (Source: BMT Doc P-J16021-1, 2016)

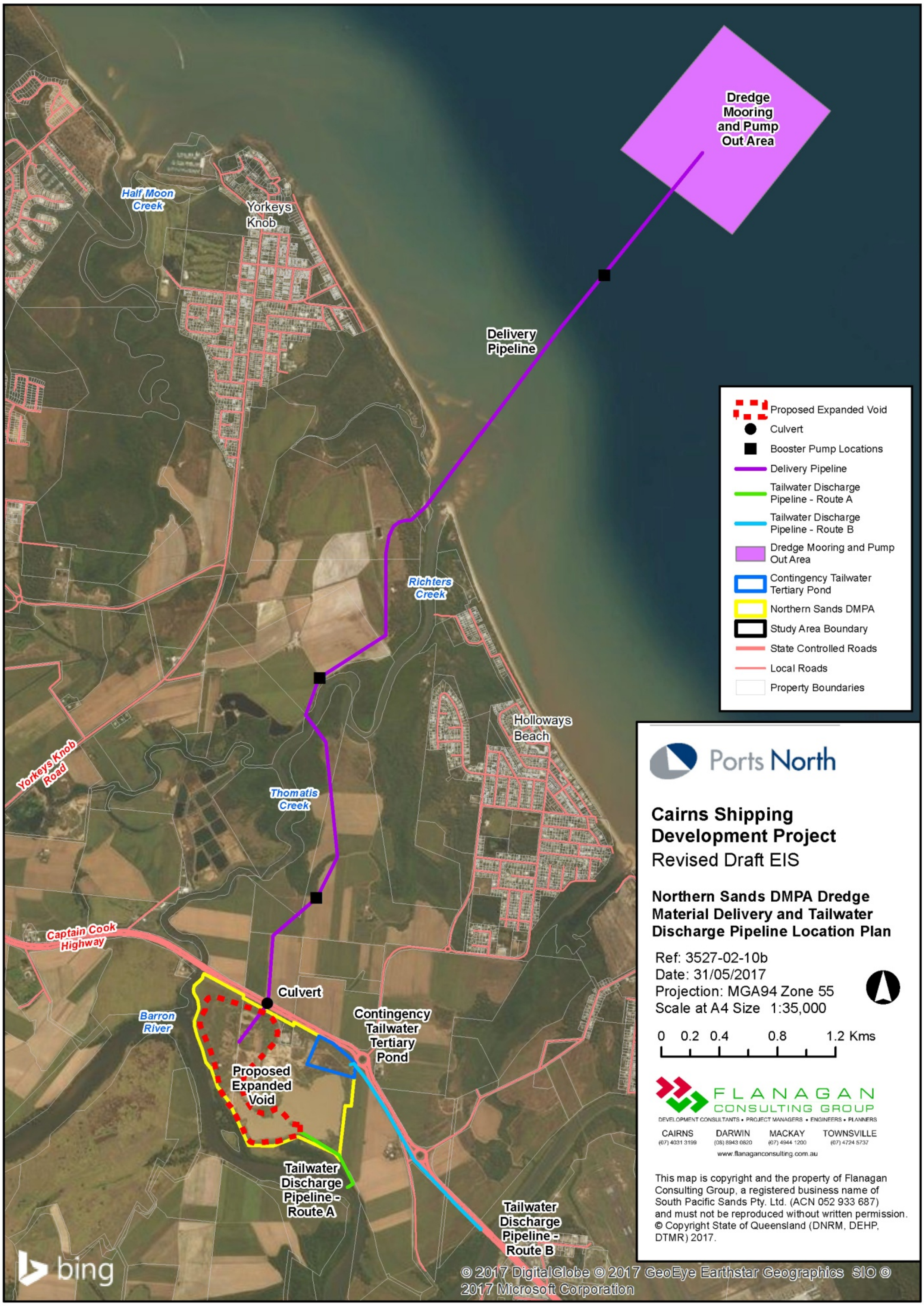

Figure 3.10 Pipeline Route and Tailwater Discharge Options

3.7.1 Temporary Pipeline Route

The recalibrated project anticipates a reduced total in-situ dredge volume of up to 900,000 m^3 to be dredged by a Trailer Suction Hopper Dredge (TSHD). Conceptual arrangements showing pipeline routes, pipe storage and pipe fabrication areas, indicative booster locations and DMPA location are provided in **Figure 3.11**.

The following temporary pipelines will be required for the project:

- dredge material pipeline from the pump out location to the DMPA
- tailwater pipeline(s) from the DMPA to the discharge point

The dredged material pipeline consists of a single pipeline nominally 1 metre diameter in size which will include some or all of the following components:

- A floating line (up to 50 metres) will connect the riser to the TSHD depending on the type of mooring.
- A riser is a small section of flexible line used to bring submerged line to the surface for connection to the floating line / connection point the seaward end. A small pontoon / buoy anchored to the seafloor is used to provide access to the surface end of the riser and to maintain its position.
- The submerged line is the component of the pipeline that connects the riser line to the onshore pipeline. This submerged line is made from steel and is not typically anchored, as it filled with seawater and / or dredged material at all times and holds its position on the seafloor through its self weight.
- The mild steel onshore pipeline connects the floating or submerged pipeline to the onshore disposal area.

Booster pumps will be required along the slurry pipeline. The location of these has not been finalised and will be as part of detailed design. Locations shown in **Figure 3.11** for on-shore boosters #1 and #2 are as recommended by the noise assessment study. However the configuration is not known until the contractor has been appointed and the Terms of Reference require the air quality assessment to include a worst case scenario. Therefore an additional booster #3 has been included in the air quality assessment in case it is required.

The tailwater pipeline is used to remove the excess tailwater (with a pump) to the proposed discharge point back into the environment.

Figure 3.11 Northern Sands Pipeline Route with Potential Marine Booster and Tailwater Pump Locations

3.7.2 DMPA and Pipeline Site Establishment

It is expected that the equipment required on land will be:

- front end loaders
- excavators
- rigid pipe delivery trucks
- mobile cranes / telescopic handlers
- water pumps
- booster pump stations.

3.7.3 Pipeline Construction

The submerged pipeline required for the Barron Delta DMPA site will be fabricated by welding pipe components together onshore into ‘strings’ between 300m to 1,000m long. Pipe strings will be capped with blank flanges to allow them to float and to be transported (towed) over water by multicat / tug.

The floating pipeline is mild steel pipeline encapsulated in floatation material which keeps it buoyant even when filled with seawater and / or dredged material. It is fabricated onshore to the desired length and towed into position and provides the link between the riser and the TSHD at the pump out station.

The onshore pipeline is joined by bolted, flanged connections and the pipe is seated on discrete earthen mounds of sufficient height to stabilise the pipe and to just elevate the flanges above ground. It will require a construction corridor and road access along the length of its route. The corridor needs to be of sufficient width (7 to 10 metres) to allow for delivery of the pipe by truck, the unloading and installation of pipe components by excavator such as a CAT330 or CAT380, and vehicle access for inspection and maintenance throughout the dredging program.

The onshore pipeline will be delivered to Cairns by road transport in components typically up to 12 metres in length. The pipe components will need to be transported by road to a laydown area(s) that is located near to both the DMPA and dredge material pipeline shore crossing location. The preliminary estimates of truck movements required to transport this length of pipe are 225 B-Double movements each way (i.e. 450 total for mobilisation and demobilisation).

Laydown areas of sufficient size up to 1 hectare will be required for pipe storage, handling and fabrication. In addition, up to 0.5 hectares will be required for a submerged pipeline fabrication yard and the dredging contractor will need a further 1 hectare for his general works area (e.g. storage of plant and equipment, temporary workshop etc.).

3.7.4 Pipeline Booster Stations

It is expected that two land booster pumps and possibly one floating booster pump will be required for the Barron Delta pipeline. A booster pump is a very large, portable pump which is connected into the dredge pipeline to boost pumping pressure. Multiple booster stations can be connected in series when required, and they can be either land based or located offshore on barges.

Floating booster stations are barge-mounted and are towed to position before they are anchored to the seafloor. They are typically located close to the dredge and out of the surf zone. The booster pump station is connected either side to small lengths of floating line which are linked to the submerged line by risers.

Land based booster stations are delivered by road transport and sufficient access needs to be maintained at all times to allow inspections, maintenance and refuelling.

It is expected that the Northern Sands DMPA will operate 24 hours per day, but boosters and the tailwater pump will only operate when material is being off-loaded from the TSHD.

3.8 Mitigation Inherent in Design

3.8.1 Construction

Air quality modelling assumes that the following measures are to be included in the detailed Contractors Construction Environmental Management Plan and are inherent in the proposal:

- The location of the Northern Sands DMPA was chosen to minimise the need for earthworks in preparing a cavity for placement.
- Dust and wind will be monitored on site and work that may generate dust will cease if strong winds occur.
- All project personnel and relevant sub-contractors will receive training in air quality control practices at induction, toolboxes and targeted training for specific activities.
- Water carts, sprinklers, sprays and dust screens will be used where appropriate to control dust emissions from exposed surfaces and dust generating activities at a frequency appropriate to conditions.
- Rumble grids and coarse aggregate will be installed at exit roads to prevent soil being deposited onto public roads. Manual cleaning of vehicles and roads will be conducted as required.
- Waste will be segregated and collected regularly to control odours.
- Construction equipment including dredging vessels will be properly maintained to ensure exhaust emissions comply with relevant standards.

3.8.2 Operation

Air quality modelling assumes that the following measures are included in the ports operational requirements and are considered assumptions inherent in this assessement of impacts for the Project:

- Cruise ship owners are to be encouraged to implement measures including:
  - regular maintenance and engine tuning
  - reduced idling time at berth before departure and after arrival.
- Expected uptake of ship engine scrubber technology is as incorporated into the Brisbane Port study described by DSITI (2007). The mandated use of low sulfur fuel is included in the 2028 modelling scenario.
- Minimise standing losses, working losses and spills in fuel storage and dispensing activities.

4. Air Quality Values and Criteria

4.1 Relevant Pollutants

This section identifies the air pollutants anticipated from the sources to be assessed. Construction of bunded areas and placement of dredged material has the potential to generate particulates and odour. Construction activities at the wharf also have potential to generate particulates. Ship engine exhausts will emit combustion products including sulphur dioxide (SO_2), nitrogen oxides (NO_x), particulates, carbon monoxide (CO) and volatile organic compounds (VOCs). VOCs may include benzene, benzo(a)pyrene, formaldehyde, toluene and xylene.

4.2 State Legislative Instruments

The Terms of Reference for the impact assessment issued by the Queensland Coordinator-General, identifies the environmental values defined in the Environmental Protection (Air) Policy (EPP Air) (2008) under the Environmental Protection Act (1994).

The EPP (Air) provides objectives for air quality indicators (pollutants). Those objectives that are relevant to this project and human health and wellbeing have been summarised in **Table 4.1**.

Table 4.1 Air Quality Criteria (EPP Air) for Health and Wellbeing

Air Quality Indicator	Period	Criteria (µg/m^3)
benzene	1 year	10
benzo(a)pyrene	1 year	0.3 ng/m^3
CO	8 hours	11,000 [2]
formaldehyde	1 day	54
NO_2	1 hour	250 [2]
	1 year	62
$PM_{2.5}$	1 day	25
	1 year	8
PM_{10}	1 day	50 [1]
sulfur dioxide	1 hour	570
	1 day	230
	1 year	57
toluene	30 minutes	1100
	1 day	4100
	1 year	410
Total Suspended Particulates (TSP)	1 year	90
xylenes	1 day	1,200
	1 year	950

Notes: 1.Five allowable exceedances are currently allowed although the intent of this was to cater for regional events.

2. Allowance is made to exclude one day.

Note that the EPP Air also contains a criterion for visibility reducing particles, but this is a measure of regional air quality and is not relevant to point sources. The impact of visible particles from point sources is addressed by the $PM_{2.5}$ criteria.

4.3 National Environmental Protection (Ambient Air Quality) Measure

The EPP(Air) incorporates the goals nominated within the previous 2003 version of the National Environmental Protection (Ambient Air Quality) Measure. The current NEPM (Ambient Air Quality) dated February 2016 has multiple changes including the new standards and goals listed in **Table 4.2**. Exceedances of particulate standards are no longer allowed apart from the exceptional events defined below.

Table 4.2 New Standard and Goals in 2016 NEPM (Ambient Air Quality)

Air Quality Indicator	Period	Criteria ($\mu g/m^3$)
$PM_{2.5}$ goals for 2025	1 day	20
	1 year	7
PM_{10}	1 year	25

Notes: For the purpose of reporting compliance against PM_{10} and $PM_{2.5}$ 1 day average standards, jurisdictions shall exclude monitoring data that has been determined as being directly associated with an exceptional event (bushfire, jurisdiction authorised hazard reduction burning or continental scale windblown dust that causes exceedance of 1 day average standards).

These goals have not yet been adopted into the EPP(Air) so it is thus not clear how much reduction of existing background concentrations is expected to assist with achievement of the 2025 goals, and how much is to be achieved by restrictions on development. Thus these goals have not been adopted for this assessment.

4.4 National Environmental Protection (Air Toxics) Measure

The EPP(Air) also incorporates as standards, the investigation levels contained in the National Environmental Protection (Air Toxics) Measure.

4.5 Dust Deposition

Whilst there are no quantitative limits for dust deposition specified in legislation, there are guidelines designed to avoid nuisance caused by dust deposition fallout onto near horizontal surfaces.

The Department of Environment and Heritage Protection (EHP 2013a) suggests the guideline that deposited matter averaged over one month should not exceed 120 $mg/m^2/day$ (3.6 $g/m^2/month$). For extractive industries, it is the insoluble component of analysed dust that is used.

The NSW Department of Environment and Conservation (2005) specifies an annual average limit of 4 $g/m^2/month$ (130 $mg/m^2/day$), and states that it is the insoluble component of analysed dust that is to be used.

It should be noted that these values are a guideline for the level that may cause nuisance at a sensitive receptor such as a residence or sensitive commercial land use. It is not normally necessary to achieve this level at the boundary, but boundary measurement can assist in the assessment of whether there is risk of nuisance occurring or not.

4.6 Odour

EHP (2013b) specifies an annoyance threshold for odour of 0.5 ou (odour units) for wake-free stacks and 2.5 ou for other sources, to be compared to the 99.5 percentile one hour model predictions.

4.7 Summary of Air Quality Values and Criteria

Those criteria adopted for the assessment are summarised in **Table 4.3**.

Table 4.3 Adopted Criteria for this Assessment

Air Quality Indicator	Period	Criteria (µg/m^3)
benzene	1 year	10
benzo(a)pyrene	1 year	0.3 ng/m^3
CO	8 hours	11,000 [2]
formaldehyde	1 day	54
NO_2	1 hour	250 [2]
	1 year	62
$PM_{2.5}$	1 day	25
	1 year	8
PM_{10}	1 day	50 [1]
sulfur dioxide	1 hour	570
	1 day	230
	1 year	57
toluene	30 minutes	1100
	1 day	4100
	1 year	410
TSP	1 year	90
xylenes	1 day	1,200
	1 year	950
odour from fugitives	99.5% 1 hour	2.5 ou
dust deposition	1 month	120 mg/m^2/day

Notes:

1. *Five allowable exceedances are currently allowed although the intent of this was to cater for regional events.*
2. *Allowance is made to exclude one day.*

5. Impact Assessment Methodology

5.1 TAPM Meteorological Modelling

The meteorological component of The Air Pollution Model (TAPM) was used to provide wind fields over the region. Wind speed and direction has been monitored at the Cairns airport and this data was assimilated into the modelling. No other site specific meteorological data is publicly available for the vicinity.

Detailed configuration of the model is described in ASK 2016 (report 8434 R01V01).

5.2 Calmet Modelling Configuration.

Calmet modelling of the wharf and inner channel domain was undertaken previously as described in ASK 2016 (report 8434 R01V01). Calmet modelling of the Northern Sands DMPA area has now also been completed.

5.2.1 Northern Sands Calmet Configuration

The Calmet configuration used is consistent with NSW OEH guidance (TRC 2011).

The model was run over the full year of 2006 based on a three-dimensional grid produced using the Caltapm utility program to convert TAPM data to MM5 format suitable for Calmet to read. The Calmet grid was set to grid spacing of 100 metres and 50 by 80 grid points. Twelve vertical layers were modelled with cell face heights of 0, 20, 40, 80, 160, 300, 450, 650, 900, 1200, 1700, 2300, and 3200 metres. This is greater than the normal number of vertical layers in order to provide better resolution of vertical layers.

Mixing height calculation parameters were set to default values except the minimum overland mixing height was lowered to 25 metres to accommodate the influence of low mixing heights on ground level sources, considering that the surface roughness in this area is low. The maximum mixing height was set to 3000 metres. Temperature prediction parameters were set to default.

Divergence minimisation was used. The critical Froude number was set to 1. Slope flow effects were included. The radius of influence of terrain features was set to 1.5 kilometres being approximately the distance from the plain to the top of Mount Whitfield to the south of the site.

The output from Calmet was a three-dimensional grid of wind-field data for incorporation into Calpuff.

5.2.2 Calmet Windfields

The frequency distributions of occurrences of winds for each direction sector and for each wind class (wind rose) as generated by Calmet for Cairns and Northern Sands are illustrated in **Figure 5.1** and **Figure 5.2** respectively. These show similar patterns but with a higher proportion of high wind speeds from the south-east. This may be due to less shielding influence from May Peak the mountain to the south-east of Cairns.

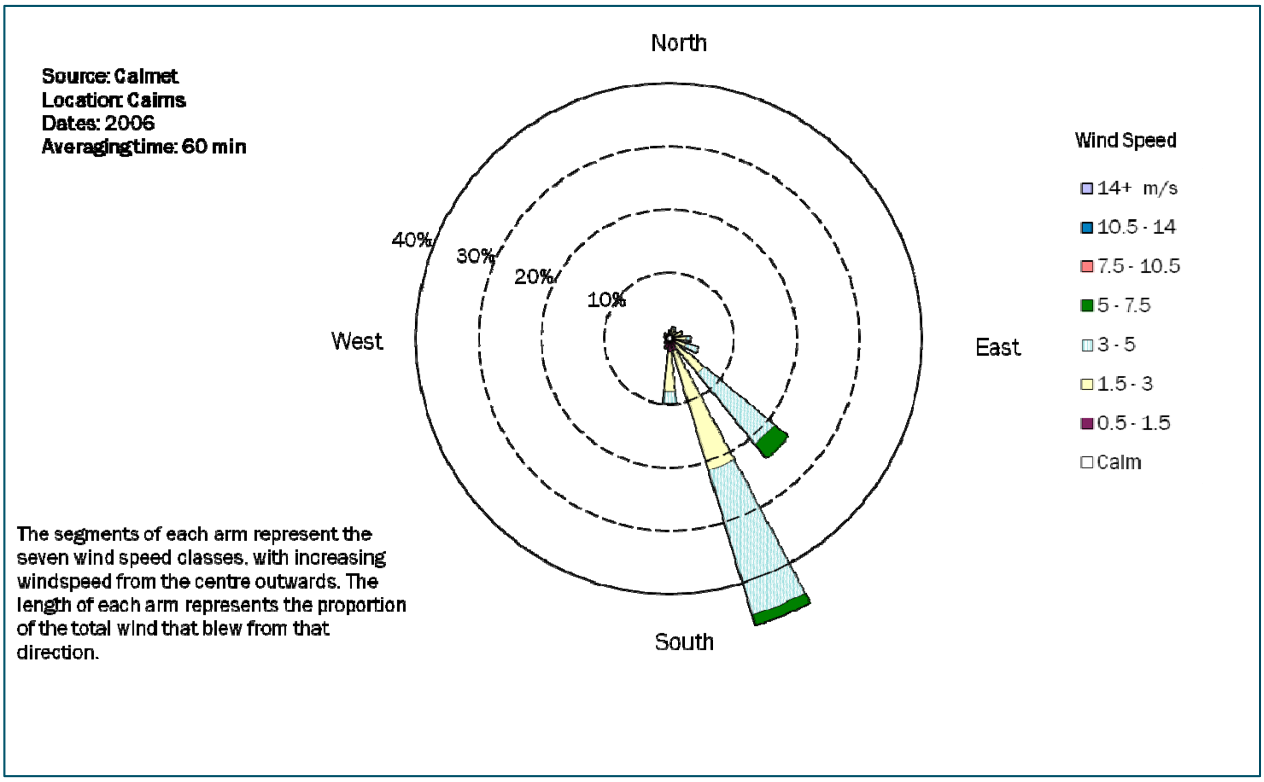

Figure 5.1 Wind Rose from Calmet for Cairns City Area

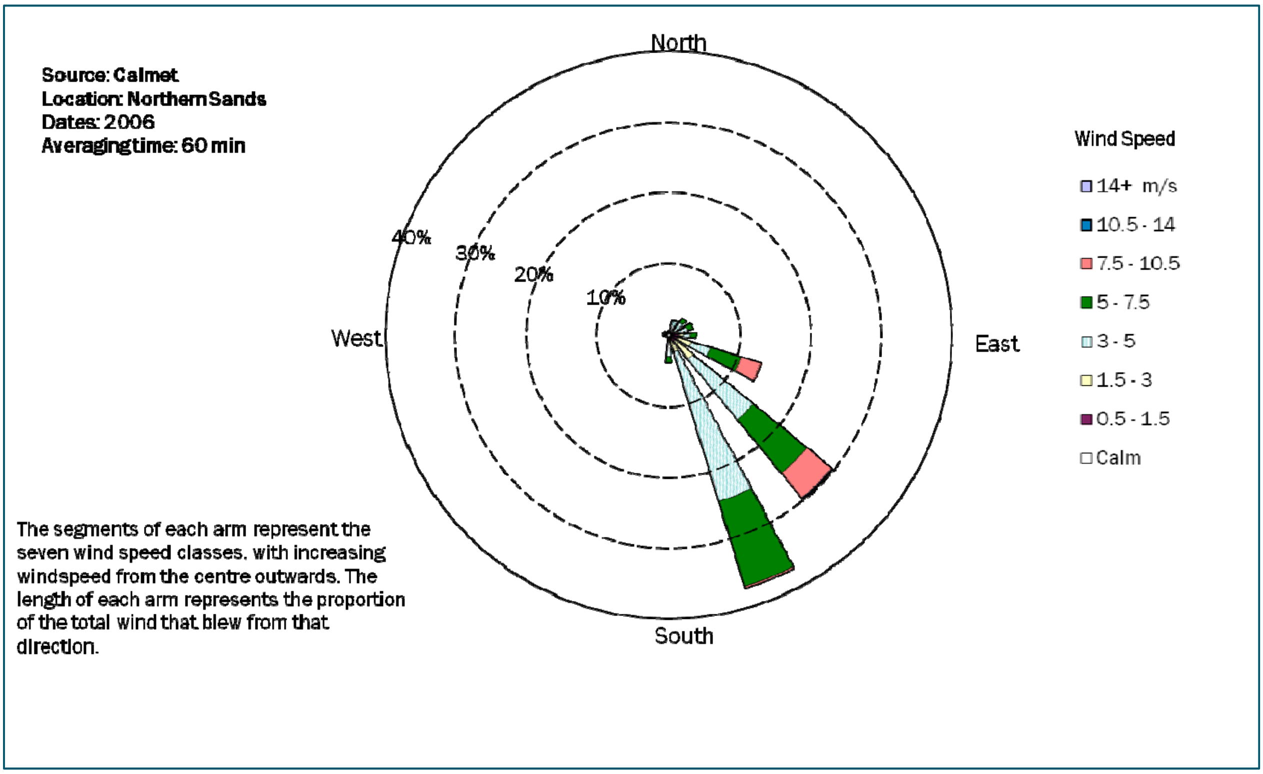

Figure 5.2 Wind Rose from Calmet for Northern Sands Vicinity

Figure 5.3 and Figure 5.4 show, respectively, the frequency of stable conditions throughout the day, and the variation of mixing height throughout the day.

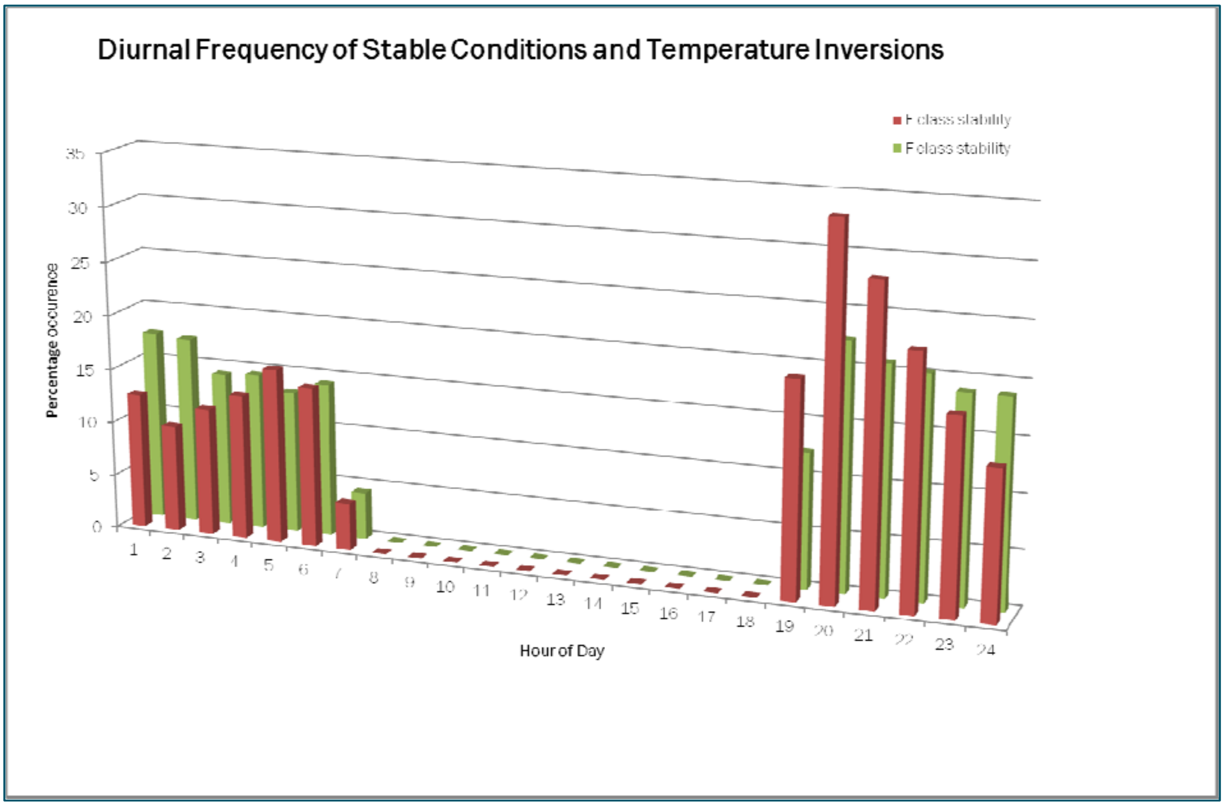

Figure 5.3 Diurnal Frequency of Stable Conditions

Day time conditions are either neutral or unstable. There is an unusually high frequency of E class stability especially in the evening. The frequency of F class stability is correspondingly low.

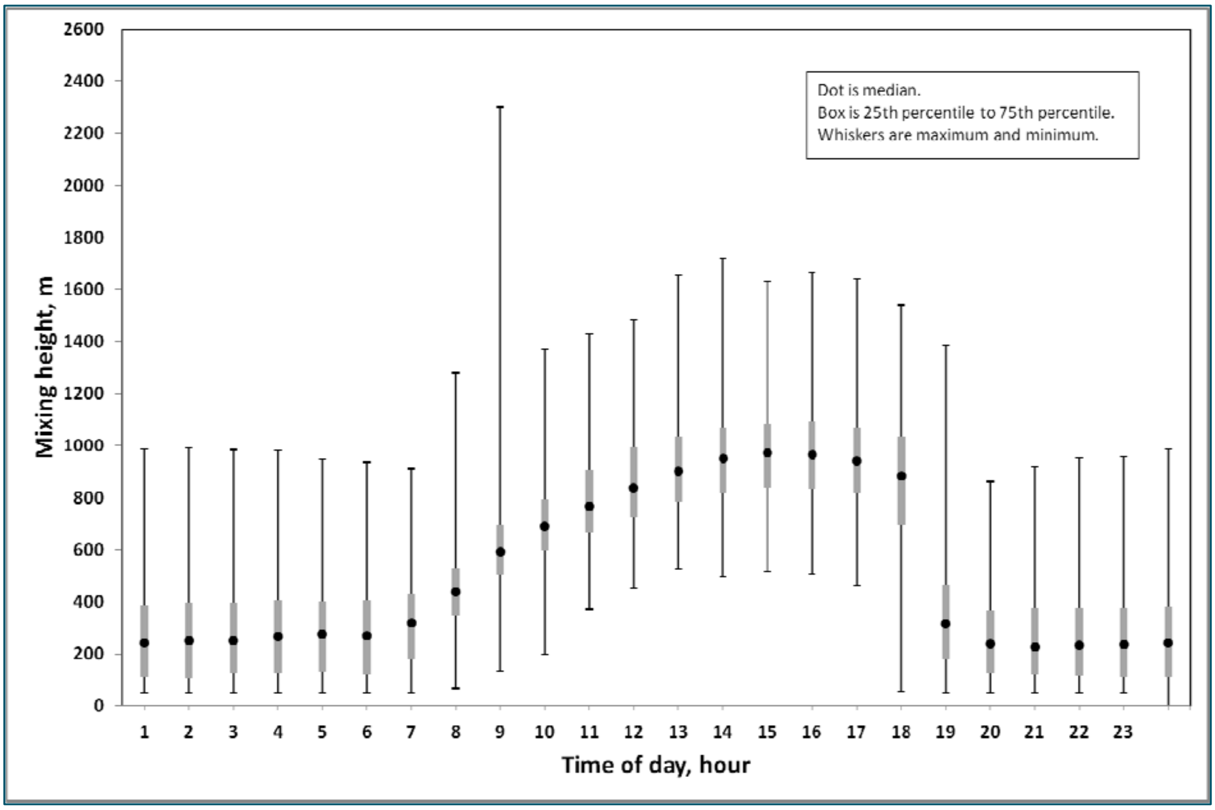

Figure 5.4 Prediction of Mixing Height from Calmet Model

In the morning the median mixing height rises up gradually reaching approximately 1 kilometre by the afternoon, then reforming at ground level again at nightfall. The maximum has an unusual peak at 9am. The 99.5 percentile mixing height at 9am was 1288 metres, which is similar to the maxima at other times. The median at 9am follows the regular pattern. Hence this is unlikely to influence the modelling of anything other than tall stacks.

6. Existing Air Quality

6.1 Summary of Air Emission Sources in the Vicinity

Existing wharf and shipping operations are discussed in **Section 3**. In addition, a survey of the surrounding area was conducted on Monday 21st November 2016 and the results are summarised in **Table 6.1**. The locations of air emission sources are shown in **Figure 6.1.** These include service stations, beverage processing, dry cleaning, port facilities, metal fabrication, surface coating, galvanising, and concrete batching.

Table 6.1 List of Nearby Industrial Activities

ID	Name	Activity Observed
1	Shell	Service station
2	Unknown operator	Fuel storage tank farm
3	Caltex	Service station
4	Liquid	Beverage supply
5	Cairns Laundry and Linen	Dry cleaning
6	Cement Australia	Bulk load-out facility
7	Austral Fisheries	Warehouse
8	Pupstars	Daycare Kennels
9	Volks Centre Auto repairs	No spray booth evident
10	Pete's Welding	Steel and aluminium fabrication
11	Centrepoint Windowscreens & Tinting	Windscreen replacement
12	S&B Automotive Spray Painting	2 Extraction stacks visible.
13	Cairns Regional Council	Offices
14	Australian Professional Galvanising	
15	Department of Defence & FSU Surface Finishing	3 stacks visible
16	Boral	Concrete batching
17	Cleanaway Bins	
18	Hume Timber & Doors	No spray booth evident
19	Cairns City Paint & Panel	Spray booth
20	Stanleys Panel Works	1 or 2 spray booths
21	Cairns Raw Materials	Soils and gravel in three-sided bins
22	Hansons	Concrete batching
23	Sims Metal	
24	Origin Energy	
25	Queensland Sugar Limited	
26	Tonkins Steel	
27	Hastings Deering CAT equipment repairs	Spray booth
28	Cranleys Smash Repairts	Spray booth
29	Viridian Glass	
30	Police station	

Figure 6.1 Location of Neighbouring Activities with Potential Air Emission Sources

6.2 Ambient Monitoring

The air quality values and criteria are listed in **Section 4**.

In addition benzo(a)pyrene has been added to the list for completeness since emission factors for PAHs are included in the DSITI (2017) study. ASK is not aware of any data on airborne concentrations of benzo(a)pyrene in North Queensland. Brisbane background concentrations of benzo(a)pyrene have been reported in five studies:

- Kumar (2008) found an average of 0.1 ng/ m^3 in 56 PM_{10} samples at Rocklea in 2003 and 2004.
- Yang (1991) found an average of 0.89 ng/ m^3 in TSP samples at a roadside location in Brisbane.
- Muller (1998) found an average of 0.32 ng/ m^3 in TSP samples at a roadside location in Brisbane.
- Lim et al (2005) found that benzo(a)pyrene in TSP samples were below detection limits (0.001 ng/ m^3) at ANZ stadium in Robertson in 2002. Lim et al (2005) also measured other PAHs.
- Martin & Mejia (2010) reported that in 10 samples analysed for PAHs at Willawong in 2010, all benzo(a)pyrene measurements were below the limit of reporting 0.4 ng/ m^3.

The Kumar study appears to be a robust measure of background and was used in this assessment.

The estimated background air quality for key pollutants has been summarised with the estimated concentrations listed in **Table 6.2**. These are well within the criteria contained in **Table 4.3**. It is anticipated that the criteria would only be exceeded during regional events such as bushfires, dust storms or the afternoon cane fire haze events during harvesting season.

Table 6.2 Estimated Background Air Quality

Pollutant	Averaging period	Assumed Background (µg/m^3)
TSP	1 year	24
PM_{10}	24 hours	18
$PM_{2.5}$	24 hours	6.7
	1 year	5.8
NO_2	1 hour	30
	1 year	9
SO_2	1 hour	5
	24 hours	3
	1 year	1
CO	8 hours	2.2
Benzene	1 year	5
Toluene	24 hours	12
	Annual average	6
Xylene	24 hours	79
	Annual average	44
Formaldehyde	24 hours	5
Benzo(a)pyrene	Annual average	0.1 ng/m^3
Dust deposition	Annual average	50 mg/m^2/day

7. Detailed Pollution Modelling Methodology

7.1 Overview

In order to predict what happens to the pollutants after they are emitted to air, a mathematical model is used to simulate their dispersion and deposition. It is accepted by regulatory agencies that this type of modelling has associated uncertainties. These are normally addressed by using statistics over long simulation times, and deriving emission rates based on published emission factors or data representing high emission conditions.

With sources close to ground level, the critical wind conditions tend to be near-calm i.e. low wind speeds. Gaussian plume models such as Ausplume and Aermod cannot model calm conditions and have low accuracy in light winds, especially in valleys where katabatic flows are present and where drainage flows turn to follow the valley. Calpuff, being a non-steady-state Lagrangian puff model, is able to simulate stagnation over time, which is critical in near-calm conditions. Its meteorological pre-processor Calmet performs diagnostic simulation of terrain effects on the wind field. It has a specific slope flow algorithm that predicts katabatic flows (Scire, J.S. & Robe, F.R., 1997).

Due to the low source height for emissions sources associated with the Project, the worst conditions may be near-calm conditions. In near-calm conditions there is little turbulent mixing and less dilution by incoming wind.

Thus Calpuff (Version 7.2.1) was chosen as the most appropriate model. The predictions undertaken for this assessment are based on the following method:

- The activity scenario selected for modelling was based on the highest potential to cause impact to nearby sensitive receivers.
- The main emission calculation methods utilised are included in **Section 7.3**.
- Prediction of input meteorology was completed using TAPM developed by the CSIRO Division of Atmospheric Research. TAPM has a prognostic 3 dimensional meteorological component which can be used to generate hourly meteorological data for input into dispersion models. TAPM was run over a full representative year (2006) to include all seasons. It uses gridded terrain data at approximately 300 metre grid spacing to shape the windfields.
- TAPM input meteorology was enhanced using Calmet, the meteorological pre-processor for Calpuff. This fits the windfields to the terrain based on gridded terrain data at approximately 30 metre grid spacing.
- Dust and gas concentrations and dust deposition were predicted using Calpuff.

The emission rates entered into the dispersion modelling are based on the activity and source information provided by Ports North as listed in **Section 3**. **Appendix B** provides the calculation methods, for significant particulate sources.

7.2 Shipping

7.2.1 Global NO_x Emission Limits for Shipping

Current global emission limits (IMO 2008) for NO_x emissions from ships vary depending on the size and installation date of the engine. Tier 1 limits apply to engines >5000 kW in ships constructed from 1990 to 2010 and engines >130 kW in ships constructed from 2000 to 2010 with more than 130 kW marine diesel engine power. Tier 2 limits apply to ships constructed from 2011 onward. Tier 3 limits apply in emission control areas not relevant to this report.

The Tier 1 and Tier 2 limits are shown in **Table 7.1.** These are applied when the engines are running on marine diesel fuel. The emission rates when these engines run on residual fuel oil are not directly limited.

Table 7.1 NO_x Emission Limits

Engine Maximum Operating Speed (rpm)	Tier 1	Tier 2
n < 130	17.0	14.4
130 <= n < 2000	$45 \times n^{-0.2}$	$44 \times n^{-0.23}$
n >= 2000	9.8	7.7

Note: n = engine maximum operating speed (rpm).

The DSITI (2017) assessment is based on the ship engine control technology of the current shipping fleet, but may not adequately include the uptake of the future shipping fleet. Thus the assessment is conservative and will tend to over-estimate impacts.

7.2.2 Global SO_2 Fuel Content Limits for Shipping

Global fuel content limits (IMO 2008) for the sulfur content of residual fuel oil are:

- 3.50% before 1 January 2020
- 0.50% on and after 1 January 2020.

7.2.3 Regulation and Compliance in Australia

In Australian waters, the IMO limits described in Sections 7.2.1 are enforced either by State Government (within 3 nautical miles of land where enacted by State Legislation) or the Australian Maritime Safety Authority (AMSA) elsewhere.

Some state legislation prescribes higher limits such as the New South Wales Protection of the Environment Operations (Clean Air) Amendment (Cruise Ships) Regulation 2015, which regulates cruise ship emissions while berthed in Sydney Harbour. It mandates that cruise ships use a maximum fuel oil sulphur content limit of 0.1 per cent while at berth, or use an alternative method to achieve the same outcome.

AMSA have advised that there are no plans to implement a similar policy at other ports. Ports North have advised that the following will apply to Cairns:

- Compliance with fuel sulfur content will be in accordance with IMO and state regulations at the time.
- There is no intention to install shore power.

7.2.4 Emission Factors

The following information was obtained from DSITI (2017).

- During manoeuvring the main engine load is less than 20% of total rated engine power.
- Fuel consumption calculation equations as detailed in Table 1 and Table 2 of DSITI (2017). Table 3 provides proportion of fuel type. These factors require vessel tonnage, speed, distance, time in mode, fuel type proportion, slow/medium/high speed engines, ship type.
- Emission factors per unit fuel consumption are provided from Table 4 of DSITI (2017). NO_x can be corrected for meeting IMO emission standards, however was conservatively not done so in this assessment. The SO_2 emission factors were however corrected as discussed below.
- Stack height of 40m, diameter of 1m, velocity of 8m/s, temperature of 300 degrees C. (For cruise ships having a scrubber, a temperature of 50 degrees C was used instead.)

The DSITI (2017) emission factors are derived from those derived by Goldsworthy & Goldsworthy (2014). Those assumed sulfur content in residual oil of 2.7% and in marine diesel of 0.5%. For the 2028 scenario, the sulfur emission factors in this study, for ships using residual oil, have been scaled down by the factor 0.5/2.7 on the basis that all fuels will be limited to 0.5 % sulfur or a scrubber technology will be used to achieve similar SO_2 emissions. This is a future control that will be enforced by AMSA.

The particulate emissions presented in Table 7.2 were reduced by 75% for the modelling of cruise ships using scrubber and by 73% for the modelling of cruise ships using fuel with up to 0.5% sulfur:

- The 75% reduction of particulate emissions with the use of scrubber is based on a study by Fridell and Salo (2014). Most of the marine scrubber manufacturers have specified a maximum reduction of 80 to 90% particulate emissions, and higher efficiency scrubbers should be more readily available in the future. In the absence of information regarding the reduction of different particle size fractions, the 75% reduction was applied to all the assessed particle size fractions.
- The 73% reduction of particle emissions with the use of fuel of up to 0.5% sulfur was based on the calculation by IMO (2009). Similarly, the 73% reduction was applied to all the assessed particle size fractions.

Table 7.2 presents the fuel-based emission factors used in this study.

Table 7.2 Fuel based emission factors used in the model

Pollutant	Unit	ME SSD RO	ME MSD RO	ME MSD MD	AE MSD RO	AE MSD MD	AB RO
NO_x [a]	g/kg	93	65	64	65	64	7
SO_2 [b]	mg/kg	9782	9819	9756	9789	9770	9775
PM_{10} [a]	mg/kg	7282	6651	1512	6344	1475	4820
$PM_{2.5}$ [a]	mg/kg	6718	6140	1415	5815	1336	4426
VOCs [a]	mg/kg	1538	930	976	1762	1843	328
CO [a]	mg/kg	2564	5116	5366	4846	5069	656
PAHs [a]	mg/kg	23	20	12	19	12	14
Benzene [c]	mg/kg	15	9.3	9.8	18	18	3.3
Formaldehyde [c]	mg/kg	1.5	0.93	0.98	1.8	1.8	0.33
Toluene [c]	mg/kg	5.4	3.3	3.5	6.2	6.5	1.2
Xylene [c]	mg/kg	3.8	2.3	2.4	4.3	4.5	0.81
Benzo(a)pyrene [d]	mg/kg	0.028	0.024	0.015	0.023	0.015	0.017
TSP [e]	mg/kg	10256	9368	1839	8935	1794	6789

**ME = main engine; AE = auxiliary engine; AB = auxiliary boiler; SSD = slow speed diesel engine; MSD = medium speed diesel engine; RO = residual oil; MD = marine distillate*

[a] Source: DSITI (2017). Cruise ships using a scrubber were assumed to have 75% less particulate emissions while cruise ships using fuel with 0.5% sulfur were assumed to have 73% less particulate emissions.

[b] SO_2 emission factors from DSITI (2017) for ships using residual oil were scaled down by the factor 0.5/2.7 on the basis of the IMO limits described in Sections 7.2.1..

[c] The emission factors were estimated using the same proportion of speciated VOCs to TVOCs as presented in Table 44 and 45 of NPI (2008)

[d] The emission factors were estimated using the same proportion of benzo(a)pyrene to PAH as presented in Table 3.4-4 of (USEPA, 1996)

[e] The emission factors were estimated using the same proportion of TSP to PM_{10} as presented in USEPA (2010) for ships using residual oil and in USEPA (1996) for ships using diesel fuel.

7.2.5 Modelling Scenarios

The three scenarios modelled were the projected baseline in 2028 and the with-project impacts in 2028, assuming all cruise ships use scrubber to reduce its SO_2 emissions equivalent to using a fuel with 0.5% sulfur, and the project impacts in 2028 assuming 68% of cruise ships use scrubbers while the rest use fuel with 0.5% sulfur. The assumed 68% of cruise ships using scrubber is based on the proportion of current fleet having scrubber as presented in **Table 8.2**.

Ships moving through the channel were modelled as buoyant area sources while ships swinging in the swing basins and ships docked at the wharves were modelled as point sources. **Figure 7.1** presents the locations of the modelled emission sources. Building wakes were taken into account in the modelling of the sources.

Figure 7.1 Modelled emission sources

Table 7.3 presents the modelled frequency of arrival of the ships. The ships were modelled as arriving at random times of the day, taking an hour to travel from the outer channel to the wharves and another hour back and staying at the port for 24 hours. The maintenance TSHD during operation was modelled as buoyant area sources representing its movement between the outer channel and near the first swing basin. In reality it will undergo a short campaign of dredging throughout the day. However, since the time of year is unknown, it is modelled as occuring for a period of 24 hours per day, one day every week.

Emissions from 19 existing fuel tanks and one proposed fuel tank were also included in the model.

Table 7.3 Modelled frequency of arrival

Ships	Number of ships per year	Modelled frequency of arrival
Cruise ships	51 (baseline) 180 (project)	Random days with six days in a year of two ships at berth at overlapping times (baseline) Random days with 30 days in a year of two ships at berth at overlapping times (project)
Bulk cargo ships (sugar)	19	1 every 19 days
Bulk cargo ships (fertiliser)	9	1 every 40 days
Tanker ships (fuel)	51	1 every week
General cargo ships	182	Generally 1 every 2 days unless the a second cruise ship is at berth.
Fishing vessels	1171	3 or 4 everyday
TSHD (maintenance dredging)	365 hours per year	1 every two days

Source parameters used in the model for the point and area sources are presented in **Table 7.4** and **Table 7.5**, respectively.

Table 7.4 Modelled parameters for the point sources

Ship/Vessel	Easting (m) WGS84	Northing (m) WGS84	Base elevation (m)	Release height (m)	Exit temperature (°C)	Diameter of stack (m)	Exit velocity (m/s)
Cruise ships (Wharves 1-3)	370147	8128185	0	40	50 (scrubber) 300 (no scrubber)	1	8
Bulk cargo ships (sugar) (Wharves 5-6)	370096	8127896	0	40	300	1	8
Bulk cargo ships (fertiliser) (Wharves 7-8)	370077	8127573	0	40	300	1	8
Tanker ships (fuel) (Wharf 10)	370022	8127308	0	40	300	1	8
General cargo ships (Wharf 4)	370114	8128044	0	20	300	0.5	8
Swing basin (cruise ships)	370338	8128248	0	40	300	1	8
Swing basin (other ships)	370288	8126584	0	40	300	1	8

Table 7.5 Modelled parameters for the area sources

Source	Effective height of emission (m)	Elevation of ground (m)	Exit temperature (°C)	Effective rise velocity (m/s)	Effective radius (m) for rise calculation	Initial vertical spread (m)
Channel	15	0	50 (scrubber) 300 (no scrubber)	8	0.5	7

7.3 Wharf Construction Dredging

Emissions from wharf construction were modelled including sources summarised in **Table 7.6** and **Table 7.7** and illustrated in **Figure 7.2**.

The point sources backhoe dredger and barges were modelled to be constantly emitting. The backhoe dredger and barge tug point sources were assumed to be loading stiff clay relatively close to the wharves while the other barge point source was assumed to be unloading near Tingira St.

Table 7.6 Capital dredging point sources

Source	Easting (m) WGS84	Northing (m) WGS84	Base elevation (m)	Release height (m)	Exit temperature (°C)	Diameter of stack (m)	Exit velocity (m/s)
Backhoe dredger	370296	8128096	0	20	300	0.5	8
Barge	370283	8128054	0	15	300	0.2	8
Barge	369238	8125526	0	15	300	0.2	8

The barge and tug pairs were also modelled as buoyant area sources emitting every 5 and 6 hours alternating which represents the transit of the pair between the backhoe dredger and Tingira St DMPA. The drag bar was also modelled as buoyant area sources constantly emitting between 7am to 7pm, while the TSHD was modelled as constantly emitting 24 hours per day.

Table 7.7 Capital dredging buoyant area sources

Source	Effective height of emission (m)	Elevation of ground (m)	Exit temperature (°C)	Effective rise velocity (m/s)	Effective radius (m) for rise calculation	Initial vertical spread (m)
TSHD	10	0	300	8	0.25	5.1
Barges, and tugs and drag bar	7.5	0	300	8	0.1	2.8

7.4 Landside Works and Wharf Construction

Emissions from wharf construction were modelled including sources summarised in **Table 7.8**. The land construction emission sources in the wharf and tank farm were modelled from 7am to 7pm, Monday to Saturday, except for the particulate emissions from the excavators which were modelled to be emitting 24/7 for simplicity as the dust emissions were varied according to wind speed. In reality, construction activities would only occur between 6:30am to 6:30pm, Monday to Saturday. It is understood that these activities will include demolition and reconstruction of wharf 6, installation of underground services, potentially a new fuel tank, and piling in the channel.

Table 7.8 Land construction sources

Source	Source Type	Easting (m) WGS84	Northing (m) WGS84	Base elevation (m)	Release height (m)	Initial horizontal spread (m)	Initial vertical spread (m)
Excavator (Wharf)	Volume	370088	8128194	6	5	20	4.7
Excavator (Tank farm)	Volume	369720	8127301	6	5	20	4.7
35-80 tonne mobile crane (Wharf)	Volume	370084	8128193	6	2.5	1.16	2.3
35-80 tonne mobile crane (Tank farm)	Volume	369731	8127305	6	2.5	1.16	2.3
20 tonne mobile crane (Wharf)	Volume	370085	8128188	6	1.5	0.58	1.4
20 tonne mobile crane (Wharf)	Volume	370077	8128178	6	1.5	0.58	1.4
20 tonne mobile crane (Tank farm)	Volume	369726	8127294	6	1.5	0.58	1.4
Dump trucks	Road	-	-	Varies from 5 to 15m	3	2.21	1.4

Dust emission controls proposed to be used to reduce particulate emissions that have been included in the dispersion modelling are presented in **Table 7.9**. The control efficiencies of these technologies are derived from Environment Australia (2012).

Table 7.9 Dust Emission Controls

Emission Source	Control(s) Utilised	Control Efficiency Applied
Vehicles on surfaces	Water truck spraying trafficable surfaces	75%
Excavator	Water sprays during dry, windy conditions	75%
Wind erosion	Water sprays during dry, windy conditions	75%

Figure 7.2 Modelled construction sources and channel / dredge path centreline

7.5 Northern Sands DMPA

7.5.1 Construction

Emissions from the construction of the pipeline system which would be used to pump out the clay extracted by the TSHD to the Northern Sands DMPA placement area were modelled as volume sources and are summarised in **Table 7.10** and illustrated in **Figure 7.3**. The emissions were modelled as occurring from 7am to 7pm, Monday to Saturday. Since the month of activities was unknown, this was assumed to occur all year long. However, it is understood activities are likely to be restricted to the dry season, so this is a conservative approach.

Table 7.10 Northern Sands DMPA and pipeline construction sources

Source	Easting (m) WGS84	Northing (m) WGS84	Base elevation (m)	Release height (m)	Initial horizontal spread (m)	Initial vertical spread (m)
Dozer	364275	8137239	6	2.5	9.3	9.3
Front-end loader (north)	364167	8138383	5	2.5	9.3	9.3
Front-end loader (south)	364173	8136916	8	2.5	9.3	9.3
Excavator (north)	364169	8138384	5	5.0	9.3	4.7
Excavator (south)	364182	8136936	8	5.0	9.3	4.7
Grader	364281	8137220	6	2	9.3	0.93
Crane (north)	364165	8138386	5	2.5	1.2	2.3
Crane (south)	364194	8136933	8	2.5	1.2	2.3
Dump trucks (wheel dust generation)	-	-	Varies from 4 to 11	2.6	24.2	2.4

Dust emission controls proposed to be used to reduce particulate emissions that have been included in the dispersion modelling are presented in **Table 7.11**. The control efficiencies of these technologies are derived from Environment Australia (2012).

Table 7.11 Dust Emission Controls

Emission Source	Control(s) Utilised	Control Efficiency Applied
Vehicles on unpaved roads	Water trucks spraying access route	50%

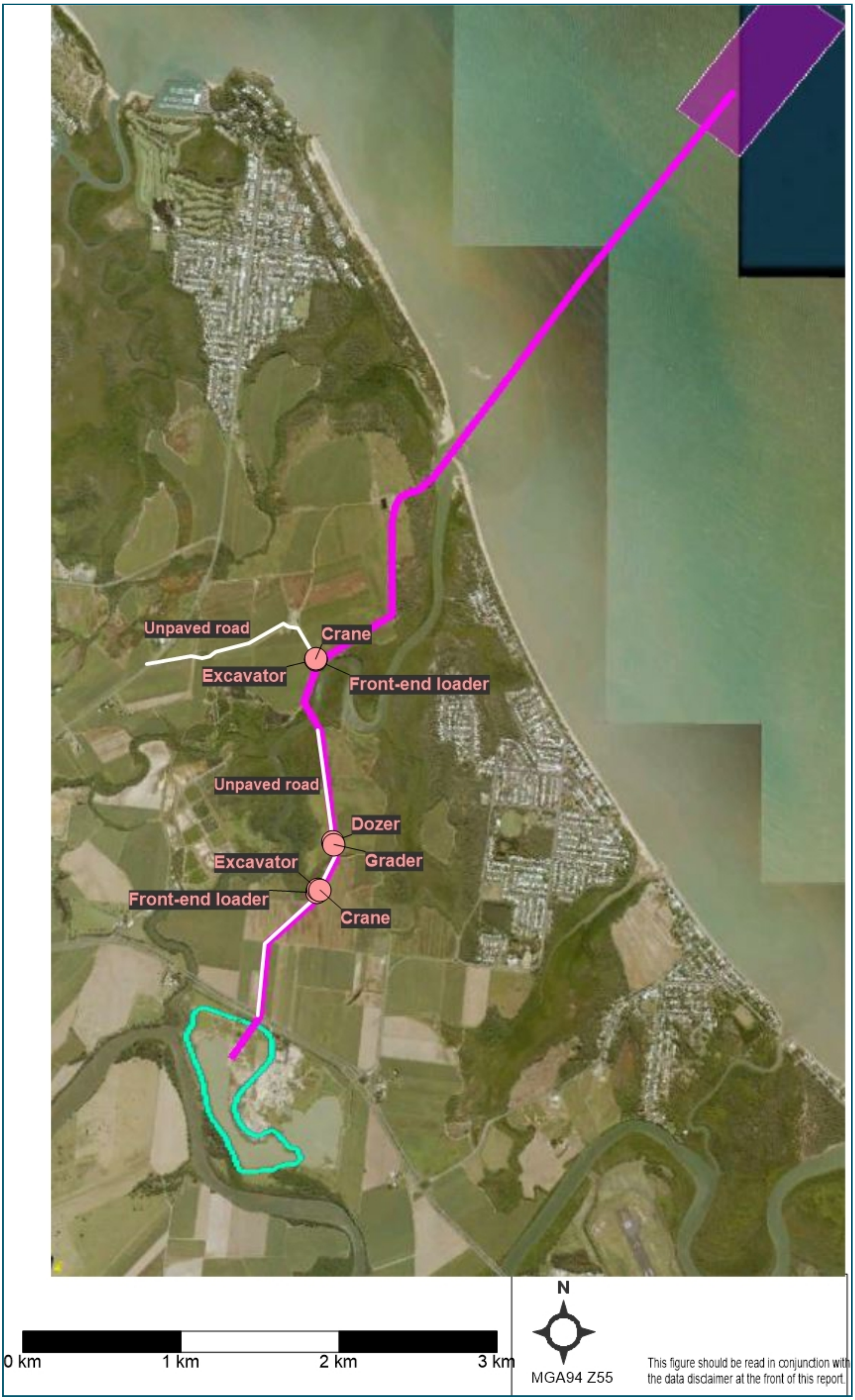

Figure 7.3 Modelled Northern Sand construction emission sources

7.5.2 Operation

The emissions from the operation of the Northern Sand DMPA were modelled as point sources and are summarised in **Table 7.12** and illustrated in **Figure 7.4**. The sources were modelled to be simultaneously emitting for a period of 1.5 hours every 6-hour cycle.

Table 7.12 Northern Sand DMPA operational point sources

Source	Easting (m) WGS84	Northing (m) WGS84	Base elevation (m)	Release height (m)	Exit temperature (°C)	Diameter of stack (m)	Exit velocity (m/s)
Marine Booster	366123	8141151	0	4	300	0.3	8
On-shore booster 1	364667	8139416	5	4	300	0.3	8
On-shore booster 2	364245	8137576	6	4	300	0.3	8
On-shore booster 3 (alternative location if required)	364148	8136868	7	4	300	0.3	8
Tailwater pump from DMPA	364029	8135261	2	1	300	0.15	8
Tailwater pump from tertiary	364389	8135660	7	1	300	0.15	8
TSHD	366603	8141746	0	20	300	0.5	8

Figure 7.4 Modelled Northern Sand operation emission sources

7.6 Calpuff Configuration

The three dimensional wind fields from Calmet were entered into Calpuff for the full year 2006. Calpuff was run over a smaller computational grid (7.0 kilometres x 8.0 kilometres) with spacing of 100 metres, and with receptors gridded over the same domain with a nesting factor of 1 to achieve a resolution of 100 metres. Chemical transformation was not included in the modelling which causes an over-prediction of airborne concentrations.

Dry deposition was modelled with vegetation state set to the default setting (active and unstressed). Gravitational settling was included due to the large particle size in the dust being modelled.

Wind speed profile was set to the Industrial Source Complex (ISC) Urban-1 exponents. Calm conditions were not invoked until the wind speed dropped below 0.2 m/s. Transitional plume rise and partial penetration of boundary layers for point sources were included. Briggs rise algorithm was used since the sources are not very hot.

The emissions were modelled as puffs (not slugs) since there are no receptors in the near vicinity of area sources. Puff-splitting was turned off and the maximum number of puffs released per source per time step was set to 99.

Dispersion coefficients were derived by the model using turbulence generated by micrometeorology. The Heffter curve was used to compute time-dependent dispersion beyond 550 metres. The partial plume height adjustment method was used to allow winds to approach hills as terrain increases.

The minimum turbulence velocity, sigma v, was set to 0.2 m/s.

For the purpose of calculating the influence of deposition, Calpuff only allows each particulate species to be characterised by a single mean diameter and standard deviation. Therefore suspended TSP concentrations were modeled as three separate components: $PM_{2.5}$, coarse (between 2.5 and 10 microns) and “dust” (between 10 and 75 microns). Emission rates of the species “dust” were calculated as the difference between TSP and PM_{10} emissions from the inventory. Emission rates of the species “coarse” were calculated as the difference between PM_{10} and $PM_{2.5}$ emissions from the inventory. The predicted TSP results were then calculated as the sum of the model outputs for each of the three components. Similarly dust deposition was predicted as the sum of the deposition of each of the three components.

7.7 Building Downwash

Building downwash was modelled using the BPIP processor and the Prime algorithm since the length to width ratio of the buildings were less than 10. Buildings included were:

- the cruise ships, bulk cargo ships and tankers with 30 metre height;
- the general cargo ships and dredger with 15 metre height; and,
- barges with 10 metre height.

7.8 Nitrogen Dioxide Modelling

7.8.1 Overview

Most of the NO_x emitted by combustion engines are in the form of nitric oxide (NO). This reacts with other gases in the atmosphere to form NO_2. Because the fraction of NO_2 emitted by vehicles is highly dependent on the configuration of each individual vehicle, emission factors are only available as NO_x.

A typical proportion of NO_2 in urban airsheds during peak concentration events is 20%. This includes both regional sources and local sources. The contribution from regional sources would have built up over a longer time period i.e. NO emissions would have had substantial time to react to form NO_2. In a rural environment, the proportion would be lower.

The rate of conversion from NO to NO_2 is related to a large number of factors. The most critical are ozone concentration, hydrocarbon concentration and the amount of sunlight, which increases the rate of the reverse reaction. Both hydrocarbons and ozone can be responsible for oxidising NO to form NO_2. Generally, the conditions that favour NO_2 formation are when ozone concentrations are high and sunlight low. This scenario could occur in the late afternoons following a clear day. In rural areas, ozone concentrations are low, so NO_2 formation is not favoured.

As a guide, under worst conditions, ozone can oxidise approximately 5% of NO in 10 minutes. Oxidation by hydrocarbons is more dependent on pre-existing quantities of different species. Over time periods longer than 10 minutes, polluted air will be substantially mixed with the regional background air.

7.8.2 Janssen Method

The Janssen Method (Middleton et al 2007) is a popular technique for estimating conversion of nitrogen oxides to NO_2 downwind of a source. It is based on aircraft-based measurements taken downwind of power stations. The Janssen equation is as follows:

$$\frac{NO_2}{NO_x} = A(1 - e^{-\alpha x})$$

Where the values of A and α are presented in Janssen et al (1988) and varies according to ozone concentration, wind speed and season of the year, and x is the distance travelled by the plume.

7.8.3 Conversion Relevant to this Study

The Janssen Method was used in this assessment as the sources are similar to power stations which are applicable to this method.

The distance from sources to receptors range from 160 to 810 metres. Typical ozone concentrations in Brisbane are 20 ppb. Using the factors for spring/autumn and ozone concentration between 10-20ppb, and distance of 2,000 metres, the Jansenn method gives a NO_2 to NO_X ratio of 0.115. This calculated ratio has been used in the assessment of NO_2 concentrations. A distance of 2,000 metres has been chosen for conservatism and also because the closest distance that Janssen et al. (1988) could practically measure the plume to determine the best value of α was between 1 to 2 kilometres.

7.9 Calpost Processing

To calculate 30 minute averages from one hour averages, the power law was used:

$$C_p / C_m = A\left(T_m / T_p\right)^p$$

where C_p = peak concentration;
C_m =mean hourly average concentration;
T_m = mean time of 60 minutes;
T_p = peak time of 30 minutes;
A = constant close to unity;
p = coefficient ranges from 0.15 for volume sources up to 0.4 for tall stacks.

For A=1 and p = 0.3, the ratio for converting 60 minutes to 30 minutes is 1.2.

8. Qualitative Assessments

8.1 Odour from Dredging, Placement and Tailwater

According to EPA (2001), odour from anaerobic sediments from dredging is rarely more than a temporary problem. When first discharged it is initially anaerobic and may smell, but the smell is lost within a few days of its exposure to air.

Odour is also associated with hydrogen sulphide (H_2S) released from acid sulphate materials. Sulphur varies according to soil texture as listed in **Table 8.1**.

Table 8.1 Oxidisable Sulphur Typical of Soil Textures

Sediment texture	Oxidisable Sulphur (% dry basis)
Sandy to loamy sands	0.03
Sandy loams to light clay	0.06
Medium to heavy clays and silty clays	0.1

Note: 1. Source is EPA (2007).

As discussed in **Section 3.6.1**, the majority of the dredged material to be taken to the Northern Sands DMPA will be very soft silty clay. This has potential to form hydrogen sulfide as a by-product of the oxidation of pyrite. If the material is drained, it will be readily oxidised. However, at Northern Sands it is to be placed and remain under water and so oxidation will be limited.

The odour is expected to be highest at the outlet of the pipeline where agitation of the surface may occur. However this should be minimal provided the outlet is kept below the surface. Additionally this location is distant from sensitive receptors.

Whilst on the THSD and at the pump-out location it will be exposed to air for relatively short time periods. However the pump out location is more than 2 kilometres from the nearest sensitive location, and the relatively low odour will disperse well before the wind carries it that far.

8.2 Dark Smoke from Ship Exhausts

High emission levels of fine particulates are observable as dark smoke. These typically occur when a large diesel engine starts up or is under high engine load. Ship engines are typically under high load when arriving at or departing from the wharf.

Future uptake of particulate filter controls and scrubbers on new modern engines should prevent this from occurring. Emission controls for particulates are not mandated. However, there is an indirect mechanism that may lead to uptake of scrubbers. In 2020, it may be difficult to obtain fuel that is compliant with the IMO (2008) requirement that the sulfur content of fuel be limited to 0.5% (and 0.1% in emission control areas). IMO will allow ships to continue using fuel with up to 3.5% sulfur if they install and operate scrubbers that will reduce SO_2 emissions by a factor that offsets the fuel content. It is anticipated that major cruise ship companies (refer **Table 8.2**) will meet the 2020 regulations with the scrubber technology option giving the ships greater flexibility when in regions with variable supply of low sulfur fuels. For ships that take up this option, there will be the additional benefit that the scrubbers will reduce particulate (and hence black smoke) emissions. Future ship engines such as LNG will see particulate emissions reduced further.

Table 8.2 Examples of Cruise Ships with Scrubbers Installed (provided by Ports North)

Brand	Total Fleet Number of Ships	Number of Ships with Scrubbers
Carnival	101	70
Royal Caribbean	23	19
Norwegian	14	8
Genting	9	3

In addition to the above, the use of marine diesel instead of fuel oil would greatly reduce these emissions.

Use of shipboard incinerators is not permitted whilst alongside or at the Port, hence these will not contribute to dark smoke.

8.3 Odour from Ship Waste

Ship waste is to be removed directly off the cruise ships and taken off site by contractors. Odour emissions should be similar to those from waste removal from land-based restaurants (without the storage emissions). Proper handling to avoid spillage and uncovered loads should reduce odour detection to the immediate vicinity of activities. Thus these activities should not cause odour nuisance at sensitive receptors.

This is also the current practice for existing ships, so emissions will not be worse, just more frequent.

9. Dispersion Modelling Results

9.1 Limitations

The uncertainties associated with this type of assessment are normally only dealt with in a qualitative manner, but include:

- emission factor estimation techniques
- source strength variability
- meteorological data variability
- inherent uncertainty in dispersion modelling.

Typically 95% confidence intervals are estimated to require a multiplicative factor of 2 or 3. In this case, the uncertainty is mostly due to assumptions regarding the details of emission sources and operating information. As per the Terms of Reference requirements, this has been addressed by conservative assumptions that will over-predict the ambient concentrations including the following:

- In the absence of detailed activity data, the plant was assumed to operate continuously.
- The project shipping scenario modelled assumes high projections and consequent more frequent emissions.
- The model assumes that the high emission rates coincide with most adverse meteorological conditions, which is unlikely.
- During adverse meteorological conditions, additional effort is given to management measures such as spraying and reducing drop heights, and the model doesn’t allow for this.
- Assumed SO_2 emission rates from cruise ships are based on achieving compliance with the 0.5% IMO global fuel guideline. It is expected that scrubbers installed on most cruise ships will achieve compliance with the 0.1% guideline so that they can travel into the specific locations requiring that compliance.

9.2 Shipping and Maintenance Dredging Operations

9.2.1 Suspended Particulate Results

The results of the particulate modelling assuming all cruise ships use a scrubber based on the projected 2028 baseline scenario are illustrated in **Figure 9.1**, **Figure 9.2** and **Figure 9.3** by ground level pollution contours overlayed onto an aerial photo. The same contours for the 2028 project scenario are included in **Figure 9.4**, **Figure 9.5** and **Figure 9.6**. For 2028 with the project, the predicted levels are similar for the two scenarios: assuming all cruise ships use a scrubber; and assuming 68% of cruise ships use a scrubber. Hence, the ground level pollution contours for the latter were not presented.

The predicted concentrations at sensitive receptors are shown respectively in **Table 9.1** to **Table 9.4** for the baseline and project scenarios assuming all cruise ships use a scrubber, and for the project scenario assuming 68% of cruise ships use a scrubber, along with the criteria. The estimated background levels are shown in the tables separately but have not been added to the predicted concentrations shown. The cumulative impact is assessed by adding the background to the predicted values provided in the data tables. The maximum cumulative 24-hour $PM_{2.5}$ concentration at the worst-affected receptor for the project scenarios is 28 µg/m^3, marginally exceeding the criterion of 25 µg/m^3. This only occured on one day in the modelled year. To illustrate the likelihood of exceedance, the 6th highest 24-hour $PM_{2.5}$ concentrations are presented in **Table 9.2** and **Table 9.3** for the project scenarios. The model predicted exceedances occur at Receptor C at three of the assessed building heights (0 metre, 10 metre and 20 metres above ground level) all occurring on the same day. The wind speed during the exceedance day is moderate and the wind was blowing from the southeast all throughout the day. The stability class is neutral and the mixing height is relatively high. The convective conditions have likely brought the pollutants to and near ground-levels. No other exceedances of particulates are predicted on other days.

The annual average $PM_{2.5}$ for the project scenarios is 10 µg/m^3, marginally exceeding the criterion of 8 µg/m^3. All other suspended particulate results are within their respective criteria.

Concentrations provided in tabular form are a prediction at a point in space and hence more accurate than the contours, which are graphical interpolations.

The peak impacts shown on the figures appear to be offset from the wharf. These are predictions of the model at ground level, whereas the ship stacks are elevated, so worst impacts reach ground level away and downwind of the sources.

Table 9.1 Predicted Suspended Particulate Concentrations for Baseline 2028 Scenario (100% of cruise ships using scrubber)

Receptor ID#	Annual Average TSP ($\mu g/m^3$)	Maximum 24 h average PM_{10} ($\mu g/m^3$)	Maximum 24 h Average $PM_{2.5}$ ($\mu g/m^3$)	Annual Average $PM_{2.5}$ ($\mu g/m^3$)
Criterion	90	50	25	8
Background	24	18	7	5.8
A (0m)	1	9	8	1
A (10m)	1	8	8	0
A (20m)	1	6	6	0
B (0m)	1	15	14	1
B (10m)	1	14	13	1
B (20m)	1	15	14	1
B (30m)	1	10	9	1
B (40m)	1	6	6	0
B (45m)	0	6	5	0
C (0m)	2	19	17	1
C (10m)	2	18	16	1
C (20m)	2	18	17	1
C (30m)	1	14	13	1
C (40m)	1	6	6	0
C (42m)	1	6	6	0
D (0m)	1	13	12	1
D (10m)	1	11	10	1
D (20m)	1	9	9	1
D (30m)	1	7	6	0
D (40m)	1	6	5	0
E (0m)	1	12	11	1
E (10m)	1	11	10	1
E (20m)	1	7	7	0
E (30m)	1	5	5	0
F (0m)	0	3	2	0
F (10m)	0	3	2	0
F (20m)	0	3	2	0
F (30m)	0	3	2	0
G (0m)	0	3	2	0
G (10m)	0	3	2	0
G (20m)	0	3	2	0
G (30m)	0	3	3	0
G (40m)	0	3	3	0
H (0m)	0	3	2	0
H (10m)	0	3	2	0
H (20m)	0	3	2	0
I	0	2	2	0

Table 9.2 Predicted Suspended Particulate Concentrations for Project 2028 Scenario (100% of cruise ships using scrubber)

Receptor ID#	Annual Average TSP (µg/m³)	Maximum 24 h average PM_{10} (µg/m³)	Maximum 24 h Average $PM_{2.5}$ (µg/m³)	6th highest 24 h Average $PM_{2.5}$ (µg/m³)	Annual Average $PM_{2.5}$ (µg/m³)
Criterion	90	50	25	25	8
Background	24	18	7	7	5.8
A (0m)	3	10	9	7	2
A (10m)	2	9	9	6	2
A (20m)	2	8	8	5	1
B (0m)	4	14	13	12	2
B (10m)	4	14	13	12	2
B (20m)	4	15	13	13	2
B (30m)	3	11	10	9	2
B (40m)	2	9	8	6	1
B (45m)	2	9	8	5	1
C (0m)	6	20	19	15	4
C (10m)	6	20	19	15	4
C (20m)	6	23	21	16	4
C (30m)	4	16	15	12	3
C (40m)	2	9	9	6	2
C (42m)	2	8	8	6	1
D (0m)	5	17	16	12	3
D (10m)	4	16	14	10	3
D (20m)	3	13	12	8	2
D (30m)	2	8	7	5	2
D (40m)	2	7	6	4	1
E (0m)	3	14	13	10	2
E (10m)	3	13	12	9	2
E (20m)	2	7	7	6	1
E (30m)	2	6	5	4	1
F (0m)	0	3	3	2	0
F (10m)	0	3	3	2	0
F (20m)	0	3	3	2	0
F (30m)	0	4	3	2	0
G (0m)	0	3	3	2	0
G (10m)	0	3	3	2	0
G (20m)	0	3	3	2	0
G (30m)	0	3	3	2	0
G (40m)	0	4	3	2	0
H (0m)	0	3	2	1	0
H (10m)	0	3	2	1	0
H (20m)	0	3	2	1	0
I	0	4	4	1	0

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Table 9.3 Predicted Suspended Particulate Concentrations for Project 2028 Scenario (68% of cruise ships using scrubber)

Receptor ID#	Annual Average TSP (µg/m^3)	Maximum 24 h average PM_{10} (µg/m^3)	Maximum 24 h Average $PM_{2.5}$ (µg/m^3)	6th highest 24 h Average $PM_{2.5}$ (µg/m^3)	Annual Average $PM_{2.5}$ (µg/m^3)
Criterion	90	50	25	25	8
Background	24	18	7	7	5.8
A (0m)	2	10	9	6	2
A (10m)	2	9	9	6	1
A (20m)	2	8	7	5	1
B (0m)	3	14	13	11	2
B (10m)	3	14	13	11	2
B (20m)	3	15	13	11	2
B (30m)	3	11	10	9	2
B (40m)	2	9	8	6	1
B (45m)	2	9	8	5	1
C (0m)	5	20	19	15	3
C (10m)	5	20	19	15	3
C (20m)	5	23	21	16	3
C (30m)	4	16	14	11	3
C (40m)	2	8	8	5	1
C (42m)	2	8	7	5	1
D (0m)	4	15	14	10	3
D (10m)	4	13	12	9	2
D (20m)	3	11	10	8	2
D (30m)	2	8	7	5	1
D (40m)	2	7	6	4	1
E (0m)	3	13	12	9	2
E (10m)	3	11	10	8	2
E (20m)	2	7	6	5	1
E (30m)	2	6	5	4	1
F (0m)	0	3	3	2	0
F (10m)	0	3	3	2	0
F (20m)	0	3	3	1	0
F (30m)	0	4	3	2	0
G (0m)	0	3	3	1	0
G (10m)	0	3	3	1	0
G (20m)	0	3	3	1	0
G (30m)	0	3	3	2	0
G (40m)	0	4	3	2	0
H (0m)	0	3	2	1	0
H (10m)	0	3	2	1	0
H (20m)	0	3	2	1	0
I	0	4	4	1	0

Figure 9.1 Trinity Wharves – Year 2028 Baseline Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 24-hour PM_{10} Concentrations (µg/m^3)

Figure 9.2 Trinity Wharves – Year 2028 Baseline Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m^3)

Figure 9.3 Trinity Wharves – Year 2028 Baseline Scenario (100% of Cruise Ships Using Scrubber) Cumulative Annual Average $PM_{2.5}$ Concentrations (µg/m^3)

Figure 9.4 Trinity Wharves – Year 2028 Project Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 24-hour PM_{10} Concentrations (µg/m³)

Figure 9.5 Trinity Wharves – Year 2028 Project Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 24-hour $PM_{2.5}$ Concentrations (µg/m^3)

Figure 9.6 Trinity Wharves – Year 2028 Project Scenario (100% of Cruise Ships Using Scrubber) Cumulative Annual Average $PM_{2.5}$ Concentrations (µg/m^3)

9.2.2 Gas Concentration Results with All Cruise Ships Using Scrubber

The cumulative maximum 1-hour NO_2 and 1-hour SO_2 concentrations are predicted to be closest to their criteria for the baseline scenario. The 1-hour SO_2 concentrations are predicted to be close to the criterion and the 1-hour NO_2 concentrations are predicted to exceed their criterion for the project scenario, among all the pollutants assessed. Hence, the results for the cumulative maximum 1-hour NO_2 and SO_2 concentrations for the baseline and project scenarios are illustrated in **Figure 9.7** to **Figure 9.10**. The results of all other pollutants assessed are not presented in a plot as they are well within their criteria.

The predicted concentrations (not including background concentrations) at sensitive receptors are shown in **Table 9.4** and **Table 9.5** along with the criterion. The estimated background levels are listed separately and not included in the predicted concentrations. As the maximum 1-hour NO_2 concentrations exceed the criterion for the project scenario, the 99.9th percentile (9th highest hour) concentrations are also presented which exceed the criterion, but marginally.

Further investigation of the elevated 1-hour NO_2 levels suggest that these levels occur for ten hours in the modelled year from within 6pm to 7am, when winds were light and blowing from the south and southeast and mostly having low mixing (inversion) heights at approximately 50 metres.

The peak impacts shown on the figures appear to be offset from the wharf. These are predictions of the model at ground level, whereas the ship stacks are elevated, so worst impacts reach ground level away and downwind of the sources. In **Figure 9.9** and **Figure 9.10**, there are also impacts to the east across Trinity Inlet and to the north-east over the inlet. This is due to the short-term averaging period of one hour associated with this criterion. The contour plots of ground level concentrations do not show levels above the criteria as the exceedances occur at higher building levels (i.e. elevated heights above ground).

Table 9.4 Predicted Gaseous Concentrations for Baseline 2028 Scenario

Receptor ID#	CO (µg/m^3)	NO$_2$ (µg/m^3)		SO$_2$ (µg/m^3)		
Period	8 Hours	1 Hour	1 Year	1 Hour	24 Hour	1 Year
Criterion	11,000	250	62	570	230	57
Background	2.2	30	9	5	3	1
A (0m)	41	96	3	150	75	4
A (10m)	37	94	3	148	69	4
A (20m)	30	90	2	140	50	3
B (0m)	81	143	4	226	126	6
B (10m)	80	143	4	226	119	6
B (20m)	88	160	4	252	122	6
B (30m)	45	113	3	177	84	5
B (40m)	30	135	2	211	52	3
B (45m)	30	145	2	227	48	2
C (0m)	89	169	6	267	153	10
C (10m)	90	170	6	268	148	10
C (20m)	96	197	6	311	151	10
C (30m)	76	159	5	250	115	8
C (40m)	33	92	2	144	52	4
C (42m)	30	104	2	164	50	3
D (0m)	83	192	5	303	104	9
D (10m)	72	193	5	304	89	8
D (20m)	57	169	4	266	76	7
D (30m)	38	98	3	155	55	4
D (40m)	32	84	2	132	47	3
E (0m)	77	171	4	269	99	7
E (10m)	70	163	4	257	90	6
E (20m)	47	110	3	173	59	4
E (30m)	40	97	2	152	44	3
F (0m)	21	72	0	113	18	1
F (10m)	22	74	0	116	18	1
F (20m)	23	79	0	125	20	1
F (30m)	25	85	0	133	21	1
G (0m)	20	73	0	116	16	0
G (10m)	20	76	0	120	17	1
G (20m)	22	82	0	130	18	1
G (30m)	24	89	0	141	20	1
G (40m)	27	93	0	146	22	0
H (0m)	16	60	0	93	13	0
H (10m)	16	60	0	94	13	0
H (20m)	17	61	0	95	14	0
I	4	25	0	59	5	0

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Table 9.5 Predicted Organic Gas Concentrations for Baseline 2028 Scenario

Receptor ID#	Benzene (µg/m^3)	Benzo(a)pyrene (ng/m^3)	Formaldehyde (µg/m^3)	Toluene (µg/m^3)			Xylene (µg/m^3)	
Period	1 Year	1 Year	24 Hour	30 Minute	24 Hour	1 Year	24 Hour	1 Year
Criterion	10	0.3	54	1,100	4,100	410	1,200	950
Background	5		5		12	6	79	44
A (0m)	0.007	0.010	0.011	0.10	0.04	0.002	2	0.09
A (10m)	0.006	0.009	0.010	0.10	0.04	0.002	2	0.08
A (20m)	0.005	0.008	0.008	0.09	0.03	0.002	2	0.07
B (0m)	0.009	0.013	0.019	0.15	0.07	0.003	2	0.08
B (10m)	0.009	0.013	0.018	0.15	0.06	0.003	2	0.08
B (20m)	0.009	0.013	0.019	0.17	0.07	0.003	1	0.07
B (30m)	0.008	0.011	0.013	0.12	0.05	0.003	1	0.05
B (40m)	0.005	0.007	0.008	0.14	0.03	0.002	1	0.04
B (45m)	0.004	0.006	0.007	0.15	0.03	0.001	1	0.04
C (0m)	0.015	0.022	0.023	0.18	0.08	0.005	2	0.08
C (10m)	0.015	0.022	0.023	0.18	0.08	0.005	2	0.08
C (20m)	0.015	0.022	0.023	0.21	0.08	0.005	1	0.07
C (30m)	0.012	0.017	0.018	0.17	0.06	0.004	1	0.05
C (40m)	0.006	0.009	0.008	0.10	0.03	0.002	1	0.04
C (42m)	0.005	0.008	0.008	0.11	0.03	0.002	1	0.04
D (0m)	0.013	0.019	0.016	0.20	0.06	0.005	2	0.08
D (10m)	0.012	0.017	0.014	0.20	0.05	0.004	2	0.08
D (20m)	0.010	0.015	0.012	0.18	0.04	0.004	1	0.06
D (30m)	0.007	0.010	0.008	0.10	0.03	0.002	1	0.05
D (40m)	0.005	0.007	0.007	0.09	0.03	0.002	1	0.04
E (0m)	0.010	0.015	0.015	0.18	0.05	0.004	1	0.07
E (10m)	0.009	0.013	0.014	0.17	0.05	0.003	1	0.07
E (20m)	0.006	0.009	0.009	0.13	0.03	0.002	1	0.06
E (30m)	0.005	0.007	0.007	0.12	0.02	0.002	1	0.05
F (0m)	0.001	0.002	0.003	0.07	0.01	0.000	1	0.05
F (10m)	0.001	0.002	0.003	0.08	0.01	0.000	1	0.05
F (20m)	0.001	0.001	0.003	0.08	0.01	0.000	1	0.04
F (30m)	0.001	0.001	0.003	0.09	0.01	0.000	1	0.04
G (0m)	0.001	0.001	0.003	0.08	0.01	0.000	1	0.05
G (10m)	0.001	0.001	0.003	0.08	0.01	0.000	1	0.05
G (20m)	0.001	0.001	0.003	0.09	0.01	0.000	1	0.04
G (30m)	0.001	0.001	0.003	0.09	0.01	0.000	1	0.04
G (40m)	0.001	0.001	0.003	0.10	0.01	0.000	1	0.03
H (0m)	0.000	0.001	0.002	0.06	0.01	0.000	1	0.03
H (10m)	0.000	0.001	0.002	0.06	0.01	0.000	1	0.03
H (20m)	0.001	0.001	0.002	0.06	0.01	0.000	1	0.03
I	0.000	0.000	0.001	0.03	0.00	0.000	1	0.03

Table 9.6 Predicted Gaseous Concentrations for Project 2028 Scenario

Receptor ID#	CO (µg/m³)	NO2 (µg/m³)			SO2 (µg/m³)		
Period	8 Hours	1 Hour	1 Hour (9th highest)	1 Year	1 Hour	24 Hour	1 Year
Criterion	11,000	250		62	570	230	57
Background	2.2	30		9	5	3	1
A (0m)	53	139	99	10	218	81	15
A (10m)	49	141	97	9	221	77	14
A (20m)	44	126	92	8	197	66	12
B (0m)	80	185	166	13	292	118	21
B (10m)	81	185	166	13	292	117	20
B (20m)	80	215	180	13	339	120	21
B (30m)	60	153	124	11	241	92	18
B (40m)	51	149	134	7	234	71	11
B (45m)	55	214	141	6	338	73	10
C (0m)	94	215	190	21	339	169	33
C (10m)	96	215	189	21	339	167	32
C (20m)	109	269	238	21	424	193	33
C (30m)	70	184	148	16	290	130	26
C (40m)	47	132	102	8	208	76	13
C (42m)	49	172	102	8	271	69	12
D (0m)	83	192	160	17	303	142	27
D (10m)	77	193	154	15	304	129	24
D (20m)	71	169	137	13	266	108	20
D (30m)	48	111	94	9	175	66	13
D (40m)	47	147	92	7	231	56	10
E (0m)	83	171	144	13	269	113	20
E (10m)	75	167	141	11	263	106	18
E (20m)	60	155	108	8	244	59	13
E (30m)	54	141	100	6	222	46	10
F (0m)	28	93	59	1	132	26	2
F (10m)	29	96	60	1	132	27	2
F (20m)	31	103	63	1	147	28	2
F (30m)	34	107	63	1	168	30	2
G (0m)	26	89	58	1	138	23	1
G (10m)	27	85	59	1	132	24	1
G (20m)	29	90	61	1	141	26	1
G (30m)	32	102	62	1	161	28	1
G (40m)	35	115	66	1	181	30	1
H (0m)	19	84	43	0	131	16	1
H (10m)	20	84	45	0	131	16	1
H (20m)	20	84	48	1	131	16	1
I	45	223	39	0	241	25	0

Table 9.7 Predicted Organic Gas Concentrations for Project 2028 Scenario

Receptor ID#	Benzene (µg/m^3)	Benzo(a)pyrene (ng/m^3)	Formaldehyde (µg/m^3)	Toluene (µg/m^3)			Xylene (µg/m^3)	
Period	1 Year	1 Year	24 Hour	30 Minute	24 Hour	1 Year	24 Hour	1 Year
Criterion	10	0.3	54	1,100	4,100	410	1,200	950
Background	5		5	12	12	6	79	44
A (0m)	0.02	0.03	0.012	0.20	0.04	0.008	2	0.10
A (10m)	0.02	0.03	0.012	0.20	0.04	0.008	2	0.09
A (20m)	0.02	0.03	0.010	0.19	0.04	0.007	2	0.07
B (0m)	0.03	0.05	0.018	0.20	0.06	0.011	2	0.09
B (10m)	0.03	0.05	0.018	0.20	0.06	0.011	2	0.08
B (20m)	0.03	0.05	0.018	0.22	0.06	0.011	1	0.07
B (30m)	0.03	0.04	0.014	0.16	0.05	0.010	1	0.06
B (40m)	0.02	0.03	0.011	0.16	0.04	0.006	1	0.04
B (45m)	0.01	0.02	0.011	0.22	0.04	0.005	1	0.04
C (0m)	0.05	0.07	0.026	0.23	0.09	0.018	2	0.09
C (10m)	0.05	0.07	0.025	0.23	0.09	0.018	2	0.09
C (20m)	0.05	0.07	0.029	0.28	0.10	0.018	1	0.08
C (30m)	0.04	0.06	0.020	0.19	0.07	0.014	1	0.06
C (40m)	0.02	0.03	0.012	0.14	0.04	0.007	1	0.04
C (42m)	0.02	0.03	0.011	0.18	0.04	0.007	1	0.04
D (0m)	0.04	0.06	0.022	0.20	0.08	0.015	2	0.09
D (10m)	0.04	0.05	0.020	0.20	0.07	0.013	2	0.08
D (20m)	0.03	0.05	0.016	0.18	0.06	0.011	1	0.07
D (30m)	0.02	0.03	0.010	0.14	0.04	0.007	1	0.05
D (40m)	0.02	0.02	0.009	0.15	0.03	0.006	1	0.04
E (0m)	0.03	0.05	0.017	0.18	0.06	0.011	1	0.07
E (10m)	0.03	0.04	0.016	0.17	0.06	0.010	1	0.07
E (20m)	0.02	0.03	0.009	0.16	0.03	0.007	1	0.06
E (30m)	0.02	0.02	0.007	0.15	0.03	0.005	1	0.05
F (0m)	0.00	0.00	0.004	0.10	0.01	0.001	1	0.05
F (10m)	0.00	0.00	0.004	0.10	0.01	0.001	1	0.05
F (20m)	0.00	0.00	0.004	0.11	0.02	0.001	1	0.05
F (30m)	0.00	0.00	0.005	0.11	0.02	0.001	1	0.04
G (0m)	0.00	0.00	0.004	0.09	0.01	0.001	1	0.05
G (10m)	0.00	0.00	0.004	0.09	0.01	0.001	1	0.05
G (20m)	0.00	0.00	0.004	0.09	0.01	0.001	1	0.04
G (30m)	0.00	0.00	0.004	0.11	0.02	0.001	1	0.04
G (40m)	0.00	0.00	0.005	0.12	0.02	0.001	1	0.04
H (0m)	0.00	0.00	0.002	0.09	0.01	0.000	1	0.03
H (10m)	0.00	0.00	0.002	0.09	0.01	0.000	1	0.03
H (20m)	0.00	0.00	0.003	0.09	0.01	0.000	1	0.03
I	0.02	0.00	0.004	0.19	0.02	0.000	1	0.03

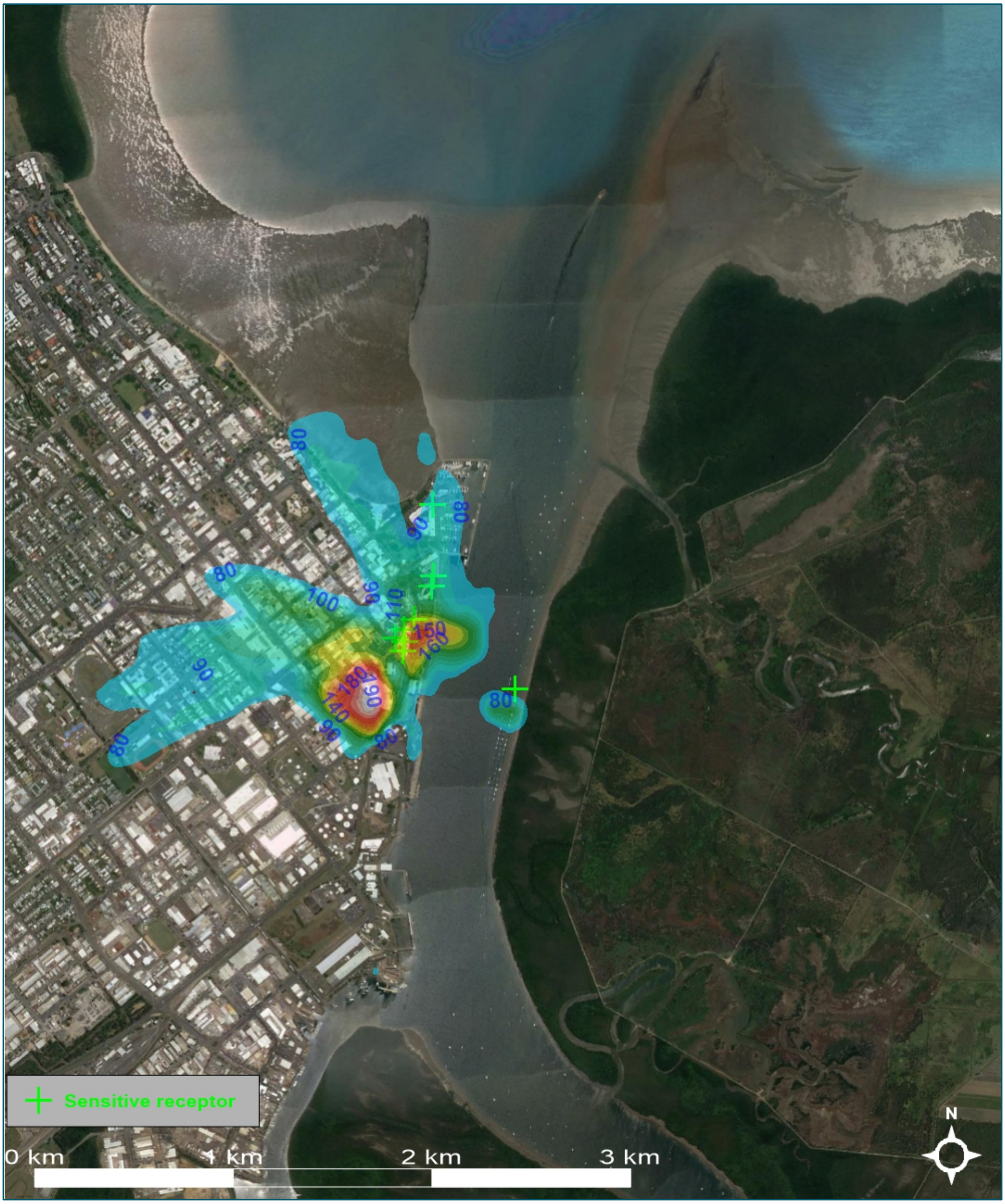

Figure 9.7 Trinity Wharves – Year 2028 Baseline Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 1-Hour NO_2 Concentrations (µg/m^3)

Figure 9.8 Trinity Wharves – Year 2028 Baseline Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 1-Hour SO_2 Concentrations (µg/m^3)

Figure 9.9 Trinity Wharves – Year 2028 Project Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 1-Hour NO_2 Concentrations (µg/m^3)

Figure 9.10 Trinity Wharves – Year 2028 Project Scenario (100% of Cruise Ships Using Scrubber) Cumulative Maximum 1-Hour SO_2 Concentrations (µg/m^3)

9.2.3 Gas Concentration Results with 68% of Cruise Ships Using Scrubber

As discussed in the previous section, the pollutants with the most potential to exceed the criteria are NO_2 and SO_2. Hence, these pollutants were assessed in the project scenario with 68% of the cruise ships using a scrubber. The predicted concentrations (not including background concentrations) at sensitive receptors are shown in **Table 9.8** along with the criterion. The estimated background levels are listed separately and not included in the predicted concentrations. The predicted levels are similar to the project scenario with all the cruise ships using a scrubber especially for the short-term averaging periods. For long-term averaging periods, the levels predicted for this scenario are slightly lower.

Table 9.8 Predicted Gaseous Concentrations for Project 2028 Scenario

Receptor ID#	NO2 (µg/m^3)			SO2 (µg/m^3)		
Period	1 Hour	1 Hour (9th highest)	1 Year	1 Hour	24 Hour	1 Year
Criterion	250	not applicable	62	570	230	57
Background	30	30	9	5	3	1
A (0m)	139	98	8	218	81	13
A (10m)	141	97	8	221	77	12
A (20m)	126	92	7	197	65	11
B (0m)	179	159	11	282	116	17
B (10m)	181	162	11	285	115	17
B (20m)	206	169	11	325	120	18
B (30m)	153	123	10	241	91	16
B (40m)	144	119	7	227	71	10
B (45m)	214	125	6	338	73	9
C (0m)	215	189	18	339	169	28
C (10m)	215	189	18	339	167	28
C (20m)	269	235	18	424	193	29
C (30m)	184	145	14	290	130	23
C (40m)	132	101	8	208	69	12
C (42m)	172	99	7	271	63	11
D (0m)	192	158	15	303	126	23
D (10m)	193	143	13	304	110	21
D (20m)	169	134	11	266	90	18
D (30m)	111	93	8	175	66	12
D (40m)	147	91	6	231	56	10
E (0m)	165	143	11	260	104	17
E (10m)	167	139	10	263	91	15
E (20m)	155	105	7	244	55	11
E (30m)	141	97	6	222	46	9
F (0m)	93	54	1	132	26	2
F (10m)	96	56	1	132	27	2
F (20m)	103	58	1	147	28	2
F (30m)	107	61	1	168	30	2
G (0m)	89	56	1	138	23	1

Receptor ID#	NO2 (µg/m^3)			SO2 (µg/m^3)		
G (10m)	85	56	1	132	24	1
G (20m)	90	58	1	141	26	1
G (30m)	102	59	1	161	28	1
G (40m)	115	60	1	181	30	1
H (0m)	84	41	0	131	16	1
H (10m)	84	40	0	131	16	1
H (20m)	84	42	0	131	16	1
I	223	33	0	241	25	0

9.2.4 Dust Deposition Results

The predicted dust deposition levels at sensitive receptors are shown in **Table 9.9** along with the criterion and estimated background levels. The cumulative level including background at the most affected receptor is 54 mg/m^2/day, 61 mg/m^2/day and 60 mg/m^2/day for the Baseline Scenario and the Project Scenario with 100% of cruise ships using scrubber and the Project Scenario with 68% of cruise ships using scrubber, respectively, within the criterion of 120 mg/m^2/day.

Table 9.9 Predicted Dust Deposition Levels for the Baseline and Project Scenarios

Receptor ID#	Maximum 30-day Average Dust Deposition (mg/m^2/day)		
	Baseline 2028 Scenario (100% Cruise ships use scrubber)	Project 2028 Scenario (100% of Cruise ships use scrubber)	Project 2028 Scenario (68% of Cruise ships use scrubber)
Criterion for insoluble dust	120		
Background	50		
A	4	11	10
B	1	3	2
C	2	2	2
D	3	8	6
E	1	3	3
F	1	2	2
G	1	1	1
H	0	1	1
I	0	0	0

9.3 Wharf and Channel Construction

Table 9.10 to **Table 9.13** presents the predicted levels at the sensitive receptors due to the wharf and land infrastructure construction activities and construction dredging of the channel.

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Table 9.10 Predicted Suspended Particulate Concentrations for the Wharf Construction

Receptor ID#	Annual Average TSP (µg/m^3)	Maximum 24 h average PM_{10} (µg/m^3)	Maximum 24 h Average $PM_{2.5}$ (µg/m^3)	Annual Average $PM_{2.5}$ (µg/m^3)
Criterion	90	50	25	8
Background	24	18	7	5.8
A (0m)	12	42	39	9
A (10m)	11	43	40	9
A (20m)	10	41	38	8
B (0m)	13	42	39	10
B (10m)	13	41	38	10
B (20m)	12	42	39	9
B (30m)	10	38	35	7
B (40m)	8	36	33	6
B (45m)	6	35	33	5
C (0m)	16	47	44	12
C (10m)	15	49	45	12
C (20m)	14	52	48	10
C (30m)	12	39	36	9
C (40m)	9	38	36	7
C (42m)	8	38	35	6
D (0m)	17	36	34	12
D (10m)	16	37	34	12
D (20m)	15	37	35	11
D (30m)	12	36	34	9
D (40m)	10	37	34	7
E (0m)	22	35	32	16
E (10m)	21	33	31	16
E (20m)	20	36	33	14
E (30m)	16	36	34	12
F (0m)	12	28	25	9
F (10m)	12	29	26	9
F (20m)	11	33	30	8
F (30m)	10	33	30	7
G (0m)	9	24	22	7
G (10m)	10	27	24	7
G (20m)	9	30	27	6
G (30m)	8	30	28	6
G (40m)	6	31	29	5
H (0m)	5	21	20	4
H (10m)	7	22	21	5
H (20m)	7	24	22	5
I	1	21	20	1

Table 9.11 Predicted Gaseous Concentrations for the Wharf Construction

Receptor ID#	CO (µg/m^3)	NO2 (µg/m^3)		SO2 (µg/m^3)		
Period	8 Hours	1 Hour	1 Year	1 Hour	24 Hour	1 Year
Criterion	11,000	250	62	570	230	57
Background	2.2	30	9	5	3	1
A (0m)	113	331	12	231	60	12
A (10m)	78	227	11	232	63	12
A (20m)	88	227	10	247	60	11
B (0m)	171	576	15	267	56	12
B (10m)	78	270	14	270	55	12
B (20m)	95	268	12	278	55	11
B (30m)	86	274	10	294	49	9
B (40m)	92	283	7	345	47	8
B (45m)	94	390	6	511	47	7
C (0m)	124	410	16	259	67	15
C (10m)	81	260	16	261	70	15
C (20m)	107	259	14	267	74	14
C (30m)	94	262	11	316	57	12
C (40m)	99	293	9	368	51	10
C (42m)	100	298	7	376	50	8
D (0m)	117	320	16	230	52	18
D (10m)	84	230	15	231	54	17
D (20m)	92	228	14	242	54	16
D (30m)	92	242	12	308	48	13
D (40m)	95	247	10	308	49	11
E (0m)	109	268	20	217	50	24
E (10m)	87	221	19	217	48	24
E (20m)	84	219	18	227	49	22
E (30m)	91	217	15	246	48	18
F (0m)	82	158	11	165	39	14
F (10m)	84	165	11	165	38	14
F (20m)	88	182	10	205	41	13
F (30m)	90	201	9	212	42	11
G (0m)	78	145	8	153	34	10
G (10m)	81	150	9	149	38	11
G (20m)	84	162	8	179	42	10
G (30m)	86	175	7	183	38	9
G (40m)	85	187	6	227	39	7
H (0m)	66	162	5	137	26	6
H (10m)	66	163	6	142	28	7
H (20m)	68	167	6	161	32	8
I	80	210	1	162	21	1

Table 9.12 Predicted Organic Gas Concentrations for Project 2028 Scenario

Receptor ID#	Benzene (µg/m³)	Benzo(a)pyrene (ng/m³)	Formaldehyde (µg/m³)	Toluene (µg/m³)			Xylene (µg/m³)	
Period	1 Year	1 Year	24 Hour	30 Minute	24 Hour	1 Year	24 Hour	1 Year
Criterion	10	0.3	54	1,100	4,100	410	1,200	950
Background	5		5	12	12	6	79	44
A (0m)	0.03	0.03	0.5	0.1	0.02	0.005	0.01	0.003
A (10m)	0.03	0.03	0.4	0.1	0.02	0.004	0.01	0.003
A (20m)	0.02	0.03	0.4	0.1	0.02	0.004	0.01	0.003
B (0m)	0.05	0.03	0.7	0.1	0.02	0.005	0.01	0.004
B (10m)	0.04	0.03	0.5	0.1	0.02	0.005	0.01	0.003
B (20m)	0.03	0.03	0.4	0.1	0.02	0.004	0.01	0.003
B (30m)	0.02	0.02	0.4	0.1	0.02	0.003	0.01	0.002
B (40m)	0.02	0.02	0.4	0.2	0.02	0.003	0.01	0.002
B (45m)	0.01	0.02	0.3	0.2	0.02	0.002	0.01	0.002
C (0m)	0.04	0.04	0.5	0.1	0.02	0.006	0.02	0.004
C (10m)	0.04	0.04	0.4	0.1	0.02	0.005	0.02	0.004
C (20m)	0.03	0.03	0.4	0.1	0.02	0.005	0.02	0.003
C (30m)	0.03	0.03	0.4	0.1	0.02	0.004	0.01	0.003
C (40m)	0.02	0.02	0.3	0.2	0.02	0.003	0.02	0.002
C (42m)	0.01	0.02	0.3	0.2	0.02	0.003	0.01	0.002
D (0m)	0.03	0.04	0.4	0.1	0.02	0.006	0.01	0.004
D (10m)	0.03	0.04	0.4	0.1	0.02	0.006	0.01	0.004
D (20m)	0.03	0.04	0.4	0.1	0.02	0.006	0.01	0.004
D (30m)	0.02	0.03	0.3	0.1	0.02	0.005	0.01	0.003
D (40m)	0.02	0.03	0.3	0.1	0.02	0.004	0.01	0.003
E (0m)	0.03	0.06	0.5	0.1	0.02	0.008	0.01	0.006
E (10m)	0.03	0.06	0.4	0.1	0.02	0.008	0.01	0.006
E (20m)	0.03	0.05	0.4	0.1	0.02	0.008	0.01	0.005
E (30m)	0.02	0.05	0.4	0.1	0.02	0.006	0.01	0.004
F (0m)	0.02	0.03	0.4	0.1	0.01	0.005	0.01	0.003
F (10m)	0.01	0.03	0.4	0.1	0.01	0.005	0.01	0.003
F (20m)	0.01	0.03	0.4	0.1	0.02	0.004	0.01	0.003
F (30m)	0.01	0.03	0.4	0.1	0.02	0.004	0.01	0.003
G (0m)	0.01	0.03	0.4	0.1	0.01	0.004	0.01	0.003
G (10m)	0.01	0.03	0.4	0.1	0.01	0.004	0.01	0.003
G (20m)	0.01	0.03	0.4	0.1	0.01	0.003	0.01	0.002
G (30m)	0.01	0.02	0.4	0.1	0.01	0.003	0.01	0.002
G (40m)	0.01	0.02	0.4	0.1	0.01	0.003	0.01	0.002
H (0m)	0.01	0.02	0.3	0.1	0.01	0.002	0.01	0.002
H (10m)	0.01	0.02	0.3	0.1	0.01	0.003	0.01	0.002
H (20m)	0.01	0.02	0.3	0.1	0.01	0.003	0.01	0.002
I	0.00	0.00	0.4	0.1	0.01	0.000	0.01	0.000

Table 9.13 Predicted Dust Deposition Levels for the Wharf Construction

Receptor ID#	Maximum 30-day Average Dust Deposition (mg/m^2/day) Baseline 2028 Scenario
Criterion for insoluble dust	120
Background	50
A	53
B	48
C	68
D	85
E	73
F	55
G	39
H	16
I	2

9.4 Northern Sands DMPA Construction

Table 9.14 and **Table 9.15** present the predicted concentrations at the sensitive receptors due to Northern Sands DMPA construction activities. As shown, the predicted levels of the assessed pollutants at the sensitive receptors are well below their respective criteria. All other pollutants that were not assessed are considered less critical and would also most likely be well below their respective criteria.

Table 9.14 Predicted Suspended Particulate Concentrations for Northern Sands DMPA Construction

Receptor ID#	Annual Average TSP (µg/m^3)	Maximum 24 h average PM_{10} (µg/m^3)	Maximum 24 h Average $PM_{2.5}$ (µg/m^3)	Annual Average $PM_{2.5}$ (µg/m^3)
Criterion	90	50	25	8
Background	24	18	7	5.8
J	0	0	0.0	0.00
K	0	0	0.0	0.00
L	0	0	0.1	0.00
M	3	2	1.0	0.27
N	0	0	0.1	0.00
O	0	1	0.3	0.00
P	0	0	0.2	0.00
Q	0	1	0.3	0.00
R	0	1	0.5	0.01
S	0	1	0.2	0.01
T	0	0	0.2	0.02
U	0	0	0.2	0.01
V	0	0	0.1	0.00
W	0	0	0.1	0.00
X	0	0	0.1	0.00
Y	0	0	0.0	0.00

Table 9.15 Predicted Gaseous Concentrations for Northern Sands DMPA Construction

Receptor ID#	CO (µg/m^3)	NO_2 (µg/m^3)		Benzene (µg/m^3)	Formaldehyde (µg/m^3)
Period	8 Hours	1 Hour	1 Year	1 Year	24 Hour
Criterion	11,000	250	62	10	54
Background	2.2	30	9	5	5
J	0	1	0.00	0.0000	0.00
K	0	1	0.00	0.0000	0.00
L	0	1	0.00	0.0000	0.01
M	4	9	0.19	0.0015	0.10
N	1	2	0.00	0.0000	0.01
O	2	2	0.00	0.0000	0.03
P	1	3	0.00	0.0000	0.02
Q	1	3	0.00	0.0000	0.03
R	3	5	0.01	0.0001	0.05
S	1	3	0.00	0.0000	0.03
T	1	2	0.01	0.0001	0.02
U	1	1	0.01	0.0001	0.02
V	1	2	0.00	0.0000	0.01
W	0	1	0.00	0.0000	0.01
X	0	1	0.00	0.0000	0.01
Y	0	0	0.00	0.0000	0.01

9.5 Northern Sands DMPA Operation

Table 9.1 and **Table 9.2** present the predicted particulate and gaseous concentrations, respectively, at the sensitive receptors due to the Northern Sands DMPA operation. The cumulative maximum 1-hour NO_2 concentration at the most affected receptor is 356 µg/m^3, exceeding the criterion of 250 µg/m^3. **Figure 9.11** presents the contour plot of the cumulative maximum 1-hour NO_2 concentrations. All the assessed pollutants are predicted to have maximum cumulative concentrations below their respective criteria.

Table 9.16 Predicted Suspended Particulate Concentrations for Northern Sands DMPA Operation

Receptor ID#	Annual Average TSP (µg/m^3)	Maximum 24 h average PM_{10} (µg/m^3)	$PM_{2.5}$ (µg/m^3) Maximum 24 h Average	$PM_{2.5}$ (µg/m^3) Annual Average
Criterion	90	50	25	8
Background	24	18	7	5.8
J	0.1	2	2	0.1
K	0.2	3	3	0.2
L	0.1	2	2	0.1
M	0.6	5	4	0.4
N	0.1	2	1	0.1
O	0.1	2	2	0.1
P	0.1	1	1	0.1
Q	0.1	2	2	0.1
R	0.2	5	5	0.2
S	0.1	5	4	0.1

Receptor ID#	Annual Average TSP (µg/m³)	Maximum 24 h average PM_{10} (µg/m³)	$PM_{2.5}$ (µg/m³) Maximum 24 h Average	$PM_{2.5}$ (µg/m³) Annual Average
T	0.2	1	1	0.2
U	0.2	1	1	0.2
V	0.2	8	8	0.2
W	0.4	12	12	0.3
X	0.4	13	13	0.4
Y	0.1	2	2	0.1

Table 9.17 Predicted Gaseous Concentrations for Northern Sands DMPA Operation

Receptor ID#	CO (µg/m³)	NO_2 (µg/m³)		Benzene (µg/m³)	Formaldehyde (µg/m³)	Toluene (µg/m³)			Xylene (µg/m³)	
Period	8 Hours	1 Hour	1 Year	1 Year	24 Hour	30 Minute	24 Hour	1 Year	24 Hour	1 Year
Criterion	11,000	250	62	10	54	1,100	4,100	410	1,200	950
Background	2.2	30	9	5	5	12	12	6	79	44
J	28	54	0.1	0.0005	0.002	0.4	0.01	0.001	0.01	0.001
K	48	62	0.3	0.0011	0.004	0.4	0.04	0.001	0.03	0.001
L	38	68	0.1	0.0005	0.002	0.5	0.02	0.001	0.01	0.001
M	85	115	1	0.0037	0.008	0.9	0.06	0.005	0.05	0.004
N	22	40	0.1	0.0006	0.002	0.2	0.01	0.001	0.01	0.001
O	32	47	0.2	0.0006	0.003	0.3	0.02	0.001	0.01	0.001
P	25	41	0.1	0.0005	0.001	0.3	0.01	0.001	0.01	0.001
Q	40	63	0.2	0.0006	0.002	0.4	0.02	0.001	0.02	0.001
R	86	144	0.4	0.0016	0.006	1.0	0.06	0.002	0.04	0.002
S	42	91	0.2	0.0011	0.015	1.1	0.07	0.002	0.05	0.001
T	16	26	0.3	0.0018	0.003	0.3	0.01	0.003	0.01	0.002
U	14	19	0.3	0.0015	0.003	0.2	0.01	0.002	0.01	0.002
V	71	178	0	0.0020	0.030	2.1	0.12	0.003	0.10	0.002
W	112	326	1	0.0032	0.047	3.8	0.19	0.005	0.15	0.004
X	120	301	1	0.0038	0.049	3.5	0.20	0.005	0.16	0.004
Y	19	54	0.1	0.0006	0.007	0.6	0.03	0.001	0.02	0.001

Figure 9.11 Northern Sands Operation Cumulative Maximum 1-Hour NO_2 Concentrations (µg/m^3)

9.6 Summary of Results

9.6.1 Operational Impacts at Wharf

Predicted concentrations and levels of all indicators are summarised in **Table 9.18** and **Table 9.19** for the worst-affected receptor, Jack & Newel Apartments C. $PM_{2.5}$ concentrations are close to but within the criteria for the baseline scenario, and exceed the criteria for the project scenario. The exceedance only occured on one day in the modelled year, when there was moderate south-easterly wind with neutral stability class and relatively high mixing height throughout the 24-hour day.

The 1-hour NO_2 concentrations for the baseline scenario are close to but within the criterion. The 1-hour NO_2 concentrations for the project scenario exceed the criteria for ten hours in the modelled year from within 6pm to 7am, when winds were light and blowing from the south and southeast and mostly having low mixing (inversion) heights at approximately 50 metres.

The concentrations of all other pollutants arising from the project are expected to be less than the criteria.

The similarity of the maximum predicted levels of the scenarios with all cruise ships using a scrubber and with 68% of cruise ships using a scrubber suggests that the elevated levels are due to the emissions of cruise ships using a scrubber. Although the modelled particle emissions of cruise ships using a scrubber are less than that of cruise ships with better fuel quality, the significantly higher exhaust temperature of the cruise ships not using a scrubber more than offsets the impacts due to their higher emissions. Due to this, the predicted impacts for the project scenario with 68% of cruise ships using a scrubber is slightly lower than that of the project scenario with all cruise ships using a scrubber especially for the longer-term average period.

Table 9.18 Summary of predicted levels at the most affected receptor for baseline scenario (100% of cruise ships using scrubber)

Pollutant	Averaging period	Assumed Background ($\mu g/m^3$)	Concentration at most affected receptor due to ships ($\mu g/m^3$)	Cumulative concentration at most affected receptor ($\mu g/m^3$)	Criteria ($\mu g/m^3$)
TSP	1 year	24	2	26	90
PM_{10}	24 hours	18	19	37	50
$PM_{2.5}$	24 hours	6.7	17	24	25
	1 year	5.8	1	7	8
NO_2	1 hour	30	197	227	250
	1 year	9	6	15	62
SO_2	1 hour	5	311	316	570
	24 hours	3	153	156	230
	1 year	1	10	11	57
CO	8 hours	2.2	96	98.2	11,000
Benzene	1 year	5	0.015	5	10
Toluene	30 minutes	12	0.21	12	1,100
	24 hours	12	0.08	12	4,100
	Annual average	6	0.005	6	410
Xylene	24 hours	79	2	81	1,200

Pollutant	Averaging period	Assumed Background ($\mu g/m^3$)	Concentration at most affected receptor due to ships ($\mu g/m^3$)	Cumulative concentration at most affected receptor ($\mu g/m^3$)	Criteria ($\mu g/m^3$)
	Annual average	44	0.09	44	950
Formaldehyde	24 hours	5	0.023	5	54
Benzo(a)pyrene	Annual average	0.1 ng/m^3	0.022 ng/m^3	0.12 ng/m^3	0.3 ng/m^3
Dust deposition	Annual average	50 mg/m^2/day	4 mg/m^2/day	54 mg/m^2/day	120 mg/m^2/day

Table 9.19 Summary of predicted levels at the most affected receptor for project scenario (100% of cruise ships using scrubber)

Pollutant	Averaging period	Assumed Background ($\mu g/m^3$)	Concentration at most affected receptor due to ships ($\mu g/m^3$)	Cumulative concentration at most affected receptor ($\mu g/m^3$)	Criteria ($\mu g/m^3$)
TSP	1 year	24	6	30	90
PM_{10}	24 hours	18	23	41	50
$PM_{2.5}$	24 hours	6.7	21	**28**	25
	1 year	5.8	4	**10**	8
NO_2	1 hour	30	269	**299**	250
	1 year	9	21	30	62
SO_2	1 hour	5	424	429	570
	24 hours	3	193	196	230
	1 year	1	33	34	57
CO	8 hours	2	109	111	11,000
Benzene	1 year	5	0.05	5	10
Toluene	30 minutes	12	0.28	12	1,100
	24 hours	12	0.10	12	4,100
	Annual average	6	0.018	6	410
Xylene	24 hours	79	2	81	1,200
	Annual average	44	0.096	44	950
Formaldehyde	24 hours	5	0.029	5	54
Benzo(a)pyrene	Annual average	0.1 ng/m^3	0.07 ng/m^3	0.17 ng/m	0.3 ng/m^3
Dust deposition	Annual average	50 mg/m^2/day	11 mg/m^2/day	61 mg/m^2/day	120 mg/m^2/day

9.6.2 Wharf and Channel Construction

Predicted concentrations and levels of all indicators are summarised in **Table 9.20** for the worst-affected receptors: B, C, D or E (apartments on the corner of Lake, Wharf and Abbott Streets) depending on the criterion. PM_{10}, $PM_{2.5}$, NO_2, and dust deposition levels exceed the criterion. The concentrations of all other pollutants arising from the project are expected to be less than the criteria.

The exceedances predicted due to the wharf construction activities are likely due to the conservatism of the model which includes the following assumptions:

- The backhoe dredge and the manoeuvring engines of the barge are modelled as constantly emitting whilst dredging in the channel relatively close to the sensitive receptors, leading to high predictions of $PM_{2.5}$. The proportion of stiff clay needing removal near the wharf is minor so, in reality, this scenario will only occur for a few days of the construction process.
- The backhoe dredge, barge and tugs were modelled as using fuel oil but they currently use marine diesel and it is anticipated will continue to do so, further leading to high predictions of $PM_{2.5}$.
- The excavator and crane emissions are modelled as constantly emitting from 7am to 7pm, Monday to Saturday. The exhaust emissions from the excavators and cranes were calculated from conservative NPI emission factors.
- It was assumed the cranes would use diesel and not have any SCR controls, which has led to over-prediction of the NO_2 impacts since most modern mobile cranes have SCR.
- Wharfside and services construction work is to be constructed over a 12 month period prior to dredging. As the exact timing of each construction activity is currently unknown, the model assumes that activities occur all year, so long-term averages of relevant pollutants are conservatively high.

Additional mitigation measures to reduce particulate and NO_x emissions are proposed in **Section 10**.

Table 9.20 Summary of predicted levels at the most affected receptor during Wharf Construction

Pollutant	Averaging period	Assumed Background (µg/m^3)	Concentration at most affected receptor due to construction (µg/m^3)	Cumulative concentration at most affected receptor (µg/m^3)	Criteria (µg/m^3)
TSP	1 year	24	22	46	90
PM_{10}	24 hours	18	52	**70**	50
$PM_{2.5}$	24 hours	7	48	**55**	25
	1 year	5.8	16	**22**	8
NO_2	1 hour	30	576	**606**	250
	1 year	9	20	29	62
SO_2	1 hour	5	197	202	570
	24 hours	3	74	77	230
	1 year	1	24	25	57
CO	8 hours	2	171	173	11,000
Benzene	1 year	5	0.05	5	10
Toluene	30 minutes	12	0.2	12	1,100
	24 hours	12	0.02	12	4,100
	Annual average	6	0.008	6	410
Xylene	24 hours	79	0.02	79	1,200
	Annual average	44	0.006	44	950
Formaldehyde	24 hours	5	0.07	5	54

Pollutant	Averaging period	Assumed Background ($\mu g/m^3$)	Concentration at most affected receptor due to construction ($\mu g/m^3$)	Cumulative concentration at most affected receptor ($\mu g/m^3$)	Criteria ($\mu g/m^3$)
Benzo(a)pyrene	Annual average	0.1 ng/m^3	0.06 ng/m^3	0.16 ng/m^3	0.3 ng/m^3
Dust deposition	Annual average	50 mg/m^2/day	85 mg/m^2/day	**135 mg/m^2/day**	120 mg/m^2/day

9.7 Northern Sands DMPA

For construction, predicted concentrations for all pollutants are well within the criteria. For operation, predicted concentrations and levels of all indicators are summarised in **Table 9.21** for the worst-affected receptors: M, W or X depending on the criterion. The maximum 1-hour NO_2 concentrations exceeds the criterion. This is based on the assumption that the tailwater pumps have no emission controls. The concentrations of all other pollutants arising from the project are expected to be less than the criteria.

Additional mitigation measures to reduce particulate and NO_x emissions are proposed in **Section 10**.

Table 9.21 Summary of predicted levels at the most affected receptor near Northern Sands

Pollutant	Averaging period	Assumed Background ($\mu g/m^3$)	Concentration at most affected receptor due to construction ($\mu g/m^3$)	Cumulative concentration at most affected receptor ($\mu g/m^3$)	Criteria ($\mu g/m^3$)
TSP	1 year	24	0.6	25	90
PM_{10}	24 hours	18	13	31	50
$PM_{2.5}$	24 hours	7	13	20	25
	1 year	5.8	0.4	6.2	8
NO_2	1 hour	30	326	**356**	250
	1 year	9	1	10	62
CO	8 hours	2	120	122	11,000
Benzene	1 year	5	0.004	5	10
Toluene	30 minutes	12	3.8	16	1,100
	24 hours	12	0.2	12	4,100
	Annual average	6	0.005	6	410
Xylene	24 hours	79	0.16	79	1,200
	Annual average	44	0.004	44	950
Formaldehyde	24 hours	5	0.05	6	54

10. Recommendations

10.1 Standard Recommendations

10.1.1 Wharf Area Construction Site

- Haul truck loads leaving the site are to be covered.
- Mobile plant engines are to be maintained to adhere to relevant emission criteria.
- A rumble strip is to be used to shake dust of wheels leaving the site.
- Daily monitoring is to be undertaken by site supervisors including visual checks for dust crossing the site boundary.
- Drop heights when front end loaders load onto trucks should be reduced to less than two metres.
- Any complaints from public are to trigger assessment by the operator and liaison between the operator, Ports North, EHP and the complainant to determine appropriate control measures.

10.1.2 DMPA area measures

The following generic measures should be implemented during construction and operation:

- Undertake watering of all haul routes at a rate suitable for the conditions.
- Mobile plant engines are to be maintained to adhere to relevant emission criteria.
- Unsealed tracks and area are to be watered as required.
- A speed limit of 20 km/h is to be enforced on site.
- A rumble strip is to be used to shake dust of wheels leaving the site.
- Vegetation is to be maintained on the site boundaries.
- Daily monitoring is to be undertaken by site supervisors including visual checks for dust crossing the site boundary and odour surveys close to the site boundary.
- Any complaints from public are to trigger assessment by the operator and liaison between the operator, Ports North, EHP and the complainant to determine appropriate control measures.

10.2 Mitigation by Further Design Changes

- The tailwater discharge pumps at the Northern Sands DMPA are to have exhaust stacks at least 4 metres high and NOx selective catalytic reduction (SCR) control technology. They are not to run for more than two hours when the wind is blowing from the west. SCR typically reduces NO_x emissions by 90%, so this would provide a major reduction in NO_x impacts. Alternatively, after a specific pump and location is selected, modelling can be repeated to assess the impacts and required controls more accurately.
- A survey of fuel consumption and fuel type, whilst berthed at the wharf is to be undertaken to include at least cruise ships and tankers. This data can then be used to enhance and improve model predictions. This will allow more accurate assessment of impacts, inform management mitigation planning, and potentially refine the control measures required.
- Cranes are to be powered by mains electricity or for mobile cranes to have installed SCR for NO_x reduction. SCR typically reduces NO_x emissions by 90%, so this would provide a major reduction in NO_x emissions.

10.3 Mitigation by Management

- The backhoe dredge and associated tugs will use marine diesel when operating in the vicinity of the wharf (inside beacon 20). The ratio of $PM_{2.5}$ emission factors in **Table 7.2** for marine diesel to fuel oil for medium speed main diesel engines is 1415 to 6140 i.e. less than one quarter. This would provide a major reduction in particulate and black smoke emissions.
- If long-term monitoring demonstrates that the existing air quality is such that exceedances may occur with future increases in shipping numbers, then further management measures include increasing the use of marine diesel, IFO or 0.1% sulfur fuel while at berth or use of high efficiency scrubber technology to achieve an equivalent SO_2 emission.
- The ratio of $PM_{2.5}$ emission factors in **Table 7.2** for marine diesel to fuel oil for medium speed main diesel engines is 1415 to 6140 i.e less than one quarter. This would provide a major reduction in particulate and black smoke emissions.
- The construction management plan for the wharf and associated land area is to include hourly visual monitoring for dust and having a high pressure water spray available when the excavator is loading trucks.

10.4 Monitoring

Monitoring during operation provides a measure of actual impacts at the monitoring locations and can be used to validate or calibrate models. Similarly monitoring prior to construction provides additional information that improves the assumptions regarding the background air quality.

- Monitor NO_2 and $PM_{2.5}$ concentrations at a location representative of the apartments on Wharf Street between Lake and Abbott Streets using an Australian Standard method such as the following for one year, and reviewed to determine the extent of future monitoring. This should commence as soon as practical to obtain baseline data and continue until further assessment of the data and future emissions model demonstrates that exceedances are not likely to occur as a result of the wharf operation:
    - *AS/NZS 3580.9.10 Determination of suspended particulate matter – $PM_{2.5}$ low volume sampler – Gravimetric method*. This monitoring should be undertaken every sixth day.
    - *AS/NZS 3580.9.12 Determination of suspended particulate matter – $PM_{2.5}$ beta attenuation monitors*.
    - *AS/NZS 3580.9.13 Determination of suspended particulate matter – $PM_{2.5}$ continuous direct mass method using a tapered element oscillating microbalance monitor*.
    - *AS/NZS 3580.5.1 Determination of oxides of nitrogen – Direct-reading instrumental method*.
- Should a valid complaint regarding dust nuisance be received, undertake dust deposition monitoring at a site representative of the complainant's residence according to *AS/NZS 3580.10.1 Methods for sampling and analysis of ambient air – Determination of particulate matter – Deposited matter – Gravimetric method*. This monitoring would be undertaken for 12 months and the results reviewed to determine the extent of future monitoring.

11. Risk Assessment of Impacts With and Without Mitigation

11.1 Risk Assessment

Based on the results of the air quality assessment and the identified mitigation measures, a risk assessment has been undertaken for impacts associated with the construction and operation of the CSD Project. The risk assessment has applied the significance criteria outlined in **Table 11.1**, and the likelihood of impact criteria in **Table 11.2** to determine the overall risk of impact for individual project activities based on **Table 11.3**. The derived risk rating for each of the project activities is then summarised in **Table 11.4** with and without the additional mitigation measures discussed in **Section 10.2** and **Section 10.3** and summarised in **Section 11.2**.

Table 11.1 Significance Criteria

Impact Significance/Consequence	Description of Significance
Very High	The impact is considered critical to the decision-making process. A substantial exceedance of an air quality criterion occurs that may lead to death.
High	The impact is considered likely to be important to decision-making. An exceedance of an air quality criterion occurs that may lead to serious but non-fatal health effects.
Moderate	The effects of the impact are relevant to decision-making including the development of management measures. Predictions are that the cumulative impacts will exceed a health criterion by up to a factor of two, or exceed a nuisance criterion.
Minor	Impacts are recognisable/detectable but acceptable. Predictions are that incremental impacts are below the criterion, but within an order of magnitude, and cumulative impacts are also below the criterion.
Negligible	Minimal change to the existing situation. Predictions are that incremental impacts will be an order of magnitude below the criterion.
Beneficial	Action results in an improvement to air quality.

Table 11.2 Likelihood of Impact

Likelihood of Impacts	Risk Probability Categories
Highly Unlikely	Highly unlikely to occur but theoretically possible
Unlikely	May occur during construction of the project but probability well below 50%; unlikely, but not negligible
Possible	Less likely than not but still appreciable; probability of about 50%
Likely	Likely to occur during construction or during a 12 month timeframe; probability greater than 50%
Almost Certain	Very likely to occur as a result of the proposed project construction and/or operations; could occur multiple times during relevant impacting period

Table 11.3 Risk Matrix

Likelihood	Significance				
	Negligible	Minor	Moderate	High	Very High
Rare	Negligible	Negligible	Low	Medium	High
Unlikely	Negligible	Low	Low	Medium	High
Possible	Negligible	Low	Medium	Medium	High
Likely	Negligible	Medium	Medium	High	Extreme
Almost Certain	Low	Medium	High	Extreme	Extreme

Table 11.4 Air Emission Impact Assessment Table

Sources and Location	Impacts	Initial Assessment with Standard Mitigation Measures			Residual Assessment with Additional Mitigation in Place		
		Significance	Likelihood	Risk Rating	Significance	Likelihood	Risk Rating
Construction							
Construction of wharf and tank farm and dredging of channel	Exceedance of 24h particulate criteria	moderate	likely	medium	minor	unlikely	low
	Exceedance of annual $PM_{2.5}$ criterion	moderate	possible	medium	minor	unlikely	low
	Exceedance of dust deposition criterion	minor	possible	low	minor	possible	low
	Exceedance of gas criteria	moderate	possible	medium	minor	unlikely	low
Construction of pipeline	Exceedance of 24h particulate criteria	negligible	unlikely	negligible	negligible	unlikely	negligible
	Exceedance of annual $PM_{2.5}$ criterion	negligible	unlikely	negligible	negligible	unlikely	negligible
	Exceedance of gas criteria	negligible	unlikely	negligible	negligible	unlikely	negligible
Operation of DMPA, boosters and pumps at Northern Sands	Exceedance of 24h particulate criteria	moderate	possible	medium	minor	unlikely	low
	Exceedance of annual $PM_{2.5}$ criterion	negligible	unlikely	negligible	negligible	unlikely	negligible
	Exceedance of gas criteria	high	likely	high	minor	unlikely	low

Sources and Location	Impacts	Initial Assessment with Standard Mitigation Measures			Residual Assessment with Additional Mitigation in Place		
	Odour from dredged material	negligible	possible	negligible	negligible	possible	negligible
Operation							
Shipping and dredging at wharf and channel	Exceedance of 24h particulate criteria	moderate	possible	medium	minor	possible	low
	Exceedance of annual $PM_{2.5}$ criterion	moderate	possible	medium	minor	possible	low
	Exceedance of dust deposition criterion	negligible	unlikely	low	negligible	unlikely	low
	Exceedance of gas criteria	moderate	possible	medium	minor	possible	low
	Visible black smoke from ship exhausts	minor	likely	medium	minor	possible	low
	Nuisance odour from ship waste	negligible	unlikely	negligible	negligible	unlikely	negligible
Shipping and ferries at Yorkeys Knob	Particulate emissions	beneficial	almost certain	NA	beneficial	almost certain	NA
Vehicular traffic near wharf	Exhaust emissions	negligible	unlikely	negligible	negligible	unlikely	negligible

Notes: 1. NA = Not applicable as no risks associated with a benefit.

The implications of the risk ratings are listed in **Table 11.5**. Impacts are further summarised in **Table 11.7** including reference to the duration criteria in **Table 11.6**.

Table 11.5 Risk Rating Legend

Risk Rating	Risk Probability Categories
Extreme	An issue requiring change in project scope to reduce risk.
High	An issue requiring further detailed investigation and planning to manage and reduce risk. For air quality this rating requires gathering of detailed project-specific data to improve the accuracy of the assessment, and/or extensive monitoring to ensure control measures are effective.
Medium	An issue requiring project scope specific controls and procedures to manage.
Low	Manageable by standard mitigation and similar operating procedures.
Negligible	No additional management required.

Table 11.6 Duration Criteria

Classification	Duration
Temporary	Days (criteria averaging periods from 30 mins to 24 hour)
Short Term	Weeks
Medium Term	Months (criteria averaging period of one month)
Long Term	3 Months (12 Weeks) (annual average criteria)
Permanent	In excess of 10 Years

Table 11.7 Air Quality Impact Category Summary

Element	Adverse Impact	Consequential Impact	Cumulative Impact	Duration	Reversibility	Predictability
Operation of cruise ships	Air quality criteria exceeded	Emissions from ships	Short-term criteria exceeded	Temporary	Reversible	Unpredictable because criteria within uncertainty range of predictions
Operation of cruise ships	Air quality criteria exceeded	Particulate emissions from ships	Long-term criterion exceeded	Long term	Irreversible	Unpredictable because criteria within uncertainty range of predictions
Operation of cruise ships at Yorkeys Knob	Poor air quality	Reduction in emissions from ships and ferries	Long-term and short-term particulate levels reduced	Long-term	Reversible	Unpredictable because criteria within uncertainty range of predictions
Construction of channel	Air quality criteria exceeded	Emissions from backhoe dredge	Short-term criteria exceeded	Temporary	Reversible	Unpredictable because criteria within uncertainty range of predictions
Operation of pipeline and Northern Sands DMPA	Air quality criteria exceeded	Emissions from tailwater pumps	Short-term criteria exceeded	Temporary	Reversible	Unpredictable because criteria within uncertainty range of predictions

11.2 Management and Monitoring Commitments

The following measures are recommended so that the risk of impacts is reduced to a low level:

(1) The backhoe dredge and associated tugs are to use marine diesel when operating in the vicinity of the wharf (inside beacon 20).

(2) The tailwater discharge pumps at the Northern Sands DMPA are to have exhaust stacks at least 4 metres high and NOx selective catalytic reduction (SCR) control technology. They are not to run for more than two hours when the wind is blowing from the west.

(3) A survey of fuel consumption and fuel type, whilst berthed at the wharf is to be undertaken to include at least cruise ships and tankers. This data can then be used to enhance and improve

model predictions. This will allow more accurate assessment of impacts, inform management mitigation planning, and potentially refine the control measures required.

(4) Cruise ships that do not have scrubbers on engines are to be required to use 0.5% sulfur fuel oil, IFO, or marine diesel whilst berthed at the wharf.

(5) Monitoring of $PM_{2.5}$ and NO_2 concentrations, using one of the Australian Standard methods listed in **Section 10.4,** is to be undertaken at a location representative of the apartments on Wharf Street between Lake and Abbott Streets. This should commence as soon as practical to obtain baseline data and continue until further assessment of the data and future emissions model demonstrates that exceedances are not likely to occur as a result of the wharf operation.

(6) If long-term monitoring demonstrates that the existing air quality is such that exceedances may occur with future increases in shipping numbers, then further management measures are to be implemented to comply potentially including increasing use of the following whilst at berth:

   (a) marine diesel

   (b) IFO

   (c) 0.1% sulfur fuel or

   (d) high efficiency scrubber technology to achieve an equivalent SO_2 emission.

(7) Cranes are to be powered by mains electricity or for mobile cranes to have installed SCR for NO_x reduction.

(8) The construction management plan for the wharf and associated land area is to include hourly visual monitoring for dust and having a high pressure water spray available when the excavator is loading trucks.

12. Conclusion

An air quality assessment has been conducted for the proposed Cairns Shipping Development Project. The results of the assessment are summarised as follows:

- Emissions from shipping should not cause exceedences of the air quality criteria if ships at berth use marine diesel or 0.1% low sulfur fuel or a high efficiency scrubber to achieve equivalent. Worst case modelling predicts that there is a potential for the cruise ships to cause exceedances of the $PM_{2.5}$ and NO_2 criteria for the project scenario. The $PM_{2.5}$ exceedance only occured on one day in the modelled year, when there was moderate south-easterly wind with neutral stability class and relatively high mixing height throughout the 24-hour day. NO_2 exceedances are predicted for ten hours in the modelled year from within 6pm to 7am, when winds were light and blowing from the south and southeast and mostly having low mixing (inversion) heights at approximately 50 metres.
- If monitoring indicates potential exceedances may occur, increasing the use of marine diesel, 0.1% IFO, 0.1% sulfur fuel or more efficient scrubbers equivalent to 0.1%, should achieve compliance.
- Dust deposition levels from shipping are predicted to be within the nuisance criterion but deposition of diesel soot may accumulate over time and be observable due its dark colour. This will be reduced by the uptake of scrubbers or use of low sulfur fuel in cruise ships.
- If the backhoe dredge and associated tugs continue to use marine diesel when near the wharf, PM_{10} and $PM_{2.5}$ concentrations should meet the criteria. The impacts of the dredge and tugs predicted by the model conservatively assume these will coincide with other land-based construction activities, but it is understood dredging should occur after construction, and then only for a few days near the wharf. The impacts of dredge exhausts will also be less than the previous development proposal due to the reduction in quantity of dredging required.
- The use of SCR emission controls on diesel cranes and tailwater pumps during construction should lead to compliance with the criteria.
- Management of construction dust by providing hourly visual monitoring and having a high pressure water spray available when the excavator is loading trucks in the construction management plan, should lead to compliance with the criteria. If excavators were loading dump trucks without sprays throughout the year, modelling predicts minor exceedance of the 30-day dust deposition nuisance criterion at nearest receptors to wharf.
- Dark smoke from ship engines under load can be reduced by using marine diesel fuel or low sulfur fuel instead of a high sulfur fuel oil in ships that do not have scrubbers, when arriving to and departing from the wharf.
- In summary, there is low risk associated with project provided the recommendations in **Section 10** are implemented.

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Appendix A Glossary

Parameter or Term	Description
ASK	ASK Consulting Engineers Pty Ltd
BoM	Bureau of Meteorology
CO	Carbon monoxide
CSD	Cairns Shipping Development
DMPA	Dredge material placement area
DSITI	Department of Science, Information Technology and Innovation
Dust fallout deposition	Dust that has fallen out of the air onto a horizontal surface
EHP	Queensland Department of Environment and Heritage Protection
EPP (Air)	Queensland Environmental Protection (Air) Policy 2008
FEL	Front end loader
$g/m^2/month$	Grams per square metre per month
IFO	Intermediate Fuel Oil
m/s	Metres per second
$mg/m^2/day$	Milligrams per square metre per day
mg/m^3	Milligrams per cubic metre
NPI	National Pollutant Inventory
NEPM	National Environmental Protection (Ambient Air Quality) Measure
NO_x	Oxides of nitrogen including nitric oxide and nitrogen dioxide
NO_2	Nitrogen dioxide
$PM_{2.5}$	Particulates suspended in air with aerodynamic diameter less than 2.5 microns
PM_{10}	Particulates suspended in air with aerodynamic diameter less than 10 microns
ppb	Parts per billion by volume
ppm	Parts per million by volume
SO_2	Sulphur dioxide
TAPM	The Air Pollution Model developed by CSIRO and used by ASK for meteorological modelling
TSHD	Trailing suction hopper dredge
TSP	Total particulates suspended in air
$\mu g/m^3$	Micrograms per cubic metre
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UTM	Universal Transverse Mercator coordinate system
VOCs	Volatile organic compounds

Appendix B Emission Inventory Equations for Particulates

Loading Overburden to Trucks by Excavator

Equation 10 of Environment Australia (2012) has been used because it provides a method of varying emission rates with wind speed.

$$E = 0.0016\,k\,\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

where

E = Emission Factor with units kg/t of overburden

U = mean wind speed (m/s)

M = soil moisture content (%)

k = 0.74 for TSP

k = 0.35 for PM_{10}

Bulldozing Overburden

Equations 16 and 17 of Environment Australia (2012) have been used.

$$E_{TSP} = 2.6 \times \frac{(s)^{1.2}}{(M)^{1.3}}$$

$$E_{PM_{10}} = 0.34 \times \frac{(s)^{1.5}}{(M)^{1.4}}$$

where

E = Emission factor with units kg/h/vehicle

s = Material silt content (%)

M = Soil moisture content (%)

Wheel Dust Generation from Light Vehicles on Unpaved Roads

$$E = k \times \frac{\frac{s}{12} \times \left(\frac{S}{48}\right)^{B}}{\left(\frac{M}{0.5}\right)^{C}} - 0.0013$$

Where: E = Emission factor
k = Constant (1.69 for TSP, and 0.51 for PM_{10})
B = 0.6 for TSP and 0.5 for PM_{10}
C = 0.3 for TSP and 0.2 for PM_{10}
s = Material silt content (%)
S = vehicle speed (km/h)
M = Moisture content (%)

Grader

From Section A1.1.14 of Environment Australia (2012):

$$E = 0.0034 \times S^{k}$$

where

E = Emission factor with units kg/vkt (vkt = vehicle kilometre travelled)

k = 2.5 for TSP

k = 2.0 for PM_{10}

S = Mean Vehicle Speed (km/h)

Wind-blown Dust

Environment Australia (2012) provides an NPI method for estimating annual emissions of dust from wind erosion based on either a default value published in 1983 or an equation published in 1998, which has several variables including number of rain days and average wind speed. However dispersion modelling is normally based on hourly time-steps and using this equation, the model will predict a small quantity of wind-blown dust every hour of the year. In reality, peak emissions of wind-blown dust will occur only during high wind speeds conditions during dry periods. During low wind speed conditions when particulates from other sources can accumulate, wind-blown dust will be negligible. Thus using the NPI equations will lead to inaccurate and un-timely contribution of wind-blown dust to the peak 24 hour predictions.

ASK calculates variable wind-blown dust emissions from exposed surfaces based on equations 2 and 3 of USEPA (2006), which combine to become:

$$E = k \times \left(58 \times (u^{*} - u_t^{*})^2 + 25\,(u^{*} - u_t^{*})\right)$$

Where: E = Emission factor with units g/m^2/disturbance hour

k = Constant (1.0 for TSP, 0.5 for PM_{10} and 0.075 for $PM_{2.5}$)

u^* = surface friction velocity (m/s)

u_t^* = threshold friction velocity (m/s)

The surface friction velocity can be calculated for different wind speed classes (at 10 metre anemometer height, based on Equations 13.2.5-6 and 13.2.5-7 of AP-42 (USEPA 2006) using the following three factors:

(1) Based on Table 13.2.5-3 the ratio of surface wind to 10 metre approach wind over a steep stockpile area ranges from 0.2 to 1.1. Parts of the stockpile where the ratio is 0.2 will likely never be eroded by wind. Parts of the stockpile where the ratio is 0.6 will trigger rarely if ever for coal only. Overburden will only trigger when the ratio reaches 1.1, which is 4% of less of the stockpile.

(2) Using equation 13.2.5-7, the surface friction velocity is one tenth of the surface wind.

(3) However these calculations are based on “fastest-mile” wind speeds, which approximate the fastest 1-minute mean wind speed (Graybeal 2006). The wind speeds used in modelling are one hour means. Ratios (“G_{60}”) of 1 minute means to one hour means are estimated by Ashcroft (1984) for different terrain types. For mostly open, fairly level terrain with a few buildings, G_{60} = 1.26.

Therefore for overburden, the surface friction velocity is calculated as 1.1 x 0.1 x 1.26 times the 10 metre approach wind. For coal the ratio is assumed to be 0.6 x 0.1 x 1.26 x the 10 metre approach wind.

For each wind speed category, the geometric mean surface friction velocities are shown in **Table 12.1** and **Table 12.2**.

Table 12.1 Wind Speeds and Corresponding Surface Friction Velocities (m/s) for 4% of Exposed Earth and Overburden

Pasquill Wind Speed Class	Corresponding Surface Friction Velocities	Mean Surface Friction Velocity
0 – 1.54	0 – 0.21	0.11

1.54 – 3.09	0.21 – 0.43	0.30
3.09 – 5.14	0.43 – 0.71	0.55
5.14 – 8.23	0.71 – 1.14	0.90
8.23 – 10.80	1.14 – 1.50	1.31
> 10.80	> 1.50	1.52

Table 12.2 Wind Speeds and Corresponding Surface Friction Velocities (m/s) for 15% of Exposed Coal

Pasquill Wind Speed Class	Corresponding Surface Friction Velocities	Mean Surface Friction Velocity
0 – 1.54	0 – 0.17	0.09
1.54 – 3.09	0.17 – 0.35	0.25
3.09 – 5.14	0.35 – 0.58	0.45
5.14 – 8.23	0.58 – 0.93	0.74
8.23 – 10.80	0.93 – 1.22	1.07
> 10.80	> 1.22	1.25

The threshold friction velocity (Table 13.2.5-2, USEPA 2006) for overburden is 1.02 m/s, and for fine coal dust on concrete stockpile pads is 0.54 m/s. The resultant emission rates for different Pasquill wind speed classes are given in **Table 12.3**.

Table 12.3 Wind Erosion Emission Rates for Exposed Surfaces

Pasquill Wind Speed Class (m/s)	TSP (kg/ha/hour)	PM10 (kg/ha/hour)	PM2.5 (kg/ha/hour)
5.15 – 8.23	0.7	0.3	0.03
8.24 – 10.80	5	2	0.2
> 10.80	10	5	0.4