Cairns Shipping Development Project

Ports North

APPENDIX D.7

Draft : Environmental Impact Statement

# Appendix D.7

## Noise and Vibration Technical Report

# Appendix D7 Noise and Vibration

## D7.1 Baseline Noise Measurements

A desktop survey was conducted to identify potential noise sensitive receptors prior to site surveys. A noise survey was conducted by qualified Arup acousticians from the 27th to 30th August 2013, with both attended and unattended measurements to establish the existing noise environment at the site. The site investigation confirmed the identified noise-sensitive receptors.

Attended noise measurements were undertaken at locations which were identified as representative of noise sensitive receptors that may potentially be exposed to noise from the construction and operation of the proposed CSDP. The measurements were conducted to obtain details of representative conditions in the absence of a cruise ship docked at the Port of Cairns in order to derive noise criteria for operation of the Cruise Ship Terminal, so that the noise impacts from future cruise ship port visits may be evaluated against the existing noise impacts from Business as Usual (BAU) conditions.

Unattended noise measurements were conducted using environmental noise loggers. These measurements have been used to compliment the attended noise measurement and validate these measurements over a longer period.

Underwater baseline measurements were not conducted as the impact criteria are absolute criteria (in terms of physical damage or behavioural impacts to the animal) and are independent of the existing noise environment. Typical underwater noise levels (based on the Wenz curves (Wenz, 1962) will be used to provide context to the predicted underwater noise levels.

## D7.2 Measurement Locations

Noise measurements have been conducted at the locations shown in Figures B10.4.3a and B10.4.3b to establish the existing baseline noise levels.

Measurement locations are described in further in Table D7.2a below.

Table D7.2a Description of Measurement Locations

| Location Reference | Description of noise sensitive receptor catchment area represented by measurement location | Type of measurement (attended/unattended) |
|---|---|---|
| 1 | Wharf St/Port access intersection | Attended and Unattended |
| 2 | Wharf St/Port access intersection | Attended |
| 3 | Wharf St (adjacent to the Hilton Hotel) | Attended |
| 4 | Wharf St (adjacent to the Hilton Hotel) | Unattended |
| 5 | Hotel receptor (Hilton) | Attended |
| 6 | Residences at East Trinity (southern) | Attended |
| 7 | Residences at East Trinity (northern) | Attended |
| 8 | Residences at East Trinity (northern) | Attended |
| 9 | Trinity Inlet (houseboat) | Attended |
| 10 | Trinity Inlet (houseboat) | Attended |
| 11 | Trinity Inlet (houseboat) | Attended |

The sound level meter was held with a microphone at 1.5m above ground level and set to *fast* time response for all measurements. The $L_{Aeq}$, $L_{Amax}$, $L_{A10}$ and $L_{A90}$ noise indices were measured in free-field conditions (i.e. away from noise reflecting structures).

Noise measurements were performed in general accordance with Australian Standards AS1055(Standards Australia 1997) and AS2702 (Standards Australia 1984) and the Queensland (QLD) Noise Measurement Manual (QLD Environmental Protection Agency, 2000).

Weather conditions were noted throughout the measurement periods and there were no adverse weather conditions that could have affected noise measurements.

### D7.3 Equipment

The equipment used to measure the noise levels during attended measurements was a Brüel and Kjær Type 2270 sound level meter (serial number 2754328). The equipment used to measure the noise levels during unattended measurements were RTA Type 4 noise loggers (serial numbers T229736 and T229740). The equipment was checked for calibration before and after each set of measurements using a Brüel and Kjær Type 4231 calibration exciter, with no significant drift occurring.

### D7.4 Assumptions and Technical Limitations

The following assumptions have been made in obtaining the ambient noise levels:

- Noise loggers were located at representative locations of the nearest noise sensitive receptors during 'typical' conditions
- Vandalism of the logger situated at Location 1 at approximately 0200 on the 28th September resulted in inaccurate measurements after this time. Measured night-time noise levels until 0200 are still considered relevant. To compensate for the loss of this logger data, additional attended measurements were taken at this location
- Noise levels measured by the logger at Location 4 were affected by mechanical services noise emissions from the Hilton Hotel over the day and evening periods. During site investigations, Arup observed that the noise environment at the nearby sensitive receptors on Wharf Street is characterised by mechanical services noise from other buildings in the vicinity and hence these logger results are considered representative of the Wharf Street vicinity.

### D7.5 Measured Background Noise Levels

For short-term measurements (i.e. attended measurements) the representative background noise level is the lowest background level ($L_{A90}$) measured during the survey.

For long-term measurements (i.e. unattended measurements) the representative background level is the Rating Background Level (RBL, $minL_{A90,1hour}$) determined using the "tenth percentile" method as detailed in the PNCG.

The representative measured background noise levels are summarised in Table D7.5a below for the daytime, evening and night-time periods.

The noise levels at receptors along Wharf St are dominated by noise from local traffic and mechanical plant from surrounding buildings.

Measurements at East Trinity showed a fairly steady ambient noise environment, being typically dominated by natural noise sources, such as ocean wave sound and wind causing vegetation to rustle. Very little man-made noise was noticed at these locations, with the exception of intermittent aircraft noise from air traffic from/to Cairns Airport. Traffic from local roads was audible or just audible at location 6 and location 8 (see Figure B10.4.3b).

Similarly, measurements at residential receptors living on boats on the inlet were dominated by ocean wave sounds, with the occasional small boat pass-by and aircraft flypast.

Table D7.5a: Representative measured background noise levels, noise sensitive receptors

| Measurement location | Measured background noise level, $L_{A90,15min}$, dB(A) (representative level) | | |
|---|---|---|---|
| | Day<br>0700-1800 | Evening<br>1800-2200 | Night<br>2200-0700 |
| 1* | 46** | 43** | 41** |
| 2 | 51 | - | - |
| 3 | - | - | - |
| 4* | 54 | 48 | 46 |
| 5 | 52 | - | - |
| 6 | 40 | - | - |
| 7 | 46 | - | - |
| 8 | 46 | - | - |
| 9 | 42 | - | - |
| 10 | 44 | - | - |
| 11 | 49 | - | - |

* Determined using "tenth-percentile" method as per *Planning for Noise Control Guideline*

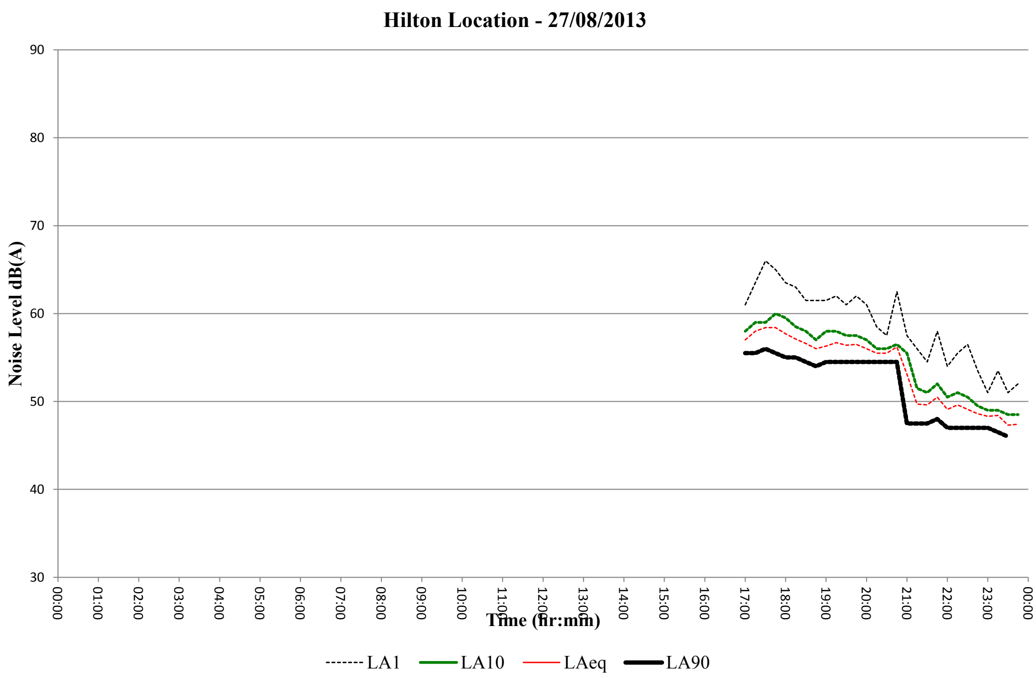
** Determined from only one day of the logger data (up to 0200 when this logger was vandalised).

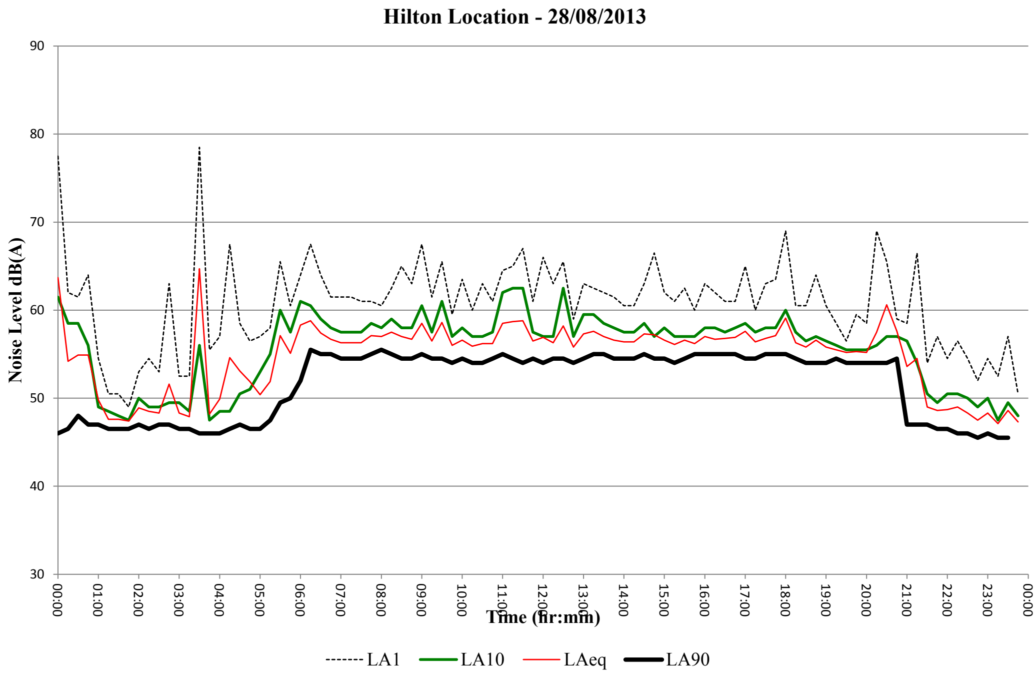
### D7.5.1 Attended Measurement Results

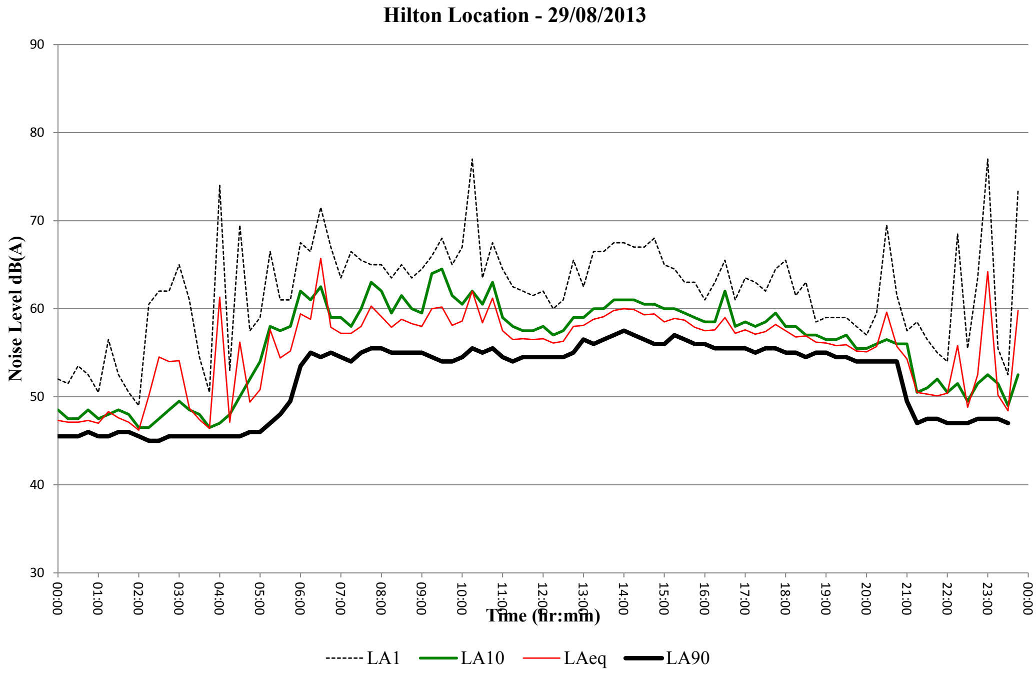
Table D7.5.1a Measured noise levels- attended

| Location | Date | Start | Duration | LAeq | LAmax | LA1 | LA10 | LA90 | Description |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 28/08/13 | 12:35 PM | 15:01 | 61 | 75 | 67 | 59 | 48 | Off peak, but traffic still dominant noise source. Voices audible from time to time. |
| 1 | 28/08/13 | 7:18 PM | 0:15:03 | 57 | 67 | 61 | 56 | 46 | Local (carpark) traffic. Voices from apartment quite loud. Some traffic on main road. |
| 1 | 28/08/13 | 9:15 PM | 0:10:01 | 59 | 77 | 66 | 53 | 43 | Light traffic on main road. Voices of people on street- quite noisy. Stopped due to really noisy “bike taxi” race. |
| 2 | 28/08/13 | 7:57 AM | 0:15:01 | 68 | 80 | 73 | 68 | 49 | Traffic noise dominant (morning peak). When there is a lull in traffic, mechanical services noise audible. |
| 2 | 29/08/13 | 11:10 AM | 0:15:01 | 65 | 76 | 71 | 66 | 51 | Off peak day. Local traffic and mechanical services are dominant noise sources. |
| 2 | 28/08/13 | 5:02 PM | 0:15:01 | 70 | 82 | 75 | 69 | 54 | Peak traffic is dominant noise source. Steady traffic flow for measurement duration. Mechanical services noise just audible. |
| 3 | 28/08/13 | 8:20 AM | 0:15:02 | 69 | 81 | 74 | 68 | 55 | Traffic noise dominant (morning peak). Aircraft overhead at end of measurement. |
| 3 | 28/08/13 | 5:22 PM | 0:10:01 | 66 | 76 | 71 | 66 | 54 | Peak traffic is dominant noise source. Traffic slowed towards end of measurement. |
| 5 | 28/08/13 | 8:46 AM | 0:29:25 | 61 | 80 | 62 | 56 | 51 | Departure of morning reef boats. Voices of patrons just audible. Loud birds. Buses turning in nearby culdesac. Waves lapping against channel edge. |
| 5 | 29/08/13 | 11:37 AM | 0:15:31 | 57 | 65 | 60 | 56 | 52 | Large boat pulled up and idled outside shed 2. Low frequency rumble. Small boats passing by throughout measurement. Some traffic from Wharf St audible. |
| 5 | 29/08/13 | 5:02 PM | 0:10:01 | 61 | 66 | 62 | 60 | 57 | Reef boats returning. Water lapping, voices of people along Marina. |
| 6 | 28/08/13 | 10:47 AM | 0:10:01 | 55 | 63 | 58 | 49 | 40 | Trees rustling, waves lapping on shore. Bird noise. Medium boat passed by, inaudible at 250m. Traffic from main road just audible. |
| 7 | 28/08/13 | 11:10 AM | 0:15:05 | 53 | 61 | 57 | 52 | 46 | Aircraft/ helicopter passing overhead, trees rustling, boats visible at 250m but inaudible. |
| 8 | 28/08/13 | 11:37 AM | 0:14:39 | 55 | 67 | 59 | 53 | 46 | Intermittent aircraft noise. Traffic noise intermittent but clearly audible. Ocean noise. Bird noise. Distant boat pass-by just audible. |
| 9 | 27/08/13 | 12:10 AM | 0:15:00 | 46 | 61 | 59 | 51 | 42 | Ocean noise dominant noise source. Intermittent boat pass-bys. Voices from nearby fishing boat just audible. Aircraft overhead. |
| 10 | 27/08/13 | 11:44 AM | 0:15:00 | 49 | 71 | 64 | 55 | 44 | Ocean noise dominant noise source. Intermittent boat pass-bys. Reef boat pass-by with amplified voices. Some bird noise. |
| 11 | 27/08/13 | 11:20 AM | 0:15:00 | 53 | 70 | 66 | 57 | 49 | Dominant noise source ocean noise. Intermittent helicopter/ aeroplane above. |

## D7.5.2 Unattended Measurement Results





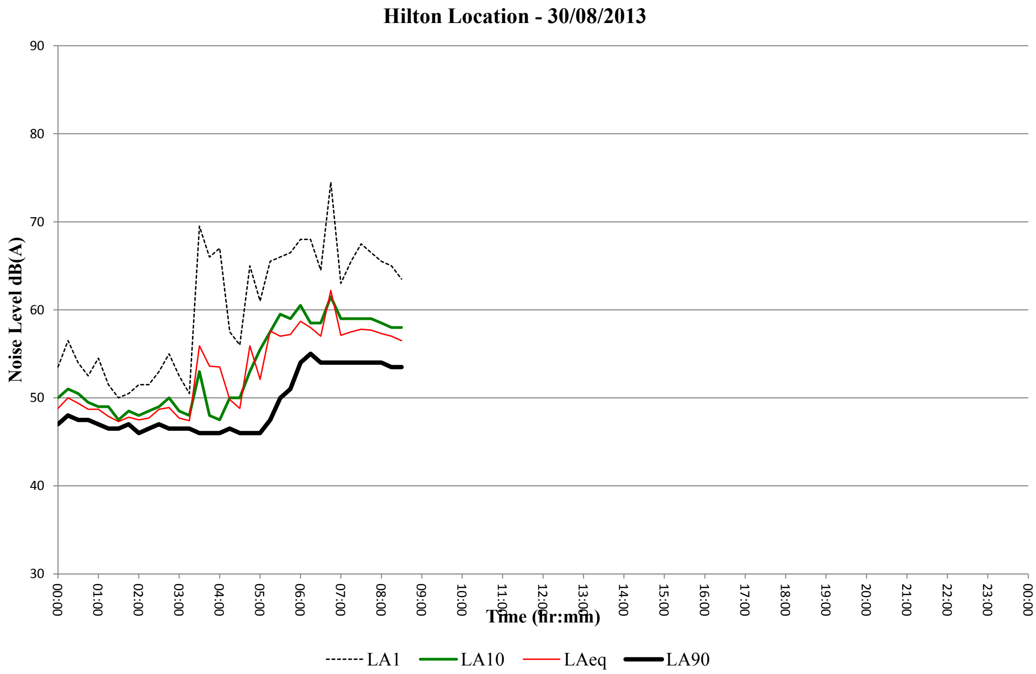
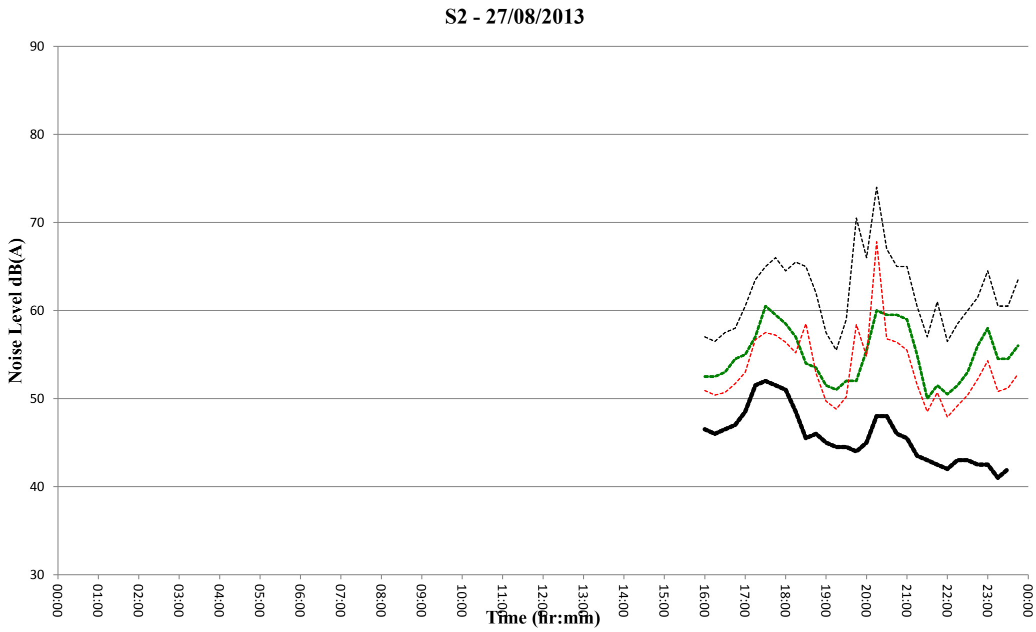




Figure D7.5.2a Ambient Noise Levels at Hilton Hotel Logger



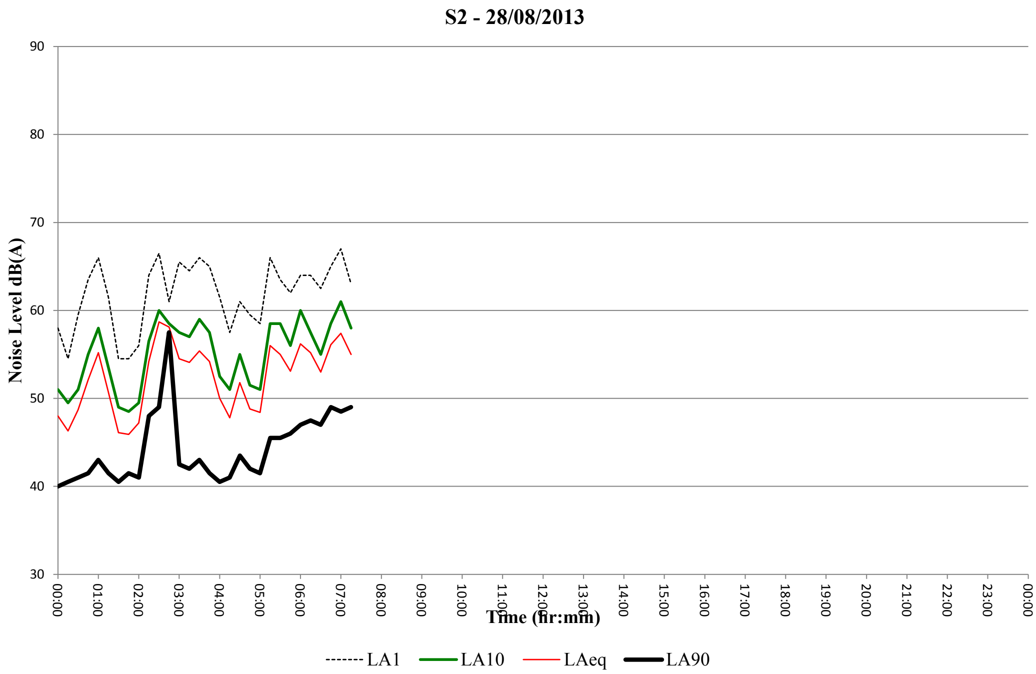




Figure D7.5.2b Ambient Noise Levels at Shed 2 Logger (note logger data beyond 28/8 affected by vandalism of logger)

### D7.5.3 Typical Underwater Ambient Noise Levels

In the absence of any underwater ambient noise measurements taken as part of this study, or within the Port of Cairns, Wenz curves are proposed to be used to describe underwater typical ambient noise levels in the vicinity of the CSDP.

The Wenz curves (Wenz, 1962) are a family of curves showing typical ambient noise levels in open ocean areas for different sea state conditions and for different water depths from both natural and man-made noise sources. Refer to **Figure D7.5.3a** for a summary of the Wenz curves and typical noise sources contributing to the underwater ambient noise in each frequency region.

Note that the assessment criteria for underwater noise impacts are absolute level criteria – i.e. they are independent of the background noise – and hence knowledge of the existing background noise only affects the range at which noise levels from the Project will be inaudible, but does not affect the ranges at which potential adverse impacts will occur.

The Port of Cairns area is a shallow water and high-energy coastal environment. The shallow water depth means that noise from the ocean boundaries (wind and wave noise) will be higher than in deep water.

The presence of existing commercial, recreation and naval vessel movements combined with the narrow width of Trinity Inlet means that underwater ambient levels in the region are expected to be at the upper boundary of the Wenz curves at low frequencies (i.e. following the "heavy traffic noise" curve shown by the dotted red line in **Figure D7.5.3a**.

Noise levels above one kilohertz (kHz) will largely be variable depending on the sea state and weather conditions.

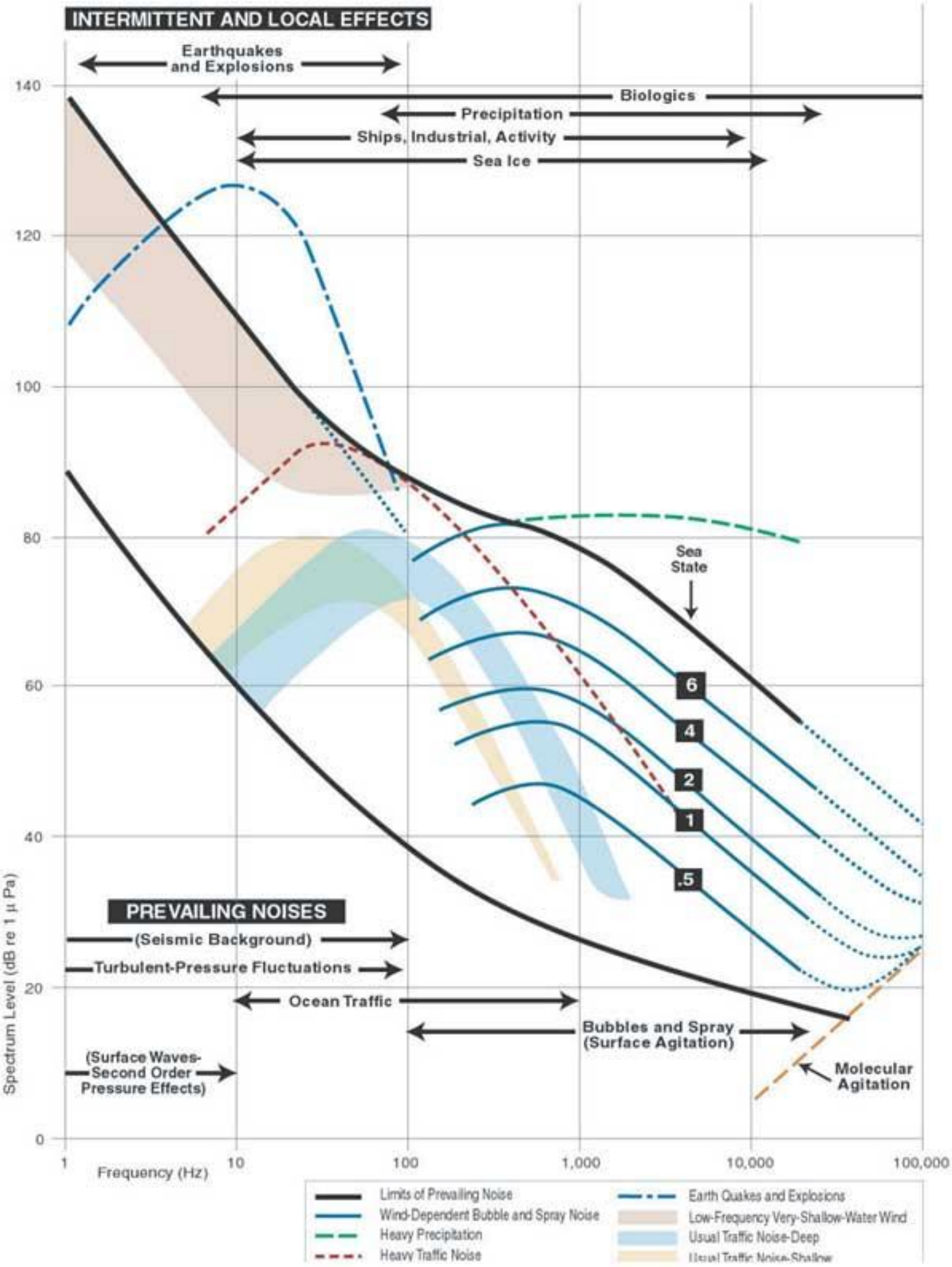



Figure D7.5.3a Wenz curves, adapted from Ocean Noise and Marine Mammals (National Research Council, 2003)

## D7.6 Impact Criteria – Airborne Noise and Vibration

### D7.6.1 Operational Noise

The Queensland environmental noise guideline relating to industrial noise is the Planning for Noise Control Guideline (PNCG), (QLD Environmental Protection Agency, 2004), which is used to set planning limits for noise emission from plant and equipment on the subject site. The PNCG provides planning limits to allow the environmental goals of the EPP (Noise) to be achieved in the long term.

The objective of the Guideline is to protect residential areas from noise generated by commercial, industrial or trade premises, and to restrict long-term increases in background noise levels. Noise limits are set based on land use in the area and existing background noise levels. Compliance is achieved if the adjusted $L_{eq}$ or $L_{90}$ noise level at any residence affected by noise from the project is below the noise limit. The adjusted $L_{eq}$ is determined by applying corrections for such noise characteristics as duration, intermittency, tonality, and impulsiveness.

The assessment of noise emission under the Guideline is based on the calculation of a noise limit at a receptor position, taking into account the land-use in the surrounding area and the existing noise levels.

The Guideline separates the day into three different time periods – day, evening and night.

Table D7.6.1a Planning for Noise Control Guideline Time Periods

| Period | Day of Week | Time Period |
|---|---|---|
| Day | Monday-Saturday<br>Sunday, Public Holidays | 0700-1800<br>0900-1800 |
| Evening | Monday-Sunday | 1800-2200 |
| Night | Monday-Saturday<br>Sunday, Public Holidays | 2200-0700<br>2200-0900 |

However, in certain cases, it is sometimes reasonable to modify these time periods to reflect the characteristics of the particular ambient noise environment. Examination of logger data for Port of Cairns shows a consistent increase in noise levels from 0600, with noise levels ramping up to be approximately at daytime values from 0600. Accordingly, adjusting the Day and Night time periods so that the Night period is 2200-0600 and the Day time period is 0600-1800 is considered to better represent the particular ambient noise conditions of Port of Cairns.

The Guideline provides guidance on acceptable noise levels from the introduction of new industrial noise sources to an area. For the purposes of noise assessment, a development such as CSDP is considered an “industrial” noise source.

The assessment procedure for industrial noise sources has three components:

- Controlling intrusive noise impacts in the short term for residences
- Maintaining overall industrial noise levels for particular land uses at acceptable level
- Limiting the increase of existing background noise levels.

Each of these components results in noise criteria that should not be exceeded in order to reduce the risk of any adverse noise impacts on the affected areas. All criteria should be taken into account when assessing the noise impact of industrial source(s) associated with the proposed development, and the lowest of the noise criteria is adopted as the project-specific noise criterion.

For CSDP, the noise sources associated with operation of the development will consist of additional discrete ship visit events (over and above the existing ship visit events associated with current operation of the Port of Cairns). Hence the implementation of the CSDP will not result in permanent increases to the background noise level at surrounding receptors.

Accordingly, only the provisions of the PNCG relating to control of annoyance (intrusive noise) and preservation of acoustic amenity are relevant to CSDP and the “background noise creep” criteria are not discussed further.

### D7.6.1.1 Specific Noise Level (Intrusiveness) Criterion

The specific noise level criterion is defined as follows:

$L_{Aeq,1\ hour} \leq minL_{A90,1hour\ (Background\ Level)} + 3$ dB

Because of the variable nature of background noise levels, the Guideline specifies single number background noise levels for use in setting the specific noise level criterion. These background noise levels are calculated using the “tenth percentile” method. The Assessment Background Level (ABL) for each time period of a day is the level exceeded by 90 % of the $L_{A90,1hour}$ measurements during that time period.

This method results in a ‘minimum repeatable’ background noise level for the subject location rather than the absolute minimum background noise level measured during the noise survey.

The Rating Background Level (denoted min $L_{A90,1hr}$ in the Guideline) for a particular time period is the median of the ABL values for that time period for each day of the measurement period. Refer for Section 3.3 for details of the measured noise levels.

**Table D7.6.1.1a** describes the Specific Noise Level criteria for each group of noise sensitive receptors.

Table D7.6.1.1a Derivation of Specific Noise Level Criteria

| **Receptors** | **Time Period** | **$minL_{A90,1hr}$** | **Specific Noise Level** |
|---|---|---|---|
| | | **dB(A)** | **$minL_{A90,1hr}$ + 3 dB(A)** |
| Wharf Street Residential | Day | 54* | 57 |
| | Evening | 48* | 51 |
| | Night | 46* | 49 |
| East Trinity | Day | 40** | 43 |
| | Evening | 35*** | 38 |
| | Night | 30*** | 33 |
| Trinity Inlet | Day | 42** | 45 |
| | Evening | 40**** | 43 |
| | Night | 40**** | 38 |

* Based on Hilton Hotel logger data

** Based on lowest measured background noise level from attended measurements

*** Based on the recommended outdoor background noise planning levels for “rural residential” areas in the *Planning for Noise Control* guideline in the absence of night-time measurements at these locations (due to safe access requirements)

**** Site surveys show that the characteristic background noise source at moored residential receivers on Trinity Inlet is wave noise, which is likely to be present at all times of the day. Hence, evening and night time background noise levels are anticipated to be similar to daytime background noise for this location.

### D7.6.1.2 Planning Noise Level (Amenity) Criterion

The *Planning for Noise Control* Guideline gives criteria for the protection of acoustic amenity for various types of receptor and different times of the day. The amenity criterion is set so that the $L_{Aeq}$ noise level from the industrial noise source does not increase the total industrial noise levels at the receptor above the Planning Noise Level (PNL) for that receptor.

Recommended PNL values are given in **Table D7.6.1.2a** of the Guideline for different noise area categories.

The Wharf Road receptors have been assessed as being in category Z6, for receptors with dense transportation and/or within commercial or bordering industrial districts.

The Trinity Inlet receptors have been assessed as category Z5, for receptors in areas with some commerce and industry.

The East Trinity receptors have been assessed as category Z3, for receptors in areas with low-density transportation.

The amenity criterion is set based on how close the existing average $L_{Aeq}$ *industrial* noise levels are to the PNL, using the adjustment factors given in Table 4 of the Guideline. In areas with no existing industrial noise exposure, the amenity criterion is equal to the PNL.

In cases where the existing $L_{Aeq,average}$ noise levels exceed the PNL by more than 2 dB(A), and the existing noise levels are unlikely to decrease in future, then the amenity criterion is set to be 10 dB(A) lower than the existing noise levels at the receptor.

Table D7.6.1.2a Derivation of Planning Noise Level (Amenity) Criteria

| **Location** | **Time period** | **Existing Industrial Leq, dB(A) (from site survey)** | **Planning Noise Level, PNL $L_{Aeq,1hour}$ dB(A)** | **Modification to PNL (Table 4, Guideline)** | **Amenity Criterion Existing $L_{Aeq}$ + modification of PNL ($L_{Aeq,1hour}$ dB(A))** |
|---|---|---|---|---|---|
| Wharf Street Receptors | Day | 58* | 70 | PNL-0 | 70 |
| | Evening | 56* | 65 | PNL-0 | 65 |
| | Night | 54* | 60 | PNL-0 | 60 |
| Trinity Inlet Receptors | Day | -** | 65 | PNL-0 | 65 |
| | Evening | -** | 60 | PNL-0 | 60 |
| | Night | -** | 55 | PNL-0 | 55 |
| East Trinity Receptors | Day | -** | 55 | PNL-0 | 55 |
| | Evening | -** | 50 | PNL-0 | 50 |
| | Night | -** | 45 | PNL-0 | 45 |

* Measured $L_{Aeq}$ from Hilton noise logger, which is dominated by existing mechanical plant noise from surrounding buildings (i.e. existing industrial noise exposure).

** No industrial noise sources were audible at these locations.

The most stringent of the Specific Noise Level and Planning Noise Level criteria applies as the limiting criterion for noise emission from CSDP.

The Specific Noise Level criterion is the most stringent in each case. This is due to the lack of existing industrial noise exposure for the majority of receptors which means that a background-noise based “intrusiveness” criterion applies over an amenity-based criterion.

### D7.6.1.3 Project-Specific Limiting Criteria

Table 1.3.2.1d: Limiting Noise Criteria for CSDP

| Receptors | Time Period | Project Noise Criterion |
|---|---|---|
| | | $L_{Aeq,1hour}$ dB(A) |
| Wharf Street Residential | Day | 57 |
| | Evening | 51 |
| | Night | 49 |
| East Trinity | Day | 43 |
| | Evening | 38 |
| | Night | 33 |
| Trinity Inlet | Day | 45 |
| | Evening | 43 |
| | Night | 43 |

### D7.6.1.4 Maximum Noise Level for Sleep Disturbance

The *Planning for Noise Control* Guideline gives criteria for maximum noise level impacts on sleep disturbance and are generally derived in reference to World Health Organisation guidelines.

**Table D7.6.1.4a** is an excerpt from the guideline relevant to this study. It gives the number of permissible noise events for different external maximum noise levels for a probability of 10 percent awakening for partially closed windows (with a noise reduction of 10 dB(A)). This criterion has been selected to protect at least 90 percent of the population from the adverse effects of transient noise.

Note that the figures derived in **Table D7.6.1.4a** are from studies into sleep disturbance in low-noise environments - i.e. absolute levels causing sleep disturbance. In practice it is also necessary to consider how "emergent" the sound source is above the existing ambient noise to determine whether any auditory masking effects will decrease the incidence of sleep disturbance.

Although auditory masking is a complex phenomenon, other Australian states have some guidance in determining whether auditory masking effects will be significant that can be used to provide additional context in applying the levels presented in **Table D7.6.1.4a**.

The NSW Road Noise Policy (NSW DECCW, 2011), its predecessor the NSW Environmental Criteria for Road Traffic Noise (NSW EPA, 1999), and the NSW RTA Environmental Noise Management Manual (NSW RTA, 2001) discuss sleep disturbance research in some detail. In addition to absolute levels for sleep disturbance, which are derived partially from WHO guidelines, the NSW guidance for sleep disturbance also includes a screening criterion of background + 15 dB(A) for "emergence" - i.e. in cases where the ambient noise is within 15 dB(A) of the noise source in question, then auditory masking effects are likely to result in reduced sleep disturbance compared to the same noise source in a low-noise environment.

Table D7.6.1.4a Emergence thresholds for maximum noise levels

| Receptors | Time Period | $minL_{A90,1hr}$ | Emergence Noise Level |
|---|---|---|---|
| | | dB(A) | $minL_{A90,1hr}$ + 15 dB(A) |
| Wharf Street Residential | Night | 46 | 61 |
| East Trinity | Night | 30 | 45 |
| Trinity Inlet | Night | 40 | 55 |

Table D7.6.1.4b Number of permissible noise events for various external maximum noise levels for partially closed windows (10% probability of awakening)

| $MaxL_{pA}$ (dBA) | 47 | 52 | 57 | 62 |
|---|---|---|---|---|
| Number of events (n) | 32 | 10 | 3 | 1 |

Consideration of sleep disturbance impacts will be made considering the following factors:

- Whether maximum noise levels exceed the ‘emergence’ thresholds in **Table D7.6.1.4a**
- The number of noise events likely to occur per night
- The absolute level of the maximum noise event relative to the thresholds in **Table D7.6.1.4b**.

**D7.6.2 Road Traffic Noise**

Road Traffic noise management in Queensland falls under the scope of the Department of Transport and Main Roads (DTMR) Road Traffic Noise Management Code of Practice (CoP) (QLD DTMR, 2007) when the road is State-controlled and under the local council when the road is not State-controlled.

There are no State controlled roads within the study area, and hence applying the CoP is not mandatory, but may be used for guidance. The Environmental Protection (Noise) Policy 1997 (QLD Government 1997) provided planning levels for road traffic noise. Although the EPP(Noise) 1997 has since been replaced by the EPP(Noise) 2008, the 2008 version does not discuss road traffic noise, and hence using the 1997 version is considered reasonable for guidance.

For non-State controlled roads, the planning level is a $L_{A10,18hr}$ noise level of 63 dB(A). This level would form the base ‘impact’ criterion for road traffic noise; however in practice it is common for existing road traffic noise levels to exceed the planning level.

It is common practice in Australia in cases where existing baseline levels already exceed the criteria to assess whether the increase in traffic noise levels due to the additional traffic associated with the development is significant. Otherwise a development may be unreasonably required to provide noise mitigation in cases where the existing traffic flows exceed the criteria.

No upgrades to roads will be constructed as a part of the development; however there will be an increase in road traffic volumes on Wharf Street and other surrounding city streets during cruise ship berthing.

As there are no current State criteria which apply to this situation (since Wharf Street and surrounding streets are not State-controlled); based on Arup’s previous project experience, the advice of the old TMR Code of Practice (QLD DTMR, 2000) and advice provided in the Design Manual for Roads and Bridges (UK) (UK DFT, 2011), noise impacts as a result of the change in road traffic volumes will be assessed against the criteria in **Table D7.6.2a** below.

Table D7.6.2a: Impact of road traffic noise increases

| Predicted Noise Change | Significance of increase |
|---|---|
| Increase of more than 15dB | Very major increase |
| Increase of 10-15 dB | Major increase |
| Increase of 6-10dB | Moderate increase |
| Increase of 3-5dB | Minor increase |
| Increase of less than 3dB | Negligible change |
| Decrease of more than 3dB | Slight decrease |

### D7.6.3 Construction Noise

Legislative requirements with respect to construction noise impacts do not exist in Queensland, with the exception of restrictions on the hours of work of construction sites which produce audible noise at a noise sensitive receptor. The EP Act restricts construction works such that no work should occur during the following hours:

- Before 6:30 am or after 6:30 pm Monday to Saturday
- At all times on a Sunday or public holiday.

For a major project such as CSDP work during the restricted hours may be necessary for reasons of public safety or to minimise disruption to essential services.

Dredging is proposed to occur 24 hours per day, while piling is proposed to be restricted to the standard hours wherever possible.

Accordingly, it is important to adopt a procedure for managing noise impacts from construction of CSDP both during standard construction hours and outside standard hours, since it is not feasible to undertake dredging activities entirely during standard hours.

In the absence of State noise criteria, the NSW Interim Construction Noise Guideline (ICNG) (NSW DECC, 2009) has been adopted. ICNG represents Australian best practice for the management of construction noise impacts from major projects.

The ICNG provides recommended noise levels for airborne construction noise at sensitive land uses. The guideline provides construction managers with noise levels above which all feasible and reasonable work practices should be applied to minimise the construction noise impact.

The ICNG sets out management levels for noise at sensitive receptors, and how they are to be applied. Management levels are based on the existing background noise levels in the absence of construction activity (represented by the Rating Background Level (RBL) parameter). Refer to Section 3.3 for details of the noise survey.

These management noise levels for residential receptors are reproduced below, in **Table D7.6.3a** (modified slightly to reflect the QLD standard hours for construction). Noise levels apply at the worst affected property boundary of the residence, at a height of 1.5 metres (m) above ground level. If the property boundary is more than 30 m from the residences, the noise levels apply at the most noise-affected point within 30 m of the residence.

Table D7.6.3a ICNG management levels for airborne construction noise at residences

| Time of day | Management level, LAeq(15min) | How to apply |
|---|---|---|
| Recommended standard hours: Monday to Saturday<br>6:30 am to 6:30 pm<br>No work on Sundays or Public Holidays | Noise affected<br>RBL + 10 dB | The noise affected level represents the point above which there may be some community reaction to noise.<br>Where the predicted or measured LAeq (15 min) is greater than the noise affected level, the proponent should apply all feasible and reasonable work practices to meet the noise affected level.<br>The proponent should also inform all potentially impacted residents of the nature of works to be carried out, the expected noise levels and duration, as well as contact details. |
| | Highly noise affected<br>75 dB(A) | The highly noise affected level represents the point above which there may be strong community reaction to noise.<br>Where noise is above this level, the relevant authority (consent, determining or regulatory) may require respite periods by restricting the hours that the very noise activities can occur, taking into account:<br>Times identified by the community when they are less sensitive to noise (such as before and after school for works near schools, or mid-morning or mid-afternoon for works near residences).<br>If the community is prepared to accept a longer period of construction in exchange for restrictions on construction times. |
| Outside recommended standard hours | Noise affected<br>RBL + 5 dB | A strong justification would typically be required for works outside the recommended standard hours.<br>The proponent should apply all feasible and reasonable work practices to meet the noise affected level.<br>Where all feasible and reasonable practices have been applied and noise is more than 5 dB(A) above the noise affected level, the proponent should negotiate with the community. |

For out-of-hours work, the ICNG uses a level 5 dB above the noise-affected level as a threshold where the proponent should negotiate with the community.

Although the ICNG does not use this terminology, in this assessment, the term “Highly-Noise Affected Level” has been used to refer to this level (i.e. 5 dB(A) above the Noise Affected Level for out-of-hours work) for reasons of brevity.

This results in the following construction noise targets for CSDP as outlined in **Table D7.6.3b**.

Table D7.6.3b Construction Noise Impact Criteria, CSDP

| Receptors | Time Period | minLA90,1hr (RBL) | Noise Affected Level | Highly-Affected Noise Level |
|---|---|---|---|---|
| | | dB(A) | dB(A) | dB(A) |
| Wharf Street Residential | Day | 54 | 64 | 75 |
| | Evening | 48 | 53 | 58 |
| | Night | 46 | 51 | 56 |
| East Trinity | Day | 40 | 50 | 75 |
| | Evening | 35 | 40 | 45 |
| | Night | 30 | 35 | 40 |
| Trinity Inlet | Day | 42 | 52 | 75 |
| | Evening | 40 | 45 | 50 |
| | Night | 40 | 45 | 50 |

It is important to note that the ICNG targets are not noise limits as such, but screening criteria for assessing whether construction noise is likely to have adverse impacts and hence whether "feasible and reasonable" work practices should be implemented during the construction process in order to reduce noise levels.

### D7.6.4 Vibration

#### D7.6.4.1 Human Comfort

Legislative requirements with respect to vibration do not exist in Queensland, however, guidance for vibration limits for human comfort is provided in the NSW EPA *Assessing vibration: A Technical Guideline 2006* document (NSW Department of Environment and Conservation, 2006), which is referenced in AS2436 (Standards Australia, 2010) as providing standard guidance for vibration from construction activities.

Vibration generating equipment from CSDP construction (such as piling) is best characterised as being intermittent vibration sources.

The *Assessing Vibration* guideline recommends impact threshold levels to manage vibration impacts from intermittent vibration, using the Vibration Dose Value (VDV) parameter, which is a complicated parameter taking into account both the level of vibration and its duration.

BS 5228.2(BSI 2009) also provides guidelines for human comfort, but using a simplified metric (the Peak Particle Velocity), which only takes into account the maximum level of vibration. These are broadly similar to the maximum recommended values for human comfort from AS 2670.2.

The VDV parameter is more robust, but requires more information and is more difficult to measure, while the PPV parameter is relatively straightforward to apply. Hence, the VDV criteria should be assessed wherever possible, but for some equipment or vibration sources there may not be enough information to calculate VDV at this stage of assessment and a simplified assessment using PPV may be necessary. Hence, criteria for both parameters are presented, but the VDV criteria should take precedence wherever it is practicable to assess VDV. Vibration impact criteria are given in **Table 1.3.1.2a**.

For intermittent vibration, the following impact threshold values are recommended based on BS 5228.2 and the *Assessing Vibration* guideline.

Table D7.6.4.1a Vibration impact criteria for construction vibration – Human Comfort

| Impact Category | PPV (mm/s) | VDV ($m/s^{1.75}$) | | Subjective Impact (from BS5228.2) |
|---|---|---|---|---|
| | | Day (0700-2200) | Night (2200-0700) | |
| Negligible | PPV ≤ 0.3 | VDV ≤ 0.2 | VDV ≤ 0.13 | Vibration just perceptible |
| Minor | 0.3 < PPV ≤ 1.0 | 0.2 < VDV ≤ 0.4 | 0.13 < VDV ≤ 0.26 | Vibration perceptible, potential for complaint |
| Moderate | 1.0 < PPV ≤ 10 | 0.4 < VDV ≤ 0.8 | 0.26 < VDV ≤ 0.52 | Complaints likely |
| Major | PPV > 10 | VDV > 0.8 | VDV > 0.52 | Vibration likely intolerable |

### D7.6.4.2 Building Damage

There is little reliable data on the threshold of vibration-induced damage in buildings. Although vibrations induced in buildings by ground-borne excitation are often noticeable, there is little evidence that they produce even cosmetic damage (BRE 1995). This lack of data is one of the reasons that there is variation between international standards, why the British Standards Institution (BSI) did not provide guidance before 1992 and why there are still no International Organisation for Standardisation (ISO) guidance limits.

There are however several standards that can be referred to, including German Standard DIN 4150, which is commonly used in Australia for assessing impacts to heritage or other sensitive building structures.

DIN 4150: Part 3: 1986 gives guidelines for short-term and steady state structural vibration. For short-term vibration in buildings the following limits are given:

Table D7.6.4.2a Guideline Values of Vibration Velocity, $v_i$, for Evaluating the Effects of Short-term Vibration

| Structure type | Vibration Velocity in mm/s | | | |
|---|---|---|---|---|
| | Foundation | | | Plane of floor of uppermost full storey |
| | less than 10Hz | 10 to 50Hz | 50 to 100Hz | Frequency mixture |
| Commercial, Industrial or Similar | 20 | 20 to 40 | 40 to 50 | 40 |
| Dwellings or Similar | 5 | 5 to 15 | 15 to 20 | 15 |
| Particularly Sensitive | 3 | 3 to 8 | 8 to 10 | 8 |

The guidelines state that:

"*Experience to date has shown that, provided the values given in Table A2 are observed, damage due to vibration, in terms of a reduction in utility value, is unlikely to occur. If the values of table A2 are exceeded, it does not necessarily follow that damage will occur. Should these values be significantly exceeded, further investigation is necessary*"

Hence, adopting 3 mm/s as a screening criterion for impacts to the heritage wharf structure is considered appropriate, with a screening criterion of 5 mm/s for residential structures. If construction vibration does not exceed these thresholds, no building damage impacts are likely.

### D7.7 Impact Criteria for Marine and Terrestrial Fauna

In the absence of specific legislative criteria for assessing impacts on marine and terrestrial fauna, a literature review has been conducted to identify the hearing characteristics of species and derive appropriate impact criteria for each species.

#### D7.7.1 Hearing Characteristics of Species

##### D7.7.1.1 Marine Mammals

The hearing abilities of marine mammals are well documented. Behavioural audiograms (animal hearing capability measurements plotted against the frequency of sound, including hearing thresholds) have been taken for several species (Nedwell et. al, 2004). The effects of sound masking have been partially investigated, as has the ability of species to discriminate in terms of both frequency and direction of sound.

While the hearing abilities of most marine mammal species have been tested, only one or two individuals in each species have been studied, so variations in hearing ability among individuals is not known (Nedwell et. al, 2004).

However, available data shows reasonably consistent patterns within the following groups:

- Mysticetes (Baleen Whales that have a filtering system) ("low-frequency cetaceans") [e.g. Humpback Whales, which are unlikely to frequent the shipping channel but may be present in open waters near the DMPA]
- Small and medium-sized Odontocetes (toothed Whales and Dolphins) ("mid-frequency cetaceans") [e.g. Australian Snubfin Dolphin and Indo-Pacific Humpback Dolphin, which may possibly utilise Cairns Harbour]

<u>Mysticetes</u>

Mysticetes produce primarily low-frequency sound (below one kHz (Richardson, 1995)), although humpback whales produce sounds with frequencies above one kHz. Baleen whale vocalisations are a combination of low-frequency "moans"; noise-like impulsive "grunt" or "ratchet" calls, and complex "whale song" (National Research Council, 2003).

Very little data are available about the hearing capabilities of Mysticetes and no audiograms have been published in the available literature; however studies based on the physiology of Mysticete hearing mechanisms suggests that most Mysticetes can hear down to approximately 20 Hertz (Hz) (Ketten, 1997) with greatest hearing sensitivity in the range 100-5000Hz (Ketten, 1997).

<u>Odontocetes</u>

Odontocetes (dolphins) produce mainly high-frequency sound, a combination "clicks" used for echo-location and vocalisation "whistles" used for communication between individuals. Hearing ranges from existing Odontocete data have been shown to range up to approximately 110kHz, with greatest sensitivity in the range of 8–90kHz. Hearing is relatively insensitive below 1kHz, but is generally very accurate above this range A graph of underwater audiograms of various Odontocetes is shown in **Figure D7.7.1.1a**.

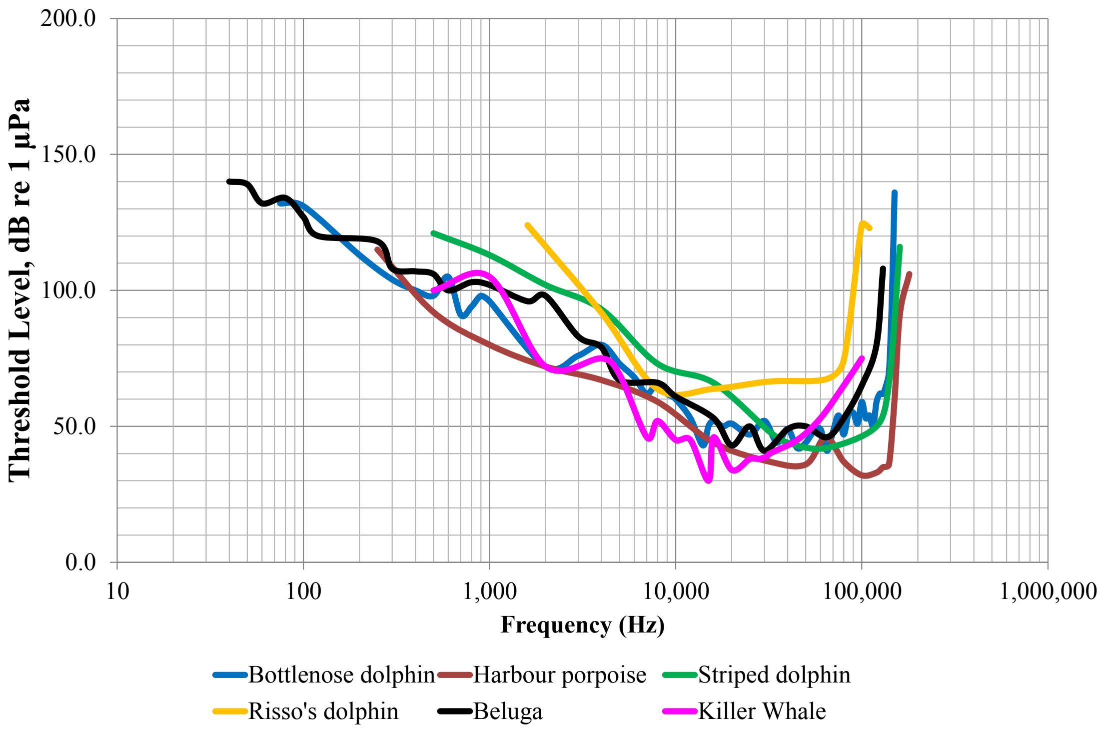



Figure D7.7.1.1a Underwater audiograms of various Odontocetes, using data from Nedwell et al, 2004

Odontocetes appear to be largely insensitive to low-frequency sounds, with measured hearing thresholds generally greater than 100 decibels (dB) (relative to one micropascal (µPa) – i.e. dB re 1 µPa) at frequencies below 1kHz (Richardson et al, 1995)) but may be sensitive to some combination of low-frequency particle motion and pressure fluctuations when in the near-field of the acoustic source – in other words, they may 'feel' the sound through the movement of the water itself rather than 'hearing' it through their ears, but only when close to the source.

Unfortunately, studies are frequently inconclusive as to the precise level at which these impacts occur, and the level of sensitivity of different species to noise varies (Richardson et al, 1995).Hence, it is often necessary to adopt a conservative approach to managing noise impacts (under the Precautionary Principle) since the actual safe level of noise exposure is not always known.

In the absence of specific audiometric studies of the Australian snubfin dolphin (*Orcaella heinsohni*) and Indo-Pacific Humpback dolphin (*Sousa chinensis*), the bottlenose dolphin (*Tursiops truncatus*) has been adopted as a representative species for assessing noise impacts on odontocetes.

<u>Dugongs</u>

There is limited data in the literature as to the sensitivity of dugongs (with only one audiogram referred to in the literature: unpublished work by Ketten that is referenced in Hodgson 2004), which indicates that dugongs have a hearing range of 4-32 kHz.

There are, however, a small number of published audiograms for the related manatee, which indicates that dugongs are likely to have highly-sensitive hearing, with lowest thresholds of the order of 80 dB re 1 µPa for frequencies below 1 kHz (based on published audiograms from Gerstein et al 1999 in Nedwell et al 2004).

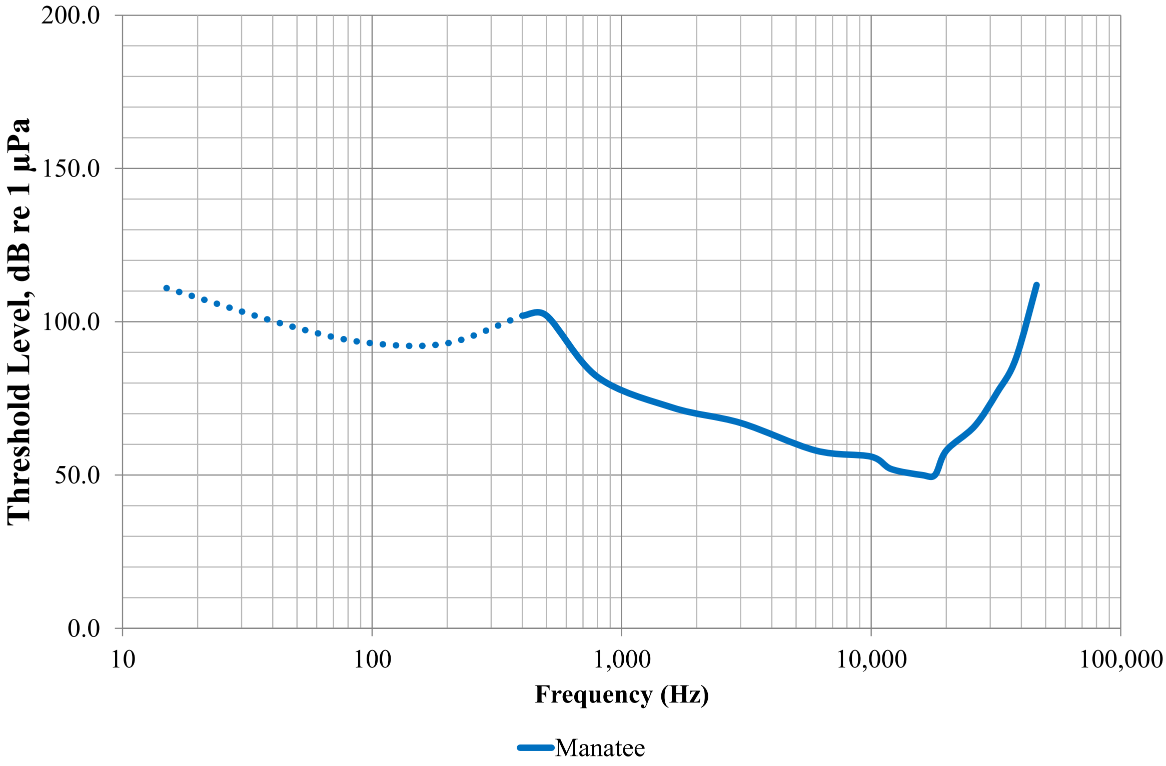



Figure D7.7.1.1b Underwater audiograms of sirenians, using data from Nedwell et al, 2004 (note data below 400 Hz may be vibration "felt" response rather than auditory "heard" response)

The threshold of sirenians at frequencies below 1 kHz appear to be approximately 10 dB more sensitive than those for odontocetes over the frequency range 400 Hz-1kHz, although Gerstein et al cautioned that the data for frequencies below 400 Hz may be the result of the test animal feeling the sound signal via vibration (in the small test pool) rather than a true hearing threshold, since the "hearing" below 400 Hz was only observed in this animal after months of repeated tests.

**D7.7.1.2 Fish**

Fish have an inner ear similar to mammals, but lack an outer ear. Hence there is no mechanism for external sound pressure to be directly transmitted to the inner ear, and fish hearing depends on the particular anatomy of the fish as to how efficiently an external sound is transmitted to the inner ear. This results in a wide variety of hearing capabilities between species of fish. Nedwell et al (2006) have broadly split the hearing abilities of fish into three groups of low, medium and high hearing sensitivity. Differences are a result of the anatomy of the fish, including whether it has a swimbladder (a gaseous structure that helps the fish stay at a constant depth) and whether the swimbladder is mechanically coupled to the inner ear of the fish (Nedwell et al, 2004). The hearing thresholds of several "hearing generalist" fish species are shown in **Figure D7.7.1.1c** below.

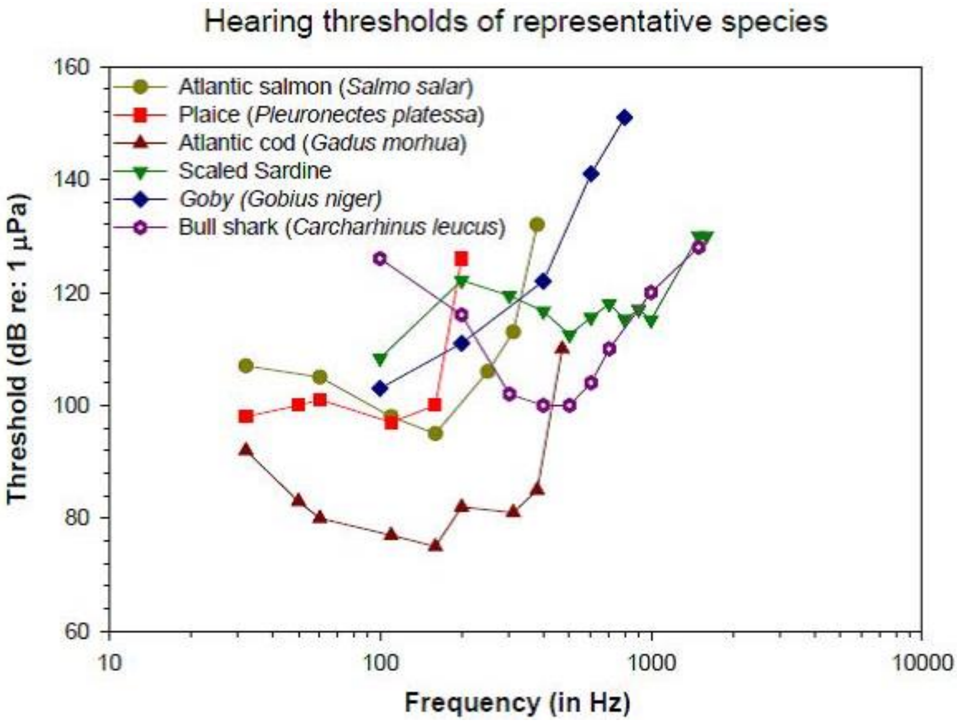


Figure D7.7.1.1c Hearing thresholds of several "hearing generalist" fish species, adapted from Hastings and Popper (2005).

The majority of research into hearing capabilities of fish has been done on northern hemisphere species, and few (if any) studies have been undertaken on species likely to be found in the vicinity of the Port of Cairns. Hence it is necessary to estimate the likely hearing sensitivity of species relevant to this Project based on the known anatomical characteristics of these species.

With regard to the important fish species present in the Coral Sea, the Snapper, Whiting and Yellowfish, all these species have swimbladders, but are not known to have efficient coupling between the inner ear and the swimbladder. Hence these species are expected to have medium hearing sensitivity, similar to the Cod audiogram presented in **Figure D7.7.1.1c**.

<u>Sharks</u>

Sharks are mainly sensitive to low-frequency (below 1 kHz) sound (Hastings & Popper, 2005) although sharks are known to be highly sensitive to particle motion via their lateral lines. Shark hearing extends down to "infrasonic" frequencies (below the normal lower threshold of human hearing of 20 Hz), although it is unclear how much of this relates to perception of pressure or perception of particle motion.

In the absence of widespread research into the acoustic sensitivity of sharks, impacts on sharks will be modelled using criteria derived for fish.

### D7.7.1.3 Chelonians

Sea turtle hearing (hearing ability and dependency on sound) for survival cues is not well documented or understood. Hearing was shown by Ridgway et al to be most sensitive at around 400 Hz, and to stop at around 1 kHz (Marine Mammal Commission, 2007), while Richardson et al reported that sea turtles have limited vocalisation ability in the 100-700 Hz range (Richardson et al, 1995). Hearing thresholds have not been determined conclusively; each life stage of sea turtles is marked by exceptional differences in auditory structures. These correspond to, for example, the differences between the shallow water habitats of the juvenile and adult which are much noisier than the open ocean environment of the hatchling stage (Marine Mammal Commission, 2007)

### D7.7.1.4 Migratory and Shorebirds

There is little or no information available in the literature as to the underwater hearing characteristics for migratory birds or shorebirds.

Airborne hearing characteristics of birds are similar to those of humans, although birds generally have a higher hearing threshold than humans (~10-20 dB less sensitive) and are sensitive over a narrower frequency range (1-5 kHz) (Dooling and Popper, 2007). Audiograms are available for approximately 50 bird species, mainly songbirds or parrots, but including some waterfowl (e.g. mallard duck) (Dooling 2002).

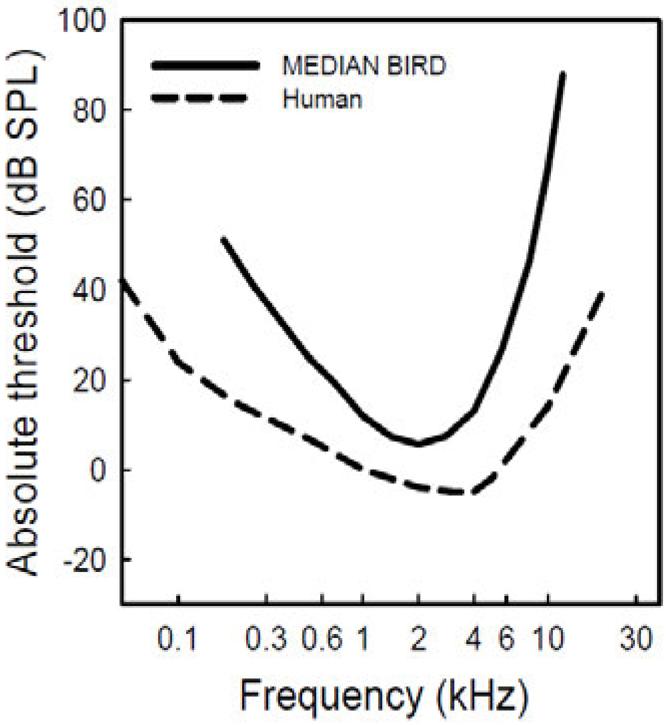



Figure D7.7.1.1c Average airborne hearing thresholds of birds, with average human hearing threshold for comparison, adapted from Dooling and Popper (2007).

**D7.7.2 Underwater Noise Impact Criteria**

Research into the effects of underwater noise and blasting on marine animals and plants is frequently inconclusive, and there are difficulties in applying the results of research for one species to another. However, available noise criteria are summarised in the following sections.

Various studies on marine animal behaviour, including reactions to noise, are available in the literature. Sound stimuli range from frequency-specific stimuli to explosions/seismic airguns. These studies have shown that underwater noise can have adverse behavioural or physiological effects on underwater life.

The adverse effects, in ascending level of impact (and in ascending order of noise exposure) are, broadly:

1) Auditory masking (the presence of noise causes important biological sounds to be obscured). This has generally impacts that persist only as long as the masking sound is on operation (i.e. generally short-term except in cases of chronic noise exposure), for example:

- Missing out on feeding opportunities
- Impeded communication (social interaction, mating calls, etc.)
- Decreased ability to detect predators or danger.

2) Avoidance behaviour (animals becoming stressed and leaving the vicinity of the noise source). This can have long-term adverse effects on a species, for example:

- Disruption of migration, breeding or feeding patterns
- Separation of infant animals from adult animals (and consequent increased vulnerability to predators)
- In cases of chronic exposure, long-term physiological impacts due to prolonged increase in levels of stress hormones

- In extreme cases, physical injury or death if behavioural changes lead to vessel collisions or strandings.

3) Temporary hearing damage, due to fatigue/exhaustion of the auditory system. Hearing ability recovers over a timeframe of hours or days. This has short-term adverse impacts such as:

- Increased vulnerability to predators
- Disorientation (for species that rely wholly or partially on sound for navigation or hunting), reducing ability to feed and increasing the risk of stranding
- Reduced ability to communicate (disrupting group social behaviour, ability to hear mating calls.).

4) Permanent hearing damage, due to cell death of the auditory system (either physical damage to the hearing structures or nerve damage to the auditory nerve). This has similar impacts to temporary hearing damage, but the impacts are permanent rather than short term.
5) Physical trauma/injury (especially to gas-containing structures), which can lead to death.
6) Fatality.

### D7.7.2.1 Masking

Marine Mammals

Masking occurs if the noise source has similar level and frequencies to the biologically significant sound. Therefore, masking from construction or operation of CSDP would be more likely to occur for mysticetes, which communicate using low-frequency sound at similar frequencies to piling or shipping noise.

Masking for odontocetes, which communicate using mid- to high-frequency sound, would be expected to be less likely to occur, although low-frequency noise can cause some masking of higher frequencies in what is termed "upward masking", which has been observed in *odontocetes* (Branstetter, 2007).

There are few studies into the effects of masking for marine animals, although some studies have suggested that marine animals can compensate for masking effects by lengthening their call duration (Miller, 2000). As a result, few criteria for avoiding masking are available.

Diederichs et al (2008) quote a study by Lucke et al (2007) into masking of harbour porpoise calls by noise from wind turbines, which concluded that no significant masking effects occurred below a level of 115 dB at 1µPa.

In the absence of more detailed research into the effects of masking on marine mammals, the criterion of 115 dB at 1 µPa from Lucke et al has been adopted for use in this study.

Other Species

No available information on auditory masking could be found in the literature for other species.

### D7.7.2.2 Behavioural Response

Nedwell (2007a) has proposed a metric for assessing behavioural response and hearing damage for species in terms of the perceived loudness of a sound above the hearing threshold of the species (hence $dB_{\text{hearing threshold (ht)}}$ = "dB hearing threshold"). $dB_{ht}$ values in general must include the species (e.g. $dB_{ht(\textit{Tursiops truncatus})}$ when assessing the bottlenose dolphin). $dB_{ht}$ is essentially equivalent to the dB(A) weighting used for measuring the subjective human response to noise (an expression of the relative loudness of sound in air as perceived by the human ear– i.e. dB(A) is effectively the $dB_{ht}$ for humans).

$dB_{ht}$ adjusts the sound field based on the ability of the animal to perceive the sound (e.g. ignoring energy that lies in a frequency range where the animal is not sensitive).

This has advantages in that it allows the response of different species to be assessed using consistent units – essentially, in terms of the perceived loudness of the sound on a species-by-species basis – but has disadvantages that the audiogram of the species must be known, and that results must be calculated separately for each species.

Studies (summarised in Nedwell et al, 2005) have indicated that extensive (>50%) avoidance reactions begin above approximately 50 $dB_{ht}$; above a level of 90 $dB_{ht}$ for each species approximately corresponds to strong avoidance behaviour for virtually all individuals; levels above 70 $dB_{ht}$ correspond to the region where temporary hearing damage may occur for prolonged levels of exposure, with the required exposure decreasing with level up until levels greater than 130 $dB_{ht}$ where instantaneous permanent hearing damage occurs. These are approximately analogous to the known characteristics of human hearing in air.

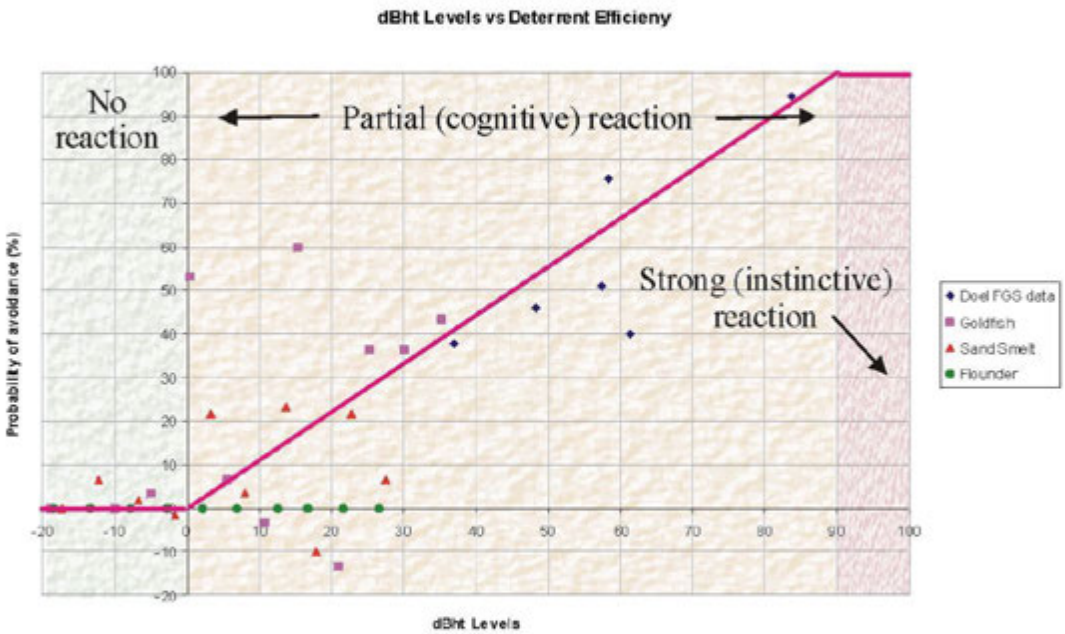



Figure D7.7.2.2a Approximate relationship between dBht and reaction to noise (adapted from Nedwell, 2005)

However, this is based on the assumption that the total dynamic range of hearing is approximately constant for all species (approximately 130 dB as per humans) – while this is well-justified for many species, in some cases this may not be true and hence $dB_{ht}$ should be used with caution due to the lack of other studies.

Noting this potential limitation, using a level of 90 $dB_{ht}$ is considered to be a generally useful threshold for strong avoidance for some species (e.g. fish and marine mammals) where it has been verified by other studies and where the physiological assumption of 130 dB dynamic range is valid, but should be used with caution for other animals (e.g. chelonians) that are more biologically-distinct from humans.

Marine Mammals

Gaining conclusive criteria for behavioural changes is very difficult as it requires observation of what 'normal' behaviour of the animal in the absence of noise (and, potentially, in the absence of human observers) would be, and in that the studies only concern short-term reactions of the animals.

Assessing disturbance is complicated by the uncertainty in the hearing capabilities of some species discussed previously, as it can be difficult to know whether a noise source was audible for a particular animal when a 'disturbance' reaction was observed.

However, there is some guidance in the literature that gives some indications of likely levels where disturbance to marine mammals may occur. The level of disturbance differs depending on whether the noise source is impulsive or continuous.

Richardson et al (2004) present a summary of research into the reactions of whales to drilling noise (i.e. a continuous noise source). Research has mainly been conducted into northern-hemisphere species, particularly the bowhead whale and the grey whale. Reactions of whales to drilling noise were sometimes inconsistent, with whales sometimes reacting to noise at a particular level, but showing no reaction at other times.

For bowhead whales, approximately 50percent of whales showed avoidance behaviour (turning away, etc.) at levels of approximately 115 dB re 1 μPa (Richardson, 1988); a similar result was obtained by Malme et al (1984), with 50 percent avoidance being observed for grey whales at a level of 117 dB re 1 μPa.

Strong avoidance reactions in bowhead whales were observed by Richardson et al at a received level of 124 dB re 1 μPa, while Malme et al observed 90percent avoidance of grey whales at a level of 122 dB re 1 μPa.

The US National Oceanic and Atmospheric Administration (NOAA) (2011) presents interim guidelines for behavioural response for marine mammals of 160 dB re 1 μPa for impulsive noise sources and 120 dB re 1 μPa for continuous noise sources. This is largely consistent with the other research discussed in this Section.

These guidelines have been incorporated into the South Australian *Underwater Piling Noise Guidelines* (SA DPTI, 2012).

In cases where the background noise is close to or exceeds 120 dB re 1 μPa a raised threshold for disturbance would be expected, although the NOAA does not provide guidance as to how much higher the raised threshold would be.

Although this research was mainly conducted on northern hemisphere populations of whales, in the absence of research on Australian whale populations it is considered reasonable to use this available data to obtain the following criteria for disturbance reactions:

- Continuous Noise 120 dB re 1 μPa
- Impulsive Noise 160 dB re 1 μPa

<u>Dugongs</u>

There have been some limited studies into the behavioural response of dugongs and other sirenians to human activities. Anderson (1982) discusses some instances of dugongs exhibiting avoidance behaviour from unfamiliar sources; however other studies (e.g. Kinnaird 1983, Hodgson 2004) showed no significance disturbance reactions, even at levels up to 197 dB re 1 μPa. Studies have concluded that sirenians appear to habituate to noise sources in high-traffic areas (e.g. Hodgson's studies in Moreton Bay) and therefore that given the existing presence of shipping traffic in Trinity Inlet that disturbance/avoidance reactions are unlikely to occur for CSDP.

As an interim, the disturbance criteria for whales will be adopted for dugongs.

<u>Fish</u>

Hastings and Popper (2005) present an overview of research into behavioural impacts of fish. Available research is inconclusive; although studies showed that fish may exhibit a behavioural response at levels over 160 dB re 1 μPa (peak), another study showed no behavioural impacts at levels of 210 dB re 1 μPa (peak).

A further study (Mieller-Blenkle et al, 2010) of the effects of pile driving noise on fish showed avoidance reactions from cod in the range 140-160 dB re 1 μPa (peak), and from sole in the range 144-156 dB re 1 μPa (peak).

Although the studies cited by Hastings and Popper showed that fish avoided the area around loud underwater noise sources (specifically seismic surveys), fish appeared to return to the area after several days.

In light of the lack of consistent findings from the available literature, it is difficult to set a criterion beyond using the 140 dB re 1 μPa level as a very conservative threshold for possible behavioural impacts.

Use of the 90 $dB_{ht}$ metric (where possible) is considered a more appropriate criterion.

Chelonians

McCauley et al (2000) also investigated the impacts on sea turtles (individuals of Green Turtle and Loggerhead Turtle) of a seismic air gun array, and observed a possible avoidance reaction at received levels of 165 dB re 1 μPa and possible alarm reactions (strong avoidance) at received levels of ~175 dB re 1 μPa.

Hence the following criteria are recommended for sea turtles:

- Medium disturbance: 165 dB re 1 μPa
- Strong disturbance: 175 dB re 1 μPa

Migratory and Shorebirds

Manci et al (1988) discuss impact criteria for wildlife exposed to aircraft noise sources. Although the studies referenced in Manci et al relate to airborne noise, applying the findings to noise from CSDP is considered conservative because the rise time of shipping noise is significantly longer than the rise time of aircraft noise – hence shipping noise (of the same absolute level) is less likely to cause a startle reaction.

Manci et al quote results from Jehl and Cooper (1980), who observed startle responses and disturbed nesting behaviour from seabirds when exposed to sonic booms with received levels of between 72-89 dB(A).

Cutts et al (2013) have developed a toolkit for assessing disturbance to waterbirds from activities from estuarine construction projects that sets indicative disturbance thresholds. They concluded that:

- Noise levels below 55 dB(A) are unlikely to cause disturbance responses
- Noise levels above 60 dB(A) are likely to cause moderate disturbance (some disturbance of birds, particularly for very-sensitive species)
- Noise levels above 72 dB(A) are likely to cause high (major) disturbance (most birds exhibiting avoidance behaviour, and reduced foraging effectiveness of remaining birds)

These figures are for repeated/intermittent noise sources (e.g. typical construction activities), and for areas with quiet ambient noise (disturbance thresholds would be higher in levels with high ambient noise since birds will habituate). Isolated noise events are likely to be more disturbing since birds will habituate to repeated noise events).

Adopting an airborne disturbance criterion of 72 dB(A) $L_{max}$ is considered to be an appropriate criterion. Significant disturbance to migratory habitat areas on the mudflats within Trinity Inlet is considered unlikely if levels are below the 72 dB(A) screening criterion.

### D7.7.2.3 Temporary Hearing Damage

<u>Cetaceans</u>

Most available studies into temporary threshold shift (TTS) in marine mammals from underwater noise exposure have focussed on *odontocetes* in the context of exposure to sonar signals (i.e. high frequency), and therefore little or no data for *mysticetes*, or for low-frequency noise sources is available. A common definition between studies is the use of a criterion of six dB threshold shift to define the onset of "significant" TTS, since threshold shifts below this threshold cannot be reliably measured (Finneran, 2005).

Nachtigall et al (2004) discuss the onset of TTS in bottlenose dolphins exposed to high-frequency sound (eight kHz and above) at levels of 160 dB re 1 µPa – although this is from continuous exposure (30 mins); studies with short (approximately one second) exposure times showed much higher thresholds for TTS (e.g. 195 dB re 1 µPa in a study by Ridgeway et al, 1997), and studies with impulsive sound sources showed higher peak levels are required to cause significant TTS.

For impulsive low-frequency sound, the only available data is that of Finneran et al (2002), who observed TTS in a beluga exposed to a seismic source of 226 dB re 1 µPa, although no TTS was observed in a bottlenose dolphin for exposure at the same level.

A further complication is that piling consists of repeated short pressure spikes, and hence noise exposure is cumulative from multiple exposures. Hence, SEL (Sound Exposure Level) is a better descriptor for determining TTS thresholds than SPL (Sound Pressure Level), since the SPL required to cause TTS is a function of exposure time, whereas the SEL required to cause the onset of significant TTS is essentially constant (approximately 195 dB re 1 $\mu Pa^2 \cdot s$) (McCauley et al, 2000).

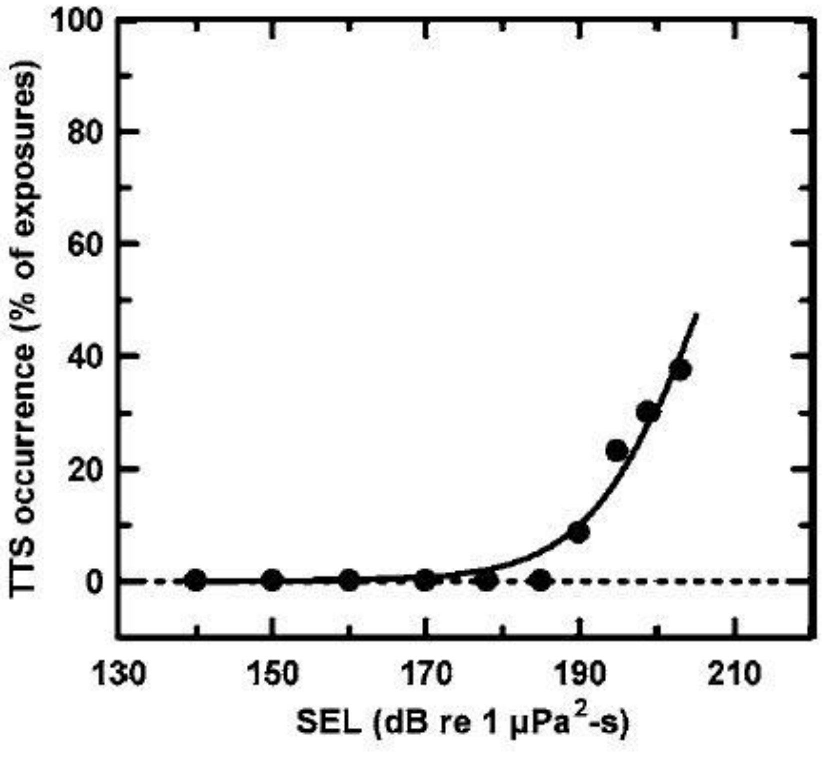



Figure D7.7.2.3a Approximate relationship between SEL and percent occurrence of significant TTS in mid-frequency odontocetes, adapted from Figure 8 of Finneran et al (2005)

A criterion of 160 dB re 1 µPa (unweighted) has been adopted for *continuous noise* for all marine mammals (derived from the Nachtigall et al data for 15-minute exposure (Nachtigal, 2004), although the frequency of underwater construction activities (e.g. workboats) is significantly lower than the frequencies used to obtain this criterion, hence this is considered to be a conservative criterion.

For impulsive noise, the criteria presented in Southall et al (2007) are considered most appropriate, since they that include criteria for the sound exposure level, using the M-weighting, which accounts for the differing sensitivity of different types of cetacean. These criteria have been adopted in the South Australian *Underwater Piling Noise Guidelines* (DPTI, 2012).

The M-weighting functions $M_{lf}$ for low-frequency cetaceans (i.e. baleen whales) and $M_{mf}$ for mid-frequency cetaceans (i.e. toothed whales) are shown in **Figure D7.7.2.3b**.

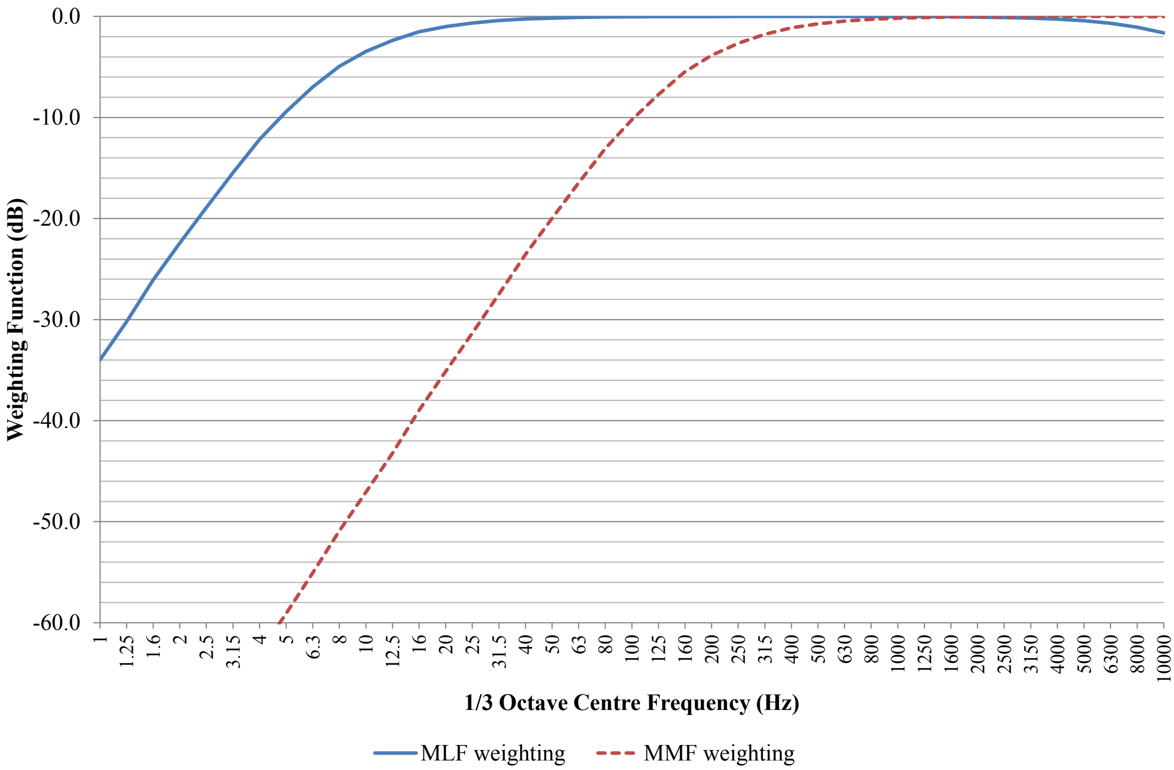



Figure D7.7.2.3b M-weighting functions for baleen whales and toothed whales

In addition, the 70 $dB_{ht}$ level may be useful as an alternate indicator for onset of TTS (Nedwell. 2007a), with significant TTS occurring above approximately 90 $dB_{ht}$.

Dugongs

There is not enough available data in the literature to set separate noise impact criteria for dugongs (with the exception of criteria based on the $dB_{ht}$ approach using the audiogram for manatees).

Due to their similar hearing frequency range, it is considered reasonable to use the criteria for odontocetes ($M_{MF}$ weighting) as a model for sirenian hearing. However, considering the more-sensitive hearing of sirenians, criteria 10 dB below those for odontocetes are proposed.

Migratory and Shorebirds

Birds have the ability to regenerate damaged or destroyed hair cells (Dooling and Popper 2007) and hence birds are resistant to permanent hearing damage; however the timeframe for full recovery may be significant (months or years) and thus it is useful to distinguish between short-term ("temporary") and long-term ("semi-permanent" hearing loss).

Dooling and Popper (2007) present interim guidelines for assessing potential hearing damage impacts on bird species, based on a summary of available literature. They conclude that airborne noise levels above 93 dB(A) may pose a risk of inducing TTS for continuous noise; although there is not enough information in the literature to set a criterion for impulsive noise sources.

An interim criterion of 110 dB(A) for impulsive noise is proposed for this study in the absence of information in the literature, based on the approximately 15 dB difference between TTS and PTS criteria for continuous noise and the quoted levels in Dooling and Popper for PTS from impulsive noise sources.

### D7.7.2.4 Permanent Hearing Damage

By analogy to human hearing, where a cumulative noise exposure of 90 dB $L_{epd}$ (i.e. 90 dB(A) over eight hours or equivalent energy) is considered the threshold of permanent hearing damage, Nedwell et al (2007a) have proposed using the equivalent 90 $dB_{ht}$ eight hour dose as a threshold for hearing damage.

Converting to a SEL (i.e. 10log (eight hours / one second)), this results in a SEL limit of 135 $dB_{ht}$ re 1 $\mu Pa^2 \cdot s$.

<u>Marine Mammals</u>

Recommended exposure criteria for various species are discussed in Parvin, Nedwell and Harland (2007) and in Diederichs et al (2008), and in Southall et al (2007). These criteria are presented for impulsive noise sources such as pile driving or blasting, where the noise is emitted as a short, powerful pulse.

For permanent hearing damage (Permanent Threshold Shift), Southall et al present an injury criterion of 230 dB re 1 µPa peak pressure for cetaceans.

<u>Fish</u>

Studies in the literature have concluded that permanent hearing damage from fish occurs from exposure to loud underwater noise, but are not conclusive as to the level at which permanent hearing damage occurs.

McCauley et al (2003) investigated hearing damage of Pink Snapper exposed to seismic airgun noise of approximately 180 dB re 1 µPa and observed damage to hair cells 18 hours after exposure (although not statistically significant), as well as statistically significant permanent damage to hair cells 58 days after exposure. Although fish can regenerate hair cells (unlike mammals) and hence some recovery of hearing loss is possible, the prolonged nature of the hearing damage indicates that a significant period of time (months or years) would be required to recover hearing and hence the damage should be considered "quasi-permanent" . However, the fish were kept caged and hence did not have the opportunity to flee the area, and thus their duration of exposure to the noise source was greater than would be expected for "wild" fish.

Hastings and Popper (2005) discuss several studies where permanent hearing damage occurred due to exposure to sound above 100 dB above the species hearing threshold; however the exposure time was generally greater than one hour and hence not necessarily representative of transient impacts on fish from pile driving.

Given the limited data available in the literature, the 90 $dB_{ht}$ "equivalent dose" approach (i.e. 135 $dB_{ht}$ SEL) is considered to be the most appropriate method for estimating permanent hearing damage for fish.

<u>Chelonians</u>

A review of scientific information by Fisheries and Oceans Canada (2004) concludes the following on the impact of anthropogenic noise (specifically seismic airgun noise) on sea turtles:

1. Auditory studies suggest that sea turtles, specifically loggerhead and green turtles, are able to hear and respond to low frequency sound, but their hearing threshold appears to be high. (Refer Section D7.7.1.3 for a discussion on *Chelonian* hearing).
2. Sea turtles may become accustomed to low-frequency noise over time, but results of three studies were inconclusive on this matter.
3. Loss of hearing sensitivity and physiological stress response has also been considered as a possible consequence of exposure of sea turtles to low-frequency noise, but the one study reviewed was inconclusive.
4. The response, if any, of free-ranging sea turtles to low-frequency noise conducted under field operating conditions is unknown.
5. Based on studies that have been conducted to date, it is considered unlikely that sea turtles are more sensitive to low-frequency noise than *cetaceans* or some fish. However sea turtles are harder to detect both visually and acoustically than many species of *cetaceans*, so mitigation strategies based on sightings or acoustic detection are expected to be less effective for turtles than for *cetaceans*.

Migratory and Shorebirds

As discussed previously, birds are highly-resistant to hearing damage and hence “permanent” threshold shift may not occur. However, the recovery time for high levels of hearing damage may take months or years (depending on the species), and it is very difficult to estimate the recovery rate based on a species physiological characteristics (Dooling and Popper 2007).

Hence, hearing damage that persists over a period of months/years can be considered to be “semi-permanent” damage.

Dooling and Popper (2007) present interim guidelines for assessing potential hearing damage impacts on bird species, based on a summary of available literature. They conclude that airborne noise levels above 110 dB(A) may pose a risk of inducing long-term hearing damage (i.e. PTS) for continuous noise.

For continuous noise, airborne levels of 140 dB(A) (for a single event) and 125 dB(A) (for repeated impulsive events, e.g. piling) are proposed as thresholds for PTS.

### D7.7.2.5 Fatality

At high levels, underwater sound can cause direct physical injury to animals, particularly to species possessing lungs, a swimbladder or other gas-containing structures. Damage is a combination of (Hastings & Popper, 2005):

- tissue damage from movement induced by pressure differentials between (compressible) gas-containing structures and (largely incompressible) tissue;
- damage from gas embolism in the bloodstream induced by the pressure spike; and
- neural injury from trauma of the brain (likely due to motion of the brain during the pressure event).

<u>Marine Mammals</u>

- Parvin, Nedwell and Howland (2007) summarise the available data on the impact of impulsive transient underwater sound on marine mammals:
- Levels above 260 dB re 1 µPa are always immediately lethal;
- Levels between 240 dB re 1 µPa and 260 dB re 1 µPa will result in serious injury, with probability of short-term mortality increasing with received level;
- Levels between 220 dB re 1 µPa and 240 dB re 1 µPa may result in direct injury to gas-containing structures or auditory organs;
- Levels below 220 dB re 1 µPa are unlikely to cause auditory injury.

There is some overlap between the criteria used by Parvin et al and those recommended by Southall et al (2007) for auditory injury, although they are broadly consistent: levels above 220 dB re 1 µPa are likely to cause temporary or permanent auditory injury, combined with non-auditory injury as the received sound level increases.

For physical injury to the lungs, damage is in inverse proportion to lung size. Hence, smaller or juvenile animals are at greatest risk to damage from underwater sound.

<u>Fish</u>

Hastings and Popper (2005) present an overview of physical damage mechanisms to fish. Similarly to marine mammals, smaller fish are more vulnerable to damage than larger fish.

Based on published data from Yelverton et al (1973) for underwater explosions, Hastings and Popper presented curves estimating the fish mortality for different sizes of fish as a function of sound exposure level. These curves are likely to be conservative since the original data is for underwater explosions, which have a sharper rise time of the pressure wave than piling noise.

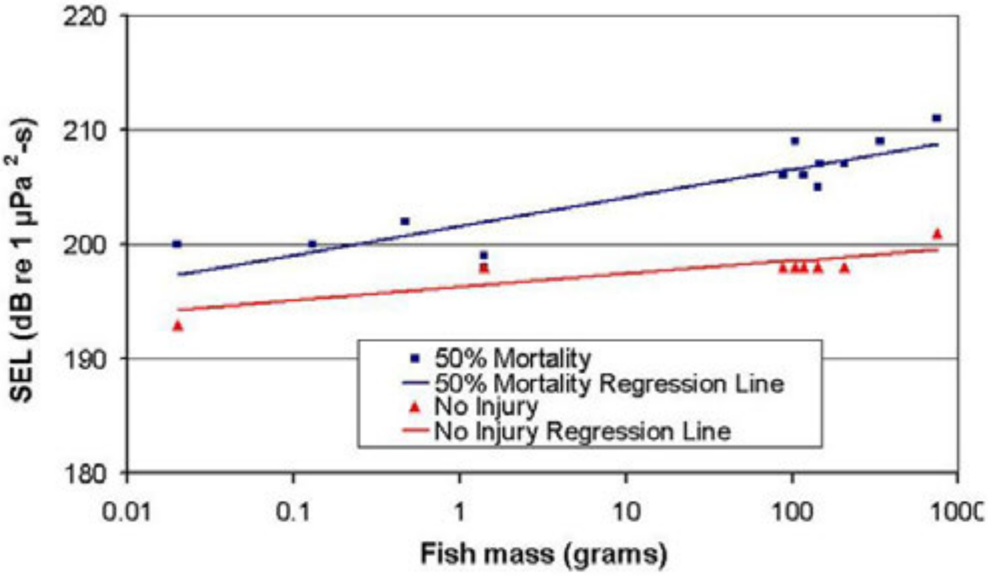



Figure D7.7.2.5a Estimated Probability of Fish Mortality as a Function of Sound Exposure Level, from Hastings and Popper (2005)

This data indicates that at received SELs of below 195 dB re 1 µPa²·s, fish mortality is unlikely to occur, even for immature fish/larvae, but that at levels significantly exceeding 210 dB re 1 µPa²·s significant fish mortality would occur.

<u>Migratory Birds and Shorebirds</u>

Yelverton et al (1973) present damage criteria for diving seabirds in terms of the received SEL from an underwater blast. As for fish, using this data is expected to be conservative due to the sharper rise time of a blast wave. Damage thresholds for surfaced seabirds are significantly (a factor of 6) higher than for diving seabirds.

**D7.7.2.6 Summary of Underwater Noise Impact Criteria**

Table D7.7.2.6a Summary of approximate Noise Thresholds for Species[1]

| **Impact** | **Species** | **Sound Pressure dB re 1 µPa** | **Sound Exposure Level dB re 1 µPa²·s** |
|---|---|---|---|
| 50% Mortality (all sizes) | Fish | | 210dB |
| | Migratory birds and shorebirds | | 198dB |
| Serious Physical Injury | Marine Mammals | $240dB_{peak}$ | |
| | Fish | | 195dB (onset of mortality) |
| | Migratory birds and seabirds (diving) | | 195dB (onset of mortality) |
| Permanent Hearing Damage (PHD) | All species | $130dB_{ht}$ | $135dB_{ht}$ |
| | Whales –Baleen | $230dB_{peak}$ | $198dB(M_{lf})$ (impulsive)<br>$215dB(M_{lf})$ (continuous) |
| | Whales – Toothed | $230dB_{peak}$ | $198dB(M_{mf})$ (impulsive)<br>$215dB(M_{mf})$ (continuous) |

[1] There are limited studies to determine noise criteria for underwater fauna. These limits are approximate only.

| **Impact** | **Species** | **Sound Pressure dB re 1 µPa** | **Sound Exposure Level dB re 1 µPa²·s** |
|---|---|---|---|
| | Dugongs | 220 dBpeak | 188dB($M_{mf}$) (impulsive)<br>205dB($M_{mf}$) (continuous) |
| | Seabirds (airborne) | 110 dB(A) (continuous)<br>125 dB(A) (impulsive) | |
| | Seabirds (diving) | | 193dB |
| Temporary Hearing Damage (TTS) | Whales –Baleen | 224$dB_{peak}$<br>160$dB_{rms}$ (continuous) | 183dB($M_{lf}$) (impulsive) |
| | Whales – Toothed | 224$dB_{peak}$<br>160$dB_{rms}$ (continuous) | 183dB($M_{mf}$) (impulsive) |
| | Dugongs | 214$dB_{peak}$<br>150$dB_{rms}$ (continuous) | 173dB($M_{mf}$) (impulsive) |
| | Seabirds (airborne) | 93 dB(A) (continuous)<br>110 dB(A) (impulsive) | |
| | Seabirds (diving) | | 190dB<br>(safe level for no injuries) |
| Disturbance – Strong (~90% avoidance) (SA) | All species | 90$dB_{ht}$ | |
| | Marine Mammals | 160$dB_{rms}$ (impulsive)<br>120$dB_{rms}$ (continuous) | |
| | Fish | 140-160$dB_{peak}$ (impulsive) | |
| | Seabirds (airborne) | 72 dB(A) | |
| Masking | Whales – Toothed and Baleen | 115$dB_{rms}$ | |
| Detection | Whales -Toothed | 90 dB (for frequencies below 1000 Hz) | |
| | Dugongs | 80 dB (for frequencies below 1000 Hz) | |

### D7.7.3 Prediction Methodology

#### D7.7.3.1 Airborne Noise

Noise Model Settings

The SoundPlan environmental noise modelling program has been used for assessment of noise impacts from the development. Calculations results have been verified with single-point calculations for some receivers.

The following inputs have been used in the SoundPlan noise model:

| Input Parameter | Details |
|---|---|
| Propagation methodology | CONCAWE |
| Ground absorption factor | 0.6 |
| Façade reflection | Included, calculated as per CONCAWE methodology |
| Receptor height | 1.5m above ground level |
| Weather conditions - Neutral | Wind speed 0m/s<br>Temperature 25°C<br>Humidity 80%<br>Pasquil stability category D |
| Weather conditions - Adverse | Wind speed 6.5m/s (downwind from source to receiver)<br>Temperature 25°C<br>Humidity 80%<br>Pasquil stability category D |
| Terrain height | GIS data |
| Development alignment, plant locations and source heights | GIS data |

#### D7.7.3.2 Operational Noise Source Levels

Operational activities were separated into three categories for the assessment:

- Cruise ships entering/leaving port
- Cruise ships berthing at the cruise terminal, including ship refuelling, goods and passenger loading and unloading activities (including associated dockside traffic movements).
- Berthed cruise ship (constant noise from ship auxiliary engines and ventilation system)

As part of site works for the Cairns Shipping Development Project, Arup conducted source noise measurements of the following cruise ships:

- *Rhapsody of the Seas* (279 m, 78,000 ton, 1997)
  - Measured docked at Sydney Overseas Passenger Terminal, 26/11/2013
  - Measured on entry to Port of Brisbane, 28/11/2013
  - Measured docked at Port of Brisbane, 28/11/2013
- *Carnival Spirit* (293 m, 86,000 tons, 2001)
  - Measured docked at Sydney Overseas Passenger Terminal, 5/12/2013
- *Sun Princess* (261 m, 77,000 ton, 1995)
  - Measured docked at Brisbane Portside Cruise Terminal, 19/11/2013
  - Measured transiting Brisbane River, 19/11/2013

- *Pacific Dawn* (245 m, 70,000 ton, 1991)
  - Measured docked at Brisbane Portside Cruise Terminal, 15/3/2014
- *Pacific Jewel* (245 m, 70,000 ton, 1990)
  - Measured arriving Sydney Harbour, 14/3/2014
- *Queen Mary 2* (345 m, 148,500 ton, 2004)
  - Measured docked at Sydney Overseas Passenger Terminal, 14/3/2014

N.B. *Rhapsody of the Seas* is the largest ship currently regularly accessing the existing Port of Cairns.

These ships have been divided into two categories based on similar noise emission characteristics:

- Medium ships (e.g. Pacific Dawn, Sun Princess)
- Large ships (e.g. Rhapsody of the Seas, Radiance of the Seas)

Medium ships such as *Pacific Dawn/ Pacific Jewel/ Pacific Pearl* and *Sun Princess* /*Dawn Princess* collectively represented ~60% of cruise ship visits mooring off Yorkey's Knob.

Although Queen Mary 2 is too large to visit the Port of Cairns, noise levels from Queen Mary 2 when docked have been used to obtain representative sound power levels for similar "very large" cruise ships.

Although there is a significant different between the sound power levels of "medium" size cruise ships such as *Sun Princess*/*Pacific Dawn* and the sound power levels of the large ships, noise levels of each "size" of ship are fairly consistent. The logarithmic average of the measured sound power levels has been used as the source level for each class of ship.

The following activities and associated sound power levels have been included in the model:

Table D7.7.3.2a Sound power levels used in modelling, $L_{eq}$ dB re 1 x 10-12W

| Activity | Noise Source Reference | Input Type | Overall Sound Power Level, $L_w$, dB(A) | Sound Power Level, Octave Band Centre Frequency, Hz | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
| Docked medium cruise ship exhaust stack, e.g. *Pacific Dawn* *Sun Princess* | Arup measurements of cruise ships using existing ports | $L_{eq}$ | 102.1 | 114.3 | 108.2 | 100.9 | 98.5 | 97.4 | 93.2 | 87.1 | 80.4 |
| Docked large cruise ship exhaust stack, e.g. *Rhapsody of the Seas* | Arup measurements of cruise ships using existing ports and from published literature (DiBella and Remigi 2013) | $L_{eq}$ | 114.3 | 122.0 | 117.3 | 113.1 | 110.6 | 107.6 | 106.2 | 105.5 | 102.0 |
| Cruise ship engine room vent when docked | Arup measurements of cruise ships using existing ports | $L_{eq}$ | 90.7 | 91.9 | 91.3 | 88.0 | 88.2 | 86.4 | 83.4 | 70.6 | 56.0 |
| Fuel pump | Empirical data | $L_{eq}$ | 98.6 | 89 | 90 | 92 | 92 | 95 | 92 | 88 | 82 |
| Forklift operating length of dock | Arup measurements of cruise ships using existing ports | $L_{eq}$ | 101.8 | 105.4 | 99.7 | 99 | 98.9 | 96.6 | 95.4 | 87.3 | 76.8 |
| Forklift operating length of dock | Arup measurements of cruise ships using existing ports | $L_{max}$ | 113.3 | 115.0 | 111.8 | 108.1 | 109.8 | 106.2 | 108.5 | 101.8 | 91.2 |
| Forklift unloading cruise ship | Arup measurements of cruise ships using existing ports | $L_{eq}$ | 101.0 | 102.9 | 99.7 | 99.3 | 98.2 | 96.4 | 93.7 | 86.5 | 76.6 |
| Forklift unloading cruise ship | Arup measurements of cruise ships using existing ports | $L_{max}$ | 116.6 | 110.6 | 113.9 | 115.5 | 112.5 | 110.7 | 110.9 | 104.1 | 91.8 |
| Medium cruise ship berthing rope motor | Empirical data | $L_{eq}$ | 98.7 | 88.8 | 90.8 | 91.8 | 91.8 | 96.8 | 90.8 | 81.8 | 73.8 |
| Cruise ship PA chime | Arup measurements of cruise ships using existing ports | $L_{max}$ | 115.1 | 106.6 | 105 | 120.7 | 114.3 | 102.1 | 98.3 | 92.5 | 82.1 |
| Medium cruise ship entering/leaving port, e.g. *Pacific Dawn* *Sun Princess* | Arup measurements of cruise ships using existing ports | $L_{eq}$/m | 72.8 | 81.9 | 75.9 | 73.1 | 70.4 | 67.5 | 63.3 | 57.4 | 56.4 |
| | Arup measurements of cruise ships using existing ports | $L_{max}$ | 121.9 | 126.1 | 119.2 | 117.3 | 113.5 | 118.6 | 115.0 | 108.8 | 110.5 |

| Activity | Noise Source Reference | Input Type | Overall Sound Power Level, $L_w$, dB(A) | Sound Power Level, Octave Band Centre Frequency, Hz | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 63 | 125 | 250 | 500 | 1k | 2k | 4k | 8k |
| Large cruise ship entering/leaving port, e.g. *Rhapsody of the Seas* | Arup measurements of cruise ships using existing ports. Published SEL measurements from Di Bella (nd) | $L_{eq}$/m | 77.9 | 83.9 | 80.1 | 75.7 | 66.4 | 69.2 | 69.7 | 67.7 | 74.8 |
| | Arup measurements of cruise ships using existing ports | $L_{max}$ | 134.0 | 130.9 | 120.9 | 117.1 | 129.6 | 122.7 | 129.8 | 122.9 | 126.9 |
| Trucks/busses entering site | Arup database – measurements of previous projects | $L_{eq}$/m | 82.6 | 91.6 | 85.2 | 81.3 | 80.3 | 77.3 | 73.6 | 69.0 | 68.5 |
| Trucks/busses leaving site | Arup database – measurements of previous projects | $L_{eq}$/m | 75.2 | 87.6 | 76.7 | 75.3 | 72.8 | 70.6 | 65.4 | 58.7 | 49.9 |
| Idling trucks/busses at cruise terminal | Arup database – measurements of previous projects | $L_{eq}$ | 90.8 | 92.0 | 91.0 | 94.0 | 89 | 83.7 | 78.6 | 68.8 | 53.8 |

**Figures D7.7.3.2a** to **D7.7.3.2c** show the measured data for different cruise ship noise sources:

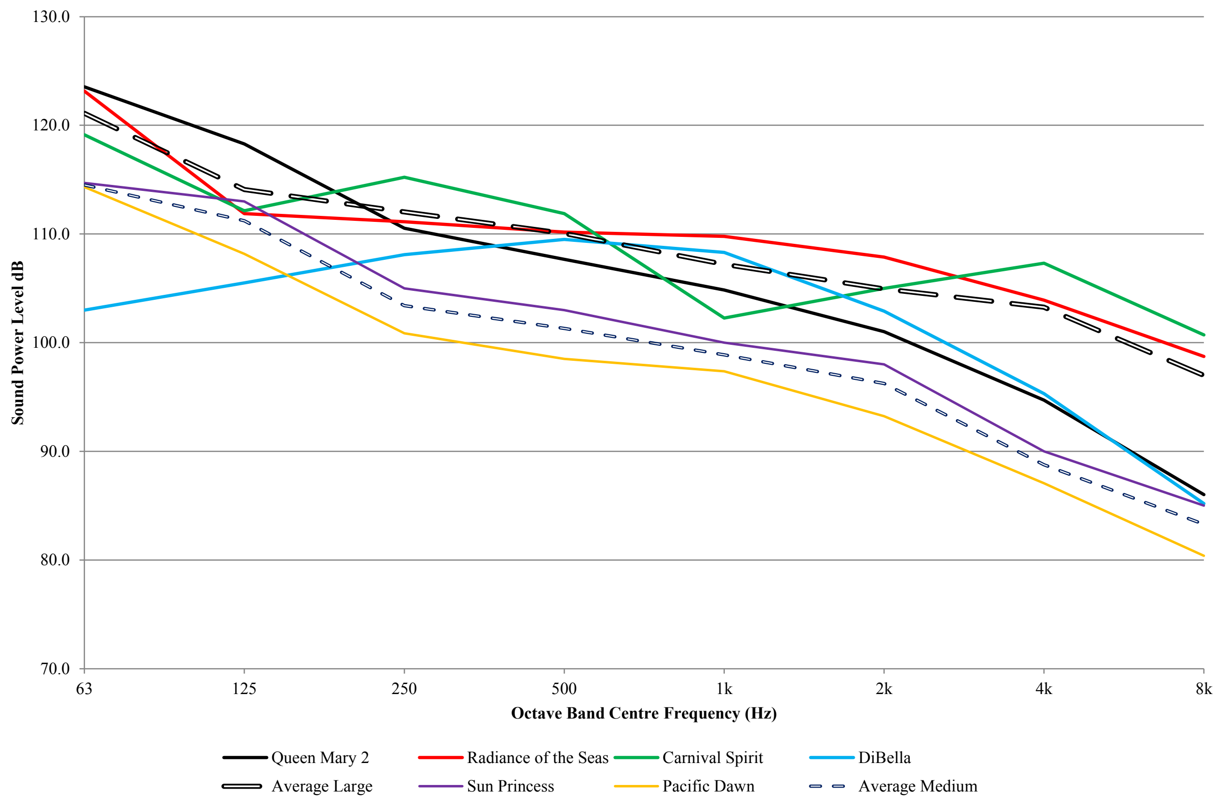



Figure D7.7.3.2a Sound Power Levels of Exhaust Stack, Measured Cruise Ships

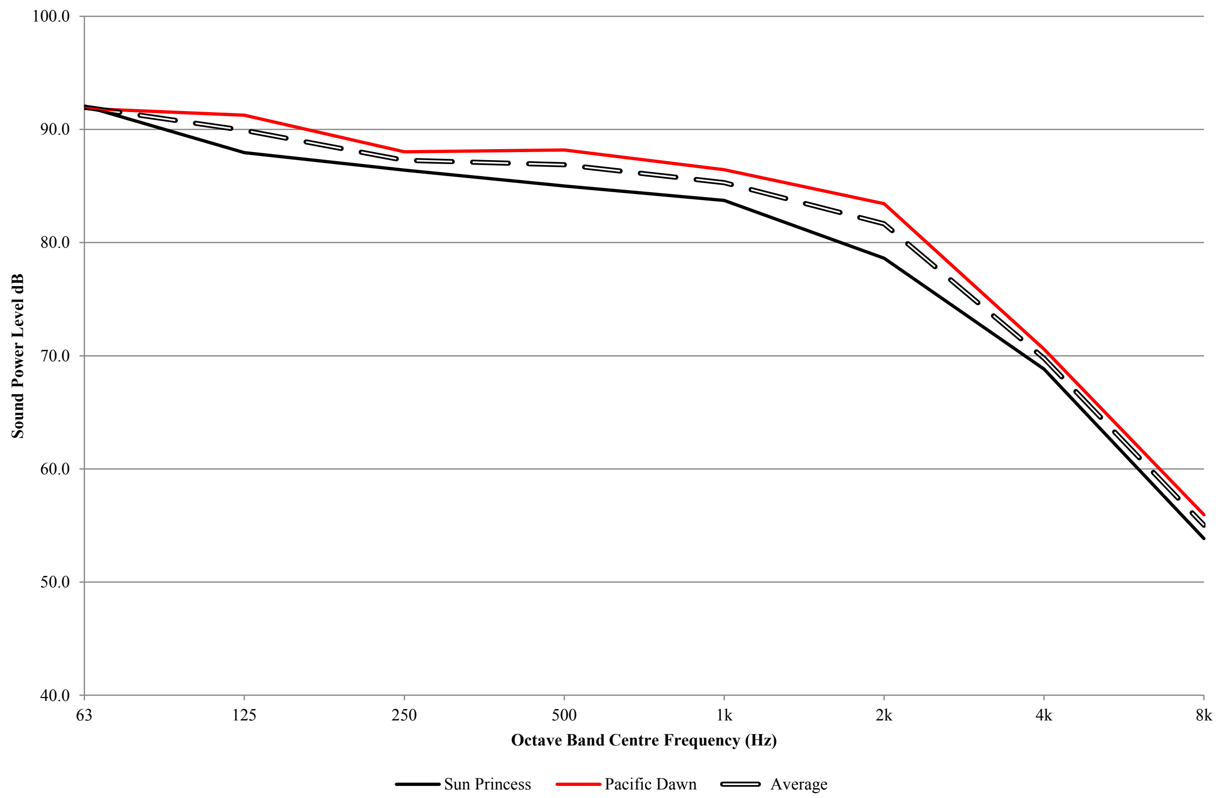



Figure D7.7.3.2b Sound Power Levels of Ventilation System, Measured Cruise Ships

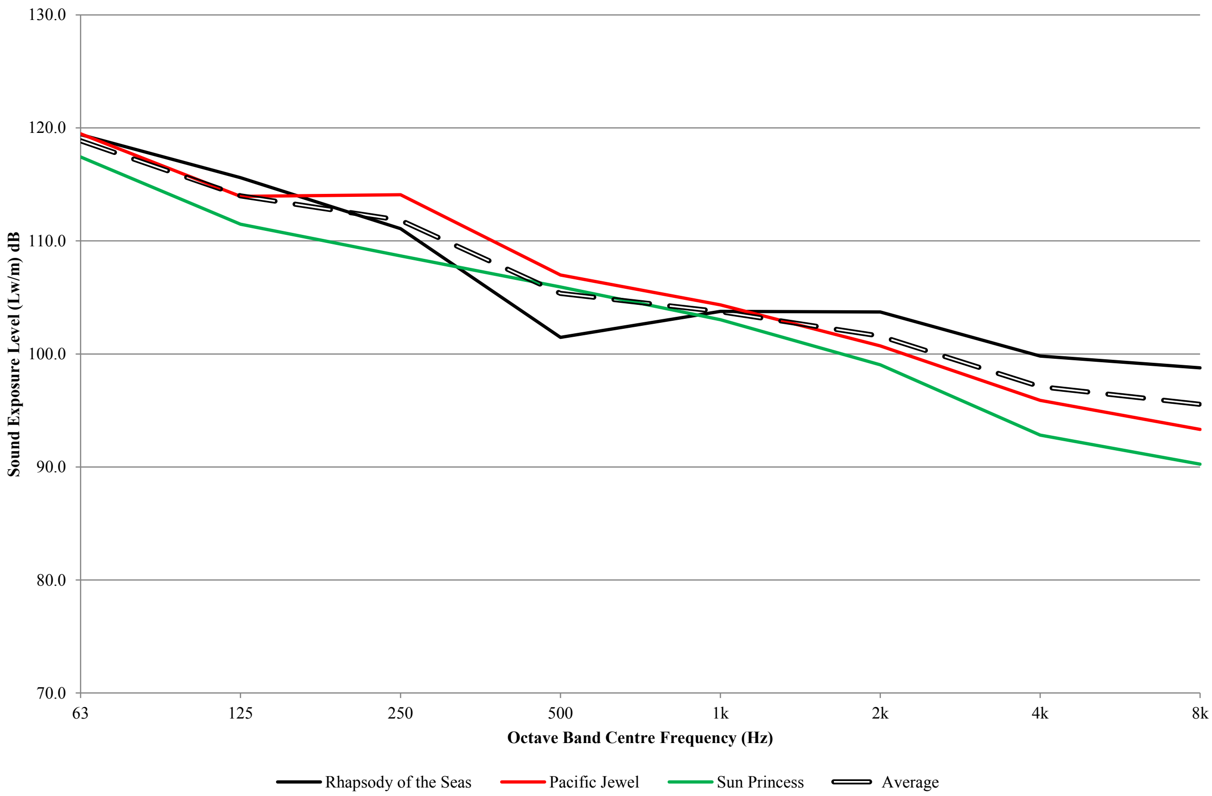



Figure D7.7.3.2c Sound Power Levels of Ship Transit (Lw/m Sound Exposure Level), Measured Cruise Ships

The following activities have been assessed for the operational noise predictions:

Table D7.7.3.2b Noise activities for prediction of operational noise impacts from the project

| **Activity** | **Noise Sources** |
|---|---|
| Cruise ship transit | Primary propulsion engines<br>Ventilation system |
| Cruise ship berthing (coming into dock) | Primary propulsion engines<br>Ventilation system<br>Berthing motors<br>PA system |
| Cruise ship loading/unloading (at dock) | Auxiliary engines<br>Ventilation system<br>Forklifts<br>Refuelling |
| Cruise ship docked | Auxiliary engines<br>Ventilation system |

Airborne operational noise levels from all activities have been predicted at the nearest affected noise sensitive receptors for the weather conditions described in **Table D7.7.3.2c**.

Table D7.7.3.2c Assessed weather conditions

| **Meteorological Condition** | **Wind Speed (m/s)** | **Temperature (°C)** | **Humidity (%)** | **Pasquil Stability Category** |
|---|---|---|---|---|
| Neutral | 0 | 25 | 80 | Neutral (D) |
| Adverse | 6.5 | 25 | 80 | Neutral (D) |

### D7.7.3.3 Construction Noise Source Levels

Construction activities described in **Chapter A2** have been used as the basis for construction noise modelling in SoundPlan. GIS data was also used in determining the source locations for dredging activities.

The following sound power levels have been included in the model for construction activities:

Table D7.7.3.3a Construction activity sound power levels used in modelling, dB re 1 x $10^{-12}$W

| **Activity** | **Noise Source Reference** | **Type** | **Overall Sound Power Level, $L_w$, dB(A)** | **Sound Power Level, Octave Band Centre Frequency, Hz** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | **63** | **125** | **250** | **500** | **1k** | **2k** | **4k** | **8k** |
| Piling | BS5228 Table C3 | $L_{eq}$ | 117 | 116 | 121 | 113 | 115 | 111 | 108 | 103 | 100 |
| | Transport for NSW Construction Noise Strategy (with adjusted spectrum from BS5228) | $L_{max}$ | 134 | 133 | 138 | 130 | 132 | 129 | 126 | 120 | 117 |
| IFO pipeline construction | BS5228 Table C3 (data for drilling/cutting and lifting of steel piles) | $L_{eq}$ | 105 | 106 | 105 | 101 | 100 | 101 | 98 | 94 | 90 |
| Backhoe dredging | Comparative literature review of published dredge sound power levels (e.g. MDA 2009, Epsilon 2006, Cinotech 2003, Sonus 2012) | $L_{eq}$ | 119 | 120 | 128 | 117 | 115 | 115 | 110 | 103 | 95 |
| Capital dredging Trailing hopper suction dredge - large | Comparative literature review of published dredge sound power levels (e.g. MDA 2009) | $L_{eq}$ | 112 | 113 | 121 | 110 | 108 | 108 | 103 | 96 | 88 |
| Maintenance dredging Trailing hopper suction dredge - medium | Comparative literature review of published dredge sound power levels (e.g. MDA 2009) | $L_{eq}$ | 110 | 111 | 119 | 108 | 106 | 106 | 101 | 94 | 86 |

Note: Trailing hopper dredges were assumed to move at approximately 2 knots while dredging.

## D7.7.4 Vibration

### D7.7.4.1 Piling

The TRL guidance recommends the use of the following relationship for the prediction of *upper bound* vibration velocity levels from piling works

$$v_{res} \le k_p \left[ \sqrt{W} / r^{1.3} \right]$$

Where $v_{res}$ is the resultant PPV velocity level (mm/s), W is the nominal hammer energy (J), *r* is the distance from the source (m) and $k_p$ is an empirical scaling factor based on ground conditions. Soft cohesive soil has been used as the basis of calculating vibration levels as being representative of the channel bed.

Predicted PPV velocity levels have been calculated for nominal typical hammer energies to the heritage wharf (30m) and nearest potentially affected residential receptors (100m). Results are presented in table for varying nominal hammer energies.

Table D7.7.4.1a Predicted construction vibration levels

| **Location** | **Nominal Hammer Energy (W)(kJ)** | **Predicted PPV velocity level (mm/s)** |
|---|---|---|
| Heritage Wharf | 25 | 1.88 |
| | 45 | 2.53 |
| | 65 | 3.04 |
| Wharf Street Residences | 25 | 0.4 |
| | 45 | 0.53 |
| | 65 | 0.64 |

It is noted that predicted vibration impacts on residential receptors are calculated to be in the range 0.3<PPV<1.0 for all nominal hammer energies. This corresponds to a “minor” impact.

**D7.7.4.2 Dredging**

There is very little data available for the vibration impacts of dredging. The TRL guidance provides ground vibration data from tunnelling operations classified according to geology. Figure D7.7.4.2a is an excerpt from TRL (Figure 49).

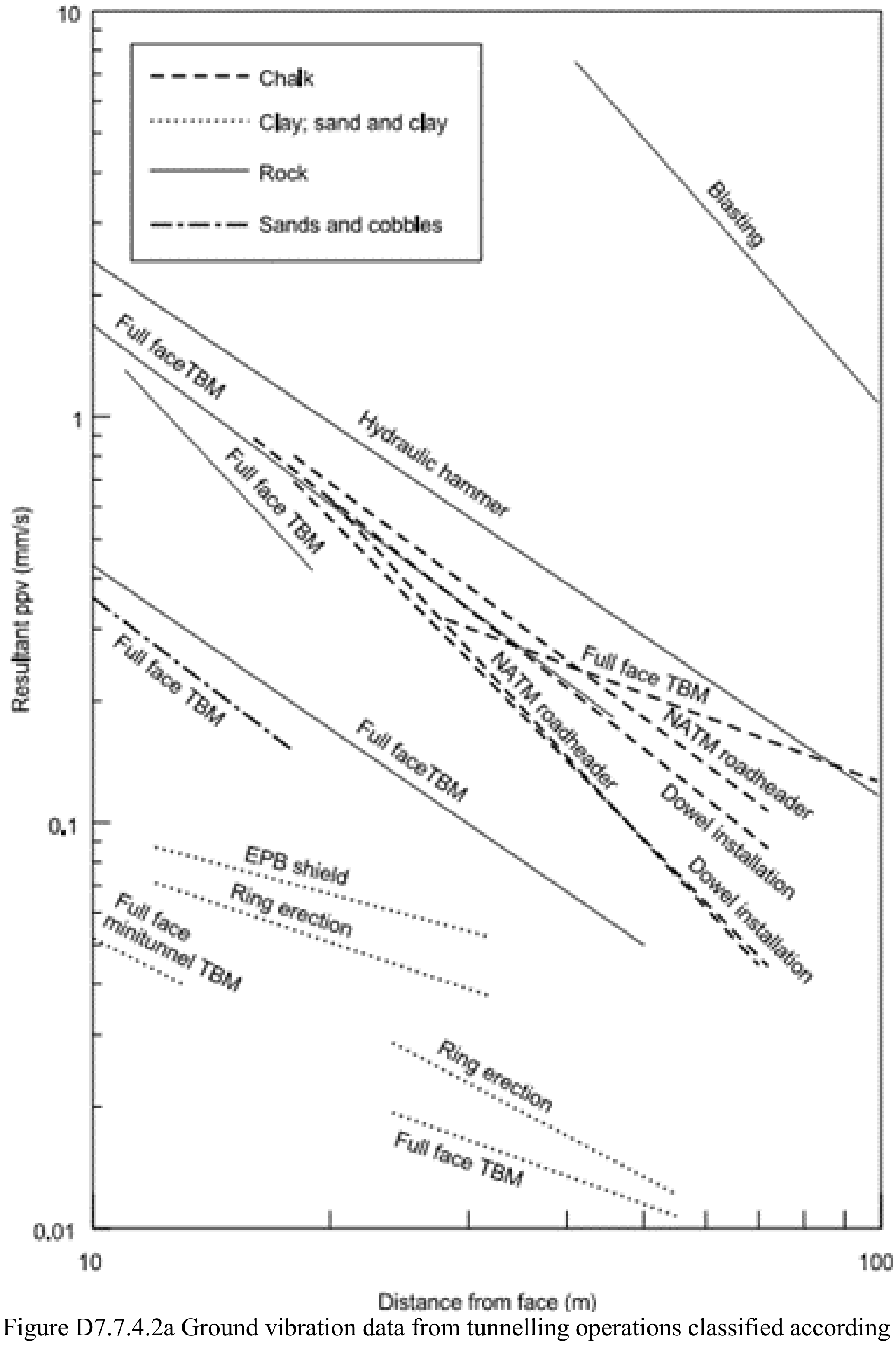


Figure D7.7.4.2a Ground vibration data from tunnelling operations classified according to geology (TRL)

As an approximation for the likely impacts from dredging, predicted vibration levels for tunnelling works in sand and clay presented in TRL have been used as a reference.

It should be noted that vibration impacts from underwater dredging are likely to be significantly lower than the data presented for tunnelling in TRL due to the large amount of energy that will dissipate into the water column for dredging as opposed to air due to the impedance mismatch between rock and air - i.e. for underwater dredging a higher proportion of the vibrational energy of the source will radiate as underwater noise, resulting in lower groundborne vibration levels compared to tunnelling in air.

### D7.7.4.3 Drilling

Data in the literature for vibration from different sizes of drills is available. Data from Wiss 1981 and Hiller Bowers and Crabb (2001) has been used to obtain typical source levels for drills of 1-3 mm/s at 10 m distance.

## D7.7.5 Underwater Noise Source Levels

### D7.7.5.1 Piling

Piling noise is generally more tonal than seismic airgun or explosive waveforms, and may, in extreme cases, cause damage due to resonance effects on underwater life, such as by exciting the resonant frequency in gaseous areas – such as the 25 Hz resonant frequency of the human lung (Nedwell et al, 2007b).

The waveform from a piling impact involves reflection and reverberation effects, including resonance of the pile as it is struck, and secondary noise generation from the seafloor by vibration travelling down the pile. Some piling methods cause additional secondary noise pulses from the piling hammer "bouncing" on the pile head. Typical piling time history data and secondary pile 'bounces' are shown in **Figure D7.7.5.1a** below.

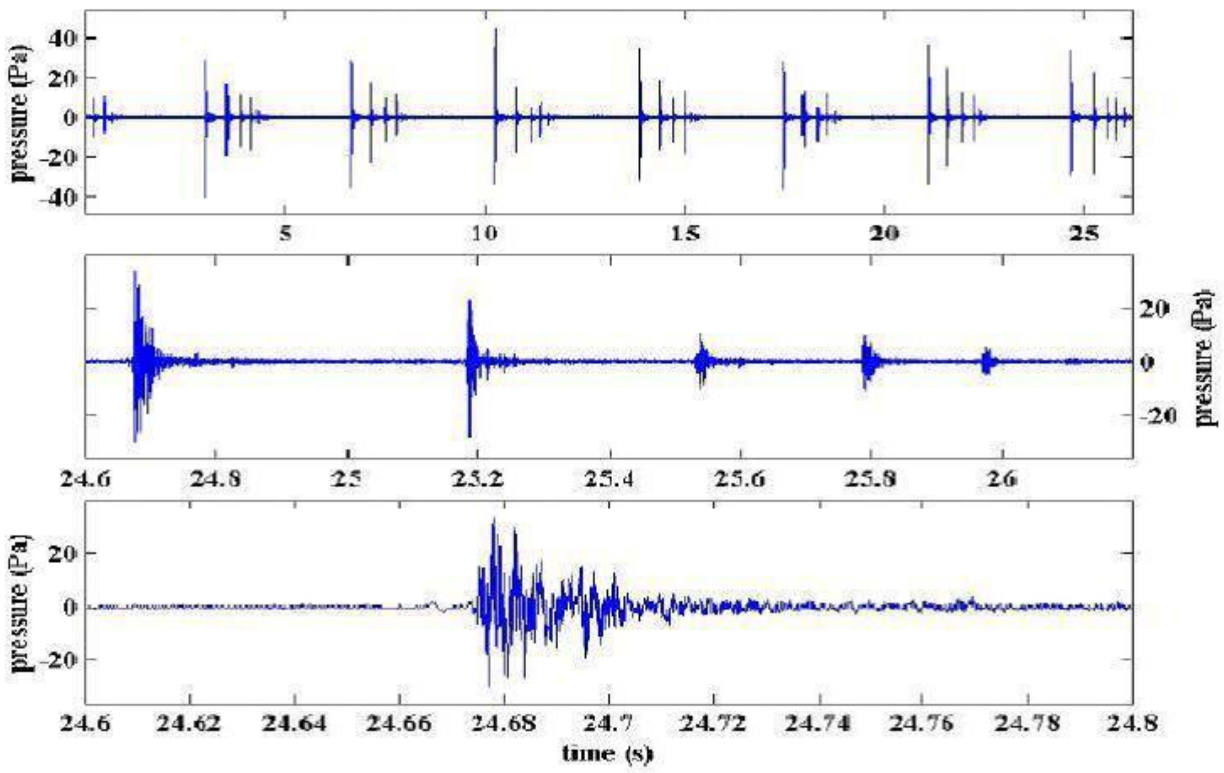



Figure D7.7.5.1a Typical piling time history data, from McCauley et al (2002) showing secondary pile "bounces". The middle and bottom plots are zoomed-in plots of the last piling pulse in the upper plot showing the "bounces" (middle) and the primary impact (bottom).

The dominant frequency range is low-frequency (between 100 Hz and 1 kHz) (Finneran, 2002) as demonstrated by the example spectra in **Figures D7.7.5.1b** and **c**.

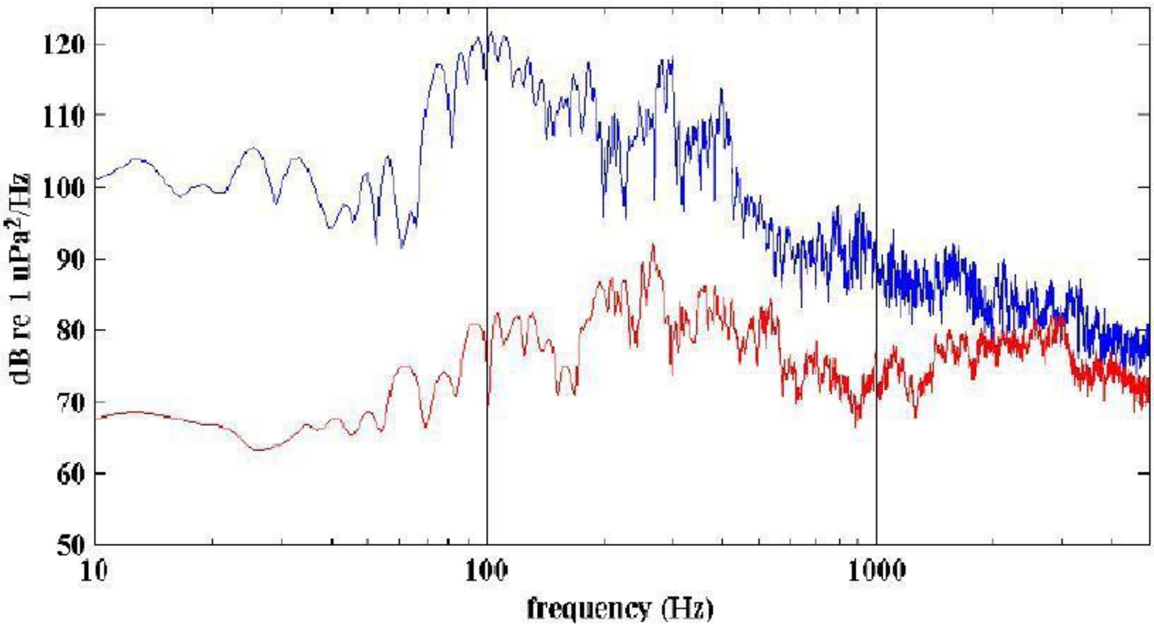



Figure D7.7.5.1b Frequency spectra of impact piling, adapted from McCauley et al (2002) Blue curve is at approximately 300m from source; red curve is at approximately 600m from source

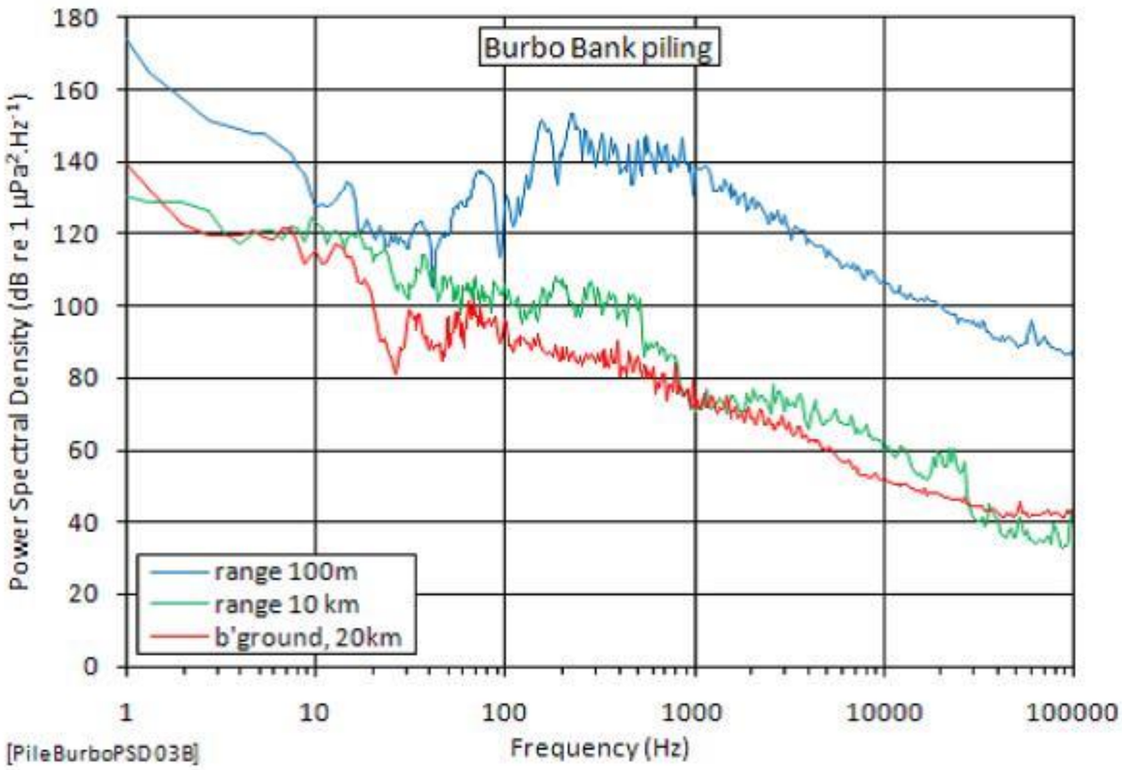



Figure D7.7.5.1c Frequency spectra of impact piling (4.3 m diameter pile) in shallow water, adapted from Nedwell et al (2007b). Blue curve is at approximately 100 m from source; green curve is at approximately 10 km from source, red curve is background noise at approximately 20 km from source.

Noise from the impact of piling hammers is directly correlated to the pile diameter (Diederichs et al, 2008), as shown in **Figure D7.7.5.1d**.

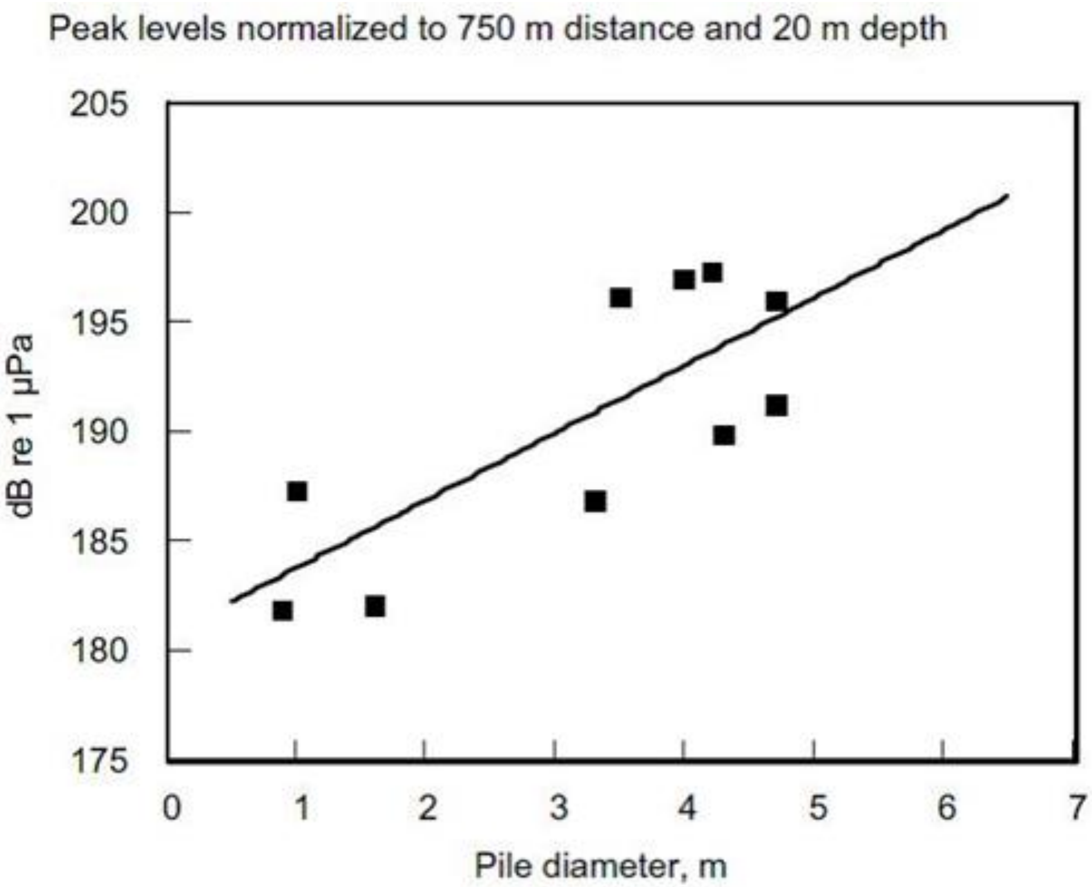


Figure D7.7.5.1d Approximate relationship between pile diameter and peak sound pressure level (normalised to 20 m water depth and 750 m distance from source), from Diederichs et al (2008)

Peak noise levels from large-diameter (4-5 m) piles were recorded at approximately 240-250 dB re 1 µPa (peak) and 200-215 dB re 1 µPa²s SEL at 1 m (Diederichs et al, 2008). For a 1.2 m maximum diameter pile, such as proposed for CSDP, this equates to a nominal source level of approximately 230-235 dB re 1 µPa at 1 m (peak) and 195-200 dB re 1 µPa²·s at 1m (SEL). The upper values within these ranges have been used as source levels in this assessment with spectra adjusted using the spectra presented in Nedwell et al (2007b) for shallow-water piling.

A source level of 235 dB re 1 µPa at one metre (peak) and 200 dB re 1 µPa²·s at one metre (SEL) was assumed for the impact piling at the dock. The source spectrum was based on the presented spectrum for shallow water piling from Nedwell et al (2007b).

Piling predictions were conducted for source location at the wharf.

**D7.7.5.2 Dredging**

The World Association of Dredging Associations (WODA 2013) presents a Technical Guidance paper on underwater sound from dredging that is a useful overview of sources of dredging noise and provides typical source levels.

The WODA technical paper provides a summary of noise levels from different types of dredge.

Noise levels from a TSHD include noise from the ship itself, noise from thrusters used to keep position while dredging, pump noise from the suction tube, and noise from the draghead itself. Noise levels below 1 kHz are similar to shipping noise for comparable-sized ships; however above 1 kHz the source spectrum for a TSHD is higher than a typical ship due to the dredging pumps and noise from the dredging material itself (Robinson et al 2011).

Data from Robinson el at (2011) suggests that high-frequency noise emission may increase when dredging “harder” materials (e.g. gravel) by ~5 dB compared to “soft” material such as sand or mud. Data from de Jong et al (2010) suggests that (for “soft material”, at least) noise levels from discharging dredged material is likely to be lower than noise level from the dredging operation itself or from noise from the dredge in transit.

Backhoe or grab dredging is conducted from stationary barges and hence there are fewer noise sources associated with backhoe dredging compared to TSHD dredging. Major noise sources include the machinery noise from the excavator itself (which is located on top of the barge and hence is only weakly-coupled to the water column), noise from any attendant tugs or work boats, plus the digging noise from the dredging activity itself.

Available noise data for backhoe dredging is very limited; however the available data suggests that TSHD dredging produces higher underwater noise levels than backhoe dredging (CEDA 2011), and hence underwater noise impacts for CSDP will be predicted for all locations for TSHD dredging as a conservative approach.

Source levels for TSHD or the similar cutter-suction dredger (CSD) are generally in the range 180-190 dB re 1 µPa at 1 m, e.g.

- CEDA presents results from Thomsen et al 2009 giving a source level of 186-188 dB re 1 µPa at 1 m for TSHD dredging
- Underwater noise measurements of two CSD dredges at Port Curtis QLD reported source levels of 180-187 dB re 1 µPa at 1 m for CSD dredges (Blue Planet Marine 2013)
- A report by Robinson et al (2011) for the Marine Aggregate Levy Sustainability Fund (MALSF) presents measured source levels for seven TSHD dredges with source levels between 176-190 dB re 1 µPa at 1 m.
- A summary of dredge noise measurements (type unknown) by JASCO (2011) presented in SKM (2012) includes source levels between 175-187 dB re 1 µPa at 1 m, as shown in **Figure D7.7.5.2a**.

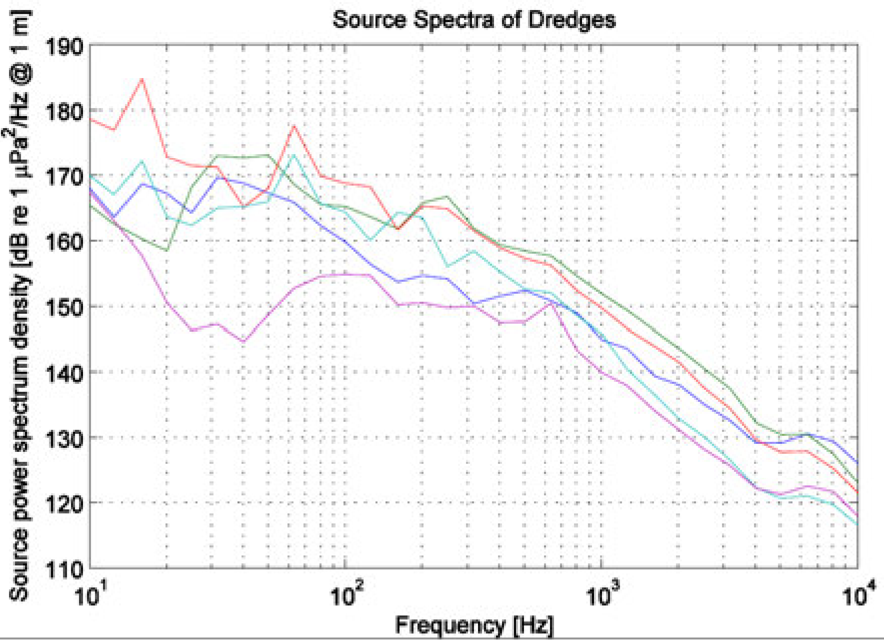



Figure D7.7.5.2a Source Spectra of various dredges (type unknown), from JASCO (2011) as presented in SKM (2012)

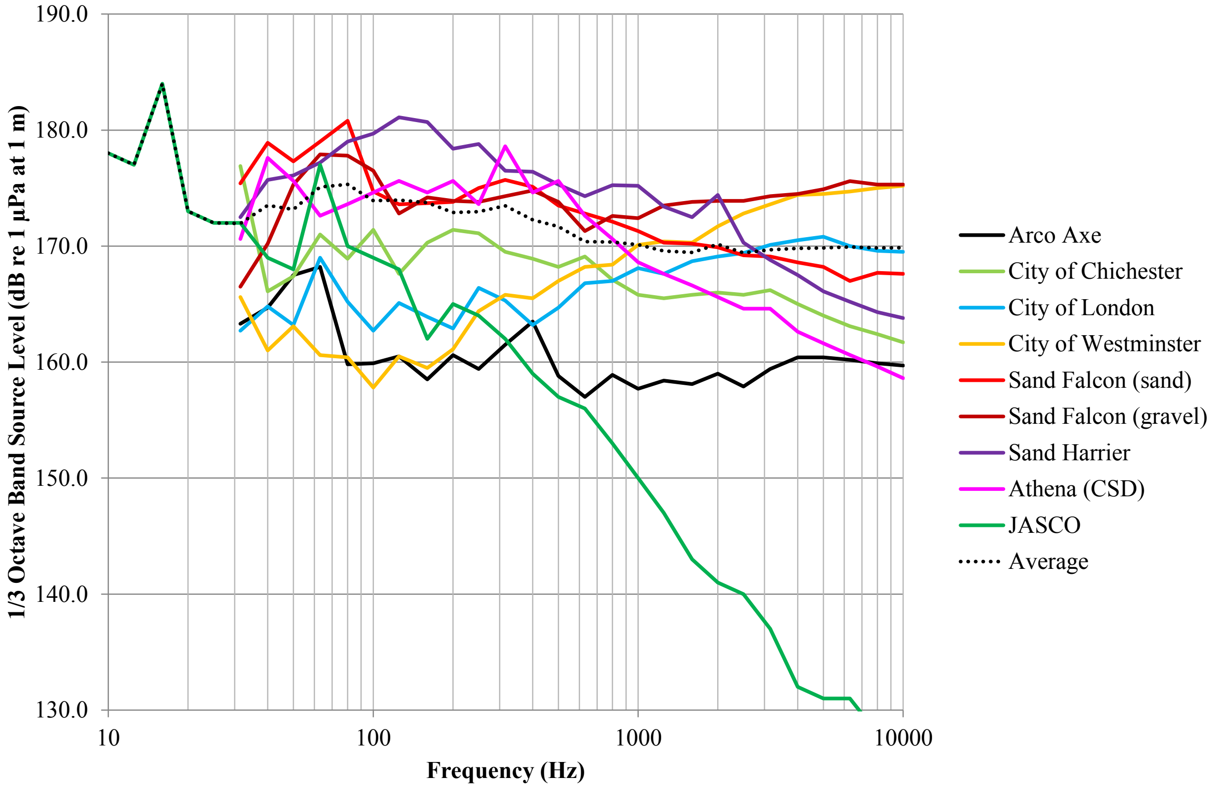



Figure D7.7.5.2b Average dredge source levels from Port Curtis, Robinson et al (2011) and JASCO (2011) data, showing logarithmic-average source level (189 dB re 1 µPa at 1 m) used for prediction.

### D7.7.5.3 Cruise Ships

Cruise Ship noise is comprised of machinery noise (hull-radiated) plus hydrodynamic noise (which is generally dominated by propeller noise). Hydrodynamic noise is generally dominant at higher frequencies (above ~500 Hz) with machinery-noise dominant at lower frequencies.

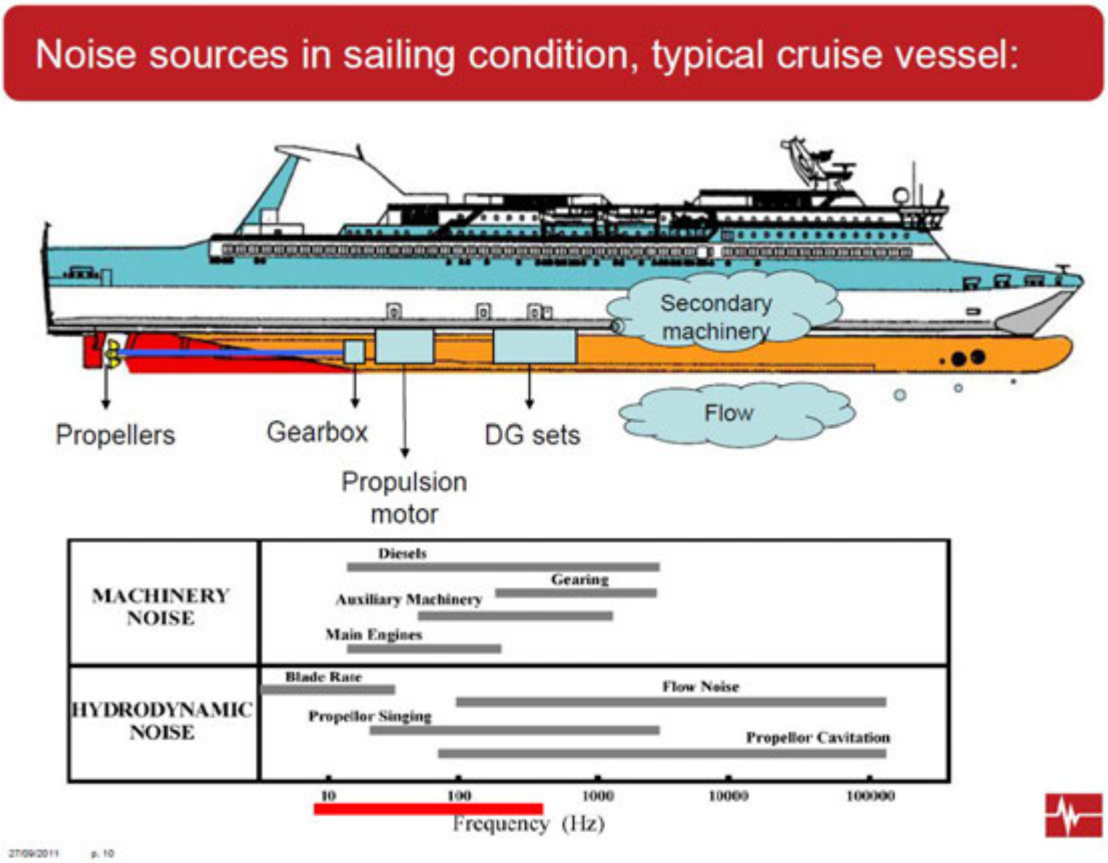



Figure D7.7.5.3a Typical noise sources for cruise ships, from Cunningham (nd)

Underwater source noise measurements are available of several cruise ships, all measured by the US Naval Surface Warfare Centre (Kipple 2002, Kipple 2004a, Kipple 2004b) in Alaskan waters. These measurements include the ships *Volendam*, *Statendam* and *Dawn Princess* which are frequent visitors to Australia. *Volendam* (61,000 tons) and *Statendam* (55,000 tons) are typical medium-size cruise ships which currently regularly visit the Port of Cairns while *Dawn Princess* (77,000 tons), *Norwegian Sky* (77,000 tons) and the 91,500 ton *Coral Princess* can be considered to be representative of typical underwater noise levels from the new medium and large size cruise ships likely to visit the Port of Cairns as part of CSDP.

International programs (e.g. the SILENV and BESST initiatives sponsored by the European Union) are aiming to reduce underwater noise emission from new-build ships. SILENV as part of its “Green Label” initiative provides a maximum design curve for underwater noise emission from new-build commercial vessels (SILENV 2012).

It is expected that as new-build cruise ships which comply with the EU noise guidelines become widely-used in Australia underwater noise levels from CSDP may decrease in the long-term due to a progressive change to quieter vessels.

Noise levels are shown for 10 knots which is likely to be representative of the worst-case noise emission from ships transiting the channel to/from Port of Cairns.

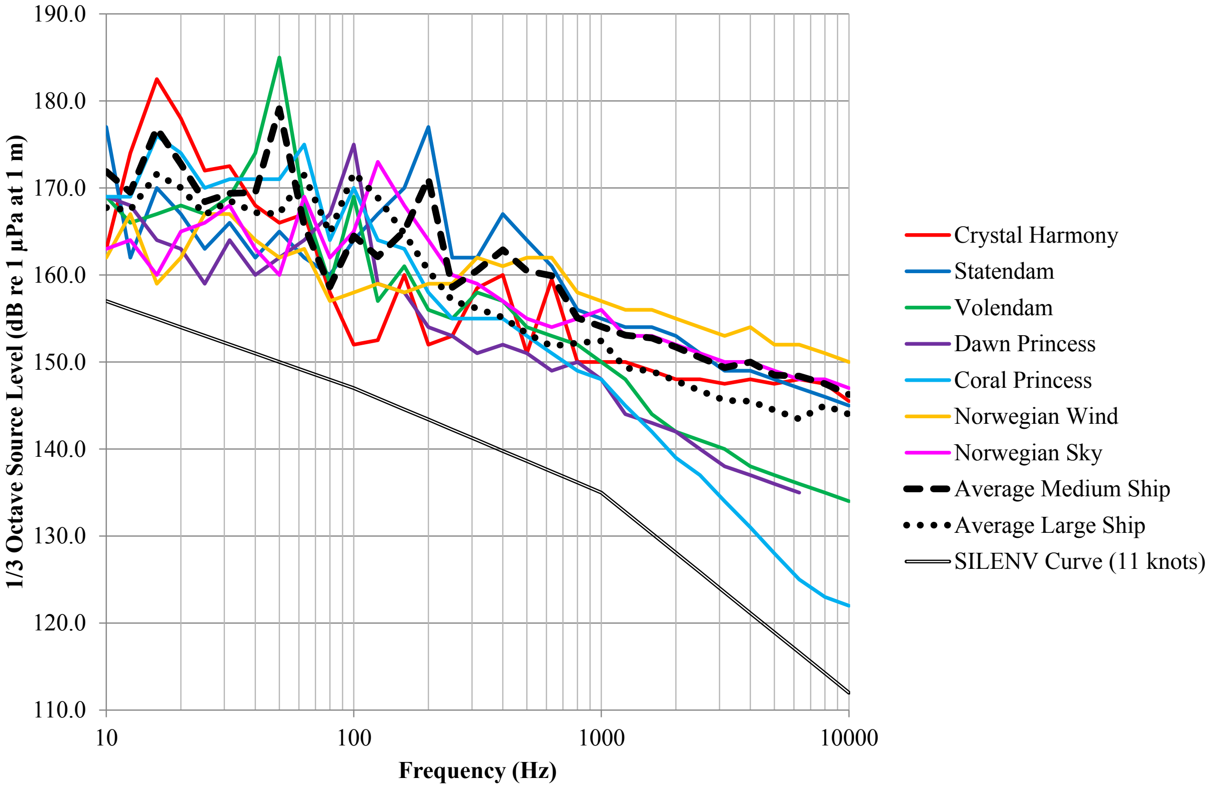



Figure D7.7.5.3b Summary of underwater noise level measurements from cruise ships at 10 knots, from Kipple 2002, Kipple 2004a, Kipple 2004b, with SILENV "Green Label" curve (SILENV 2012) for reference.

Although the large cruise ships have higher tonnage, their underwater noise emission in general is slightly lower than medium cruise ships. This is likely to be due to larger ships generally being newer than smaller ships, and hence receiving the benefit from improvements in propulsion technology (e.g. quieter propellers and thrusters).

Therefore, underwater noise impacts from CSDP have been assessed for the following scenarios:

"Near future" conditions using measured data of existing ships

- Average medium ship 184 dB re 1 µPa at 1 m
- Average larger ship 180 dB re 1 µPa at 1 m

"Future" conditions using SILENV "Green Label" maximum design levels (164 dB re 1 µPa at 1 m).

Shipping noise predictions were conducted for sources located at the Dock and in the Channel.

### D7.7.5.4 Summary of Source Levels

The source levels used for prediction are shown in **Figure D7.7.5.4a**.

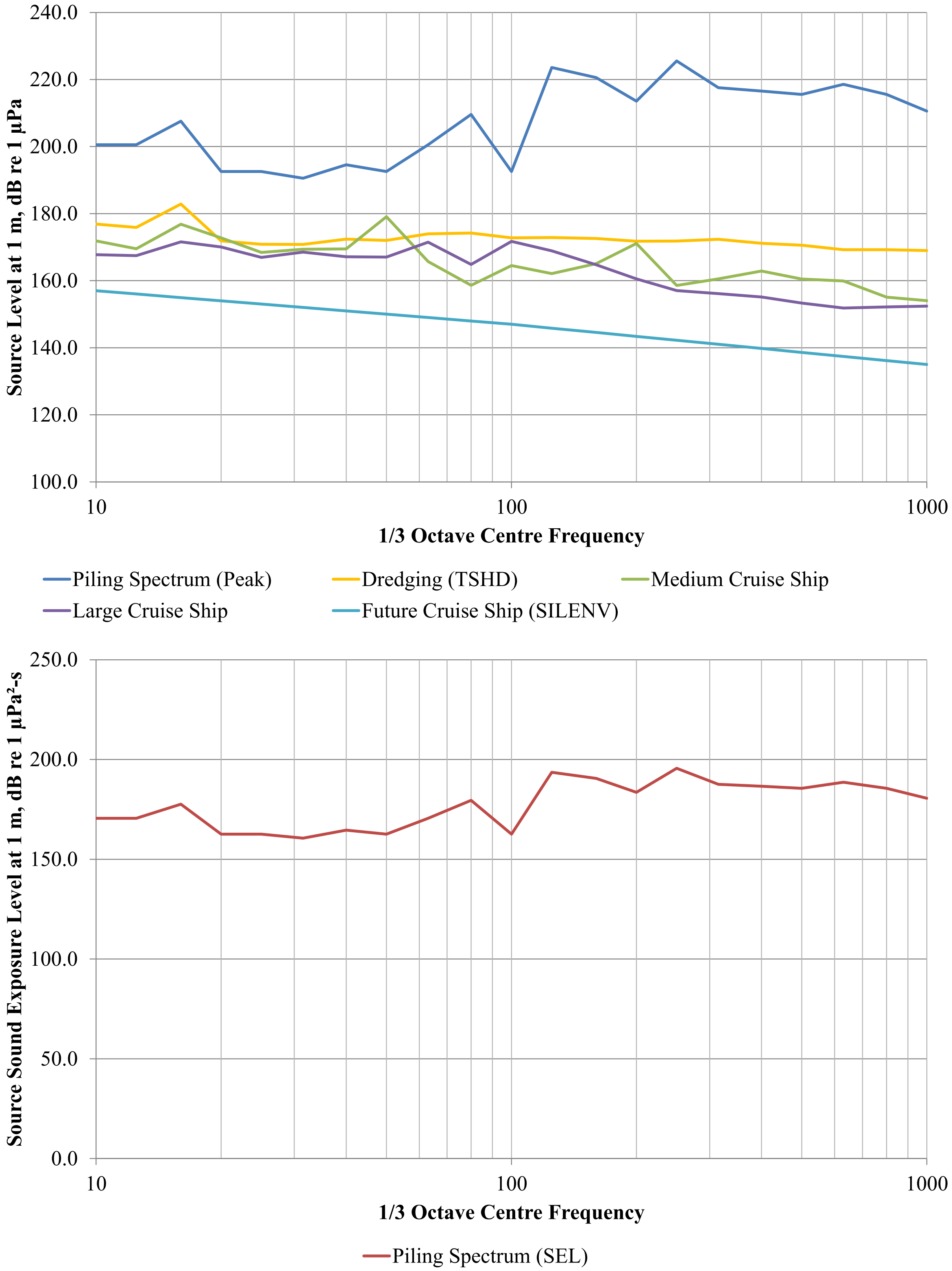



Figure D7.7.5.4a Source Levels used for CSDP

### D7.7.6 Underwater Acoustic Modelling

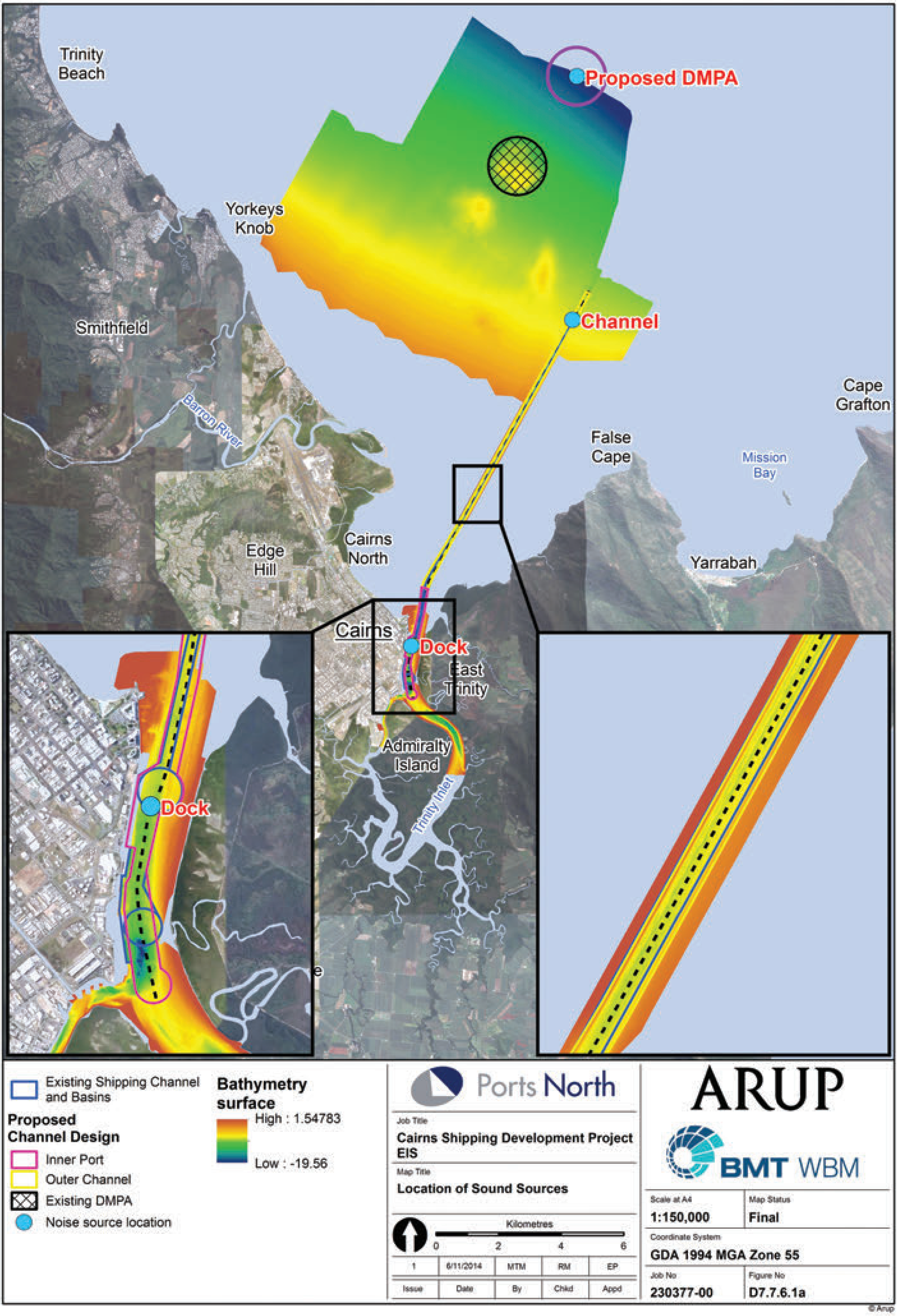
#### D7.7.6.1 Source Location

Three source locations were used:

- Inshore (dock)– vessels, piling and dredging at the new dock
- In-Channel– vessels and dredging in the new channel
- Offshore disposal area– disposal of dredge waste

Bathymetry data was obtained from the Geoscience Australia 250 m electronic bathymetry grid.

Figure D7.7.6.1a Location of Sound Sources, showing bathymetry traces used for prediction and DMPA



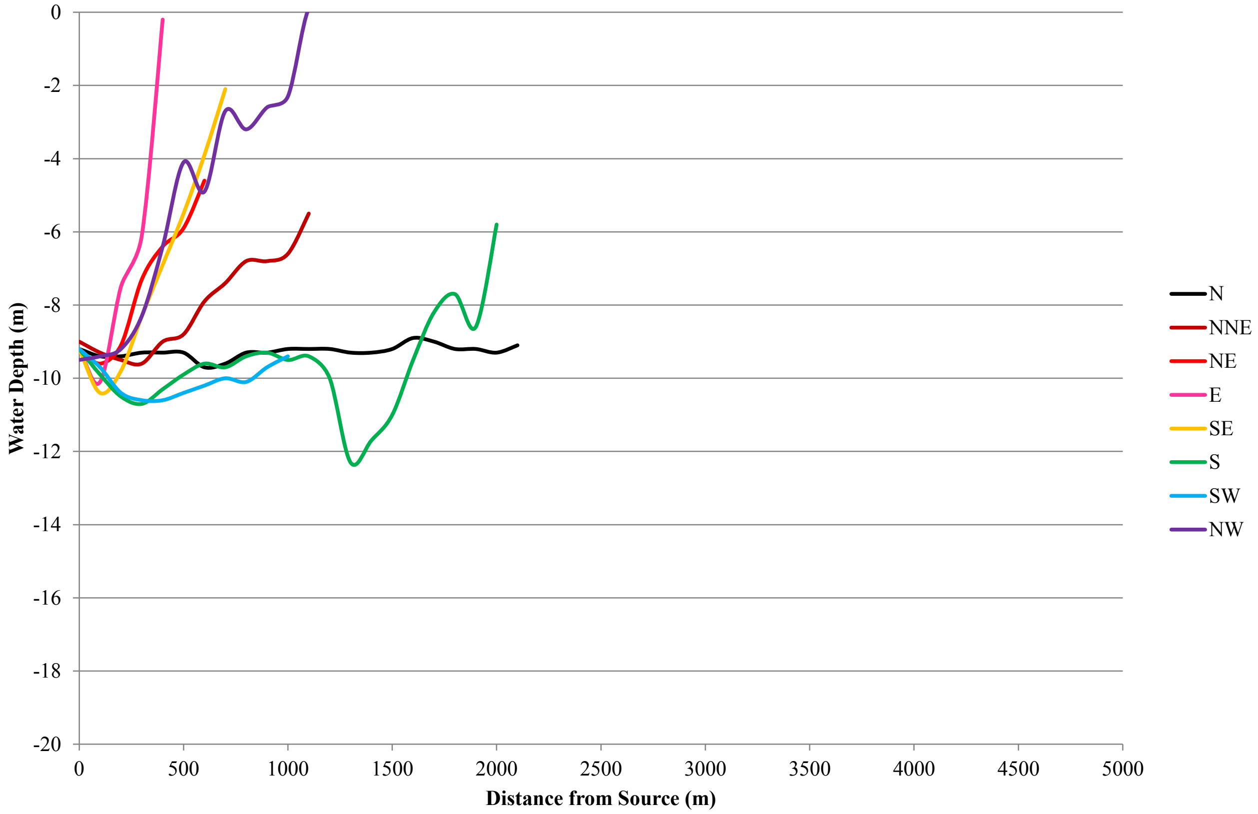



Figure D7.7.6.1b Bathymetry traces for “wharf” sources (labelled according to bearing from source)

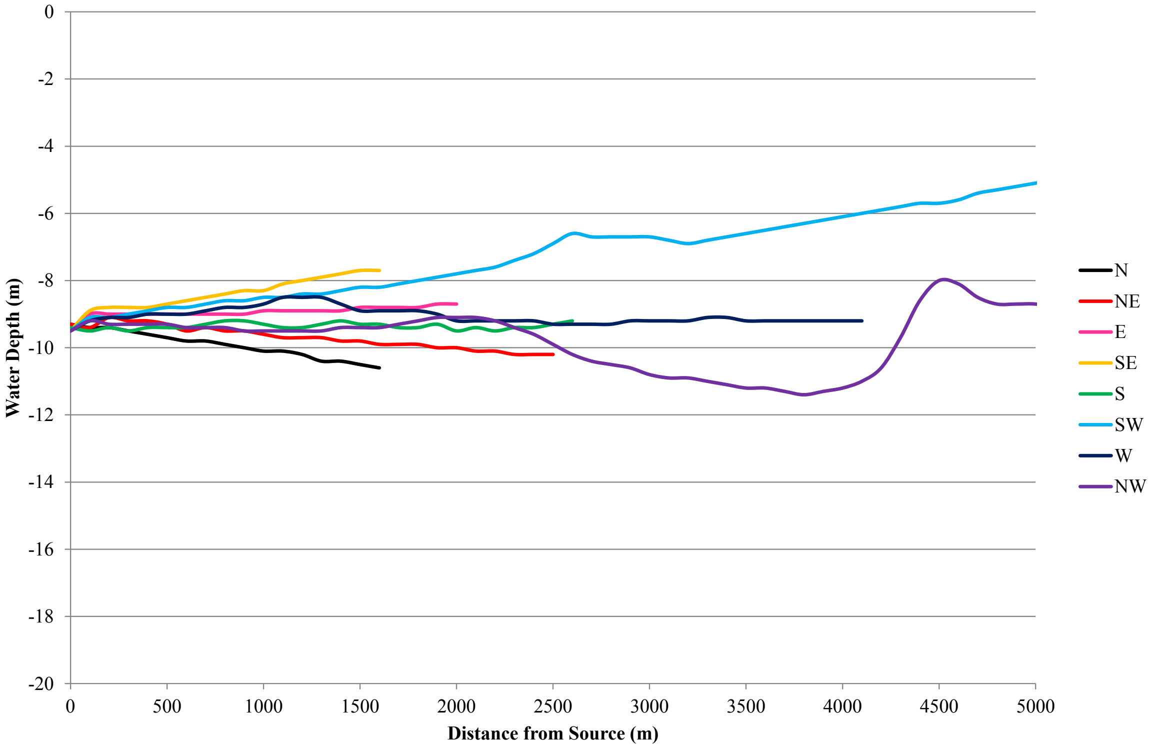



Figure D7.7.6.1c Bathymetry traces for “Channel” sources (labelled according to bearing from source)

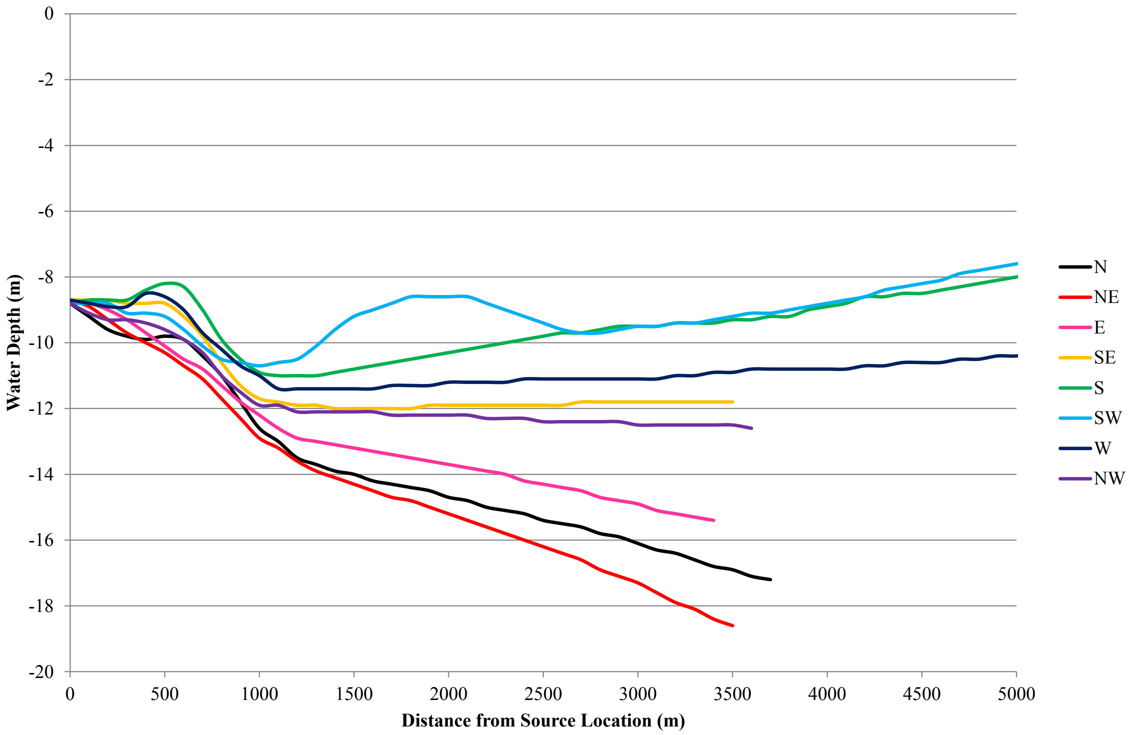



Figure D7.7.6.1d Bathymetry traces for “Dredging Disposal” sources (labelled according to bearing from source)

### D7.7.6.2 Acoustic Properties

The sound speed profile within the water column was calculated using data from the World Ocean Database (US National Oceanographic Data Centre, 2013) using four measurement points just offshore from Port of Cairns:

- **Point A:** Latitude 16.87° south, Longitude 145.83° east
- **Point B:** Latitude 16.82° south, Longitude 145.88° east
- **Point C:** Latitude 16.83° south, Longitude 145.95° east
- **Point D:** Latitude 16.828° south, Longitude 145.88° east

Points A-D are all within 15 km of the Project site. These locations are shown in **Figure D7.7.6.2a**. The measurements were taken in May 1984, July 1988, October 1979 and March 1989 respectively.

Figure D7.7.6.2a Locations of World Ocean Database measurement points relative to Cairns Port

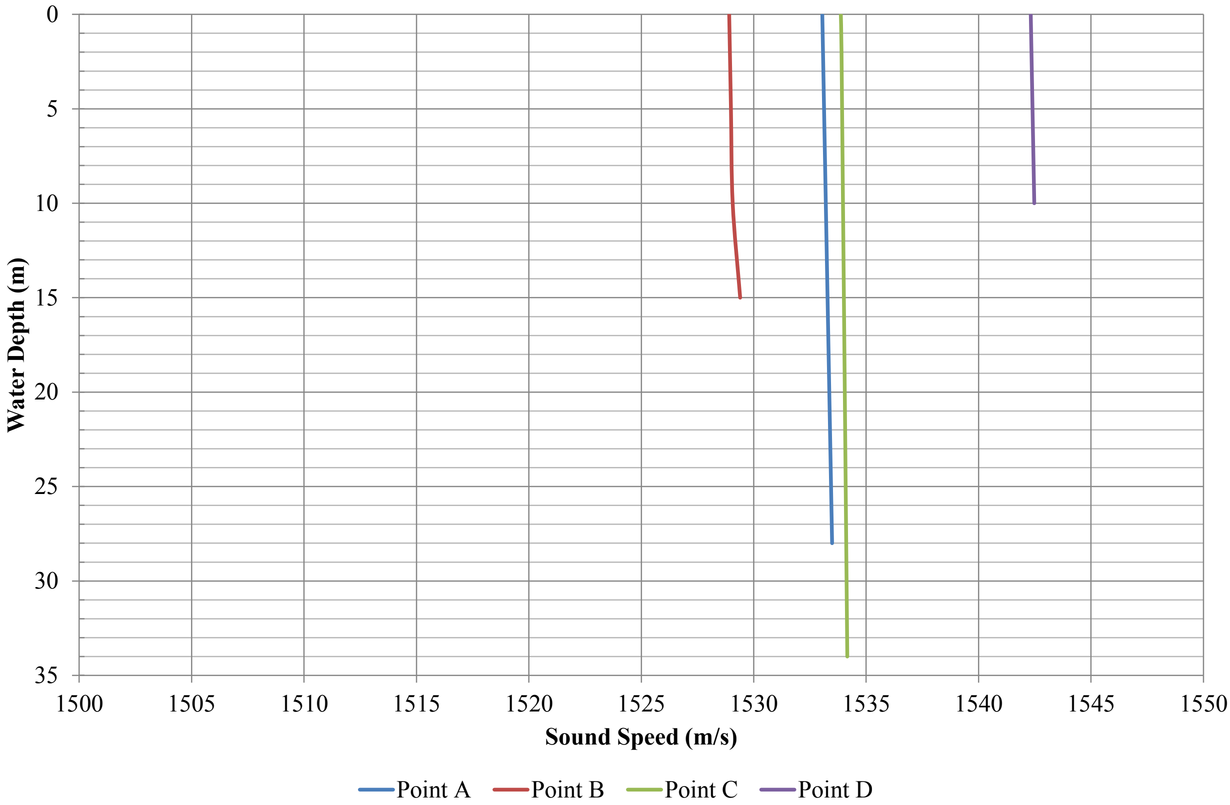



Figure D7.7.6.2b Sound Speed Profiles for CSD

Table D7.7.6.2a Ocean conditions and resulting calculated sound speed profile, Cairns Port

| Location | Depth (m) | Temperature (°C) | Salinity (PSU)* | Density** (kg/m³) | Sound Speed*** (m/s) |
|---|---|---|---|---|---|
| A | 0 | 24.5 | 35.0 | 1023.5 | 1533.0 |
| | 28 | 24.5 | 35.0 | 1024.7 | 1533.5 |
| B | 0 | 22.8 | 35.0 | 1023.9 | 1528.9 |
| | 5 | 22.8 | 35.0 | 1024.0 | 1529.0 |
| | 10 | 22.9 | 35.0 | 1024.0 | 1529.1 |
| | 15 | 22.9 | 35.0 | 1024.1 | 1529.4 |
| C | 0 | 24.8 | 35.0 | 1023.5 | 1533.8 |
| | 2 | 24.8 | 35.0 | 1023.5 | 1533.9 |
| | 34 | 24.7 | 35.0 | 1023.6 | 1534.2 |
| D | 0 | 28.5 | 35.0 | 1022.2 | 1542.3 |
| | 10 | 28.5 | 35.0 | 1022.3 | 1542.5 |

* Salinity data not available, assumed to be standard seawater salinity (35 PSU) for all measurements

** Calculated using the Millero et al equation (Millero et al, 1980)

*** Calculated using the Del Grosso equation (Del Grosso, 1974)

The temperature, salinity and density profiles are essentially constant with depth, and the change in pressure within the water column is not sufficient to result in a significant change in the sound speed. The change in sound speed between measurement points is fundamentally a function of the water temperature throughout the year. Hence, assuming constant water properties (based on average conditions across the year) will result in minimal error.

Water properties of temperature 24.5 Degrees Celsius (°C), density of 1024.5kg/m³ and sound speed of 1534 metres per second (m/s) were used as typical average water conditions for prediction.

**D7.7.7 Predicted Transmission Loss**

The underwater transmission loss (TL) was predicted using the RAMGeo model for each bathymetry trace for each source location. The model was calculated for the 1/3 octave bands from 10 Hz to 1 kHz (i.e. over 21 1/3 octave bands). For the inshore source, results are only presented for the 16 Hz band and above since the water is too shallow to predict transmission loss accurately at frequencies below 16 Hz.

The source depth was set as three metres for the inshore (dock) source location and 5m for the offshore (channel and disposal) locations – i.e. approximately at the mid-point in the water column. This corresponds approximately to noise radiation from the mid-section of a driven pile, or noise radiation from the underwater structure of a vessel (for the offshore locations).

The predicted transmission loss was significantly higher for the north source (in shallow water, which is a less-efficient transmission path for sound). TL was generally greater for low frequencies than high frequencies. This is the inverse of typical underwater conditions where low-frequency propagation is efficient, and occurs because the water is too shallow to efficiently propagate low frequencies.

Note that since the RAMGeo model predicts the interaction between the water column and the seafloor, transmission loss data includes wave propagation in the seafloor and the rock substrate below. Hence, sometimes the TL plots show sound “escaping” the water column into the seabed (usually for steeper angles of incidence closer to the source.

A receptor depth of 3 m was used for all predictions.

An example plot of TL vs. distance (for the Channel source location, 90° bearing) is given in **Figure D7.7.7a**.

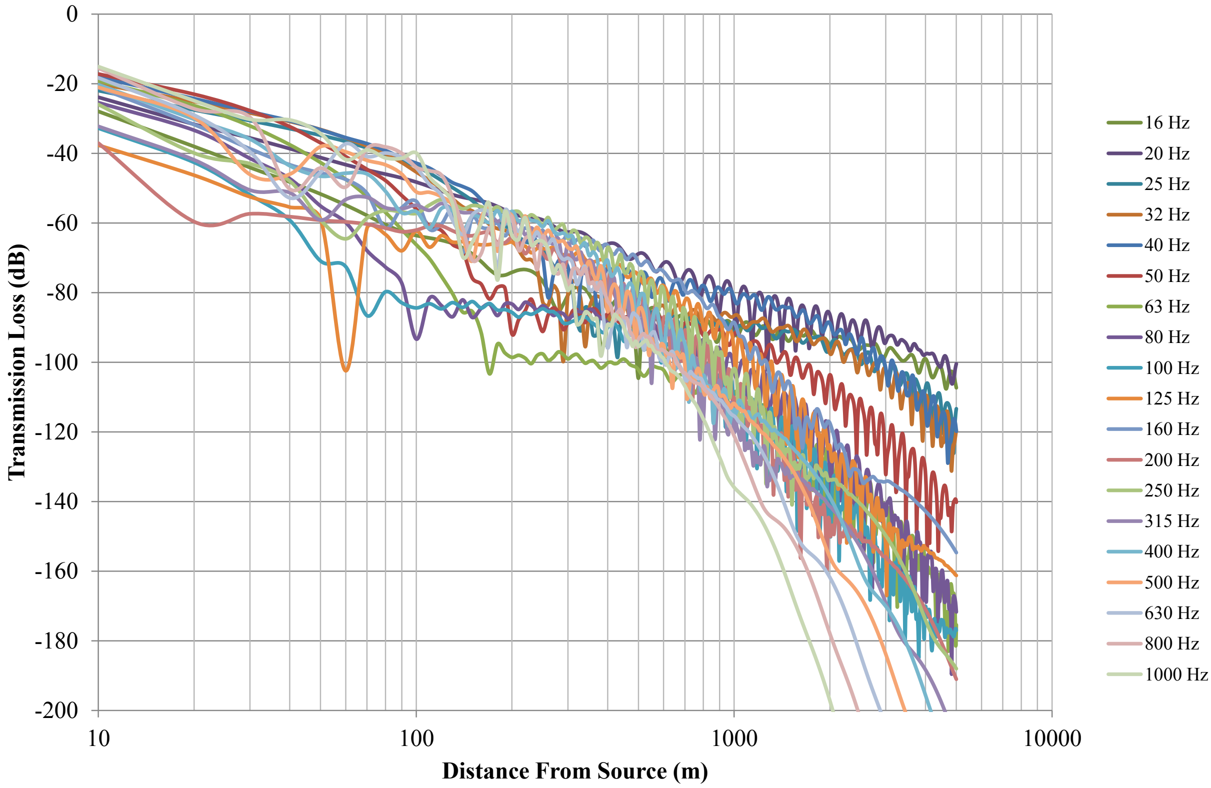



Figure D7.7.7a Example Transmission Loss Plot, CSDP

**D7.8 Predicted Noise Levels**

When assessing impacts on receivers the expected duration of the noise impact has been determined as either up to 1 month or greater than 1 month.

- TSHD dredging is expected to have a noise impact of less than one month at any particular receiver because the dredge source will move as dredging progresses.
- Backhoe dredging is expected to have a noise impact of greater than one month because the backhoe dredge will stay within the swing basin for approximately 23 weeks during capital dredging.
- IFO pipeline construction is expected to take longer than 1 month.

Piling is expected to be conducted over a construction period of 7-8 months.

Noise contour maps have been produced for construction and operation. They have been included at the end of this Appendix.

### D7.8.1 Construction Noise

Table D7.8.1a Predicted construction noise levels, dB re 20µPa

| Receptor | Activity | Expected Duration of Impact | Noise Criteria | | Predicted noise level, dB(A) | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Noise Affected** | **Highly Affected** | **Neutral weather conditions (Pasquil stability category D)** | **Adverse weather conditions (Pasquil stability category B)** | | | |
| Site 1: Wharf Street | Capital Dredging – TSHD | <1 month | Day – 64<br>Evening – 53<br>Night – 51 | Day – 75<br>Evening – 58<br>Night – 55 | 48 | 52 | Negligible | Almost certain | Low |
| | Capital Dredging - Backhoe | >1 month | Day – 64<br>Evening – 53<br>Night – 51 | Day – 75<br>Evening – 58<br>Night – 55 | **68** | **68** | Minor (construction within standard hours)<br>High (construction outside standard hours) | Almost certain (standard hours)<br>Likely (outside hours) | Medium (standard hours)<br>High (outside hours) |
| | Maintenance Dredging – TSHD | <1 month | Day – 64<br>Evening – 53<br>Night – 51 | Day – 75<br>Evening – 58<br>Night – 55 | 46 | 50 | Negligible | Almost certain | Low |
| | IFO Pipeline construction | >1 month | Day – 64<br>Evening – 53<br>Night – 51 | Day – 75<br>Evening – 58<br>Night – 55 | 51 | 51 | Negligible | Almost certain | Low |
| | Piling | >1 month | Day – 64<br>Evening – 53<br>Night – 51 | Day – 75<br>Evening – 58<br>Night – 55 | **67** | **67** | Minor (construction within standard hours<br>High(construction outside standard hours) | Almost certain (standard hours)<br>Possible (outside hours) | Low (standard hours)<br>Medium (outside hours) |

| **Receptor** | **Activity** | **Expected Duration of Impact** | **Noise Criteria** | | **Predicted noise level, dB(A)** | | **Significance of Impact** | **Probability** | **Risk Rating** |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Noise Affected** | **Highly Affected** | **Neutral weather conditions (Pasquil stability category D)** | **Adverse weather conditions (Pasquil stability category B)** | | | |
| Site 2: East Trinity | Capital Dredging – TSHD | <1 month | Day – 50<br>Evening – 40<br>Night – 35 | Day – 75<br>Evening – 45<br>Night – 40 | 32 | 37 | Negligible | Almost certain | Low |
| | Capital Dredging - Backhoe | >1 month | Day – 50<br>Evening – 40<br>Night – 35 | Day – 75<br>Evening – 45<br>Night – 40 | 22 | 26 | Negligible | Almost certain (standard hours)<br>Likely (outside hours) | Low (standard hours)<br>Negligible (outside hours) |
| | Maintenance Dredging – TSHD | <1 month | Day – 50<br>Evening – 40<br>Night – 35 | Day – 75<br>Evening – 45<br>Night – 40 | 30 | 35 | Negligible | Almost certain | Low |
| | IFO Pipeline construction | >1 month | Day – 50<br>Evening – 40<br>Night – 35 | Day – 75<br>Evening – 45<br>Night – 40 | 0 | 0 | Negligible | Almost certain | Low |
| | Piling | >1 month | Day – 50<br>Evening – 40<br>Night – 35 | Day – 75<br>Evening – 45<br>Night – 40 | 16 | 21 | Negligible | Almost certain (standard hours)<br>Possible (outside hours) | Low (standard hours)<br>Negligible (outside hours) |

| Receptor | Activity | Expected Duration of Impact | Noise Criteria | | Predicted noise level, dB(A) | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|---|
| | | | Noise Affected | Highly Affected | Neutral weather conditions (Pasquil stability category D) | Adverse weather conditions (Pasquil stability category B) | | | |
| Site 3: Trinity Inlet | Capital Dredging – TSHD | <1 month | Day – 52<br>Evening – 45<br>Night – 45 | Day – 75<br>Evening – 50<br>Night – 50 | **53** | **56** | Negligible (construction within standard hours)<br>Minor (construction outside standard hours) | Almost certain (standard hours)<br>Likely (outside hours) | Low (standard hours)<br>Medium (outside hours) |
| | Capital Dredging - Backhoe | >1 month | Day – 52<br>Evening – 45<br>Night – 45 | Day – 75<br>Evening – 50<br>Night – 50 | **58** | **62** | Minor (construction within standard hours)<br>High (construction outside standard hours) | Almost certain (standard hours)<br>Likely (outside hours) | Medium (standard hours)<br>High (outside hours) |
| | Maintenance Dredging – TSHD | <1 month | Day – 52<br>Evening – 45<br>Night – 45 | Day – 75<br>Evening – 50<br>Night – 50 | 51 | **54** | Negligible (construction within standard hours)<br>Minor (construction outside standard hours) | Almost certain (standard hours)<br>Likely (outside hours) | Low (standard hours)<br>Medium (outside hours) |
| | IFO Pipeline construction | >1 month | Day – 52<br>Evening – 45<br>Night – 45 | Day – 75<br>Evening – 50<br>Night – 50 | 41 | 46 | Negligible | Almost certain | Low |
| | Piling | >1 month | Day – 52<br>Evening – 45<br>Night – 45 | Day – 75<br>Evening – 50<br>Night – 50 | **54** | **59** | Minor (construction within standard hours)<br>Moderate (construction outside standard hours) | Almost certain (standard hours)<br>Possible (outside hours) | Low (standard hours)<br>Medium (outside hours) |

### D7.8.1.1 Maximum Noise Levels - Construction

Table D7.8.1.1a Predicted maximum noise levels at nearest noise sensitive receptors – Construction

| Source | Location | Sleep Disturbance Screening Criteria dB(A) re 20µPa $L_{Amax}$ | | Sound pressure level dB(A) re 20µPa $L_{Amax}$ | | Significance of Impact | Risk Rating |
|---|---|---|---|---|---|---|---|
| | | Emergence | Absolute | Meteorological conditions | | | |
| | | | | Neutral | Adverse | | |
| Dredging – backhoe | Wharf St | 61 | 62 | 68 | 68 | Minor | Medium<br>(backhoe dredging is likely to occur outside standard hours) |
| | East Trinity | 45 | 62 | 43 | 48 | Negligible | Negligible |
| | Trinity Inlet | 55 | 62 | 64 | 67 | Minor | Medium<br>(backhoe dredging is likely to occur outside standard hours) |
| | Migratory birds | 72 | | 29 | 34 | Negligible | Negligible |
| Dredging - TSHD | Wharf St | 61 | 62 | 62 | 64 | Negligible | Low |
| | East Trinity | 45 | 62 | 0 | 0 | Negligible | Negligible |
| | Trinity Inlet | 55 | 62 | 67 | 69 | Minor | Medium<br>(TSHD dredging may occur in the vicinity of receivers outside standard hours) |
| | Migratory Birds | 72 | | 50 | 55 | Negligible | Negligible |
| IFO Pipeline | Wharf St | 61 | 62 | 56 | 57 | Negligible | Negligible |
| | East Trinity | 45 | 62 | 0 | 0 | Negligible | Negligible |
| | Trinity Inlet | 55 | 62 | 46 | 51 | Negligible | Negligible |
| | Protected Birds | 72 | | 6 | 12 | Negligible | Negligible |

| Source | Location | Sleep Disturbance Screening Criteria dB(A) re 20µPa $L_{Amax}$ | | Sound pressure level dB(A) re 20µPa $L_{Amax}$ Meteorological conditions | | Significance of Impact | Risk Rating |
|---|---|---|---|---|---|---|---|
| | | Emergence | Absolute | Neutral | Adverse | | |
| Piling | Wharf St | 61 | 62 | 77 | 77 | Moderate | Low<br>(Piling will likely be confined to standard hours) |
| | East Trinity | 45 | 62 | 27 | 32 | Negligible | Low |
| | Trinity Inlet | 55 | 62 | 65 | 69 | Minor | Low<br>(Piling will likely be confined to standard hours) |
| | Protected Birds | 72 | | 43 | 49 | Negligible | Low |

**Note:** Bold – predicted exceedance of noise impact criteria

### D7.8.2 Operational Noise

Table D7.8.2a Predicted operational noise levels at nearest noise sensitive receptors – Existing Scenario (*Rhapsody of the Seas*).

| Source | Location | Time Period | Noise Impact Criteria dB(A) re 20µPa $L_{Aeq}$ | Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | Adverse | | | |
| Cruise ship docked | Wharf St | Day | 57 | 54 | 55 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Almost Certain | Low |
| | | Night | 49 | | | Minor | Almost Certain | Low* |
| | East Trinity | Day | 43 | 18 | 22 | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |

| Source | Location | Time Period | Noise Impact Criteria dB(A) re 20µPa $L_{Aeq}$ | Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions: Neutral | Adverse | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 45 | 49 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Almost Certain | Low |
| | | Night | 43 | | | Negligible | Almost Certain | Low |
| Cruise ship loading/unloading | Wharf St | Day | 57 | 54 | 55 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Negligible |
| | | Night | 49 | | | Minor | Unlikely | Low** |
| | East Trinity | Day | 43 | 15 | 19 | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 44 | 48 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Possible | Negligible |
| | | Night | 43 | | | Negligible | Unlikely | Negligible |
| Cruise ship berthing | Wharf St | Day | 57 | 54 | 55 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Negligible |
| | | Night | 49 | | | Minor | Unlikely | Low** |
| | East Trinity | Day | 43 | 9 | 13 | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |

| Source | Location | Time Period | Noise Impact Criteria dB(A) re 20µPa $L_{Aeq}$ | Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | Adverse | | | |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 38 | 42 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Possible | Negligible |
| | | Night | 43 | | | Negligible | Unlikely | Negligible |
| Cruise ship transit | Wharf St | Day | 57 | 50 | 51 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Low |
| | | Night | 49 | | | Negligible | Unlikely | Low |
| | East Trinity | Day | 43 | 29 | 33 | Negligible | Almost Certain | Low |
| | | Evening | 38 | | | Negligible | Possible | Low |
| | | Night | 33 | | | Negligible | Unlikely | Low |
| | Trinity Inlet | Day | 45 | 50 | 54 | Minor | Almost Certain | Low*** |
| | | Evening | 43 | | | Moderate | Possible | Low*** |
| | | Night | 43 | | | Moderate | Unlikely | Low*** |

* Assessed as Low risk since although impacts would be expected to occur whenever a large cruise ship stays overnight at Port of Cairns, there is no history of complaints for residents being exposed to this noise level from existing port operation.

** Assessed as Low risk since loading/unloading activities are unlikely to occur at the quietest time of Night (which the noise criteria are based on)

*** Assessed as Low risk since ship entry/exit will be a discrete activity only occurring once per assessment time period; hence the risk of a cruise ship entry/exit occurring at the same time as the quietest part of the assessment period (which the criteria are based on) is low. Additionally, it is not reasonable to expect receivers located adjacent to a shipping channel not to be exposed to shipping noise.

Table D7.8.2b Predicted operational noise levels at nearest noise sensitive receptors – Future Medium ship (e.g. *Pacific Dawn, Sun Princess*)

| Source | Location | Time Period | Noise Impact Criteria dB(A) re 20µPa $L_{Aeq}$ | Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | Adverse | | | |
| Medium cruise ship docked | Wharf Street | Day | 57 | 46 | 46 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Almost Certain | Low |
| | | Night | 49 | | | Negligible | Almost Certain | Low |
| | East Trinity | Day | 43 | 9 | 13 | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 36 | 40 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Almost Certain | Low |
| | | Night | 43 | | | Negligible | Almost Certain | Low |
| Medium cruise ship loading/unloading | Wharf St | Day | 57 | 51 | 52 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Negligible |
| | | Night | 49 | | | Negligible | Unlikely | Negligible |
| | East Trinity | Day | 43 | 3 | 8 | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 37 | 41 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Possible | Low |
| | | Night | 43 | | | Negligible | Unlikely | Low |
| Medium cruise ship berthing | Wharf St | Day | 57 | 52 | 53 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Negligible |
| | | Night | 49 | | | Negligible | Unlikely | Negligible |

| Source | Location | Time Period | Noise Impact Criteria dB(A) re 20µPa $L_{Aeq}$ | Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | Adverse | | | |
| | East Trinity | Day | 43 | - | - | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 34 | 39 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Possible | Negligible |
| | | Night | 43 | | | Negligible | Unlikely | Negligible |
| Medium cruise ship transit | Wharf St | Day | 57 | 46 | 47 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Negligible |
| | | Night | 49 | | | Negligible | Unlikely | Negligible |
| | East Trinity | Day | 43 | 26 | 31 | Negligible | Almost Certain | Low |
| | | Evening | 38 | | | Negligible | Possible | Negligible |
| | | Night | 33 | | | Negligible | Unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 46 | 50 | Negligible | Almost Certain | Low* |
| | | Evening | 43 | | | Minor | Possible | Low* |
| | | Night | 43 | | | Minor | Unlikely | Low* |

* Ship entry/exit will be a single event occurring in each time period and is therefore an "occasional" noise event. Cruise ships generally enter and leave port during the Day or Evening time periods and hence the risk of a Night time noise impact occurring is low.

Table D7.8.2c Predicted operational noise levels at nearest noise sensitive receptors – Future Large ship (e.g. *Radiance of the Seas*, *Carnival Spirit*)

| **Source** | **Location** | **Time Period** | **Noise Impact Criteria dB(A) re 20µPa LAeq** | **Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions** | | **Significance of Impact** | **Probability** | **Risk Rating** |
|---|---|---|---|---|---|---|---|---|
| | | | | **Neutral** | **Adverse** | | | |
| Large cruise ship docked | Wharf St | Day | 57 | 53 | 54 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Almost Certain | Low |
| | | Night | 49 | | | Minor | Almost Certain | Low* |
| | East Trinity | Day | 43 | 17 | 21 | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 44 | 48 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Almost Certain | Low |
| | | Night | 43 | | | Negligible | Almost Certain | Low |
| Large cruise ship loading/unloading | Wharf St | Day | 57 | 54 | 55 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Negligible |
| | | Night | 49 | | | Minor | Unlikely | Low** |
| | East Trinity | Day | 43 | 15 | 19 | Negligible | Highly unlikely | Negligible |

| Source | Location | Time Period | Noise Impact Criteria dB(A) re 20µPa LAeq | Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions Neutral | Adverse | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 44 | 48 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Possible | Negligible |
| | | Night | 43 | | | Negligible | Unlikely | Negligible |
| Large cruise ship berthing | Wharf St | Day | 57 | 53 | 54 | Negligible | Almost Certain | Low |
| Large cruise ship berthing | | Evening | 51 | | | Negligible | Possible | Negligible |
| | | Night | 49 | | | Minor | Unlikely | Low** |
| | East Trinity | Day | 43 | 8 | 12 | Negligible | Highly unlikely | Negligible |
| | | Evening | 38 | | | Negligible | Highly unlikely | Negligible |
| | | Night | 33 | | | Negligible | Highly unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 37 | 41 | Negligible | Almost Certain | Low |
| | | Evening | 43 | | | Negligible | Possible | Negligible |
| | | Night | 38 | | | Negligible | Unlikely | Negligible |
| Large cruise ship transit | Wharf St | Day | 57 | 49 | 50 | Negligible | Almost Certain | Low |
| | | Evening | 51 | | | Negligible | Possible | Negligible |

| Source | Location | Time Period | Noise Impact Criteria dB(A) re 20µPa LAeq | Sound pressure level dB(A) re 20µPa $L_{Aeq}$ Meteorological conditions | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | | | Neutral | Adverse | | | |
| | | Night | 49 | | | Negligible | Unlikely | Negligible |
| | East Trinity | Day | 43 | 28 | 32 | Negligible | Almost Certain | Low |
| | | Evening | 38 | | | Negligible | Possible | Negligible |
| | | Night | 33 | | | Negligible | Unlikely | Negligible |
| | Trinity Inlet | Day | 45 | 49 | 53 | Minor | Almost Certain | Low*** |
| | | Evening | 43 | | | Moderate | Possible | Low*** |
| | | Night | 43 | | | Moderate | Unlikely | Low*** |

* Assessed as Low risk since no complaints have been received for existing visits by Rhapsody of the Seas which has very similar noise emission to future large cruise ships

** Assessed as Low risk since loading/unloading activities are unlikely to occur at the quietest time of Night (which the noise criteria are based on)

*** Assessed as Low risk since ship entry/exit will be a discrete activity only occurring once per assessment time period; hence the risk of a cruise ship entry/exit occurring at the same time as the quietest part of the assessment period (which the criteria are based on) is low. Additionally, it is not reasonable to expect receivers located adjacent to a shipping channel not to be exposed to shipping noise.

#### D7.8.2.1 Maximum Noise Levels

Table D7.8.2.1a Predicted maximum noise levels at nearest noise sensitive receptors – Medium ship

| **Source** | **Location** | **Sleep Disturbance Screening Criteria dB(A) re 20µPa $L_{Amax}$** | | **Sound pressure level dB(A) re 20µPa $L_{Amax}$** | | **Significance of Impact** | **Probability** | **Risk Rating** |
|---|---|---|---|---|---|---|---|---|
| | | **Emergence** | **Absolute** | **Meteorological conditions** | | | | |
| | | | | **Neutral** | **Adverse** | | | |
| Medium cruise ship loading/ unloading | Wharf St | 61 | 62 | 60 | 61 | Negligible | Unlikely | Negligible |
| | East Trinity | 45 | 62 | - | - | Negligible | Unlikely | Negligible |
| | Trinity Inlet | 55 | 62 | 34 | 39 | Negligible | Unlikely | Negligible |
| | Protected Birds | 72 | | 21 | 27 | Negligible | Unlikely | Low |
| Medium cruise ship berthing | Wharf St | 61 | 62 | 62 | 62 | Negligible | Unlikely | Negligible |
| | East Trinity | 45 | 62 | 16 | 21 | Negligible | Unlikely | Negligible |
| | Trinity Inlet | 55 | 62 | 54 | 58 | Negligible | Unlikely | Negligible |
| | Protected Birds | 72 | | 38 | 41 | Negligible | Unlikely | Low |
| Medium cruise ship transit | Wharf St | 61 | 62 | **66** | **66** | Minor | Unlikely | Low |
| | East Trinity | 45 | 62 | 34 | 40 | Negligible | Unlikely | Negligible |
| | Trinity Inlet | 55 | 62 | **64** | **67** | Minor | Unlikely | Low |
| | Protected Birds | 72 | | 48 | 54 | Negligible | Unlikely | Negligible |

Table D7.8.2.1b Predicted maximum noise levels at nearest noise sensitive receptors – Large ship

| Source | Location | Sleep Disturbance Screening Criteria dB(A) re 20µPa $L_{Amax}$ | | Sound pressure level dB(A) re 20µPa $L_{Amax}$ | | Significance of Impact | Probability | Risk Rating |
|---|---|---|---|---|---|---|---|---|
| | | Emergence | Absolute | Meteorological conditions | | | | |
| | | | | Neutral | Adverse | | | |
| Large cruise ship loading/ unloading | Wharf St | 61 | 62 | 60 | 61 | Negligible | Unlikely | Low |
| | East Trinity | 45 | 62 | 0 | 0 | Negligible | Unlikely | Low |
| | Trinity Inlet | 55 | 62 | 34 | 39 | Negligible | Unlikely | Low |
| | Protected Birds | 72 | | 21 | 26 | Negligible | Unlikely | Low |
| Large cruise ship berthing | Wharf St | 61 | 62 | 62 | 62 | Negligible | Unlikely | Low |
| | East Trinity | 45 | 62 | 16 | 21 | Negligible | Unlikely | Low |
| | Trinity Inlet | 55 | 62 | 54 | 58 | Negligible | Unlikely | Low |
| | Protected Birds | 72 | | 38 | 41 | Negligible | Unlikely | Low |
| Large cruise ship transit | Wharf St | 61 | 62 | **74** | **75** | Moderate | Unlikely | Low* |
| | East Trinity | 45 | 62 | 41 | 46 | Negligible | Unlikely | Low* |
| | Trinity Inlet | 55 | 62 | **73** | **76** | Moderate | Unlikely | Low* |
| | Protected Birds | 72 | | 55 | 60 | Negligible | Unlikely | Low* |

* Assessed as Low risk since ship entry/exit will be a discrete activity only occurring once per assessment time period; hence the risk of a cruise ship entry/exit occurring at the same time as the quietest part of the assessment period (which the criteria are based on) is low.

### D7.8.3 Underwater Noise

### D7.8.3.1 Impact Piling Noise

Predicted underwater levels from piling operation without mitigation measures being applied at the Dock are shown in **Figure D7.8.3.1a** to **D7.8.3.1f**.

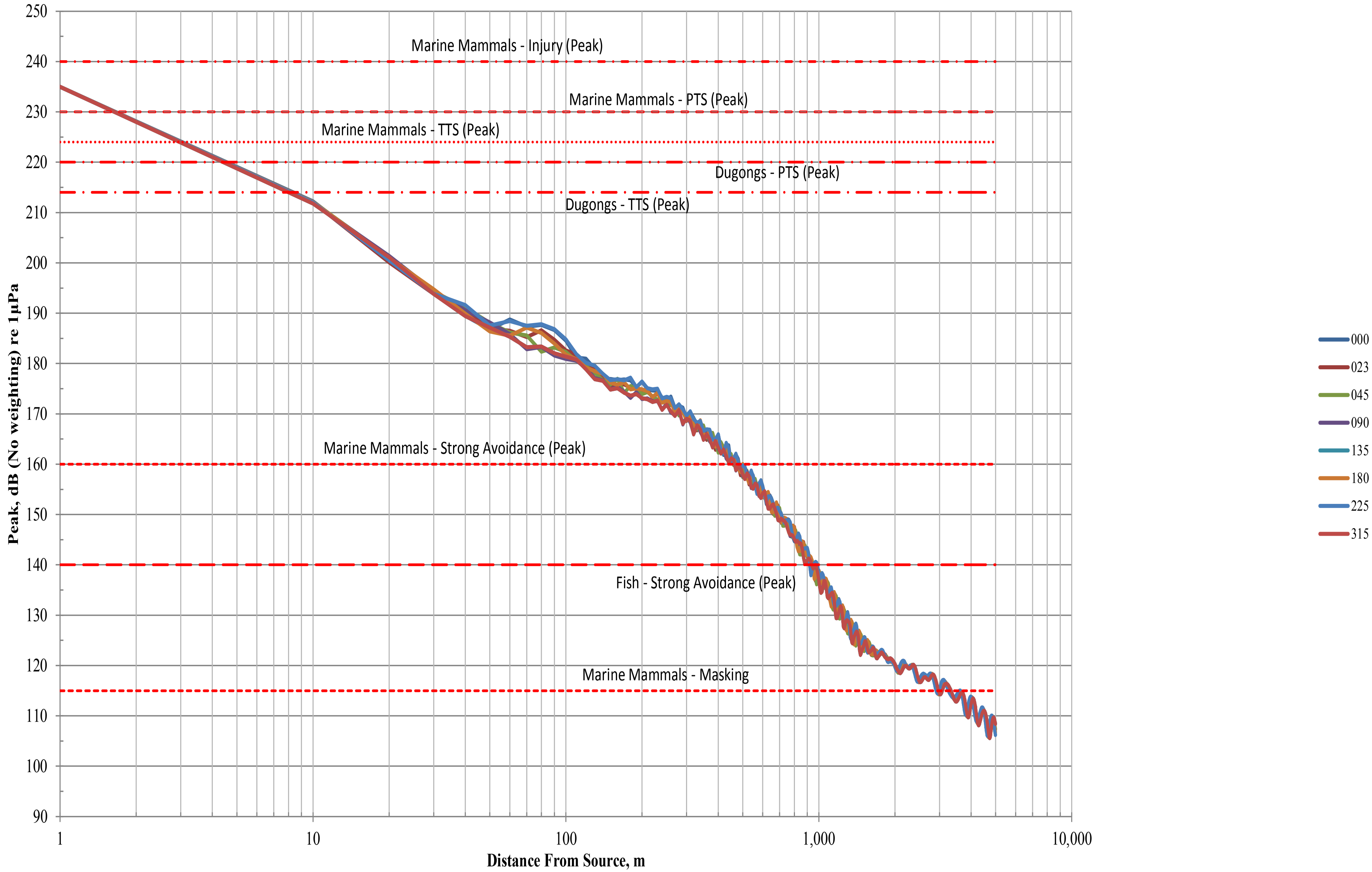



Figure D7.8.3.1a Predicted peak pressure (dB re 1 µPa) from piling at Wharf (labelled to show bearing from source – i.e. 000 is north, 180 is south etc.)

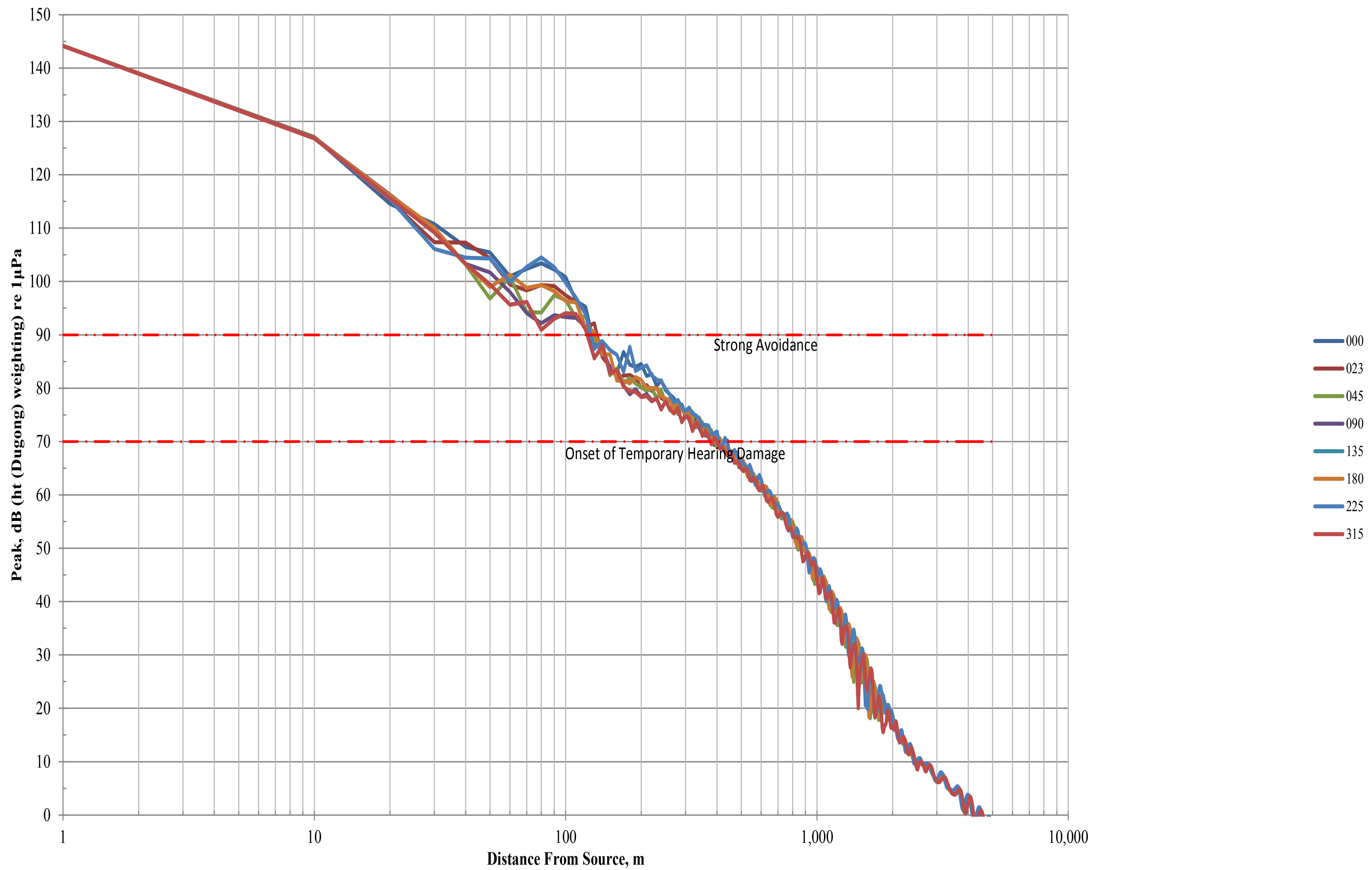



Figure D7.8.3.1b Predicted peak pressure ($dB_{ht(\textit{Dugong dugon})}$) re 1 µPa) from piling at Wharf

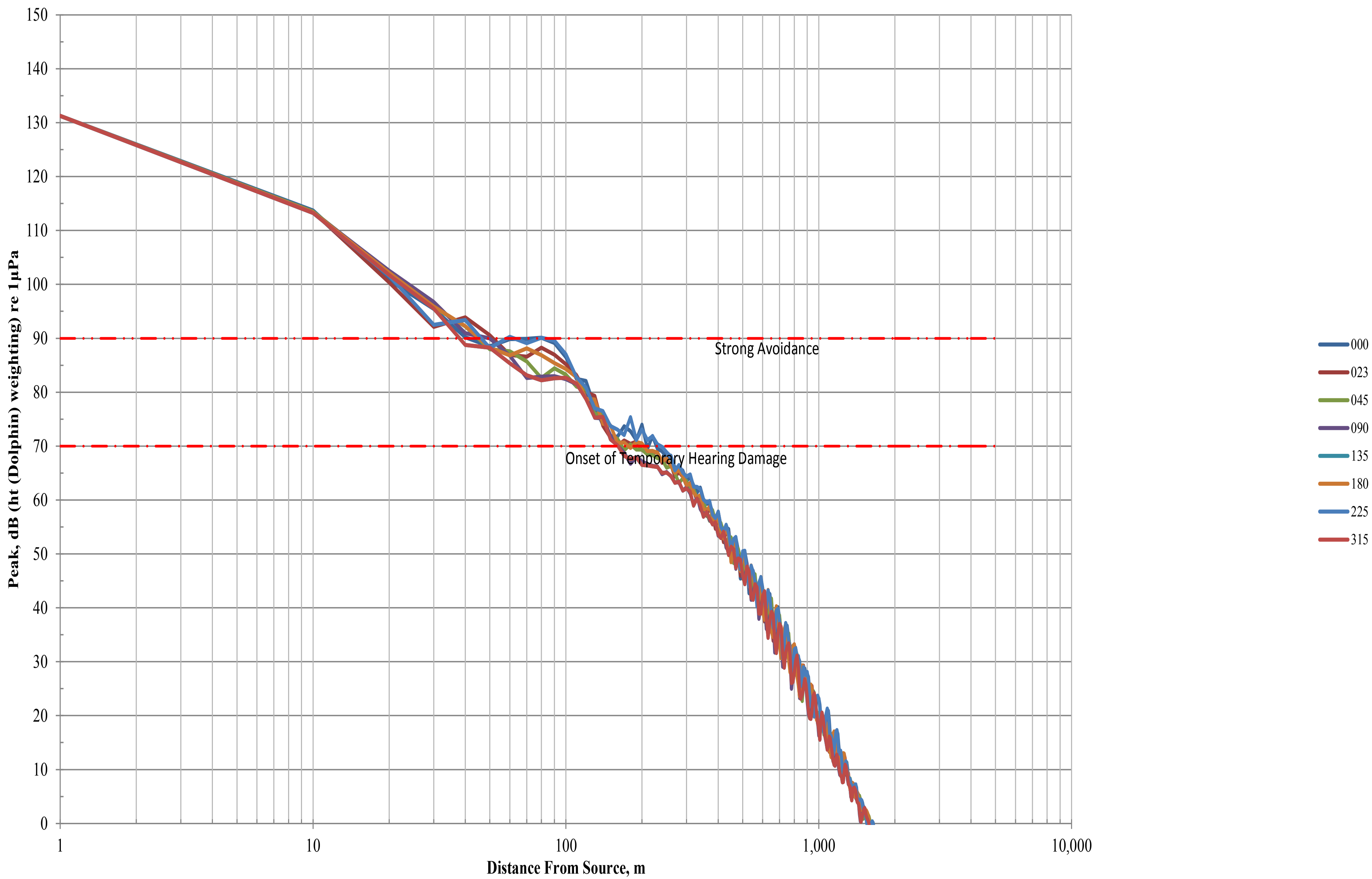



Figure D7.8.3.1c Predicted peak pressure ($dB_{ht(\textit{Tursiops truncatus})}$) re 1 μPa) from piling at Wharf

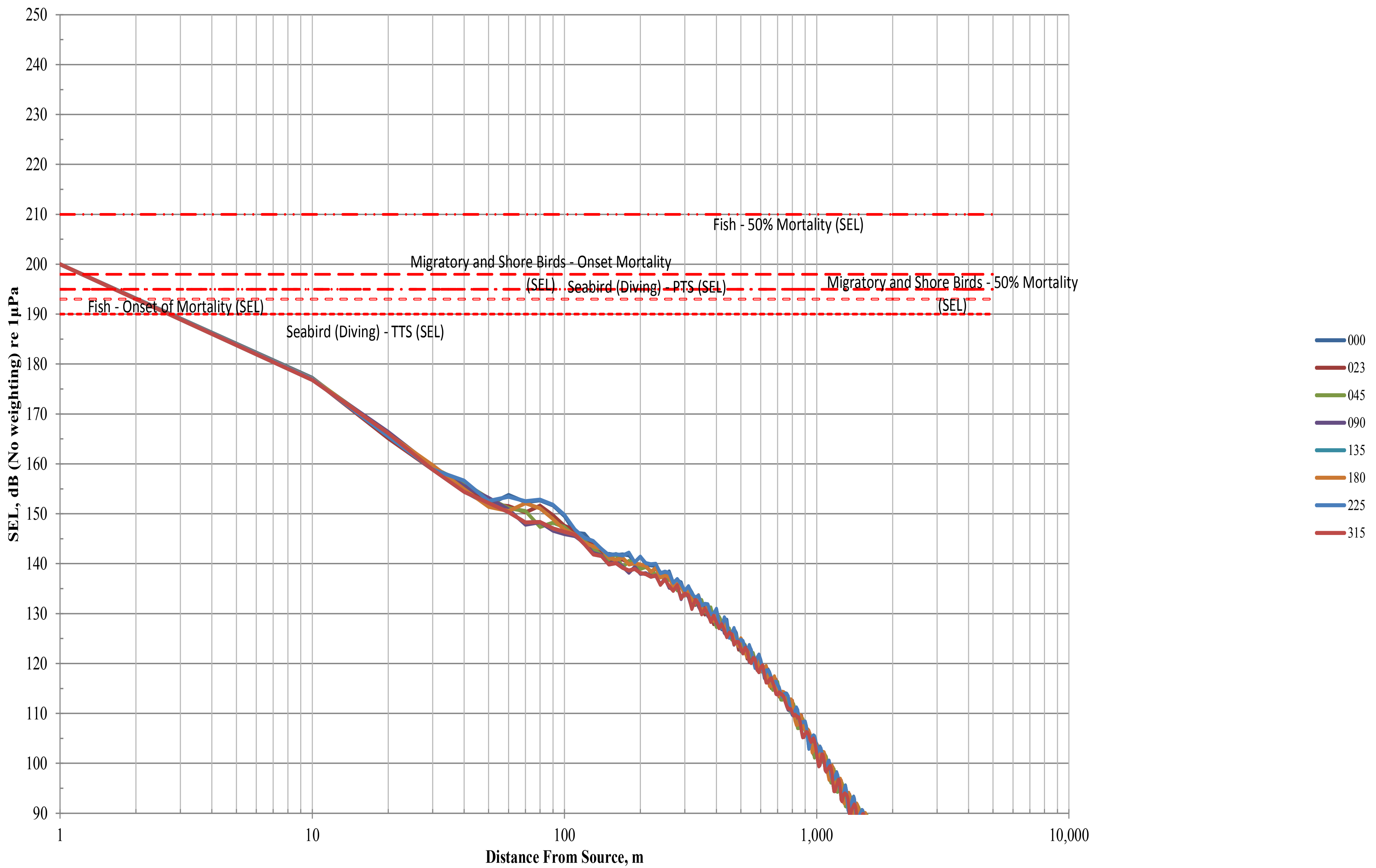



Figure D7.8.3.1d Predicted Sound Exposure Level (dB re 1 µPa²-s) from piling at Wharf

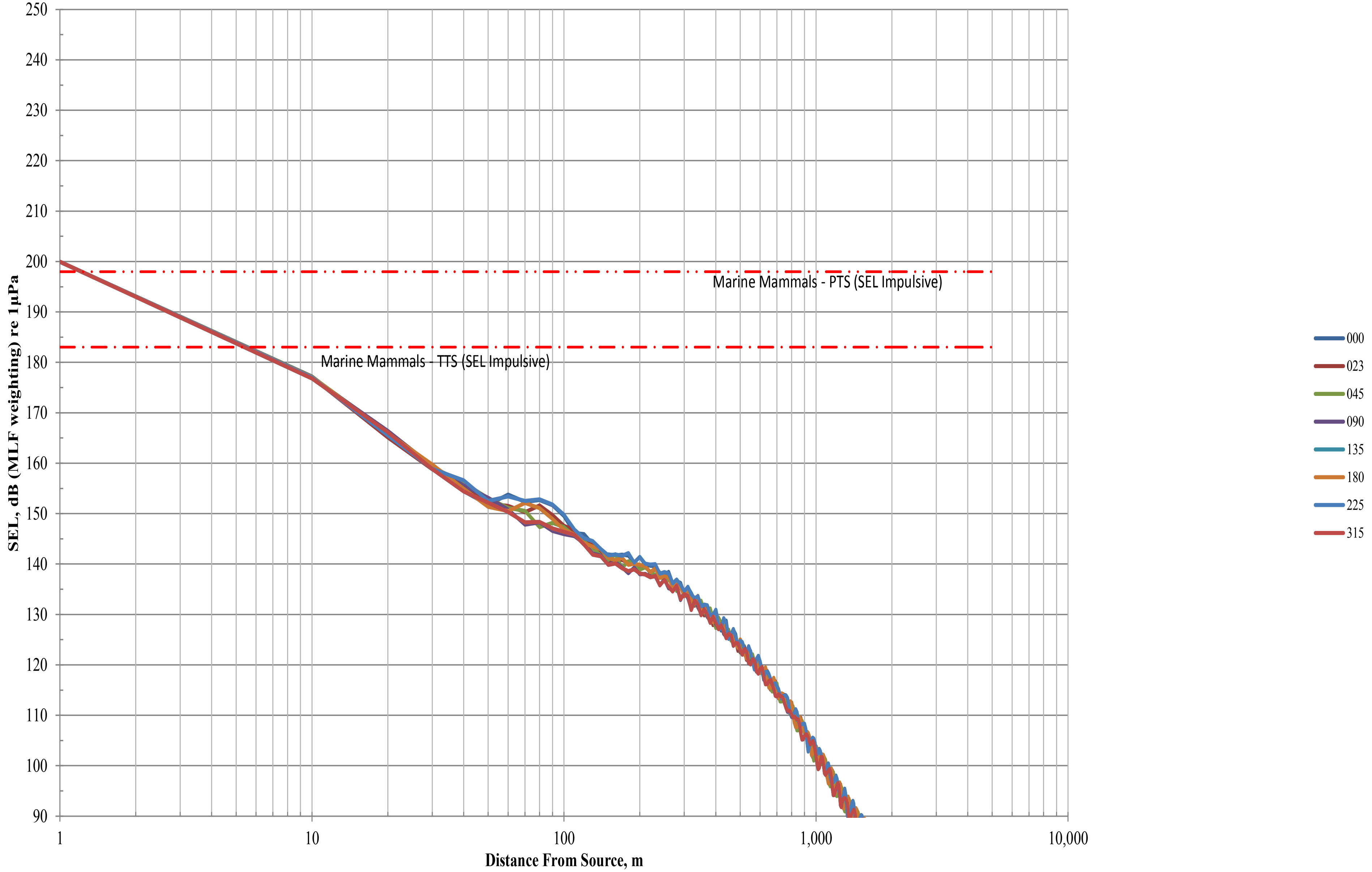



Figure D67.8.3.1e Predicted Weighted Sound Exposure Level (dB re 1 µPa²-s , MLF weighted) from piling at Wharf

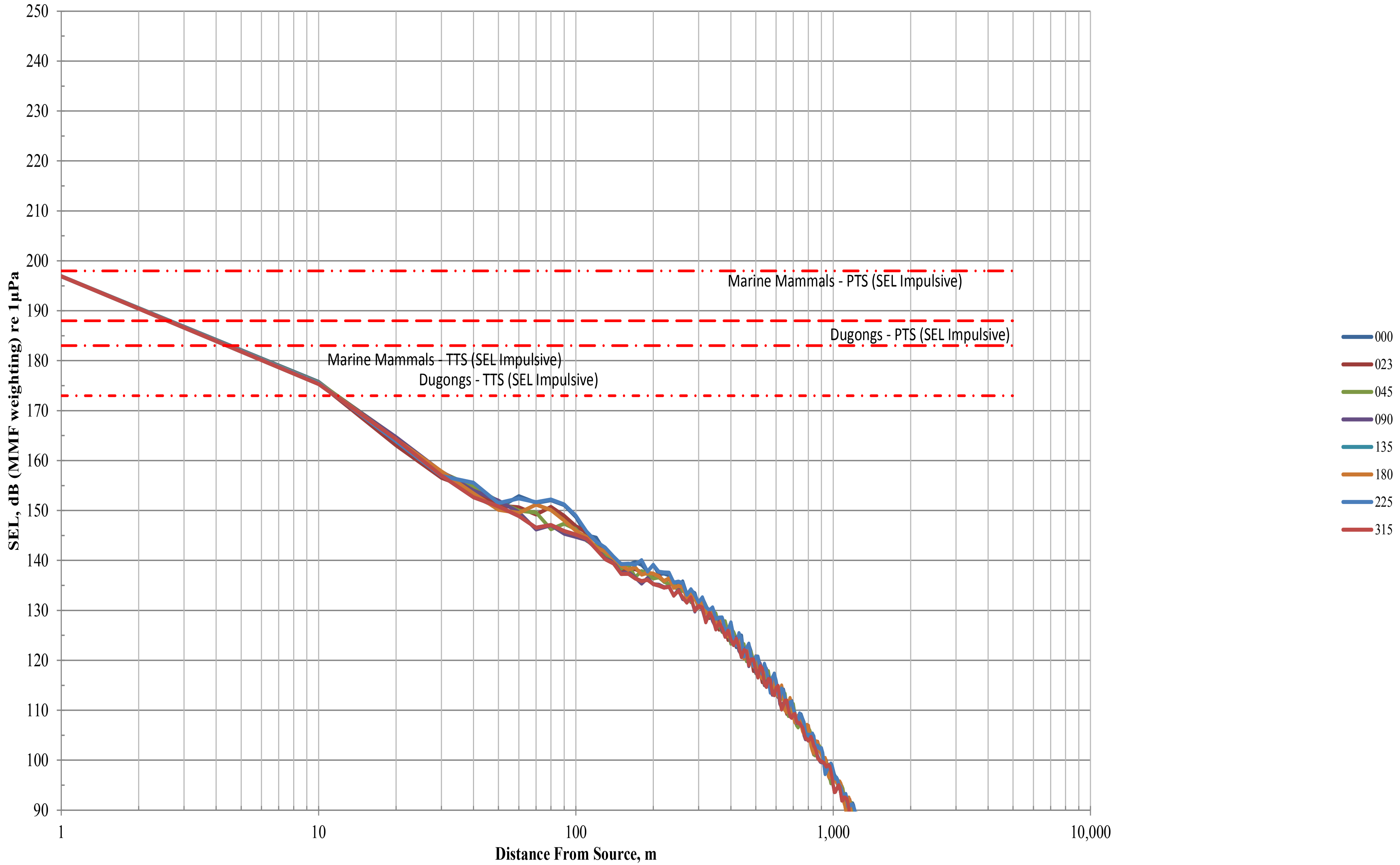



Figure D7.8.3.1f Predicted Weighted Sound Exposure Level (dB re 1 µPa²-s MMF weighted) from piling at Wharf

The following impacts are expected from piling at the Wharf:

- Whales and dugongs may experience permanent hearing damage at distances less than 10 m.
- Whales and dugongs may experience temporary hearing damage at distances less than ~20 m (for short term exposure e.g. individual strike) or ~500 m (based on the 70 $dB_{ht}$ lowest threshold for temporary hearing damage from prolonged exposure).
- Seabirds may experience permanent hearing damage or physical injury at distances less than 10 m (whilst underwater)
- Strong avoidance behaviour is expected from dugongs and whales within ~500 m of the pile.
- Strong avoidance behaviour is expected from fish within ~1000 m of the pile.
- Auditory masking may occur for marine mammals within ~3000 m of the pile.

Impacts are expected to be approximately equivalent in all directions from the piling.

**D7.8.3.2 Dredging Noise**

Predicted underwater levels from TSHD dredge operation are shown in **Figure D7.8.3.2a** to **D7.8.3.2i.**.

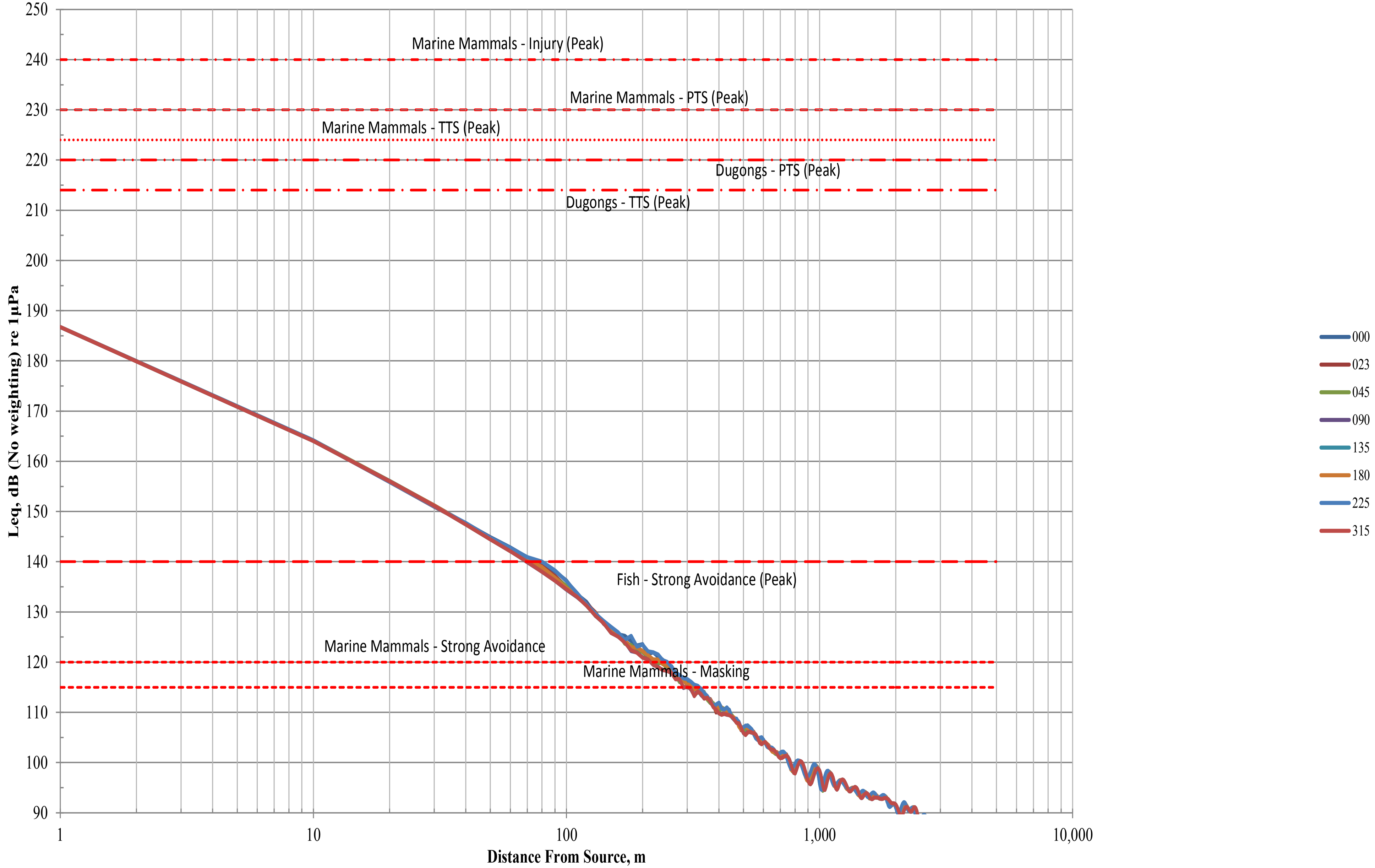



Figure D7.8.3.2a Predicted Equivalent Continuous Noise Level ($L_{eq}$ dB re 1 µPa) from dredging at Dock

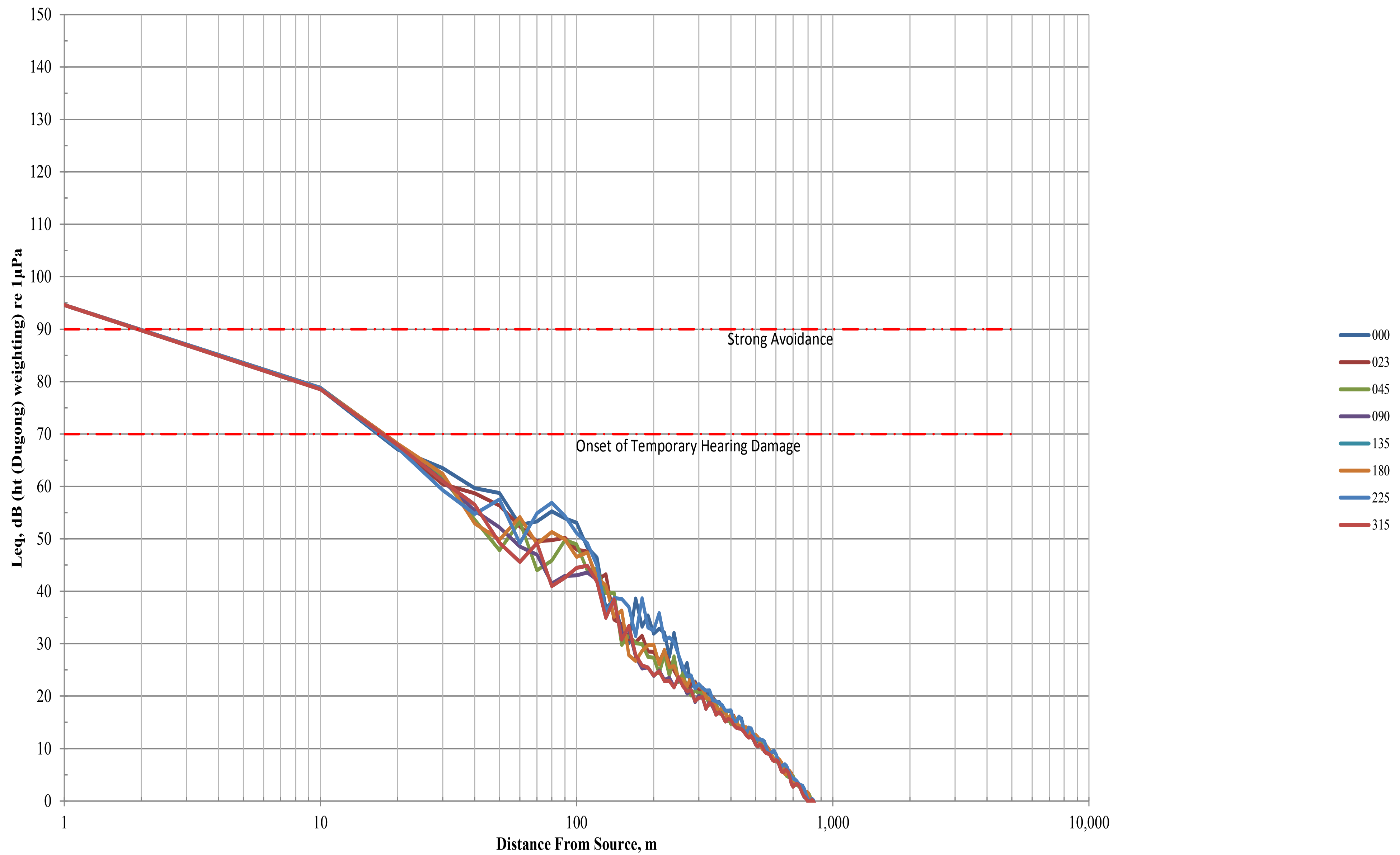



Figure D7.8.3.2b Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\mathit{Dugong\ dugon})}$) from dredging at Wharf

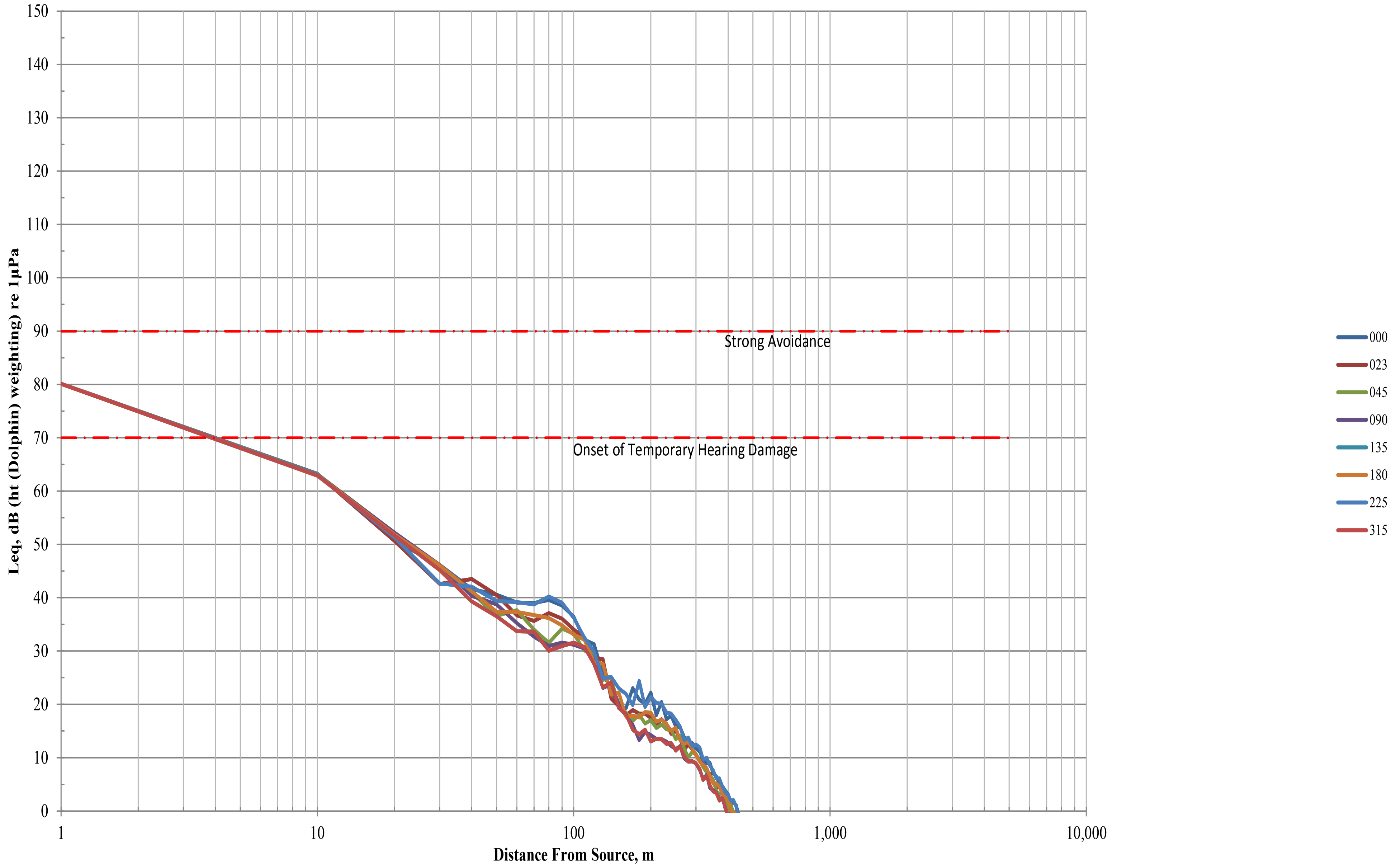



Figure D7.8.3.2c Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\textit{Tursiops truncatus})}$ from dredging at Wharf

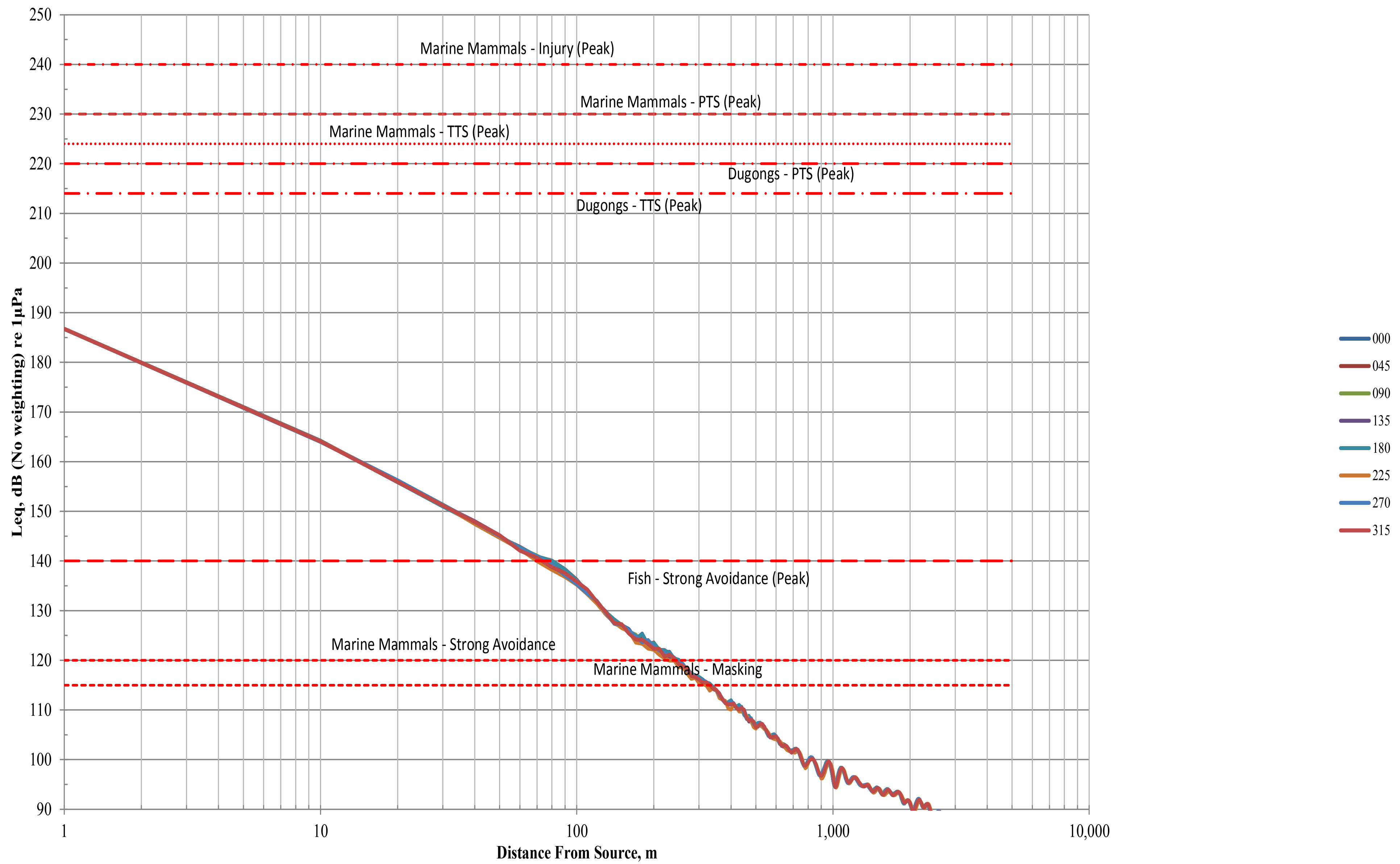



Figure D7.8.3.2d Predicted Equivalent Continuous Noise Level ($L_{eq}$ dB re 1 µPa) from dredging at Channel

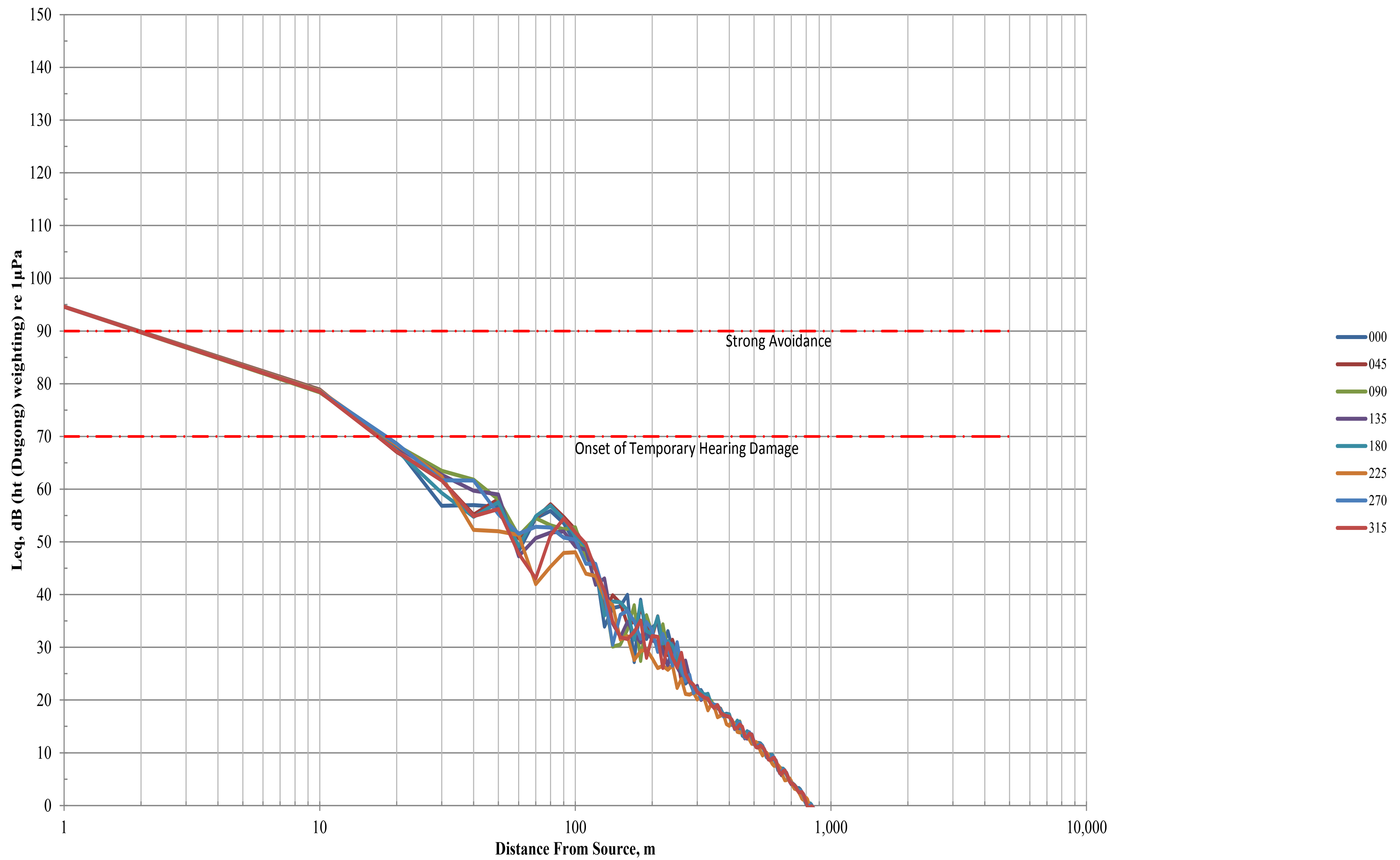



Figure D7.8.3.2e Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Dugong\ dugon)}$) from dredging at Channel

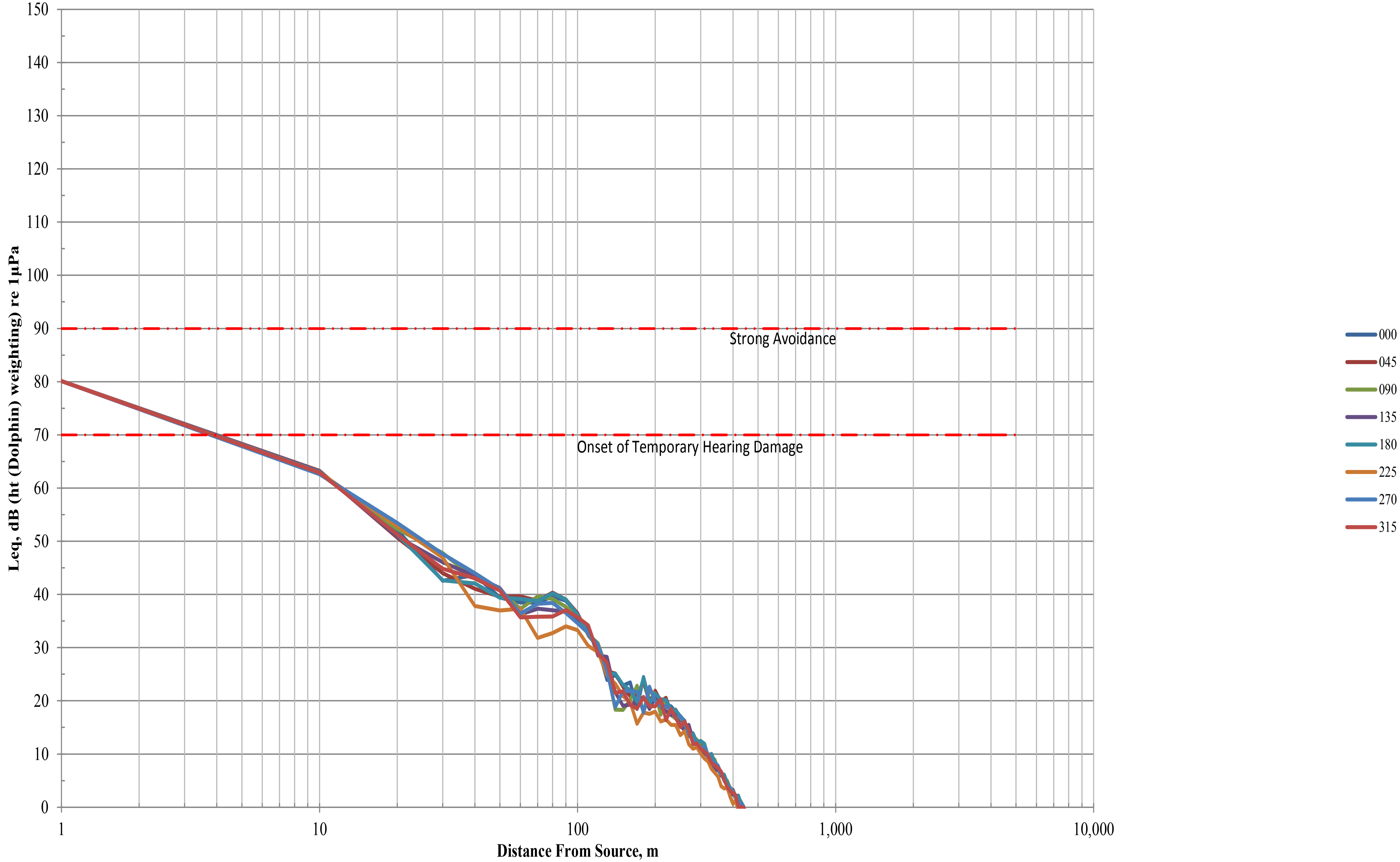



Figure D7.8.3.2f Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\textit{Tursiops truncatus})}$) from dredging at Channel

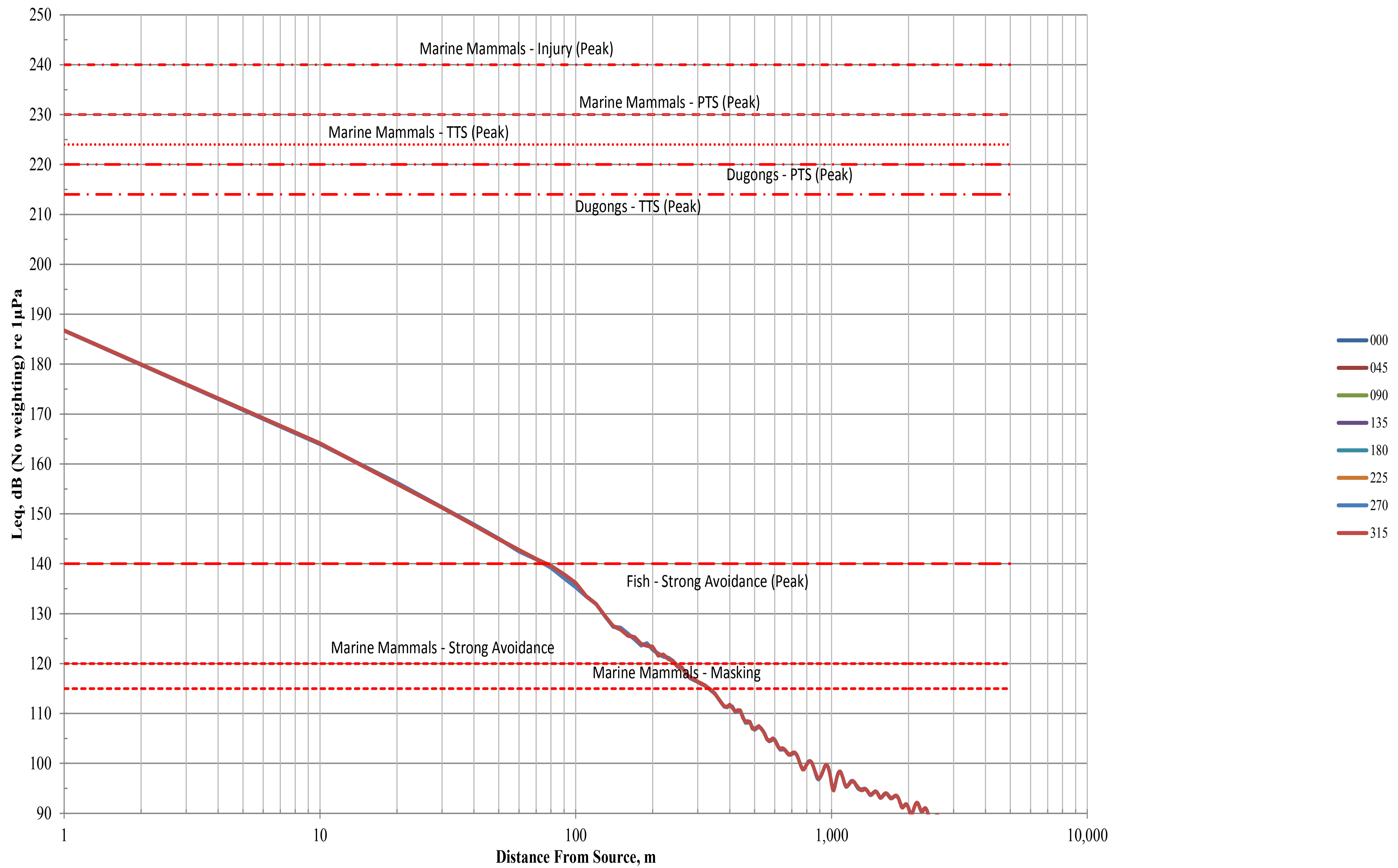



Figure D7.8.3.2g Predicted Equivalent Continuous Noise Level ($L_{eq}$ dB re 1 µPa) from dredging at DMPA

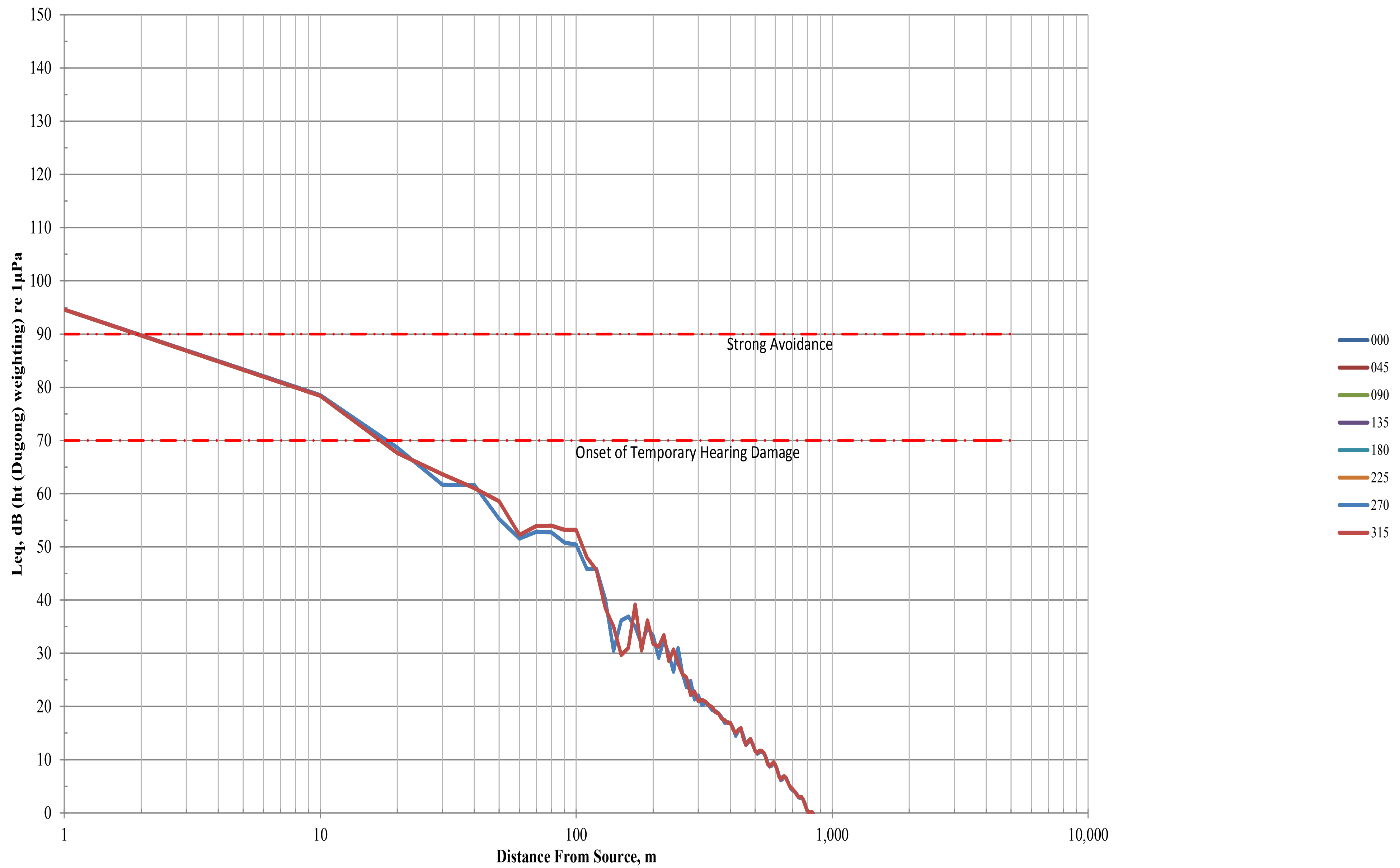



Figure D7.8.3.2h Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Dugong\ dugon)}$) from dredging at DMPA

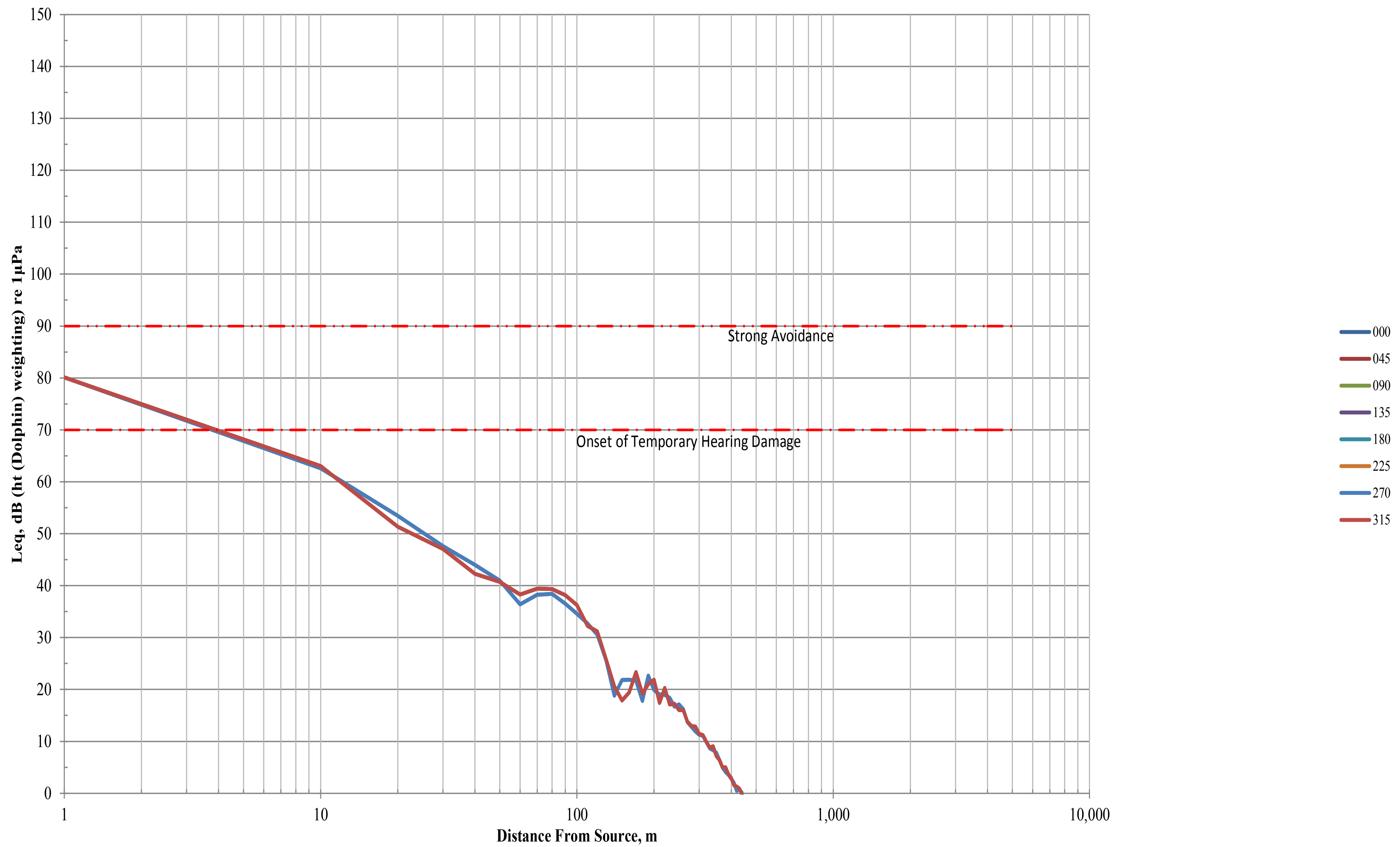



Figure D7.8.3.2i Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\textit{Tursiops truncatus})}$) from dredging at DMPA

The following can be observed from the predicted results for TSHD dredging.

Zones of impacts are approximately the same at all three modelled locations (Dock, Channel and DMPA).

- Hearing damage to dugongs or whales would only be expected to occur in the immediate vicinity of the dredger (~10 m) after prolonged exposure.
- Dugongs and whales may exhibit strong avoidance behaviours within ~250 m of the dredger.
- Fish may exhibit strong avoidance behaviours within ~100 m of the dredger.
- Marine mammals may experience auditory masking from the dredger within ~300 m.

### D7.8.3.3 Vessel Noise

Predicted underwater levels from cruise ships on approach/docking to the Cairns Cruise Liner Terminal are shown in **Figure D7.8.3.3a** to **D7.8.3.3r**.

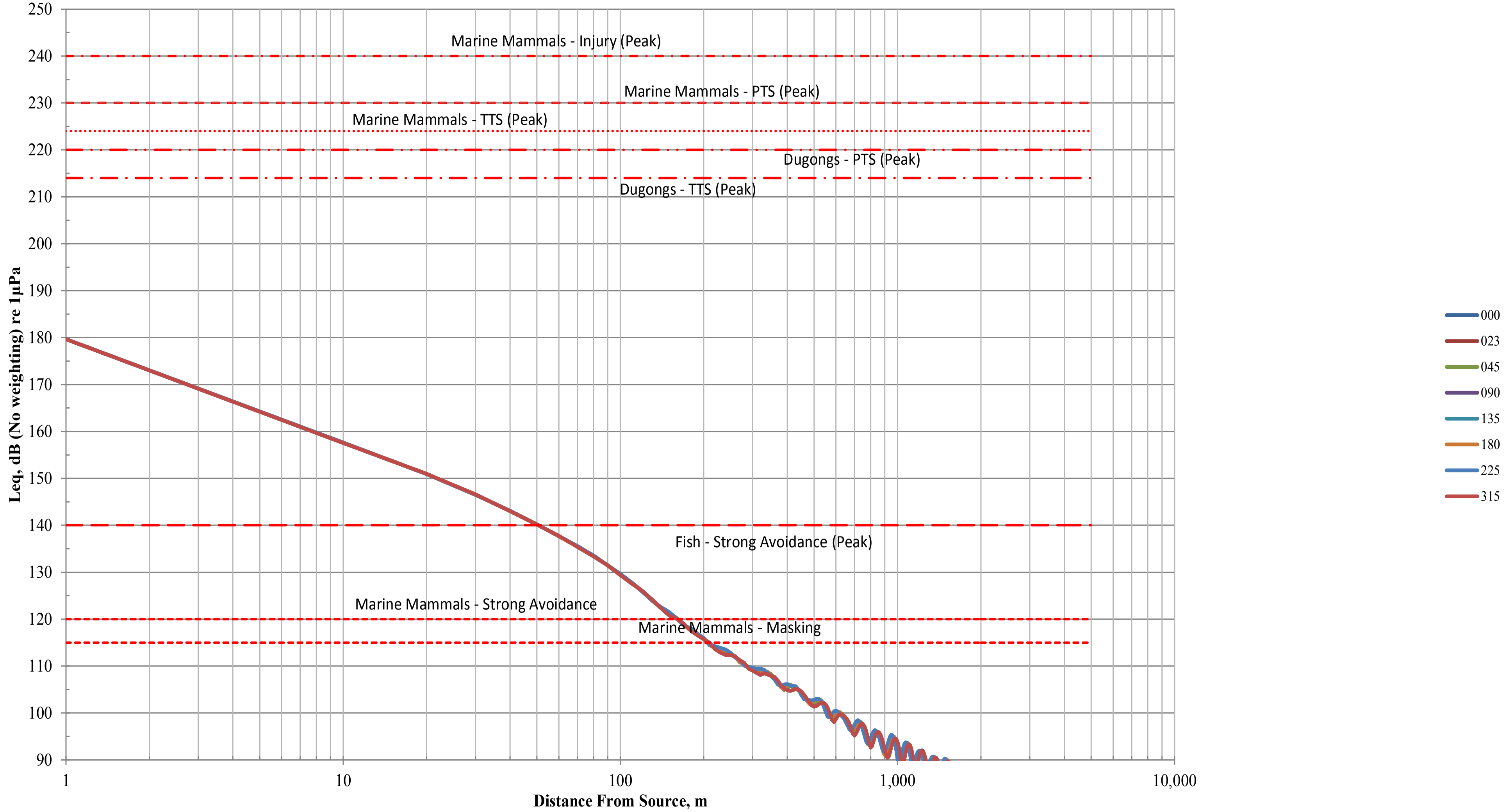



Figure D7.8.3.3a Predicted Equivalent Continuous Noise Level ($L_{eq}$ dB re 1 µPa) from shipping at Wharf – Large Cruise Ship

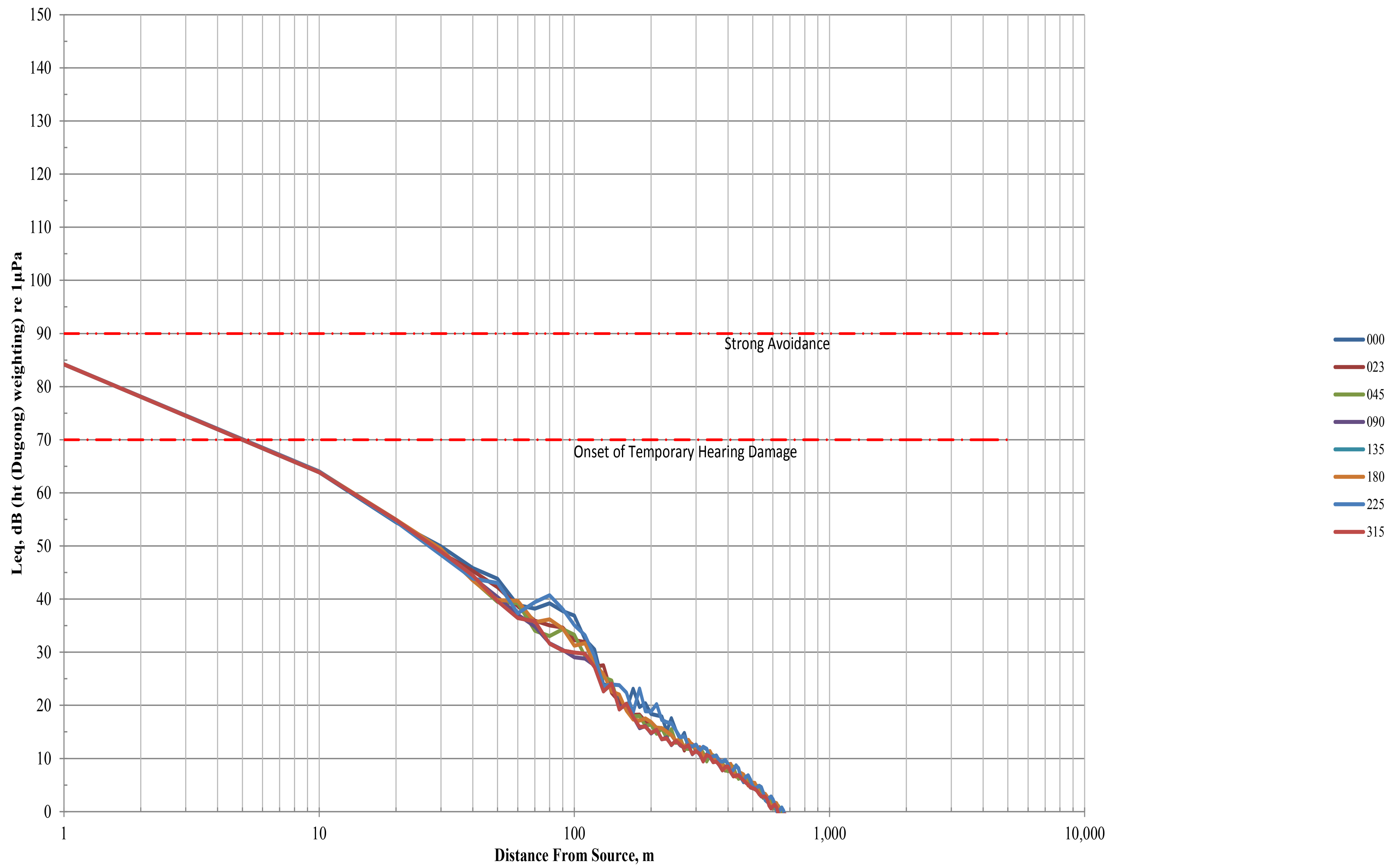


Figure D7.8.3.3b Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Dugong\ dugon)}$) from shipping at Wharf – Large Cruise Ship

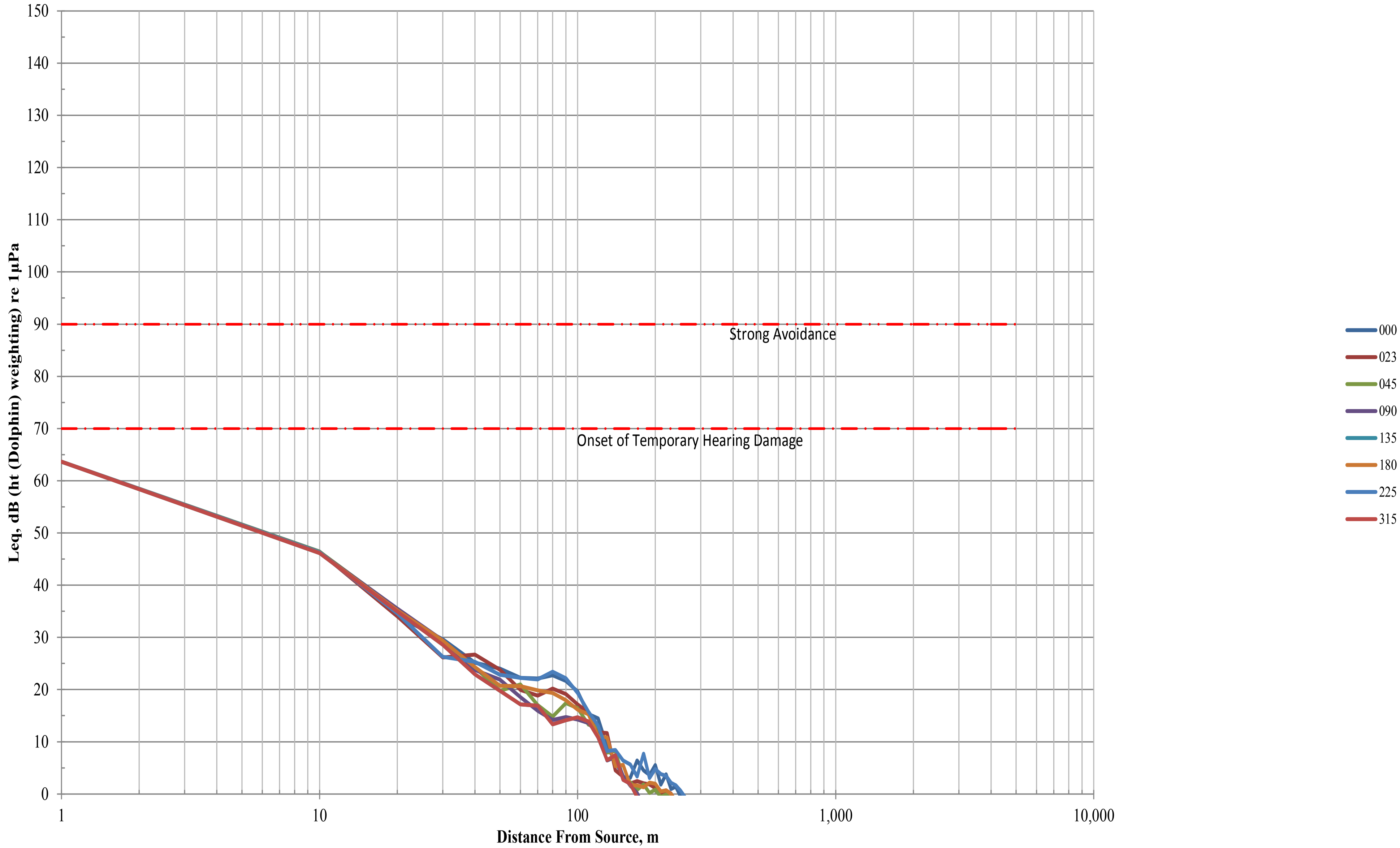



Figure D7.8.3.3c Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\mathit{Tursiops\ truncatus})}$) from shipping at Wharf – Large Cruise Ship

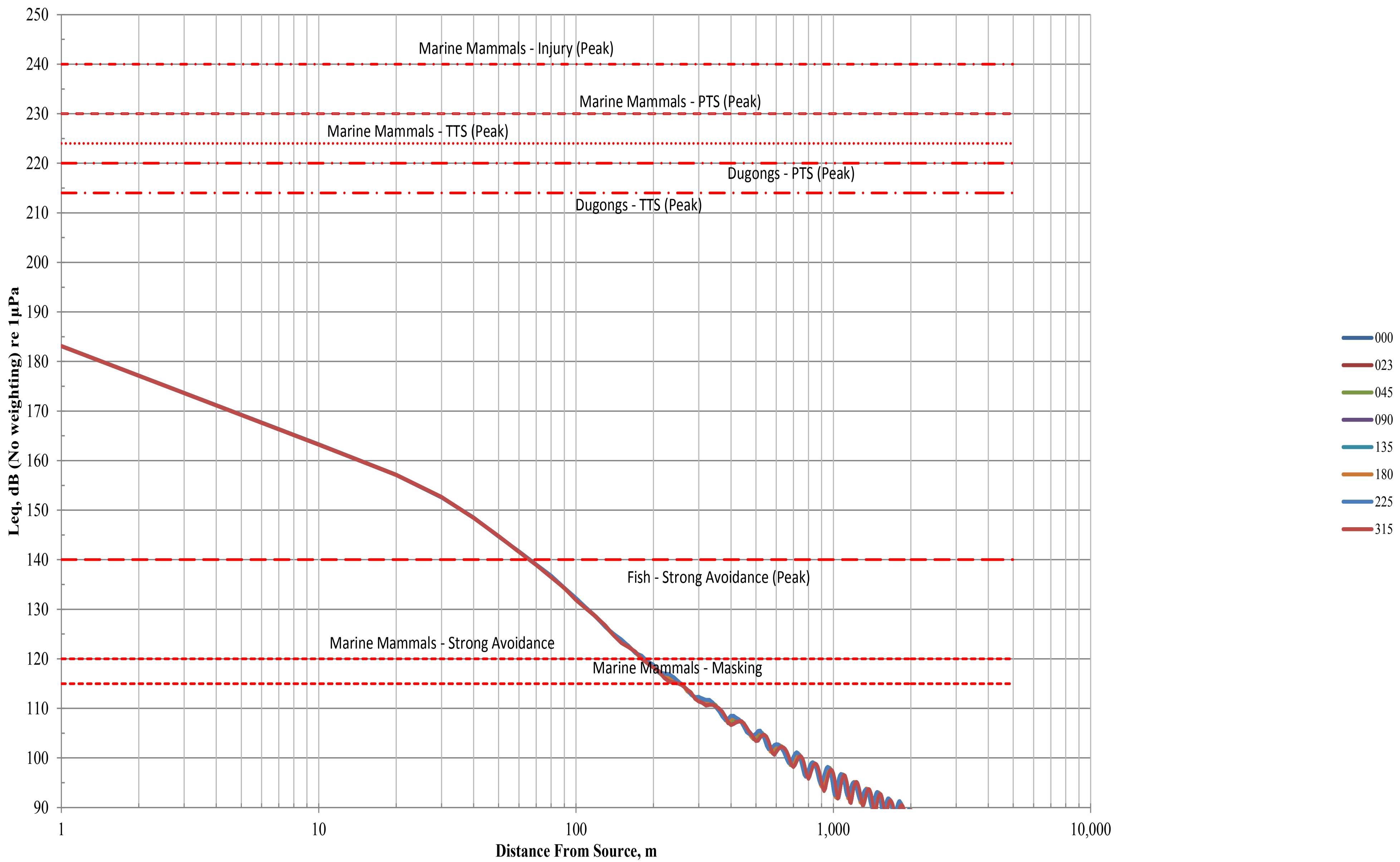



Figure D7.8.3.3d Predicted Equivalent Continuous Noise Level (Leq dB re 1 µPa) from shipping at Wharf – Medium Cruise Ship

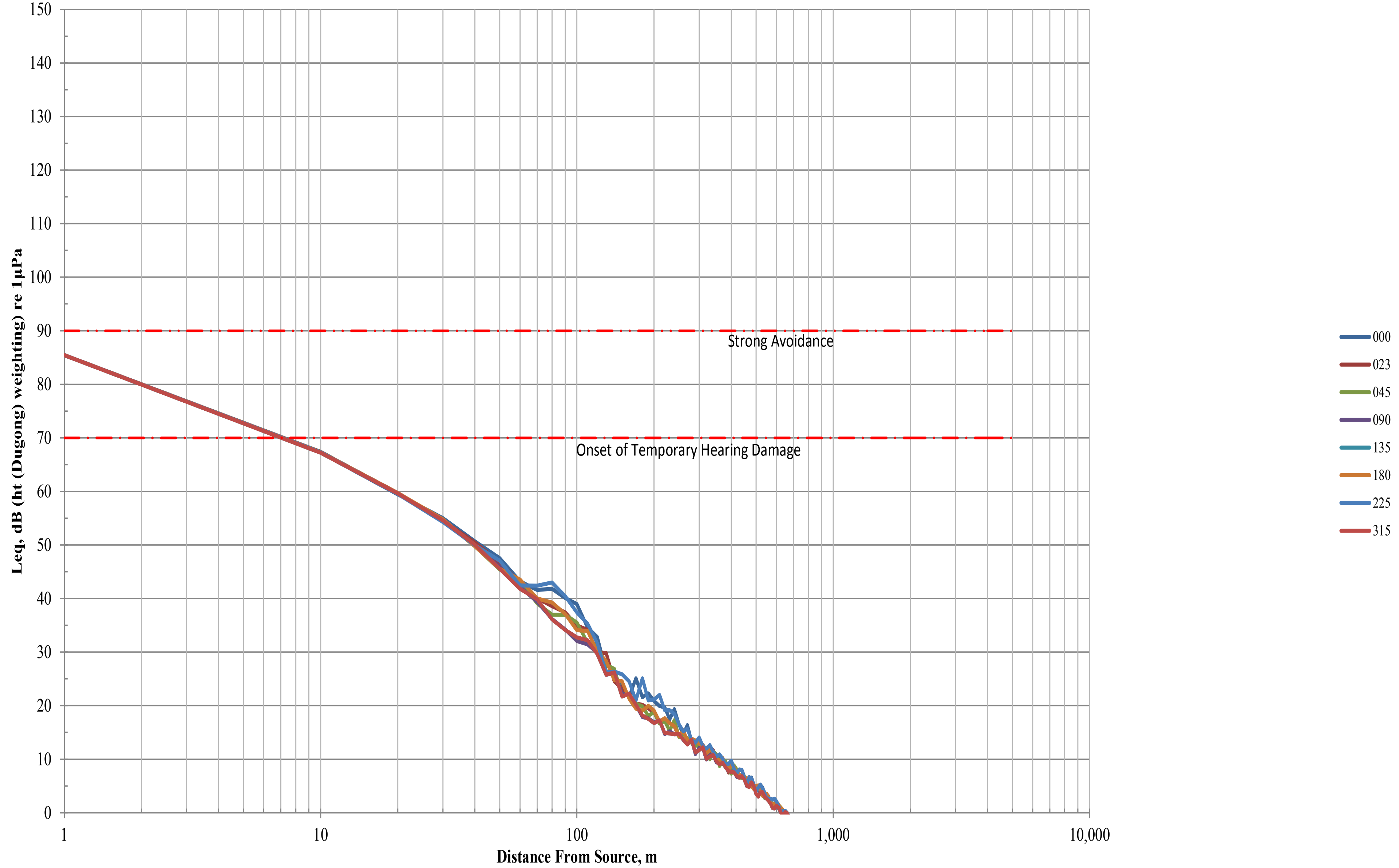



Figure D7.8.3.3e Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Dugong\ dugon)}$) from shipping at Wharf – Medium Cruise Ship

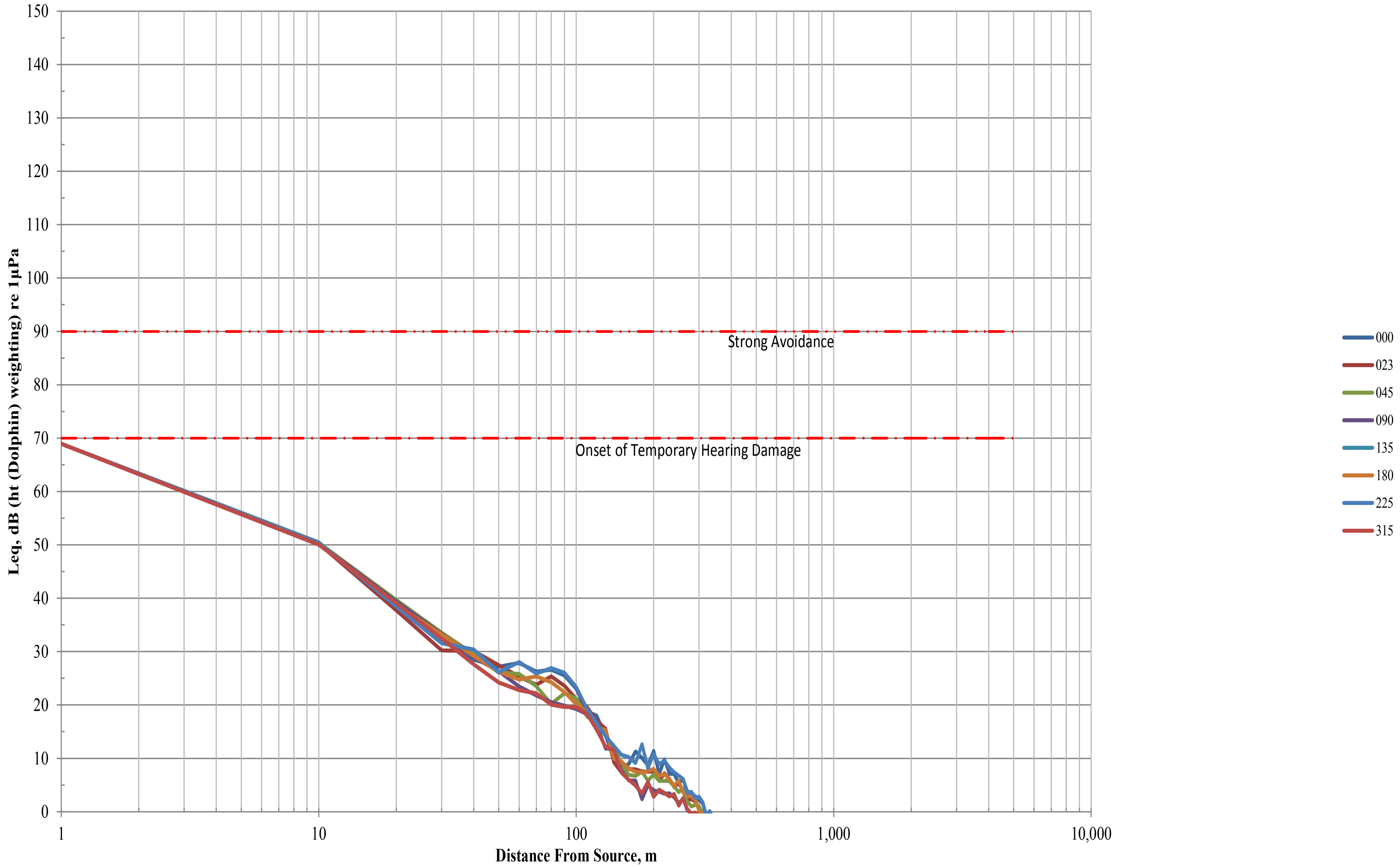



Figure D7.8.3.3f Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\mathit{Tursiops\ truncatus})}$) from shipping at Wharf – Medium Cruise Ship

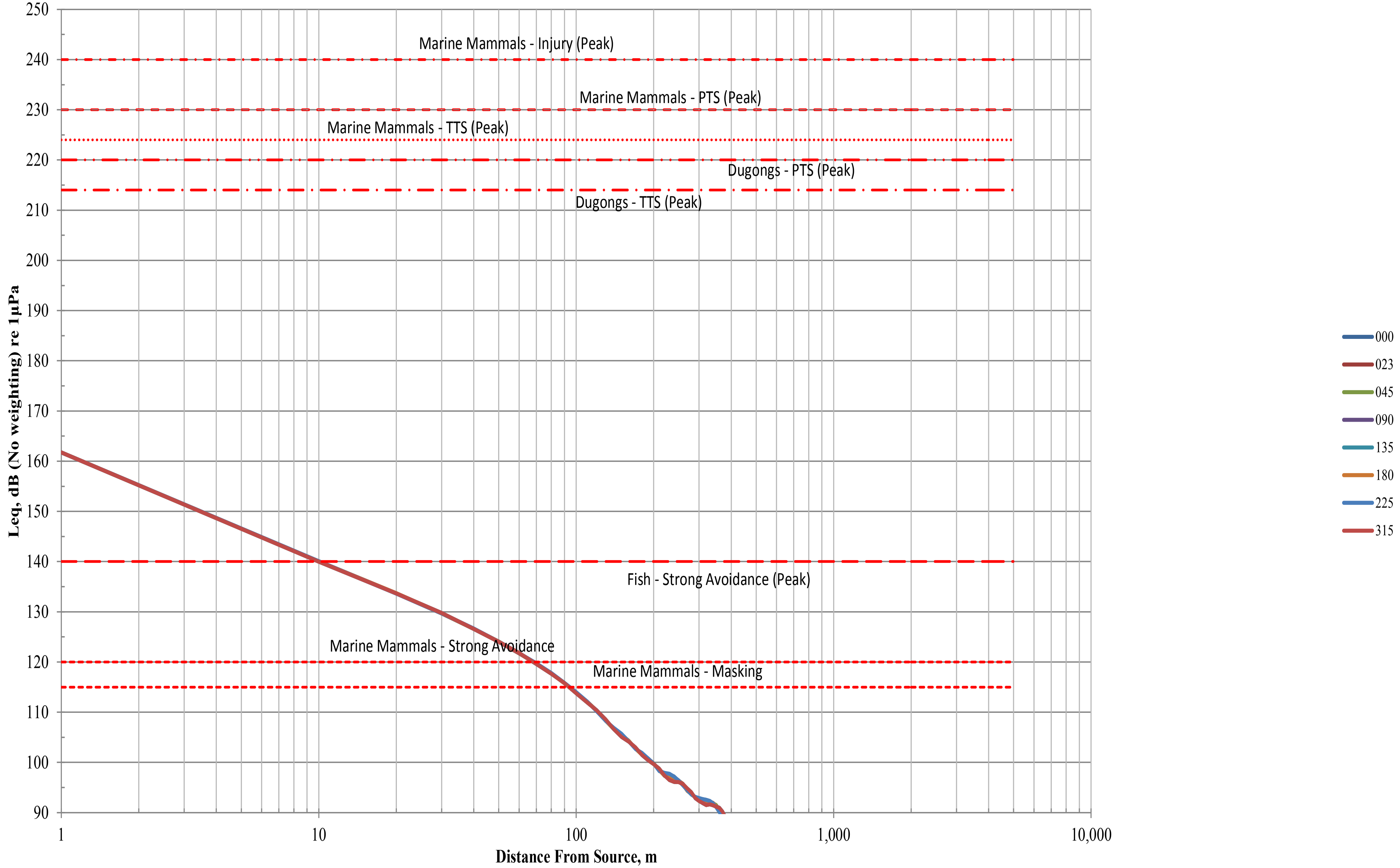



Figure D7.8.3.3g Predicted Equivalent Continuous Noise Level (Leq dB re 1 µPa) from shipping at Wharf– Future (SILENV) Cruise Ship

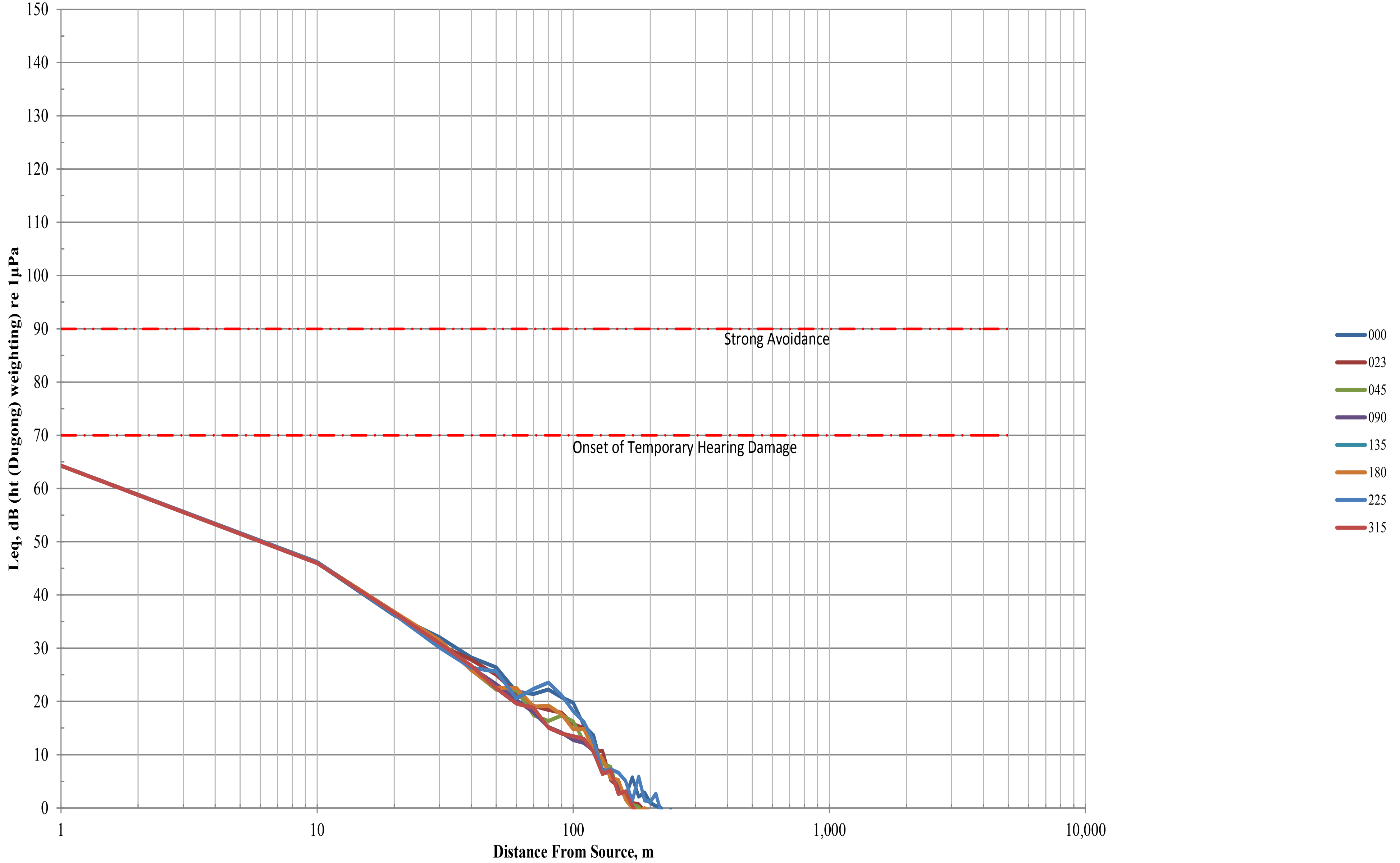



Figure D7.8.3.3h Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Dugong\ dugon)}$) from shipping at Wharf – Future (SILENV) Cruise Ship

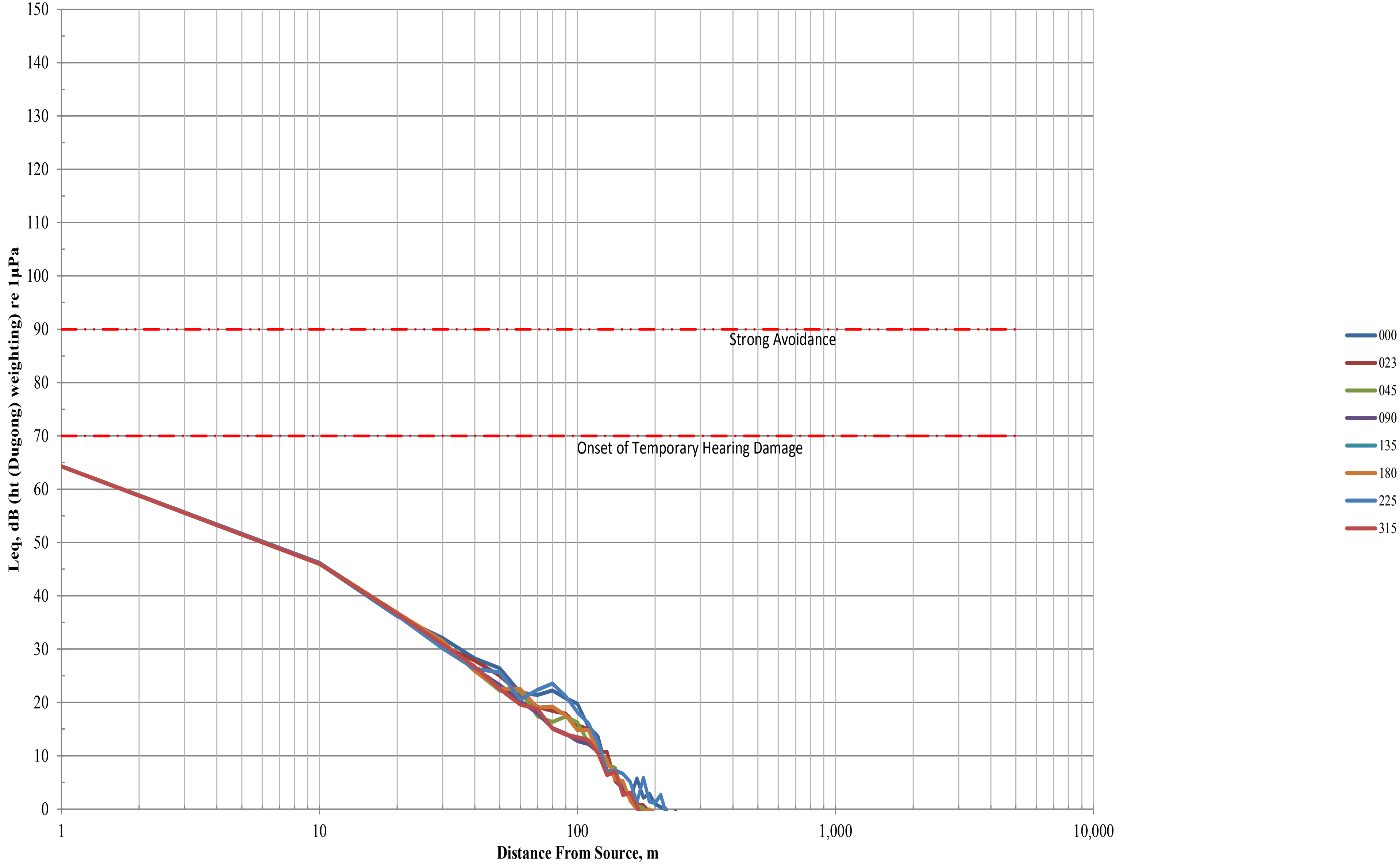



Figure D7.8.3.3i Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\textit{Tursiops truncatus})}$) from shipping at Wharf – Future (SILENV) Cruise Ship

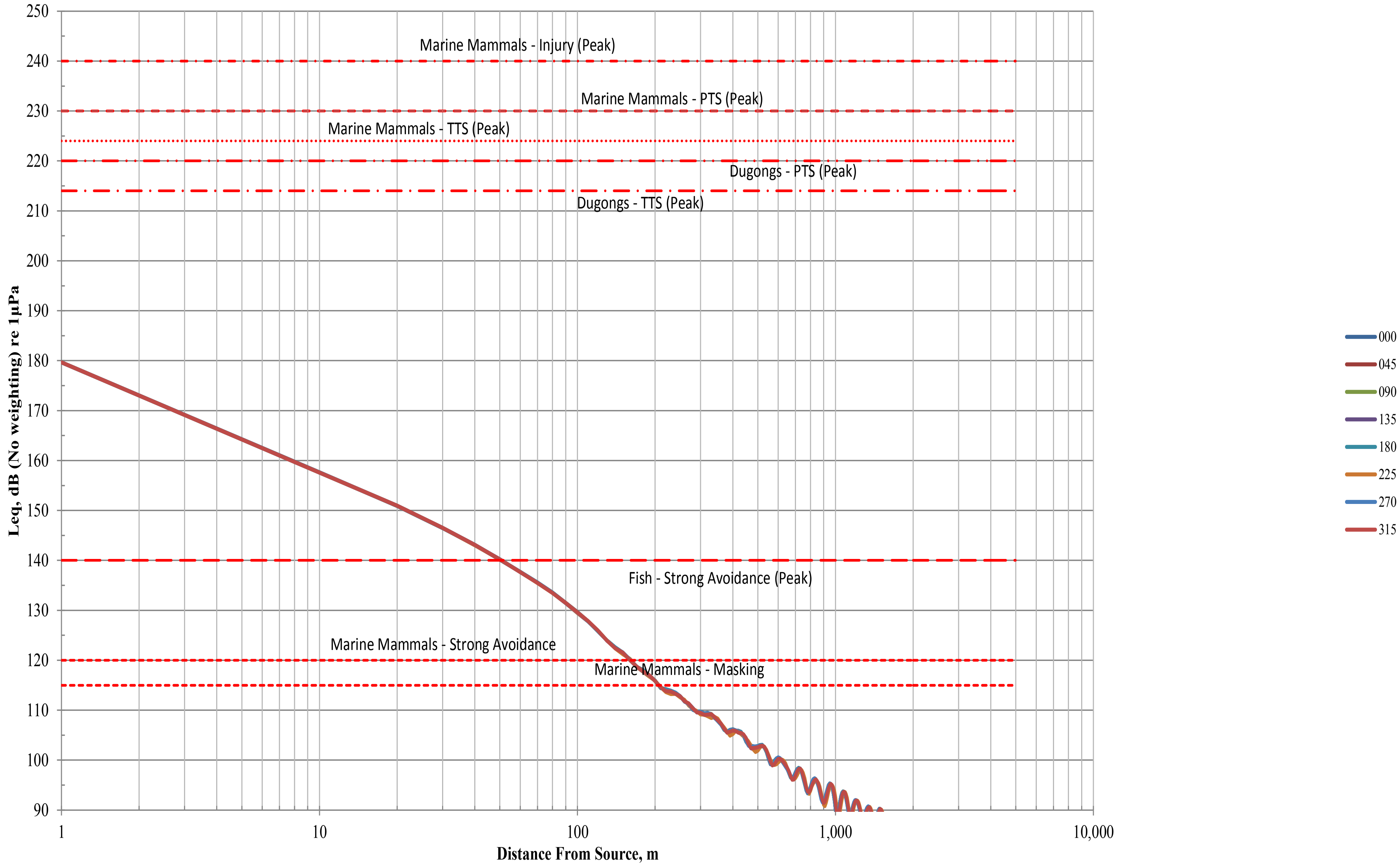



Figure D7.8.3.3j Predicted Equivalent Continuous Noise Level ($L_{eq}$ dB re 1 µPa) from shipping at Channel – Large Cruise Ship

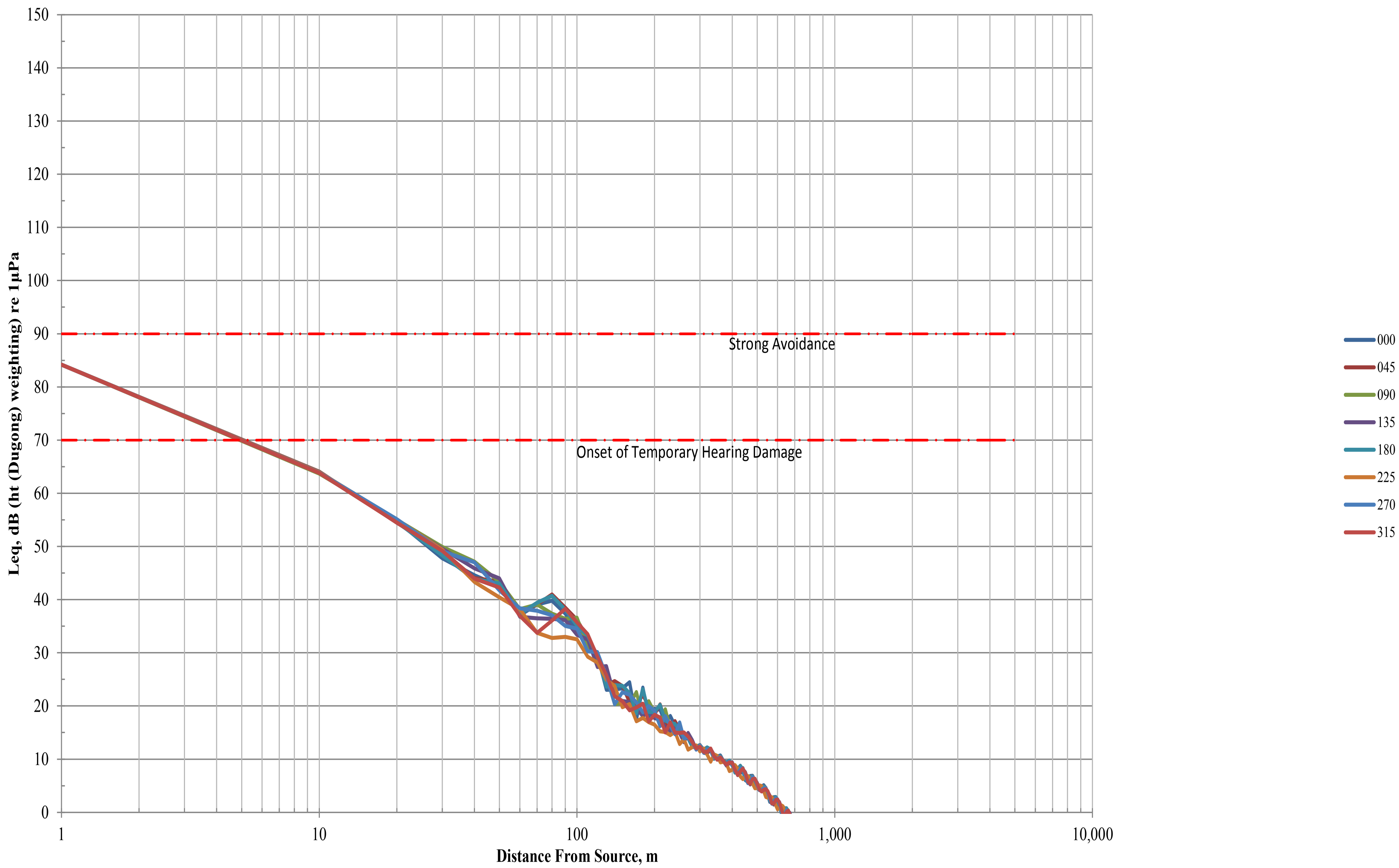



Figure D7.8.3.3k Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\textit{Dugong dugon})}$) from shipping at Channel – Large Cruise Ship

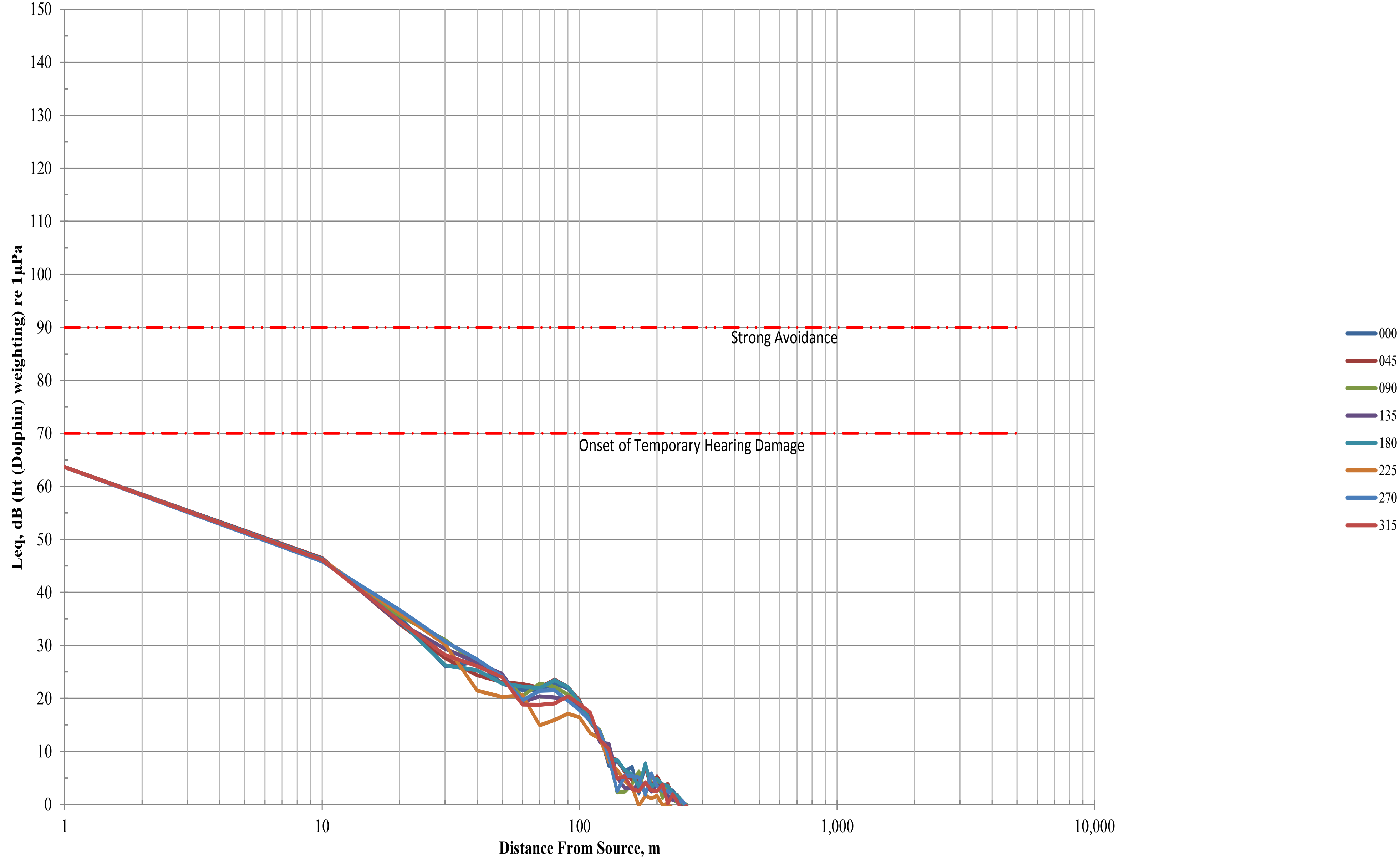



Figure D7.8.3.31 Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Tursiops\ truncatus)}$) from shipping at Channel – Large Cruise Ship

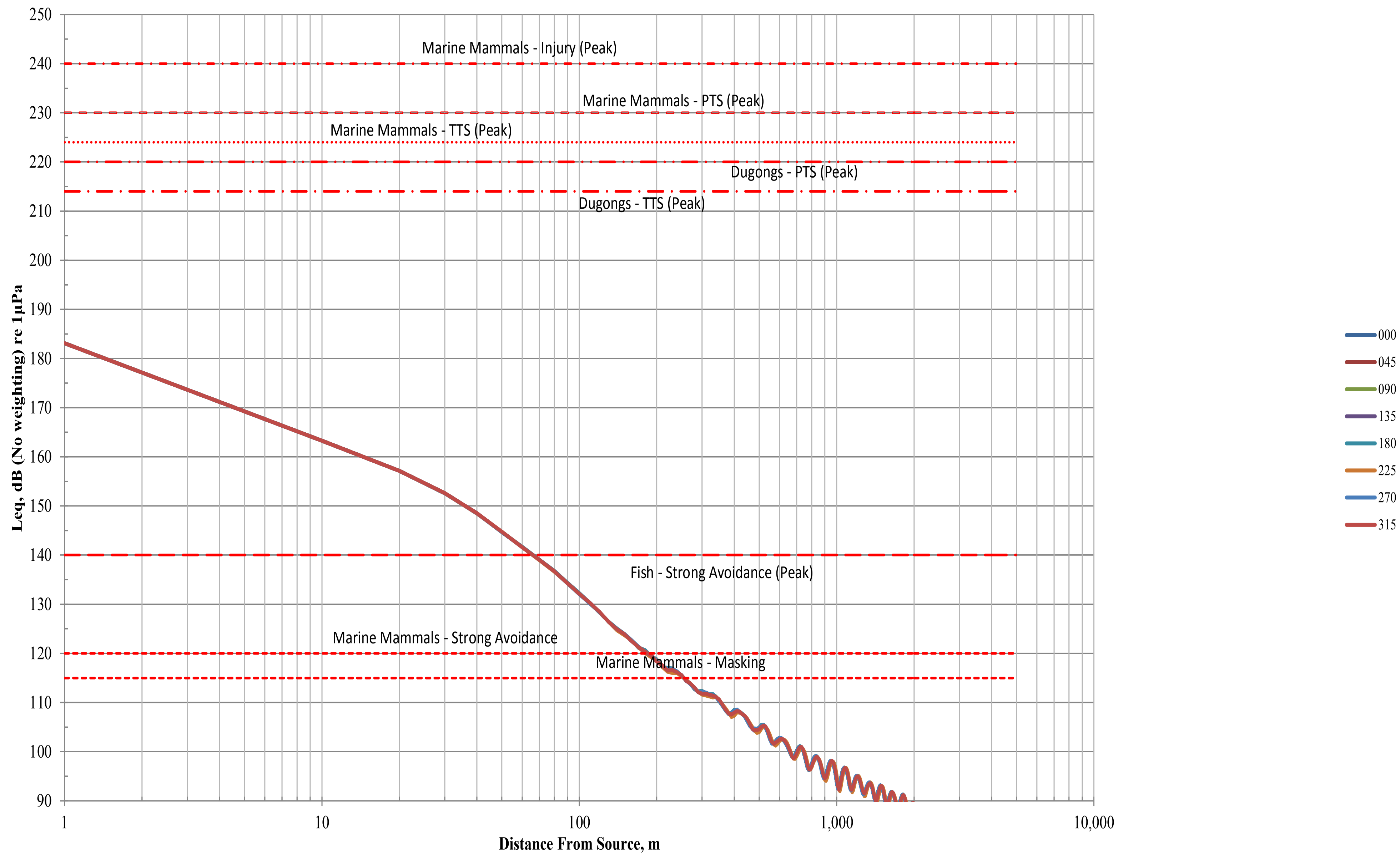



Figure D7.8.3.3m Predicted Equivalent Continuous Noise Level ($L_{eq}$ dB re 1 µPa) from shipping at Channel– Medium Cruise Ship

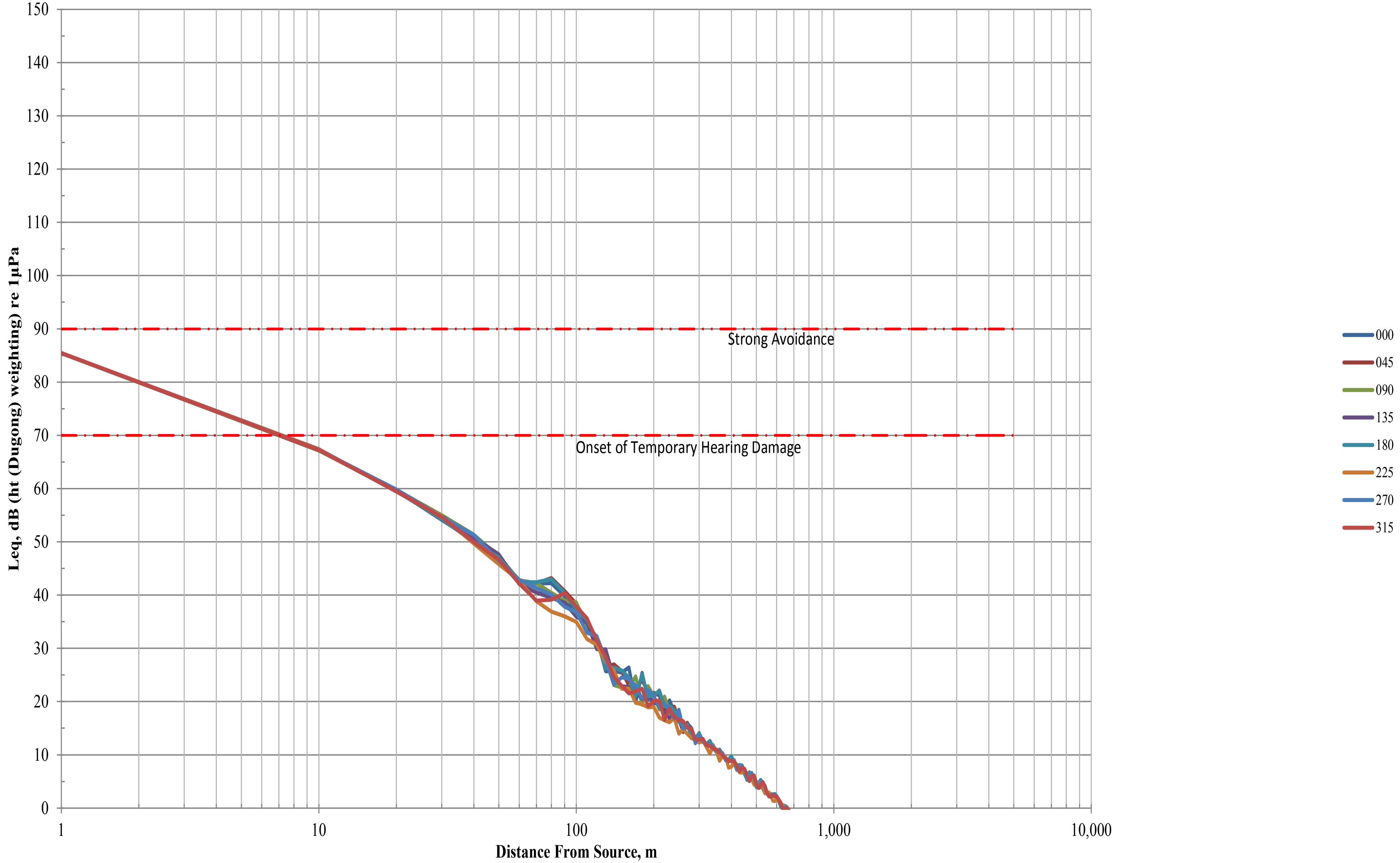



Figure D7.8.3.3n Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Dugong\ dugon)}$) from shipping at Channel– Medium Cruise Ship

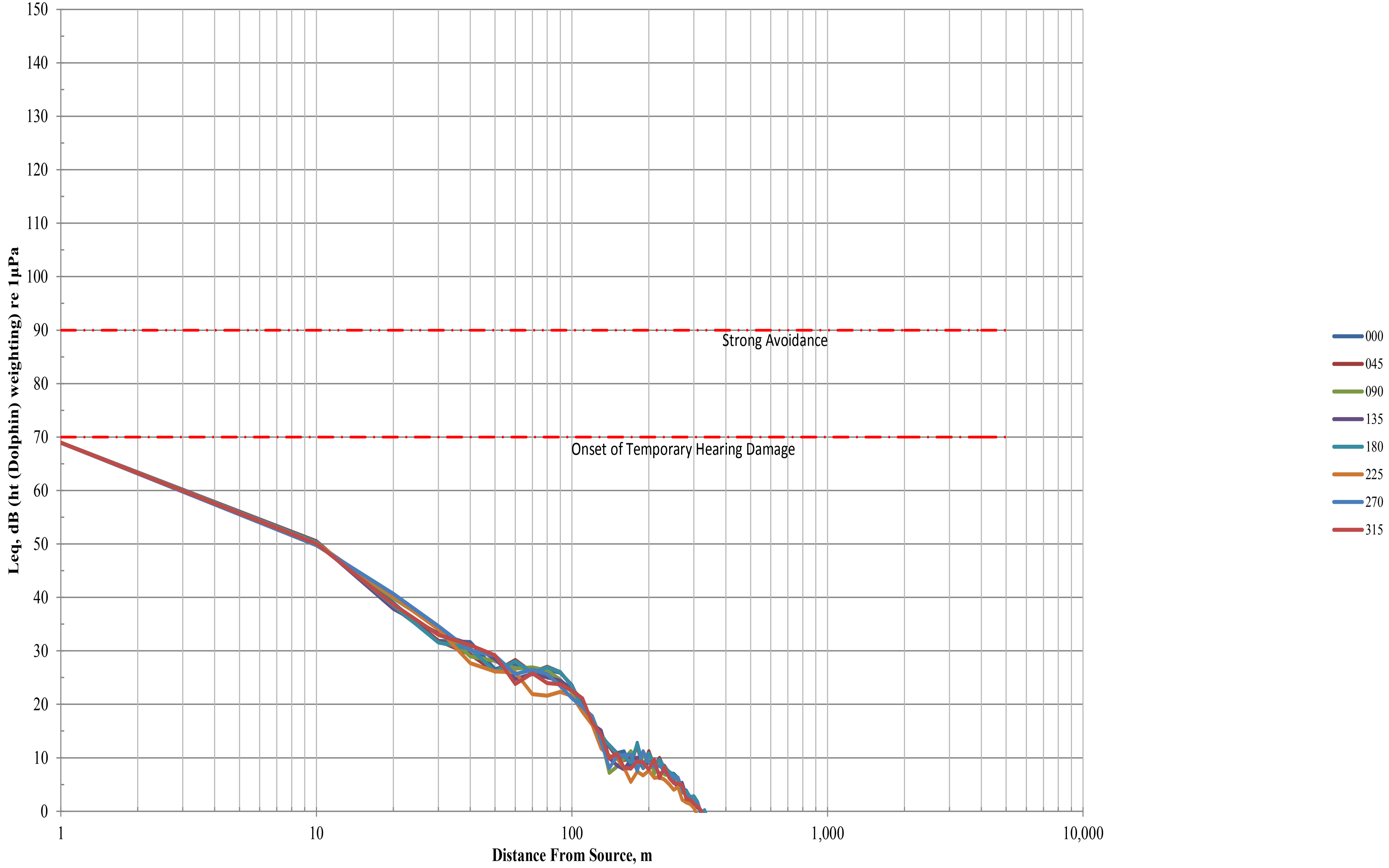



Figure D7.8.3.3o Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Tursiops\ truncatus)}$) from shipping at Channel– Medium Cruise Ship

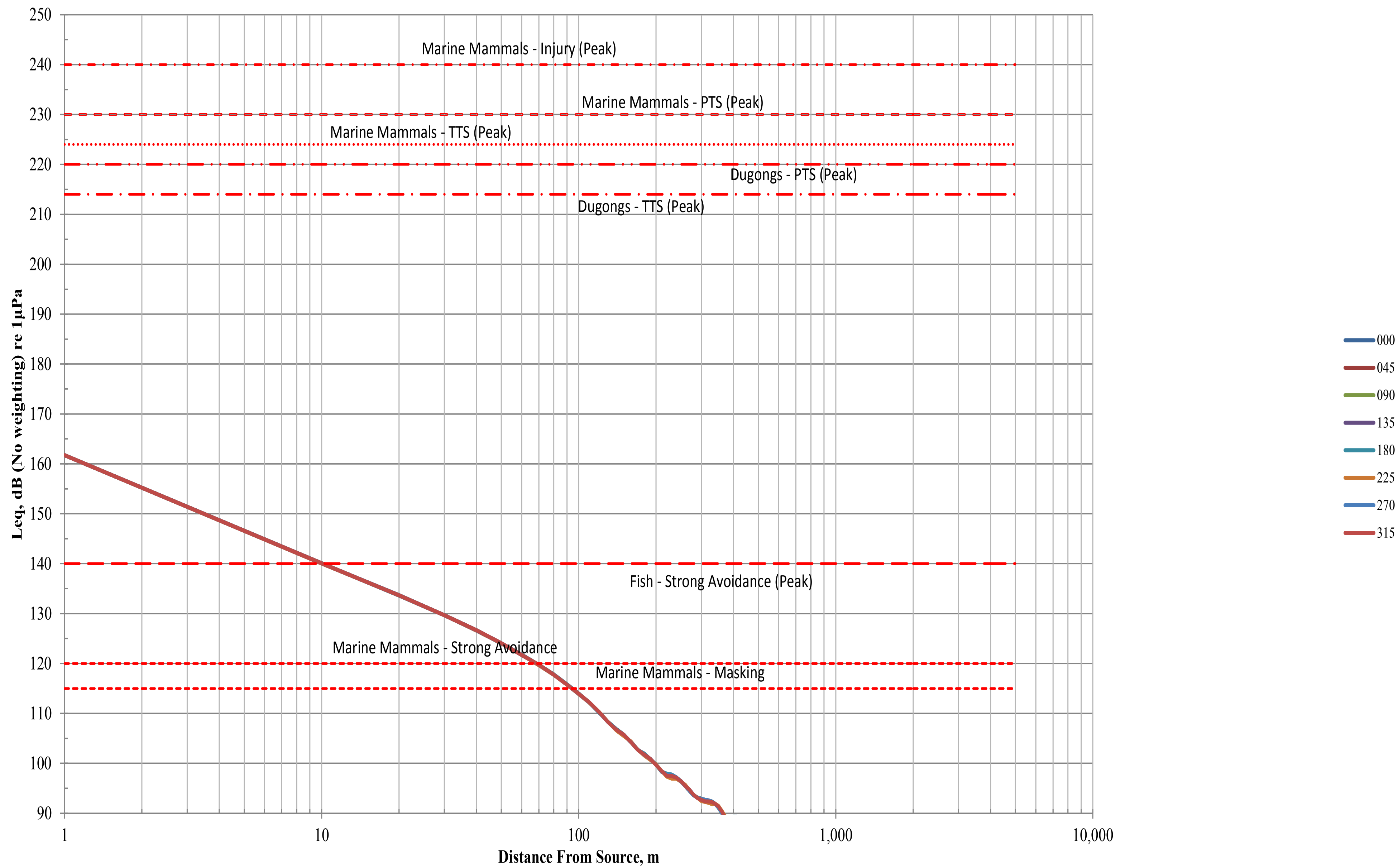



Figure D7.8.3.3p Predicted Equivalent Continuous Noise Level ($L_{eq}$ dB re 1 µPa) from shipping at Channel – Future (SILENV) Cruise Ship

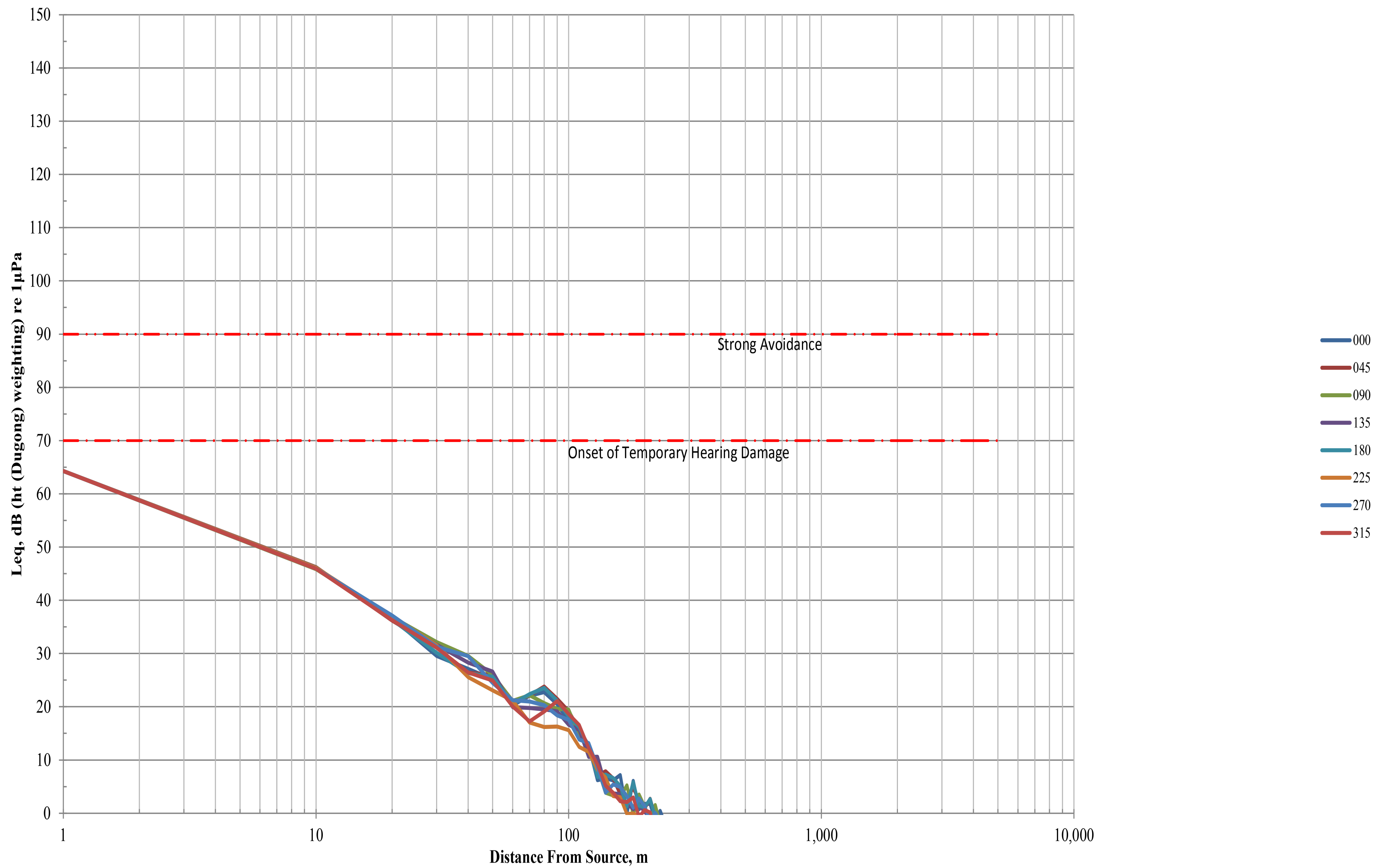



Figure D7.8.3.3q Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(Dugong\ dugon)}$) from shipping at Channel – Future (SILENV) Cruise Ship

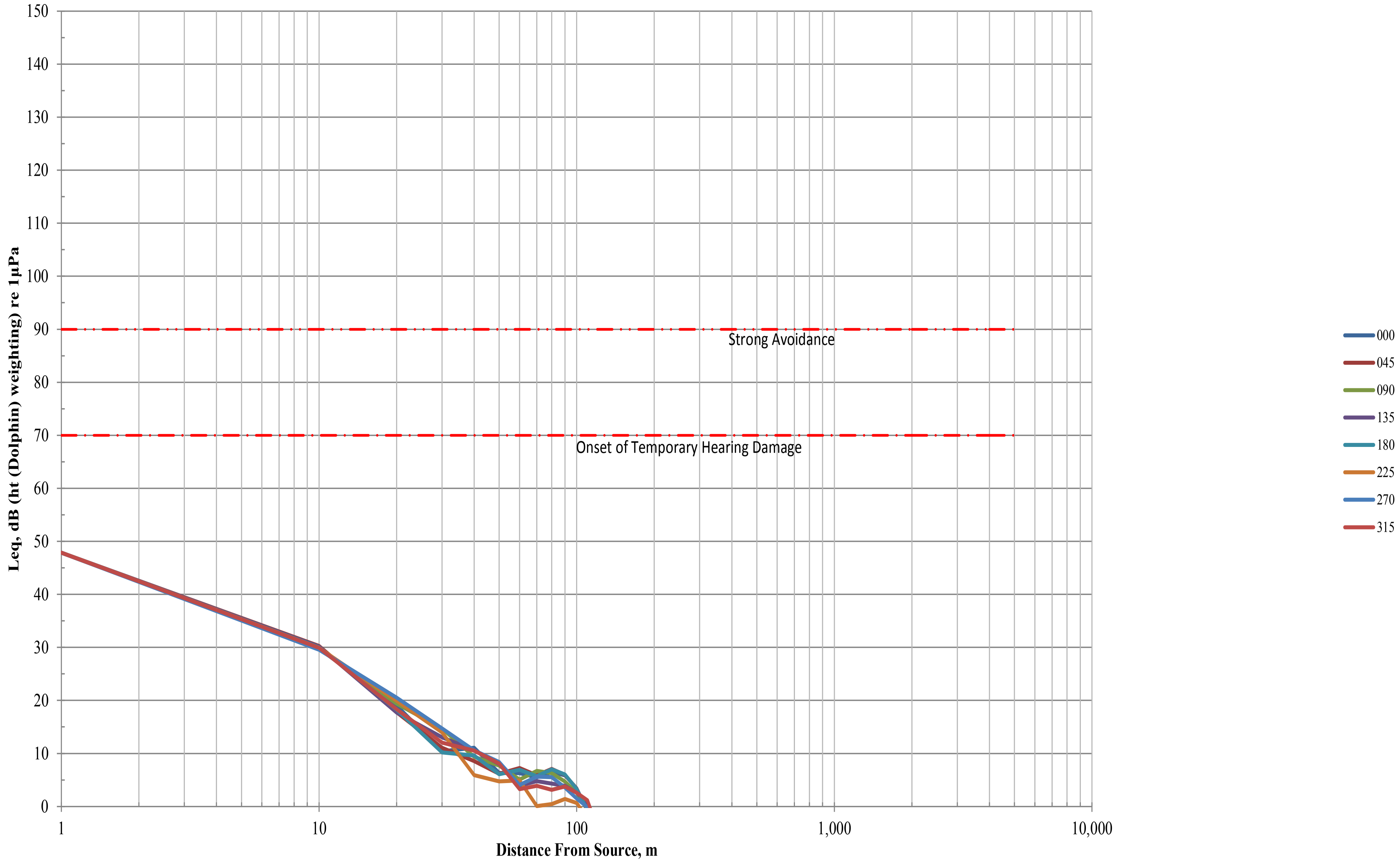



Figure D7.8.3.3r Predicted Equivalent Continuous Noise Level ($L_{eq}$ $dB_{ht(\textit{Tursiops truncatus})}$) from shipping at Channel – Future (SILENV) Cruise Ship

For existing cruise ships (medium and large):

- Hearing damage to dugongs or whales would only be expected to occur in the immediate vicinity of the ship (~10 m) after prolonged exposure.
- Marine mammals may exhibit strong avoidance behaviour within ~150-200 m of the ship
- Marine mammals may experience auditory masking from ships within ~200-250 m.

For future cruise ships (complying with the SILENV noise emission targets):

- No hearing damage would be expected from exposure to SILENV underwater noise levels.
- Marine mammals may exhibit strong avoidance behaviour within ~80 m of a SILENV ship
- Marine mammals may experience auditory masking from SILENV ships within ~100 m.

### D7.9 Consideration of Mitigation Measures for Underwater Noise

The predicted zones of adverse impact are generally within the immediate vicinity of the noise source, with the only impacts predicted to occur beyond ~100 m being behavioural response or auditory masking.

Nevertheless, it is relevant to consider potential mitigation measures that could be considered for CSDP in order to satisfy the requirement under the EP Act to “take all reasonable and practical measures” to prevent environmental harm.

Due to the complex propagation of underwater sound waves (particularly in shallow water) there are fewer available techniques to reduce underwater noise impacts than in airborne noise mitigation.

Available techniques are largely restricted to either reducing the source level, or avoiding impacts by making sure that sensitive animals are not in the vicinity of the noise source when it is operational.

South Australia has published a guideline (South Australian Underwater Piling Noise Guidelines (SA DPTI, 2012b)), which provides a suite of standard mitigation measures to be implemented for any offshore piling construction works. These mitigation measures are recommended to be adopted for CSDP since they represent current Australian best practice for managing offshore construction underwater noise impacts.

#### D7.9.1 Safety/Exclusion Zones

It is common to adopt safety zones around the sound source and to monitor for animals entering these zones, shutting down the sound source if necessary if the animal continues to approach the source.

This approach typically relies on detection of animals by trained observers, and hence is most effective for marine mammals, which must periodically come to the surface to breathe. Reliably detecting other animals may be difficult or impossible. In cloudy water such as Trinity Inlet, visibility is reduced, and observation may be additionally difficult.

The requirement to visually detect animals means that piling activities must occur during daylight hours.

An alternate approach, using passive acoustic monitoring to detect noise signals from animals has been proposed (Parvin et al, 2007) and is theoretically more effective for detecting marine mammals before they enter the damage zone for piling noise, allowing the activity to be shut down. However, this relies on the ability of the operator to recognise animal signals and thus requires highly-trained operators, and is not yet considered sufficiently reliable to replace visual observation.

The *South Australian Underwater Piling Noise Guidelines* (DPTI, 2012b), which is the only Australian guidance for underwater construction noise management sets out two safety zones:

- The observation zone (where animals are detected and monitored, and the activity is prepared to be ceased if the animal continues to approach)

- The shut-down zone (where piling shuts down as soon as reasonably practicable if the animal enters this zone).

The size of these zones is determined based on the source emission from the piling activity (based on the SEL from a single pile strike). These safety zones are shown in **Table 15.6a** below.

Table D7.9.1a Underwater Piling Noise Guidelines Safety Zones (DPTI, 2012b)

| **Received Noise Level SEL dB(M) re 1 µPa²·s** | **Observation Zone** | **Shut Down Zone** |
|---|---|---|
| ≤ 150 dB at 100 m | 1 km | 100 m |
| ≤ 150 dB at 300 m | 1.5 km | 300 m |
| > 150 dB at 300 m | 2 km | 1 km |

Note that these zones are evaluated for each and every relevant group of marine mammals– i.e. using $M_{mf}$, $M_{lf}$, $M_{pw}$ etc. and hence a different safety zone may apply for different groups – e.g. a one kilometre observation zone for mid-frequency cetaceans, but a two kilometre observation zone for low-frequency cetaceans.

For CSDP, the SEL from one pile strike is approximately 145-150 dB(M) at 100 m (depending on whether the $M_{lf}$ or $M_{mf}$ weighting is used).

Hence the recommended observation zone is 1 km and the shut-down zone 100 m for piling associated with CSDP.

The required shut down zones are significantly larger than the predicted zone in which damage to marine mammals is predicted to occur and hence no injury is expected to marine mammals if these zones are followed in construction.

### D7.9.2 Acoustic Scaring Devices

The use of acoustic alarms or small underwater blasts to scare away animals from the construction zone prior to the main construction activity has been suggested (Marine Mammal Commission, 2007) for marine mammals, but other research (Coker & Hollis, 1950) has concluded that explosions have no apparent deterrent effect on fish.

Acoustic harassment devices (i.e. electronic devices emitting high levels of underwater sound at high frequencies, where seals are most sensitive) have been used to deter seals from fish farms by inducing avoidance behaviours, although habituation of animals has been observed (due to the benefits of food outweighing the acoustic disturbance). However, acoustic harassment devices have been observed to be effective at deterring porpoises, although the zone of deterrence may not be sufficient to avoid damage from high-energy pile driving (Hoescle et al, 2011).

Nedwell et al (2010) present source levels for four acoustic harassment devices, which produce source levels of approximately130 dBht at one metre for seals and odontocetes (different devices are available which are tailored for seals or dolphins/porpoises), which suggests that deterrence (levels greater than approximately 90 dBht) is likely for distances of up to 100m from the harassment device. Hence it may be necessary to use multiple devices arranged as a perimeter around the construction location in order to maintain an effective deterrence function for greater distances.

Due to the project mitigation measure of observation and shut-down zones around the piling rig (as discussed further in Section B10.6.1) which are significantly larger than the effective zone of acoustic scaring devices, the use of acoustic scaring devices is not recommended as a primary noise mitigation measure. However, scaring devices may be considered as a future management measure during construction if there are difficulties in reliably detecting animals entering the observation zone.

### D7.9.3 Soft Start

Since damage (generally) increases with closer distance to the source, “ramping up” sound levels can potentially be an effective mitigation measure to avoid animals being suddenly exposed to loud sound levels, e.g. if animals happened to be in the immediate vicinity of the source when it started up.

A gradual increase of sound levels is theorised to allow animals to flee the area without experiencing permanent damage.

The *South Australian Underwater Piling Noise Guidelines* (SA DPTI, 2012b) require a soft start of ten minutes at the beginning of piling and after any prolonged (>30 minute) break in piling. This measure will be adopted for the piling for CSDP.

### D7.9.4 Sound Screening

The US Marine Mammal Commission (2007) also suggested that the use of sound screening measures around stationary sources (such as piling) may be effective in minimising the propagation of the pressure wave. Bubble curtains, blasting mats and damping screens were suggested as potential control measures.

Bubble curtains theoretically may provide a significant reduction benefit by providing an impedance mismatch between the water column and the mixed air/water bubble curtain. Sound propagates less-effectively through this interface. Bubble curtains may also decrease the received sound level by increasing sound scattering – increasing the area affected but decreasing the received level.

Several studies have investigated the effectiveness of bubble curtains for piling noise. Effectiveness of blasting mats and damping screens has not been extensively studied.

Würsig et al (2000) reported on using a bubble curtain to reduce transmitted noise levels from piling in shallow depth water. Effectiveness of the bubble curtain, shown in **Figure D7.9.4a**, was found to vary depending on bubble size (larger bubbles were less effective as they merged together), and also the orientation of the source barge relative to the receptor (i.e. reflection via the underside of the barge was “short-circuiting” the bubble curtain). Overall reductions were in the range 3-5 dB, with best performance in the frequency range 400-6400 Hz.

Lucke et al (2011) reported reductions generally in the range of approximately 10-15 dB due to operation of a bubble curtain to shield porpoises in an enclosure from piling noise, with mean reductions of 14 dB for peak pressure and 13 dB for SEL.

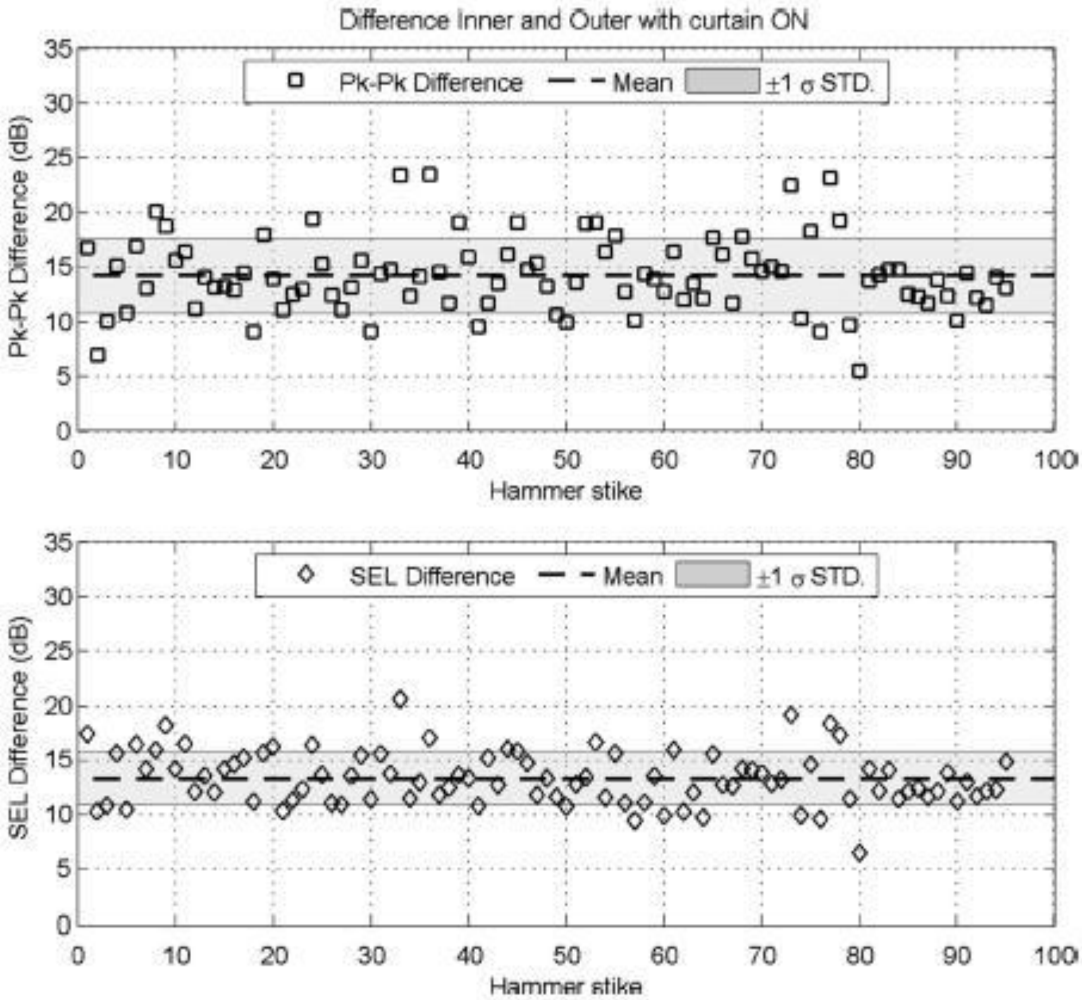



Figure D7.9.4a Effectiveness of bubble curtain (reduction due to bubble curtain) for peak sound levels (top) and SEL (bottom), from Nedwell et al (2010)

Porpoises initially exhibited avoidance behaviour from the piling noise (with no bubble curtain), but the avoidance behaviour ceased when the bubble curtain was operating. The bubble curtain appeared to be beneficial in providing masking noise to decrease disturbance as well as reducing the received sound level.

The studies indicate that a properly-designed and configured bubble curtain is able to provide a reduction of approximately10dB or greater in received piling levels.

IHC Merwede supplies a commercially-available pile screen, known as the Noise Reduction System (NRS), which consists of a flexible “bellows” sleeve that is placed around the piling rig. The noise reduction is achieved through a combination of a bubble curtain and the impedance mismatch between water and the double-walled “bellows” sleeve. Quoted noise reductions for the NRS are 10 dB or greater, which is approximately the same as a well-designed bubble curtain.

Bubble curtains (or similar mitigation measures such as the NRS) may make the construction process less-efficient and hence prolong noise impacts.

As such, given that significant impacts on marine mammals are only predicted within ~10-20 m of the piling source, the recommended mitigation measure of maintaining observation and shutdown zones is considered to be more suitable for CSDP.

### D7.9.5 Reduced Impact Energy

The sound level from impact piling is correlated to the amount of energy in the blow (IHC Merwede, n.d.(b)), with an approximate linear relationship between impact energy and acoustic energy (i.e. sound level scales with ~10 log[Energy]).

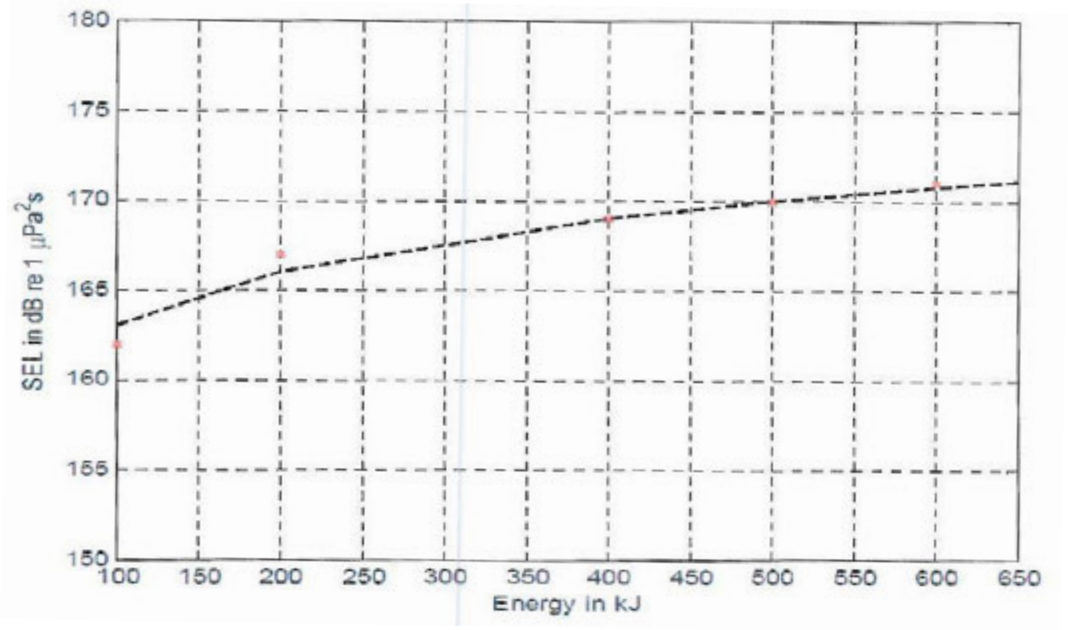



Figure D7.9.5a Approximate relationship between piling impact energy and Sound Exposure Level, from IHC Merwede (n.d. (b))

This indicates that sound levels from piling may be reduced by reducing the impact energy, although at the cost of requiring a greater number of pile impacts to bring the pile to completion.

In cases where the peak pressure (not the SEL) is the governing factor for noise impacts, reducing the impact energy may be an effective way of reducing impacts.

In cases where the SEL is the governing factor for noise impacts, this is not expected to be an effective mitigation technique, because the number of pile impacts to finish the pile will increase and hence the overall energy dose will be approximately the same.

The predicted levels indicate that sound exposure levels are generally controlling impact zones, and therefore adjusting the pile impact energy is unlikely to have a significant benefit, although a larger number of lower-energy pile impacts spread over a longer time may allow animals to avoid the vicinity of the pile.

This may be required in any case in order to control vibration impacts onto the heritage wharf structure, in which case there will be additional benefits in reducing the underwater noise emissions from piling.

### D7.9.6 Monitoring

Underwater noise monitoring will be conducted at the beginning of construction to calibrate the predicted impact zones based on the actual piling rig selected and the precise bathymetry of the piling site.

## D7.10 Acoustic Terminology

### D7.10.1 Ambient Noise Level

The ambient noise level is the overall noise level measured at a location from multiple noise sources. When assessing noise from a particular development, the ambient noise level is defined as the remaining noise level in the absence of the specific noise source being investigated. For example, if a fan located on a city building is being investigated, the ambient noise level is the noise level from all other sources without the fan running. This would include sources such as traffic, birds, people talking and other nearby fans on other buildings.

### D7.10.2 Background Noise Level

The background noise level is the noise level that is generally present at a location at all or most times. Although the background noise may change over the course of a day, over shorter time periods (e.g. 15 minutes) the background noise is almost-constant. Examples of background noise sources include steady traffic (e.g. motorways or arterial roads), constant mechanical or electrical plant and some natural noise sources such as wind, foliage, water and insects.

### D7.10.3 Assessment Background Level (ABL)

A single-number figure used to characterise the background noise levels from a single day of a noise survey. ABL is derived from the measured noise levels for the day, evening or night time period of a single day of background measurements. The ABL is calculated to be the tenth percentile of the background LA90 noise levels – i.e. the measured background noise is above the ABL 90% of the time.

### D7.10.4 Rating Background Level (RBL / minLA90,1hour)

A single-number figure used to characterise the background noise levels from a complete noise survey. The RBL for a day, evening or night time period for the overall survey is calculated from the individual Assessment Background Levels (ABL) for each day of the measurement period, and is numerically equal to the median (middle value) of the ABL values for the days in the noise survey. This parameter is denoted RBL in NSW, and minLA90,1hour in QLD.

### D7.10.5 Decibel (dB)

The ratio of sound pressures which we can hear is a ratio of 106:1 (one million:one). For convenience, therefore, a logarithmic measurement scale is used. The resulting parameter is called the 'sound pressure level' ($L_p$) and the associated measurement unit is the decibel (dB). As the decibel is a logarithmic ratio, the laws of logarithmic addition and subtraction apply.

### D7.10.6 dB(A)

The unit used to define a weighted sound pressure level, which correlates well with the subjective response to sound. The 'A' weighting follows the frequency response of the human ear, which is less sensitive to low and very high frequencies than it is to those in the range 500Hz to 4kHz.

In some statistical descriptors the 'A' weighting forms part of a subscript, such as $L_{A10}$, $L_{A90}$, and $L_{Aeq}$ for the 'A' weighted equivalent continuous noise level.

### D7.10.7 Equivalent continuous sound level

An index for assessment for overall noise exposure is the equivalent continuous sound level, $L_{eq}$. This is a notional steady level which would, over a given period of time, deliver the same sound energy as the actual time-varying sound over the same period. Hence fluctuating levels can be described in terms of a single figure level.

### D7.10.8 Frequency

Frequency is the rate of repetition of a sound wave. The subjective equivalent in music is pitch. The unit of frequency is the hertz (Hz), which is identical to cycles per second. A 1000Hz is often denoted as 1kHz, eg 2kHz = 2000Hz. Human hearing ranges approximately from 20Hz to 20kHz. For design purposes the octave bands between 63Hz to 8kHz are generally used. The most commonly used frequency bands are octave bands, in which the mid frequency of each band is twice that of the band below it. For more detailed analysis, each octave band may be split into three one-third octave bands or in some cases, narrow frequency bands.

### D7.10.9 Maximum noise level

The maximum noise level identified during a measurement period. Experimental data has shown that the human ear does not generally register the full loudness of transient sound events of less than 125ms duration and fast time weighting (F) has an exponential time constant of 125ms which reflects the ear's response. Slow time weighting (S) has an exponential time constant of 1s and is used to allow more accurate estimation of the average sound level on a visual display.

The maximum level measured with fast time weighting is denoted as $L_{Amax, F}$. The maximum level measured with slow time weighting is denoted $L_{Amax, S}$.

### D7.10.10 Sound power level

The sound power level ($L_w$) of a source is a measure of the total acoustic power radiated by a source. The sound power level is an intrinsic characteristic of a source (analogous to its volume or mass), which is not affected by the environment within which the source is located.

### D7.10.11 Sound pressure level

The sound power emitted by a source results in pressure fluctuations in the air, which are heard as sound.

The sound pressure level ($L_p$) is ten times the logarithm of the ratio of the measured sound pressure (detected by a microphone) to the reference level of 2 x $10^{-5}$Pa (the threshold of hearing).

Thus Lp (dB) = 10 log (P1/Pref)2 where Pref, the lowest pressure detectable by the ear, is 0.00002 pascals (ie 2x10-5 Pa).

The threshold of hearing is 0dB, while the threshold of pain is approximately 120dB. Normal speech is approximately 60dB$L_A$ and a change of 3dB is only just detectable. A change of 10dB is subjectively twice, or half, as loud.

### D7.10.12 Statistical noise levels

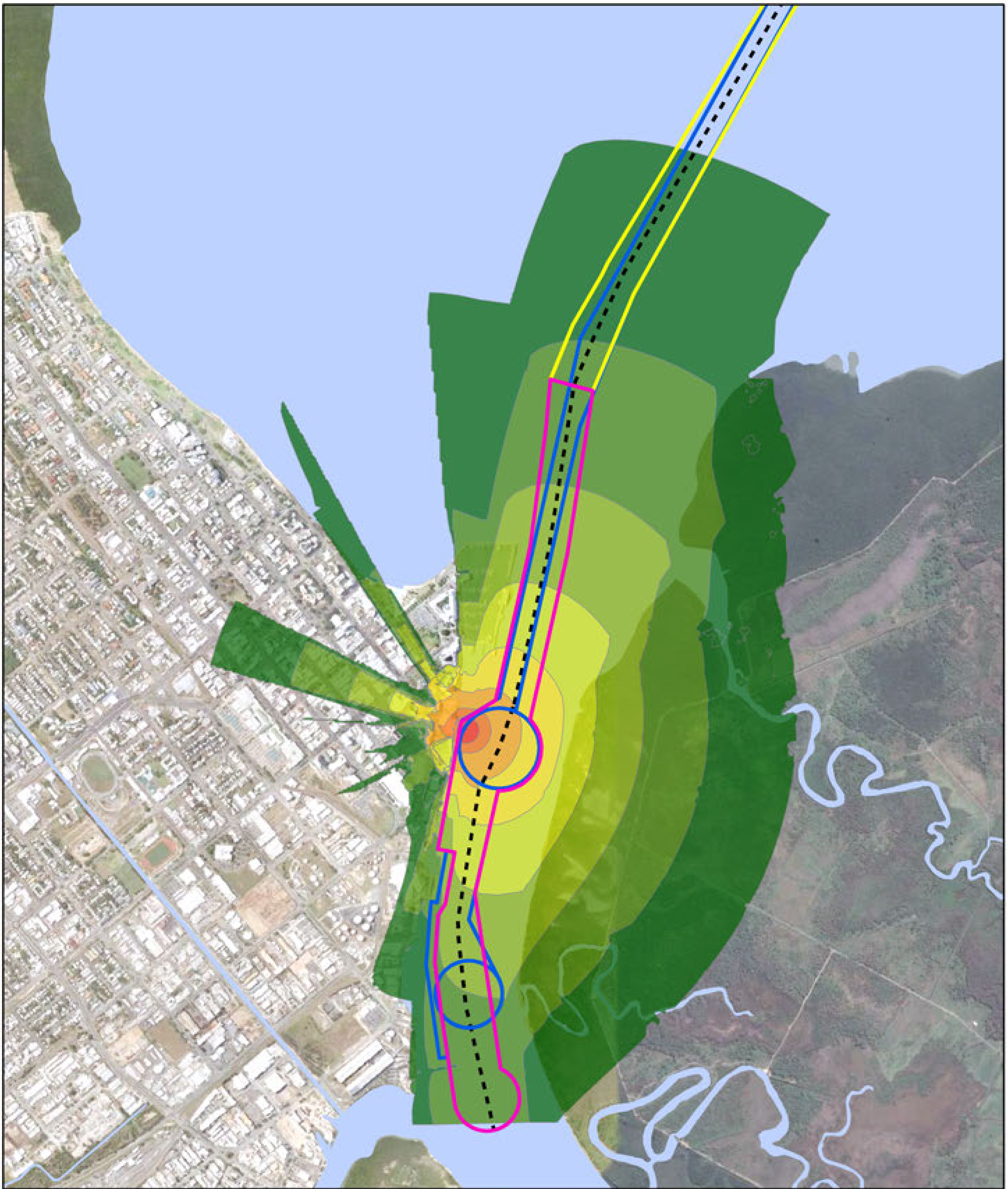
For levels of noise that vary widely with time, for example road traffic noise, it is necessary to employ an index which allows for this variation. The $L_{10}$, the level exceeded for 10% of the time period under consideration, and can be used for the assessment of road traffic. The $L_{90}$, the level exceeded for 90% of the time, has been adopted to represent the background noise level. The $L_1$, the level exceeded for 1% of the time, is representative of the maximum levels recorded during the sample period. A weighted statistical noise levels are denoted $L_{A10}$, dB$L_{A90}$ etc. The reference time period (T) is normally included, e.g. dB$L_{A10, 5min}$ or dB$L_{A90, 8hr}$.

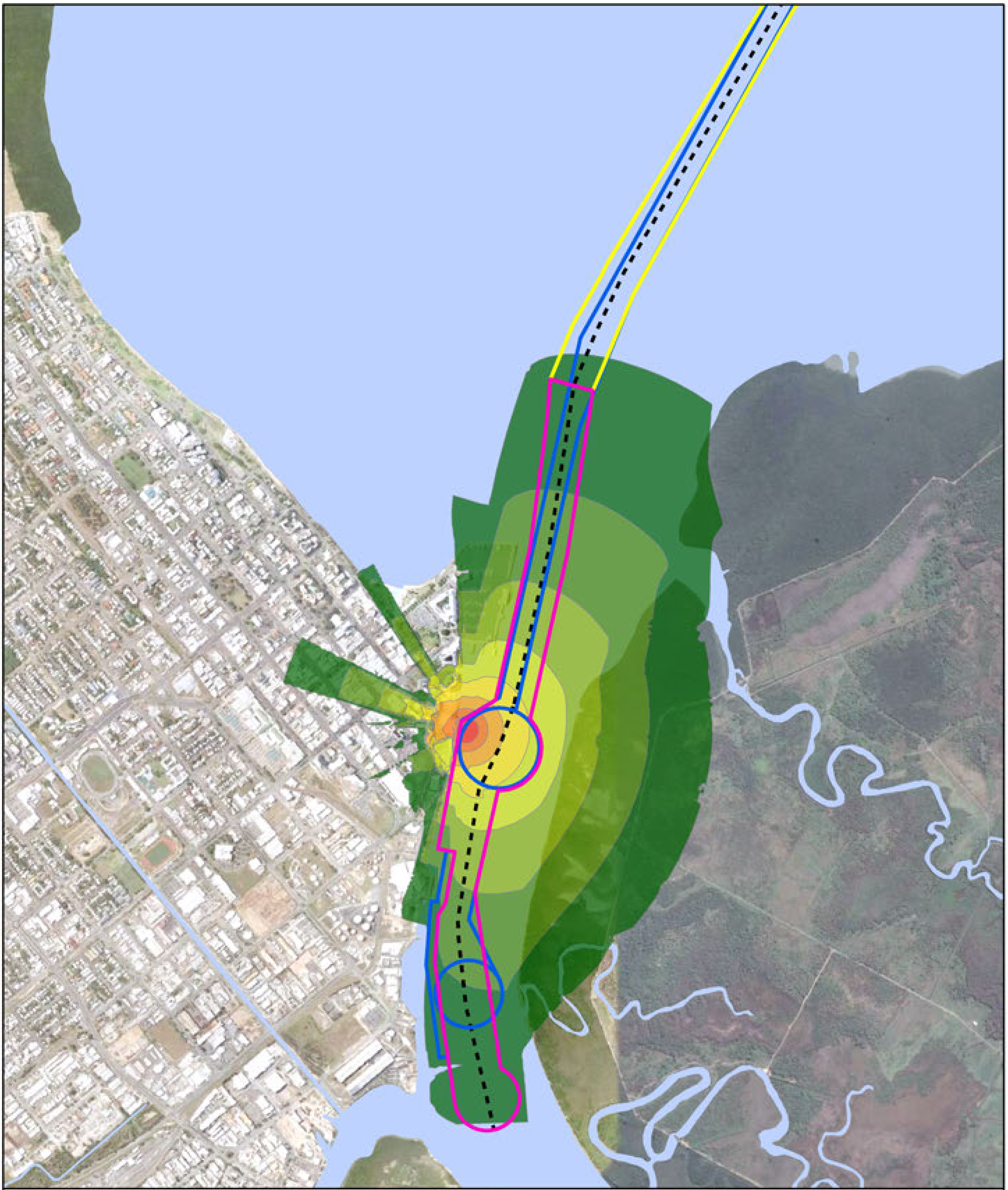
### D7.10.13 Typical levels

Some typical dB(A) noise levels are given below:

| **Noise Level, dB(A)** | **Example** |
|---|---|
| 130 | Threshold of pain |
| 120 | Jet aircraft take-off at 100m |
| 110 | Chain saw at 1m |
| 100 | Inside disco |
| 90 | Heavy lorries at 5m |
| 80 | Kerbside of busy street |
| 70 | Loud radio (in typical domestic room) |

| **Noise Level, dB(A)** | **Example** |
|---|---|
| 60 | Office or restaurant |
| 50 | Domestic fan heater at 1m |
| 40 | Living room |
| 30 | Theatre |
| 20 | Remote countryside on still night |
| 10 | Sound insulated test chamber |





| Existing Shipping Channel and Basins | Noise Level (dB): |
|---|---|
| **Proposed Channel Design** | 40 - 45 |
| Inner Port | 45 - 50 |
| Outer Channel | 50 - 55 |
| | 55 - 60 |
| | 60 - 65 |
| | 65 - 70 |
| | 70 - 75 |
| | > 75 |

Ports North

Job Title
**Cairns Shipping Development Project EIS**

Map Title
**Construction - Dredging Backhoe (Neutral Weather Conditions)**

Kilometres
0 0.2 0.4 0.6 0.8 1

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

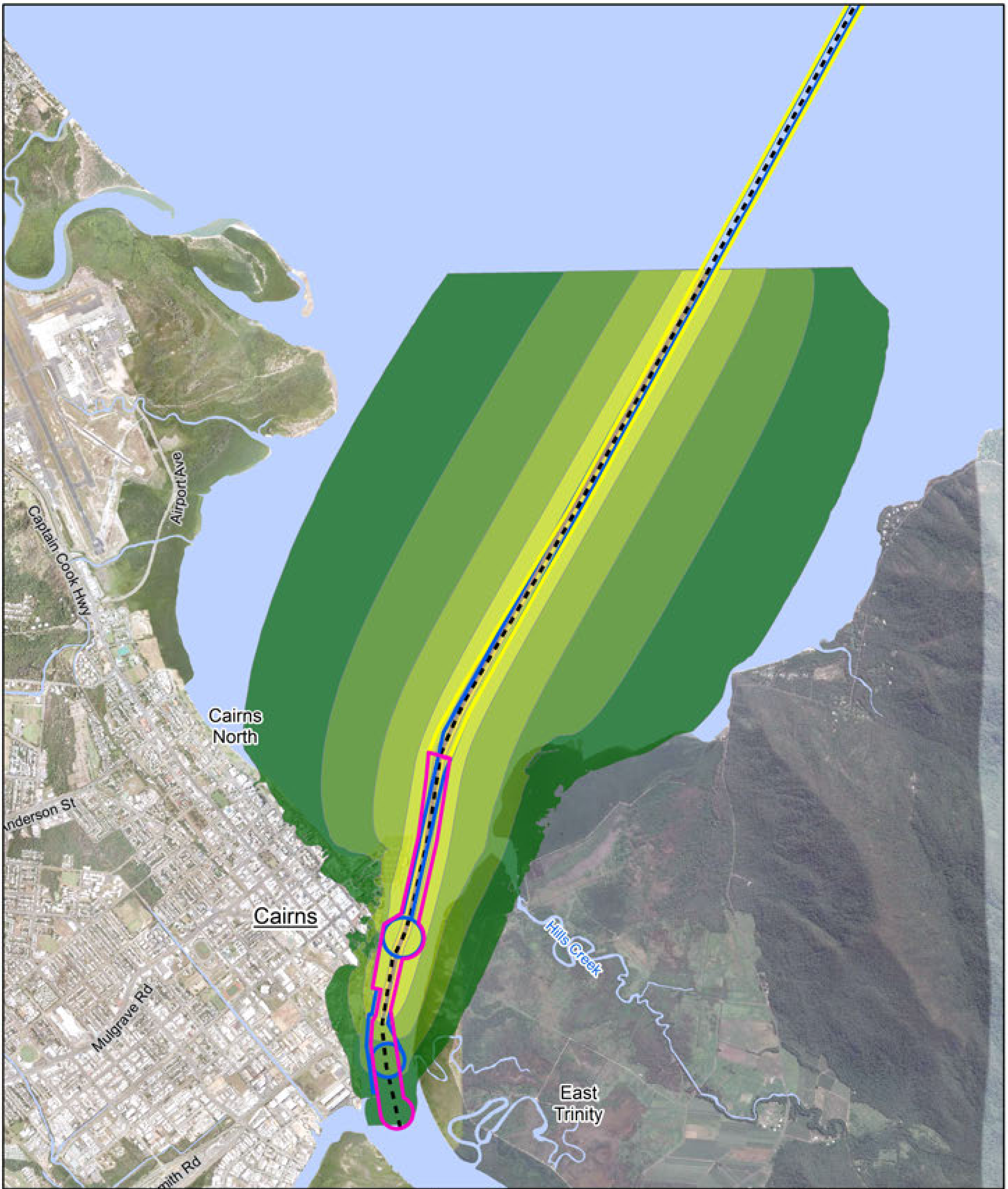
ARUP

BMT WBM

| Scale at A4 | Map Status |
|---|---|
| 1:25,000 | Final |

Coordinate System
**GDA 1994 MGA Zone 55**

| Job No | Figure No |
|---|---|
| 230377-00 | D7.8.1b |




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

55 - 60

60 - 65

65 - 70

70 - 75

> 75

Ports North

ARUP

BMT WBM

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Construction - Dredging Barge (Adverse Weather Conditions)**

Kilometres

0 0.5 1 1.5 2

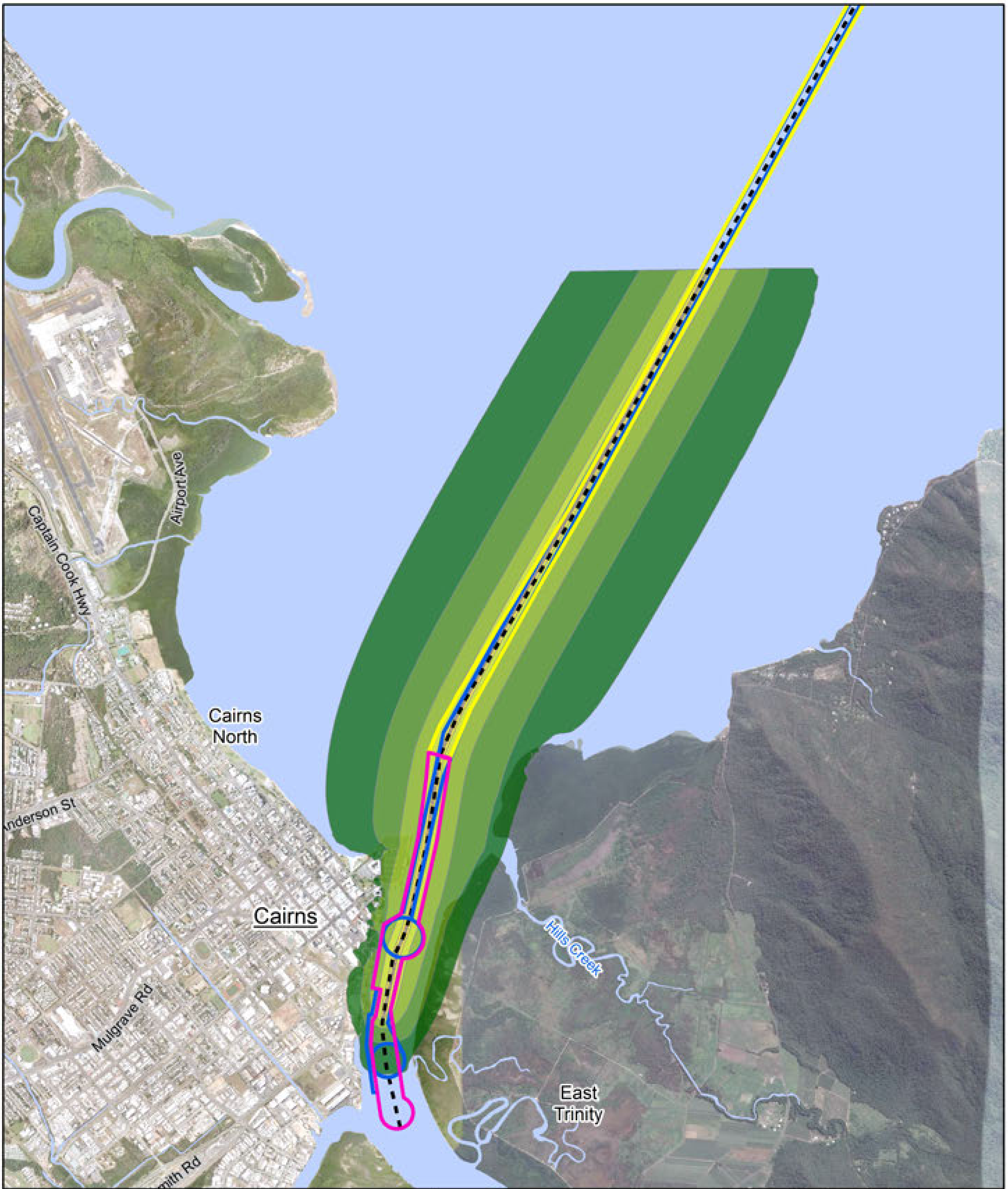
| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

| Scale at A4 | Map Status |
|---|---|
| **1:50,000** | **Final** |

Coordinate System

**GDA 1994 MGA Zone 55**

| Job No | Figure No |
|---|---|
| **230377-00** | **D7.8.1c** |




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- > 75

Ports North

ARUP

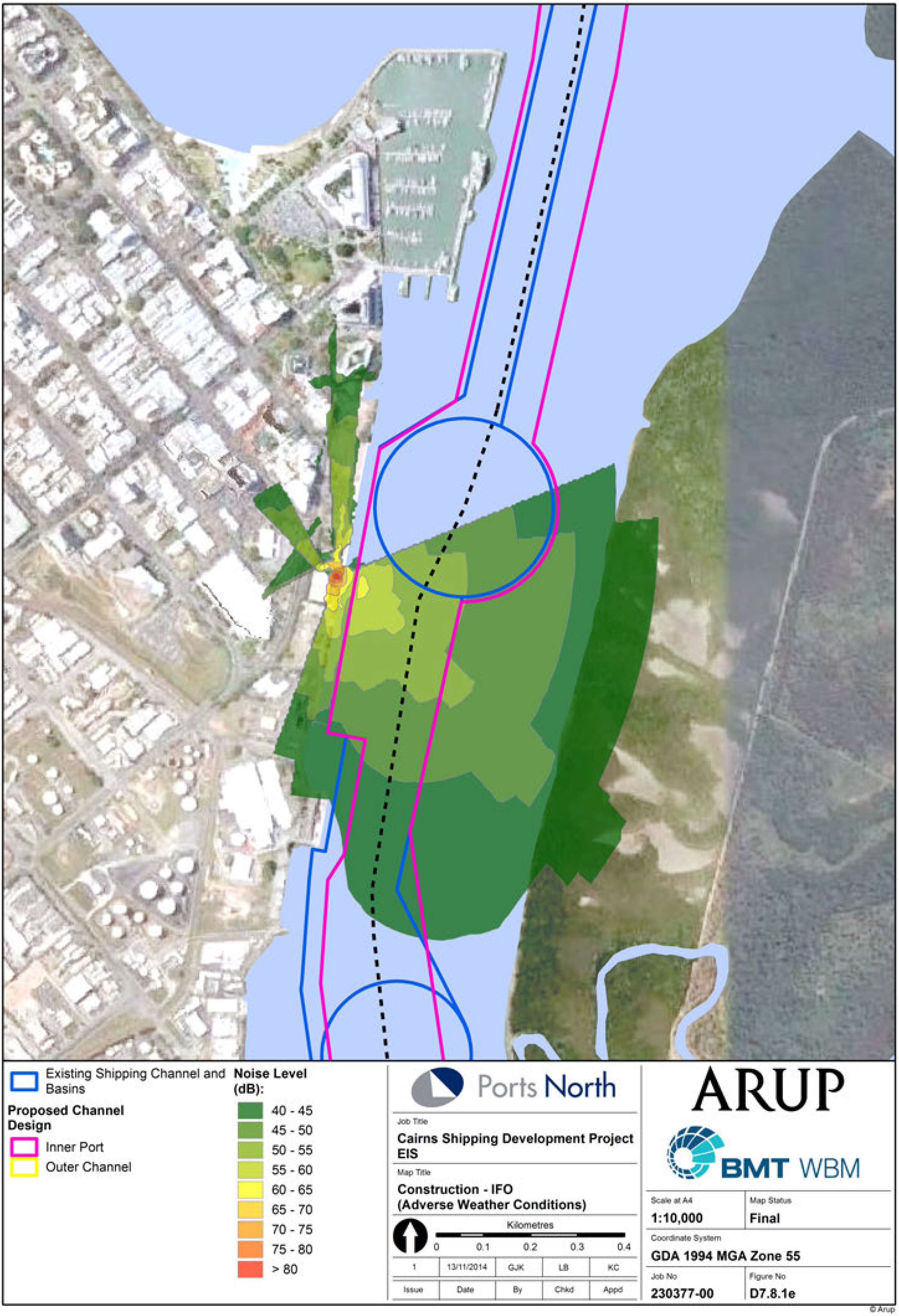
BMT WBM

| Job Title | |
|---|---|
| **Cairns Shipping Development Project EIS** | |
| Map Title | |
| **Construction - Dredging Barge (Neutral Weather Conditions)** | |

Kilometres: 0, 0.5, 1, 1.5, 2

| 1 | 13/11/2014 | GJK | LB | KC |
|---|---|---|---|---|
| Issue | Date | By | Chkd | Appd |

| Scale at A4 | Map Status |
|---|---|
| **1:50,000** | **Final** |
| Coordinate System | |
| **GDA 1994 MGA Zone 55** | |
| Job No | Figure No |
| **230377-00** | **D7.8.1d** |


Existing Shipping Channel and Basins
Proposed Channel Design
Inner Port
Outer Channel
Noise Level (dB):
40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
75 - 80
> 80
Ports North
Job Title
Cairns Shipping Development Project EIS
Map Title
Construction - IFO (Adverse Weather Conditions)
Kilometres
0 0.1 0.2 0.3 0.4
1 13/11/2014 GJK LB KC
Issue Date By Chkd Appd
ARUP
BMT WBM
Scale at A4
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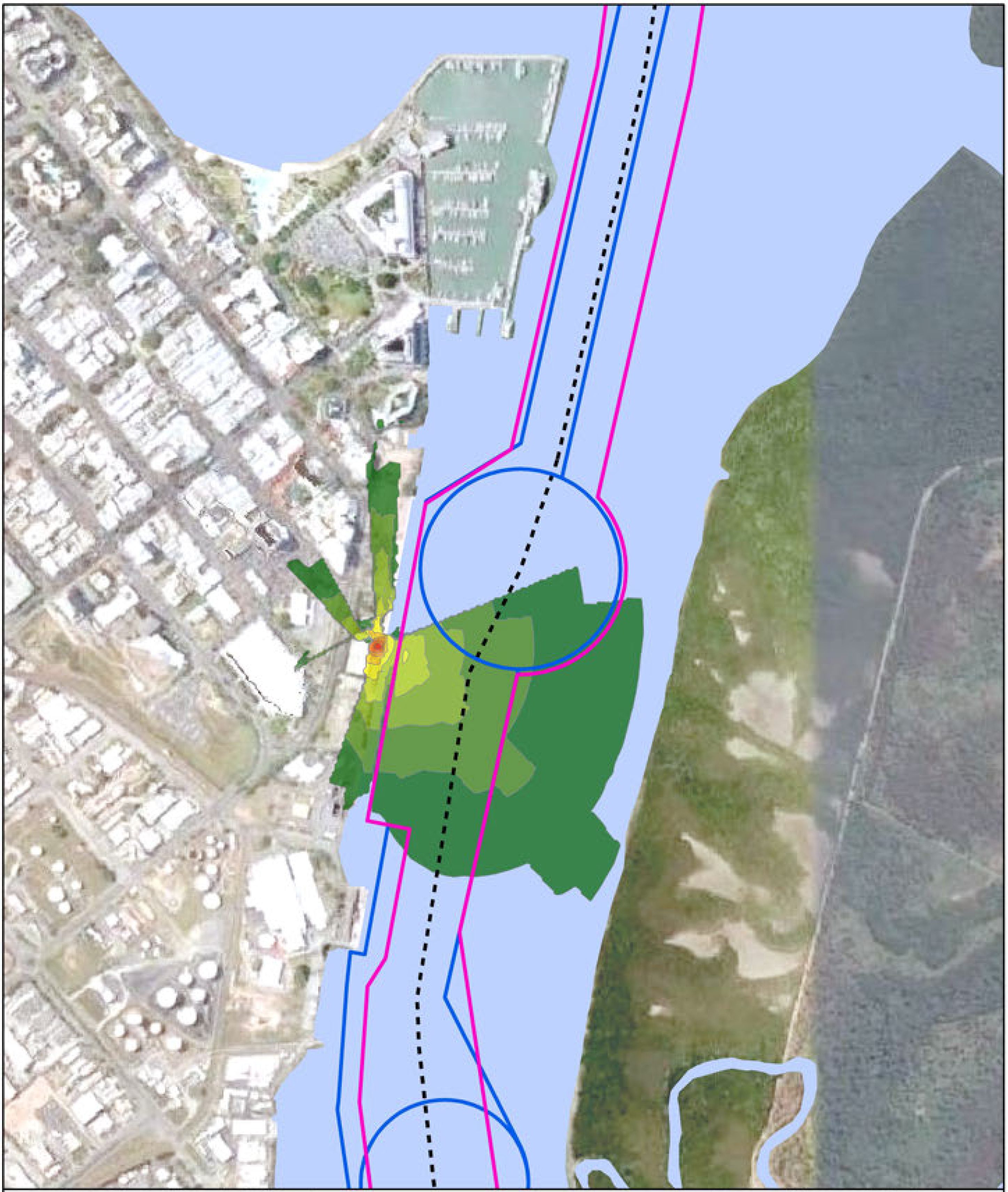
Map Status
Final
Coordinate System
GDA 1994 MGA Zone 55
Job No
230377-00
Figure No
D7.8.1e



Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45
45 - 50
50 - 55
55 - 60
60 - 65
65 - 70
70 - 75
75 - 80
> 80

Ports North

Job Title
**Cairns Shipping Development Project EIS**

Map Title
**Construction - IFO (Neutral Weather Conditions)**

Kilometres
0 0.1 0.2 0.3 0.4

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

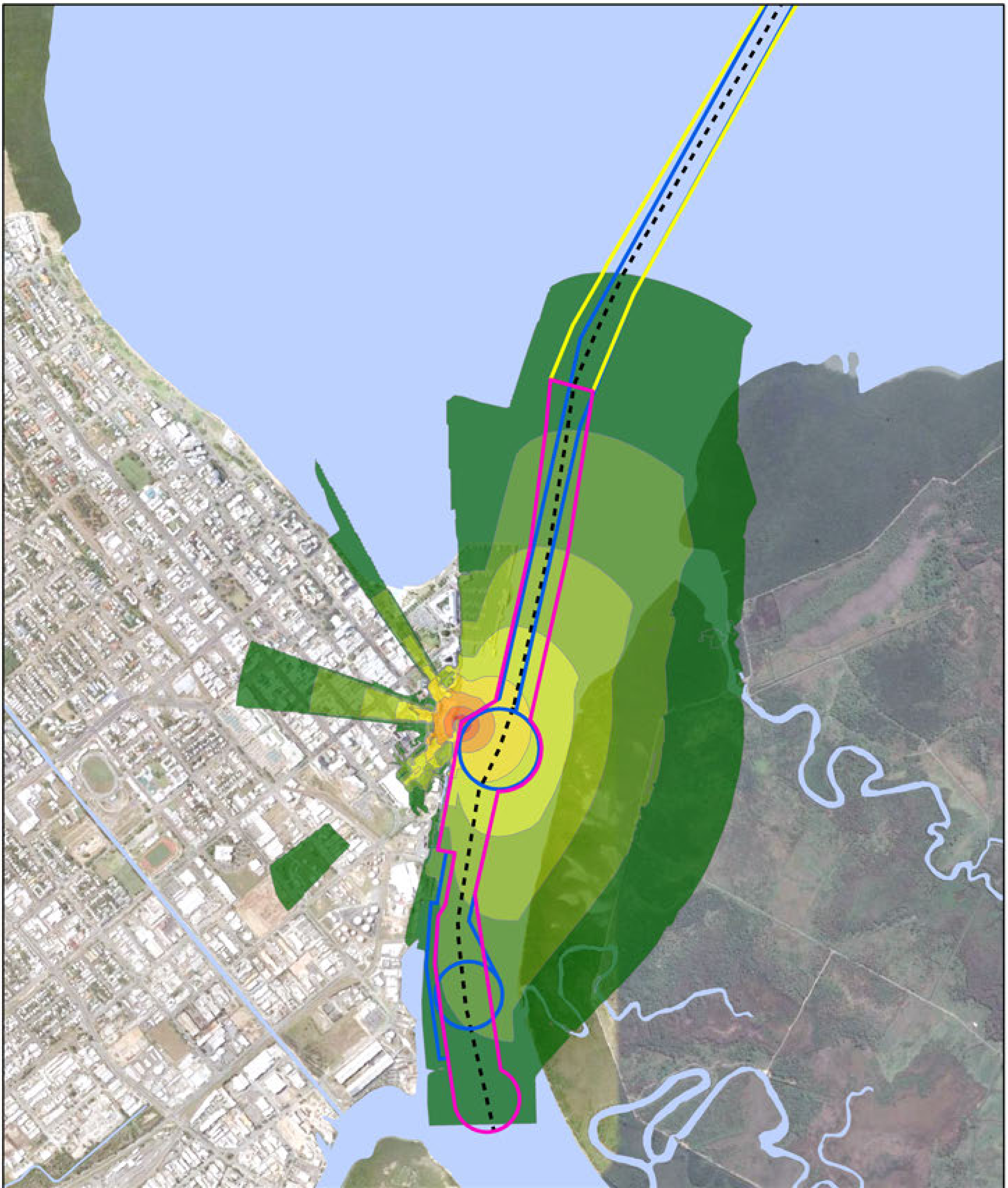
Scale at A4
**1:10,000**

Map Status
**Final**

Coordinate System
**GDA 1994 MGA Zone 55**

Job No
**230377-00**

Figure No
**D7.8.1f**



Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- > 75

Ports North

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Construction - Piling (Adverse Weather Conditions)**

Kilometres

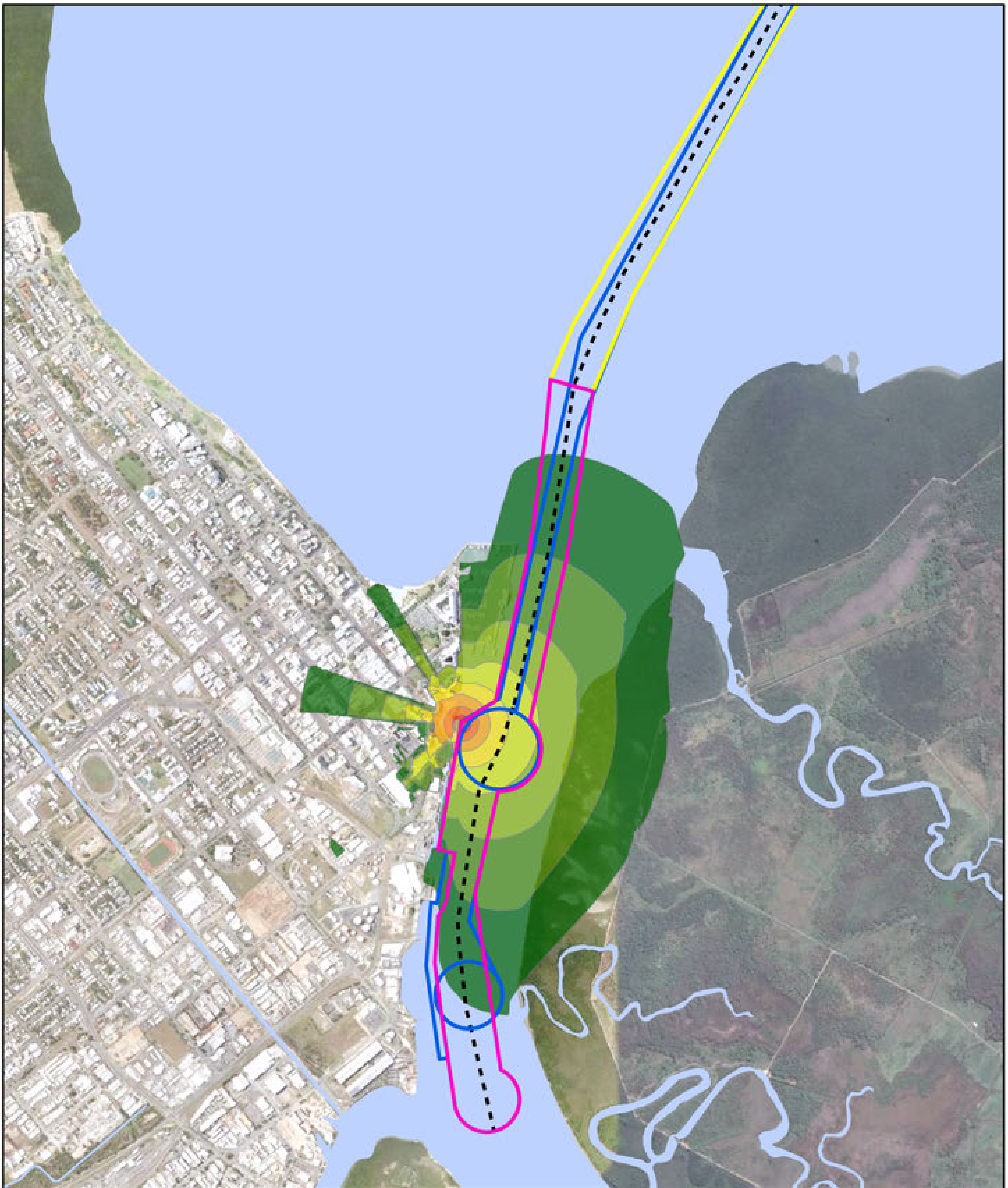
0 0.2 0.4 0.6 0.8 1

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

| | |
|---|---|
| Scale at A4<br>1:25,000 | Map Status<br>Final |
| Coordinate System<br>GDA 1994 MGA Zone 55 | |
| Job No<br>230377-00 | Figure No<br>D7.8.1g |



**Existing Shipping Channel and Basins**

**Proposed Channel Design**

**Inner Port**

**Outer Channel**

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- > 75

Ports North

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Construction - Piling (Neutral Weather Conditions)**

Kilometres

0 0.2 0.4 0.6 0.8 1

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

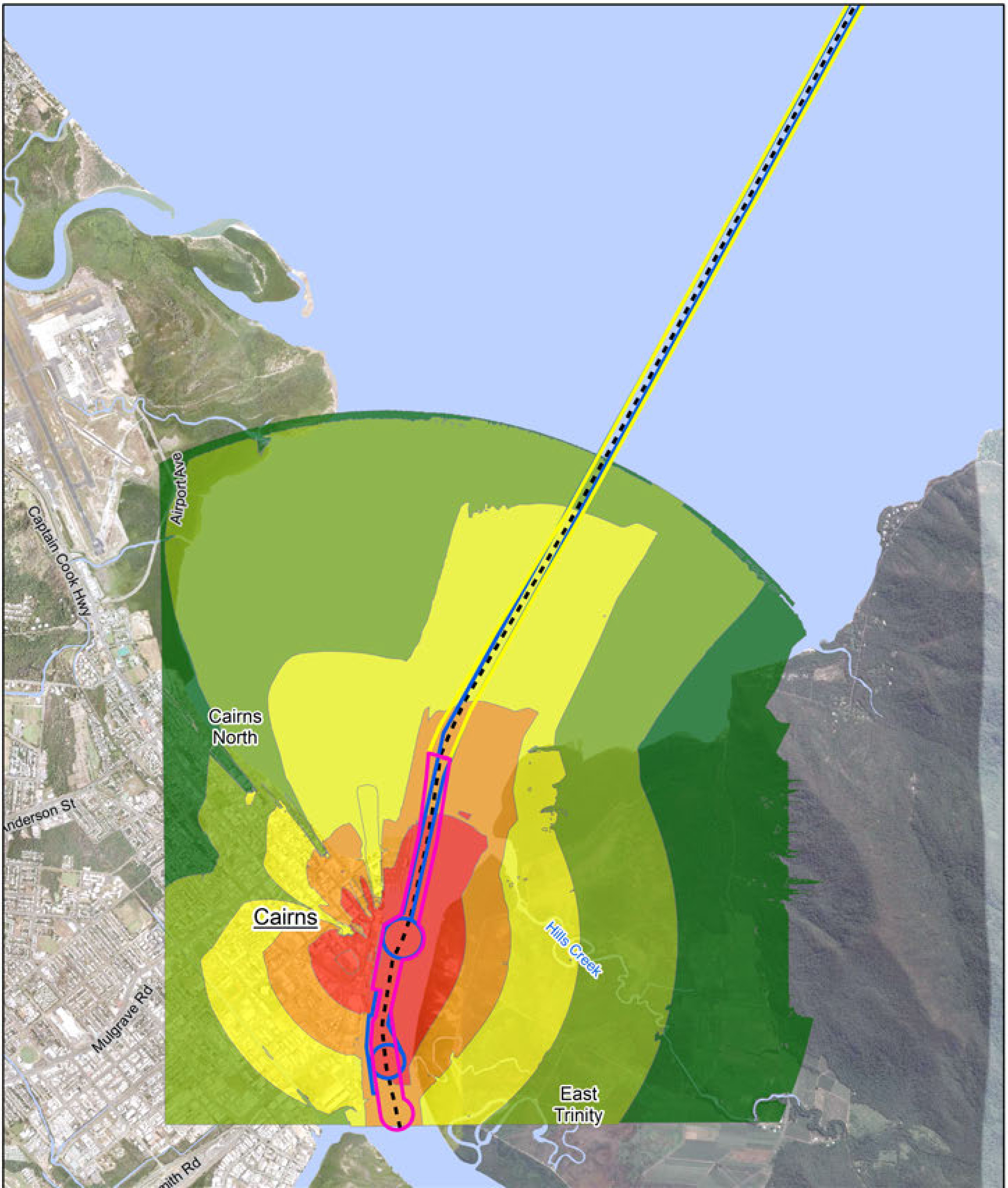
BMT WBM

| Scale at A4 | Map Status |
|---|---|
| **1:25,000** | **Final** |

Coordinate System

**GDA 1994 MGA Zone 55**

| Job No | Figure No |
|---|---|
| **230377-00** | **D7.8.1h** |




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

55 - 60

> 60

Ports North

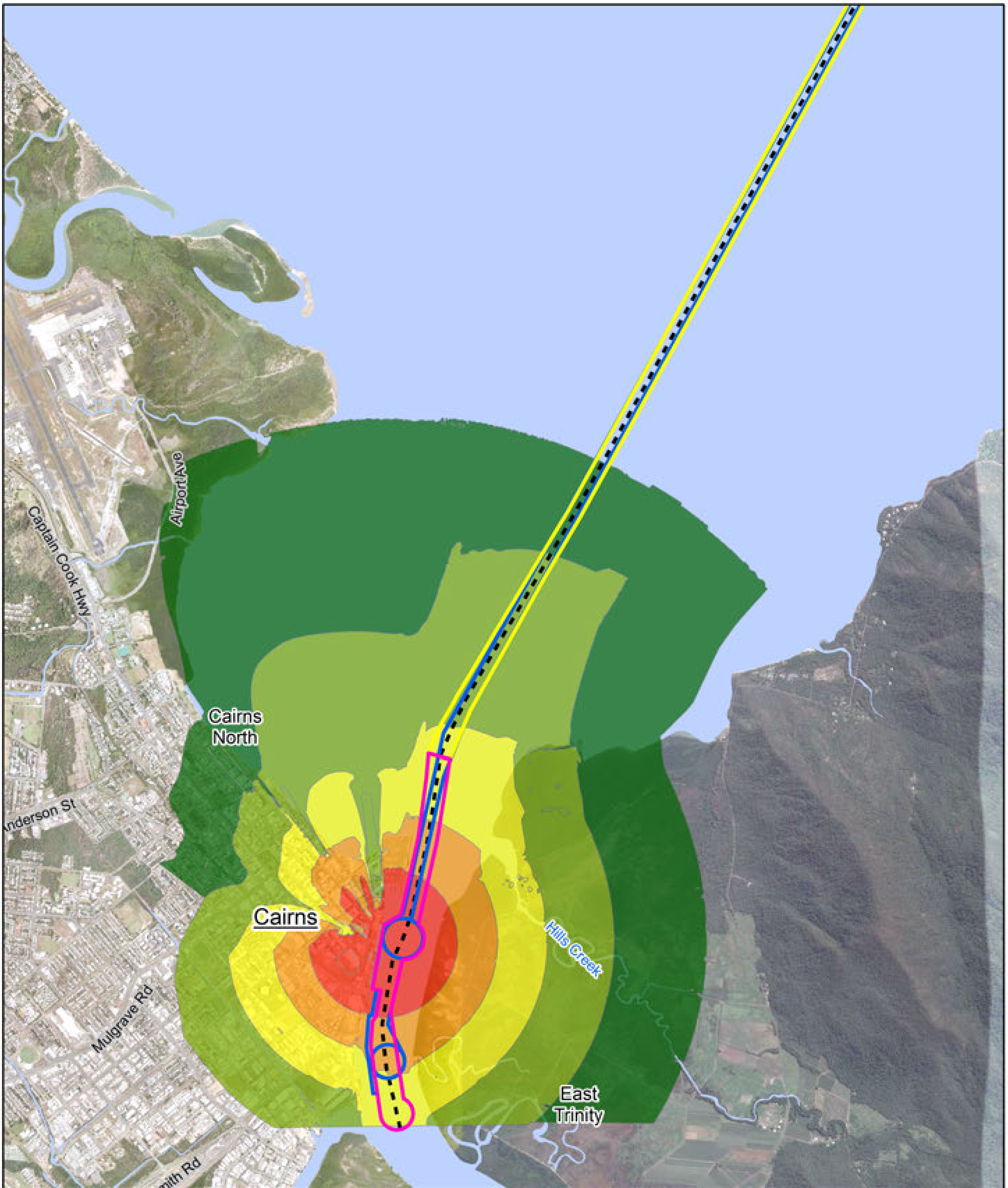
ARUP

BMT WBM

| | |
|---|---|
| Job Title | **Cairns Shipping Development Project EIS** |
| Map Title | **Operation - Large Ship - Berthing (Adverse Weather Conditions)** |
| Scale at A4 | **1:50,000** |
| Map Status | **Final** |
| Coordinate System | **GDA 1994 MGA Zone 55** |
| Job No | **230377-00** |
| Figure No | **D7.8.2a** |

Kilometres 0 0.5 1 1.5 2

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

55 - 60

> 60

Ports North

ARUP

BMT WBM

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Large Ship - Berthing (Neutral Weather Conditions)**

Kilometres

0 0.5 1 1.5 2

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

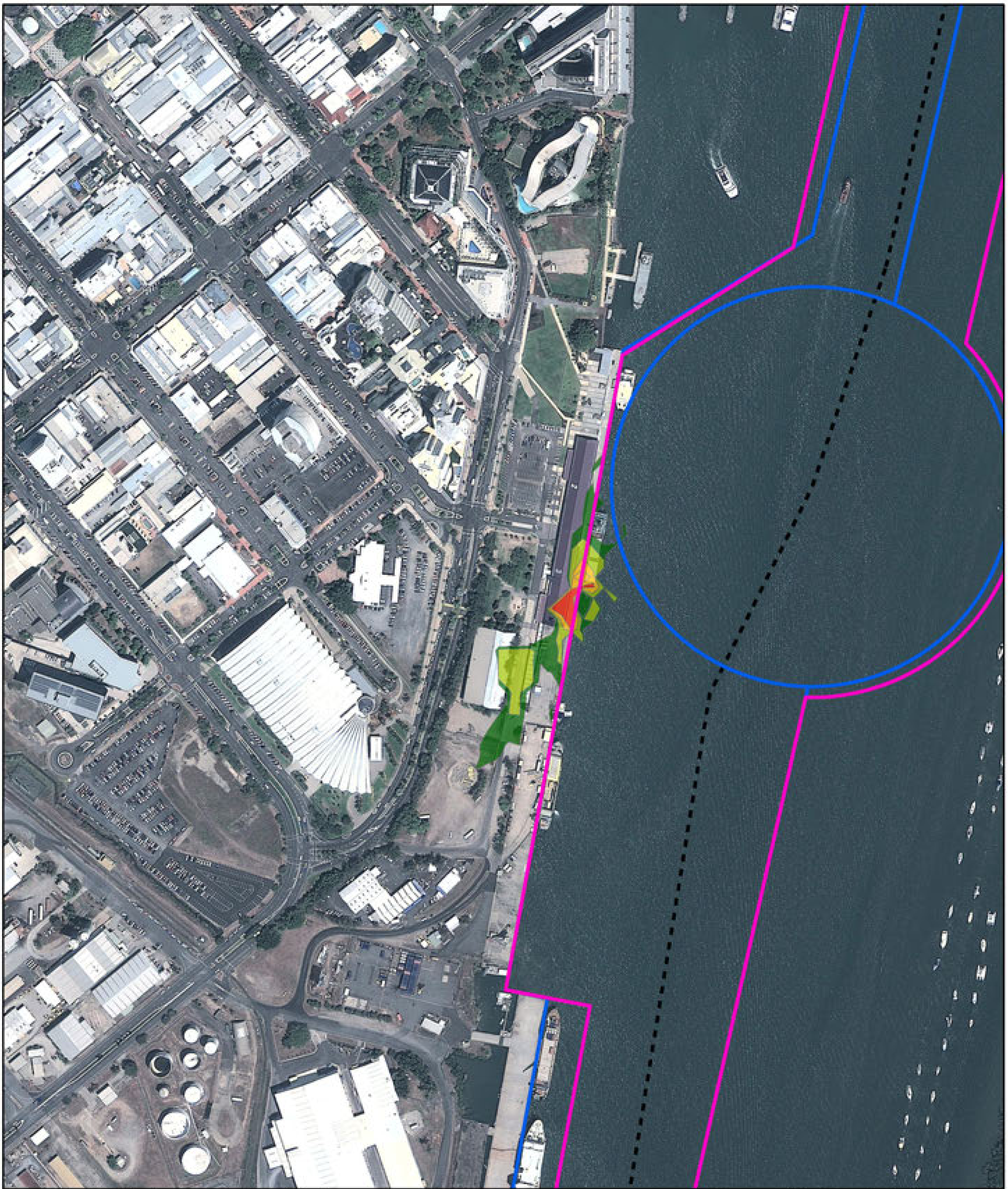
Scale at A4: **1:50,000**

Map Status: **Final**

Coordinate System: **GDA 1994 MGA Zone 55**

Job No: **230377-00**

Figure No: **D7.8.2b**



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

40 - 45

45 - 50

50 - 55

> 55

Ports North

ARUP

BMT WBM

Job Title

Cairns Shipping Development Project EIS

Map Title

Operation - Large Ship - Dock (Shore Power) (Adverse Weather)

Meters

0 50 100 150 200

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

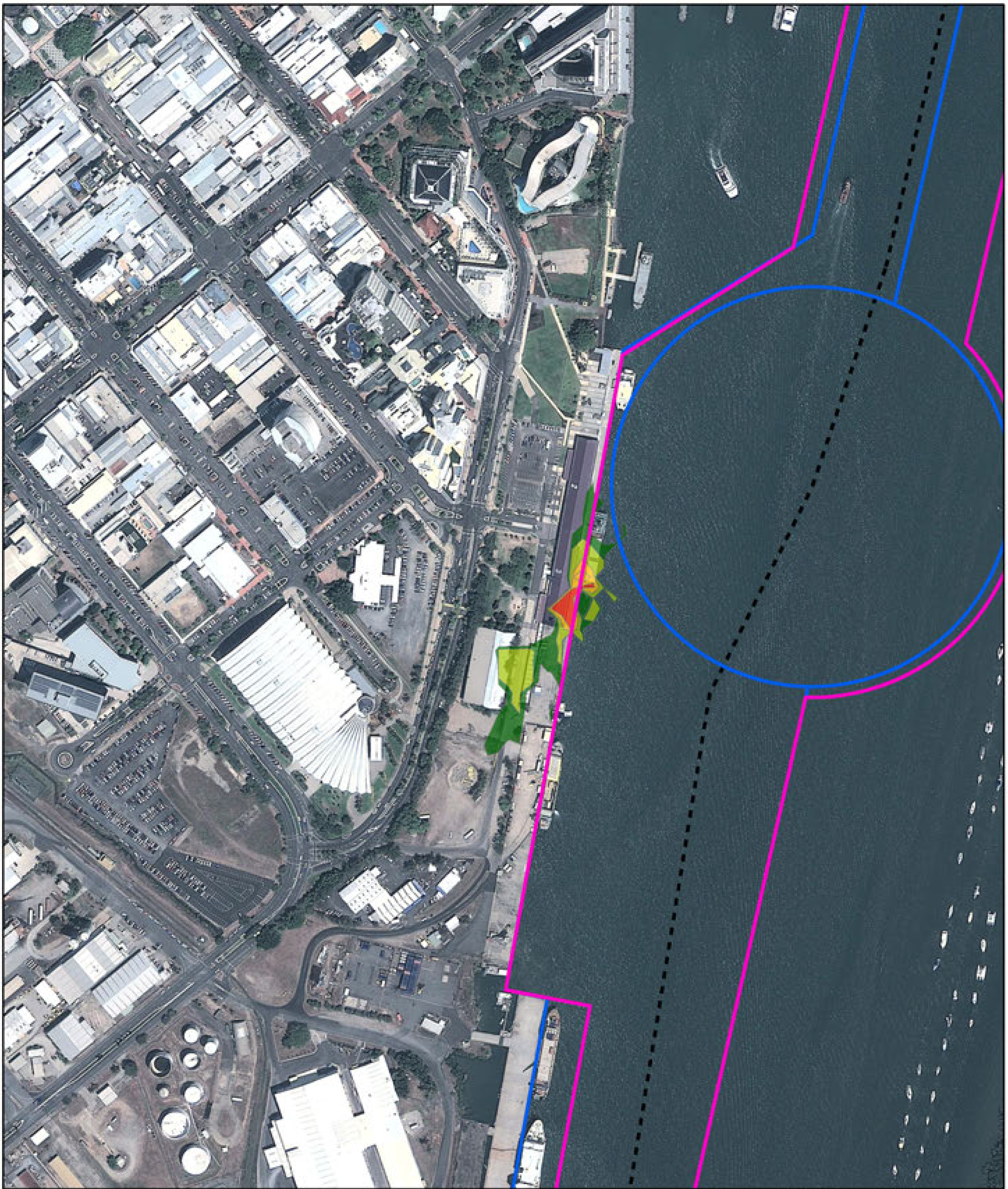
Scale at A4: 1:5,000

Map Status: Final

Coordinate System: GDA 1994 MGA Zone 55

Job No: 230377-00

Figure No: D7.8.2c



| | |
|---|---|
| Existing Shipping Channel and Basins | |
| **Proposed Channel Design** | |
| Inner Port | |
| Outer Channel | |

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- > 55

Ports North

ARUP

BMT WBM

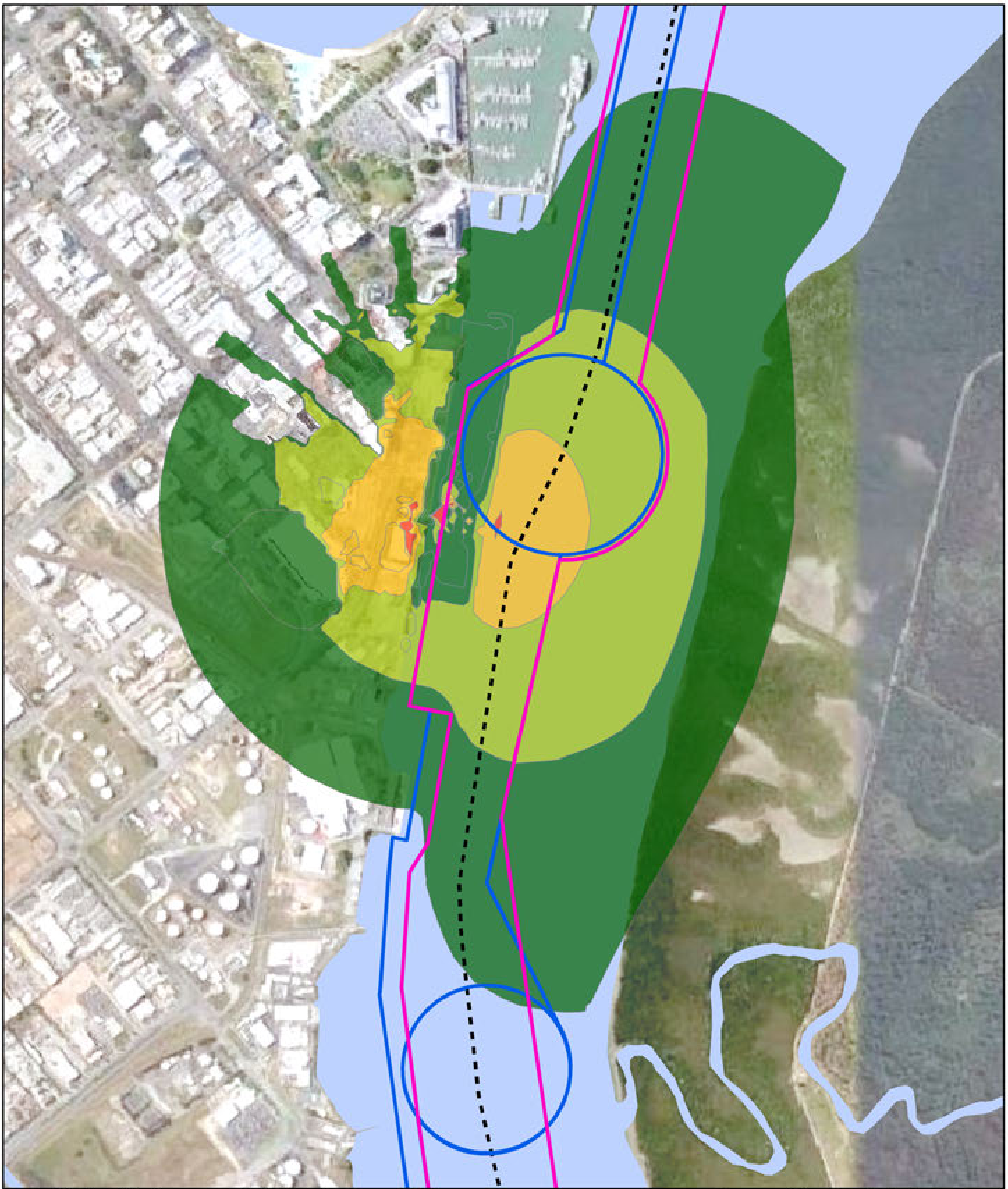
Job Title: Cairns Shipping Development Project EIS

Map Title: Operation - Large Ship - Dock (Shore Power) (Neutral Weather)

Meters: 0 50 100 150 200

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

| | |
|---|---|
| Scale at A4: 1:5,000 | Map Status: Final |
| Coordinate System: GDA 1994 MGA Zone 55 | |
| Job No: 230377-00 | Figure No: D7.8.2d |



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

40 - 45

45 - 50

50 - 55

> 55

Ports North

ARUP

BMT WBM

Job Title

Cairns Shipping Development Project EIS

Map Title

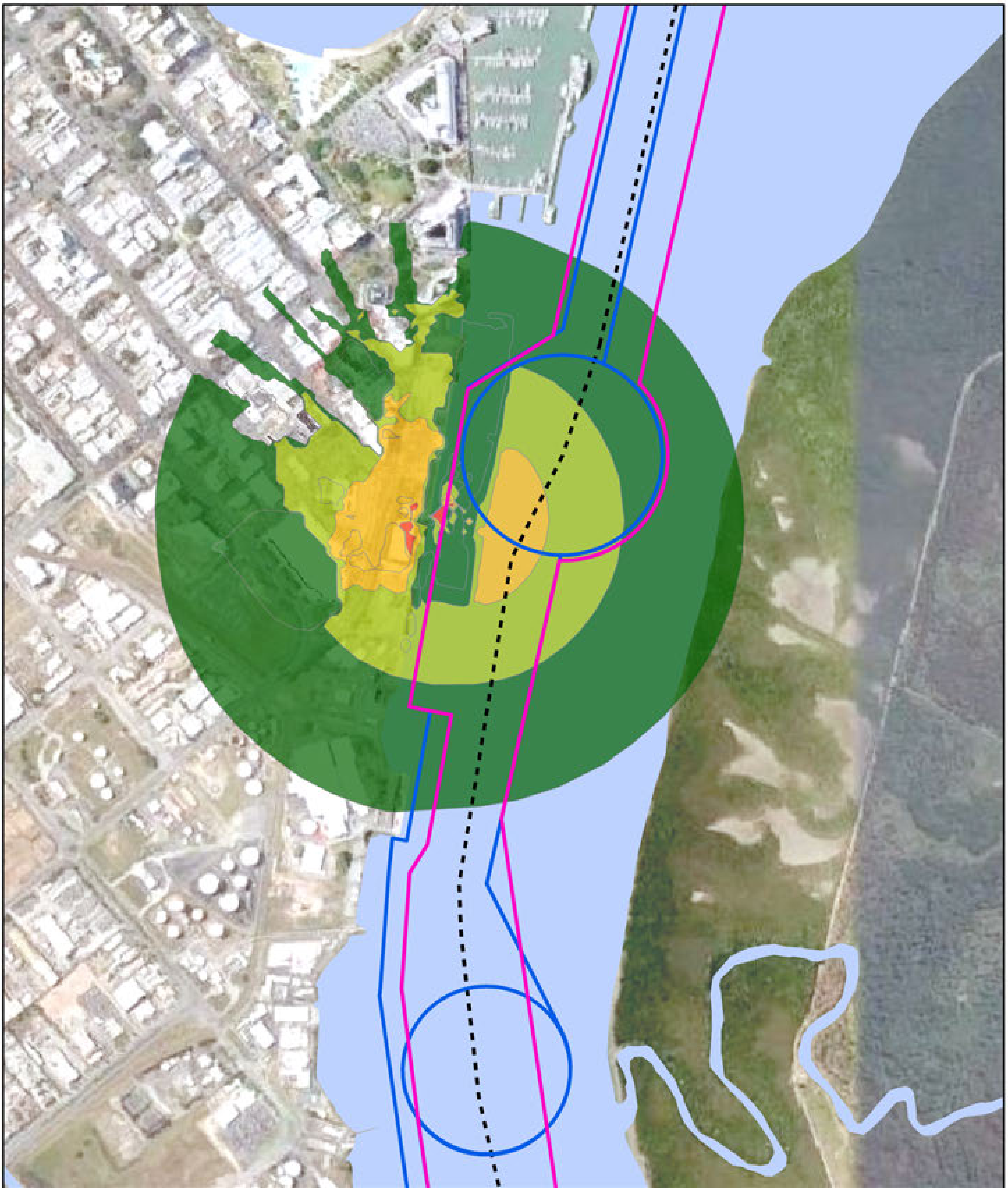
Operation - Large Ship - Dock (Stack & Vent) (Adverse Weather)

Meters

0 100 200 300 400

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

| | |
|---|---|
| Scale at A4<br>1:10,000 | Map Status<br>Final |
| Coordinate System<br>GDA 1994 MGA Zone 55 | |
| Job No<br>230377-00 | Figure No<br>D7.8.2e |



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

40 - 45

45 - 50

50 - 55

> 55

Ports North

Job Title

Cairns Shipping Development Project EIS

Map Title

Operation - Large Ship - Dock (Stack & Vent) (Neutral Weather)

Meters

0 100 200 300 400

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

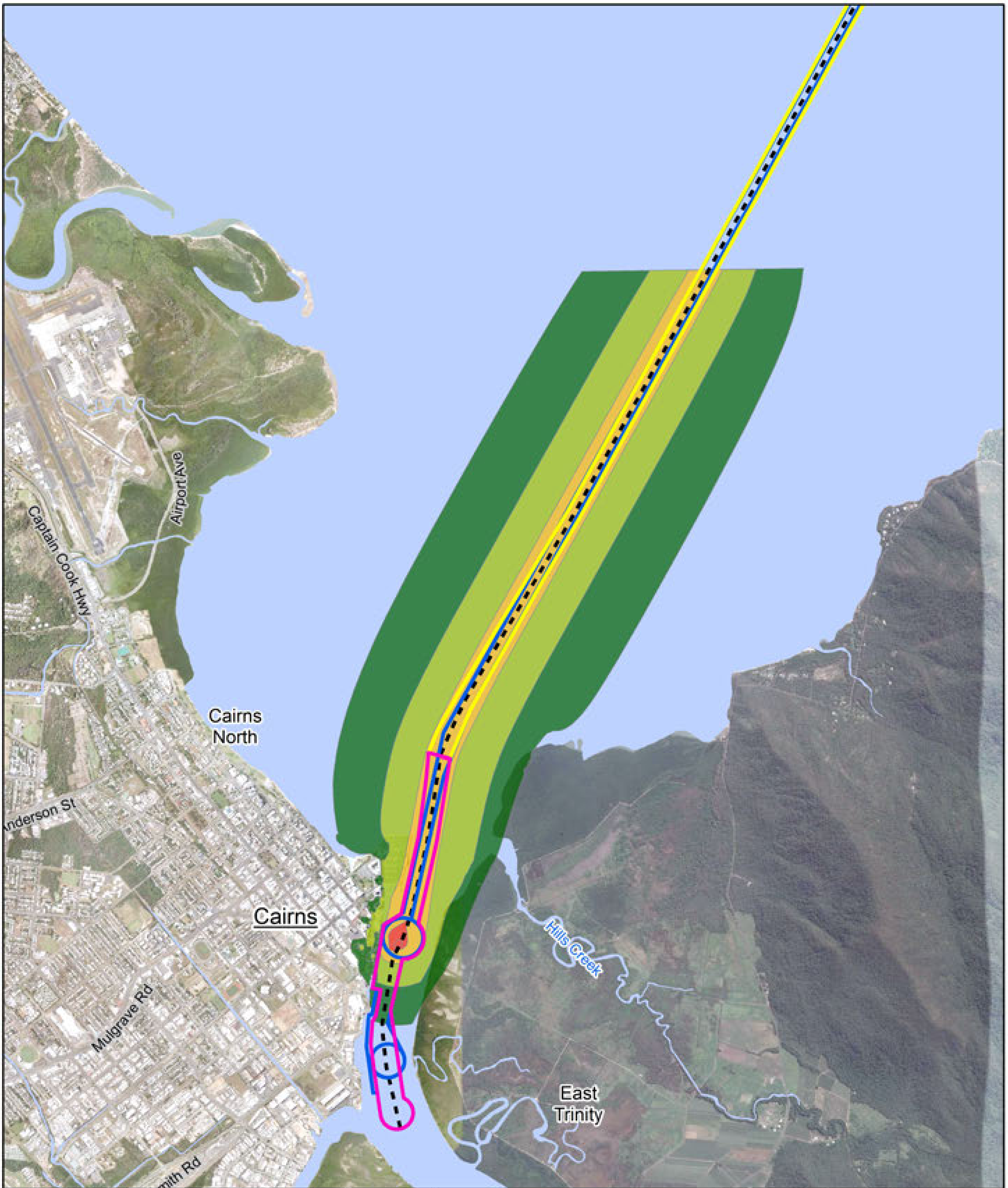
Scale at A4: 1:10,000

Map Status: Final

Coordinate System: GDA 1994 MGA Zone 55

Job No: 230377-00

Figure No: D7.8.2f




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

> 55

Ports North

ARUP

BMT WBM

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Large Ship - Entering Port (Adverse Weather Conditions)**

Kilometres

0 0.5 1 1.5 2

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

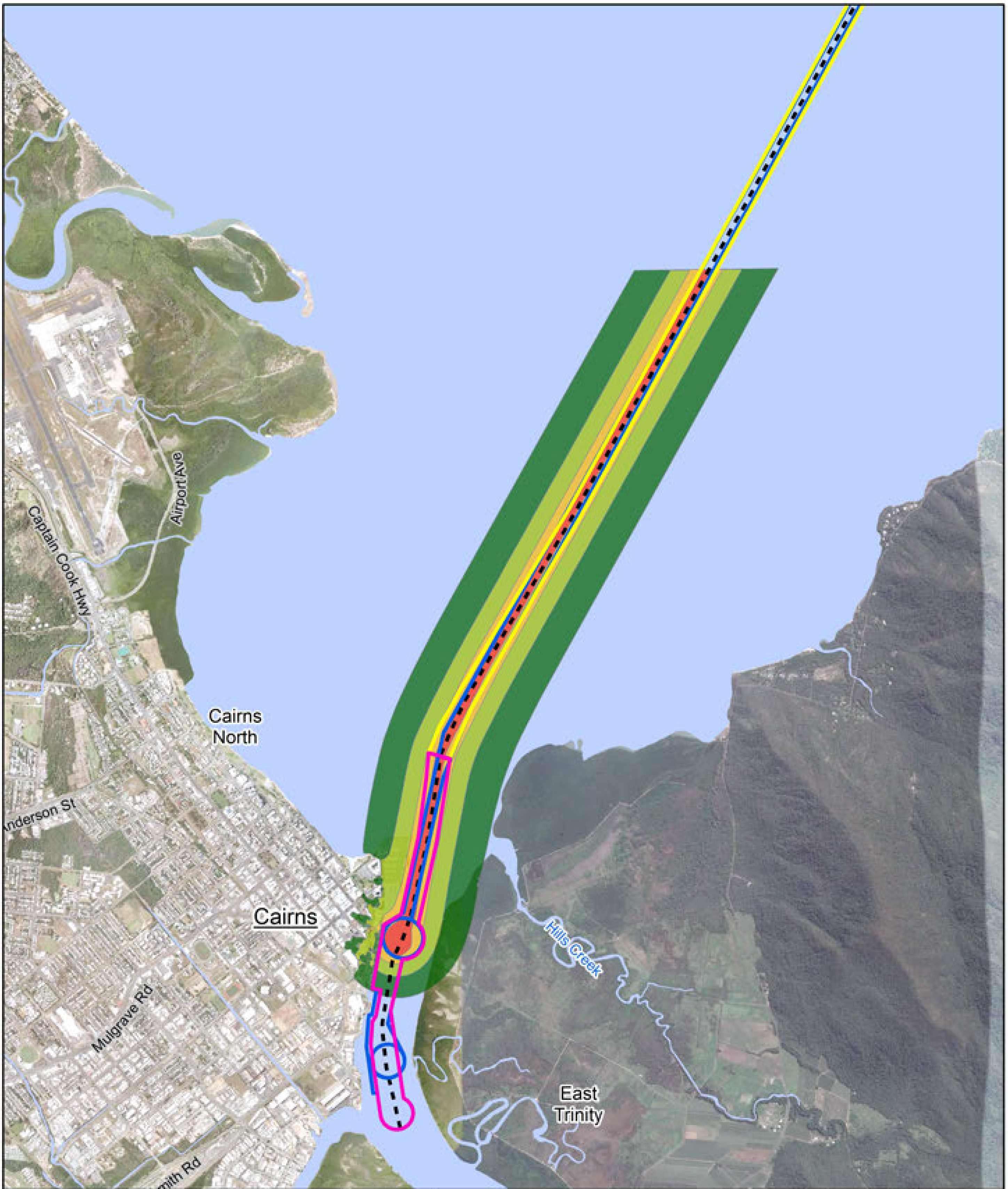
Scale at A4: **1:50,000**

Map Status: **Final**

Coordinate System: **GDA 1994 MGA Zone 55**

Job No: **230377-00**

Figure No: **D7.8.2g**




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

> 55

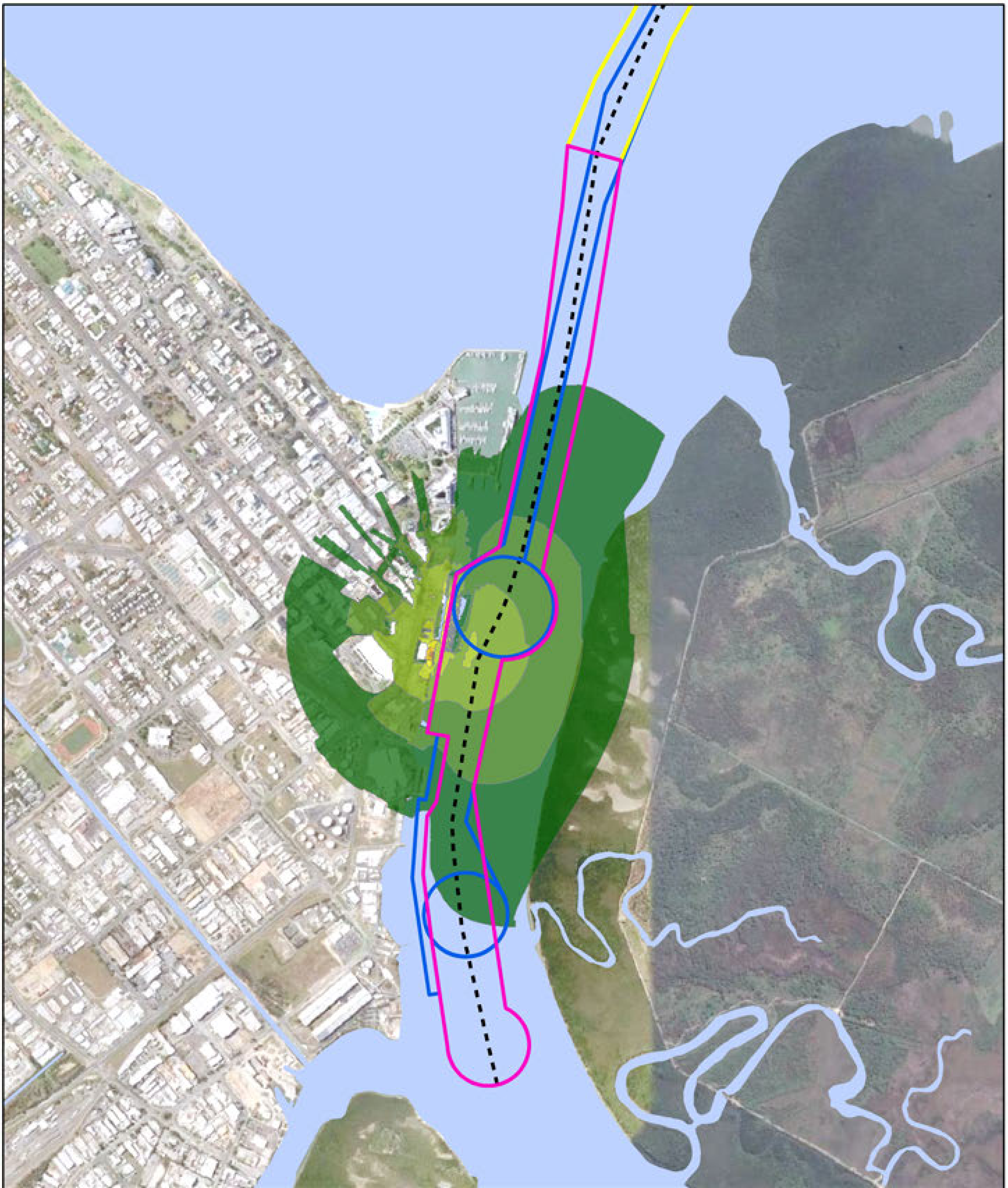
Ports North

ARUP

BMT WBM

| | | | | |
|---|---|---|---|---|
| Job Title | Cairns Shipping Development Project EIS | | | |
| Map Title | Operation - Large Ship - Entering Port (Neutral Weather Conditions) | | | |
| Kilometres | 0 | 0.5 | 1 | 1.5 | 2 |
| 1 | 13/11/2014 | GJK | LB | KC |
| Issue | Date | By | Chkd | Appd |

| | |
|---|---|
| Scale at A4: **1:50,000** | Map Status: **Final** |
| Coordinate System: **GDA 1994 MGA Zone 55** | |
| Job No: **230377-00** | Figure No: **D7.8.2h** |



Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- > 80

Ports North

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Large Ship - Loading (Adverse Weather Conditions)**

Kilometres

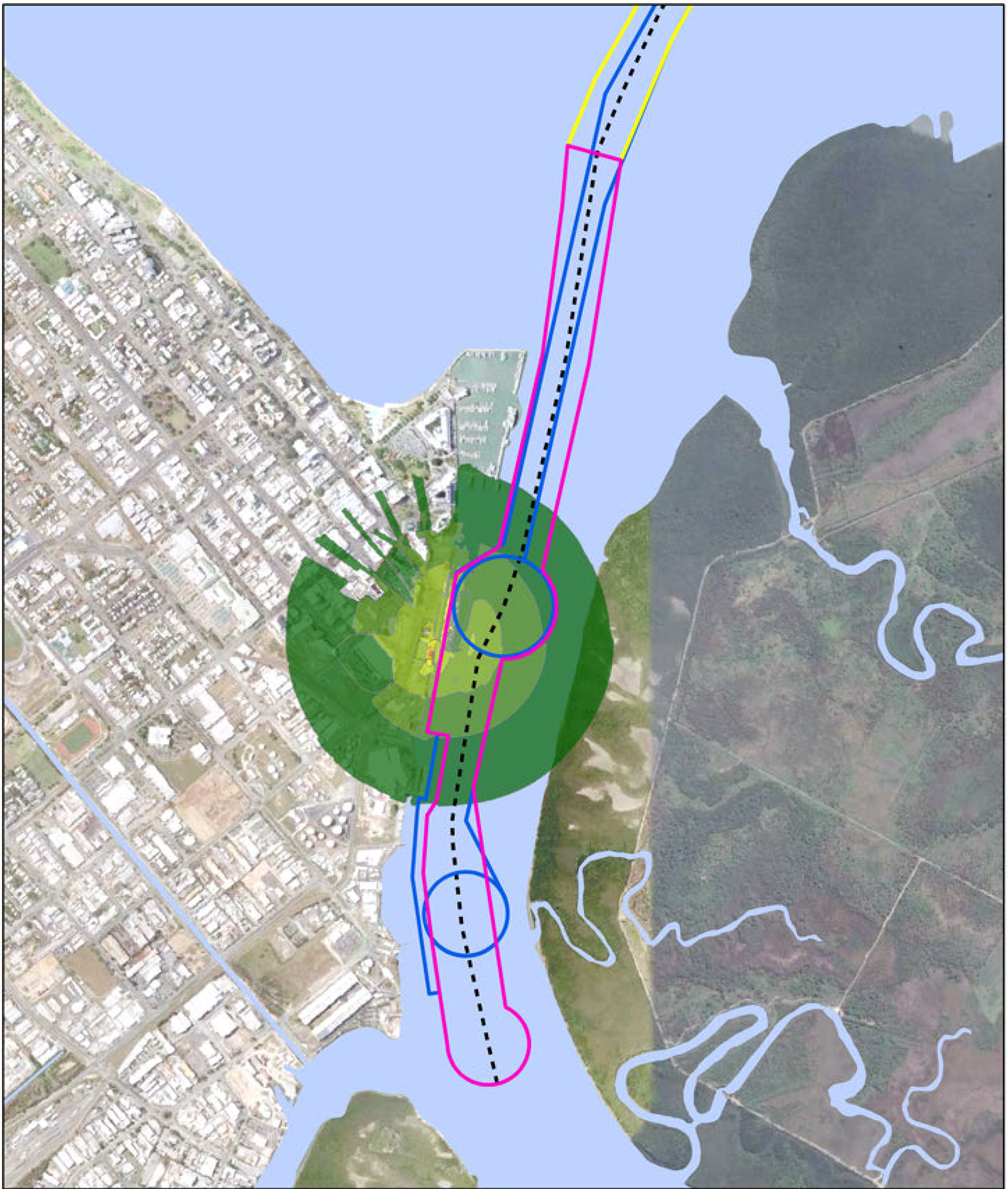
0 0.2 0.4 0.6 0.8

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

| | |
|---|---|
| Scale at A4 **1:20,000** | Map Status **Final** |
| Coordinate System **GDA 1994 MGA Zone 55** | |
| Job No **230377-00** | Figure No **D7.8.2i** |



Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

55 - 60

60 - 65

65 - 70

70 - 75

75 - 80

> 80

Ports North

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Large Ship - Loading (Neutral Weather Conditions)**

Kilometres

0 0.2 0.4 0.6 0.8

| 1 | 13/11/2014 | GJK | LB | KC |
|---|---|---|---|---|
| Issue | Date | By | Chkd | Appd |

ARUP

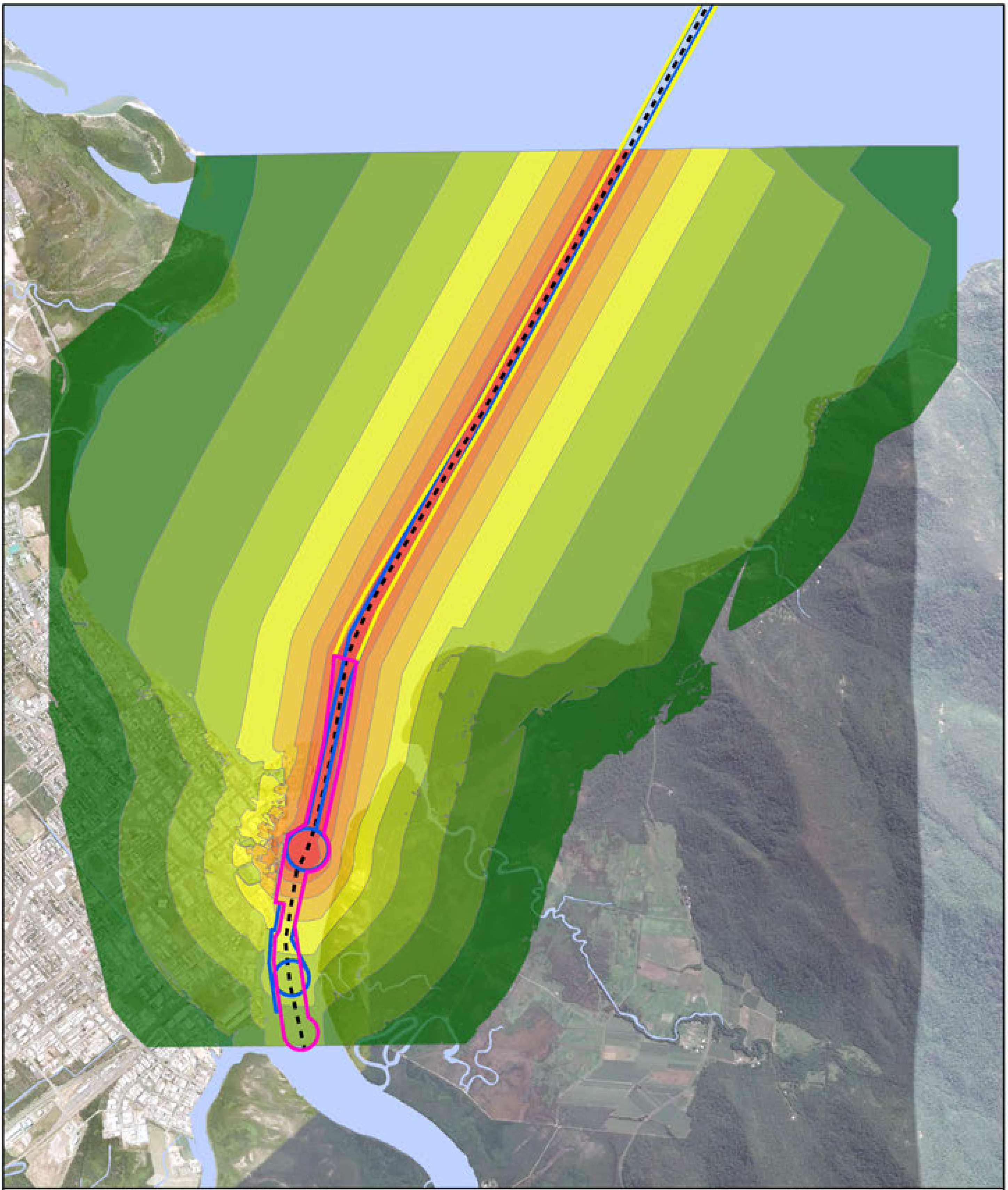
BMT WBM

| Scale at A4 | Map Status |
|---|---|
| 1:20,000 | Final |

Coordinate System

GDA 1994 MGA Zone 55

| Job No | Figure No |
|---|---|
| 230377-00 | D7.8.2j |



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

40 - 45

45 - 50

50 - 55

55 - 60

60 - 65

65 - 70

70 - 75

75 - 80

> 80

Ports North

Job Title

Cairns Shipping Development Project EIS

Map Title

Operation - Large Ship - Transit (Lmax)

Kilometres

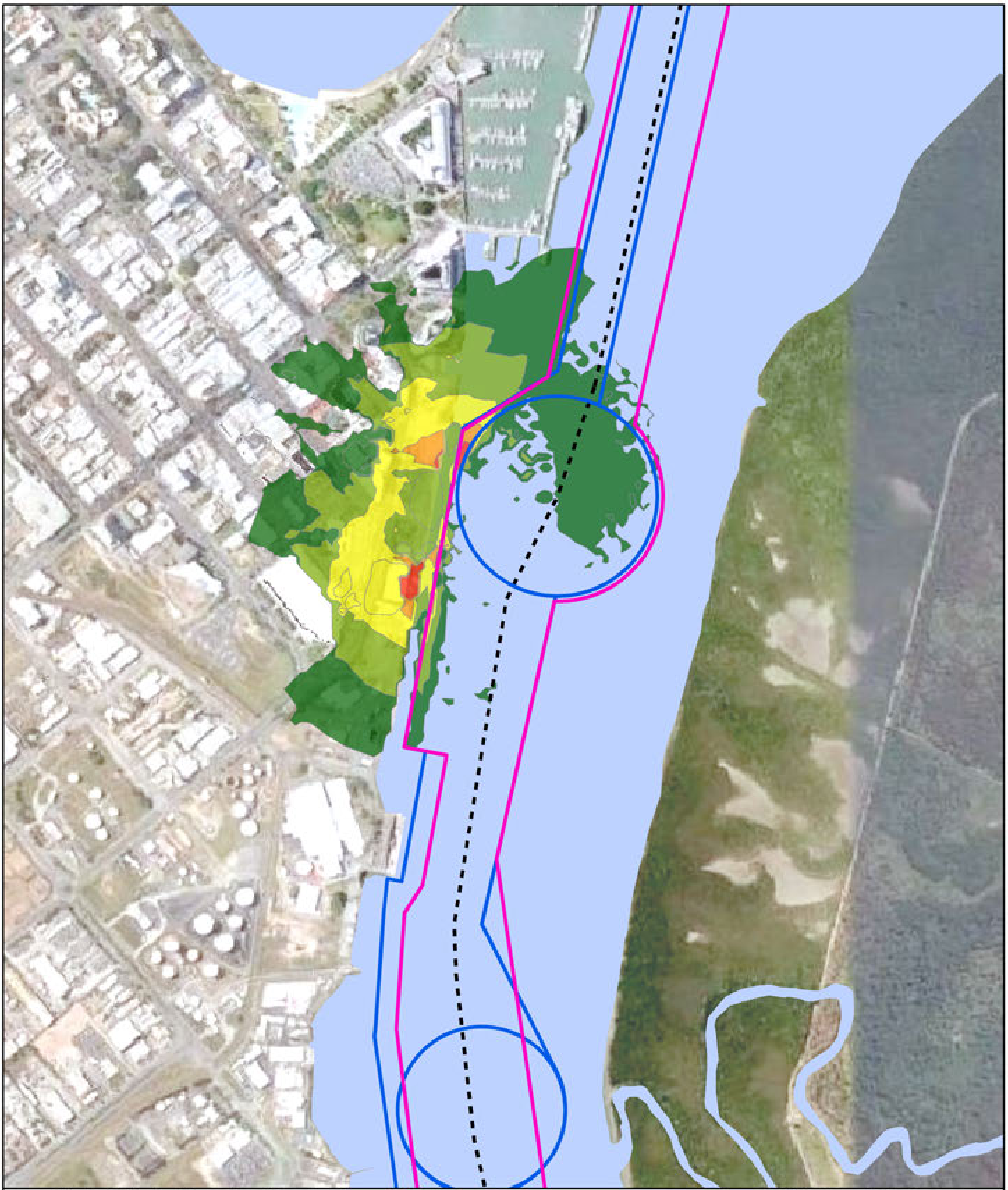
0 0.5 1 1.5 2

| 1 | 13/11/2014 | GJK | LB | KC |
|---|---|---|---|---|
| Issue | Date | By | Chkd | Appd |

ARUP

BMT WBM

| Scale at A4 | Map Status |
|---|---|
| 1:47,690 | Final |
| Coordinate System | |
| GDA 1994 MGA Zone 55 | |
| Job No | Figure No |
| 230377-00 | D7.8.2u |



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

40 - 45

45 - 50

50 - 55

55 - 60

> 60

Ports North

Job Title

Cairns Shipping Development Project EIS

Map Title

Operation - Medium Ship - Berthing (Adverse Weather Conditions)

Kilometres

0 0.1 0.2 0.3 0.4

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

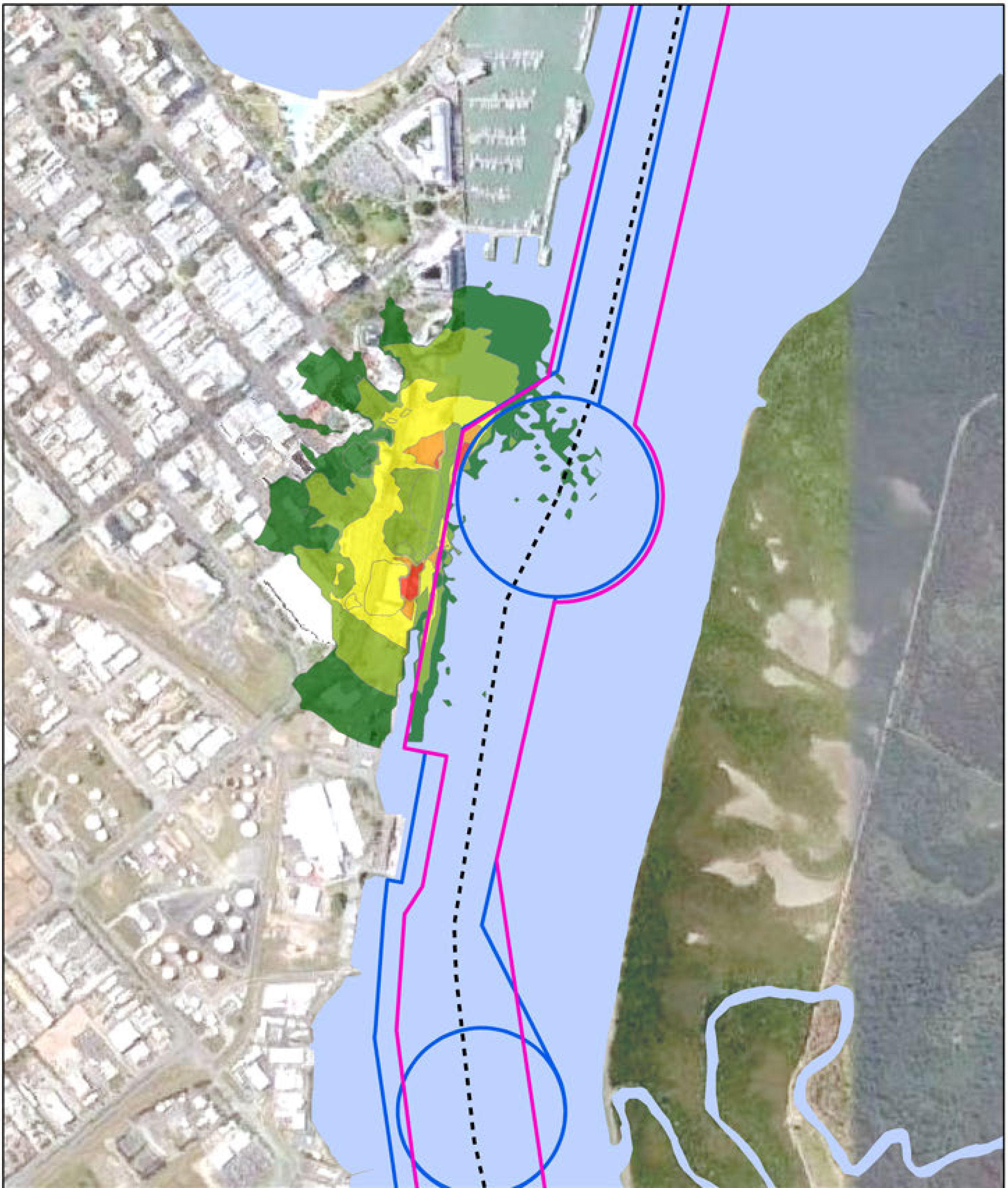
Scale at A4: 1:10,000

Map Status: Final

Coordinate System: GDA 1994 MGA Zone 55

Job No: 230377-00

Figure No: D7.8.2k



| Existing Shipping Channel and Basins | Noise Level (dB): |
| --- | --- |
| **Proposed Channel Design** | 40 - 45 |
| Inner Port | 45 - 50 |
| Outer Channel | 50 - 55 |
| | 55 - 60 |
| | > 60 |

Ports North

ARUP

BMT WBM

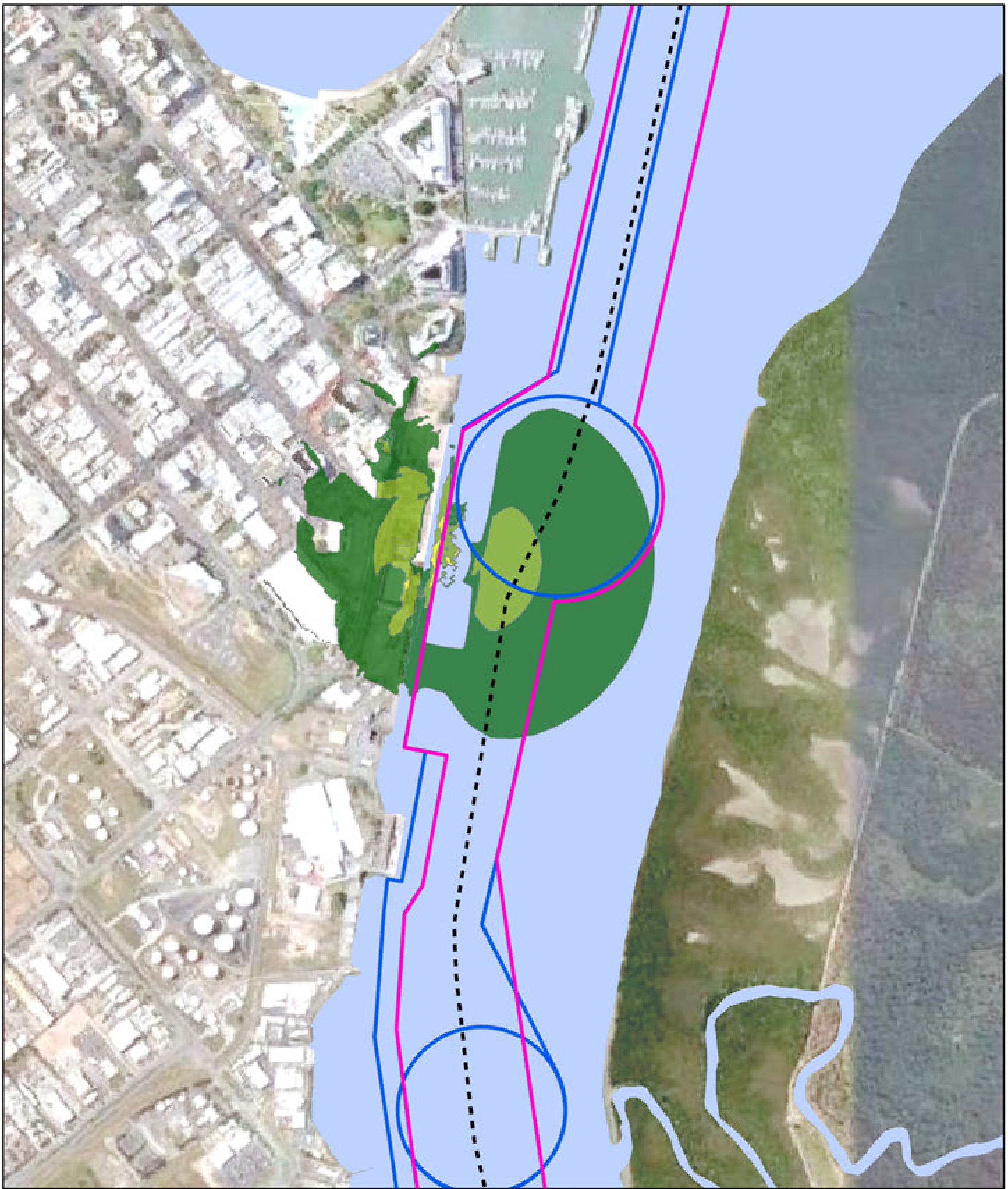
Job Title
**Cairns Shipping Development Project EIS**

Map Title
**Operation - Medium Ship - Berthing (Neutral Weather Conditions)**

Kilometres
0 0.1 0.2 0.3 0.4

| Issue | Date | By | Chkd | Appd |
| --- | --- | --- | --- | --- |
| 1 | 13/11/2014 | GJK | LB | KC |

| Scale at A4 | Map Status |
| --- | --- |
| 1:10,000 | Final |
| Coordinate System | |
| GDA 1994 MGA Zone 55 | |
| Job No | Figure No |
| 230377-00 | D7.8.2I |



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- > 60

Ports North

ARUP

BMT WBM

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Medium Ship - Dock (Adverse Weather Conditions)**

Kilometres

0 0.1 0.2 0.3 0.4

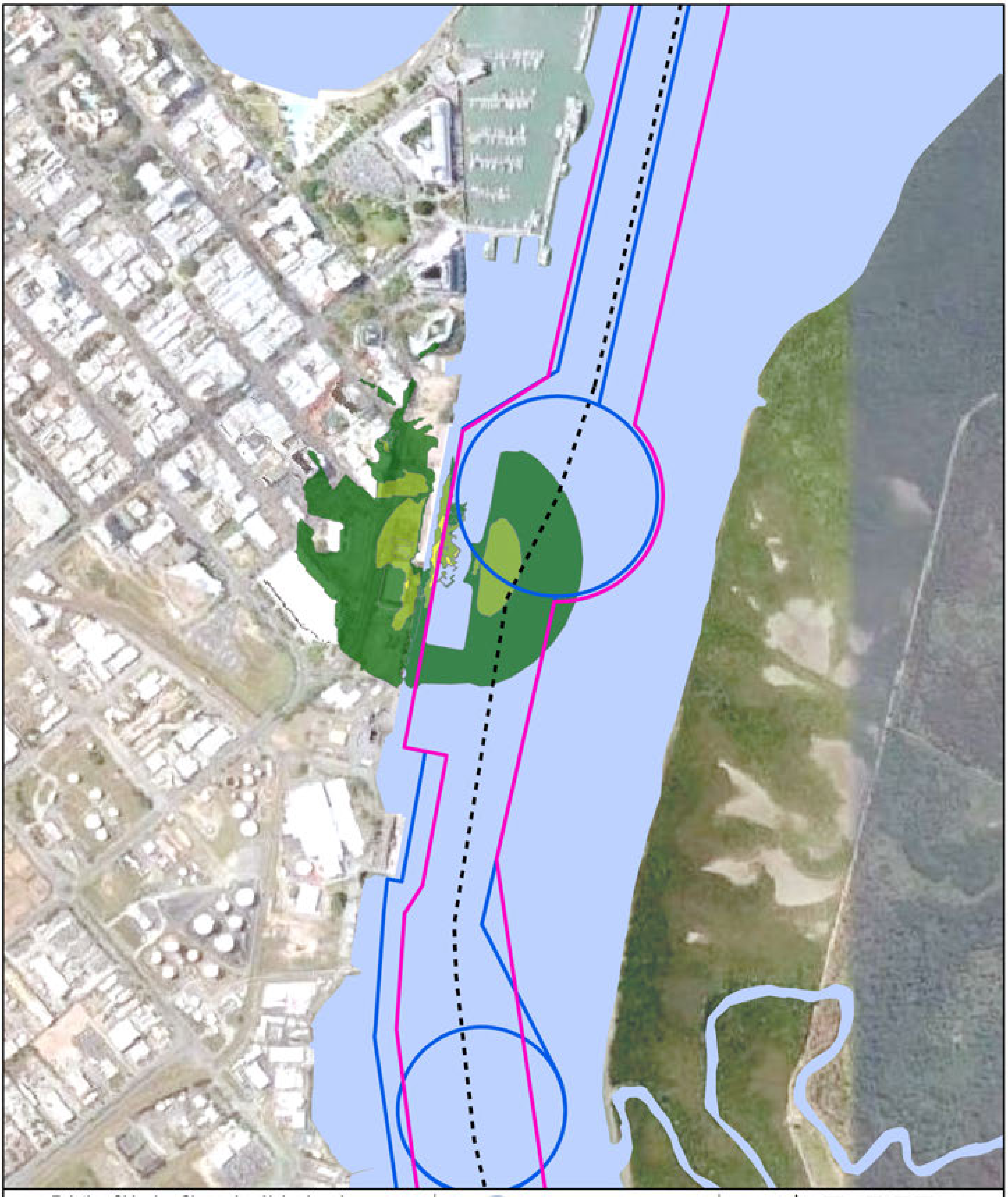
| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

| Scale at A4 | Map Status |
|---|---|
| 1:10,000 | Final |

Coordinate System

**GDA 1994 MGA Zone 55**

| Job No | Figure No |
|---|---|
| 230377-00 | D7.8.2m |



| | |
|---|---|
| Existing Shipping Channel and Basins | |
| Proposed Channel Design | |
| Inner Port | |
| Outer Channel | |

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- > 60

Ports North

Job Title
**Cairns Shipping Development Project EIS**

Map Title
**Operation - Medium Ship - Dock (Adverse Weather Conditions)**

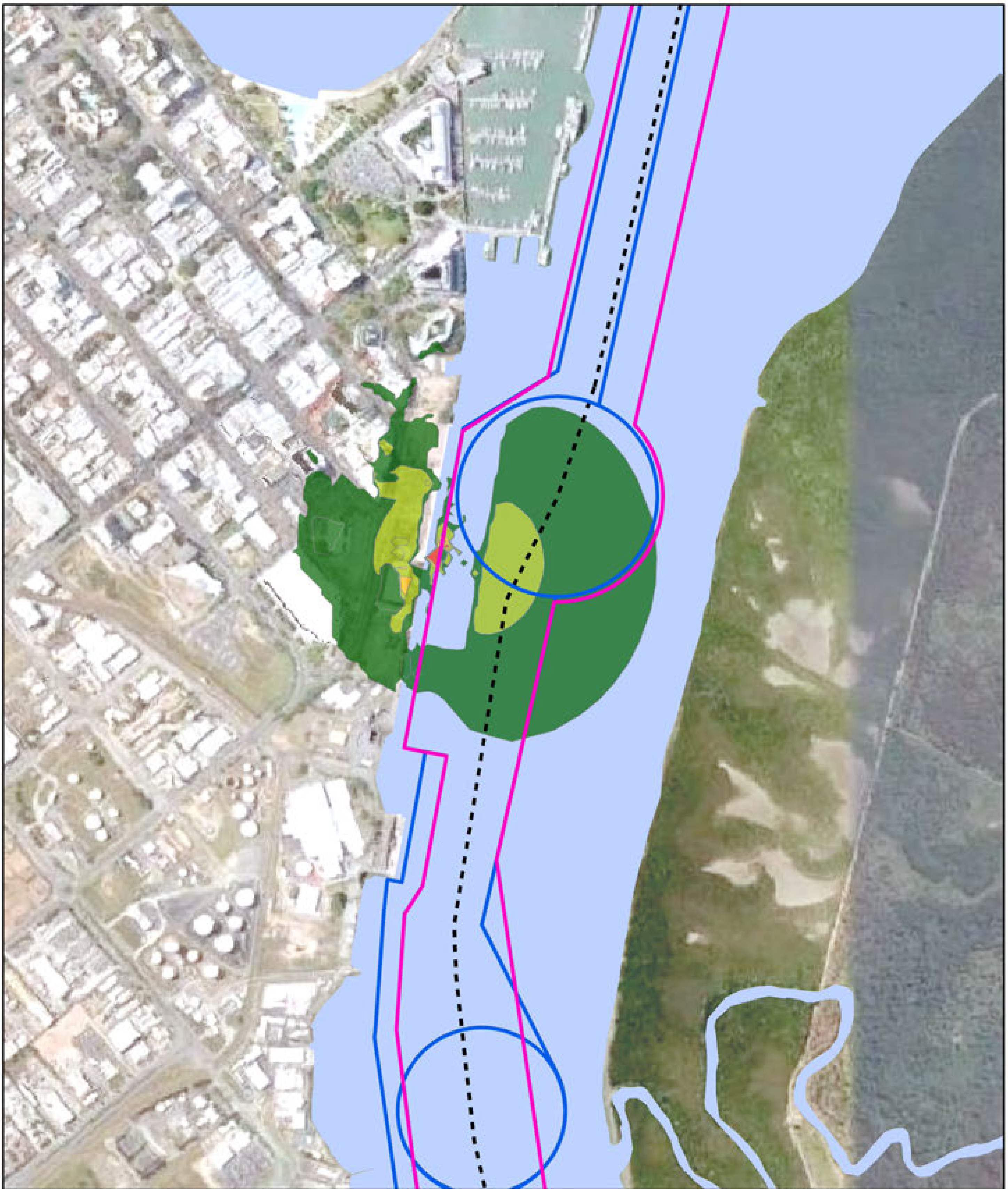
Kilometres
0 0.1 0.2 0.3 0.4

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

| | |
|---|---|
| Scale at A4: **1:10,000** | Map Status: **Final** |
| Coordinate System: **GDA 1994 MGA Zone 55** | |
| Job No: **230377-00** | Figure No: **D7.8.2n** |



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

40 - 45

45 - 50

50 - 55

> 55

Ports North

Job Title

Cairns Shipping Development Project EIS

Map Title

Operation - Medium Ship - Dock (Stack & Vent) (Adverse Weather)

Kilometres

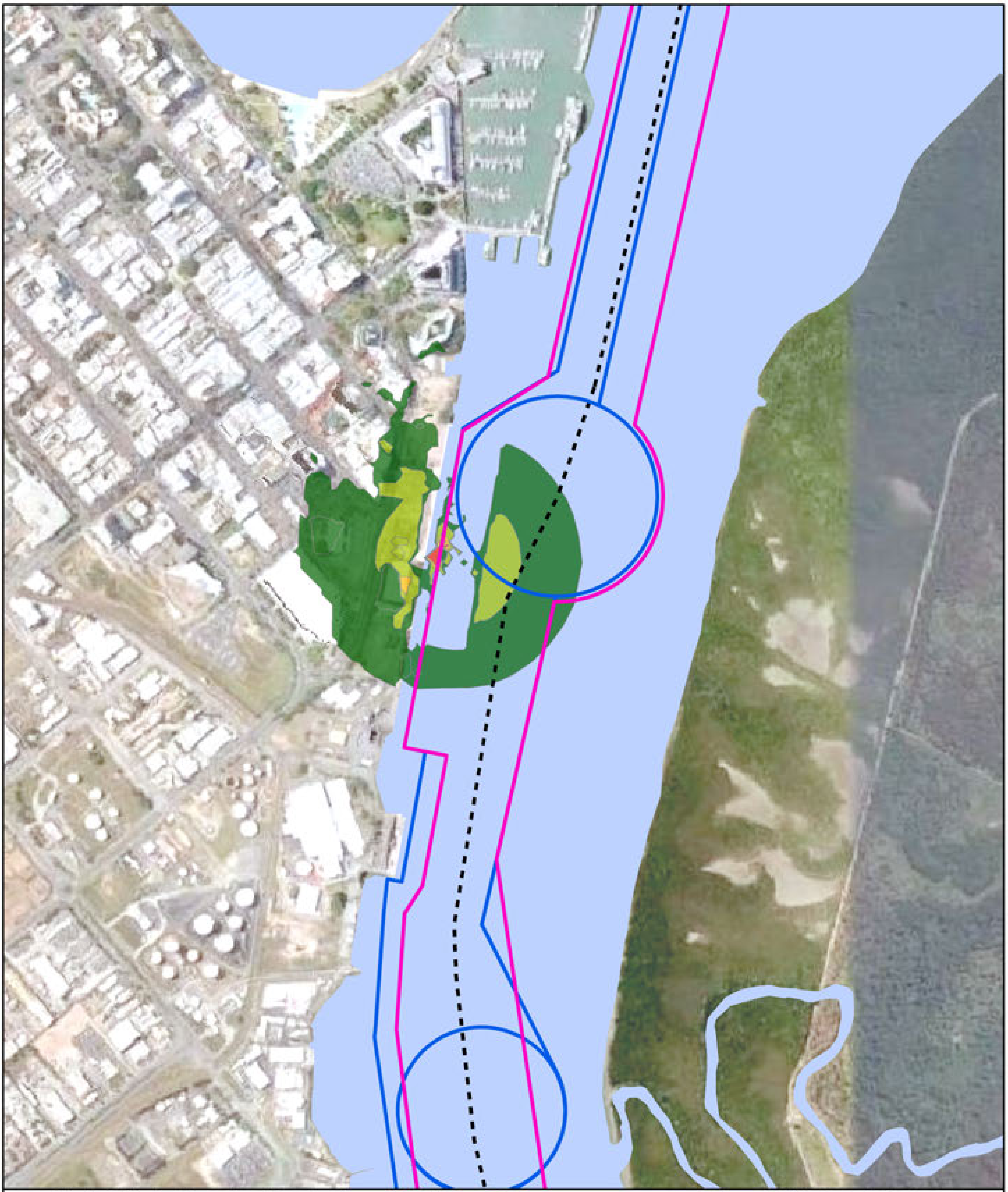
0 0.1 0.2 0.3 0.4

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

| | |
|---|---|
| Scale at A4: 1:10,000 | Map Status: Final |
| Coordinate System: GDA 1994 MGA Zone 55 | |
| Job No: 230377-00 | Figure No: D7.8.2o |



Existing Shipping Channel and Basins

Proposed Channel Design

Inner Port

Outer Channel

Noise Level (dB):

40 - 45

45 - 50

50 - 55

> 55

Ports North

ARUP

BMT WBM

Job Title

Cairns Shipping Development Project EIS

Map Title

Operation - Medium Ship - Dock (Stack & Vent) Neutral Weather)

Kilometres

0 0.1 0.2 0.3 0.4

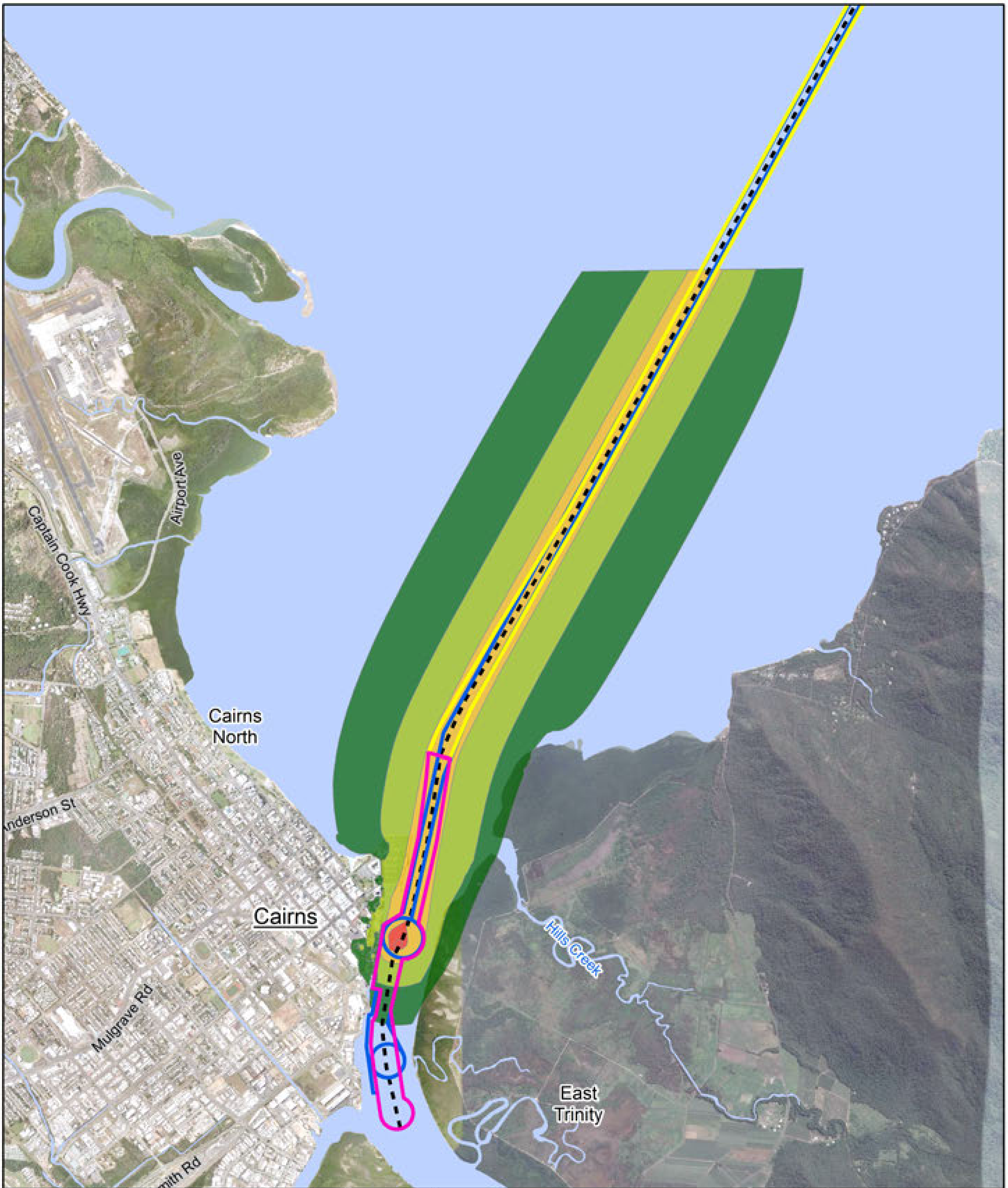
| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

| Scale at A4 | Map Status |
|---|---|
| 1:10,000 | Final |

Coordinate System

GDA 1994 MGA Zone 55

| Job No | Figure No |
|---|---|
| 230377-00 | D7.8.2p |




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

> 55

Ports North

ARUP

BMT WBM

Job Title
**Cairns Shipping Development Project EIS**

Map Title
**Operation - Medium Ship - Entering Port (Adverse Weather Conditions)**

Kilometres
0 0.5 1 1.5 2

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

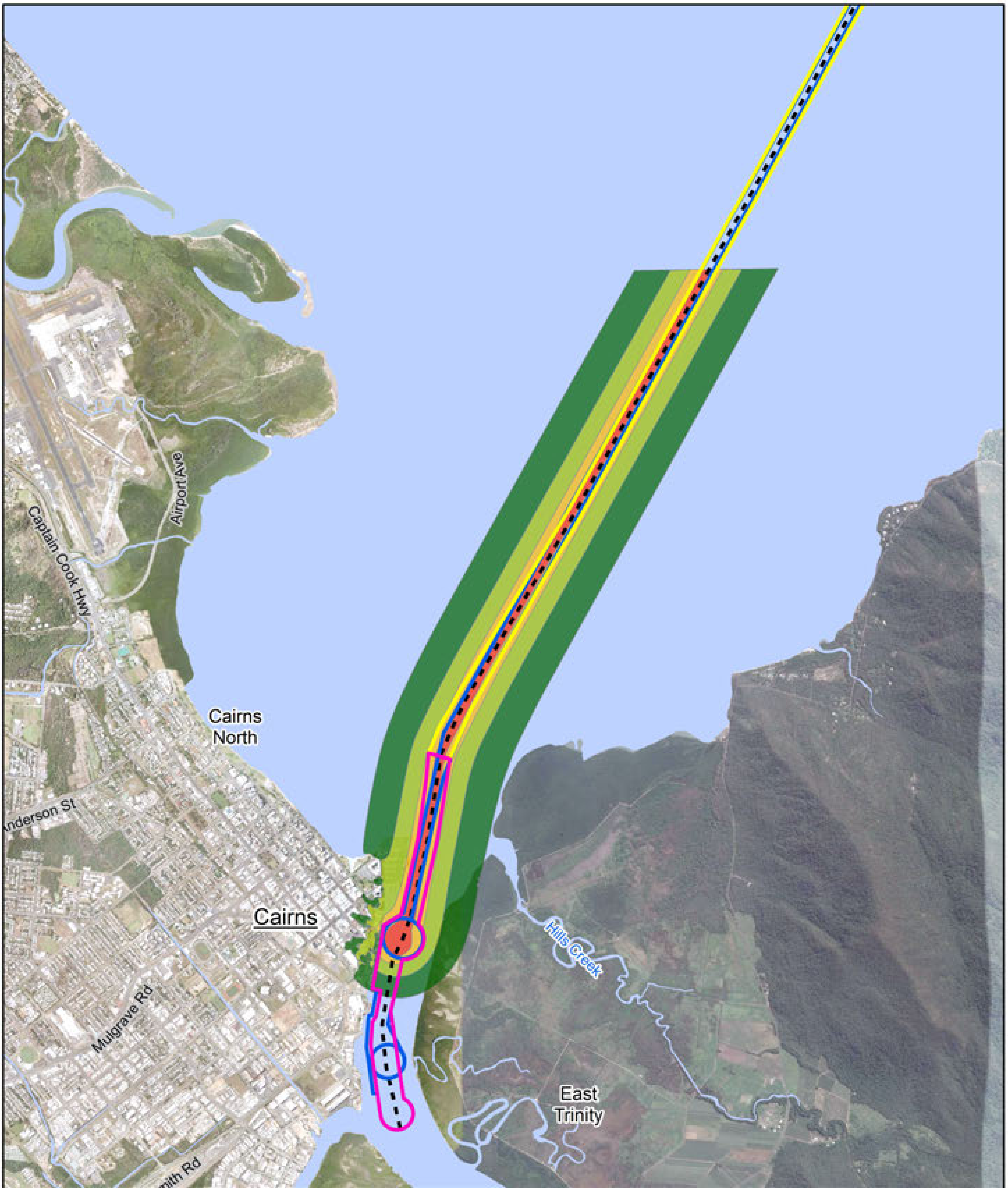
Scale at A4
**1:50,000**

Map Status
**Final**

Coordinate System
**GDA 1994 MGA Zone 55**

Job No
**230377-00**

Figure No
**D7.8.2r**




Existing Shipping Channel and Basins

**Proposed Channel Design**

Inner Port

Outer Channel

**Noise Level (dB):**

40 - 45

45 - 50

50 - 55

> 55

Ports North

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Medium Ship - Entering Port (Neutral Weather Conditions)**

Kilometres: 0, 0.5, 1, 1.5, 2

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

BMT WBM

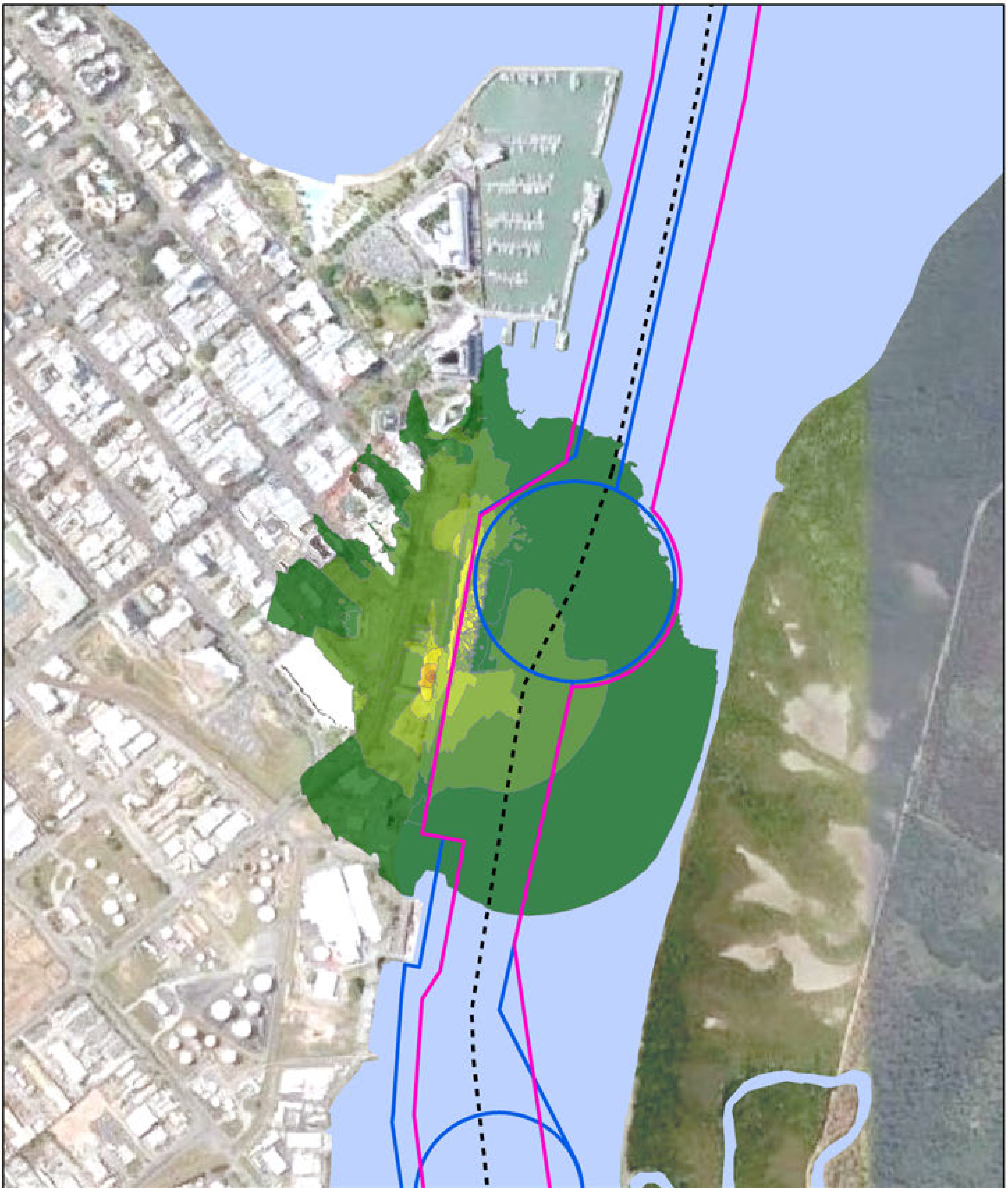
Scale at A4: **1:50,000**

Map Status: **Final**

Coordinate System: **GDA 1994 MGA Zone 55**

Job No: **230377-00**

Figure No: **D7.8.2q**



**Existing Shipping Channel and Basins**

**Proposed Channel Design**

- **Inner Port**
- **Outer Channel**

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- > 80

Ports North

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Medium Ship - Loading (Adverse Weather Conditions)**

Kilometres

0 0.1 0.2 0.3 0.4

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

ARUP

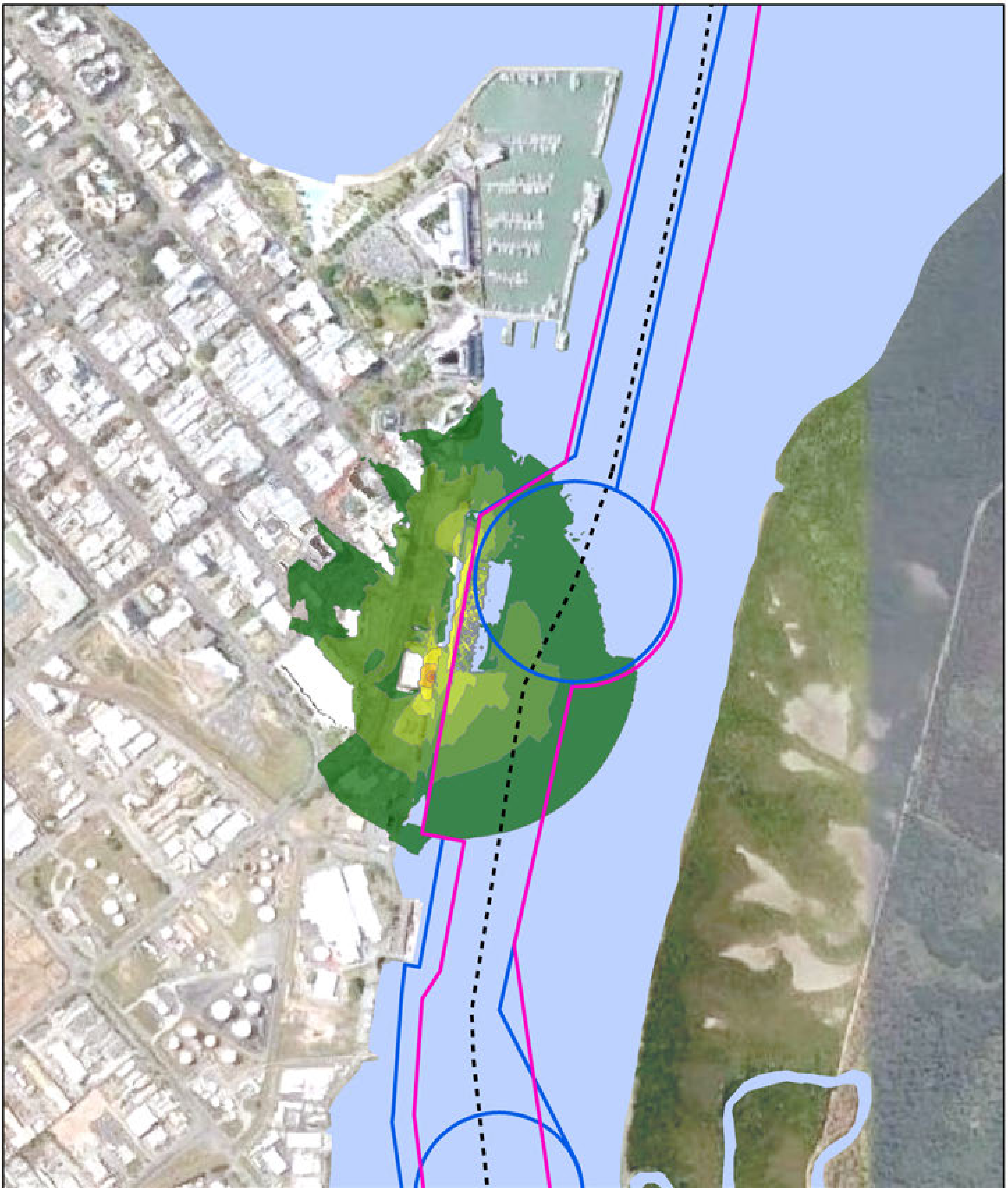
BMT WBM

| Scale at A4 | Map Status |
|---|---|
| **1:10,000** | **Final** |

Coordinate System

**GDA 1994 MGA Zone 55**

| Job No | Figure No |
|---|---|
| **230377-00** | **D7.8.2v** |



| | |
|---|---|
| Existing Shipping Channel and Basins | |
| Proposed Channel Design | |
| Inner Port | |
| Outer Channel | |

Noise Level (dB):

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
- > 80

Ports North

ARUP

BMT WBM

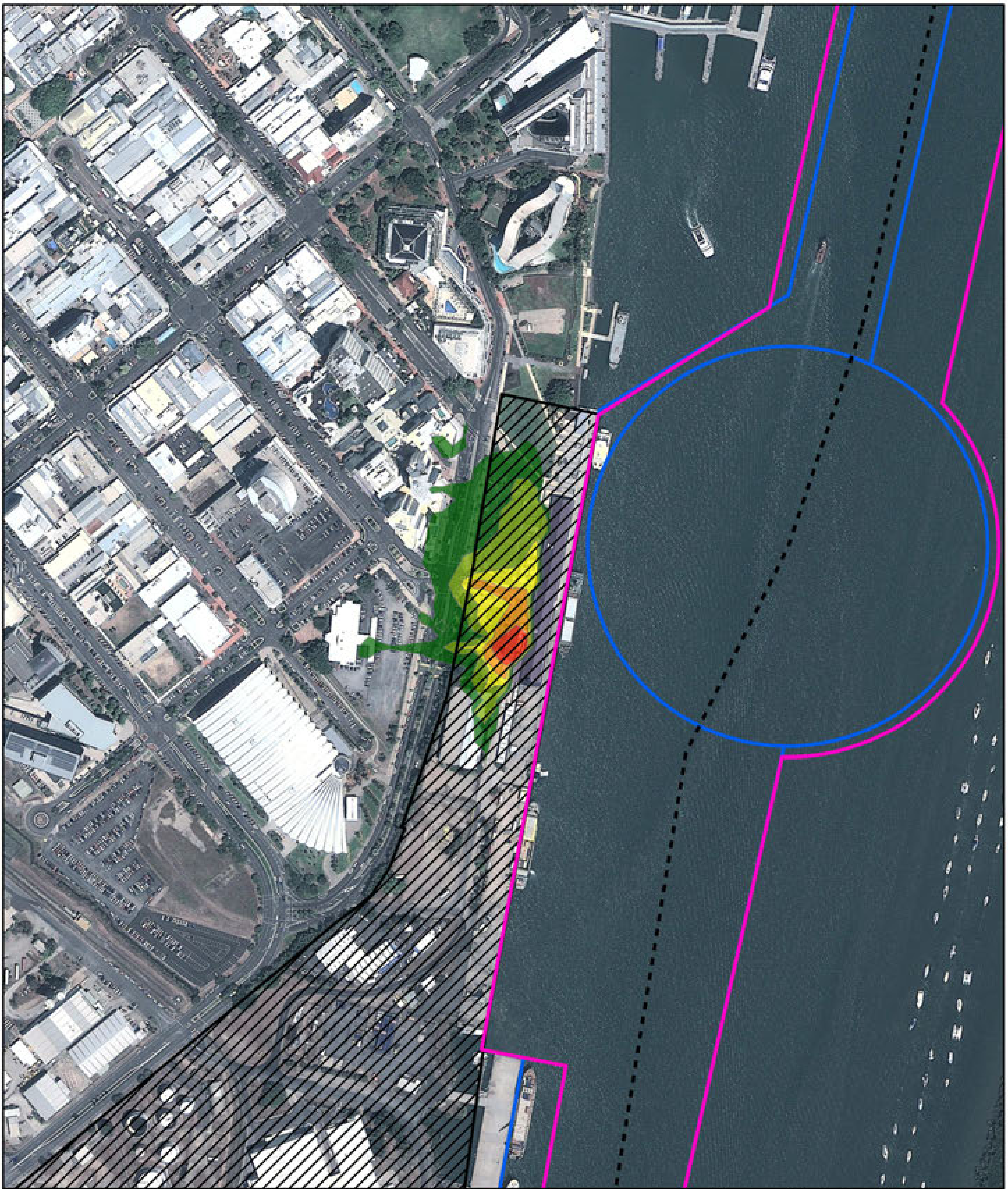
Job Title
**Cairns Shipping Development Project EIS**

Map Title
**Operation - Medium Ship - Loading (Neutral Weather Conditions)**

Kilometres
0 0.1 0.2 0.3 0.4

| 1 | 13/11/2014 | GJK | LB | KC |
|---|---|---|---|---|
| Issue | Date | By | Chkd | Appd |

| Scale at A4 | Map Status |
|---|---|
| 1:10,000 | Final |
| Coordinate System | |
| GDA 1994 MGA Zone 55 | |
| Job No | Figure No |
| 230377-00 | D7.8.2w |



Existing Shipping Channel and Basins

**Proposed Channel Design**

- Inner Port
- Outer Channel
- Channel Centreline
- Land-Side Works Extent

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- > 60

Ports North

ARUP

BMT WBM

Job Title

**Cairns Shipping Development Project EIS**

Map Title

**Operation - Traffic (Adverse Weather Conditions)**

Metres

0 50 100 150 200

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

| Scale at A4 | Map Status |
|---|---|
| **1:5,000** | **Final** |

Coordinate System

**GDA 1994 MGA Zone 55**

| Job No | Figure No |
|---|---|
| **230377-00** | **D7.8.2t** |

| | |
|---|---|
| Existing Shipping Channel and Basins | |
| **Proposed Channel Design** | |
| Inner Port | |
| Outer Channel | |
| Channel Centreline | |
| Land-Side Works Extent | |

**Noise Level (dB):**

- 40 - 45
- 45 - 50
- 50 - 55
- 55 - 60
- > 60

Ports North

ARUP

BMT WBM

Job Title
**Cairns Shipping Development Project EIS**

Map Title
**Operation - Traffic (Neutral Weather Conditions)**

Metres: 0 50 100 150 200

| Issue | Date | By | Chkd | Appd |
|---|---|---|---|---|
| 1 | 13/11/2014 | GJK | LB | KC |

| | |
|---|---|
| Scale at A4: **1:5,000** | Map Status: **Final** |
| Coordinate System: **GDA 1994 MGA Zone 55** | |
| Job No: **230377-00** | Figure No: **D7.8.2s** |