TotalEnergies E&P South Africa BV

OFFSHORE PRODUCTION RIGHT AND ENVIRONMENTAL AUTHORISATION APPLICATIONS FOR BLOCK 11B/12B

Marine Acoustics Technical Report

REPORT NO: 41105306-358512-5
AUGUST 2023

PUBLIC

TotalEnergies E&P South Africa BV

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Marine Acoustics Technical Report

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Report number	41105306-358512-5

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ACRONYMS AND ABBREVIATIONS

Abbreviation	Explanation
AcTUP	Acoustic Toolbox User interface and Post Processor
CA	Competent Authority
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
GTL	Gas To Liquids
HF	High Frequency
LF	Low Frequency
NEMA	National Environmental Management Act (Act 107 of 1998)
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OCW	Other Marine Carnivores in Water
PCW	Phocid Carnivores in Water
PR	Production Right
PTS	Permanent Threshold Shift
RAM	Range-dependent Acoustic Model
re	Reference
SEL	Sound Exposure Level
SEL_{24h}	24-Hour Sound Exposure Level
SI	Sirenians
SPL	Sound Pressure Level
SPL_{peak}	Peak Sound Pressure Level
SPL_{rms}	Root Mean Square Sound Pressure Level
TL	Transmission Loss
TTS	Temporary Threshold Shift
TEEPSA	TotalEnergies Exploration and Production South Africa B.V.
VHF	Very High Frequency
VSP	Vertical Seismic Profiling

UNITS OF MEASURE

Unit	Explanation
°	Degree
°C	Degree centigrade
CUI	Cubic inch
dB	Decibel
dB(A)	Decibel average weighted
Hz	Hertz
"	Inch = 2.54 cm
kHz	Kilohertz
km	Kilometre
km^2	Square Kilometre
kg/m^3	Kilograms per metres cubed
m	Metre
m/s	Meters per second
ms	Millisecond
Pa	Pascal
ppt	Parts per Thousand
psi	Pounds per square inch
µPa	Micropascal
μPa^2-s	Micropascal squared second

DETAILS OF THE SPECIALIST

A comprehensive CV is included in Appendix A

Details of Specialist	
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Company Name:	**WSP Canada Inc.**

Qualifications

Specialist Qualifications	
Education:	B.Sc. Mechanical Engineering (with Distinction), University of Alberta 2002
Professional affiliations:	Institute of Noise Control Engineers (USA)
Summary of experience:	Over 20 years of completing environmental assessments in the energy, power generation, oil and gas, mining, and infrastructure industries

DECLARATION OF INDEPENDENCE BY SPECIALIST

I, Andrew Faszer declare that I –

- Act as the independent specialist for the undertaking of a specialist section for the TEEPSA Offshore Production Right and Environmental Authorisation Applications for Block 11B/12B;
- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed;
- Do not have nor will have a vested interest in the proposed activity proceeding;
- Have no, and will not engage in, conflicting interests in the undertaking of the activity; and
- Undertake to disclose, to the competent authority, any information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document.

SPECIALIST REPORT REQUIREMENTS IN TERMS OF NEMA

This report is compiled in such a manner that it adheres to the EIA Regulation requirements as detailed in Appendix 6 of the NEMA EIA Regulations of 2014, as amended.

This document is a supporting document that will be appended to the ESIA and does not require all of the following sections, as it is a technical report contributing to other specialist reports.

Section	Requirements	Section addressed in report
(a)	Details of	
	(i) the specialist who prepared the report; and	Details of the Specialist
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae;	Appendix A
(b)	A declaration that the specialist is independent in a form as may be specified by the competent authority;	Declaration of Independence of Specialist
(c)	An indication of the scope of, and the purpose for which, the report was prepared, the quality and age of base data used for the specialist report and a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 1.3
(d)	The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 2.4.1
(e)	A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 2
(f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	n/a
(g)	An identification of any areas to be avoided, including buffers (if and where applicable);	n/a
(h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers (if and where applicable);	Figure 2-1
(i)	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 2.5
(j)	A description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Section 4
(k)	Any mitigation measures for inclusion in the EMPr;	n/a
(l)	Any conditions for inclusion in the environmental authorisation;	n/a
(m)	Any monitoring requirements for inclusion in the EMPr or environmental authorization;	n/a

Section	Requirements	Section addressed in report
(n)	A reasoned opinion—	
	(i) whether the proposed activity, activities or portions thereof should be authorized regarding the acceptability of the proposed activity or activities; and	n/a
	(ii) if the opinion is that the proposed activity, activities, or portions thereof should be authorised, an avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	n/a
(o)	A description of any consultation process that was undertaken during the course of preparing the specialist report;	n/a
(p)	A summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	n/a
(q)	Any other information requested by the competent authority.	n/a

EXECUTIVE SUMMARY

TotalEnergies EP South Africa B.V. (TEEPSA), together with its joint venture partners, QatarEnergy, Canadian Natural Resources International South Africa Limited, and a South African consortium, MainStreet 1549, held an Exploration Right over Block 11B/12B, located offshore from the Southern Cape coast, South Africa and have now applied for a Production Right (PR) over this Block, due to recent gas and condensate discoveries in the south western portion of the Block. The PR application was submitted in early September 2022. If a PR is granted and if commercial agreements for the sale of the gas onto the domestic market can be achieved, TEEPSA is planning to develop Block 11B/12B.

In accordance with the regulatory requirements, TEEPSA must conduct an Environmental and Social Impact Assessment (ESIA) process, in support of an environmental authorisation (EA) application, for undertaking the proposed development and production related activities in Block 11B/12B. Marine acoustics modelling has been done in support of the ESIA process.

This marine acoustics assessment estimated underwater noise levels due to the Project and compared them to marine mammal, sea turtle, fish, penguin and diving bird noise sensitivity thresholds. Relevant permanent or temporary injury and behaviour thresholds for marine mammals and sea turtles are divided based on the frequency weightings of their hearing sensitivities, whereas thresholds for fish depend on the presence or absence of a swim bladder and its role in their ability to hear.

Within Block 11B/12B, the following Project activities have the potential to impact underwater noise levels:

- Drilling of up to six (6) development and appraisal wells, with supply and support vessels in the Project Development Area;
- Additional drilling of up to four (4) exploration wells in the Exploration Priority Area;
- Vertical seismic profiling (VSP) in areas where drilling may take place;
- Sonar surveys on drilling and pipeline areas; and
- Helicopter use to transport personnel to and from the offshore facilities as required.

Noise from these activities is expected to represent the greatest noise impacts throughout the Project phases, including drilling, offshore surveys, construction, production and decommissioning.

Underwater noise levels due to Project drilling, VSP, and sonar surveys were predicted using the underwater acoustic propagation modelling software Acoustic Toolbox User interface and Post processor (AcTUP). AcTUP, a publicly available MATLAB-based programme which implements a range-dependent acoustic model. Key modelling inputs such as noise source levels and environmental parameters were established based on previous studies completed in the Project area and publicly available information. Distances from each activity to each applicable threshold were predicted.

For drilling activities, maximum predicted distances out to temporary threshold shift (TTS) thresholds for **marine mammals** ranged from 60 m (Other Marine Carnivores in Water [OCW]) to 9 km (Low Frequency [LF] Cetaceans) considering 24-hour exposure, and from less than 10 m to 790 m (Very High Frequency [VHF] Cetaceans) considering 30-minute exposure. Maximum predicted distances out to permanent threshold shift (PTS) thresholds for marine mammals ranged from less than 10 m to 400 m (VHF Cetaceans) considering 24-hour exposure, and from less than 10 m to 20 m (LF and VHF Cetaceans) considering 30-minute exposure. Maximum predicted distances out to TTS thresholds for **sea turtles** were up to 330 m considering 24-hour exposure, and 10 m when considering 30-minute exposure. Maximum predicted distances out to PTS thresholds for sea turtles were up to 10 m considering 24-hour exposure, and less than 10 m when considering 30-minute exposure. The distances to peak thresholds were smaller than those to the 24-exposure thresholds. The maximum predicted distance to thresholds for **fish** was 30 m for a recoverable injury and up to 160 m for TTS. Maximum predicted distances to the marine mammal, sea turtle, fish, and penguin/diving bird behavioural **thresholds** were up to 66 km, 10 m, 440 m, and 11.8 km, respectively.

For VSP worst-case scenario (250 pulses), maximum predicted distances out to 24-hour sound exposure TTS thresholds for **marine mammals** ranged from less than 10 m to 2.2 km (LF Cetaceans). Maximum predicted distances out to 24-hour sound exposure PTS thresholds for marine mammals ranged from less than 10 m to 210 m (LF Cetaceans). For 24-hour sound exposure for **sea turtles**, the maximum predicted distance to TTS thresholds was 170 m and to PTS thresholds was 20 m. The predicted distances to thresholds for mortality and potential mortal injury to **fish** ranged from less than 10 m to 30 m. The predicted distances to thresholds for recoverable injury to fish ranged from less than 10 m to 40 m. The maximum predicted distance to thresholds for TTS for fish was 400 m. The distances to peak thresholds were smaller than those to the 24-exposure thresholds. Maximum predicted distances to the marine mammal, sea turtle, fish, and penguin/diving bird **behavioural** thresholds were up to 2 km, 350 m, 7 km, and 19.2 km, respectively.

For sonar surveys, maximum predicted distances out to 24-hour sound exposure TTS thresholds for **marine mammals** ranged from less than 10 m to 860 m (VHF Cetaceans). Maximum predicted distances out to 24-hour sound exposure PTS thresholds for marine mammals ranged from less than 10 m to 350 m (VHF Cetaceans). High frequency sources, such as sonar sources with a frequency range of 40 kHz or greater, are not expected to cause adverse hearing impacts on **sea turtles** due to their low frequency hearing ranges. The predicted distances to thresholds for 24-hour exposure for mortality and potential mortal injury, recoverable injury or TTS to **fish** were up to 10 m. The predicted distances to thresholds for peak exposure were 20 m to 40 m. Maximum predicted distances to the marine mammal, fish, and penguin/diving bird **behavioural** thresholds were up to 1.1 km, 1.5 km, and 2.5 km, respectively.

Helicopters will be used to transport personnel to and from the offshore facilities as required. Noise from helicopters will be transient and the majority of the sound will be reflected by the surface of the ocean. Underwater noise levels from helicopters range from 101 dB to 109 dB re 1 µPa, and helicopter noise has been documented to be detectible for less than one minute under water. Therefore, underwater noise impacts from helicopter noise are expected to be much less than those from other Project activities.

1 INTRODUCTION AND SCOPE OF REPORT

1.1 PROJECT BACKGROUND AND LOCATION

TotalEnergies EP South Africa B.V. (TEEPSA), together with its joint venture partners, QatarEnergy, Canadian Natural Resources International South Africa Limited, and a South African consortium, MainStreet 1549, held an Exploration Right (Exploration Right Ref. No.: 12/3/067) over Block 11B/12B, located offshore from the Southern Cape coast, South Africa, which expired in September 2022. TEEPSA has now applied for a Production Right (PR) which was submitted in September 2022. If a PR is granted and if commercial agreements for the sale of the gas onto the domestic market can be achieved, TEEPSA is planning to develop Block 11B/12B.

The Block 11B/12B application area is located offshore the south coast of South Africa and covers approximately 12 000 km^2. The closest north-eastern point of the application area is about 75 km offshore from Cape St Francis, whereas the closest north-western point is about 120 km offshore from Mossel Bay (Figure 1-1). Development and production related activities are proposed for the western portion of Block 11B/12B, in the Project Development Area. TEEPSA proposes to conduct further investigations in the eastern portion of the block, referred to as the Exploration Priority Area, including exploration and appraisal drilling, to enable further refinement of the geological and reservoir understanding, as is typical of developments of this nature.

In accordance with the regulatory requirements, TEEPSA must conduct an Environmental and Social Impact Assessment (ESIA) process for undertaking the proposed development and production related activities in Block 11B/12B. WSP Group Africa (Pty) Ltd (WSP) has been appointed by TEEPSA to undertake the ESIA process in support of an environmental authorisation (EA) application. The Final Scoping Report was accepted by the Competent Authority (CA) on 18 May 2023, indicating that the Impact Assessment Phase could commence and the specialist studies completed.

Marine acoustics modelling has been done in support of the ESIA process. The objective of this assessment was to estimate underwater noise levels due to the Project and compare them to marine mammal, sea turtle, fish, penguin and diving bird noise sensitivity thresholds. This report presents the methods and results of the underwater noise modelling assessment carried out in support of the ESIA.

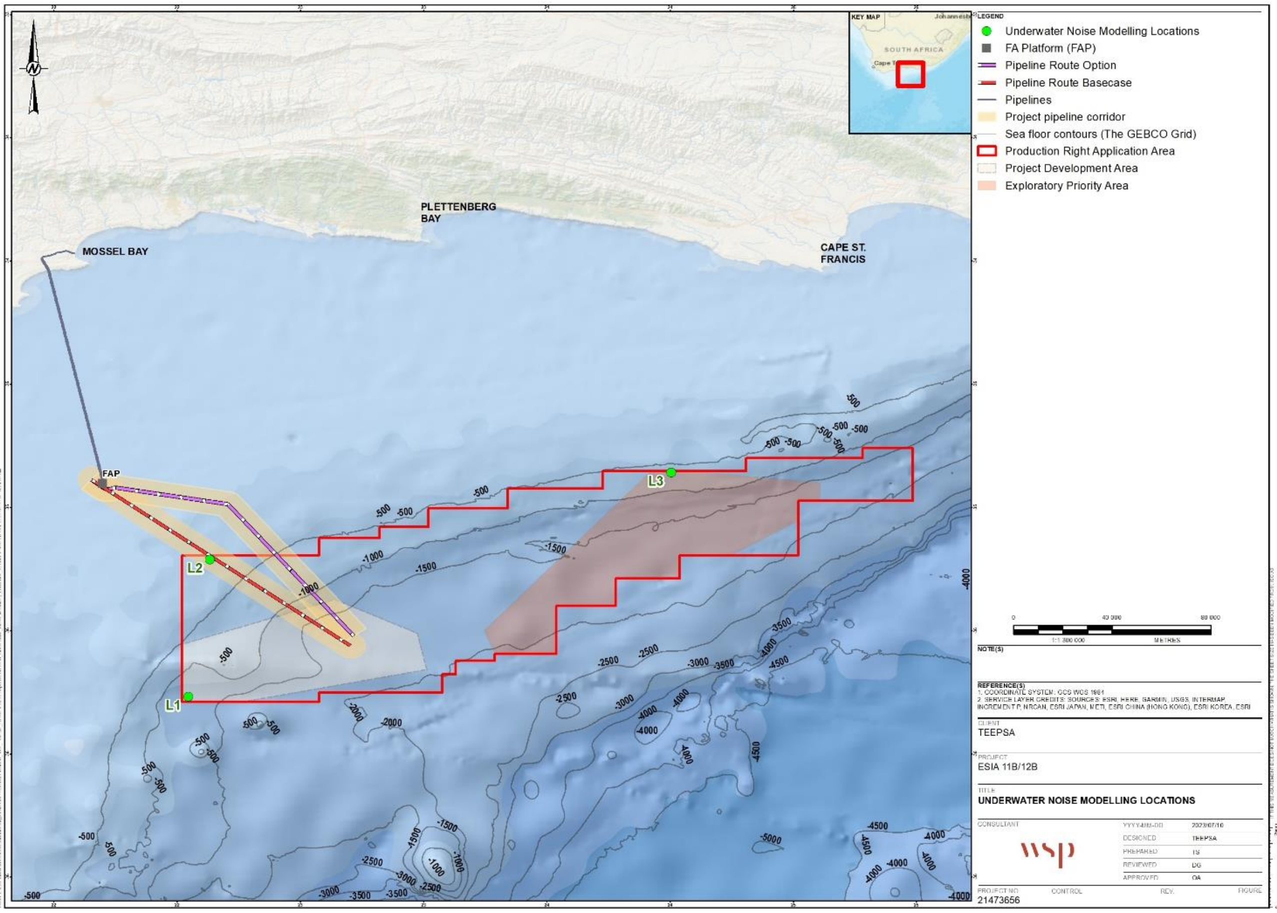

Figure 1-1 - Localities of Project Development Area, Exploration Priority Area and Pipeline Corridors

1.2 PROJECT COMPONENTS AND ACTIVITIES

The section below and Table 1-1 provide information regarding these activities and summarises the Project activities and components together with the location and phasing. The following subsections are focused on the Project components considered in this assessment.

Table 1-1 – Details of Project Activities

Aspect	Details
Proposed exploration and appraisal drilling activities (Eastern Portions of Block, Exploration Priority Area)	▪ Mobilisation of drill unit to site. ▪ Drilling of up to four (4) exploration and appraisal wells. ▪ Possible flow testing, VSP, well logging for each well drilled. ▪ Plugging and abandonment of each well. ▪ Demobilisation of drill unit from site. ▪ Onshore support.

Aspect	Details
Proposed offshore surveys (Whole Block)	▪ Mobilisation of specialised vessels for survey work. ▪ Bathymetry and sonar surveys. ▪ Seafloor sampling surveys. ▪ Metocean surveys. ▪ Demobilisation of survey vessels. ▪ Onshore support.
Proposed production development activities (Western Portion of Block, Project Development Area)	
Construction Phase	Offshore
	▪ Mobilisation of drill unit to site. ▪ Drilling of up to six (6)[1] production and appraisal wells and testing. ▪ Installation of Well-heads and Christmas-Trees (XMT). ▪ Laying of deep-water subsea production manifolds and jumpers connecting the wells. ▪ Installation of subsea production pipeline. ▪ Connection of manifolds to the F-A Platform via the production pipeline, riser and umbilical. ▪ Demobilisation of drill unit from site. ▪ Demobilisation of pipeline installation and support vessels.
	Onshore
	▪ Establishment of logistics base within the Mossel Bay port. ▪ Support vessels transport of equipment, bulk materials and general supplies from shore to drill unit, survey and pipeline laying vessels. ▪ Helicopter flights for ship/shore personnel movement and in emergency events. ▪ Periodic bulk delivery (equipment) from Gqeberha and/or Cape Town port.
Production Operations Phase	Offshore
	▪ Operation of gas field, including subsea infrastructure to supply F-A Platform. ▪ Operation of F-A Platform and associated infrastructure. ▪ Vessel movements for maintenance and inspections of subsea infrastructure and flowlines pigging.
	Onshore

[1] At this stage of the engineering design, five production wells will be drilled in the Production Development Area with the option for a sixth well should it be required.

Aspect	Details
	▪ Movement of support vessels from shore to F-A Platform for transportation of equipment, bulk materials and general supplies. ▪ Helicopter flights for ship/shore personnel rotation and in emergency events. ▪ Periodic bulk delivery (equipment) from Gqeberha and/or Cape Town port.
Decommissioning Phase	Offshore
	▪ Mobilisation of drill unit to site. ▪ Mobilisation of specialised vessel for survey/ROV work. ▪ Movement of support vessels from shore to drill unit for transportation of equipment, bulk materials and general supplies. ▪ Helicopter flights for ship/shore personnel movement and in emergency events. ▪ Decommissioning of production manifold, flowlines, umbilical and riser. ▪ Decommissioning of subsea distribution units and power cable(s). ▪ Retrieval of shallow water infrastructure, such as production risers and umbilicals. ▪ Pigging of production flowline incl. subsea tie-in. ▪ Abandonment of wells. ▪ Demobilisation of drill unit and support vessels from site.
	Onshore
	▪ Movement of support vessels from shore to drill unit for transportation of equipment, bulk materials and general supplies. ▪ Helicopter flights for ship/shore transport. ▪ Salvage of retrieved equipment and shipping to Gqeberha and/or Cape Town port.

1.2.1 DEVELOPMENT AND PRODUCTION RELATED ACTIVITIES – OFFSHORE WESTERN AREA

The Project Development Area is located approximately 110 km southeast of the existing F-A Platform. The Project development concept comprises wells and a subsea production system (SPS) in the south-west corner of Block 11B/12B to produce gas and associated condensates. The development concept also includes a subsea pipeline to carry the gas and condensate to existing treatment and export facilities on the F-A platform where it will go to shore via the existing pipelines.

The proposed development concept will connect up to 6 wells in the Project Development Area via a multiphase pipeline carrying both gas and associated condensates from the wells up to the F-A Platform. From there, it will be carried for further treatment and exporting via the existing PetroSA-operated gas and condensate pipelines onshore.

Any construction, modification or upgrades at the F-A Platform or of any onshore facility, if required by the off-taker of gas or condensates, will be subjected to a separate EA application.

The production activities programme can be summarised as below;

- Drilling of up to six (6) wells in the Project Development Area.
- Installation of the subsea production system including pipeline and connection to the F-A Platform.

1.2.2 EXPLORATION AND APPRAISAL DRILLING RELATED ACTIVITIES – OFFSHORE EASTERN AREA

In addition to the development of the gas field in the western section of Block 11B/12B, TEEPSA intends undertaking exploration and appraisal drilling work to assess the potential for additional hydrocarbons resources. This programme may include:

- Drilling of up to four (4) exploration and appraisal wells in the eastern section of Block 11B/12B. Final site selection of the wells will be based on further detailed analysis of the pre-drilling survey data and the geological target.
- Vertical seismic profiling (VSP) of the well will be conducted. VSP is an evaluation tool that is used when the well reaches target depth to generate a high-resolution seismic image of the geology in the well's immediate vicinity. The VSP images are used for correlation with surface seismic images and for forward planning of the drill bit during drilling. VSP uses a small airgun array, which is operated from the drilling unit. During VSP, receivers are positioned in a section of the well and the airgun array is discharged at intervals. This process is repeated for different stations in the well and may take between 8 to 12 hours per well to complete.

1.2.3 SONAR SURVEYS

Various offshore surveys and data collection will be conducted in Block 11B/12B subject to identification of specific needs, including sonar surveys.

Sonar surveys will be used to investigate the structure of the seabed (bathymetry) in the vicinity of future wells, if needed. Sonar surveys will be conducted from a vessel and might use multi-beam echo-sounding, single beam echo-sounding and sub-bottom profiling. Such surveys entail transmitting frequency pulses down to the seafloor to produce a digital terrain model and identify any seafloor obstructions or hazards.

1.2.4 ONSHORE SUPPORT ACTIVITIES AND COMPONENTS

The Project will include a shorebase/logistics base to support operations. It will also include a series of support and specialised vessels for specific activities. During drilling activities, support vessels will include supply vessels and tugboats.

Supporting activities will also include helicopter transportation from existing airport facilities to move personnel to and from the offshore facilities.

1.2.5 PROJECT PHASING AND TIMEFRAMES

The Project activities are associated with the timeframes as indicated in Table 1-2.

Table 1-2 - Exploration, development and production related timeframes

Project Component	Phase	Timeframe	Duration of Activities	No. of wells
Exploration	Mobilisation	To be determined	120 days per well	Not applicable
	Operations, including plugging and abandonment			Up to four (4)
	De-mobilisation			Not applicable
Offshore Surveys (for Development and Exploration)	Operations	To be determined	▪ Sonar: 15 – 30 days for 1 survey ▪ Seafloor sampling: 15 – 30 days for 1 survey ▪ Metocean Buoy: 7 – 15 days for deployment for 1 year monitoring	Not applicable
Development	Final well site selection, pipeline alignment selection	To be determined	To be determined	Not applicable
	Construction (including mobilisation)	Year 0	120 days per well	Two (2)
		Year 1	120 days per well	One (1)
		Year 10	120 days per well	Two (2)
	Production	Year 1 to Year 25	-	Year 1 to 10 – 3 wells Year 11 to 25 – 5 wells
	Decommissioning (including plugging and abandonment, and demobilisation)	Year 26	-	Five (5)

1.3 SPECIALIST STUDY SCOPE

The objective of this assessment was to establish underwater noise levels due to the Project by developing computer underwater noise prediction models for Project activities that were identified as having the potential to generate noise and comparing predicted noise levels to marine mammal, sea turtle, fish, and penguin and diving bird noise sensitivity thresholds.

Within Block 11B/12B, the following activities outlined below have the potential to impact underwater noise levels:

- The use of a drill unit to undertake additional drilling of up to four (4) exploration wells in the Exploration Priority Area, along with supply and support vessels, as part of the proposed exploration and appraisal drilling activities;

- The use of a drill unit to undertake drilling of up to six (6) development and appraisal wells, along with supply and support vessels in the Project Development Area as part of the production and development activities (construction phase);
- The use of a small airgun array to conduct vertical seismic profiling (VSP) when required before completion of appraisal well drilling;
- The use of a high-frequency sonar source to undertake sonar surveys as part of the offshore surveys; and
- Helicopter use to transport personnel to and from the offshore facilities as required as part of the Project drilling and development activities (including construction, operation, and decommissioning phases).

Noise from these activities are expected to represent the greatest noise impacts throughout Project exploration and appraisal drilling activities, offshore surveys and development activities (including construction and decommissioning).

Additional details for each noise source are provided in Section 2.3.

2 METHOD OF STUDY

2.1 BACKGROUND

2.1.1 TERMINOLOGY

Underwater noise can be described through a source-path-receiver model. An acoustic source emits sound energy that travels through the seawater and the seafloor as pressure waves. The sound level decreases with increasing distance from the acoustic source as the sound pressure waves spread out under the influence of the surrounding environment. The amount by which the sound levels decrease between a source and receiver is called **transmission loss**. The amount of transmission loss that occurs depends on the source-receiver distance, the frequency of the sound, the properties of the water column, and the properties of the seafloor layers.

Sources of noise can be categorised generally as **impulsive** (e.g., VSP, sonar surveys) or **non-impulsive/continuous** (e.g., drilling).

Underwater sound levels are expressed in decibels (dB), a logarithmic ratio relative to a fixed reference (re) pressure of 1 µPa (equal to 10^{-6} Pa) or 1 μPa^2-s. Underwater sound is typically quantified using the following metrics:

- Sound Pressure Level (SPL) – measured in dB re 1 µPa:
  - Root mean square SPL (SPL_{rms}) – average root mean square pressure level over a stated time interval.
  - Peak SPL (SPL_{peak}) – greatest absolute instantaneous sound pressure over a stated time interval.
- Sound Exposure Level (SEL) – measured in dB re 1 μPa^2-s:
  - 24-hour SEL (SEL_{24h}) – acoustic energy accumulated over a 24-hour period.

Underwater noise can affect marine fauna in a variety of ways, including the following:

- Auditory **masking** which affects marine animals' ability to communicate or echolocate.
- **Behavioural** impacts such as avoidance.
- Hearing loss, including **temporary threshold shifts** (i.e., temporary loss of hearing sensitivity, **TTS**) and **permanent threshold shifts** (i.e., permanent loss of hearing sensitivity, **PTS**).
- Other physical injury or death.

2.1.2 THRESHOLDS

Assessment of the potential effects of underwater noise on marine fauna requires acoustic thresholds against which received sound levels can be compared. As described in the following sections, there are thresholds related to various effects to marine fauna including behavioural impacts, temporary or permanent hearing loss and other injuries, or mortality.

The following sections outline the applicable thresholds considered for marine mammals, sea turtles, fish, and penguins and diving birds.

2.1.2.1 Marine Mammals

Southall *et al*. (2019) and the US National Oceanic and Atmospheric Administration's (NOAA's) National Marine Fisheries Service (NMFS, 2016, 2018) have provided technical guidance for assessing the effect of anthropogenic sound on marine mammal hearing. The guidance provides frequency weighting functions for six hearing groups based on audiogram studies, referred to as M-weighting filters (analogous to the A-weighting filter for humans), further discussed in Section 2.2.2.

The guidance also provides thresholds for onset of TTS and PTS in marine mammal hearing due to both impulsive and continuous noise sources (Table 2-1). It provides injury criteria for impulsive sounds that are based on peak sound pressure level (SPL_{peak}) and 24-hour sound exposure level (SEL_{24h}) for cumulative exposure. The SPL_{peak} criterion is not frequency weighted, whereas the SEL_{24h} is frequency weighted. The SPL_{peak} criterion is related to the risk of sounds with high peak noise levels causing direct mechanical damage to the inner ear.

Using frequency weighting for peak metrics is not considered appropriate as direct mechanical damage is not generally associated with frequencies that relate to a hearing group's sensitivity (NMFS, 2018). The SEL_{24hr} injury thresholds are higher for continuous sounds such as drilling than for impulsive sounds such as VSP and sonar surveys because the mammalian ear can temporarily reduce its sensitivity when exposed to continuous noise.

Table 2-1 – Marine Mammal Injury Thresholds for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS)

Hearing Group	Impulsive Sources				Continuous Sources	
	TTS		PTS		TTS	PTS
	SPL_{peak} (dB re 1 µPa) (Unweighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)	SPL_{peak} (dB re 1 µPa) (Unweighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)
Low Frequency (LF) Cetaceans	213	168	219	183	179	199
High Frequency (HF) Cetaceans	224	170	230	185	178	198
Very High-Frequency (VHF) Cetaceans	196	140	202	155	153	173
Sirenians (SI)	220	175	226	190	186	206
Phocid Carnivores in Water (PCW)	212	170	218	185	181	201
Other Marine Carnivores in Water (OCW)	226	188	232	203	199	219

Sources: Southall *et al*., 2019; NMFS, 2016, 2018

The current NMFS disturbance (behavioural response) threshold for all marine mammal species is 160 dB re 1 µPa (SPL_{rms}) for impulsive noise (e.g., VSP, sonar surveys) and 120 dB re 1 µPa (SPL_{rms}) for continuous noise (e.g., drilling) (NMFS, 2023), as presented in Table 2-2 . These disturbance thresholds do not consider the overall duration of the noise or its acoustic frequency distribution to account for species dependent hearing. The disturbance thresholds are much lower for continuous sounds than impulsive sounds, which is attributed to the differences in the way the ear perceives loudness for these sound types.

Table 2-2 – Marine Mammal Behavioural Thresholds

Hearing Group	Impulsive Sources	Continuous Sources
	SEL_{rms} (dB re 1 µPa)	SEL_{rms} (dB re 1 µPa)
Marine Mammals	160	120

Source: NMFS, 2023

2.1.2.2 Sea Turtles

Finneran *et al*. (2017) investigated appropriate thresholds for sea turtles related to impulsive and continuous noise sources. They derived both TTS and PTS thresholds and applicable frequency weighting functions. Table 2-3 provides the PTS and TTS thresholds for sea turtles for impulsive and continuous sources of noise.

Table 2-3 – Sea Turtle Injury Thresholds for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS)

Hearing Group	Impulsive Sources				Continuous Sources	
	TTS		PTS		TTS	PTS
	SPL_{peak} (dB re 1 µPa) (Unweighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)	SPL_{peak} (dB re 1 µPa) (Unweighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)	SEL_{24h} (dB re 1 µPa^2-s) (Weighted)
Sea Turtles	226	189	232	204	200	220

Source: Finneran *et al*., 2017

The **behavioural disturbance** noise threshold for sea turtles for both impulsive and continuous sources that will be considered in this assessment is as follows:

- 175 dB re 1 µPa (SPL_{rms}) (Finneran *et al*., 2017).

Sea turtle functional hearing is limited to frequencies below approximately 2 kHz (Finneran *et al*., 2017).

2.1.2.3 Fish

Sound exposure guidelines for fish, fish eggs, and fish larvae were developed by Popper *et al*. (Popper *et al*., 2014; Popper and Hawkins, 2019) for impulsive and continuous noise sources. Guidelines were specified for the following types of effects:

- Mortality and potential mortal injury.
- Recoverable injury.
- Temporary threshold shift.
- Masking.
- Behavioural effects.

Due to insufficient data for Popper *et al*. to develop thresholds, they determined that masking and behavioural effects are to be assessed qualitatively, in terms of relative risk (i.e., high, moderate, and low) at distances from a noise source (i.e., near, intermediate, and far); Popper *et al*. derived quantitative thresholds for other types of effects on fish. The risk ratings are included in the tables below but are not considered further in the assessment as they are highly subjective in nature; the quantitative thresholds in the tables below were considered sufficient to assess potential Project impacts on fish.

Fish are grouped into three categories depending on whether they have a swim bladder, and if it has a role in their ability to hear:

- Fishes with no swim bladder: These species are less susceptible to injury from noise exposure and only detect particle motion, not sound pressure. However, some injury may still result from exposure to sound pressure.

- Fishes with swim bladders in which hearing does not involve the swim bladder: These species are susceptible to injury although hearing only involves particle motion, not sound pressure.
- Fishes in which hearing involves a swim bladder: These species are susceptible to injury and detect sound pressure as well as particle motion.

In addition, fish eggs and larvae are considered as a separate category. Table 2-4 and Table 2-5 present thresholds for fish for continuous sounds and impulsive sounds (specifically for seismic airguns), respectively. Note that Popper *et al*. provides thresholds for low- and mid-frequency naval sonar, however they consider sonar sources that operate for long enough in duration to be considered continuous sources. Sonar surveys proposed for the Project will use a high frequency source and be limited in duration to shorter than 2 ms (see Section 2.3.3) and therefore the sonar thresholds are not considered applicable.

While the hearing range of fishes is generally considered to be from approximately 30 Hz to 10 kHz, there are some species of fish that can detect higher frequencies. In the absence of other information, the criteria for seismic airguns were considered applicable for assessing the sonar surveys.

Table 2-4 – Fish Thresholds for Continuous Sounds

Type of Fish	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	(N) Low (I) Low (F) Low	SPL_{rms}: 170 dB for 48 hrs	SPL_{rms}: 158 dB for 12 hrs	(N) High (I) High (F) High	(N) High (I) Moderate (F) Low
Fish eggs and fish larvae	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low	(N) Moderate (I) Moderate (F) Low

Source: Popper *et al*., 2014; Popper and Hawkins, 2019

Note: SPL_{rms} is measured in dB re 1 µPa. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Table 2-5 – Fish Thresholds for Impulsive Sounds

Type of Fish	Mortality and potential mortal injury	Impairment			Behaviour
		Recoverable Injury	TTS	Masking	
Fish: No swim bladder (particle motion detection)	SEL_{24h}: > 219 dB Or SPL_{peak}: > 213 dB	SEL_{24h}: > 216 dB Or SPL_{peak}: > 213 dB	SEL_{24h}: >> 186 dB	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder not involved in hearing (particle motion detection)	SEL_{24h}: 210 dB Or SPL_{peak}: > 207 dB	SEL_{24h}: 203 dB Or SPL_{peak}: > 207 dB	SEL_{24h}: > 186 dB	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F) Low
Fish: Swim bladder involved in hearing (primarily pressure detection)	SEL_{24h}: 207 dB Or SPL_{peak}: > 207 dB	SEL_{24h}: 203 dB Or SPL_{peak}: > 207 dB	SEL_{24h}: 186 dB	(N) Low (I) Low (F) Moderate	(N) High (I) High (F) Moderate
Fish eggs and fish larvae	SEL_{24h}: > 210 dB Or SPL_{peak}: > 207 dB	(N) Moderate (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low

Source: Popper *et al*., 2014; Popper and Hawkins, 2019

Note: SPL_{peak} is measured in dB re 1 µPa and SEL_{24h} is measured in re 1 µPa^2-s. All criteria are presented as sound pressure even for fish without swim bladders since no data for particle motion exist. Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

The NMFS has introduced an informal behavioural threshold (NMFS, 2023) of 150 dB re 1 µPa (SPLrms) for all types of sources (i.e., continuous or impulsive). The threshold is considered informal as the derivation and origin are not well-defined, however it provides information on where one can begin to look at potential responses from fish.

2.1.2.4 Penguins and Diving Birds

Limited information is available for sound exposure thresholds for penguins and other diving birds, however a recent study (Sørensen *et al*., 2020) examined the behavioural response of penguins to impulsive noise. Based on the findings of this study, a **behavioural threshold** of 120 dB re 1 µPa (SPL_{rms}) will be applied for impulsive and continuous noise for both penguins and diving birds.

In applying this threshold, a frequency weighting was considered to reflect the hearing sensitivities of penguins and diving birds. In the absence of specific frequency weighting functions for penguins or diving birds, the frequency weighting for other marine carnivores in water (OCW) was applied.

2.2 UNDERWATER NOISE MODELLING

2.2.1 NOISE MODEL

Underwater noise levels due to the Project were predicted using the underwater acoustic propagation modelling software Acoustic Toolbox User interface and Post processor (AcTUP V2.2L). AcTUP, developed by the Centre for Marine Science and Technology at Curtin University in Australia, is a publicly available MATLAB-based program which implements a range-dependent acoustic model (RAM).

AcTUP allows users to select from among several different implementations of RAM. The propagation algorithms selected for the Project were RAMGeo, a range dependent parabolic equation code for fluid seabeds which was used to assess drilling and VSP noise, and BELLHOP, a beam tracing model that is more efficient at high frequencies which was used for assessing the high frequency sonar source. Environmental inputs to the prediction model include sound speed profiles for the water column, bathymetry, and seabed properties, which are further discussed in Section 2.4.

AcTUP produces the transmission loss for a defined frequency as a function of range and depth along a given radial from a sound source at a defined depth. For the underwater noise modelling conducted for the Project, the transmission loss was calculated every 10°. Modelling was conducted at octave band centre frequencies between 16 Hz and 8 kHz for drilling and VSP and at 40 kHz for sonar surveys, as described further in Section 2.3.

For the RAMGeo predictions, radials were predicted out to a propagation distance of 150 km. For BELLHOP predictions, a propagation distance of 10 km was considered.

Using the source levels discussed in Section 2.3, the transmission losses along a set of two dimensional radials covering 360° from the noise source(s) were converted to noise levels as a function of range and depth for each angle resulting in noise levels across a three-dimensional space. The maximum noise levels over all modelled depths were taken to provide noise levels only as a function of range from the source. The predicted noise levels at all angles were then combined using MATLAB interpolation functions to produce two-dimensional noise contours.

The maximum distances to the marine fauna impact thresholds discussed in Section 2.1.2 were calculated from the predicted noise levels.

2.2.2 FREQUENCY WEIGHTING

Marine mammals, sea turtles, and penguins and diving birds do not have equal sensitivity to noise at all frequencies. As mentioned in Section 2.1.2, NOAA specifies frequency weightings to be considered when predicting noise levels to be compared to thresholds for different marine mammal species. Auditory weighting functions are used to emphasize frequencies where animals are more sensitive and deemphasize those where they are less sensitive.

The auditory weighting function W_{aud} is defined as follows for the parameters defined in Table 2-6:

$$W_{aud}(f) = C + 10log_{10}\left\{\frac{(f/f_1)^{2a}}{[1+(f/f_1)^2]^a[1+(f/f_2)^2]^b}\right\}$$

Finneran *et al*. (2017) derived auditory weighting function parameters for sea turtles. Figure 2-1 shows the auditory weighting functions for each of the hearing groups.

Table 2-6 – Auditory Weighting Function Parameters

Hearing Group	*a*	*b*	f_1 (kHz)	f_2 (kHz)	*C* (dB)
Low Frequency (LF) Cetaceans	1.0	2	0.2	19	0.13
High Frequency (HF) Cetaceans	1.6	2	8.8	110	1.2
Very High-Frequency (VHF) Cetaceans	1.8	2	12	140	1.36
Sirenians (SI)	1.8	2	4.3	25	2.62
Phocid Carnivores in Water (PCW)	1.0	2	1.9	30	0.75
Other Marine Carnivores in Water (OCW)	2.0	2	0.94	25	0.64
Sea Turtles	1.4	2	0.077	0.44	2.35

The two frequency parameters f_1 and f_2 represent the lower and higher frequencies, respectively, at which the weighting function amplitude transition from the flat, central portion of the curve. The constants *a* and *b* represent the exponent values which define the slope of the weighting function amplitude for lower and hight frequencies, respectively. *C* defines the vertical position of the weighting function, defined such that the maximum amplitude of the weighting function equals 0 dB, as shown in Figure 2-1.

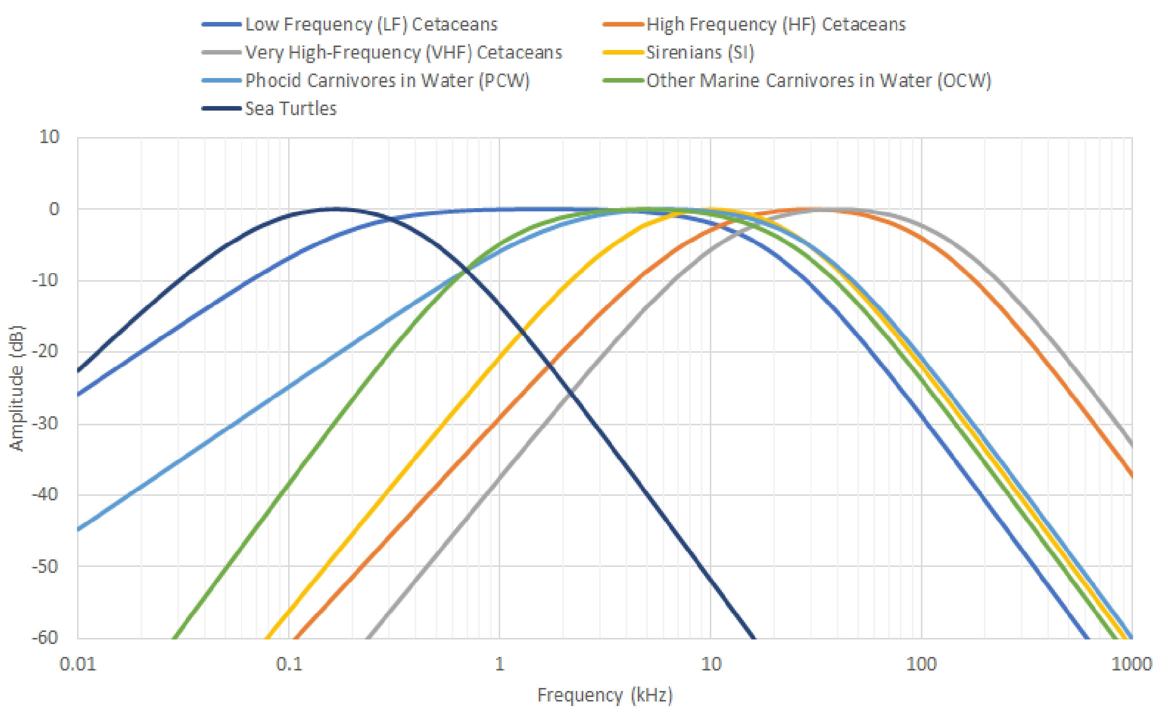

Figure 2-1 – Auditory Weighting Functions

The auditory weighting function for each of these seven hearing groups was added to the predicted noise levels for each frequency prior to calculating the distances to the weighted hearing group-specific thresholds.

As discussed in Section 2.1.2.4, in the absence of specific frequency weighting functions for penguins or diving birds, the frequency weighting for other marine carnivores in water (OCW) was applied.

2.3 NOISE SOURCE PARAMETERS

The following sections outline the parameters used to quantify the Project activities that were modelled, including drilling, VSP, and sonar surveys. Each activity was modelled at two locations, one representing deeper water and one representing shallower water; locations are shown on Figure 2-2 and are described in Table 2-7.

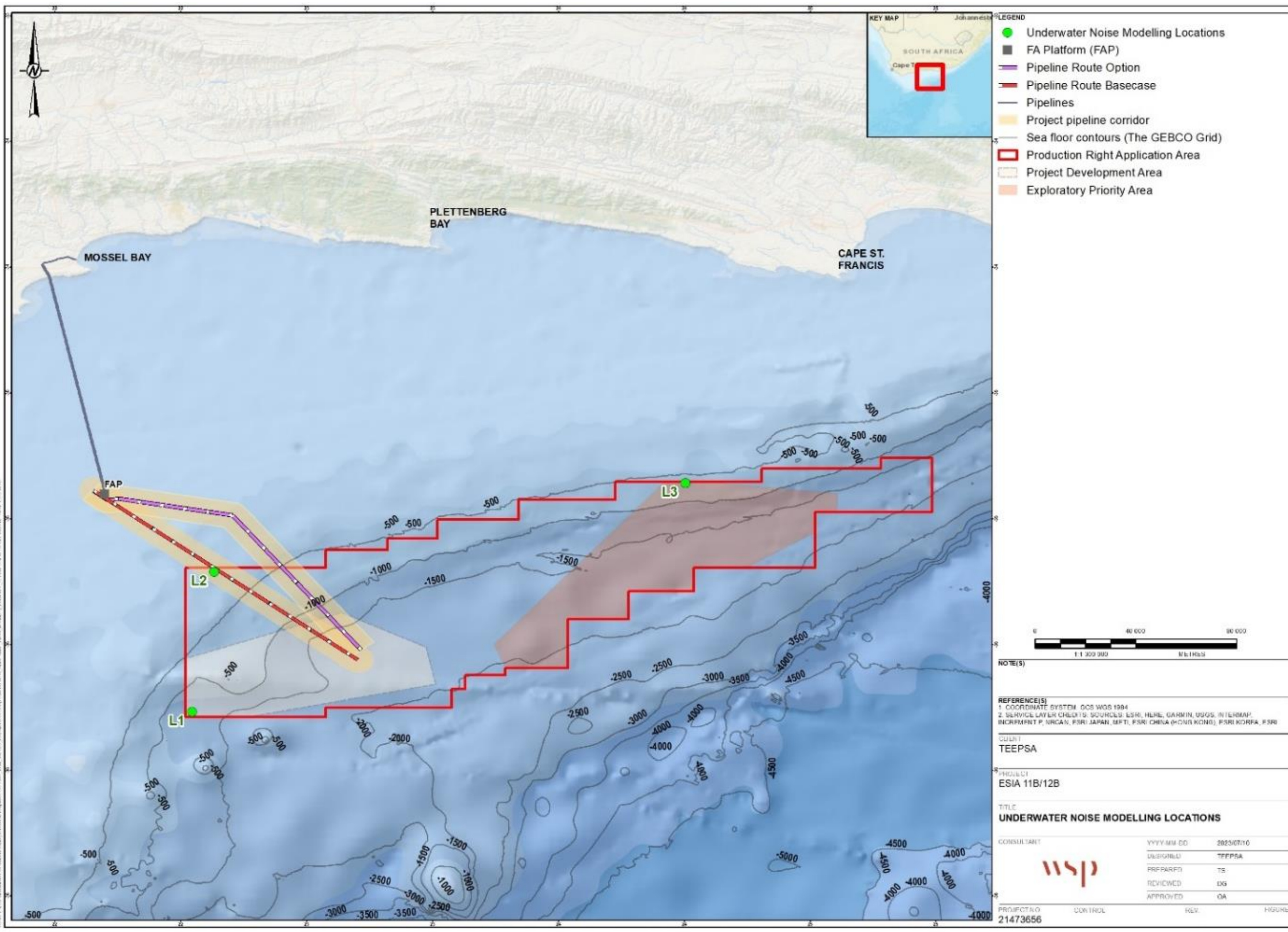

Figure 2-2 - Localities of Project Development Area, Exploration Priority Area, Pipeline Corridors, and Noise Modelling Locations

Table 2-7 – Noise Modelling Locations within Block 11B12B

Modelling Location	UTM Coordinates (Zone 34)		Water Depth (m)	Modelled Activities	Selection Rationale
	Easting	Northing			
L1	637780	6041110	1,264	Drilling VSP Sonar	Area with deeper water within Project Development Area where Project production and development activities may occur Proximity to marine sensitive receptors
L2	645764	6096425	251	Sonar	Area with shallower water along the pipeline route where sonar surveys may occur Proximity to marine sensitive receptors
L3	800072	6127954	624	Drilling VSP	Area within shallower water within the Exploration Priority Area where Project exploration and appraisal drilling activities may occur Proximity to marine sensitive receptors

Note that Project activities are not limited to the locations modelled (i.e., sonar surveys may occur at L3), however the locations were selected to represent the range of water depths of the areas where the activities may occur.

2.3.1 DRILLING ACTIVITIES

Drilling is proposed to be undertaken using a drilling unit with a dynamic positioning system, supported by one or two tugboats and supply vessels. Development and appraisal wells will be drilled in the Project Development Area and exploration and appraisal wells will be drilled in the Exploration Priority Area. Two representative locations, one in the Project Development Area in deep water (L1) and one in the Exploration Priority Area in shallower water (L3), were modelled (see Figure 2-2). The modelled scenario considered a drill unit with one tugboat and one supply vessel.

The octave band source levels considered in the underwater noise modelling for drilling and support vessels (i.e., tugs and supply vessels), shown in Figure 2-3, were estimated based on an empirical formula suggested by Brown (1976) which predicts source levels of propellers based on the propeller diameter, number of blades, and revolution rate.

The propeller specifications assumed for the thrusters on the drill unit, tugboat, and supply vessel are presented in Table 2-8. All thrusters were assumed to operate at their nominal revolution rate.

Table 2-8 – Vessel Propeller Specifications

Ship	Thruster	Propeller Diameter (m)	Nominal Revolution Rate (rpm)	Number of Blades
Drill Unit	Azimuth	3.5	187	4
Tug	Main	4.6	134	4
	Bow Tunnel	2.4	256	3
	Bow Azimuth	2.3	289	3

Ship	Thruster	Propeller Diameter (m)	Nominal Revolution Rate (rpm)	Number of Blades
	Stern Tunnel	2.4	256	3
Supply Vessel	Main	2.02	307	3
	Bow Tunnel	2.25	307	3
	Bow	1.65	382	3

The depth of the thrusters on the drilling platform was modelled at 27.75 m below the sea surface. Note that noise levels from other sources associated with the drilling platform such as the underground drill bit and vibrating drill string and casing are expected to be much lower (Erbe and McPherson, 2017) and therefore have not been considered further in this assessment. For support vessels (i.e., tug and supply vessel), the depth of the thrusters was assumed to be 5 m below the sea surface.

The overall SPL_{rms} noise levels at 1 m of the drilling platform, tug and supply vessel were 197.5 dB re 1 µPa, 192 dB re 1 µPa, and 189 dB re 1 µPa, respectively (SLR 2020). To calculate the SEL_{24h} noise levels, it was assumed that drilling could occur for 24 hours per day. As a worst-case scenario, it was assumed that the animal would stay in the vicinity of the drilling and therefore be exposed to drilling noise for the entire 24 hours. As it is unlikely that an animal would stay in the same location for a 24-hour period, a second scenario was considered that an animal would be exposed to drilling noise for a 30-minute period.

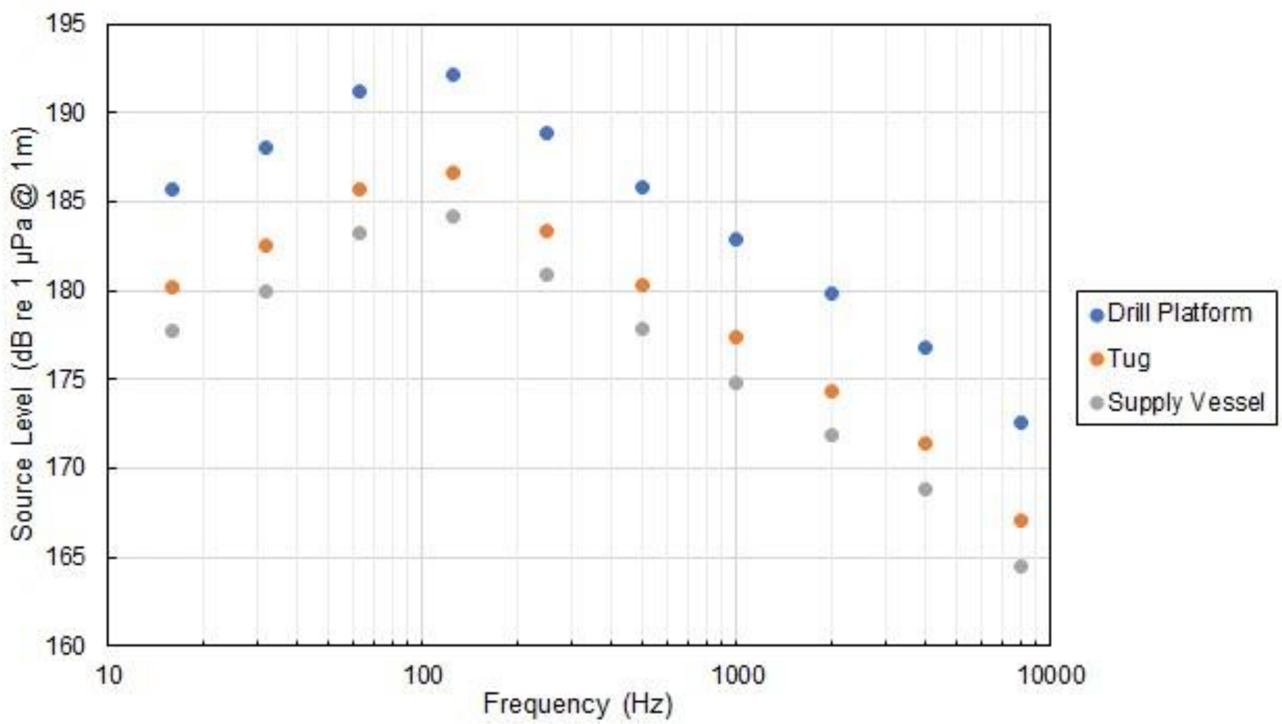

Figure 2-3 – Source Noise Levels for the Drilling Scenario

2.3.2 VERTICAL SEISMIC PROFILING

VSP uses a small airgun array that is operated from the drilling unit. It is expected that a Dual Delta Sodera G-Gun (or equivalent) will be used for the Project, which has six active G-Gun airguns (three 250 cubic inch [CUI] airguns and three 150 CUI airguns for a total of 1,200 CUI) and an operating pressure of 2,000 pounds per square inch (psi). VSP will be possibly completed where drilling occurs and therefore the same two representative locations as those modelled for drilling, L1 and L3, were modelled
(see Figure 2-2).

The source emissions for the airgun array used in the underwater noise modelling, shown in Figure 2-4, were calculated from the third octave band noise levels derived by SLR Consulting Australia Pty Ltd. (SLR) conducted in support of internal TEEPSA technical studies (unpublished) using Gundalf Designer software. The average depth of the airgun array is 10 m below the sea surface. The SEL is 213.8 dB re 1 µPa^{2}s at 1 m.(SLR 2020)

It was expected that up to 250 pulses may occur during one operation which may take 8 to 12 hours in duration. Two scenarios were considered for the SEL_{24h} modelling: that an animal could be exposed to 50 pulses or 250 pulses in a given 24 hour period.

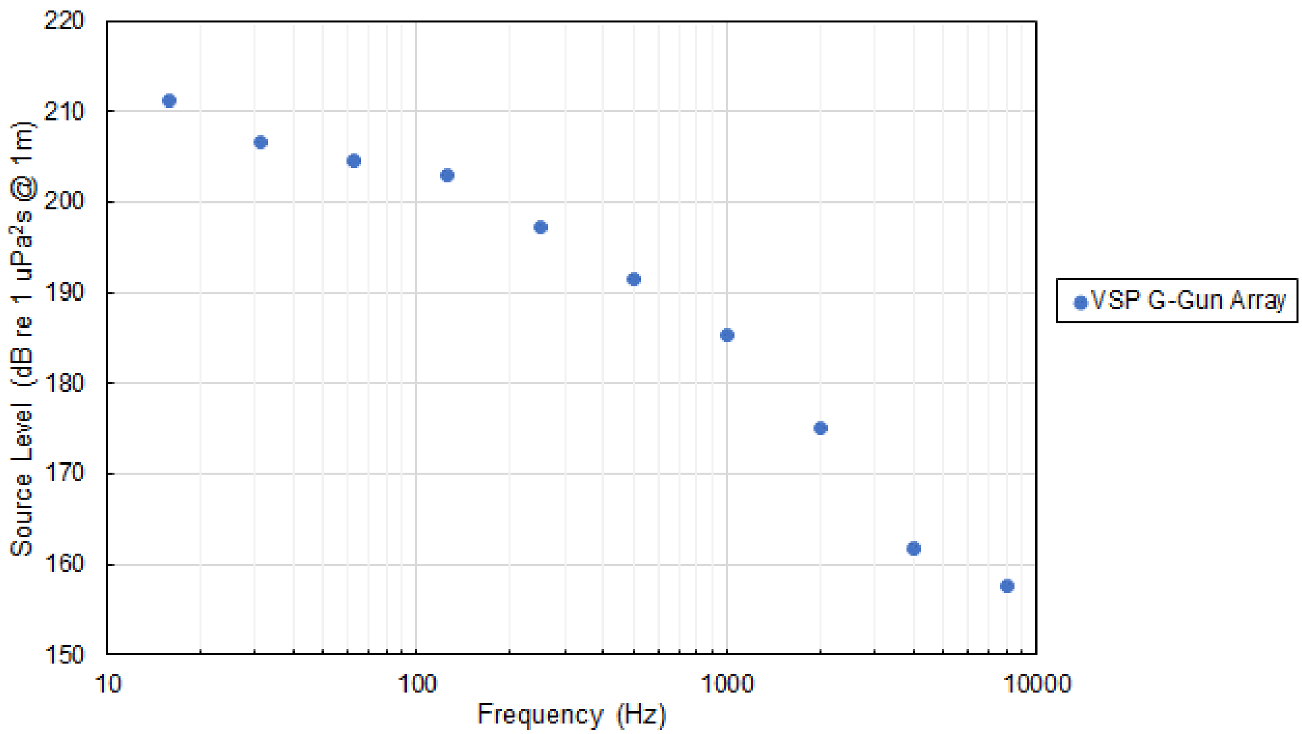

Figure 2-4 – Source Noise Levels for the VSP Scenario

Studies have shown that for received individual signals from impulsive sources (i.e., VSP), differences between received SEL, SPL_{rms} and SPL_{peak} levels increase as the distance from the source increases. Therefore, for the VSP source conversions from SEL to SPL_{rms} and SPL_{peak} were required for comparison to relevant thresholds. Relationships between SEL and SPL_{rms} and SPL_{peak} were established by SLR based on their analysis of the VSP source.

The difference between SPL_{peak} and SEL for the VSP source was found to be 18.2 dB at 1 m from the source, which was conservatively applied as the conversion from SEL to SPL_{peak} at all distances. This likely overestimates the SPL_{peak} at distances further from the source as this difference is expected to increase as the distance increases.

The following formulae were derived based on the conservative estimates established by SLR based on their VSP array modelling to estimate the range-dependent conversion between SPL_{rms} and SEL and were applied in the modelling accordingly:

$$\begin{aligned} \mathrm{SPL_{rms}} - \mathrm{SEL} &= 14.5 && for\ range \leq 100\ m \\ &= -4.5 * log10(range) + 23.5 && for\ 100\ m < range \leq 1{,}000\ m \\ &= -5 * log10(range) + 25 && for\ 1{,}000\ m < range \end{aligned}$$

2.3.3 SONAR SURVEYS

Sonar surveys are expected to occur within the Project Development Area and along the pipeline route. Two representative locations, L1 in deeper water in the development area and L2 along the pipeline route in shallower water, were modelled (see Figure 2-2).

It was assumed that the sonar surveys would be carried out using a Kongsberg EM 712 multi-beam echo-sounder (or equivalent). The sonar source's operating frequency range is approximately 40 kHz to 100 kHz for a system able to ensure acquisition up to 3,600 m water depth. As seawater absorption (described below in Section 2.4.4) increases significantly as the frequency increases, the minimum frequency in the range (i.e., 40 kHz) was selected to predict the expected worst-case impacts.

The following source levels were used in the modelling (Kongsberg, 2019):

- SPL_{peak} of 240 dB re 1 µPa @ 1m,
- SPL_{rms} of 237 dB re 1 µPa @ 1m, and
- SEL of 210 dB re µPa^2·s @ 1m (with 2 ms duration).

The sonar source has a wide beam angle in the cross-track direction and a narrow beam angle in the along-track direction (i.e., up to 140° beam angle in the cross-track direction, up to 2° beam angle in the along-track direction). Due to the source narrow directivity and its mobile nature, impacts to a single receptor over the duration of the sonar survey are expected to be due to one sonar pulse only. Noise contours and distances to the applicable thresholds were predicted assuming all directions were the cross-track direction.

2.4 ENVIRONMENTAL PARAMETERS

2.4.1 WATER SOUND SPEED

The water sound speed profile is a required input for acoustic modelling in AcTUP. The sound speed profiles considered in the assessment were provided by TEEPSA from a 3D seismic campaign held within the Block in March 2020. Figure 2-5 shows the representative sound speed profiles used for the modelling scenarios at location L1 (i.e., deeper water) and at locations L2 and L3 (i.e., shallower water).

Generally, sound speed profiles vary throughout the year due to changing water conditions; during the winter, near-surface temperatures are colder and therefore conditions are favourable for upward refraction, leading to longer-range noise propagation. Based on a review of previous seasonal data collected in the vicinity of the Project, seasonal variations observed in sound speed profiles were not significant. Therefore, the data collected in March 2020 was considered appropriate to be used for the modelling.

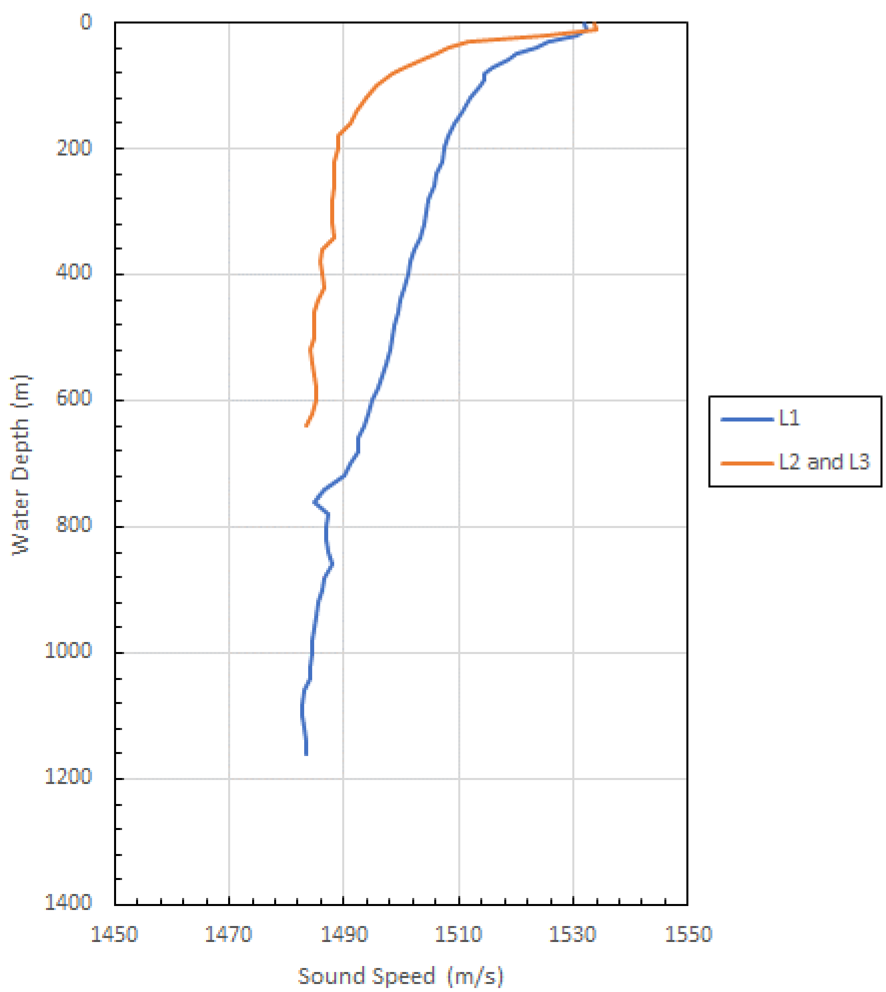

Figure 2-5 – Sound Speed Profiles

2.4.2 BATHYMETRY

Sound propagation is influenced by the water depth. The assessment used bathymetry data provided by TEEPSA which covered the Project area with contours with 100 m resolution. The data were converted into the radial format required for input to AcTUP using MATLAB.

2.4.3 SEDIMENT GEOACOUSTIC PARAMETERS

Sound propagation is influenced by the geoacoustic properties of the sediment that comprises the seafloor. AcTUP requires input parameters of the sediment layers as a function of depth, including compressional sound speed, density, and compressional wave absorption. The geoacoustic properties for sediment type considered in the assessment were based on Hamilton (1980) and Jensen *et al*. (2011).

The geoacoustic parameters considered in the modelling are presented in Table 2-9.

Table 2-9 – Sediment Geoacoustic Parameters

Sediment Type	Depth (m)	Density [kg/m^3]	Compressional Wave		Shear Wave	
			Sound Speed [m/s]	Absorption [dB/ wavelength]	Sound Speed [m/s]	Absorption [dB/ wavelength]
Silty Sand	0 to 100	1,700	1,650	0.80	150	2.0
Sand Half Space	100 to ∞	1,900	1,800	1.00		

2.4.4 SEAWATER ABSORPTION

The transmission losses predicted by AcTUP were corrected for the absorption of sound in seawater. The amount of absorption is frequency dependent and can be calculated based on seawater properties including water temperature, depth, salinity, and acidity (François and Garrison, 1982a, 1982b). The temperature and salinity used in the modelling were estimated from the temperature and salinity profiles discussed in Section 2.4.1. The values used were 15.7°C for temperature, 30 m for depth, and 35.5 parts per thousand (ppt) for salinity. A value of 8 was used for pH. The calculations were performed using the National Physical Laboratory (NPL) website (NPL, 2020), which implements François and Garrison's calculation methodology. The calculated absorption values ranged from 0.001 dB/km at 125 Hz to 9.9 dB/km at 40 kHz.

2.5 ASSUMPTIONS AND UNCERTAINTIES

The assessment is based on the following assumptions, described above and summarised here:

- Detailed specifications of the noise sources and specific operating scenarios were not available at the time of conducting this assessment and therefore assumptions were made, as described above in Section 2.3, to derive source emissions and operating times and/or frequencies.

- The prediction locations for shallow and deep water (Figure 2-2) are representative of other locations where Project sources may operate.

3 BASELINE DESCRIPTION

Existing underwater noise levels are influenced by both natural and anthropogenic sources. Each source of noise has different levels of noise at a range of frequencies. Low frequencies are generally impacted by human contributions (i.e., marine shipping) while higher frequencies may be impacted by natural physical or bioacoustics sources (i.e., surface waves, rain, marine fauna). Figure 3-1 demonstrates the frequency components of typical natural and anthropogenic noise sources.

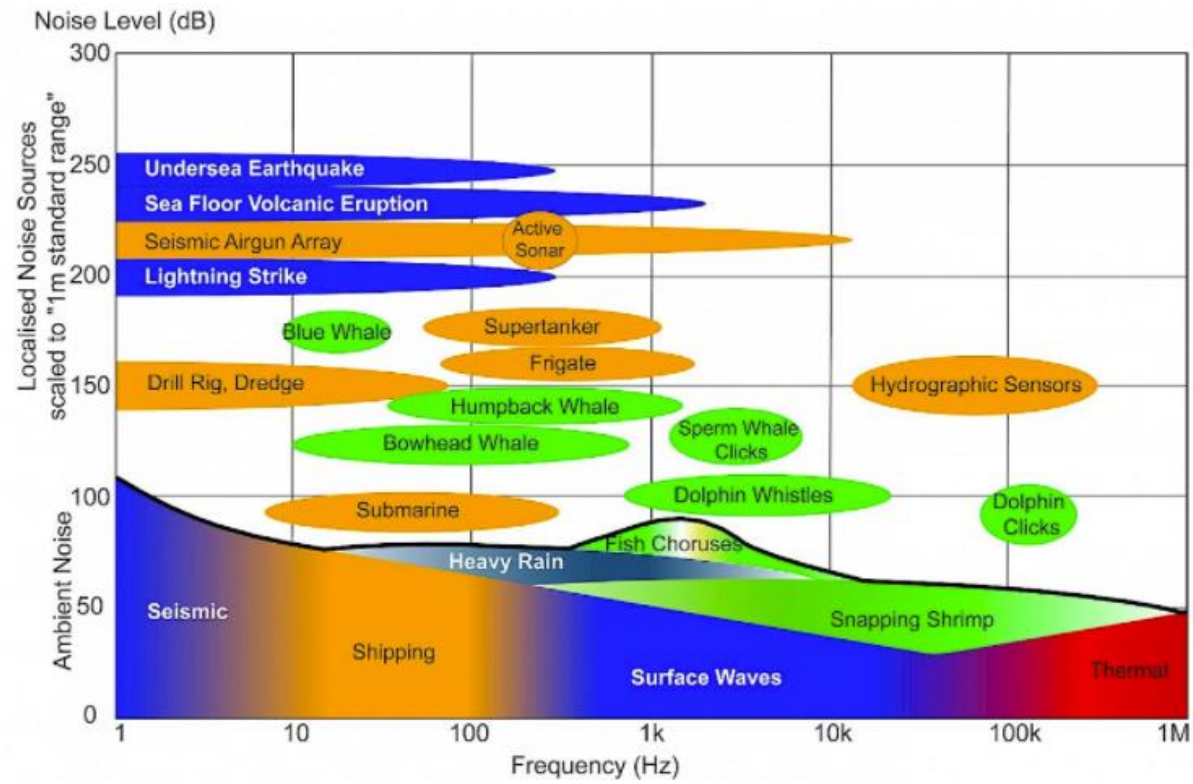

Figure 3-1 – Noise levels and frequencies of anthropogenic and natural noise sources in the marine environment. Source: https://www.ospar.org/work-areas/eiha/noise

In the vicinity of the Project, noise levels are primarily influenced by vessel traffic as well as natural sources such as wind, waves, precipitation and marine mammal vocalizations. Figure 3-2 shows the high number of existing vessel trips in 2022 in the vicinity of the Project. There are several major ports on the coast of South Africa, including Cape Town, Mossel Bay, Gqeberha, East London, and Durban. Therefore, it is expected that existing underwater noise levels in the vicinity of the Project are significantly impacted by existing vessel traffic.

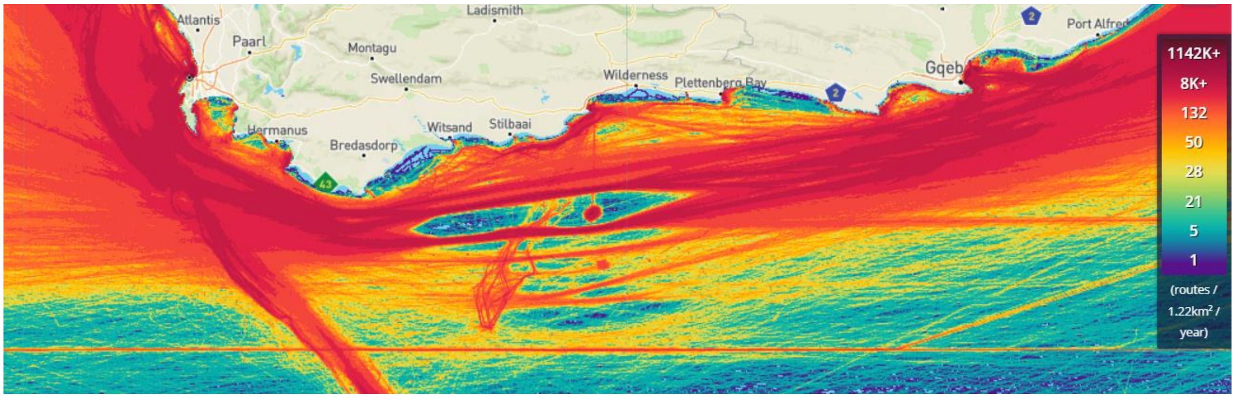

Figure 3-2 – Existing vessel traffic in 2022 in the vicinity of the Project. Source: https://www.marinetraffic.com/

Ambient noise levels generally range from 80 dB to 120 dB re 1 µPa in the frequency range of 10 Hz to 10 kHz, depending on the sea state and shipping traffic (Swan *et al*., 1994). Shipping activities may increase short term noise levels by 20 dB to 30 dB (National Research Council, 2003) and therefore, based on the local shipping traffic activity surrounding the Project, average ambient noise levels are expected to be at the higher end of the typical ambient sound level range, or slightly above (i.e., 100 dB to 130 dB re 1 µPa for the frequency range 10 Hz to 10 kHz).

4 RESULTS

The following sections present the results of the underwater noise modelling and compare predicted noise levels exposure from drilling, VSP and sonar surveys with marine species thresholds discussed in Section 2.1.2 to estimate the different zones of impacts. Appendix B presents figures showing predicted unweighted SPL_{rms} noise contours for each modelled activity and location. Helicopter noise was assessed qualitatively and is presented below.

4.1 DRILLING ACTIVITIES

Noise contours representing the unweighted SPL_{rms} noise levels from the drilling scenarios modelled, including support vessels, are presented in Figure B-1 (location L1) and Figure B-2 (location L3).

The predicted distances for the drilling scenarios modelled at L1 and L3, including one drill unit, one tugboat and one support vessel, to the TTS and PTS injury thresholds for **continuous noise** for marine mammals and sea turtles are presented in Table 4-1.

Table 4-1 – Predicted Distances to Marine Mammal and Sea Turtle Injury Thresholds for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) during Continuous Drilling Activities Considering 24-Hour or 30-Minute Exposure in a 24-Hour Period

Hearing Group	TTS			PTS		
	SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L3)		SEL24h Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L3)	
		24 Hrs	30 Mins		24 Hrs	30 Mins
Low Frequency (LF) Cetaceans	179	6,350 / 9,000	350 / 380	199	240 / 250	20
High Frequency (HF) Cetaceans	178	240 / 330	20	198	< 10	< 10
Very High-Frequency (VHF) Cetaceans	153	8,450 / 8,600	490 / 790	173	240 / 400	20
Sirenians (SI)	186	160 / 180	10	206	< 10	< 10
Phocid Carnivores in Water (PCW)	181	760 / 1,400	90	201	50	< 10
Other Marine Carnivores in Water (OCW)	199	60	< 10	219	< 10	< 10
Sea Turtles	200	310 / 330	10	220	10	< 10

Note: Single distance to threshold number indicates the same predicted result at L1 and L3.

The predicted distances for the modelled drilling scenario to the impairment thresholds for continuous noise for fish are presented in Table 4-2.

Table 4-2 – Predicted Distances to Fish Thresholds during Continuous Drilling Activities

Type of Fish	Recoverable Injury		TTS	
	SPL_{rms} for 48 Hours Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)	SPL_{rms} for 12 Hours Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)
Fish: Swim bladder involved in hearing	170	30	158	150 / 160

Note: Single distance to threshold number indicates the same predicted result at L1 and L3.

The predicted distances for the modelled drilling scenario to the behavioural thresholds for continuous noise for marine mammals, sea turtles, and penguins and diving birds are presented in Table 4-3.

Table 4-3 – Predicted Distances to Behavioural Thresholds during Drilling Activities

Hearing Group	SPL_{rms} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)
Marine Mammals	120	66,000 / 65,000
Sea Turtles	175	10
Fish	150	420 / 440
Penguins / Diving Birds	120	11,800 / 10,400

Notes: Single distance to threshold number indicates the same predicted result at L1 and L3.
Calculation of distance to threshold for penguins/diving birds includes a frequency weighting for OCW.

4.2 VERTICAL SEISMIC PROFILING

Noise contours representing the unweighted SPL_{rms} noise levels from the VSP scenarios modelled are presented in Figure B-3 (location L1) and Figure B-4 (location L3).

The predicted distances for **a single VSP pulse to the SPL_{peak}** TTS and PTS injury thresholds for **impulsive noise** for marine mammals and sea turtles are presented in Table 4-4.

Table 4-4 – Predicted Distances to Marine Mammal and Sea Turtle Injury Thresholds for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) for Peak Exposure during VSP

Hearing Group	TTS		PTS	
	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)
Low Frequency (LF) Cetaceans	213	< 10	219	< 10
High Frequency (HF) Cetaceans	224	< 10	230	< 10
Very High-Frequency (VHF) Cetaceans	196	50	202	20
Sirenians (SI)	220	< 10	226	< 10

Hearing Group	TTS		PTS	
	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)
Phocid Carnivores in Water (PCW)	212	< 10	218	< 10
Other Marine Carnivores in Water (OCW)	226	< 10	232	< 10
Sea Turtles	226	< 10	232	< 10

Note: Single distance to threshold number indicates the same predicted result at L1 and L3.

The predicted distances for the VSP scenarios modelled, including 50 pulses and 250 pulses per day, to the 24-hour SEL TTS and PTS injury thresholds for impulsive noise for marine mammals and sea turtles are presented in Table 4-5.

Table 4-5 – Predicted Distances to Marine Mammal and Sea Turtle Injury Thresholds for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) Exposure during VSP Considering 50 or 250 Pulses in a 24-Hour Period

Hearing Group	TTS			PTS		
	SEL_{24h} Threshold (dB re 1 µPa^2-s)	Distance to Threshold (m) (L1 / L3)		SEL_{24h} Threshold (dB re 1 µPa^2-s)	Distance to Threshold (m) (L1 / L3)	
		50 Pulses	250 Pulses		50 Pulses	250 Pulses
Low Frequency (LF) Cetaceans	168	550 / 600	1,450 / 2,200	183	80	200 / 210
High Frequency (HF) Cetaceans	170	< 10	< 10	185	< 10	< 10
Very High-Frequency (VHF) Cetaceans	140	30	130 / 100	155	< 10	10
Sirenians (SI)	175	< 10	< 10	190	< 10	< 10
Phocid Carnivores in Water (PCW)	170	70 / 60	150 / 160	185	< 10	20
Other Marine Carnivores in Water (OCW)	188	10	10	203	< 10	< 10
Sea Turtles	189	70	170	204	< 10	20

Note: Single distance to threshold number indicates the same predicted result at L1 and L3.

The predicted distances for a single VSP pulse to the SPL_{peak} injury thresholds for impulsive noise for fish are presented in Table 4-6.

Table 4-6 – Predicted Distances to Fish Injury Thresholds for Peak Exposure during VSP

Type of Fish	Mortality and potential mortal injury		Recoverable Injury	
	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)
Fish: No swim bladder	213	< 10	213	< 10
Fish: Swim bladder not involved in hearing	207	10	207	10
Fish: Swim bladder involved in hearing	207	10	207	10
Fish eggs and fish larvae	207	10	n/a	-

Note: Single distance to threshold number indicates the same predicted result at L1 and L3.
n/a = no threshold.

The predicted distances for the VSP scenarios modelled, including 50 pulses and 250 pulses per day, to the 24-hour SEL injury thresholds for impulsive noise for fish are presented in Table 4-7.

Table 4-7 – Predicted Distances to Fish Thresholds for 24-Hour Exposure during VSP

Type of Fish	Mortality and potential mortal injury			Recoverable Injury			TTS		
	SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L3)		SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L3)		SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L3)	
		50 Pulses	250 Pulses		50 Pulses	250 Pulses		50 Pulses	250 Pulses
Fish: No swim bladder	219	< 10	< 10	216	< 10	< 10	186	160	370 / 400
Fish: Swim bladder not involved in hearing	210	< 10	20	203	20	40	186	160	370 / 400
Fish: Swim bladder involved in hearing	207	10	30	203	20	40	186	160	370 / 400
Fish eggs and fish larvae	210	< 10	20	n/a	-	-	n/a	-	-

Note: Single distance to threshold number indicates the same predicted result at L1 and L3.
n/a = no threshold.

The predicted distances for the modelled VSP scenario to the behavioural thresholds for impulsive noise for marine mammals, sea turtles, and penguins and diving birds are presented in Table 4-8.

Table 4-8 – Predicted Distances to Behavioural Thresholds during VSP

Hearing Group	SPL_{rms} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L3)
Marine Mammals	160	1,850 / 2,000
Sea Turtles	175	330 / 350
Fish	150	6,900 / 7,050
Penguins / Diving Birds	120	16,600 / 19,200

Note: Calculation of distance to threshold for penguins/diving birds includes a frequency weighting for OCW.

4.3 SONAR SURVEYS

For high frequency sources, such as sonar sources with a frequency range of 40 kHz or greater, they are **not expected to cause adverse hearing impacts on sea turtles** due to their low frequency hearing ranges (Finneran *et al*., 2017).

Note that, as discussed in Section 2.3.3, due to the directivity of the sonar source (140° beam angle in the cross-track direction, 2° beam angle in the along-track direction), the distances below are applicable in the cross-track direction only and impacts to a single receptor are expected due to one pulse only as the source is moving.

Noise contours representing the unweighted SPL_{rms} noise levels from the sonar survey scenarios modelled are presented in Figure B-5 (location L1) and Figure B-6 (location L2).

The predicted distances for the sonar survey to the SPL_{peak} TTS and PTS injury thresholds for impulsive noise for marine mammals are presented in Table 4-9.

Table 4-9 – Predicted Distances to Marine Mammal Injury Thresholds for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) for Peak Exposure during a Sonar Survey

Hearing Group	TTS		PTS	
	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L2)	SPL_{peak} Threshold (dB re 1 µPa)	Distance to Threshold (m) (L1 / L2)
Low Frequency (LF) Cetaceans	213	20	219	< 10
High Frequency (HF) Cetaceans	224	< 10	230	< 10
Very High-Frequency (VHF) Cetaceans	196	110 / 120	202	60 / 70
Sirenians (SI)	220	< 10	226	< 10
Phocid Carnivores in Water (PCW)	212	20	218	< 10
Other Marine Carnivores in Water (OCW)	226	< 10	232	< 10

Note: Single distance to threshold number indicates the same predicted result at L1 and L2.

The predicted distances for the sonar survey to the 24-hour SEL TTS and PTS injury thresholds for impulsive noise for marine mammals are presented in Table 4-10.

Table 4-10 – Predicted Distances to Marine Mammal Injury Thresholds for Permanent Threshold Shift (PTS) and Temporary Threshold Shift (TTS) for 24-Hour Exposure during Sonar Surveys

Hearing Group	TTS		PTS	
	SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L2)	SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L2)
Low Frequency (LF) Cetaceans	168	20	183	< 10
High Frequency (HF) Cetaceans	170	70 / 80	185	10
Very High-Frequency (VHF) Cetaceans	140	640 / 860	155	270 / 350
Sirenians (SI)	175	10	190	< 10
Phocid Carnivores in Water (PCW)	170	30	185	< 10
Other Marine Carnivores in Water (OCW)	188	< 10	203	< 10

Note: Single distance to threshold number indicates the same predicted result at L1 and L2

The predicted distances for the sonar survey to the SPL_{peak} injury thresholds for impulsive noise for fish are presented in Table 4-11.

Table 4-11 – Predicted Distances to Fish Thresholds for Peak Exposure during Sonar Surveys

Type of Fish	Mortality and potential mortal injury		Recoverable Injury	
	SPL_{peak} Threshold (dB re 1 μPa)	Distance to Threshold (m) (L1 / L2)	SPL_{peak} Threshold (dB re 1 μPa)	Distance to Threshold (m) (L1 / L2)
Fish: No swim bladder (particle motion detection)	213	20	213	20
Fish: Swim bladder not involved in hearing (particle motion detection)	207	40	207	40
Fish: Swim bladder involved in hearing (primarily pressure detection)	207	40	207	40
Fish eggs and fish larvae	207	40	n/a	-

Note: Single distance to threshold number indicates the same predicted result at L1 and L2.
n/a = no threshold.

The predicted distances for the sonar survey to the 24-hour SEL injury thresholds for impulsive noise for fish are presented in Table 4-12.

Table 4-12 – Predicted Distances to Fish Thresholds for 24-Hour Exposure during Sonar Surveys

Type of Fish	Mortality and potential mortal injury		Recoverable Injury		TTS	
	SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L2)	SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L2)	SEL_{24h} Threshold (dB re 1 μPa^2-s)	Distance to Threshold (m) (L1 / L2)
Fish: No swim bladder (particle motion detection)	219	< 10	216	< 10	186	10
Fish: Swim bladder not involved in hearing (particle motion detection)	210	< 10	203	< 10	186	10
Fish: Swim bladder involved in hearing (primarily pressure detection)	207	< 10	203	< 10	186	10
Fish eggs and fish larvae	210	< 10	n/a	-	n/a	-

Note: Single distance to threshold number indicates the same predicted result at L1 and L2.
n/a = no threshold.

The predicted distances for the sonar survey to the behavioural thresholds for impulsive noise for marine mammals and penguins and diving birds are presented in Table 4-13.

Table 4-13 – Predicted Distances to Behavioural Thresholds during Sonar Surveys

Hearing Group	SPL_{rms} Threshold (dB re 1 μPa)	Distance to Threshold (m) (L1 / L2)
Marine Mammals	160	850 / 1,120
Fish	150	1,190 / 1,480
Penguins / Diving Birds	120	1,920 / 2,450

4.4 HELICOPTERS

Note that, as discussed in Section 1.2.4, helicopters will be used to transport personnel to and from the offshore facilities as required. Noise from helicopters will be transient and the majority of the sound will be reflected by the surface of the ocean (Richardson *et al*., 1995). Underwater noise levels from helicopters range from 101 dB to 109 dB re 1 µPa, and helicopter noise has been documented to be detectible for less than one minute under water (Richardson *et al*., 1995). Therefore, underwater noise impacts from helicopter noise are expected to be much less than those from other Project activities and have not been further assessed.

4.5 SUMMARY

Table 4-14 outlines a summary of the maximum distances to thresholds described in the previous sections. In the cases where a threshold type has multiple threshold values (i.e., for impulsive sources, PTS and TTS have both SPL_{Peak} and SEL_{24} thresholds), the distance provided is the maximum predicted distance.

Table 4-14 – Summary of Maximum Predicted Distances to Thresholds

Hearing Group	Threshold Type	Maximum Distance to Threshold (m)				
		Drilling		VSP		Sonar
		24 Hour	30 Min	250 Pulses	50 Pulses	
Marine Mammals	PTS	400 (VHF)	20	210 (LF)	80 (LF)	350 (VHF)
	TTS	9,000 (LF)	790 (VHF)	2,200 (LF)	600 (LF)	860 (VHF)
	Behavioural	66,000		2,000		1,120
Sea Turtles	PTS	10	<10	20	<10	n/a
	TTS	330	10	170	70	n/a
	Behavioural	10		350		n/a
Fish	Mortality and potential mortal injury	n/a		30	10	40
	Recoverable Injury	30		40	20	40
	TTS	160		400	160	10
	Behavioural	440		7,050		1,480
Penguins / Diving Birds	Behavioural	11,800		19,200		2,450

5 CONCLUSIONS

The potential impact of Project activities on marine mammals, sea turtles, fish and penguins and diving birds were assessed, based on anticipated drilling, VSP, and sonar survey activities. Relevant injury and behaviour thresholds for marine mammals and sea turtles are divided based on the frequency weightings of their hearing sensitivities, whereas thresholds for fish depend on the presence or absence of a swim bladder and its role in their ability to hear.

Distances from Project drilling, VSP, and sonar surveys to relevant thresholds were predicted. Within these distances, potential impacts (i.e., injury or changes in behaviour) to marine mammals, sea turtles, fish, and penguins and diving birds may occur.

For **drilling activities**, maximum predicted distances out to TTS thresholds for **marine mammals** were up to 9 km considering 24-hour exposure and 790 m when considering 30-minute exposure. Maximum predicted distances out to PTS thresholds for marine mammals were up to 400 m considering 24-hour exposure and 20 m when considering 30-minute exposure. Maximum predicted distances out to TTS thresholds for **sea turtles** were up to 330 km considering 24-hour exposure and 10 m when considering 30-minute exposure. Maximum predicted distances out to PTS thresholds for sea turtles were up to 10 m considering 24-hour exposure and less than 10 m when considering 30-minute exposure. The maximum predicted distance to thresholds for **fish** was 30 m for a recoverable injury and up to 160 m for TTS. Maximum predicted distances to the marine mammal, sea turtle, fish, and penguin/diving bird **behavioural** thresholds were up to 66 km, 10 m, 440 m, and 11.8 km, respectively.

For **VSP** worst case (250 pulses), maximum predicted distances out to TTS thresholds for **marine mammals** were up to 2.2 km and for **sea turtles** were up to 170 m. Maximum predicted distances out to PTS thresholds for marine mammals were up to 210 m and for sea turtles were up to 20 m. The predicted distances to thresholds for mortality and potential mortal injury to **fish** were up to 30 m and for recoverable injury to fish were up to 40 m. The maximum predicted distance to thresholds for TTS for fish was 400 m. Maximum predicted distances to the marine mammal, sea turtle, fish, and penguin/diving bird **behavioural** thresholds were up to 2 km, 350 m, 7 km, and 19.2 km, respectively.

For **sonar** surveys, maximum predicted distances for **marine mammals** out to TTS thresholds were up to 860 m and to PTS thresholds were up to 350 m. The predicted distances to thresholds for mortality and potential mortal injury or recoverable injury to **fish** were up to 40 m. The maximum predicted distance to thresholds for TTS for fish was 10 m. No impact is expected for **sea turtles**. Maximum predicted distances to the marine mammal, fish, and penguin/diving bird **behavioural** thresholds were up to 1.1 km, 1.5 km, and 2.5 km, respectively.

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Appendix A

SPECIALIST CV

ANDREW FASZER, PEng, INCE, AMIOA

Education

BSc Mechanical Engineering (Co-op) with Distinction, University of Alberta, Edmonton, 2002

Professional Certifications and Affiliations

Professional Engineer (PEng), Association of Professional Engineers and Geoscientists of Alberta and Engineers and Geoscientists BC

Member of the Institute of Noise Control Engineering

Associate Member of the Institute of Acoustics

Member of the American Society of Heating, Refrigerating and Air-Conditioning Engineers

Professional Summary

Andrew is a senior acoustical engineer with over 20 years of experience with development and execution of noise assessments. He leads the noise, light, and vibration disciplines and provides senior supervision, direction, mentoring, and technical leadership to the group. He has over 20 years experience providing technical solutions and project management in the energy, infrastructure, marine, mining, power, oil and gas sectors.

Andrew's technical background and experience in acoustics and noise control spans industries and continents. He has worked in environmental noise and acoustics, architectural acoustics, automotive noise and vibration harshness (NVH) research and development (R&D), aerospace aircraft design R&D, and industrial noise control in North America, Europe, and Japan. Andrew's PhD research was part of the Silent Aircraft Initiative, a joint Cambridge, MIT, and Industry (Boeing, Rolls Royce, etc.) to design a very quiet commercial aircraft and associated systems such as operations and economics.

Employment History

WSP Canada Inc. – Calgary, Alberta, Canada
Senior Engineer (2023 to Present)

Golder Associates Ltd. (WSP Acquisition) – Calgary, Alberta, Canada
Senior Engineer (2014 to 2022)

Noise Solutions Inc. – Calgary, Alberta, Canada
Vice President of Engineering (2011 to 2013)
Engineering Leader (2006 to 2011)
Acoustical Engineer (2002 to 2006)

Transalta Utilities Corporation – Wabamun, Alberta, Canada
Turbine/Condensate Project Leader - Co-op position (May to August 2001)

Zexel Valeo Climate Control Corporation – Kohnan, Saitama, Japan
R&D Experiment Engineer Trainee - Co-op position (May to December 2000)

Chevron Canada Resources – Calgary, Alberta, Canada
Corrosion Engineer Trainee - Co-op position (May to December 1999)

Alberta Energy and Utilities Board – Calgary, Alberta, Canada
Acoustical Technician (May to August 1998)

Faszer Farquharson & Associates Ltd. – Calgary, Alberta, Canada
Technician (January to April 1998)

Patching Associates Acoustical Engineering Ltd. – Calgary, Alberta, Canada
Technical Assistant (May 1997 to January 1998)

SELECTED PROJECT EXPERIENCE

Williams Transcontinental Gas Pipe Line New York Bay Lateral Pipeline Maintenance Project New York, USA	Senior technical review of underwater noise modelling of maintenance, construction, and operations activities to support an Incident Harassment Authorization under the Marine Mammal Protection Act for the 2022 New York Bay Lateral Pipeline Maintenance Project in New York Bay and the Atlantic Ocean, New York State, USA.
WesPac Midstream LLC **Tilbury Marine Jetty** Delta, BC	Noise (underwater and atmospheric) and light component lead and senior technical review of baseline monitoring, data analysis, project modelling, reporting, and working group participation in support of regulatory requirements and applications for the proposed Tilbury Marine Jetty in Delta, British Columbia.
Chevron Corporation **Kitimat LNG** Kitimat, BC	Noise (underwater and atmospheric) and light component lead and senior technical review of baseline monitoring, data analysis, project modelling and assessment, reporting, and working group participation in support of regulatory requirements and applications for the proposed Kitimate LNG facility expansion amendment in Kitimat, British Columbia.
Wolverine Terminals **Prince Rupert Marine Fuels Service** Prince Rupert, BC	Senior technical review of models developed to predict future noise impacts of the Prince Rupert Marine Fuels Service within the Port of Prince Rupert including noise monitoring to establish existing noise levels within the study area and the noise assessment section of the Environmental Effects Evaluation.
Port Metro Vancouver **Roberts Bank Terminal 2** Vancouver, BC	Light component lead of shipping EA amendment and technical expert support through Federal Review Panel regulatory requirements and process including indigenous and public consultation for terminal and shipping amendment in Vancouver, British Columbia.
Bureau of Land Management **Noise Training Course** Denver, CO	Developed and delivery a noise training course to the Bureau of Land Management for use in developing and evaluating environmental assessments and environmental impact statements.
NASA **Kennedy Space Center** Florida, USA	Occupational and operational field measurements and engineering studies on noise impacts and noise reduction on crawler-transporters as part of equipment uprate for the Constellation space program. Noise control equipment engineering and project management of equipment manufacturing for installation on the crawler-transporters.
Origin Energy Limited – Australia Pacific LNG Brisbane, Queensland, Australia	Detailed engineering noise impact assessment of the project infrastructure and noise reduction engineering to meet environmental noise commitments and regulation compliance while optimizing cost efficiency.
ExxonMobil Corporation **WCC LNG** Prince Rupert, BC	Noise and light component lead and senior technical review of baseline monitoring, data analysis, project modelling, reporting, and working group participation in support of regulatory requirements and applications for the proposed WCC LNG facility in Prince Rupert, British Columbia.

Appendix B

NOISE CONTOURS

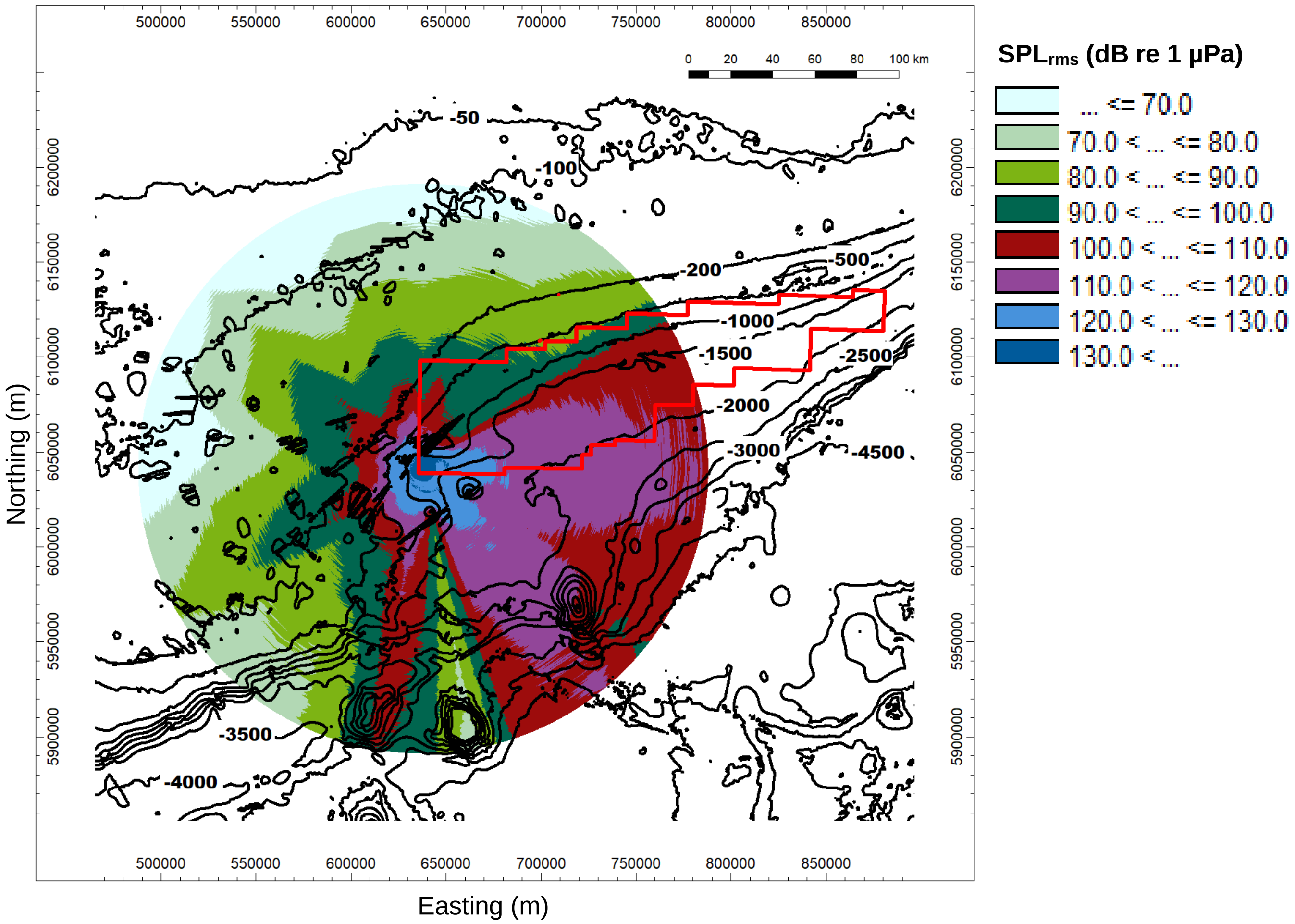

Figure B-1 – Predicted noise level contours (SPL_{rms} in dB re 1 μPa, maximum across the water column) for the modelled drilling scenario at modelling location L1

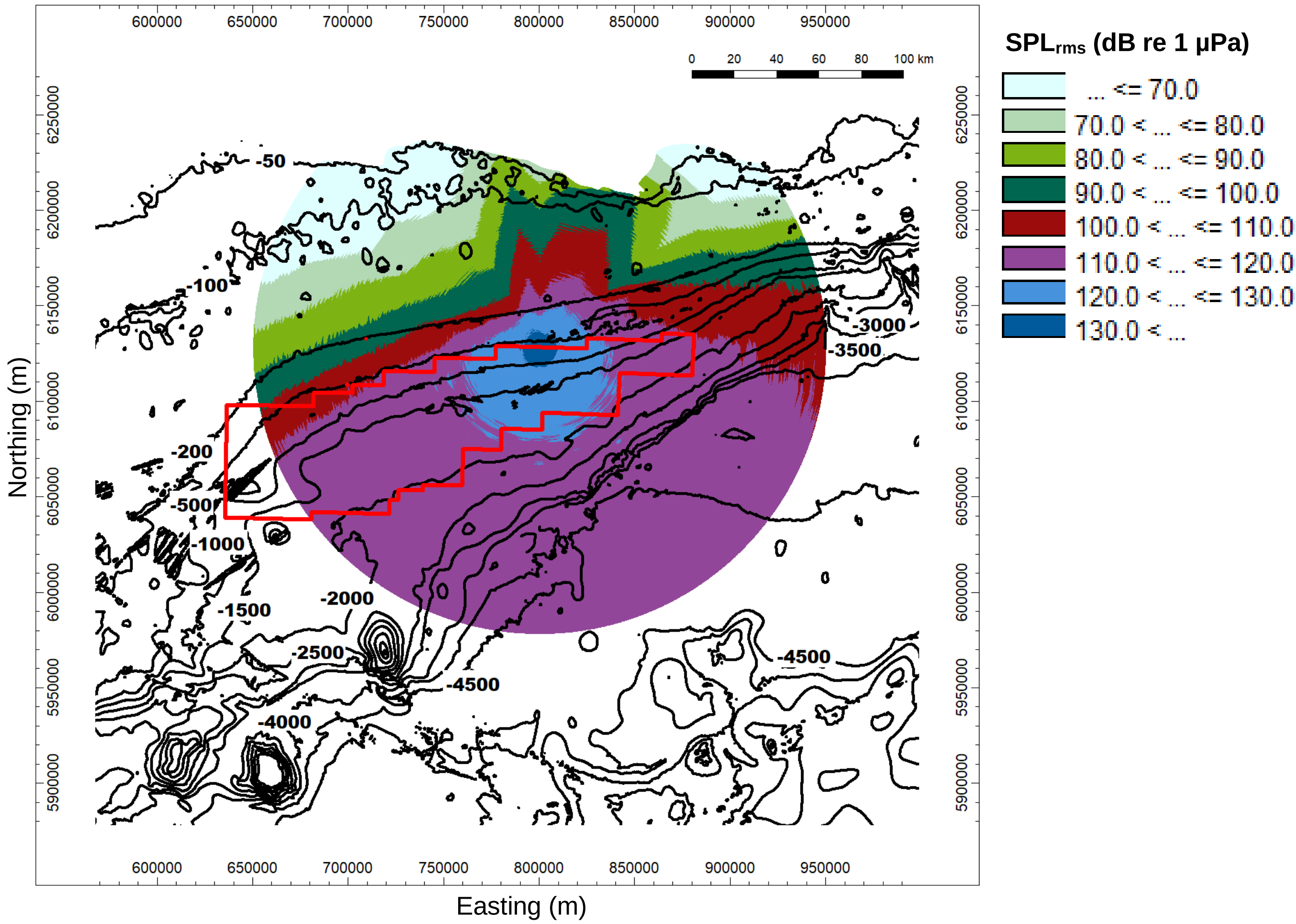

Figure B-2 – Predicted noise level contours (SPL_{rms} in dB re 1 µPa, maximum across the water column) for the modelled drilling scenario at modelling location L3

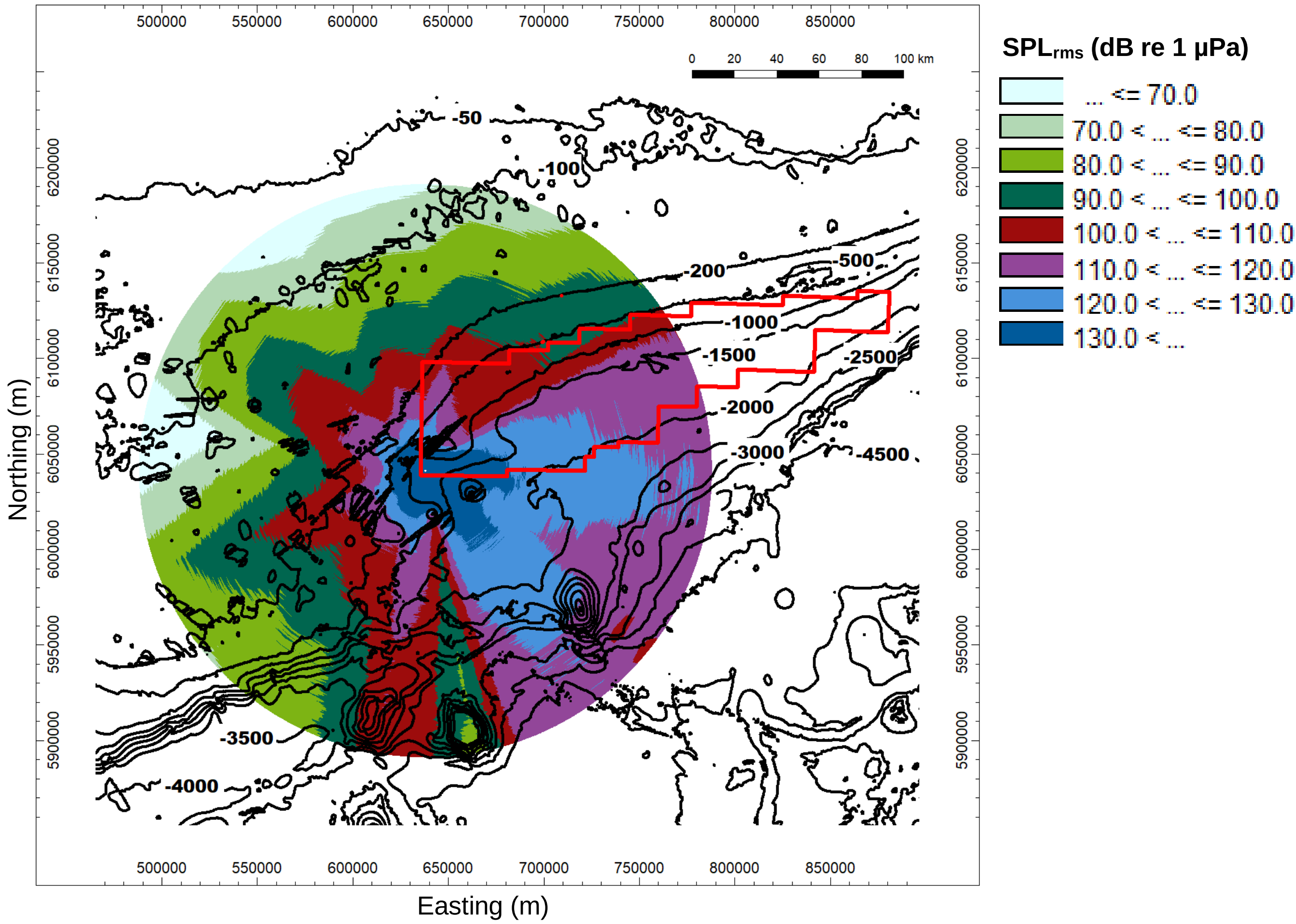

Figure B-3 – Predicted noise level contours (SPL_{rms} in dB re 1 µPa, maximum across the water column) for the modelled VSP scenario at modelling location L1

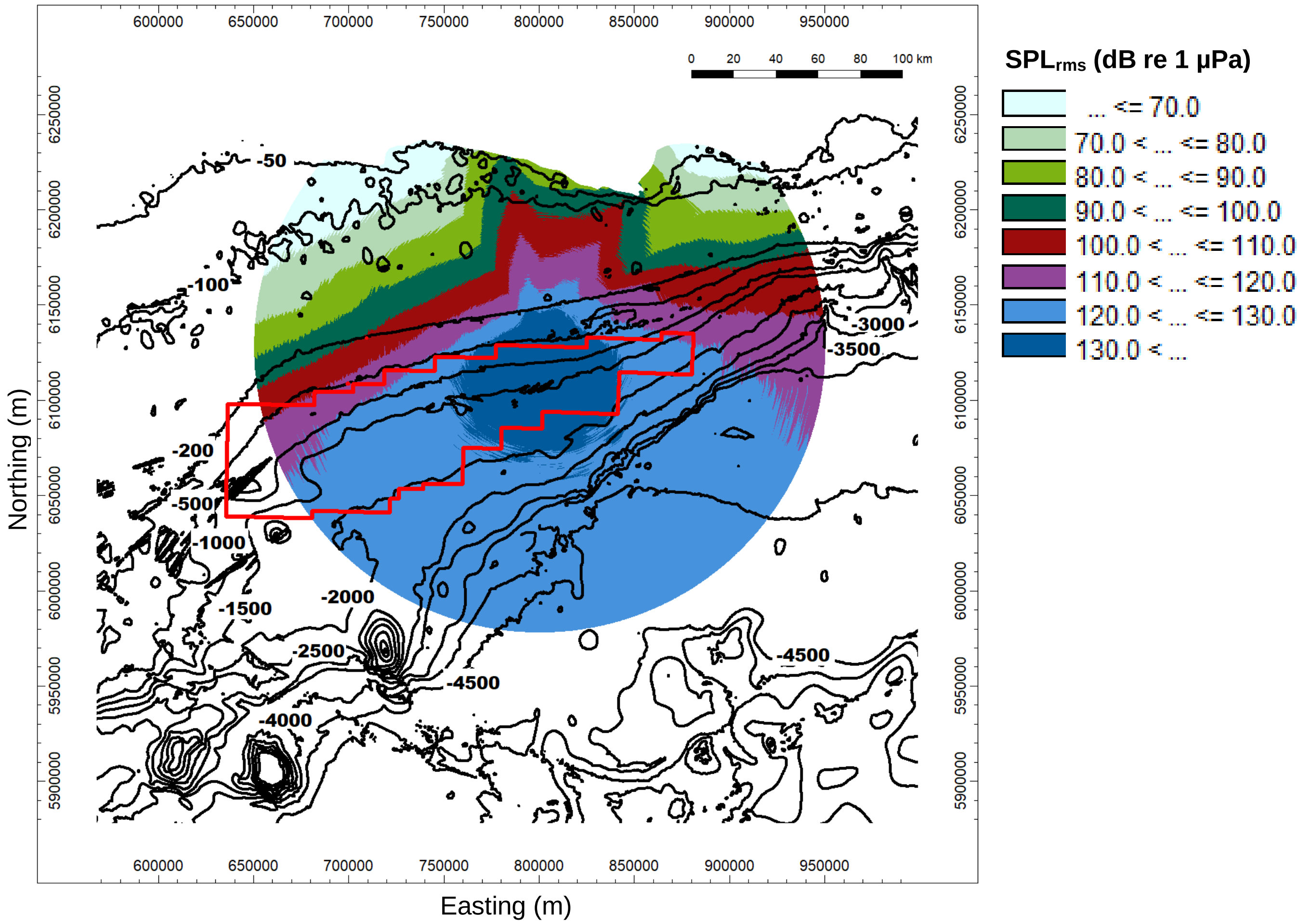

Figure B-4 – Predicted noise level contours (SPL_{rms} in dB re 1 µPa, maximum across the water column) for the modelled VSP scenario at modelling location L3

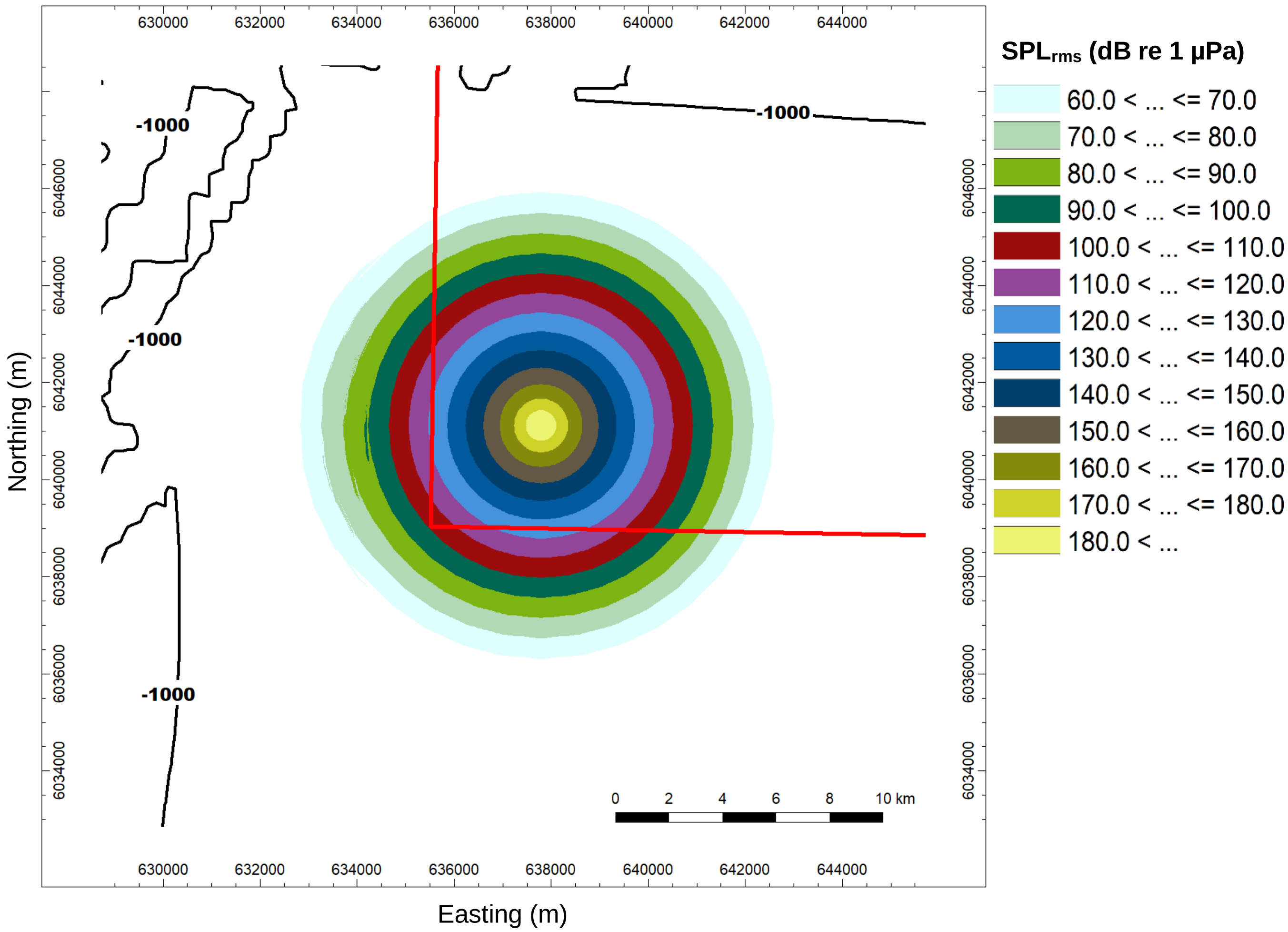

Figure B-5 – Predicted noise level contours (SPL_{rms} in dB re 1 µPa, maximum across the water column) for the modelled sonar survey scenario at modelling location L1

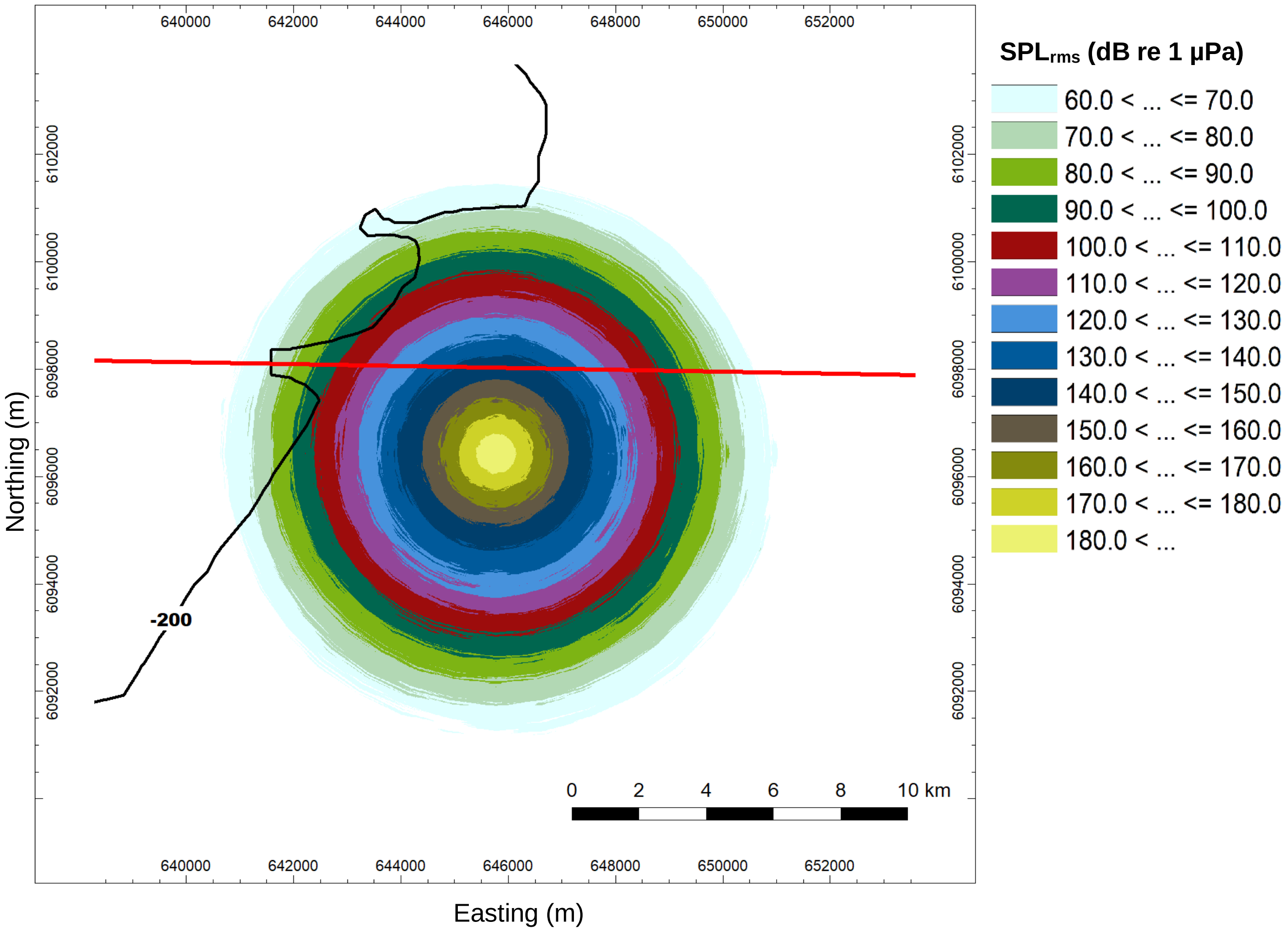

Figure B-6 – Predicted noise level contours (SPL_{rms} in dB re 1 µPa, maximum across the water column) for the modelled sonar survey scenario at modelling location L2