



# Appendix B

## Noise and Vibration Impact Assessment

## DISCLAIMER

**This disclaimer applies to and governs the disclosure and use of this Environmental Impact Statement ("EIS"), and by reading, using or relying on any part(s) of the EIS you accept this disclaimer in full.**

This Environmental Impact Statement, including the Executive Summary, and all chapters of and attachments and appendices to it and all drawings, plans, models, designs, specifications, reports, photographs, surveys, calculations and other data and information in any format contained and/or referenced in it, is together with this disclaimer referred to as the "**EIS**".

### Purpose of EIS

The EIS has been prepared by, for and on behalf of Wafi Mining Limited and Newcrest PNG 2 Limited (together the "**WGJV Participants**"), being the participants in the Wafi-Golpu Joint Venture ("**WGJV**") and the registered holders of exploration licences EL 440 and EL1105, for the sole purpose of an application (the "**Permit Application**") by them for environmental approval under the Environment Act 2000 (the "**Act**") for the proposed construction, operation and (ultimately) closure of an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management, and related support facilities and services (the "**Project**") in Morobe Province, Independent State of Papua New Guinea. The EIS was prepared with input from consultants engaged by the WGJV Participants and/or their related bodies corporate ("**Consultants**").

The Permit Application is to be lodged with the Conservation and Environment Protection Authority ("**CEPA**"), Independent State of Papua New Guinea.

### Ownership and Copyright

The EIS is the sole property of the WGJV Participants, who reserve and assert all proprietary and copyright ©2018 interests.

### Reliance and Use

The EIS is intended and will be made available to CEPA, for review by CEPA and other applicable agencies of the Government of the Independent State of Papua New Guinea ("**Authorised Agencies**"), for the purpose of considering and assessing the Permit Application in accordance with the Act ("**Authorised Purpose**"), and for no other purpose whatsoever.

The EIS shall not be used or relied upon for any purpose other than the Authorised Purpose, unless express written approval is given in advance by the WGJV Participants.

Except for the Authorised Purpose, the EIS, in whole or in part, must not be reproduced, unless express written approval is given in advance by the WGJV Participants.

This disclaimer must accompany every copy of the EIS.

The EIS is meant to be read as a whole, and any part of it should not be read or relied upon out of context.

### Limits on investigation and information

The EIS is based in part on information not within the control of either the WGJV Participants or the Consultants. While the WGJV Participants and Consultants believe that the information contained in the EIS should be reliable under the conditions and subject to the limitations set forth in the EIS, they do not guarantee the accuracy of that information.

### No Representations or Warranties

While the WGJV Participants, their Related Bodies Corporate and Consultants believe that the information (including any opinions, forecasts or projections) contained in the EIS should be reliable under the conditions and subject to the limitations set out therein, and provide such information in good faith, they make no warranty, guarantee or promise, express or implied, that any of the information will be correct, accurate, complete or up to date, nor that such information will remain unchanged after the date of issue of the EIS to CEPA, nor that any forecasts or projections will be realised. Actual outcomes may vary materially and adversely from projected outcomes.

The use of the EIS shall be at the user's sole risk absolutely and in all respects. Without limitation to the foregoing, and to the maximum extent permitted by applicable law, the WGJV Participants, their Related Bodies Corporate and Consultants:

- do not accept any responsibility, and disclaim all liability whatsoever, for any loss, cost, expense or damage (howsoever arising, including in contract, tort (including negligence) and for breach of statutory duty) that any person or entity may suffer or incur caused by or resulting from any use of or reliance on the EIS or the information contained therein, or any inaccuracies, misstatements, misrepresentations, errors or omissions in its content, or on any other document or information supplied by the WGJV Participants to any Authorised Agency at any time in connection with the Authorised Agency's review of the EIS; and
- expressly disclaim any liability for any consequential, special, contingent or penal damages whatsoever.

The basis of the Consultants' engagement is that the Consultants' liability, whether under the law of contract, tort, statute, equity or otherwise, is limited as set out in the terms of their engagement with the WGJV Participants and/or their related bodies corporate.

### Disclosure for Authorised Purpose

The WGJV Participants acknowledge and agree that, for the Authorised Purpose, the EIS may be:

- copied, reproduced and reprinted;
- published or disclosed in whole or in part, including being made available to the general public in accordance with section 55 of the Act. All publications and disclosures are subject to this disclaimer.

### Development of Project subject to Approvals, Further Studies and Market and Operating Conditions

Any future development of the Project is subject to further studies, completion of statutory processes, receipt of all necessary or desirable Papua New Guinea Government and WGJV Participant approvals, and market and operating conditions.

Engineering design and other studies are continuing and aspects of the proposed Project design and timetable may change.

## NEWCREST MINING LIMITED DISCLAIMER

Newcrest Mining Limited ("**Newcrest**") is the ultimate holding company of Newcrest PNG 2 Limited and any reference below to "Newcrest" or the "Company" includes both Newcrest Mining Limited and Newcrest PNG 2 Limited.

### Forward Looking Statements

The EIS includes forward looking statements. Forward looking statements can generally be identified by the use of words such as "may", "will", "expect", "intend", "plan", "estimate", "anticipate", "continue", "outlook" and "guidance", or other similar words and may include, without limitation, statements regarding plans, strategies and objectives of management, anticipated production or construction commencement dates and expected costs or production outputs. The Company continues to distinguish between outlook and guidance. Guidance statements relate to the current financial year. Outlook statements relate to years subsequent to the current financial year.

Forward looking statements inherently involve known and unknown risks, uncertainties and other factors that may cause the Company's actual results, performance and achievements to differ materially from statements in this EIS. Relevant factors may include, but are not limited to, changes in commodity prices, foreign exchange fluctuations and general economic conditions, increased costs and demand for production inputs, the speculative nature of exploration and project development, including the risks of obtaining necessary licences and permits and diminishing quantities or grades of reserves, political and social risks, changes to the regulatory framework within which the Company operates or may in the future operate, environmental conditions including extreme weather conditions, recruitment and retention of personnel, industrial relations issues and litigation.

Forward looking statements are based on the Company's good faith assumptions as to the financial, market, regulatory and other relevant environments that will exist and affect the Company's business and operations in the future.

The Company does not give any assurance that the assumptions will prove to be correct. There may be other factors that could cause actual results or events not to be as anticipated, and many events are beyond the reasonable control of the Company. Readers are cautioned not to place undue reliance on forward looking statements. Forward looking statements in the EIS speak only at the date of issue. Except as required by applicable laws or regulations, the Company does not undertake any obligation to publicly update or revise any of the forward looking statements or to advise of any change in assumptions on which any such statement is based.

### Non-IFRS Financial Information

Newcrest results are reported under International Financial Reporting Standards (IFRS) including EBIT and EBITDA. The EIS also includes non-IFRS information including Underlying profit (profit after tax before significant items attributable to owners of the parent company), All-In Sustaining Cost (determined in accordance with the World Gold Council Guidance Note on Non-GAAP Metrics released June 2013), AISC Margin (realised gold price less AISC per ounce sold (where expressed as USD), or realised gold price less AISC per ounce sold divided by realised gold price (where expressed as a %), Interest Coverage Ratio (EBITDA/Interest payable for the relevant period), Free cash flow (cash flow from operating activities less cash flow related to investing activities), EBITDA margin (EBITDA expressed as a percentage of revenue) and EBIT margin (EBIT expressed as a percentage of revenue). These measures are used internally by Management to assess the performance of the business and make decisions on the allocation of resources and are included in the EIS to provide greater understanding of the underlying performance of Newcrest's operations. The non-IFRS information has not been subject to audit or review by Newcrest's external auditor and should be used in addition to IFRS information.

### Ore Reserves and Mineral Resources Reporting Requirements

As an Australian Company with securities listed on the Australian Securities Exchange (ASX), Newcrest is subject to Australian disclosure requirements and standards, including the requirements of the Corporations Act 2001 and the ASX. Investors should note that it is a requirement of the ASX listing rules that the reporting of Ore Reserves and Mineral Resources in Australia comply with the 2012 Edition of the Australasian Code for Reporting of Exploration Results, Mineral Resources and Ore Reserves (the JORC Code) and that Newcrest's Ore Reserve and Mineral Resource estimates comply with the JORC Code.

### Competent Person's Statement

The information in the EIS that relates to Golpu Ore Reserves is based on information compiled by the Competent Person, Mr Pasqualino Manca, who is a member of The Australasian Institute of Mining and Metallurgy. Mr Pasqualino Manca, is a full-time employee of Newcrest Mining Limited or its relevant subsidiaries, holds options and/or shares in Newcrest Mining Limited and is entitled to participate in Newcrest's executive equity long term incentive plan, details of which are included in Newcrest's 2017 Remuneration Report. Ore Reserve growth is one of the performance measures under recent long term incentive plans. Mr Pasqualino Manca has sufficient experience which is relevant to the styles of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the JORC Code 2012. Mr Pasqualino Manca consents to the inclusion of material of the matters based on his information in the form and context in which it appears.

### HARMONY GOLD MINING COMPANY LIMITED DISCLAIMER

Harmony Gold Mining Company Limited ("**Harmony**") is the ultimate holding company of Wafi Mining Limited and any reference below to "Harmony" or the "Company" includes both Harmony Gold Mining Company Limited and Wafi Mining Limited.

### Forward Looking Statements

These materials contain forward-looking statements within the meaning of the safe harbor provided by Section 21E of the Securities Exchange Act of 1934, as amended, and Section 27A of the Securities Act of 1933, as amended, with respect to our financial condition, results of operations, business strategies, operating efficiencies, competitive positions, growth opportunities for existing services, plans and objectives of management, markets for stock and other matters. These include all statements other than statements of historical fact, including, without limitation, any statements preceded by, followed by, or that include the words "targets", "believes", "expects", "aims", "intends", "will", "may", "anticipates", "would", "should", "could", "estimates", "forecast", "predict", "continue" or similar expressions or the negative thereof.

These forward-looking statements, including, among others, those relating to our future business prospects, revenues and income, wherever they may occur in this EIS and the exhibits to this EIS, are essentially estimates reflecting the best judgment of our senior management and involve a number of risks and uncertainties that could cause actual results to differ materially from those suggested by the forward-looking statements. As a consequence, these forward-looking statements should be considered in light of various important factors, including those set forth in these materials. Important factors that could cause actual results to differ materially from estimates or projections contained in the forward-looking statements include, without limitation: overall economic and business conditions in South Africa, Papua New Guinea, Australia and elsewhere, estimates of future earnings, and the sensitivity of earnings to the gold and other metals prices, estimates of future gold and other metals production and sales, estimates of future cash costs, estimates of future cash flows, and the sensitivity of cash flows to the gold and other metals prices, statements regarding future debt repayments, estimates of future capital expenditures, the success of our business strategy, development activities and other initiatives, estimates of reserves statements regarding future exploration results and the replacement of reserves, the ability to achieve anticipated efficiencies and other cost savings in connection with past and future acquisitions, fluctuations in the market price of gold, the occurrence of hazards associated with underground and surface gold mining, the occurrence of labour disruptions, power cost increases as well as power stoppages, fluctuations and usage constraints, supply chain shortages and increases in the prices of production imports, availability, terms and deployment of capital, changes in government regulation, particularly mining rights and environmental regulation, fluctuations in exchange rates, the adequacy of the Group's insurance coverage and socio-economic or political instability in South Africa and Papua New Guinea and other countries in which we operate.

For a more detailed discussion of such risks and other factors (such as availability of credit or other sources of financing), see the Company's latest Integrated Annual Report and Form 20-F which is on file with the Securities and Exchange Commission, as well as the Company's other Securities and Exchange Commission filings. The Company undertakes no obligation to update publicly or release any revisions to these forward-looking statements to reflect events or circumstances after the date of this EIS or to reflect the occurrence of unanticipated events, except as required by law.

### Competent Person's Statement

The Wafi-Golpu Joint Venture is an unincorporated joint venture between a wholly-owned subsidiary of Harmony Gold Mining Company Limited and a wholly-owned subsidiary of Newcrest Mining Limited.

The information in the EIS that relates to Golpu Ore Reserves is based on information compiled by the Competent Person, Mr Pasqualino Manca, who is a member of The Australasian Institute of Mining and Metallurgy. Mr Pasqualino Manca, is a full-time employee of Newcrest Mining Limited or its relevant subsidiaries, holds options and/ or shares in Newcrest Mining Limited and is entitled to participate in Newcrest's executive equity long term incentive plan, details of which are included in Newcrest's 2017 Remuneration Report. Ore Reserve growth is one of the performance measures under recent long term incentive plans. Mr Pasqualino Manca has sufficient experience which is relevant to the styles of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the JORC Code 2012. Mr Pasqualino Manca consents to the inclusion of material of the matters based on his information in the form and context in which it appears.

# Wafi-Golpu Project

# Noise and Vibration Impact Assessment

Report Number 620.11677-R02

17 April 2018

Coffey
Level 1, 436 Johnston Street
Abbotsford,
Victoria 3067

Version: v2.0

# Wafi-Golpu Project

# Noise and Vibration Impact Assessment

PREPARED BY:

SLR Consulting Australia Pty Ltd
ABN 29 001 584 612
2 Lincoln Street
Lane Cove NSW 2066 Australia
(PO Box 176 Lane Cove NSW 1595 Australia)
+61 2 9427 8100 +61 2 9427 8200
sydney@slrconsulting.com www.slrconsulting.com

This report has been prepared by SLR Consulting Australia Pty Ltd with all reasonable skill, care and diligence, and taking account of the timescale and resources allocated to it by agreement with the Client. Information reported herein is based on the interpretation of data collected, which has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Coffey Environments Australia Pty Ltd and the Wafi-Golpu Joint Venture for the Wafi-Golpu Project Environmental Impact Statement.
No warranties or guarantees are expressed or should be inferred by any third parties.
This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

## DOCUMENT CONTROL

| Reference | Date | Prepared | Checked | Authorised |
|---|---|---|---|---|
| 620.11677-R02-v2.0 | 17 April 2018 | Mark Russell | John Sleeman | Mark Russell |
| 620.11677-R02-v1.0 | 27 March 2018 | Mark Russell | Martin Davenport | Draft |
| 620.11677-R02-v0.3 | 01 March 2018 | Mark Russell | | Draft |
| 620.11677-R02-v0.2 | 23 February 2018 | Mark Russell | | Draft |
| 620.11677-R02-v0.1 | 22 December 2017 | Mark Russell | Gustaf Reutersward | Draft |

# Executive Summary

## BACKGROUND

Wafi Mining Limited and Newcrest PNG 2 Limited (hereafter WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (hereafter WGJV) and propose to construct, operate and (ultimately) close an underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management, and related support facilities and services (hereinafter the "Wafi-Golpu Project" or the "Project") in the Morobe Province of the Independent State of Papua New Guinea (PNG).

The Project is located approximately 300 kilometres (km) north-northwest of Port Moresby and 65 km southwest of Lae. The focus of the Project is the proposed development and operation of:

- An underground block cave mine located in the Watut River catchment near Mount Golpu;
- Ore processing and concentrate transport/handling facilities;
- A deep sea tailings placement (DSTP) system for tailings management in the Huon Gulf near Lae; and
- Related support services.

Coffey Environments Australia Pty Ltd (Coffey) contracted SLR Consulting Australia Pty Ltd (SLR) to prepare a noise and vibration impact assessment (NVIA). This report will form part of an Environmental Impact Statement (EIS) for the Project.

## NOISE AND VIBRATION ASSESSMENT

Design data available for the Project was reviewed to identify the key project activities that have the greatest potential for impacts on local receptors. Noise emission levels for major sources were derived and modelling studies were performed to predict the magnitude of impacts to identified sensitive receptors, taking into account the local topography and meteorology. The results of the modelling studies were assessed against appropriate international noise guidelines and standards. Activities with a much lower potential for impacts were assessed qualitatively, for example, by nominating appropriate buffer distances between the activity and the nearest sensitive receptors.

Based upon a review of the project information provided, potential noise sources associated with the construction and operation of the Project have been identified as:

- The construction of the Project including the Watut and Nambonga declines, waste rock dumps, portal terraces, process plant terrace, ventilation shaft, accommodation camps and power generation facilities;
- The surface operations of the Project in relation to underground mining activities (16.8 Mtpa)
- The operation of associated borrow pits;
- The construction and operation of the Mine Access Road, Northern Access Road, concentrate, tailings and fuel pipelines and project service roads; and
- The construction and operation of the Port Facilities Area and Outfall Area.

Appropriate noise goals and criteria were developed for modelling potential impacts of the Project based on relevant international guidelines: World Health Organization (WHO) (1999) and International Finance Corporation (IFC) (2007) and on consideration of baseline noise levels collected in a number of locations around the Project Area. Where the WHO or IFC guidelines did not address specific types of activities or noise sources, Australian criteria were considered.

# Executive Summary

A summary of adopted project criteria is detailed below.

| **Activity** | **Source** | **Noise Receiver** | **Time** | Noise Criteria / Goals (measured externally) |
|---|---|---|---|---|
| Normal operations and construction periods longer than three months | Continuous | Residential | Night | 45 dBA $L_{eq,\ 1\ hour}$ |
| | | | Day | 55 dBA $L_{eq,\ 1\ hour}$ |
| | Single events | Residential | Night | 60 dBA $L_{Amax}$ [A] |
| Construction periods less than three months | Continuous | Residential | Night | 45 dBA $L_{eq,\ 1\ hour}$ |
| | | | Day | 75 dBA $L_{eq,\ 1\ hour}$ |
| | Single events | Residential | Night | 60 dBA $L_{Amax}$ [A] |
| Vehicle movements on existing main roads | Intermittent | Residential | Day | No numerical limit |
| | | | Night | 60 dBA $L_{Amax}$ [A] |

The key findings of the noise and vibration impact assessment are summarised below.

**Mine Area Construction**

- A SoundPLAN noise modelling was used to predict noise emissions for the Mine Area construction scenario.
- With the exception of Hekeng, Papas and Ziriruk, the night period project noise criterion of 45 dBA $L_{Aeq}$ is compliant at all receptors for Mine Area construction scenario. Under enhanced (worst case) meteorological conditions, noise levels of up to 50 dBA are predicted, which represents a 5 dBA exceedance of the night-time noise goal. This is considered to be a manageable excess and could be addressed through measures such as more controlled operations in proximity to villages during the night.

**Infrastructure Corridor Construction**

- Indicative noise levels as a function of distance from the noise source have been predicted for the construction of the Infrastructure Corridor, including the concentrate, tailings and fuel pipelines from the Mine Area to the Port Facilities Area and Outfall Area, and the Mine Access Road and Northern Access Road from the Mine Area to the Highlands Highway. Only short-term (i.e., less than three months), day time noise criteria have been considered, as the scheduling of works for construction of the Infrastructure Corridor would be adapted as needed based on the area under construction. This would include for example, construction only during the day when in proximity to villages, with exceptions such as through Lae, where night-work is preferential to minimise the disturbance to users of existing road infrastructure.
- The Infrastructure Corridor passes through or is close to a number of villages including Ziriruk and the city of Lae. These settlements would likely have sensitive receptors that are located within 300 m of construction activity and may experience some short-term noise impacts.
- Road or pipeline construction when passing these settlements will be short-term, with the highest noise levels likely to last for only a few days (or weeks) as the construction front passes.

# Executive Summary

- It is recommended that each settlement is notified as the construction works approach, of the times and duration that they may be affected by noise and vibration emissions from the works. Clear communication methods should be made available so that the affected communities have links to the operational managers, and substantiated complaints can be addressed appropriately and sensitively through the WGJV grievance mechanism process.
- If any blasting is necessary as part of the above construction works then careful consideration and review will be required. Appropriate communication with the local communities would be required in order to manage the impact of blasting activities.

**Port Facilities Area and Outfall Area Construction**

- Indicative offset distance calculations have been conducted for the Port Facilities Area and Outfall Area to assist with planning construction of the Project.
- The closest residential dwelling within Lae to the Port Facilities Area is approximately 1,000 m and the closest village to the Outfall Area is approximately 1,350 m. The day period project noise criterion of 55 dBA $L_{Aeq}$, is met at an offset distance of 200 m under enhanced meteorological conditions, and therefore the criteria of 55 dBA is expected to be achieved at the nearest village under all assumed meteorological conditions
- The construction noise from the Port Facilities Area and Outfall Area does not pose any significant impacts.

**Mine Operation**

- Noise levels associated with the operation of the Mine Area were predicted for both neutral and enhanced (worst case) meteorological propagation conditions. A scenario which included only the power generation facility was used to establish the contribution from the facility in isolation.

**Power Generation Facilities**

- Compliance with the night criterion of 45 dBA is predicted to be achieved at all villages with the exception of Ziriruk, where predictions indicate noise levels of up to 51 dBA under enhanced meteorological conditions. Ziriruk is the closest village to the power generation facilities and proposed management measures are discussed within this report to address this exceedance.

**Mine Operation scenario 16.8 Mtpa**

- At peak operations, noise levels at all nearby villages are predicted to be compliant with the project noise criterion with the exception of Ziriruk, where levels are predicted to be up to 51 dBA under enhanced meteorological conditions, which exceeds the night period project noise criterion of 45 dBA $L_{Aeq}$ by up to 6 dBA. Proposed management measures are discussed within this report to address this exceedance.

**Borrow Pits**

- Noise levels as a function of distance from the use of proposed borrow pits has been predicted and the required offset distance to achieve compliance with the adopted project noise guideline of 55 dBA $L_{Aeq}$ has been determined.
- Noise levels at all villages are expected to comply with the project noise criterion with the exception of Hekeng, which is located within 400m of the Miapilli clay borrow pit. Proposed management measures are discussed within this report to address this exceedance.

**Port Facilities Area Operation**

- The Port Facilities Area is proposed to be built within the port of Lae, and the nearest residential dwellings to the port are located approximately 1,000 m away. The night period project noise criterion of 45 dBA $L_{Aeq}$ is met at an offset distance of 730 m under enhanced propagation meteorological conditions, and 520 m under neutral propagation conditions.

# Executive Summary

- The Port Facilities Area operation is expected to comply with day and night criteria under all meteorological conditions.

**Outfall Area Operation**

- The closest village to the proposed Outfall Area is located at a distance of approximately 1,300 m. The night period project noise goal of 45 dBA $L_{Aeq}$, is met at an offset distance of 500 m assuming a source sound pressure level of 85 dBA at 3 m.
- The operation of the Outfall Area is expected to comply with day and night criteria under all meteorological conditions.

**Access Roads**

- Noise impacts from heavy vehicle movements have been assessed by predicting maximum pass-by noise levels at offset distances from the mine access road. Night period pass-bys are the most critical as they potentially lead to sleep disturbance.
- Analysis of vehicle pass-by noise levels shows that a buffer distance of approximately 80 m is required to achieve the night period criterion of 60 dBA, $L_{max}$.
- For the day, a buffer distance of approximately 15 m would be sufficient to achieve 75 dBA, $L_{max}$ which is considered reasonable for infrequent short-term pass-by noise levels.
- It is anticipated that the Northern Access Road and the Mine Access Road would be the primary haulage route for supplies and staff transportation from Lae to the Mine Area once constructed and as such, compliance with the sleep disturbance criteria of 60 dBA $L_{max}$ would be achieved provided villages are no closer than 80 m. As currently proposed, the distance between the Northern Access Road/Mine Access Road and villages ranges from approximately 570 m up to 2,700 m.

**Noise Impacts on Fauna**

Generally, terrestrial fauna will avoid areas where very high noise levels (sufficient to cause injury or damage) occur. It is anticipated that noise levels in excess of 100 dBA, over extensive periods, would be required to create physical damage or injury (World Health Organization, 2015). It is unlikely that any terrestrial fauna would remain in any area affected by noise levels of this order. Indeed, it is noted that the construction and operation of the Project will not include plant and equipment capable of generating noise levels required to cause such damage, even in very close vicinity to the plant and equipment.

**Vibration**

The vibration study has been divided into two categories as follows:

1. Blasting activities
2. General construction and operation vibration sources (excluding blasting) such as rock breaking, heavy vehicles, compaction, etc.

All existing identified sensitive receptors are well beyond the offset distances required for project blasting activities and therefore compliance with the project criteria would be achieved.

Vibration levels from general construction and operational activities (i.e. excluding blasting) have been predicted and assessed against the project guidelines. Due to the large distances between the project sites, project-related infrastructure and the nearest existing sensitive receptors, compliance would be readily achieved.

# Executive Summary

The predicted vibration emissions presented in this report indicate that vibration from the Project is not expected to adversely impact on the surrounding environment.

# Table of Contents

# Table of Contents

# Table of Contents



**TABLES**



**FIGURES**

# Table of Contents



## Abbreviations

| | |
|---|---|
| % | Percent |
| °C | degrees Celsius |
| AS | Australian Standards |
| BC1 | Block Cave 1 |
| BC2 | Block Cave 2 |
| CEMP | Construction Environmental Management Plan |
| CoRTN | Calculation of Road Traffic Noise |
| dBA | decibels (A weighted) |
| dBL | decibels (unweighted or linear) |
| EHS | Environmental Health & Safety |
| EIS | Environmental Impact Statement |
| EMB | Environmental Management Bureau |
| FEL | front-end loader |
| g | gram |
| G | Ground Absorption |
| ha | hectares |
| HDPE | High Density Polyethylene |
| Hz | Hertz (unit of measurement for frequency) |
| IFC | International Finance Corporation |
| INP | Industrial Noise Policy |
| IPP | Independent power producer |
| kg | kilograms |
| km | kilometres |

# Table of Contents

| | |
|---|---|
| LHD | load-haul-dump |
| m | metres |
| $m^2$ | Square metre |
| $m^3$ | Cubic metre |
| m/s | meters/second |
| MIC | Maximum Instantaneous Charge |
| mm | millimetres |
| mm/s | millimetres/second |
| Moz | Million ounces |
| Mt | Million Tonnes |
| Mtpa | Million Tonnes per annum |
| NATA | National Association of Testing Authorities |
| NAF | Non Acid Forming |
| NSW DECCW | New South Wales Department of Environment Climate Change and Water |
| NVIA | Noise and Vibration Impact Assessment |
| PAF | Potentially Acid Forming |
| PNG | Papua New Guinea |
| PPV | Peak Particle Velocity |
| RAW | Return Airway |
| ROM | Run-of-Mine |
| SAG | Single stage Semi Autogenous Grinding |
| SLR | SLR Consulting Australia Pty Ltd |
| SWL | Sound Power Level |
| t | tonne |
| USBM | United States Bureau of Mines |
| WGJV | Wafi-Golpu Joint Venture |
| WHO | World Health Organization |
| WRD | Waste Rock Dump |

# Table of Contents

## Glossary

| | |
|---|---|
| CONCAWE | CONCAWE Report 4/81 “The propagation of noise from petroleum and petrochemical complexes to neighbouring communities” prediction method |
| Fast | Time weighting constant of 125 milliseconds |
| Free-field | Noise measurement or prediction conducted at a minimum of 4 m from a building façade and where no façade reflections is observed/incorporated |
| LA10 (dBA) | Noise level (in decibels – A weighted) exceeded for 10% of the measurement period |
| LA90 (dBA) | Noise level (in decibels – A weighted) exceeded for 90% of the measurement period |
| LAeq (1hour) | Equivalent continuous (or ‘average’) noise level (in decibels – A weighted) over a 1 hour measurement period |
| LAmax | Maximum A-weighted noise level associated with site activity |
| LAmax,adj T | Noise level is the average of the maximum noise levels during time period T adjusted for tonality and impulsiveness |
| LAeq (dBA) | Equivalent continuous (or ‘average’) noise level (in decibels – A weighted) |
| dBA | “A-weighting” filter incorporated in sound level meters. The “A-weighting” filter has a frequency response corresponding approximately to that of human hearing. |
| dBL | “Linear-weighting” filter incorporated in sound level meters. The “Linear-weighting” filter has a flat (or unweighted) frequency response. |
| MIC | The Maximum Instantaneous Charge (MIC) is the maximum amount of explosive in kg on any one specific delay detonator in any one blast hole |
| Sinusoidal Vibration | A waveform whose variation as a function of time is a sine wave |
| Sleep Disturbance | Awakening and disturbance to sleep stages |

# 1 INTRODUCTION

Wafi Mining Limited and Newcrest PNG 2 Limited (WGJV Participants) are equal participants in the Wafi-Golpu Joint Venture (the WGJV). The WGJV is investigating the feasibility of constructing, operating and (ultimately) closing a proposed underground copper-gold mine and associated ore processing, concentrate transport and handling, power generation, water and tailings management, and related support facilities and services (hereinafter the "Wafi-Golpu Project" or the "Project"). The proposed mine is located beneath Mt Golpu, approximately 300 kilometres (km) north-northwest of Port Moresby and 65 km southwest of Lae in the Morobe Province of the Independent State of Papua New Guinea (PNG).

Coffey Environments Australia Pty Ltd (Coffey) contracted SLR Consulting Australia Pty Ltd (SLR) to prepare a Noise and Vibration Impact Assessment (NVIA) for the Project to address the relevant PNG regulatory requirements and international standards. This report will form part of an environmental impact statement (EIS) for the Project. It describes the method used in the assessment, summarises the results of the assessment and describes both the management measures proposed to mitigate potential impacts of the Project and the predicted residual impacts assuming these measures are implemented.

## 1.1 Structure of this Report

This report describes the study methods used in the assessment, summarises the results of the assessment and describes the management measures proposed to mitigate the potential air quality impacts of the Project and the predicted residual impacts assuming these measures are implemented.

The structure of this report is outlined below.

- **Section 1** outlines the objectives of the NVIA and the report structure.
- **Section 2** provides a brief outline of the Project and identifies the proposed construction and operational activities with the potential to give rise to noise emissions.
- **Section 3** describes the study area with respect to the topography, land use, climate, sensitive receptors and existing noise environment.
- **Section 4** defines the noise and vibration assessment criteria applicable to the project.
- **Section 5** describes the assessment methodology used to assess noise impacts associated with the proposed construction and operational activities.
- **Section 6** presents the assessment of noise impacts associated with the proposed construction and operational activities.
- **Section 7** presents the assessment of vibration impacts associated with the proposed construction and operational activities.
- **Section 8** outlines the recommended mitigation and monitoring measures.
- **Section 9** summarises the key findings of the noise and vibration assessment.

## 1.2 Assessment Method

This NVIA has been undertaken using a combination of quantitative and qualitative assessment techniques.

Project design information was initially reviewed to identify the project activities that have the greatest potential for impact on local receptors, which were then assessed quantitatively. Noise emission levels for major sources were derived and modelling studies were performed to predict the magnitude of impacts to identified receptors taking into account the local topography and meteorology. The results of the modelling studies were assessed against appropriate international noise guidelines and standards.

Activities such as blasting, construction and operation of the Port Facilities Area and Outfall Area, and construction of the Northern Access Road, Mine Access Road, haulage roads within the SML area, and concentrate, tailings and fuel pipelines, and vehicular emissions on access roads were assessed qualitatively, for example, by specifying the offset distance at which the activity will achieve compliance with a relevant criterion.

# 2 PROJECT DESCRIPTION

## 2.1 Project Overview

The Project includes mining, ore processing, concentrate transport and handling, power generation, water management, a deep sea tailings placement (DSTP) system for tailings management, access roads to the mine and related support facilities.

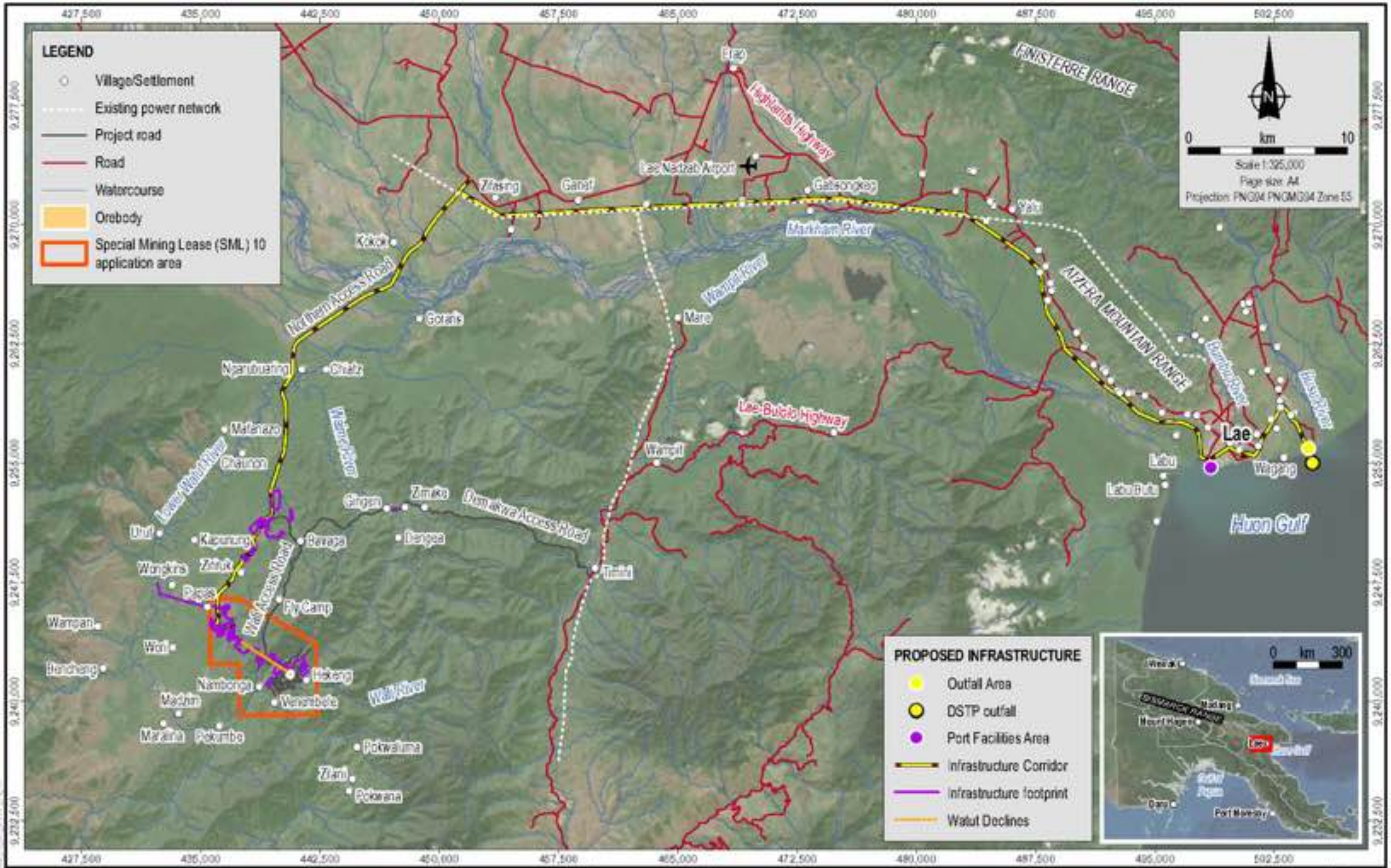
Geographically, the Project occupies a mine to coast footprint that extends from the Mine Area to the Coastal Area with an Infrastructure Corridor that links the two areas. Together these discrete areas make up the proposed Project Area:

- **Mine Area.** The area encompassing the proposed block cave mine, underground access declines and nearby infrastructure, including a portal terrace and waste rock dump supporting each of the Watut and Nambonga declines, the Watut Process Plant, power generation facilities, laydown areas, water treatment facilities, quarries, wastewater discharge and raw water make-up pipelines, raw water dam, sediment control structures, roads and accommodation facilities for the construction and operations workforces.
- **Infrastructure Corridor.** The area encompassing the proposed Project infrastructure linking the Mine Area and the Coastal Area, being corridors for pipelines and roads and associated laydown areas. The proposed concentrate pipeline, terrestrial tailings pipeline and fuel pipeline will connect the Mine Area to the Coastal Area. A proposed Mine Access Road and Northern Access Road will connect the Mine Area to the Highlands Highway. New single-lane bridges are proposed over the Markham, Watut and Bavaga rivers. Laydown areas will be located at key staging areas.
- **Coastal Area.** The Coastal Area includes the proposed Port Facilities Area and the proposed Outfall Area:
    - Port Facilities Area. Located at, or in proximity to, the Port of Lae, with a site adjacent to Berth 6 (also known as Tanker Berth) nominated as the preferred option. The proposed facilities will include the concentrate filtration plant and materials handling, storage, ship loading facilities and filtrate discharge pipeline.
    - Outfall Area. Located approximately six kilometres east of the port. The proposed facilities will include the Outfall System comprising the mix/de-aeration tank and associated facilities, seawater intake pipelines and DSTP outfall pipelines, pipeline laydown area, choke station, access track and parking turnaround area.

The WGJV has commissioned a range of studies to inform the Project's Feasibility Study Update and to prepare an Environmental Impact Statement (EIS).

Future development of the Project remains subject to ongoing deep orebody drilling and definition (after underground access has been achieved), technical studies, completion of statutory permitting processes and securing Government and WGJV Participants' approvals.

Engineering design and other studies, including environmental studies, are continuing and there is potential that aspects of the proposed Project design, layout and timetable may change.




Source:
Power network, SML and orebody from WGJV.
Villages, infrastructure and project roads from WGJV and Coffey.
Roads and watercourses from NSO.
Imagery from ArcGIS Online (capture date unknown).

coffey

Date: 22.03.2018
Project: 754-ENAUABTF10062000
File Name: 052000_10_BM_F001_GIS

WAFI-GOLPU JOINT VENTURE

Wafi-Golpu Project

General arranagement of proposed Project

Figure No: 1

## 2.2 Potential Sources of Noise Emissions

Development of the Project will require significant infrastructure and facilities to operate. The principal components of the Project (see **Figure 1**) include:

- Underground mine comprising three block caves, to be developed in stages and located beneath Mt Golpu at Reduced Level (RL) 4,400 metres (m), 4,200 m and 4,000 m, respectively. Access to the orebody will be obtained via the twin Watut Declines (3.6 km long) and the Nambonga Decline.
- Ore processing and concentrate transport/handling facilities, including a pipeline to transport concentrate slurry from the Mine Area to the Port Facilities Area at the Port of Lae.
- A deep sea tailings placement (DSTP) system for tailings management into the Markham Canyon in the Huon Gulf near Lae, with tailings transported by pipeline from the Mine Area to the Outfall Area on the Huon Gulf coast.
- On-site power generation facilities located within the Mine Area, with fuel delivered via pipeline from a third-party supplier located at the Port of Lae.
- The Watut and Nambonga waste rock dumps to store non-acid forming (NAF) and potentially acid-forming (PAF) rock generated during the development of the Watut and Nambonga declines and the ventilation shaft.
- Water and waste management facilities, including water treatment facilities, wastewater discharge and raw water make-up pipelines and raw water and sedimentation dams.

Further details of specific activities with potential to generate noise emissions are provided in the following sections.

### 2.2.1 Mine Construction and Operation

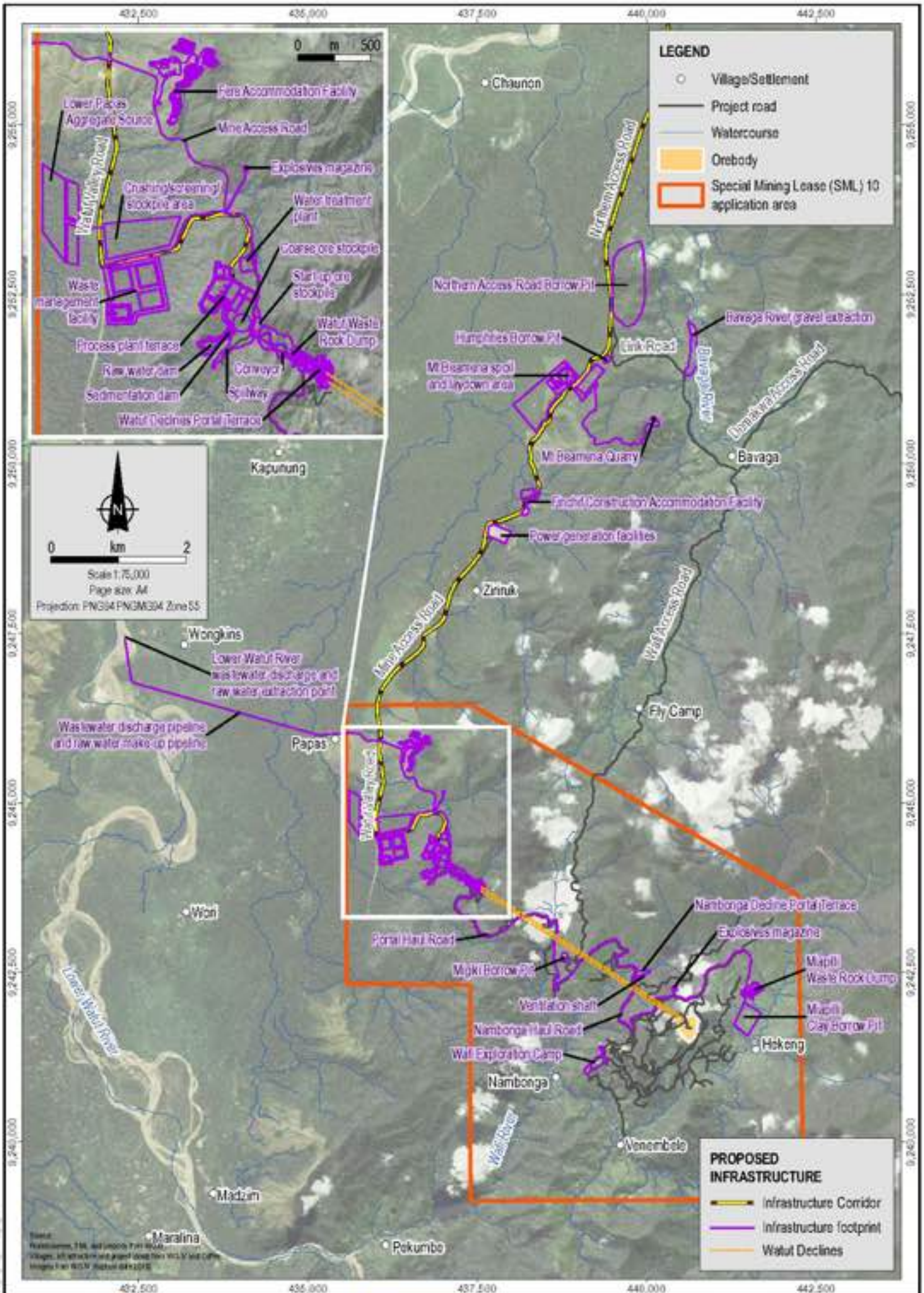
The twin Watut Declines would provide access to the underground operations from the Watut Declines Portal Terrace, and the Nambonga Decline will provide access from the Nambonga Decline Portal Terrace. The portal terrace would be constructed on fill material bounded by the valley walls. The Nambonga Decline Portal terrace would be constructed to provide a consolidated location for infrastructure associated with the Nambonga Decline. The declines would be supported by refrigeration and ventilation systems and a dewatering system for groundwater entering the declines. Construction of the ventilation shaft system would be timed for the commencement of underground operations.

It is anticipated that both PAF and NAF waste rock will be excavated from the declines. Waste rock dumps would be constructed to accommodate this waste rock. The NAF rock would be encountered in the initial portion of decline development and used in construction to provide fill for portal and process plant platforms and access roads.

During mining operations, ore from the block cave draw points would be delivered by diesel load-haul-dump (LHD) vehicles to an underground jaw crusher. The crushed ore will then be conveyed to the surface. The ore conveyor emerging at the portal terrace will continue overland to discharge onto a coarse ore stockpile adjacent to the Watut Process Plant.

### 2.2.2 Borrow Pits and Quarry

Four borrow pits and one quarry are proposed for the Project: Migiki, Humphries, Miapilli clay, and the Northern Access Road borrow pits and Mt Beamena Quarry (see **Figure 2**). Gravel would also be sourced from the Bavaga and Waime River beds and the Lower Papas aggregate source.




| | | | |
|---|---|---|---|
| coffey | Date 22.03.2018 / Project 754-ENAUABTF10052DD / File Name 052DD_10_BM_F002_GIS | WAFI-GOLPU JOINT VENTURE — Wafi-Golpu Project | General arrangement of proposed Mine Area — Figure No. 2 |

### 2.2.3 Electricity Generation

Forecast demand for electricity during construction is 20 MW. It is assumed this will be met by multiple (20 units) small and geographically diverse diesel generators. Each generator is expected to have an output of approximately 1 MW and will be provided by the construction contractors.

During the operational phase, the forecast demand for electricity for the Project is 100 MW. The electricity production philosophy assumes availability of power for 99.9% of the time. The NVIA is based on the installation of fourteen (14) Wartsila 20V32 reciprocating engine generation units burning intermediate fuel oil (IFO-160), with twelve (12) units operating at any one time to supply ore production at a 16.8 Mtpa throughput, and two (2) on standby.

### 2.2.4 Pipelines

Concentrate would be transported from the Watut Process Plant to the Port Facilities Area by a buried pipeline. The concentrate pipeline would be high density polyethylene (HDPE) lined inside a steel casing and will use high pressure (approximately 200 bar) to transport the concentrate.

Tailings would be transported from the Watut Process Plant to the Outfall Area by a buried pipeline that will be constructed adjacent to the concentrate pipeline to the Port of Lae, and then would extend further east to the Huon Gulf coast (see **Figure 2**). This pipeline would be lined with HDPE and operate at high pressure (approximately 200 bar).

## 2.3 Infrastructure corridor

Fuel would be transported to the Mine Area from the Port of Lae by a buried, steel pipeline, which will also be constructed adjacent to the concentrate pipeline and will operate at high pressure (approximately 200 bar).

### 2.3.1 Port Facilities Area

The Port Facilities Area would be constructed at the Port of Lae. The concentrate would be dewatered using a pressure filter and the filtrate treated prior to discharge into the marine environment. The concentrate filter cake would be stockpiled in a covered area or semi-enclosed building before being loaded into ships via a covered conveyor for export. The location of the plant site is shown in **Figure 1**.

### 2.3.2 Outfall Area

The Outfall Area would be constructed approximately 100m inshore of the beach, and approximately 1.5 km west of the Busu River. The Outfall System would comprise a mix/de-aeration tank located in a dry moat, a facility building and generators, a pipe and choke station area, laydown and storage area, and parking and turnaround area. Dual outfall pipelines, to deposit the tailings, and seawater intake pipelines, to supply water to the mix/de-aeration tank, would be constructed along the seafloor.

### 2.3.3 Summary of Noise Emissions

Based upon a review of the project information provided, potential noise emissions associated with the construction and operation of the Project have been identified as detailed in **Table 1**.

**Table 1 Potential Sources of Noise Identified for the Project**

| Location | Construction | Operation |
|---|---|---|
| Mine Area | Noise emissions associated with the construction of:[1]<br>1. Watut and Nambonga declines<br>2. Ventilation shaft<br>3. Process plant<br>4. Waste rock dumps<br>5. On-site portable diesel power generation<br>6. Accommodation facilities<br>7. Batch plants<br>8. Supporting facilities | Noise emissions associated with the operation of the Project.<br>Including:<br>1. Ventilation fans<br>2. Process plant operating<br>3. Onsite power generation facilities<br>4. Overland conveyors<br>5. Batch plants<br>6. Refrigeration<br>7. Accommodation camps<br>8. Onsite vehicle movements |
| Borrow Pits | Noise emissions associated with the construction of borrow pits including crushing and screening. | Noise emissions associated with the operation of borrow pits including;<br>Excavation<br>Crushing and screening operations<br>Vehicle movements<br>Blasting |
| Coastal Area | Noise emissions associated with the construction of the Port Facilities Area and Outfall Area | Noise emissions associated with the operation of the Port Facilities Area and Outfall Area. Including:<br>Choke station<br>Pumps<br>Conveyors<br>Vehicle Movements<br>Ship loading |
| Infrastructure Corridor | Noise emissions associated with the construction of the concentrate, tailings and fuel pipelines, Northern Access Road and project access roads. | Noise emissions associated with the use of access roads. |

1. Construction activities are expected to be similar to activities which would occur during closure of the Project and as such, predicted noise levels for construction activities are representative of expected noise emissions during project closure.

## 2.4 Assessment Approach

Based on the above, the most significant sources of noise will be associated with the construction and operation activities at the Mine Area. A detailed 3D model of these scenarios has therefore been constructed as detailed in **Section 6**. These scenarios include the activities listed in **Table 1** for construction and operations scenarios at the Mine Area.

Potential noise impacts associated with the operation of the access roads were assessed through a quantitative offset distance assessment as presented in **Section 6.2.4**.

Similarly, noise emissions from the construction and operation of the Port Facilities Area and Outfall Area have also been assessed quantitatively based on an offset distance assessment as addressed in **Section 6**.

Noise emissions from the construction of the Infrastructure Corridor (concentrate, tailings and fuel pipelines and Northern Access Road were assessed quantitatively based on offset distance assessment (refer to **Section 6.1.2**). Construction activities will move along the Infrastructure Corridor as works progress, resulting in changes in the surrounding topography, land use and distance to sensitive receptors which all affect the level of potential impacts that could occur.

# 3 EXISTING ENVIRONMENT

## 3.1 Site Description

The following section presents a description of the Project Area and surrounds with regards to topography, meteorology and the locations of sensitive receptors in the Project Area.

### 3.1.1 Local Topography and Land Use

The Mine Area is located on the northern side of the main dividing range of PNG. The majority of the Mine Area is rugged, steep, mountainous and densely forested. The western edge of the Mine Area is situated on the alluvial plains along the Lower Watut River valley.

The vegetation found within the Mine Area varies with altitude, topography, climate and substrate. Areas of disturbed grassland (kunai grassland) occur along the boundary of the Watut plains and Watut hills. These areas have been previously cleared of forest by local residents and are maintained and gradually extended by regular burning practices. Detailed vegetation description of the Mine Area is provided in the terrestrial ecology assessment (BAAM, 2018).

### 3.1.2 Locations of Sensitive Receptors – Mine Area

The Mine Area is situated in a remote region with a number of villages located in the surrounding area. The locations of the closest identified sensitive receptors surrounding the Mine Area are listed in Table 2. Sensitive receptors include villages, educational institution (e.g. school), health care facility and religious facilities (e.g. church). These receptors were entered into the noise model as discrete receptor locations and the assessment of impacts has focussed on these locations.

**Table 2 Sensitive Receptors Located Close to the Mine Area**

| ID | Name | Easting (m) | Northing (m) |
|---|---|---|---|
| 1 | Bavaga | 441,257 | 9,250,113 |
| 2 | Kapunung | 434,578 | 9,250,166 |
| 3 | Gingen | 446,645 | 9,252,153 |
| 4 | Wori | 433,201 | 9,243,395 |
| 5 | Wongkins | 433,173 | 9,247,336 |
| 6 | Uruf | 432,378 | 9,250,610 |
| 7 | Madzim | 433,602 | 9,239,237 |
| 8 | Wampar | 428,487 | 9,244,704 |
| 10 | Bencheng | 428,849 | 9,242,088 |
| 11 | Maralina | 432,650 | 9,238,615 |
| 12 | Ziriruk | 437,492 | 9,248,134 |
| 13 | Mafanazo | 436,476 | 9,257,118 |
| 15 | Papas | 435,404 | 9,245,949 |
| 16 | Pokwana | 444,322 | 9,234,501 |
| 17 | Zilani | 444,539 | 9,235,108 |
| 18 | Hekeng | 441,610 | 9,241,364 |
| 20 | Dengea | 447,400 | 9,250,308 |
| 21 | Zimake | 449,081 | 9,252,213 |
| 22 | Pokwaluma | 444,822 | 9,237,128 |

| ID | Name | Easting (m) | Northing (m) |
|---|---|---|---|
| 23 | Venembele | 439,612 | 9,239,958 |
| 24 | Pekumbe | 436,148 | 9,238,475 |
| 25 | Fly Camp | 439,891 | 9,246,407 |
| 26 | Nambonga | 438,662 | 9,240,951 |
| 29 | Chaunon | 437,612 | 9,255,629 |
| 39 | Zindanga | 447,803 | 9,252,234 |

## 3.2 Climate and Meteorology

PNG has a tropical climate. The coastal and islands regions tend to be hot and humid, with temperature averages ranging between 20°C and 32°C. The climate at the Mine Area is mild, with maximum daily temperatures typically ranging from 20°C to 35ºC. Temperature is altitude dependent, with hot and humid conditions associated with lower altitudes and cooler conditions at higher altitudes. Report *620.11677- R1 Golpu Project: Air Quality and Greenhouse Gas Assessment* (SLR Consulting Australia, 2018) provides a more detailed description of the climate and meteorology experienced throughout the Project Area.

## 3.3 Typical Background Noise in Project Area

Acoustic environment indicative background noise measurements were conducted for selected villages in the Project Area. The results from background noise monitoring conducted in similar environments within PNG are useful for approximating the anticipated ambient noise environment

Whilst there is significant distance between these noise monitoring locations and the Project, the terrain and natural and rural environment are comparable and it is therefore reasonable to expect the ambient noise environment to be similar. The range of ambient background noise levels at similar remote receptors (i.e. villages) measured in 2009 are as follows:

- Day (7am to 6pm) - 30 dBA $L_{90}$ to 43 dBA $L_{90}$
- Evening (6pm to 10pm) - 40 dBA $L_{90}$ to 49 dBA $L_{90}$
- Night (10pm to 7am) - 34 dBA $L_{90}$ to 46 dBA $L_{90}$

The previous noise surveys indicate that the local acoustic environment is usually dominated by insects, wind noise in foliage, birds, periods of heavy rain, domestic animals, and typical village domestic activities. The previous noise surveys concluded that high insect noise levels are a common feature of the ambient environment throughout the year.

## 3.4 Indicative Background Noise in the Mine Area

A noise characterisation report was prepared in 2011 for selected villages in the Mine Area and included:

- Wongkins village, located approximately 3.8 km to nearest project components
- Wori village, located approximately 2.6 km to nearest project components
- Bavaga village, located approximately 3.5 km to nearest project components
- Madzim village, located approximately 3.7 km to nearest project components

**Figure 3** presents the location of monitoring sites and proposed infrastructure sites. Monitoring was undertaken for approximately 24 hours at each of the four villages. Results of noise monitoring are reported in the noise characterisation report (Coffey Environments, 2011). The arithmetic average of the measured 15-minute statistical levels is provided in **Table 3**. The measured results are compared with the levels measured by SLR in similar locations in PNG.

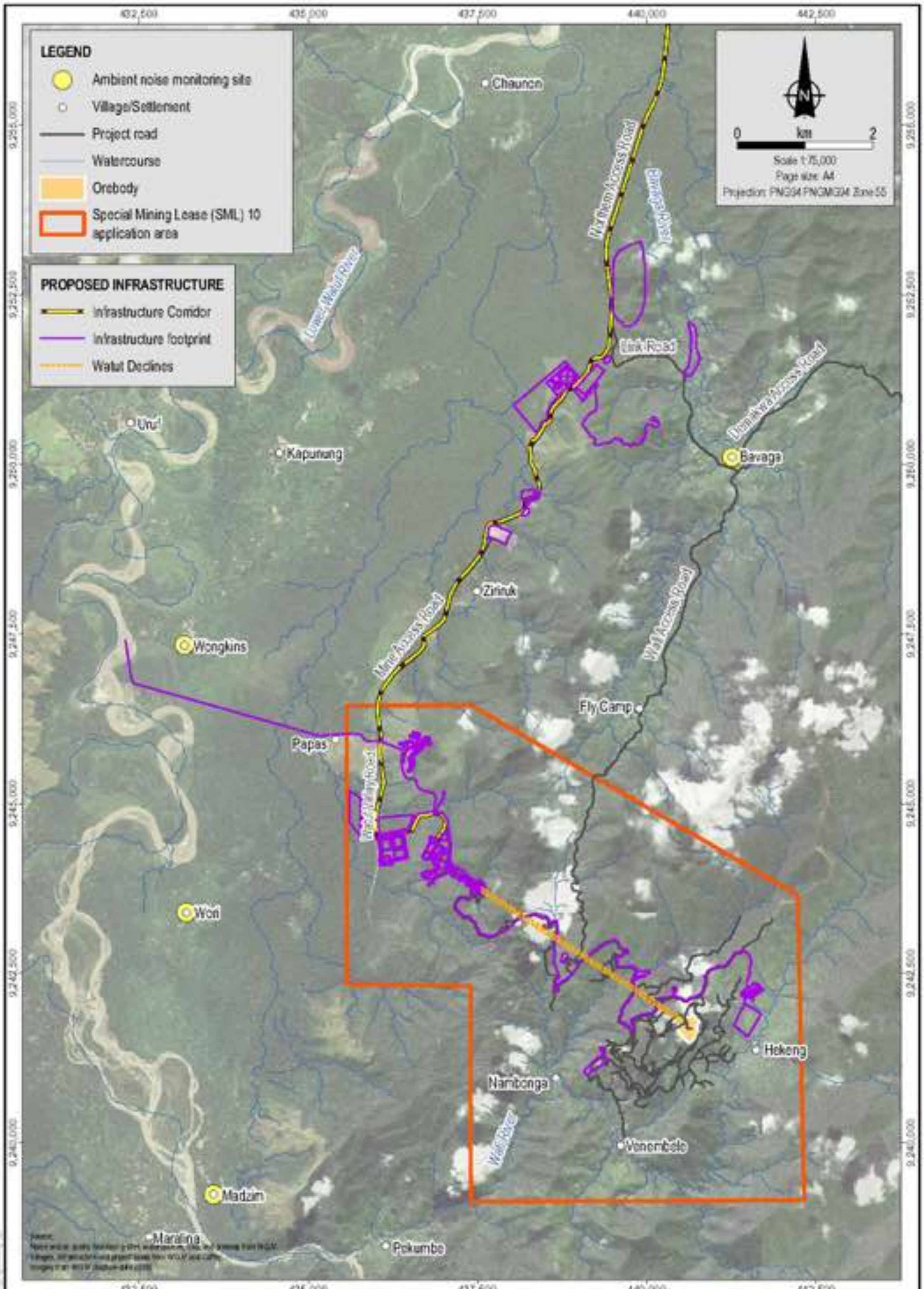
**Table 3 Noise Monitoring Results**

| Location | Date | Arithmetic Average of Measured 15 minute Noise Level, $L_{90}$ (dBA) | | | Comments |
|---|---|---|---|---|---|
| | | Day | Evening | Night | |
| Wongkins | 15-16 July 2011 | 42 | 44 | 41 | |
| Wori | 21-22 July 2011 | 44 | 47 | 43 | Rain reported through the night period. |
| Bavaga | 14-15 July 2011 | 41 | 54 | 51 | Consistently high levels from 7 pm to 6 am. Time history suggests insect noise. |
| Madzim | 24-25 July 2011 | 46 | 45 | 42 | Afternoon storm. |
| PNG (typical) | | 30-43 | 40-49 | 34-46 | |

## 3.5 Discussion

Indicative measurements of ambient noise suggest that background noise in the villages surrounding the Mine Area generally fall within the range typical of the PNG rural areas. The exception was Bavaga where high levels were measured during the evening and night periods. It is possible that such elevated levels of ambient noise are due to insects.

Background noise monitoring can be used as a basis for determining project noise goals. In this Project, a conservative approach of applying absolute limits based on internationally recognised noise criteria has been adopted. Details of criteria considered to be appropriate are provided in **Section 4.**




| | | | | |
|---|---|---|---|---|
| coffey | Date 26.02.2018 Project 754-ENAUABTF10052000 File Name | WAFI-GOLPU JOINT VENTURE | Location of survey sites | Figure No 3 |
| | | Wafi-Golpu Project | | |

# 4 IMPACT ASSESSMENT CRITERIA

## 4.1 Defining Biophysical Environmental Values

The following impact assessment criteria were identified for use in this NVIA to assess the Project's potential impacts on biophysical environmental values. A biophysical environmental value is generally defined as a quality or physical characteristic of the environment that is important to ecological health or public amenity. Based on this definition, the key environmental values relating to noise and vibration are those relating to public health and amenity and include:

- Health of humans including sleep disturbance
- Speech communication
- Health of other forms of life, including the protection of ecosystems and biodiversity
- Local amenity

## 4.2 Overview of Relevant Guidelines

The primary objective of any environmental noise guidelines is to protect people from the adverse effects of noise. Excessive noise has the potential to cause nuisance, including sleep deprivation, stress and increased blood pressure, as well as other physical, physiological and psychological effects (Basner, 2014).

Papua New Guinea does not currently have specific domestic noise guidelines. In the absence of a local noise policy, it is appropriate to consider internationally recognised guidelines. Many countries around the world have developed their own noise guidelines to protect the health and amenity of residents. The guidelines are typically based on: previous studies and experience within those countries; statistical analysis of community reaction to various levels of noise; and / or studies undertaken elsewhere around the world.

The two environmental noise guideline documents most commonly used in PNG are the World Health Organisation (WHO) *Guidelines for Community Noise* (World Health Organization, 1999) and the International Finance Corporation (IFC) and World Bank *General Environmental, Health and Safety (EHS) Guidelines: Environmental Noise Management* (International Finance Corporation and World Bank Group, 2007). The criteria presented in these documents are based on historical studies and, ultimately, are similar to criteria developed in Australia and other developed countries.

In addition to the WHO and IFC Guidelines, a number of Australian guideline documents and standards are also used to address noise sources and activities that are not covered by the WHO or IFC Guidelines. The Australian criteria are often derived from, or are based on, other international standards in addition to guidelines (British, European and American).

Standards and guidelines considered relevant to this Project are provided below.

## 4.3 Operational and Long-term Construction Noise

The Project will include both operational and long-term construction components. Operational criteria are applicable to noise sources which will operate throughout the life of the project and to noise from long-term construction activities. Whilst there's no specific criteria detailing what constitutes a long-term construction activity, best practice considers works which are continuous in nature and confined to the same area for a period of greater than 3 months to be long term. Short-term construction works are considered works which are largely transient in nature and impact the same receiver for a relatively short period of time, such as pipeline construction.

### 4.3.1 WHO Guidelines for Community Noise – 1999

The WHO guidelines provide detailed background information and cover various noise related issues such as hearing impairment (occupational noise), sleep disturbance, cardiovascular and other physiological effects.

Recommendations from the WHO guidelines relevant to the Project are provided below.

#### 4.3.1.1 Night Period – Sleep Disturbance

The WHO guidelines generally prescribe two noise levels at residential locations to ensure that sleep is not adversely affected, these being:

- 30 dBA $L_{eq}$ for continuous noise
- 45 dBA $L_{Amax}$ for single events (maxima)

The above levels are applicable at the receptor's ear position, which would typically be indoors during the night time, and the WHO guidelines suggest that a correction of 15 dBA can be applied to determine the equivalent external criteria.

Consequently, external noise limits used to model and assess potential impacts for the Project were:

- 45 dBA $L_{eq}$ for continuous noise
- 60 dBA $L_{Amax}$ for single events (maxima)

The WHO guidelines also note that special attention should be given to the following conditions when investigating sleep disturbance:

- Noise sources in an environment with a low background noise level. For example, vehicle movements at night through a village.
- Environments where a combination of noise and vibrations are produced. For example, large heavy vehicles traveling on uneven ground.
- Sources with low-frequency components. Disturbances may occur even though the sound pressure level during exposure is below 30 dBA. For example, noise emissions from large mechanical pieces of equipment such as power stations and mine processing plant.

#### 4.3.1.2 Day Period

The WHO guidelines recommend the following day period noise levels, measured externally:

- 50 dBA $L_{eq}$ to 'protect the majority of people from being moderately annoyed'
- 55 dBA $L_{eq}$ to 'protect the majority of people from being seriously annoyed'
- 70 dBA $L_{eq}$ at industrial and commercial areas to prevent hearing impairment

In addition, the WHO guidelines nominate an internal noise level inside dwellings of 35 dBA $L_{eq}$ for the purpose of allowing good speech communication.

Measurement periods are not defined in WHO (1999). For the purpose of this assessment it is assumed that the levels are to be measured over one hour.

#### 4.3.1.3 Impulsive Noise Sources

Blasting can cause high instantaneous sound levels.

The primary noise concern regarding blasting is that it should not cause damage to hearing. Studies presented in the WHO guidelines prescribe the following limits for sources such as blasts:

- 140 dBA $L_{Max}$ for adults
- 120 dBA $L_{Max}$ for children

The above levels are recommended to ensure that the potential for hearing damage is minimised.

#### 4.3.2 IFC / World Bank Noise Management Guidelines – 2007

The 2007 IFC guidelines for the management of environmental noise prescribe limits for the day and night periods. The following is an extract:

> *"Noise impacts should not exceed the levels presented in Table 1.7.1, or result in a maximum increase in background levels of 3 dB at the nearest receptor location off-site.*
>
> ***Table 1.7.1 Noise Level Guidelines***

| *Receptor* | *One Hour $L_{Aeq}$ (dBA)* | |
|---|---|---|
| | *Day (7:00 am -10:00 pm)* | *Night (10:00 pm -7:00 am)* |
| *Residential / Institutional /educational* | *55* | *45* |
| *Industrial / Commercial* | *70* | *70* |

> *Highly intrusive noises, such as noise from aircraft flyovers and passing trains, should not be included when establishing background noise level."*

The noise levels presented in the table above are derived from the WHO guidelines discussed in **Section 4.3.1** of this report. The values in the table correspond to the outdoor noise levels for continuous noise, assuming a 15 dB facade reduction. The IFC guidelines do not provide recommendations for single noise events, such as blasting.

The IFC guidelines provide a requirement that background noise levels not be increased by more than 3 dB. However, this criterion is not satisfactorily defined in the IFC document as:

- The acoustical descriptors used for the assessment of background noise level are not specified.
- It is unclear whether the criterion is meant to apply when background noise levels are very low (resulting in a greater level of acoustical amenity at quiet locations) or when background levels are very high (thereby avoiding the imposition of unnecessarily low noise limits in already noisy locations). The former definition would potentially result in more stringent noise limits than in most other parts of the world, including Australia.
- It is unclear whether the background based criterion should be incurred at all times, or during the night time only.

Given the ambiguity of the criterion, further reference to background based limits has not been included in this report.

#### 4.3.3 Low Frequency Noise

Low frequency noise is defined as the level of noise within the 20 Hz to 250 Hz frequency range.

The environmental impacts of low frequency noise can be underestimated when A-weighted criteria, such as those included in the WHO and the IFC guidelines, are used.

The New South Wales Department of Environment Climate Change and Water (NSW DECCW) Industrial Noise Policy (INP) (2000) outlines 'correction factors' to be applied to the source noise level at the noise sensitive receiver when assessing the impact of low frequency noise. The correction factor is applied to the source noise level in order to account for any potential additional annoyance caused by a noise source which is defined as having low frequency characteristics.

The INP provides the following guidance with respect to the application of a 'correction factor' to account for low frequency noise.

> *A 'correction factor' of +5 dB is to be applied to the predicted source noise level (prior to comparison with the noise criteria) where the difference between the overall C-weighted and A-weighted noise levels for that noise source is greater than or equal to 15 dB.*

### 4.3.4 A comparison of international noise criteria and guidelines

A summary and comparison of the above noise criteria are provided in **Table 4**

**Table 4 Summary of International Noise Criteria and Guidelines**

| Receiver | Acoustical Descriptor | Time | Reference | Internal Noise Level | External Noise Level | Comment |
|---|---|---|---|---|---|---|
| Residential | $L_{eq,\ 1\ hour}$ | Day | WHO 1999[A] | - | 50-55 dBA | WHO and IFC same |
| | | | IFC 2007[B] | - | 55 dBA | |
| | | Night | WHO 1999 | 30 dBA | 45 dBA | |
| | | | IFC 2007 | - | | |
| | | Day and Night[D] | NSW INP[D] | | | Add 5 dB low frequency correction to measured level where the difference between the A-weighted and C-weighted level is greater than 15 dB. |
| | $L_{max}$ | Day | WHO 1999 | - | - | Not specified – consider 'Impulsive Noise Sources' criteria |
| | | | IFC 2007 | - | - | |
| | | Night | WHO 1999 | 45 dBA | 60 dBA | |
| | | | IFC 2007 | - | - | |
| | Impulsive / Blasting | All times | WHO 1999 | | 120 Lin Peak (Children)<br>140 Lin Peak (Adults) | Adopt lowest |

| Receiver | Acoustical Descriptor | Time | Reference | Internal Noise Level | External Noise Level | Comment |
|---|---|---|---|---|---|---|
| **Commercial and Industrial** | $L_{eq,\ 1\ hour}$ | Day | WHO 1999 | - | 70 dBA | WHO and IFC same |
| | | | IFC 2007 | - | 70 dBA | |
| | | Night | WHO 1999 | - | 70 dBA | WHO and IFC same |
| | | | IFC 2007 | - | 70 dBA | |
| | Impulsive / Blasting | All times | WHO 1999 | | 120 Lin Peak (Children)<br>140 Lin Peak (Adults) | Adopt lowest |

A: WHO Guidelines for Community Noise – 1999.

B: IFC (World Bank) Noise Management Guidelines – 2007.

C: Day period: 0900 h to 2200 h; Night period: 2200 h to 0700 h (as defined in NSW DECCW Industrial Noise Policy (2000)).

D: NSW DECCW Industrial Noise Policy (INP) (2000).

## 4.4 Road Traffic Noise

Increased vehicle movements can be expected during the construction and operation of the Project. It is proposed that vehicle movements during the night period should not exceed the WHO night criterion for intermittent noise of 60 dBA $L_{max}$, (applicable at the receptor location).

No numerical limit has been proposed for vehicle movements during the day period.

## 4.5 Construction Noise

Short-term construction noise is generally dealt with separately from operational noise and long-term construction.

For construction periods of less than three months, good practice and administrative controls are typically adopted rather than numerical noise targets. However, extremely high levels of noise during construction, even for relatively short periods, can have significant noise impacts on a community.

The following are indicative criteria from each for short-term construction activities from two Australian guideline documents:

- 68 dBA – Victorian Environment Protection Authority *Noise From Industry in Regional Victoria* (2011) (Environment Protection Authority Victoria, October 2011)
- 75 dBA – NSW Department of Environment and Climate Change DECC (2009) *Interim Construction Noise Guidelines* (Department of Environment and Climate Change NSW, 2009)

The 75 dBA criterion nominated in the NSW document corresponds to ‘highly noise affected’ which could result in strong community reaction to the noise.

For construction periods of prolonged duration, that is more than three months, the operational noise limits detailed in **Section 4.3** would apply.

Irrespective of the duration of construction, noise from construction activity during the night period should generally comply with the identified sleep disturbance and operational noise criteria (45 $L_{Aeq}$ and 60 $L_{Amax}$).

## 4.6 Project Noise Criteria

A summary of the adopted Project noise criteria is provided in **Table 5**.

**Table 5 Project Noise Criteria / Goals for modelling potential impacts**

| **Activity** | **Source** | **Noise Receiver** | **Time** | Noise Criteria / Goals (measured externally) |
|---|---|---|---|---|
| Normal operations and construction periods longer than three months | Continuous | Residential | Night | 45 dBA $L_{eq,\ 1\ hour}$ |
| | | | Day | 55 dBA $L_{eq,\ 1\ hour}$ |
| | Single events | Residential | Night | 60 dBA $L_{Amax}$ [A] |
| Construction periods less than three months | Continuous | Residential | Night | 45 dBA $L_{eq,\ 1\ hour}$ |
| | | | Day | 75 dBA $L_{eq,\ 1\ hour}$ |
| | Single events | Residential | Night | 60 dBA $L_{Amax}$ [A] |
| Vehicle movements on existing main roads | Intermittent | Residential | Day | No numerical limit |
| | | | Night | 60 dBA $L_{Amax}$ [A] |

# 5 NOISE MODELLING PROCEDURE

This section presents the noise prediction method and assumptions, the investigated modelling scenarios, and main modelling inputs and procedures.

## 5.1 Computer Modelling Method

Noise prediction and assessment for the Project reflects two broad approaches:

- Where site locations and defined layouts are available (e.g. Mine Area), noise predictions have been made to discrete receptors and the surrounding area using a detailed SoundPLAN noise model.
- For construction works which are geographically linear with anticipated short-term associated impacts or detailed information regarding construction equipment or technique is lacking due to the preliminary stage of the Project, a more generalised buffer distance approach has been followed where the levels have been predicted by either a simplified SoundPLAN noise model or calculation spreadsheets depending upon available information.

### 5.1.1 SoundPLAN

In order to calculate the noise emission levels at the nearest noise sensitive receptor locations, SoundPLAN (Version 7.1) environmental computer models were developed. SoundPLAN is a software package which enables compilation of a sophisticated computer model comprising a digital ground map (containing ground contours), the location and sound power levels (SWL) of noise sources on site, and the location of sensitive receptors for assessment purposes. The computer model predicts noise propagation taking into account factors such as distance attenuation, ground hardness, air absorption and barrier shielding effects, as well as meteorological conditions.

SoundPLAN has been used successfully on other projects in PNG and is routinely used to predict noise from mining and industrial facilities. It is considered a ‘best practice’ approach to noise modelling.

### 5.1.2 CONCAWE

The SoundPLAN model utilised noise propagation calculation algorithms in accordance with CONCAWE prediction method. The CONCAWE method was developed for large open air industrial facilities and incorporates the influence of wind and atmospheric stability on propagation.

The statistical accuracy of environmental noise predictions using CONCAWE was investigated by Marsh in his article *The CONCAWE Model for Calculating the Propagation of Noise from Open-Air Industrial Plants* (Marsh, 1982). Marsh concluded that CONCAWE was accurate to ±2 dBA in any one octave band between 63 Hz and 4 kHz and ±1 dBA overall.

The CONCAWE method has been used successfully on other projects in PNG and is routinely used to predict noise from mining and industrial facilities. It is considered a ‘best practice’ approach to noise modelling.

### 5.1.3 Relevant Meteorological Conditions for Modelling

One of the objectives of the noise assessment is to consider the effects of relevant meteorological conditions (wind, temperature, humidity and temperature inversions) on noise propagation from the Project Area. The meteorological conditions used for the noise modelling have been determined in accordance with common practice techniques used for various mining projects being developed within Australia, i.e., the guidelines presented in the NSW *Industrial Noise Policy* (NSW Department of Environment and Climate Change & Water (DECCW), 2000).

In order to determine the appropriate meteorological parameters for the noise modelling study, meteorological modelling using CALMET was performed. CALMET is a diagnostic meteorological model that develops wind and temperature fields on a three-dimensional gridded modelling domain. Associated two-dimensional fields such as stability class are also included in the file produced by CALMET. The interpolated wind field and stability class field is then modified within the model to account for the influences of topography, as well as differential heating and surface roughness associated with different land uses across the modelling domain. These modifications are applied to the winds at each grid point to develop a final wind field. The final meteorological field, including wind and stability classes, thus reflects the influences of local topography and land uses.

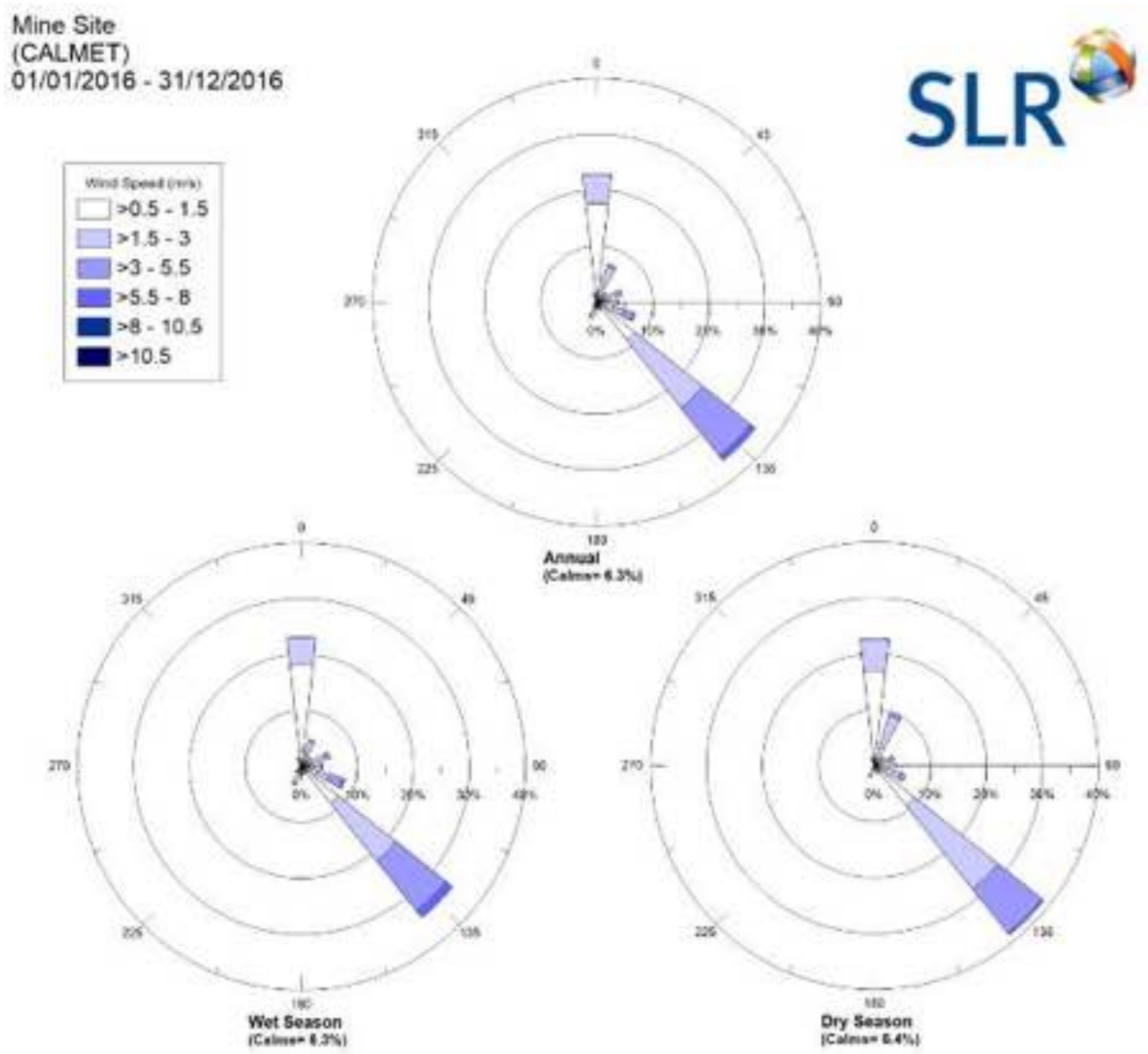
SLR prepared an air quality assessment for the Project (SLR Consulting Australia, 2018) and as part of that study a detailed analysis was undertaken to characterise prevailing weather conditions at the project site.

Year 2016 annual meteorological data (the most recent available) was analysed by SLR using the CALMET meteorological model to determine prevailing wind and atmospheric conditions and to determine whether noise modelling should account for enhanced propagation conditions (SLR Consulting Australia, 2018).

#### 5.1.3.1 Wind Effects

A summary of the annual wind behaviour predicted by CALMET for the Project Area is presented as wind roses in **Figure 4**. The wind roses indicate that winds at the Project Area predominantly blow from the north and south. There is little difference between the wind patterns experienced during the wet season (October – April inclusive) and dry season (May – September inclusive), aside from wind speeds being slightly lower and southerly winds occurring more frequently during the dry season.

**Figure 4 Annual and Seasonal Wind roses**




#### 5.1.3.2 Temperature Inversion

Atmospheric stability refers to the tendency of the atmosphere to resist or enhance vertical motion. The Pasquill-Turner assignment scheme (Turner, 1994) identifies six Stability Classes, A to F, to categorise the degree of atmospheric stability as follows:

- A = Extremely unstable conditions
- B = Moderately unstable conditions
- C = Slightly unstable conditions
- D = Neutral conditions
- E = Slightly stable conditions
- F = Moderately stable conditions

The meteorological conditions defining each Pasquill stability class are shown in **Table 6**

**Table 6 Description of Atmospheric Stability Classes (source: Pasquill, 1961)**

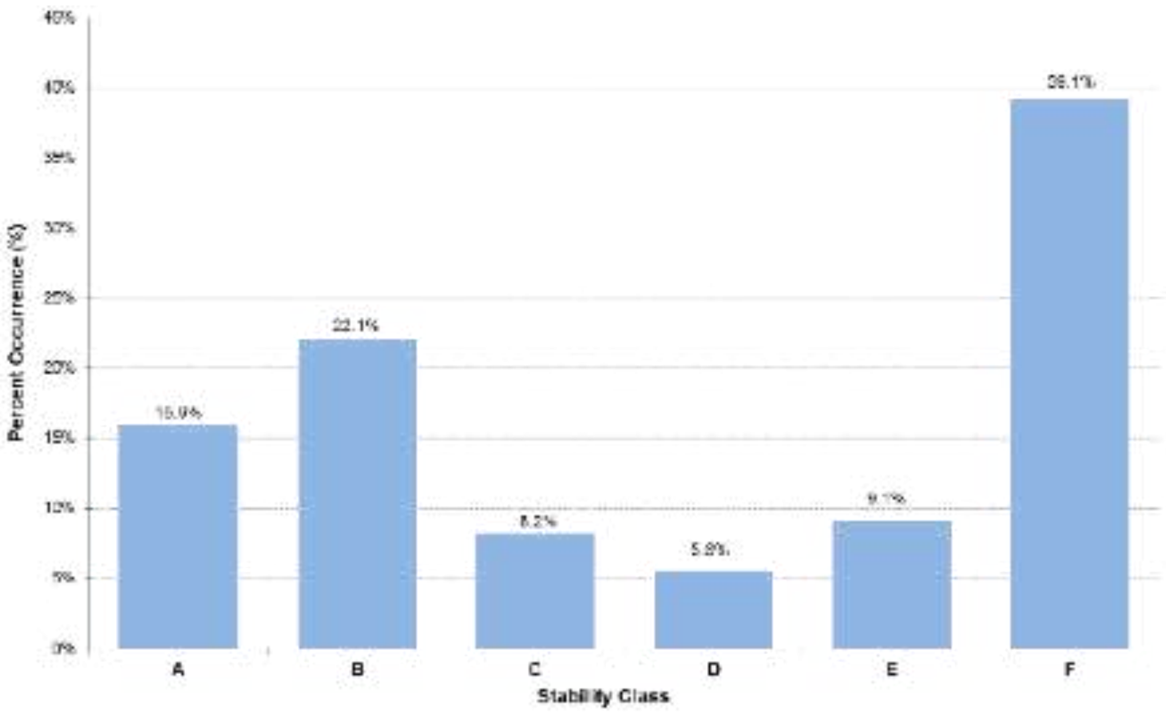
| | Daytime Insolation | | | Night-time Conditions | |
|---|---|---|---|---|---|
| **Surface wind speed (m/s)** | **Strong** | **Moderate** | **Slight** | **Thin overcast or > 4/8 low cloud** | **<= 4/8 cloudiness** |
| < 2 | A | A - B | B | E | F |
| 2 – 3 | A - B | B | C | E | F |
| 3 – 5 | B | B - C | C | D | E |
| 5 – 6 | C | C - D | D | D | D |
| > 6 | C | D | D | D | D |

Source: (Pasquill, 1961)

Temperature inversions occur during stable atmospheric conditions (low winds and clear skies) and typically between dusk and dawn. Atmospheric Stability Class F represents the conditions in which temperature inversion are likely to occur. Class D represents neutral conditions, where temperature inversions are unlikely to occur.

The calculated frequency of temperature inversions for the project site is shown in **Figure 5**.

**Figure** 5 **Atmospheric Stability Class Frequencies, as Predicted by CALMET (2016)**




Atmospheric Stability Class F was predicted to occur for more than 39% of the time and as such this would be considered to occur sufficiently often to be considered a prevailing condition and therefore it has been modelled in addition to ‘neutral’ conditions.

### 5.1.4 Modelled Meteorological Parameters

As per the findings of the meteorological data analysis detailed above, enhanced propagation conditions have been modelled based on a category F atmospheric stability class. This atmospheric class triggers CONCAWE meteorological category 6 conditions which provides for the most enhanced (worst case) propagation conditions from source to receiver.

Selected temperature and humidity conditions are based on indicative average values for the night period at the Project Area (refer to **Section** 3)**.**

**Table 7 Modelled Meteorological Parameters**

| Weather Conditions | Neutral Weather | Enhanced Weather |
|---|---|---|
| **Temperature** | 24°C | 24°C |
| **Humidity** | 86% | 86% |
| **Atmospheric Stability Class** | D | F |
| **Wind Speed** | 0 m/s | 2.5 m/s |
| **Wind Direction** | N/A | Downwind |
| **Temperature Inversion** | No | Yes |

### 5.1.5 Topographic Shielding and Ground Absorption

Local topography can dramatically affect the propagation of noise, especially if works are conducted in areas with steep terrain. The extent of change in noise levels due to topographical effects would depend on the level of shielding provided (which would be very site specific). The actual degree of noise attenuation due to topographical shielding is a function of the frequency spectrum of the noise and the length of the diffracted noise path over or around topography compared to the direct noise path.

Noise attenuation due to topographical shielding typically ranges from 5 dBA if line-of-sight between the noise source and receiver location is just obscured, and up to approximately 15 dBA where the topography provides optimal blocking of the sound transmission path.

The effect of topographical shielding is taken into account in the 3D modelling and noise predictions for the modelling scenarios described in **Section 5.4.**

The hardness of intervening ground between noise sources and receptors also affects the propagation of noise and influences how the direct and reflected acoustic ray paths interact.

The parameters assumed in the noise model for ground absorption are detailed in **Table 8.**

**Table 8 Ground Absorption**

| | |
|---|---|
| Where:<br>G= 0 for reflective hard ground<br>G= 1 absorptive soft ground | G = 1 for natural ground vegetation areas (i.e. village and mountain areas around mine pits). |
| | G = 0.25 in Mine Areas. This is considered appropriate for partially compacted ground and dirt with no vegetation. |
| | G = 0 for water bodies. |

## 5.2 Duration Adjustment, De-rating Factors and Emergency Operating Conditions

A noise model typically assumes that all noise sources are operating simultaneously at full power. For complex noise models with a large number of noise sources (especially mobile equipment typical for civil works) the predictions can overestimate a real world measured noise level as many of the noise sources do not operate continuously at full power and their operation may be intermittent or cyclical.

Recognition that all equipment will not operate 100 % of the time allows for the predicted results to be refined to represent a more realistic scenario. A de-rating factor has been applied to all equipment associated with the operation of the Project to represent realistic noise operations. The de-rating factor is based on the anticipated duty of a source. The duty of a source is the assumed percentage of time that a source is likely to operate and has been estimated based on previous experience and our current understanding of the Project. **Appendix B** provides details of the duty applied to each source.

Reversing beepers may be audible during the construction of the project support infrastructure (Northern Access Road, and concentrate, tailings and fuel pipelines) when in proximity to villages, however this is viewed as a mandatory safety requirement and typically does not come under assessment for short-term construction activities. During operations, given the typical offset distances of the villages to the project components (greater than 1 km), reversing alarms and other emergency operating conditions would generally not be audible at the surrounding villages and have therefore not been included under the noise assessment of the Project.

## 5.3 Noise Model Level of Confidence

The statistical accuracy of environmental noise predictions using CONCAWE has been comprehensively tested (Marsh, 1982). In models replicating scenarios with well-defined parameters the CONCAWE predictions were accurate to ±2 dBA in any one octave band between 63 Hz and 4 kHz and ±1 dBA overall.

Noise predictions inherently require that a large number of parameters are defined, many of which can be based initially only upon preliminary assumptions (e.g. plant and equipment assumed in each modelled scenario, sound power levels of plant and equipment, duty and durations of operation, precise locations of sources, receptors and vegetation attenuation), some of which have already been discussed in this report.

In considering the combined uncertainties of these assumptions, of which many are conservative, the authors believe that the model predicted values would be within ± 10 dBA of that realised should the Project proceed as currently described. This shall be taken into consideration when evaluating and assessing impacts with respect to the margin of compliance or exceedance.

## 5.4 Noise Modelling Scenarios

### 5.4.1 Construction

Representative modelling scenarios were developed for the following construction phases of the Project:

- Mine Construction Scenario (C1) – Including the construction of the Watut and Nambonga declines, accommodation camps, portal terraces and associated infrastructure, explosive storage pad, quarry operations, process plant terrace and associated infrastructure, ventilation shaft and the power generation facilities and the waste rock dumps. This scenario is also representative of the anticipated noise emissions during closure of the Project.
- Construction of the Port Facilities Area and Outfall Area (C3).

The mobile (and fixed) plant and equipment and associated SWL for each modelling scenario are presented in **Appendix B**, **Table B1**. The SWLs have been sourced from SLR’s noise source database.

### 5.4.2 Infrastructure Corridor Construction

The mobile plant and equipment and the associated SWL for construction of the Northern Access Road, and concentrate, tailings and fuel pipelines (C2) are presented in **Appendix B in Table B2**. The SWLs have been sourced from the SLR's Noise Source Database which has been compiled from previous measurements.

The construction of the Infrastructure Corridor will be a short-term event at any one location as it progressively moves along the route. Therefore, credible worst case noise levels have been predicted for the road and pipelines' construction (excluding reversing beepers) which is representative of the maximum noise levels as the clear and grade construction front passes any one location. The clear and grade stage has the loudest construction equipment associated with it.

The clear and grade modelling scenario has assumed the mobile plant and equipment would be distributed over approximately a 500 m moving front.

The scheduling of works for construction of the Infrastructure Corridor will be adapted as needed based on the area under construction. This would include for example, construction only during the day when in proximity to villages. However, through Lae night-works is preferential to minimise the disturbance to users of existing road infrastructure (refer to **Section 4.3)**.

Noise sources associated with the construction of the concentrate, tailings and fuel pipelines are not expected to be significant and would generally be no louder than the Northern Access Road construction activities.

### 5.4.3 Mine Operation

In order to provide representative noise impacts across the life of the mine, the mobile and fixed plant and equipment associated with the Project has been assessed for the following scenarios:

- Operation of the power generation facilities only (O1)
- Operation of the mine and process plant (peak operation) at 16.8 Mtpa including power generation facilities (O2)
- Operation of the Port Facilities Area and Outfall Area (O4)

The noise model of these operations assumes that all plant and equipment operates concurrently in order to simulate the overall maximum potential noise emission for each scenario. The mine operation modelling scenarios also include dominant noise sources associated with ventilation fans and refrigeration, the overland conveyor belt, process plant, and accommodation facilities and borrow pits.

The plant and equipment and associated SWL for each modelling scenario are presented in **Appendix B**, **Table B4.** The SWLs have been sourced from SLR's Noise Source Database.

### 5.4.4 Operation of Mine Access Road and Northern Access Road

The operation of the Mine Access Road and Northern Access Road scenario (O5) assumes the volume of Project-related traffic, which would primarily be the transportation of supplies and staff from Lae, is approximately 30 vehicles per direction per day.

The traffic volumes on the Mine Access Road and Northern Access Road are below those required to accurately predict noise levels using normal road prediction models. For example, under the UK's Department of Transport *Calculation of Road Traffic Noise (1988)* (CoRTN), the minimum traffic flow required for calculation is 1,000 vehicles in an 18 hour period. CoRTN is one of the most widely used traffic noise prediction algorithms, and is accepted by international and Australian authorities.

For infrequent pass-by events such as from the approximately 30 vehicles per day associated with the Project, it is more appropriate to conduct an assessment of individual pass-by noise levels. In particular, consideration of night period individual pass-by levels is the most critical and can be assessed with respect to WHO sleep disturbance criteria.

## 5.5 Scenario Summary

**Table 9** summarises the project scenarios and the adopted assessment method.

**Table 9 Summary of Noise Assessment Scenarios**

| | ID | Description | Modelling Approach | Equipment Comment |
|---|---|---|---|---|
| | C1-NV | Construction of the following infrastructure:<br>1. Accommodation Facilities<br>2. Portal terraces<br>3. Watut and Nambonga declines development<br>4. Refrigeration plant pad<br>5. Explosive storage pad<br>6. Migiki Borrow Pit<br>7. Process plant terrace<br>8. Waste rock dumps activities<br>9. Onsite portable diesel power generation (construction)<br>10. Batch plants (operation)<br>11. Portal ventilation fans | Computer SoundPLAN 3D Modelling – incorporating the CONCAWE prediction algorithm | Appendix B – Table B1 |
| | C2-NV | Construction of the concentrate, tailings and fuel pipelines and Northern Access Road | Minimum buffer distance approach based on spreadsheet calculations | Appendix B – Table B3 |
| | C3-NV | Construction of the Port Facilities Area and Outfall Area | Minimum buffer distance approach based on Computer SoundPLAN 3D Modelling | Appendix B – Table B4 |
| OPERATION | O1-NV | Operational Scenario 1 Including:<br>1. Power generation facilities operating only | Computer SoundPLAN 3D Modelling – incorporating the CONCAWE prediction algorithm | Appendix B – Table B5 |
| | O2-NV | Operational Scenario 2 – 16.8 Mtpa<br>Including:<br>1. Process plant operating<br>2. Power generation facilities<br>3. Overland conveyors<br>4. Migiki Borrow Pit<br>5. Batch plants<br>6. Ventilation fans and refrigeration<br>7. Waste rock dumps<br>8. Accommodation Facilities | Computer 3D Modelling – incorporating the CONCAWE prediction algorithm | Appendix B – Table B6 |
| | O3-NV | Operation of associated "secondary" borrow pits<br>Applies to all borrow pits except Migiki, which has been included in operational and construction scenarios | Minimum buffer distance approach<br>With recommended buffer distances for secondary borrow pits | Appendix B – Table B7 |

| ID | Description | Modelling Approach | Equipment Comment |
|---|---|---|---|
| O4-NV | Operation of the Port Facilities Area and Outfall Area | Minimum buffer distance approach based on Computer SoundPLAN 3D Modelling | Appendix B – Table B8 |
| O5-NV | Northern Access Road operation | Minimum buffer distance approach based on spreadsheet calculations | - |

Noise emission levels have been predicted at the nearest noise sensitive receptor(s) surrounding the Project Area. All receptors have been positioned 1.5 m above ground and assessed under free-field conditions (no façade reflection).

Noise contour plots have been produced for the nominated modelling scenarios in the area surrounding the project site. The noise contour plots are located in the following appendices:

- **Appendix C Map 1 Construction Scenario C1-NV - Neutral Meteorology**
- **Appendix C Map 2 Construction Scenario C1-NV - Enhanced Meteorology**
- **Appendix D Map 1 Operational Scenario O1-NV – Neutral Meteorology**
- **Appendix D Map 2 Operational Scenario O1-NV – Enhanced Meteorology**
- **Appendix E Map 1 Operational Scenario O2-NV – Neutral Meteorology**
- **Appendix E Map 2 Operational Scenario O2-NV – Enhanced Meteorology**

# 6 NOISE IMPACT ASSESSMENT

This section presents predicted noise levels assessed against the relevant project noise goals (refer to **Section 4**) for the modelling scenarios as defined in **Section 5.3**.

## 6.1 Construction

### 6.1.1 Construction (Scenario C1-NV)

Predicted noise levels associated with the construction activities (scenario C1) at the Mine Area are presented as noise contour plots in **Appendix C**. Both neutral and enhanced (i.e. worst case) meteorological propagation conditions are presented. A summary of the predicted noise levels is provided in **Table 10** for the nearest affected villages.

**Table 10 Mine Construction Noise Predictions, $L_{Aeq}$**

| Met Conditions | **Neutral** | **Enhanced** | **Noise Criteria (dBA)[1]** | |
|---|---|---|---|---|
| **Village** | | | **Day** | **Night** |
| Bavaga | 22 | 23 | 55 | 45 |
| Bencheng | <15 | <15 | 55 | 45 |
| Dengea | <15 | <15 | 55 | 45 |
| Fly Camp | 15 | 20 | 55 | 45 |
| Gingen | <15 | <15 | 55 | 45 |
| Hekeng | 47 | 50 | 55 | 45 |
| Kapunung | 35 | 37 | 55 | 45 |
| Madzim | <15 | <15 | 55 | 45 |
| Maralina | <15 | <15 | 55 | 45 |
| Nambonga | <15 | 20 | 55 | 45 |
| Papas | 42 | 48 | 55 | 45 |
| Pekumbe | <15 | <15 | 55 | 45 |
| Pokwaluma | <15 | <15 | 55 | 45 |
| Uruf | <15 | <15 | 55 | 45 |
| Venembele | <15 | 19 | 55 | 45 |
| Wafi | 34 | 40 | 55 | 45 |
| Wongkins | 28 | 33 | 55 | 45 |
| Wori | 30 | 35 | 55 | 45 |
| Zindanga | <15 | <15 | 55 | 45 |
| Ziriruk | 44 | 48 | 55 | 45 |

1. The project IFC criteria is 55 dBA (day) 45 dBA (night).
2. Shading represents an exceedance of the night-time criteria (45 dBA)

The predicted noise levels represent one geographical location of the village (typically the centre) and may not account for scattered dwellings which may be located closer to mine activities. As such it is possible that higher noise levels could be experienced at individual receptors on the outskirts of villages.

The noise contours and summary provided in **Table 10** show typical noise levels ranging from less than 15 dBA to 50 dBA at the nearest villages for all stages and under all weather conditions. Based on modelling assumptions and results:

- The IFC day period noise criterion of 55 dBA $L_{Aeq}$ is met at all villages under all meteorological conditions.

- The IFC night period criterion of 45 dBA $L_{Aeq}$ is exceeded at one village, Hekeng, by a nominal 2 dB under neutral meteorological conditions. Under enhanced meteorological conditions, more significant exceedances of the noise night criterion by up to 5 dB are predicted at Hekeng, Papas and Ziriruk.

Whilst the assessment has identified impacts under a worst case enhanced weather condition, it is unlikely that these conditions will occur often due to the following:

- The site-specific wind conditions shown in Figure 4 indicates that the prominent wind direction is from the south east. Potentially impacted villages Ziriuk and Hekeng are situated up wind from the dominant construction noise source and as such, enhanced noise propagation conditions in which exceedances are predicted would be infrequent.
- Whilst the frequency of temperature inversions (pascal stability class F) have the potential to occur for up to 40% of the year (refer to Figure 5), temperature inversions typically occur during the early morning or evening periods and are not generally present throughout the day.

The objective test for audible character with high levels of low frequency is detailed in **Section 4.3.3**. The difference in the C-weighted overall level and the A-weighted level at Hekeng is approximately 8 dB under neutral propagation conditions and 7 dB under enhanced propagation conditions. This indicates that the character of noise does not have sufficient low frequency content to consider a potential penalty of 5 dB.

Noise management measures may be required to reduce impacts to Hekeng, Papas and Ziriruk, refer to **Section 8.**

### 6.1.2 Infrastructure Corridor Construction (Scenario C3-NV)

Noise levels as a function of distance from the noise source have been predicted for the construction of the concentrate, tailings and fuel pipelines from the Mine Area to the Coastal Area, Mine Access Road and Northern Access Road from the Mine Area to the Highlands Highway, and other support facilities (borrow pits, etc.).

The noise predictions have assumed flat open ground between the noise sources and the receiver. Where disturbance zones have been indicated, the offset distance has been taken from the edge of the disturbance zone for construction predictions. It should be noted that topographical shielding and/or dense vegetation between the road construction and the receiver(s) can further significantly reduce noise levels compared to the predicted noise levels (refer to **Section 5.1.5**).

The scheduling of works for construction of the Infrastructure Corridor will be adapted as needed based on the area under construction. This may include for example, construction only during the day when in proximity to large villages. However, through Lae night-works is preferential to minimise the disturbance to users of existing road infrastructure. The predicted offset distance to achieve the noise goal during daytime is presented in **Table 11**. The predictions are based on the sources and sound power data provided in **Appendix B Table B3**, including a de-rating that has been applied to some sources to account for duration of operation.

**Table 11 Predicted Offset Distances to Achieve the Construction Noise Goal – Infrastructure Corridor Construction**

| Time Period | Project Criteria ($L_{Aeq}$) | Predicted Offset Distance to Achieve Criteria |
|---|---|---|
| Day | 55 dBA if more than 3 months | 300 m |
| | 75 dBA if less than 3 months* | 30 m |

*Based on NSW Department of Environment and Climate Change DECC (2009) *Interim Construction Noise Guidelines* (Department of Environment and Climate Change NSW, 2009)

Villages that have been identified as being close to the access roads and concentrate, tailings and fuel pipelines infrastructure (within 2,000 m) are noted below in **Table 12** along with the estimated offset distance.

**Table 12 Village Offset Distance to the Infrastructure Corridor and Access Roads**

| Village | Road / Infrastructure | Offset distance to roads' / pipelines' construction (m) | Compliance |
|---|---|---|---|
| Ziriruk | Mine Access Road / concentrate, tailings and fuel pipelines | 300 | Yes |
| Papas | Mine Access Road / concentrate, tailings and fuel pipelines | 600 | Yes |
| Nambonga | Portal Access Road | 1,300 | Yes |
| Hekeng | Portal Access Road | 1,200 | Yes |
| Bavaga | Mt Beamena Quarry Access Road | 1,100 | Yes |
| Kokok | Northern Access Road / concentrate, tailings and fuel pipelines | 1,400 | Yes |
| Zifasing | Northern Access Road / concentrate, tailings and fuel pipelines | 800 | Yes |
| Ngarubuaring | Northern Access Road / concentrate, tailings and fuel pipelines | 530 | Yes |
| 40 mile Waterside | Concentrate, tailings and fuel pipelines | 900 | Yes |
| Ganef | Concentrate, tailings and fuel pipelines | 800 | Yes |
| Markham Farm | Concentrate, tailings and fuel pipelines | 250 | Complies with the short-term construction noise criterion, however village may experience noise emissions above the long-term criterion |
| Durung Farm | Concentrate, tailings and fuel pipelines | <20 | Both short-term and long-term criterion may be exceeded, depending on the offset distance to residential dwellings. |
| Gabsongkeg | Concentrate, tailings and fuel pipelines | 600 | Yes |
| Mpofose | Concentrate, tailings and fuel pipelines | 390 | Yes |
| Busanim | Concentrate, tailings and fuel pipelines | 450 | Yes |
| Buwatu | Concentrate, tailings and fuel pipelines | 500 | Yes |
| Buambub | Concentrate, tailings and fuel pipelines | 900 | Yes |
| Bewapi | Concentrate, tailings and fuel pipelines | 650 | Yes |
| Simbu | Concentrate, tailings and fuel pipelines | 1000 | Yes |

| Village | Road / Infrastructure | Offset distance to roads' / pipelines' construction (m) | Compliance |
|---|---|---|---|
| Lae | Concentrate, tailings and fuel pipelines | Through town | Both short-term and long-term operational criteria may be exceeded, depending on the offset distance to residential dwellings. |
| Bowali | Tailings pipeline | 100 | Complies with the short-term construction noise criterion, however village may experience noise emissions above the long-term criterion |
| Malahang | Tailings pipeline | 300 | Yes |
| Yanga | Tailings pipeline | 350 | Yes |
| Wagang | Tailings pipeline | 1,000 | Yes |

It should be noted that whilst the construction of the Infrastructure Corridor is passing within the vicinity of villages, elevated noise levels will be short-term and the highest noise levels are likely to last for only a few days (or weeks) as the construction front passes and hence the short-term noise criterion is considered most appropriate. Any residents and other community uses (schools, hospitals etc.) within 300 m (including those within Lae) of the construction activities should be made aware of the times and duration that they may be affected by construction noise.

Locations with dense vegetation and/or some topographic shielding between construction and receiver(s) may experience lower noise levels and the noise goal could be achieved at shorter offset distances compared to those presented in **Table 11**.

Whilst the offset distance between the Infrastructure Corridor and the identified village may be greater than the required distance to achieve compliance, the village locations generally represent the geographical centre of the village and may not account for scattered dwellings, which could potentially be located closer to the works. Where such outlying dwellings are within the offset distances presented in **Table 11** of the Infrastructure Corridor then impacts may occur.

Where sensitive receptors are found to be located significantly closer to the Infrastructure Corridor than currently identified, potential noise impacts may be mitigated through consideration of options such as route deviation or restricting construction hours to day time (taking into account factors such as the findings of land investigation surveys where appropriate).

#### 6.1.3 Port Facilities Area and Outfall Area Construction (Scenario C4-NV)

Noise levels as a function of distance from the construction of the Port Facilities Area and Outfall Area have been calculated and the required offset distance to achieve compliance with the adopted project noise guideline of 55 dBA $L_{Aeq}$ has been determined and is presented in **Table 13**. Noise predictions are based on the plant and equipment detailed in **Appendix B Table B4.**

The noise predictions have assumed flat open ground between the noise sources and the receiver. It should be noted that topographical shielding and/or dense vegetation between the Port Facilities Area or Outfall Area and the receiver(s) can significantly reduce noise levels below those predicted.

**Table 13 Predicted Offset Distances to Achieve Noise Compliance**

| Time Period | Project Criteria ($L_{Aeq}$) | Predicted Offset Distance to Achieve the Noise Criteria | |
|---|---|---|---|
| | | Neutral | Enhanced |
| Day | 55 dBA if more than 3 months | 140 m | 200 m |
| | 75 dBA if less than 3 months* | 20 m | 25 m |

*Based on NSW Department of Environment and Climate Change DECC (2009) Interim Construction Noise Guidelines

Based on project information the closest residential dwelling within Lae to the Port Facilities Area is approximately 1,000 m and the closest village to the Outfall Area is approximately 1,350 m. The day period project noise criterion of 55 dBA $L_{Aeq}$, is met at an offset distance of 270 m under enhanced meteorological conditions, and therefore the criteria of 55dBA is expected to be achieved at the nearest village under all assumed meteorological conditions

## 6.2 Operation

### 6.2.1 Mine Operational Scenario (Scenario O1-NV and O2-NV)

Predicted noise levels associated with the operation of the power generation facilities and mine operation (16.8 Mtpa) are presented as noise contour plots in **Appendix D** and **E**. Both neutral and enhanced (i.e. worst case) meteorological propagation conditions are presented.

A summary of the predicted noise levels under both neutral and enhanced meteorological conditions is provided in **Table 14** for the nearest affected villages.

**Table 14 Mine Operational Noise Predictions**

| | Power generation facilities only | | Mine Operation (16.8 Mtpa) | | Noise Criteria (dBA)[1] | |
|---|---|---|---|---|---|---|
| **Met Conditions** | **Neutral** | **Enhanced** | **Neutral** | **Enhanced** | **Day** | **Night** |
| **Village** | | | | | | |
| Bavaga | <15 | <15 | <15 | <15 | 55 | 45 |
| Bencheng | <15 | <15 | <15 | <15 | 55 | 45 |
| Dengea | <15 | <15 | <15 | <15 | 55 | 45 |
| Fly Camp | <15 | <15 | <15 | <15 | 55 | 45 |
| Gingen | <15 | <15 | <15 | <15 | 55 | 45 |
| Hekeng | <15 | <15 | <15 | <15 | 55 | 45 |
| Kapunung | 25 | 30 | 25 | 30 | 55 | 45 |
| Madzim | <15 | <15 | <15 | <15 | 55 | 45 |
| Maralina | <15 | <15 | <15 | <15 | 55 | 45 |
| Nambonga | <15 | <15 | <15 | 15 | 55 | 45 |
| Papas | 23 | 27 | 29 | 34 | 55 | 45 |
| Pekumbe | <15 | <15 | <15 | <15 | 55 | 45 |
| Pokwaluma | <15 | <15 | <15 | <15 | 55 | 45 |
| Uruf | <15 | <15 | <15 | <15 | 55 | 45 |
| Venembele | <15 | <15 | <15 | <15 | 55 | 45 |
| Wongkins | 18 | 23 | 23 | 29 | 55 | 45 |
| Wori | <15 | <15 | 27 | 32 | 55 | 45 |

| | Power generation facilities only | | Mine Operation (16.8 Mtpa) | | Noise Criteria (dBA)[1] | |
|---|---|---|---|---|---|---|
| Met Conditions | Neutral | Enhanced | Neutral | Enhanced | Day | Night |
| Zindanga | <15 | <15 | <15 | <15 | 55 | 45 |
| Ziriruk | 48 | 51 | 48 | 51 | 55 | 45 |

1. The project criterion is 55 dBA (day) 45 dBA (night).
2. Shading represents an exceedance of the night-time criteria (45 dBA)

The predicted noise levels represent one geographical location of the village (typically the centre) and may not account for scattered dwellings which may be located closer to the mine activities. As such it is possible that higher noise levels could be experienced at individual receptors on the outskirts of villages.

The noise contours and summary provided in **Table 14** show typical noise levels ranging from less than 15 dBA to 51 dBA at the nearest villages for both scenarios and under all meteorological conditions. The plots also suggest that at locations such as Ziriruk, the operation of the power generation facilities dominates the predicted noise levels, which is not entirely unexpected given the location of the village in relation to the power generation facilities.

- The day period project noise criterion of 55 dBA $L_{Aeq}$ is met at all villages for both scenarios and under all meteorological conditions.
- The night period project noise criterion of 45 dBA $L_{Aeq}$ is exceeded at one village, Ziriruk, by a nominal 3 dB under neutral meteorological conditions, and a more significant 6 dB under enhanced meteorological conditions.

Whilst the assessment has identified noticeable impacts under a worst case enhance weather condition, it is unlikely that these conditions will occur often due to the following:

- The site-specific wind conditions shown in Figure 4 indicates that the prominent wind direction is from the south east. The potentially impacted village Ziriuk is situated up wind from the dominant construction noise source and as such, enhanced noise propagation conditions in which exceedances are predicted would be infrequent.
- Whilst the frequency of temperature inversions (pascal stability class f) have the potential to occur for up to 40 % of the year (refer to Figure 5), temperature inversions typically occur during the early morning or evening periods and are not generally present during the day.

The objective test for audible character with a high degree of low frequency is discussed in **Section 4.3.3**. The difference in the C-weighted overall level and the A-weighted level at Ziriruk is approximately 15 dB under neutral propagation conditions and 13 dB under enhanced propagation conditions for mining operations. This indicates that the noise character may have sufficient low frequency content to consider a potential penalty of 5 dB.

Proposed noise management measures will be required to reduce impacts to Ziriruk, refer to **Section 8**.

### 6.2.2 Project Borrow Pit Operation (Scenario O3-NV)

The mine operational scenario includes the operation of the Migiki Borrow Pit. The Project will require the use of a number of additional borrow pits sporadically throughout the life of the Project. Noise levels as a function of distance from the use of these borrow pits has been predicted and the required offset distance to achieve compliance with the adopted project noise criterion of 55 dBA $L_{Aeq}$ has been determined and is presented in **Table 15**.

The noise predictions have assumed flat open ground between the noise sources and the receiver. It should be noted that topographical shielding and/or dense vegetation between the borrow pit and the receiver(s) can significantly reduce noise levels to below the predicted noise levels (refer to **Section 5.1.5**).

**Table 15 Predicted Offset Distances – Borrow pit operation**

| Time Period | Project Criteria ($L_{Aeq}$) | Predicted Offset Distance to Achieve the Noise Criteria |
|---|---|---|
| Day | 55 dBA | 800 m |

Villages that have been identified as being close to borrow pits are noted below in **Table 16** along with the estimated offset distance.

**Table 16 Village Offset Distance To Project Borrow Pits, Quarry and Gravel Extraction**

| Village | Estimated distance from nearest borrow pit | Compliance |
|---|---|---|
| **Migiki Borrow Pit** | | |
| Nambonga | 1,700 m | Yes |
| Venembele | 2,800 m | Yes |
| Hekeng | 3,080 m | Yes |
| Pekumbe | 4,925 m | Yes |
| Fly Camp | 3,770 m | Yes |
| **Humphries Borrow Pit** | | |
| Bavaga | 2,305 m | Yes |
| Ziriruk | 3,870 m | Yes |
| Chaunon | 4,422 m | Yes |
| Kapunung | 4,970 m | Yes |
| **Miapilli Clay Borrow Pit** | | |
| Hekeng | 400 m | No |
| Venembele | 2,500 m | Yes |
| Nambonga | 2,700 m | Yes |
| **Northern Access Road Borrow Pit** | | |
| Bavaga | 2,400 m | Yes |
| Kapunung | 5,400 m | Yes |
| Ziriruk | 4,500 m | Yes |
| **Mount Beamena Quarry** | | |
| Kapunung | 5,290 m | Yes |
| Bavaga | 1,390 m | Yes |
| Fly Camp | 4,090 m | Yes |
| Uruf | 7,500 m | Yes |
| Wongkins | 7,400 m | Yes |
| Gingen | 6,890 m | Yes |
| Dengea | 7,500 m | Yes |
| **Bavaga Gravel Extraction** | | |
| Bavaga | 1,300 | Yes |
| Gingen | 6,070 | Yes |
| Dengea | 6,500 | Yes |
| **Lower Papas Aggregate source** | | |
| Papas | 1,200 m | Yes |

| Village | Estimated distance from nearest borrow pit | Compliance |
|---|---|---|
| Wori | 2,100 m | Yes |
| Wongkins | 2,800 m | Yes |

Based on the offset distance between villages and the borrow pits, quarries and gravel extraction sites (detailed in **Table 12),** the majority of sensitive receptors are located at distances greater than 1,000 m, with the exception of Hekeng which is approximately 400 m from the closet point of the Miapilli clay borrow pit. The day period project noise criterion of 55 dBA $L_{Aeq}$, is met at an offset distance of approximately 800 m, and thus compliance will be achieved for all villages with the exception of the aforementioned village, Hekeng.

Proposed management measures specifically relating to Hekeng are discussed in **Section 8.**

### 6.2.3 Port Facilities Area and Outfall Area Operation (Scenario O4-NV)

Noise levels as a function of distance from the operation of the Port Facilities Area and Outfall Area have been calculated and the required offset distance to achieve compliance with the adopted project noise guidelines has been determined and is presented in **Table 17**.

Noise predictions are based on the plant and equipment detailed in **Appendix B Table 7.**

**Table 17 Predicted Offset Distances – Port Facilities Area Operation**

| Time Period | Project Criteria for modelling($L_{Aeq}$) | Predicted Offset Distance to Achieve the Noise Modelling Criteria | |
|---|---|---|---|
| | | **Neutral** | **Enhanced** |
| **Port Facilities Area** | | | |
| Day | 55 dBA | 240 m | 300 m |
| Night | 45 dBA | 520 m | 730 m |

Based on available project information, the closest residential dwelling within Lae to the Port Facilities Area is located approximately 1,000 m away. The night period project noise criterion of 45 dBA $L_{Aeq}$, is met at an offset distance of 730 m under enhanced meteorological conditions and 520 m under neutral conditions.

The Port Facilities Area operation is expected to comply with day and night criteria under all meteorological conditions.

As a guide, **Table 18** provides indicative buffer distances based on varying source sound levels at 3 m for the choke station proposed at the Outfall Area. The supplier / manufacturer of the choke station should be able to implement practical noise control measures, such as enclosures, in order to achieve the criterion if necessary. The calculations assume soft ground and do not allow for any other shielding from ground terrain. Actual noise levels would be lower than those shown in **Table 18** where ground terrain or dense forest provides further shielding.

**Table 18 Choke Station Buffer Distances**

| Possible Noise Output of Choke Station | Predicted Offset Distance to Achieve the Noise Modelling Criteria | Comment |
|---|---|---|
| 85 dBA at 3 m | 500 m | May be achieved without specific acoustic enclosure |
| 75 dBA at 3 m | 150 m | Acoustic enclosure likely to be required for choke station to achieve this noise emission |
| 65 dBA at 3 m | 120 m | Acoustic enclosure likely to be required for choke station to achieve this noise emission |
| 50 dBA at 3 m | 8 m | Acoustic enclosure likely to be required for choke station to achieve this noise emission |

Based on available project information, the closest village to the proposed Outfall Area is located approximately 1,300 m away. The night period project noise goal of 45 dBA $L_{Aeq}$, is met at an offset distance of 500 m assuming a sound pressure level of 85 dBA at 3 m.

The Outfall Area operation is expected to comply with day and night criteria under all meteorological conditions.

### 6.2.4 Mine Access Road and Northern Access Road Transportation Noise (Scenario O5-NV)

While the Mine Access Road and Northern Access Road is being constructed, the Demakwa to Wafi Access Road will be the main transport route for all people and materials to the Project. This will include an assumed two 23t payloads per day, one transporting freight and the other fuel.

Development of the Mine Access Road and Northern Access Road will involve the construction of a new road and bridge across the Markham River, linking the Mine Area to the Highlands Highway near Zifasing.

Following the completion of the Mine Access Road and the Northern Access Road and during construction of the Project, the maximum daily traffic loading required is conservatively estimated to be 30 trucks per day, per traveling direction, excluding light vehicle movements and external public traffic on the road.

These traffic numbers are below those required to accurately predict ‘continuous’ noise levels using standard road noise prediction models (minimum requirement is 1000 vehicles per day using CoRTN).

Noise impacts from heavy vehicle movements have therefore been assessed by predicting maximum pass-by noise levels at offset distances from the access roads. In particular, the night period pass-bys are the most critical, as they can cause sleep disturbance.

The noise levels for a slow moving 20 t truck pass-by (being the loudest of all potential sources) is approximately as follows:

- 75 dBA at 15 m
- 60 dBA at 80 m
- 58 dBA at 100 m
- 52 dBA at 200 m

For the night period, in order to minimise sleep disturbance, a criterion of 60 dBA $L_{max}$ is recommended which would be achieved at a buffer distance of approximately 80 m. For the day, infrequent short-term pass-by noise levels of up to 75 dBA would be acceptable.

It is anticipated that the Northern Access Road and the Mine Access Road would be the primary haulage route for supplies and staff transportation from Lae to the Mine Area and as such, based on offset distances presented in **Table 16** compliance with the sleep disturbance criteria of 60 dBA $L_{max}$ would be achieved assuming 24hr operation.

If other roads are to be used during the night, there may be villages that are within the 80 m night criterion buffer distance. It should be considered that only a relatively low number of pass-bys would occur during the night (if 24hour traffic is assumed for the Project), and there may be further possibilities for the Project to consider reducing this to minimise potential impacts. In addition, the Mine Access Road and the Northern Access Road may have some flexibility in design to allow minor deviations to minimise or avoid potential noise impacts at sensitive receiver locations.

## 6.3 Potential Noise Impact on Fauna

The potential effects of Project-generated noise on wildlife include physical damage to hearing, increased energy expenditure or physical injury while responding to noise, interference with normal animal activities and impaired communication. Ongoing impacts of these effects might include habitat loss through avoidance, reduced reproductive success and increased mortality.

While noise impacts on people are commonly regulated, there are no government guidelines or other widely accepted guidelines as to noise levels or thresholds that may have an adverse effect on wildlife. One reason for the lack of guidelines is that noise effects on most wildlife species are poorly understood (Larkin, 1996); (Brown, 1990); (Ocean Studies Board, 2003); summarised in (AMEC Americas Limited, July 2005).

The lack of understanding of noise effects on wildlife is understandable when the following points are considered:

- Response to noise disturbance cannot be generalised across taxa. Studies of one species cannot always be extrapolated to other species.
- Hearing characteristics are species-specific. For example, noise impacts on humans are determined using a frequency weighting filter (A-weighting) which corresponds to human hearing characteristics, determined through laboratory testing. The frequency-dependent hearing characteristics of animals cannot be determined in this way.
- When studying noise effects on animals it can be difficult to separate noise effects from other sensory disturbing effects (e.g. visual or olfactory cues).
- Experimental research in a laboratory is not always applicable in a natural setting.

As with humans, an animal's response to noise can depend on a variety of factors, including noise level, frequency distribution, duration, number of events, variation over time, rate of onset, noise type, existence and level of ambient noise, time of year, and time of day. The animal's location, age, sex, and past experience may also affect their response to noise.

During the initial stages of construction of the Project when new noise sources are introduced to the environment, changes could be expected in the behaviour of some of the fauna, particularly those individuals closest to the new facilities.

Following the initial stages of construction, equilibrium is likely to be reached, involving:

- Likely changes in species composition near the Project, with less noise-tolerant species moving further away
- Selection for more noise-tolerant individuals within the populations of species close to the Project
- Habituation of some species and individuals to the noise impacts as currently displayed by some species near existing operations

It is clear that noise could have adverse effects on terrestrial fauna, with different species being more or less sensitive to noise. Extremely high noise levels can result in hearing damage or other physiological effects, although fauna generally avoid exposure to such impacts wherever possible. At lower noise levels, terrestrial fauna will generally avoid anthropogenic noise sources and prefer to occupy areas further from noise sources.

Generally, terrestrial fauna will avoid areas where very high noise levels (sufficient to cause injury or damage) occur. It is anticipated that noise levels in excess of 100 dBA, over extensive periods, would be required to create physical damage or injury (World Health Organization, 2015). It is unlikely that any terrestrial fauna would remain in any area affected by noise levels of this order. Indeed, it is noted that the construction and operation of the Project will not include plant and equipment capable of generating noise levels required to cause such damage, even in very close vicinity to the plant and equipment.

# 7 VIBRATION IMPACT ASSESSMENT

This section investigates ground vibration (from both blasting and construction sources) and airblast emissions from the Project.

## 7.1 Vibration

People are far more sensitive to vibration than noise and these sensitivities are based on reality and also on perception of reality (C Druga, 2007). For instance, people often express dissatisfaction with vibration levels which are well below limits causing any risk of damage to a building or its contents.

The actual perception of motion or vibration may not, in itself, be disturbing or annoying. An individual's response to that perception, and whether the vibration is "normal" or "abnormal", depends very strongly on previous experience and expectations, and on other connotations associated with the perceived source of the vibration. For example, the vibration that a person responds to as "normal" in a car, bus or train is considerably higher than what is perceived as "normal" in a shop, office or dwelling.

The varying degrees of perceptions experienced by people are suggested by the continuous vibration level categories given in **Table 19** (C Druga, 2007)**.**

**Table 19 Vibration Levels and Human Perception of Motion**

| Approximate Vibration Level | Degree of Perception |
|---|---|
| 0.10 mm/s | Not felt |
| 0.15 mm/s | Threshold of perception |
| 0.35 mm/s | Barely noticeable |
| 1 mm/s | Noticeable |
| 2.2 mm/s | Easily noticeable |
| 6 mm/s | Strongly noticeable |
| 14 mm/s | Very strongly noticeable |

Note: These approximate vibration levels (in floors of building) are for vibration having frequency content in the range of 8 Hz to 80 Hz.

**Table 19** suggests that people will just be able to feel continuous floor vibration at levels of about 0.15 mm/s and that the motion becomes "noticeable" at a level of approximately 1 mm/s.

As discussed above, people can detect and possibly even be annoyed at vibration levels which are well below those causing any risk of damage to a building or its contents. Still, it is the fear of structural damage to property that is the primary cause of complaints (Scannell, 1995). The fear of structural damage to the complainant's property has the potential to cause the individual stress and anxiety.

Scannell (1995) also refers to research which shows that the important psychological factors influencing the human reaction to stressful vibration events are predictability and to some extent controllability. The research shows that the individual(s) negative reaction to the vibration events can be reduced if they are predictable (i.e. the individual/building occupant is kept well informed of scheduled events).

## 7.2 Airblast Overpressure

Airblast is the pressure wave (sound) produced by blasting and transmitted through the air. It is expected that blasting may be used throughout the Project and as such the potential impacts from airblast must be considered.

The sources of airblast include a usually small air pressure pulse generated by the ground vibration, a direct air pressure pulse generated by the rock movement during blasting and an air pressure pulse caused by direct venting of gases from the region of the blast. It is important to recognize that airblast may be reflected by layers within the atmosphere and that the airblast may be refocused at distances remote from the blast.

Airblast may be heard by people if it contains energy in the audible frequency range, typically between 20 Hz and 20 kHz. A blast perceived as loud may have a low airblast level and a blast that is barely noticeable outdoors may have a high airblast level.

At distances where both effects are above perceptible levels, airblast is usually felt after any ground vibration. Ground-transmitted vibration waves from a blast normally travel faster than the air-transmitted airblast overpressure.

## 7.3 Vibration Assessment Standards and Guidelines

The primary objective of the vibration assessment is to manage the adverse effects of vibration on people. Excessive vibration has the ability to cause nuisance, including sleep deprivation, stress and increased blood pressure, as well as other physical, physiological and psychological effects.

It is expected that the major source of ground vibration associated with the Project would be due to blasting conducted within the Project borrow pits. In addition to blasting, impacts from other general construction and operation vibration generating sources such as rock breaking, heavy vehicles and compaction activities will also be addressed as part of this assessment.

There are no relevant standards or guidelines available in PNG with regard to vibration or airblast emissions. Therefore the vibration assessment has been performed based on the most relevant international standards and guidelines which are outlined below.

The following sections describe the relevant project specific vibration and airblast guideline values for the following categories:

- Blasting activities – ground vibration and airblast overpressure
- General construction and operation (excluding blasting) activities – ground vibration

### 7.3.1 Blasting – Ground Vibration

Vibration can affect human comfort and also result in structural damage in buildings if it is of a sufficiently high level. The level of vibration required to cause building damage is significantly higher than that which will cause discomfort to occupants.

Specific vibration building damage criteria are contained in British Standard *BS 7385-2:1993 Evaluation and Measurement for Vibration in Buildings – Part 2. Guide to Damage Levels from Ground-borne Vibration* (British Standard, 1993) and the United States Bureau of Mines (USBM) *Report of Investigation RI 8507* (D. E. Siskind, 1980). Similarly Appendix J4 of *AS 2187.2:2006 Explosives – Storage and Use, Part 2: Use of Explosives* (Australian Standard, 2006) contains human comfort limits for ground vibration from blasting.

A summary of the blasting vibration guidelines proposed for the Project, based on AS2187.2, BS 7385-2 and USBM, for both building damage and human comfort are provided in **Table 20**.

**Table 20 Vibration Guidelines – Building Damage and Human Comfort**

| Guideline Type | Vibration level, Peak Component Particle Velocity, mm/s | Guideline Source Reference |
|---|---|---|
| Building Damage | 15 mm/s at 4 Hz, increasing to 20 mm/s at 15 Hz and further increasing to 20 mm/s at 40 Hz 20 mm/s above 40 Hz | BS 7385-2 criteria values for “prevention of minor or cosmetic damage” |
| | 5 mm/s at 1 Hz increasing to 12.7 mm/s at 4 Hz, 12.7 mm/s between 4 Hz and 15 Hz, rising to 50 mm/s at 40 Hz and above | USBM RI 8507 “Safe blasting vibration level criteria” |
| Human Comfort | 5 mm/s for 95% of blasts, up to 10 mm/s maximum. Based on operation for more than 12 months. | AS2187.2 - commonly used criteria by regulatory authorities |

**Table 20** shows that the 5 mm/s human comfort guideline value is the most stringent of all the above and given the setting of the Project, i.e., within a pristine environment, it is therefore considered appropriate for assessment of vibration from blasting activities associated with the Project.

In addition it is also proposed that surface blasting activities will generally only be permitted during the daytime period, in order to minimise impact and annoyance due to this activity.

### 7.3.2 Blasting – Airblast

Airblast can cause discomfort to persons and, at high levels, damage to structures and architectural elements.

Based largely on work carried out by the US Bureau of Mines (USBM), the US Office of Surface Mining has presented the following regulatory limits for airblast from blasting (depending on the low frequency limit of the measuring system) as shown in **Table 21**.

**Table 21 Regulatory Airblast Limits – Building Damage (USBM)**

| Low Frequency Limit | Peak Airblast Level Limit |
|---|---|
| 2 Hz or lower | 132 dBL |
| 6 Hz or lower | 130 dBL |

The US criteria are structural damage limits based on the relationship between the level of airblast and the probability of window breakage, and include a significant safety margin. It has been well documented that windows are the elements of residential buildings most at risk to damage from airblast from blasting. The USBM levels described above are generally consistent with the level of 133 dBL nominated in AS 2187.2.

Appendix J5 of AS 2187.2 refers to airblast limits for both human comfort and building damage.

A summary of the proposed airblast guidelines for the Project, based on AS2187.2 and USBM, for both building damage and human comfort are provided in **Table 22**.

**Table 22 Airblast Guidelines – Building Damage and Human Comfort**

| Guideline Type | Peak Sound Pressure Level | Guideline Source Reference |
|---|---|---|
| Building Damage | 130 dBL for airblast with a frequency of 6 Hz or lower | USBM |
| | 132 dBL for airblast with a frequency of 2 Hz or lower | |
| | 133 dBL for airblast with a frequency above 6 Hz | AS2187.2 |
| Human Comfort | 115 dBL for 95% of blasts, up to 120 dBL maximum. Based on operation for more than 12 months. | AS2187.2 |

**Table 22** shows that the 115 dBL human comfort guideline value is the most stringent of all and is therefore considered appropriate for assessment of airblast from blasting activities associated with the Project.

In addition to the proposed airblast guideline, blasting activities will generally only be permitted during the daytime except for underground activities.

### 7.3.3 Construction and Operation Vibration

When dealing with general construction vibration, the effects can be divided into the following main categories:

- Human comfort
- Cosmetic and structural damage to above ground structures and buried services

As previously discussed the human comfort requirements are considerably more stringent than those related to damage. Accordingly the human comfort criteria are presented in full below.

#### 7.3.3.1 Human Comfort

Tactile perception of random motion, outlined in **Table 19**, indicates that people will just be able to feel continuous floor vibration at levels of about 0.15 mm/s and that the motion becomes “noticeable” at a level of approximately 1 mm/s.

Guidance in relation to assessing the potential human disturbance from ground-borne vibration inside buildings and structures is contained in *BS 6472-1: 2008 Guide to Evaluation of Human Exposure to Vibration in Buildings, Part 1: Vibration Sources other than Blasting* (British Standard, 2008).

Satisfactory magnitudes of peak vibration velocity (i.e. below which the probability of “adverse comment” is low) from BS 6472 are shown in **Table 23**.

**Table 23 Satisfactory Level of Peak Vibration Velocity (8 Hz to 80 Hz)**

| Type of Space Occupancy | Time of Day | Satisfactory Peak Vibration Levels in mm/s Over the Frequency Range 8 Hz to 80 Hz | | | |
|---|---|---|---|---|---|
| | | Continuous Vibration | | Impulsive Vibration with up to 3 Occurrences per Day | |
| | | Vertical | Horizontal | Vertical | Horizontal |
| Critical working areas (e.g. some hospital operating theatres, some precision laboratories, etc.) | Day<br>Night | 0.14 mm/s<br>0.14 mm/s | 0.4 mm/s<br>0.4 mm/s | 0.14 mm/s<br>0.14 mm/s | 0.4 mm/s<br>0.4 mm/s |
| Residential | Day<br>Night | 0.3 - 0.6 mm/s<br>0.2 mm/s | 0.8 - 1.6 mm/s<br>0.6 mm/s | 8.4 - 12.6 mm/s<br>2.8 mm/s | 24 - 36 mm/s<br>8 mm/s |
| Offices | Day<br>Night | 0.6 mm/s<br>0.6 mm/s | 1.6 mm/s<br>1.6 mm/s | 18 mm/s<br>18 mm/s | 51 mm/s<br>51 mm/s |
| Workshops | Day<br>Night | 1.2 mm/s<br>1.2 mm/s | 3.2 mm/s<br>3.2 mm/s | 18 mm/s<br>18 mm/s | 51 mm/s<br>51 mm/s |

**Table 23** indicates that in a residential context the continuous floor vibration levels, above which "adverse comment" may arise, are as follows:

- Daytime – range from approximately 0.3 mm/s to 0.6 mm/s
- Night-time – approximately 0.2 mm/s

Activities which may be considered as continuous vibration sources associated with the construction and operation phases of the Project may include compaction works (vibrator rollers); rock drilling/breaking; haul truck operation; and mineral processing.

Furthermore**, Table 23** indicates that vibration levels of up to approximately 12 mm/s can be acceptable for impulsive vibration occurring only a few times per day, which is considerably higher than that for continuous vibration sources.

## 7.4 Summary of Vibration Guidelines

### 7.4.1 Blasting Vibration and Airblast

The applicable blasting guidelines described below would prevent adverse comment by individual building occupants, adverse health effects and also structural damage to buildings:

- Ground vibration – 5 mm/s for 95% of blasts (maximum of 10 mm/s)*
- Airblast – 115 dBL for 95% of blasts (maximum of 120 dBL)*

  * Guideline percentiles are assumed over a period of 12 months.

In addition to the proposed ground vibration and airblast guidelines, it is also assumed that surface blasting activities will generally only be permitted during the daytime period and any potentially affected individuals/building occupants will be kept well informed of scheduled surface blasting events.

### 7.4.2 Non-Blasting Vibration

During the construction and operation phases of the Project, the major potential sources of vibration emission are expected to consist of rock breaking/drilling activities, compaction works (i.e. vibratory rollers) and from haul trucks. The proposed vibration guidelines, based on relevant international standards and guidelines, for these activities are shown below in **Table 24** for the various categories of criteria.

**Table 24 Construction and Operation Vibration Guidelines – Summary**

| Guideline Category | | Guideline Values (mm/s) | |
|---|---|---|---|
| | | **Day** | **Night** |
| Human Comfort (residential and office buildings) | | 0.3 to 0.6 | 0.2 |
| Structural and cosmetic damage | | 12.5 | 12.5 |
| Buried services | Steel | 100 | 100 |
| | Clay, concrete, metal (other than steel) | 80 | 80 |
| | Masonry, plastic | 50 | 50 |
| | Telecommunications services | 50 | 50 |

## 7.5 Vibration Predictions

The potential vibration impacts associated with the Project are divided into two categories as follows:

- Blasting activities
- General construction and operation vibration sources (excluding blasting) such as rock breaking, heavy vehicles, compaction, etc.

The general method for predicting vibration (and airblast) emissions from these activities is described in the following sections.

### 7.5.1 Blast Prediction Method

Ground vibration and airblast emission levels have been predicted using the formulae given in the AS 2187.2, applicable to blasting in average rock. Both methods of blast emission estimation are considered conservative.

The relevant formulae are as follows:

$PPV = 1140\ (R/Q^{0.5})^{-1.6}$ (free face)
Applicable for open pit and borrow pits.

$PPV = 5000\ (R/Q^{0.5})^{-1.6}$ (heavily confined blast, where no free face exists)
Applicable for road construction.

$dB = 164.2 - 24(\log_{10} R - 0.33 \log_{10} Q)$ (free face and confined blasts)

Where,

PPV = Ground vibration in Peak Particle Velocity Level (mm/s)
dB = Peak airblast level (dBL)
R = Distance between charge and receptor (meters)
Q = Maximum Instantaneous Charge (MIC) mass per delay (kilograms)

For the borrow pits and road construction typical MIC values have been assumed based on SLR's previous experience from similar activities.

#### 7.5.1.1 Typical Blast Design Parameters

The typical blast design parameters assumed for this assessment are presented in **Table 25** for borrow pits and **Table 26** for road construction.

**Table 25 Indicative Blast Design Details – Borrow Pits and Quarry**

| Parameter | Free Face |
|---|---|
| Bench height | 7.5 m |
| Blast-hole spacing | 4.5 m |
| Burden | 3.9 m |
| Maximum Instantaneous Charge (MIC) | 110 kg (assumed maximum) |

**Table 26 Indicative Blast Design Details – Road Construction**

| Parameter | Confined (No Free Face) |
|---|---|
| Bench height | Various |
| Blast-hole spacing | Various |
| Burden | Various |
| Maximum Instantaneous Charge (MIC) | 50 kg (assumed maximum) |

### 7.5.2 Construction and Operation Vibration Prediction Method

The method for prediction of potential vibration impacts from general construction and operation vibration sources (excluding blasting) associated with the Project is described below.

A review of all construction and operation plant and equipment was carried out in order to identify potential sources of vibration emission. The following vibration sources have been identified for assessment:

- Rock breaking
- Heavy vehicle movement
- Compaction activities (vibratory rollers)

Typical source levels for the vibration generating items of plant and equipment have been determined from SLR’s reference database of measured vibration levels. The measured vibration levels were obtained using calibrated vibration monitoring equipment with measurements taken at various offset distances from the source in order to determine the level of vibration attenuation with distance.

Ground vibration levels have been predicted at various offset distances from the identified plant and equipment in order to develop safe working distances for this equipment.

## 7.6 Vibration Impact Assessment

### 7.6.1 Blasting Vibration and Airblast

Blast emission levels (ground vibration and airblast) have been predicted for the following scenarios based on the typical blast design parameters in **Section 7.5.1.1.**

#### 7.6.1.1 Ground Vibration

The applicable ground vibration guideline for the Project caters for the inherent variation in emission levels from a given blast design by allowing 5% exceedance of the guideline limit (5 mm/s) up to a (never to be exceeded) maximum (10 mm/s). Correspondingly, "5% exceedance" and "maximum" predictions were generated for this assessment.

The resulting ground vibration as a function of distance from the blasting activities is shown in **Figure 6** and **Figure 7.**

**Figure 6 Ground Vibration (mm/s PPV) - 110 kg MIC – Project Borrow Pits**

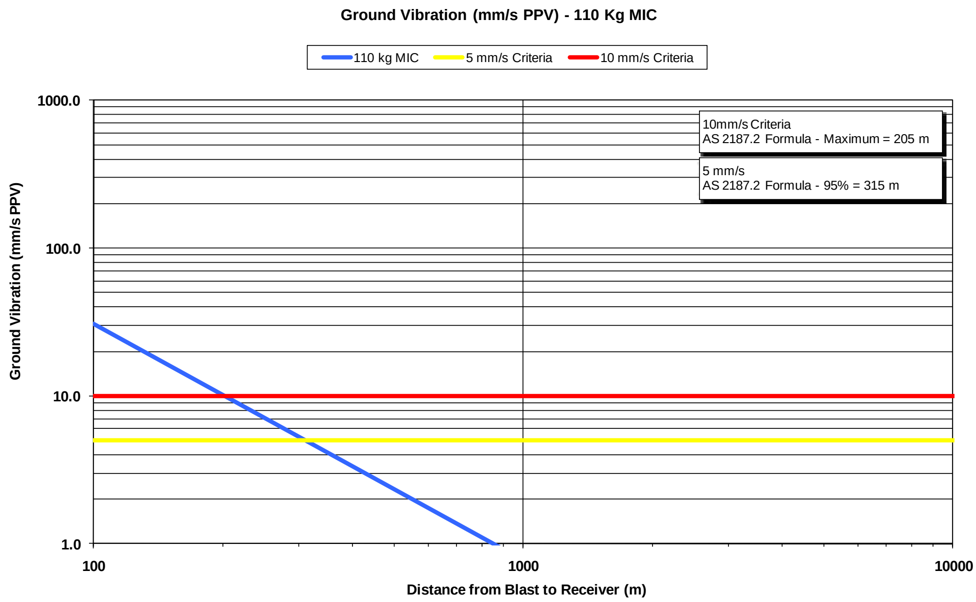
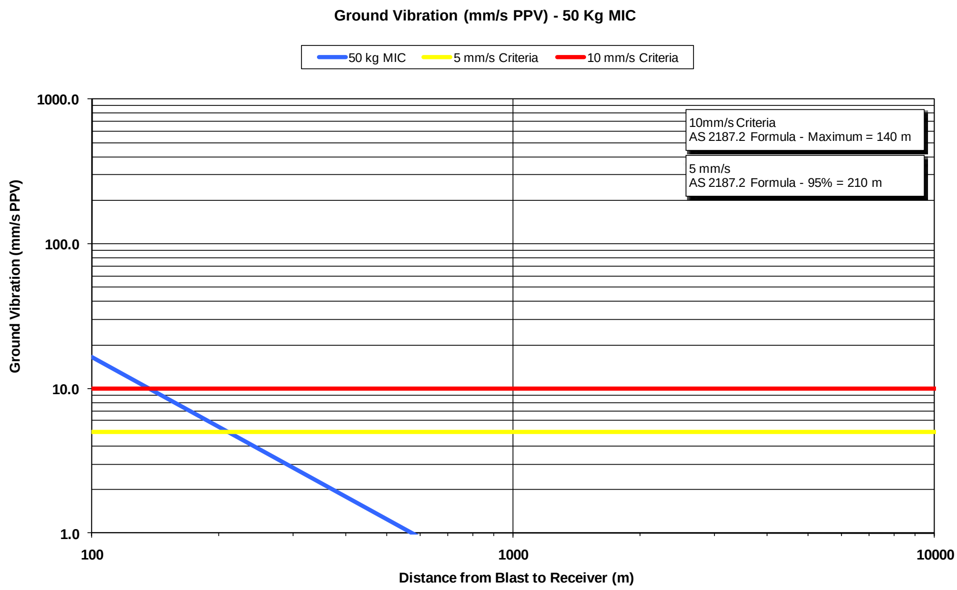



**Figure 7 Ground Vibration (mm/s PPV) - 50 kg MIC – Road Construction**




The maximum offset distances required to achieve the ground vibration guideline for blasting have been summarised in **Table 27**.

**Table 27 Predicted Offset Distances to Achieve the Blasting Ground Vibration Guideline**

| Construction Site | Ground Vibration Guideline (PPV) | | Predicted Offset Distance to Achieve the Vibration Guideline | |
|---|---|---|---|---|
| | **95%** | **Maximum** | **95%** | **Maximum** |
| Borrow Pits | 5 mm/s | 10 mm/s | 315 m | 205 m |
| Concentrate, tailings and fuel pipelines and Northern Access Road Construction | 5 mm/s | 10 mm/s | 210 m | 140 m |

#### 7.6.1.2 Airblast Overpressure

The applicable airblast overpressure guideline for the Project caters for the inherent variation in emission levels from a given blast design by allowing 5% exceedance of a general guideline (115 dBL Peak) and up to a (never to be exceeded) maximum (120 dBL Peak). Correspondingly, “5% exceedance” and “maximum” predictions were generated for this assessment.

The resulting airblast overpressure predictions for blasting activities are shown in **Figure 8** and **Figure 9**.

**Figure 8 Airblast Overpressure (dBL) - 110 kg MIC – Project Borrow Pits**

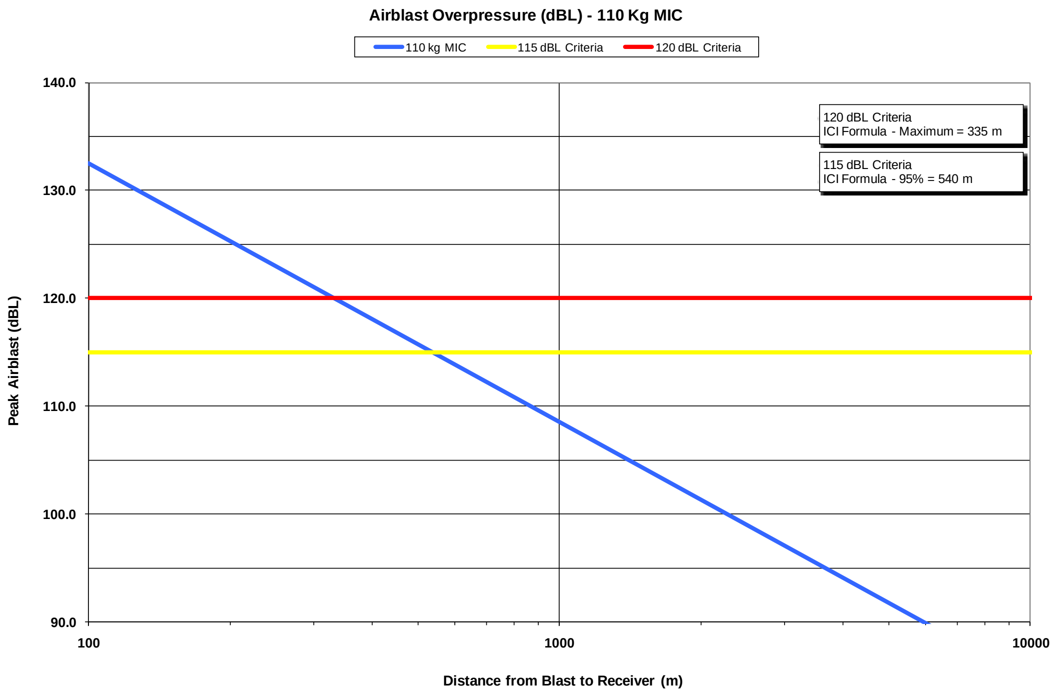
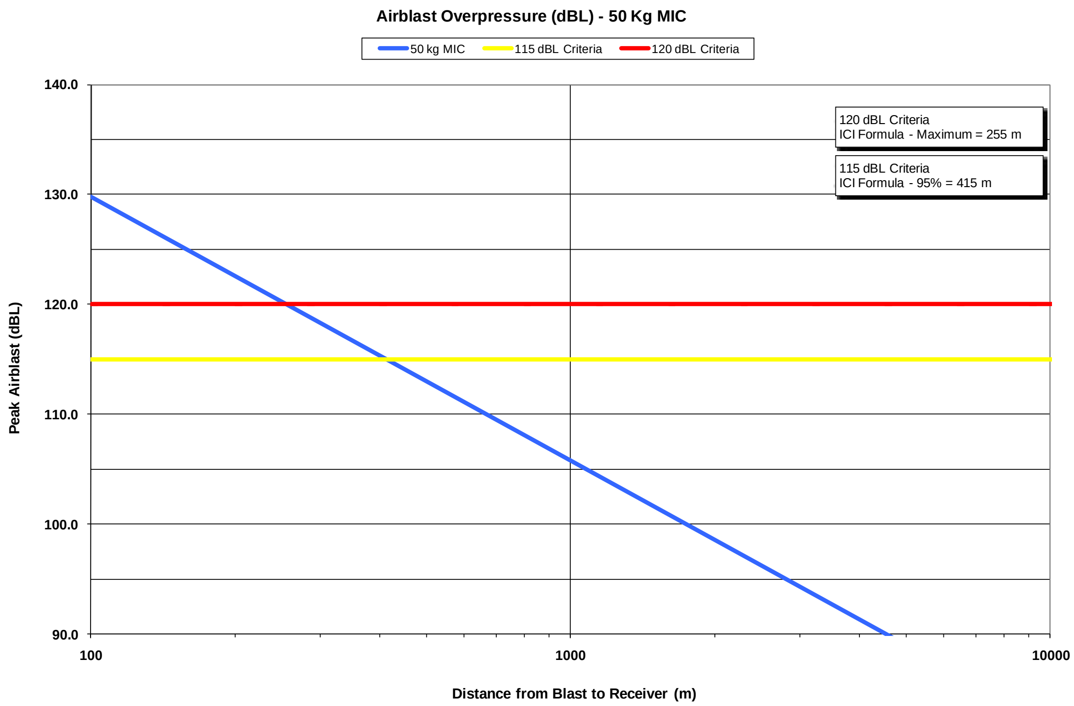


**Figure 9 Airblast Overpressure (dBL) - 50 kg MIC – Road Construction**




The maximum offset distances required to achieve the airblast overpressure guideline have been summarised in **Table 28**.

**Table 28 Predicted Offset Distances to Achieve the Airblast Overpressure Guideline**

| Construction Site | Airblast Overpressure Guideline (Peak) | | Predicted Offset Distance to Achieve the Noise Guideline | |
|---|---|---|---|---|
| | **95%** | **Maximum** | **95%** | **Maximum** |
| Project Borrow Pits | 115 dBL | 120 dBL | 540 m | 335 m |
| Road Construction | 115 dBL | 120 dBL | 415 m | 255 m |

### 7.6.2 Blasting Assessment

The nearest villages to the proposed borrow pits are detailed below in **Table 29**.

**Table 29 Village Offset Distance to Project Borrow Pits**

| Village | Estimated distance from nearest borrow pit | Compliance |
|---|---|---|
| **Migiki Borrow Pit** | | |
| Nambonga | 1,700 m | Yes |
| Venembele | 2,800 m | Yes |
| Hekeng | 3,080 m | Yes |
| Pekumbe | 4,925 m | Yes |
| Fly Camp | 3,770 m | Yes |

| Village | Estimated distance from nearest borrow pit | Compliance |
|---|---|---|
| **Lower Papas Aggregate source** | | |
| Papas | 1,200 m | Yes |
| Wori | 2,100 m | Yes |
| Wongkins | 2,800 m | Yes |
| **Miapilli Clay Borrow Pit** | | |
| Hekeng | 400 m | Blasting not proposed for Miapilli clay borrow pit. |
| Venembele | 2,500 m | - |
| Wafi | 2,100 m | - |
| Nambonga | 2,700 m | - |
| **Mount Beamena Quarry** | | |
| Kapunung | 5,290 m | Yes |
| Bavaga | 1,390 m | Yes |
| Fly Camp | 4,090 m | Yes |
| Uruf | 7,500 m | Yes |
| Wongkins | 7,400 m | Yes |
| Gingen | 6,890 m | Yes |
| Dengea | 7,500 m | Yes |
| **Bavaga Gravel Extraction – Crushing and Screening** | | |
| Bavaga | 1,300 | Yes |
| Gingen | 6,070 | Yes |
| Dengea | 6,500 | Yes |

The majority of sensitive receptors are located approximately 1,300m from the nearest borrow pit with the exception of Hekeng, which is located approximately 400 m from the Miapilli Clay Borrow pit, however blasting is not proposed at this site. Therefore anticipated vibration and airblast overpressure levels from the borrow pits and quarry where blasting is proposed, will be well below the relevant guideline values for the nearest sensitive receptors.

The specific locations for blasting during construction of the concentrate, tailings and fuel pipelines and Northern Access Road have not yet been determined. The distance between any blasting required for the concentrate, tailings and fuel pipelines and Northern Access Road construction and any sensitive receptors is expected to be typically greater than the 415 m in distance required for vibration (refer to **Table 27)** and airblast over pressure (refer to **Table 28)** criteria to be achieved.

If any blasting is required at closer distances than those identified, then specific blast management measures may be required.

### 7.6.3 Non-Blasting Vibration Assessment

A review of all construction and operation plant and equipment was carried out in order to identify potential sources of vibration emission (excluding blasting). The following vibration sources have been identified for assessment:

- Rock breaking
- Heavy vehicle movement
- Compaction activities (vibratory rollers)

It is noted that the Block Cave mining method proposed for the Project may result in intermittent vibration events as the ore body is drawn down and subsequent subsidence occurs in the strata above. It is not possible to predict the frequency of occurrence or magnitude of such events and little empirical data exists to quantify such events as impacts would be specific to each site. Whilst it is possible that vibration events of sufficient magnitude to be perceptible by people will occur it is most unlikely they would be of sufficient magnitude to cause structural damage to existing buildings or other infrastructure due to the typically light weight construction of village huts within PNG that would be considered less susceptible to structural damage.

The typical maximum levels of ground vibration as a function of distance from rock breaking, vibratory rollers and heavy vehicle movements sourced from SLR's vibration measurement database are shown in **Figure 10**.

**Figure 10 Maximum Ground Vibration – Rock-breaking, Vibratory Rollers and Heavy Vehicles**

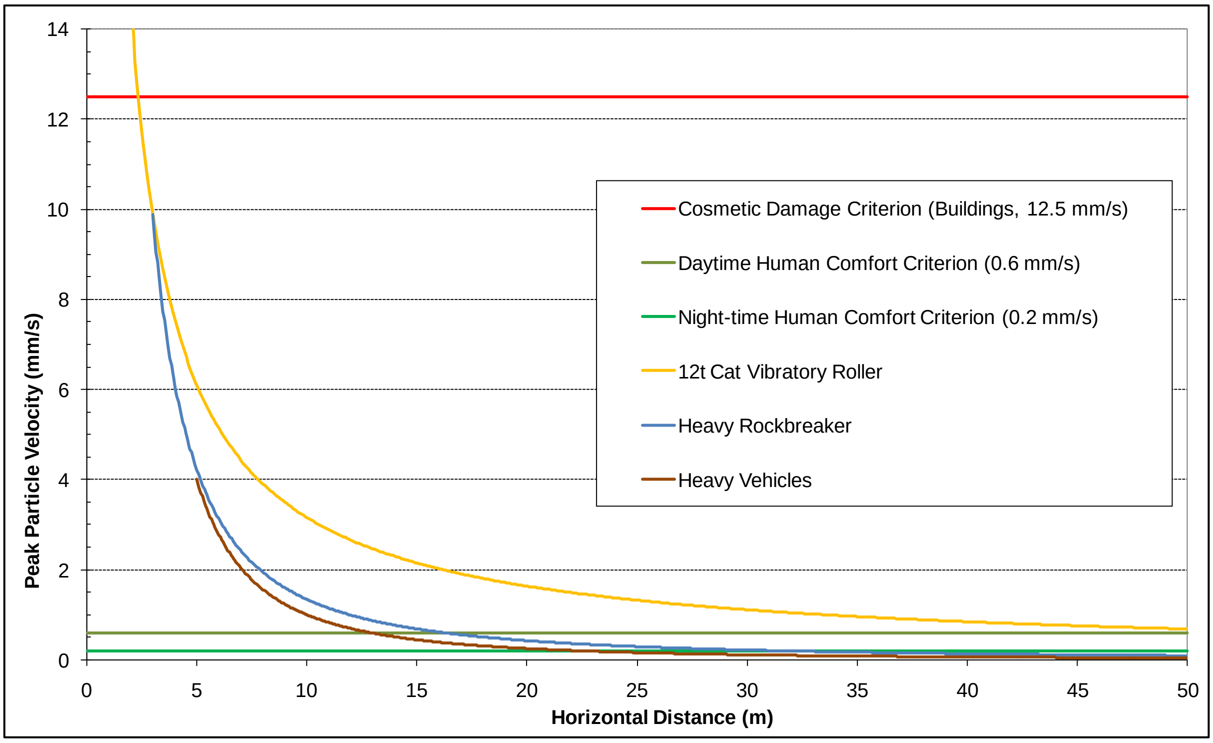



**Figure 10** shows that there is no risk for any structural damage to buildings or structures located at distances greater than 3 m from any construction activities.

For daytime construction, activity vibration levels will achieve the human comfort guideline at distances greater than 15 m from heavy rock-breaking and heavy vehicle movements and 55 m from heavy vibratory roller activity. No villages are within 55 m of the Northern Access Road, however Durung Farm is within 55 m of the concentrate, tailings and fuel pipelines, and the pipelines will also pass through Lae, as such perceptible vibration levels may be noticed during the construction of this infrastructure at these locations.

Noise and vibration monitoring may be required where sensitive receptors are located within close vicinity of activities required for the construction of the concentrate, tailings and fuel pipelines and Northern Access Road.

Due to the buffer distances between the project construction sites and project-related infrastructure and the nearest sensitive receptors, compliance with the cosmetic damage vibration criterion will be readily achieved at all existing sensitive receptors for all the above mentioned sources.

### 7.6.4 Summary of Vibration Assessment

**Blasting Vibration and Airblast**

The blast emission predictions for project-related borrow pits (assuming an MIC of 110 kg) and Northern Access Road construction (assuming an MIC of 50 kg) show that the ground vibration guideline values (5 mm/s) and the airblast overpressure guideline values (115 dBL peak) are achieved at all identified sensitive receptors.

The specific locations for blasting during construction of the concentrate, tailings and fuel pipelines are unknown; however, if blasting is required adjacent to any villages then specific blast management measures may be required.

**Non-Blasting Vibration**

Due to the buffer distances between the Project construction sites and project-related infrastructure and the nearest identified sensitive receptors, compliance with the applicable cosmetic damage vibration criterion is expected to be achieved.

Perceptible vibration levels (human comfort) may be noticed during construction of various infrastructure where receptors are within 55 m of the works utilising a heavy vibratory roller.

# 8 Proposed Management Measures

## 8.1 Construction / Operation – Mine Scenarios

Whilst the noise model represents anticipated worst-case scenarios for the Project it could be expected that actual operational scenarios may be different at times to those assumed in the model. The following proposed management measures may be implemented in order to reduce the likelihood of noise impacts:

- Where practicable, limit the hours of operation of high noise or vibration activities, especially vehicles, plant and equipment operating near sensitive receptors.
- Maximise the distance between noisy plant items and noise sensitive receptors, where practicable
- Install acoustic enclosures on permanent facilities and noise generating equipment, where required and practicable to meet PNG environment permit conditions. Options to be investigated include installation of sound baffles, silencers, physical sound barriers (walls or containers) and low frequency beepers.
- Implement a community grievance mechanism which includes:
  - Complaints register
  - Person/position responsible for investigating and resolving complaints
  - Training and induction of Project personnel and contractors in managing grievances
  - Method for communicating grievance mechanism to communities
  - Process for recording, acknowledging and resolving complaints
- Where practicable provide advanced notice of high noise activities to local communities.
- Inform potentially affected communities of noise and vibration associated with operations, including caving activities.
- Maintain site access roads.
- Procure fit-for-purpose vehicles, plant and machinery, and regularly inspect and maintain in accordance with manufacturer recommendations.

## 8.2 Mine Access Road and Northern Access Road

- Where practicable, avoid or minimise heavy vehicle traffic near villages during the night.
- Limit machinery and vehicle movements, where possible, to defined work areas and designated roads.
- Maintain site access roads.
- Where safe, minimise exhaust braking in the vicinity of villages.

## 8.3 Vibration and Blasting Proposed Management Measures

### 8.3.1 Management Measures

Proposed management measures to reduce impacts from vibration and blasting emissions could include:

- Restrict surface blasting to daylight hours.
- Inform potentially affected communities of planned surface blasting events.
- Optimise surface blast design to minimise noise and vibration, where safe and practicable.

### 8.3.2 Vibration Monitoring

If vibration generating construction activities (such as vibratory rolling) are to be carried out within 55 m of villages, vibration monitoring should be considered to evaluate potential impacts aligned with the Project vibration guideline levels. Any potential vibration impacts would be adequately managed by consultation with the impacted sensitive receptors.

Monitoring of blasting activities may be required at sensitive receptors in the vicinity of blasting activities required for the construction of the concentrate, tailings and fuel pipelines and Northern Access Road. The monitoring program and locations would be determined upon review of the proposed blasting locations and blast design parameters.

# 9 CONCLUSION

SLR has conducted a noise and vibration impact assessment for the Project.

Baseline noise monitoring around the Project Area, in conjunction with the relevant WHO, IFC and Australian Guidelines, was used to develop project specific noise and vibration criteria.

Assessment of construction, operational and closure (by way of assuming construction is representative) stages of the Project was undertaken, based on the available preliminary information.

The key findings of the assessment were as follows.

- Construction noise emissions were predicted to exceed the night time noise criterion at Ziriuk, Hekeng and Papas only, with the night time noise criterion complied with at all other villages. Other predicted construction noise impacts could be managed using standard noise and vibration control measures. Community consultation with villages / sensitive receptors within 300 m of construction activity will generally be required.
- Operational noise emissions from the Mine Area were predicted to exceed the more stringent night time noise criterion at Ziriuk. Compliance with the criterion was predicted at all other villages for all assumed meteorological and operational conditions. Management measures may be required at this village to further reduce potential impacts. In addition, the ambient environment may also contribute to the overall noise levels experienced at local villages (see Section 3.4, where typical PNG noise ranges include levels above the night time criterion). Whilst the ambient noise levels are of different frequency content to potential Project emissions, they should be taken in to consideration when evaluating Project compliance with the adopted criterion. The Project will be designed to minimise noise emissions as far as practicable, with additional design measures to be investigated such as sound baffles, silencers or sound barriers.
- The identified existing sensitive receptors are well beyond the offset distances required for blasting at the borrow pits with the exception of the village of Hekeng, however blasting is not proposed at the Miapilli Clay Borrow Pit (the borrow pit in proximity to Hekeng) and hence the required offset distance for blasting activities is achieved for all borrow pits where blasting will take place.
- Vibration levels from general construction and operation activities have been predicted and assessed against the relevant guidelines. Due to the buffer distances between the construction and operation sites and project-related infrastructure and the nearest existing sensitive receptors, compliance with the adopted project vibration guidelines will be readily achieved.
- The operation and construction of the Port Facilities Area and Outfall Area were found to be compliant with both day and night criteria.

Details of proposed management measures are provided in Section 8. With the appropriate implementation of the proposed measures, the Project should meet project noise criteria at sensitive receptors, with the exception of Ziriruk, and will successfully minimise noise and vibration impacts to surrounding communities and fauna.

# 10 REFERENCES

AMEC Americas Limited. (July 2005). *Mackenzie Gas Project Effects of Noise on Wildlife prepared for Imperial Oil Resources Ventures Limited*.

Australian Standard. (2006). *AS 2187.2 Explosives- Storage and USe Part 2: Use Of Explosives*.

Basner, M. B. (2014). Auditory and non-auditory effects of noise on health. *Lancet*, 1325-1332.

British Standard. (1993). *BS 7385: Part 2, Evaluation and Measurement for Vibration in Buildings*.

British Standard. (2008). *BS 6472-1: 2008 Guide to Evaluation of Human Exposure to Vibration in Buildings*.

Brown, A. L. (1990). *Measuring the effect of aircraft noise on sea birds School of Australian Environmental Studies*. Brisbane, Australia: Griffith University.

C Druga, D. B. (2007). Vibration and The Human Body. *Fascicle of Management and Technological Engineering.*

Coffey Environments. (2011). CR 520_34_v2 *Noise Characterisation Wafi-Golpu Project*.

D. E. Siskind, S. S. (1980). *RI 8507 Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting*.

Department of Environment and Climate Change NSW. (2009). *Interim Construction Noise Guideline*.

Environment Protection Authority Victoria. (October 2011). *Noise From Industry in Regional Victoria*.

International Finance Corporation and World Bank Group. (2007). *Environmental, Health and Safety (EHS) Guidelines, Section 1.7 Noise*.

Larkin, R. D. (1996). Recognition of the utterances of terrestrial wildlife: a new approach. *The Journal of the Acoustical Society of America, 99(4 pt. 2): , 2532*.

Marsh, K. J. (1982). The CONCAWE Model for Calculating the Propagation of Noise from Open-Air Industrial Plants. *Applied Acoustics*, 411-428.

NSW Department of Environment and Climate Change & Water (DECCW). (2000*). Industrial Noise Policy*. NSW EPA.

Ocean Studies Board. (2003). *Ocean Noise and Marine Mammals*. Washington, DC.: National Research Council, Division on Earth and Life Studies, The National Academies Press.

Pasquill, F. (1961). The estimation of the dispersion of windborne material. *The Meteorological Magazine*, Vol 90, No 1063, 33-49.

Scannell, K. (1995). Practical Aspects of Investigating Complaints from Vibration in Buildings. *Journal of Building Acoustics*, 413-517.

SLR Consulting Australia. (2018). 620.11170R1 *Wafi Golpu Project: Air Quality and Greenhouse Gas Impact Assessment*.

Turner, D. B. (1994). *Workbook of Atmospheric Dispersion Estimates - An Introduction to Dispersion Modeling, Second Edition*. Lewis.

World Health Organization. (1999). *Guidelines for Community Noise*. Geneva.

World Health Organization. (2015). Make Listening Safe. Geneva, Switzerland. Retrieved from http://www.who.int/pbd/deafness/activities/MLS_Brochure_English_lowres_for_web.pdf

## Fundamentals of Noise

Hearing is a fundamental human sense and is used constantly for communication and awareness of the surrounding environment.

Noise is generally described as being 'unwanted' or 'unfavourable' sound, and to some extent this is an individual or subjective response, as what may constitute sound to one person may be noise to another.

The measurement and assessment of sound has been developed steadily over the last century, taking into account human response measures such as hearing damage and other potential health effects such as stress. Complex sound measurement and analytical devices have also been developed.

**Frequency weighting and dB**

The overall level of a sound is usually expressed in terms of the decibel (dB). The decibel represents a logarithmic scale used to denote intensity, or pressure level, of a sound relative to the threshold of human hearing.

People's hearing is most sensitive to sounds at mid frequencies (typically 500 Hz to 4000 Hz) and less sensitive at lower and higher frequencies although the relative sensitivity changes at differing loudness levels. The *frequency weightings* used in sound level meters are related to the response of the human ear, to ensure that the meter is measuring approximately what you actually hear.

**A-weighting and 'dBA'**

The A-weighting is a filter which is applied to the decibel level to approximate the human ear's frequency response. . When the overall level of a sound has had the A-weighting filter applied to it, it is represented using the A-weighted decibel, or dBA. The level of a sound in dBA is considered a good measure of the loudness of most sounds. Different sources having the same dBA level generally sound equally as loud, although the perceived loudness can also be affected by the character of the sound (e.g., the loudness of human speech and a distant motorbike may be perceived differently, although they can both have the same measured dBA level).

A change of up to 3 dBA in the level of a sound is difficult for most people to detect, however a 3 dBA to 5 dBA increment change corresponds to a small but noticeable change in loudness. A 10 dBA change will correspond to an approximate doubling or halving in loudness.

The frequency weighting curves were originally defined for use at different average sound levels, but A-weighting, though originally intended only for the measurement of low-level sounds is now commonly used for the measurement of environmental noise and industrial noise, as well as when assessing potential hearing damage and other noise health effects at all sound levels. The use of A-frequency-weighting is now mandated for all these measurements, although it can be unsuited for these purposes, being only applicable to low levels so that it tends to devalue the effects of low frequency noise in particular.

**Typical Noise Sources**

| Sound Pressure Level (dBA) | Typical Source | Subjective Evaluation |
|---|---|---|
| 130<br>110 to | <br>Grinding on steel | Intolerable<br>Extremely noisy |
| 100<br>90 | Construction site with pneumatic hammering | Very noisy |
| 80<br>70 | Kerb side of busy street<br>Loud radio or television | Loud |
| 60<br>50 | Department store<br>General Office | Moderate to<br>Quiet |
| 40<br>30 | Inside private office<br>Inside bedroom | Quiet to<br>Very quiet |
| 20 | Unoccupied recording studio | Almost silent |

## C-weighting and dBC

At higher sound pressure levels the ear's response is flatter and the C-weighted filter is usually used for Peak measurements and also noise measurements of sources with high levels of low frequency.

## Statistical Noise Level Descriptors

As environmental noise usually varies in levels over a particular period, it is common to present the results of environmental noise testing in the form of statistical descriptors.

An explanation of noise level descriptors typically used for assessing the noise environment are illustrated and described below.

Note: The symbol (L) is commonly used to represent Sound Pressure Level and the symbol $L_A$ represents the A-weighted Sound Pressure Level.

$L_{Amax}$ The maximum A-weighted noise level associated with a noise measurement interval.

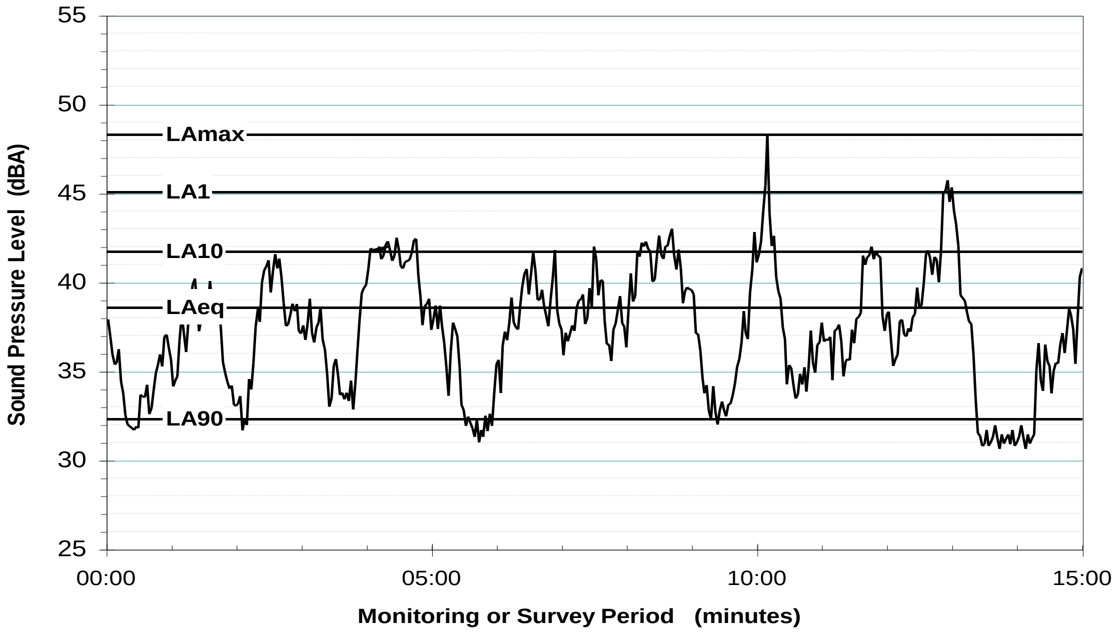
$L_{A1}$ The noise level exceeded for 1% of a given measurement period. This parameter is often used to represent the typical maximum noise level in a given interval.

$L_{A10}$ The A-weighted sound pressure level exceeded 10% of a given measurement interval and is utilised normally to characterise average maximum noise levels.

$L_{Aeq}$ The A-weighted equivalent continuous sound level. It is defined as the steady sound level that contains the same amount of acoustical energy as a given time-varying sound over the same measurement interval. Can be loosely thought of as the ‘average’.

$L_{A90}$ The A-weighted sound pressure level exceeded 90% of a given measurement interval and is representative of the average minimum sound level. Often used to describe the “background” level.

**Graphical Display Of Typical Noise Indices**




**Character**

The A-weighted noise level alone is a simplistic parameter, and may not be sufficient in providing a thorough assessment of noise. The subjective character of a sound is also a significant parameter which needs to be considered.

Some basic characteristics of sound which can make a sound more or less intrusive include:

- The frequency content of a sound – i.e. is it low frequency sound such as exhaust noise, or high frequency sound such as birds etc.
- The 'tonality' of a sound – i.e. does the sound contain one or more prominent tones such as a horn or a whistle.
- The 'impulsiveness' of a sound (i.e. a hammer, dog barking or an intermittently operating saw etc.).

The above parameters can usually be subjectively assessed, but more thorough assessment can be made with advanced sound measuring devices (i.e. using narrow band or one-third octave analysis etc.). Many noise guidelines provide an assessment method which applies penalties to sounds that exhibit particular characteristics such as the above.

**Table B1: Construction Scenario 1 – Including the construction of the twin declines, accommodation camps, portal entrance and decline development, explosive storage pad, quarry operations, watut process plant, ventilation shaft and the power generation facility.**

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level For All Noise Sources (dBA $L_{Aeq}$) |
|---|---|---|---|
| **Construction of Accommodation Camps / Refrigeration Pad / Explosive Storage and Supporting Infrastructure Pads / laydown areas and future power generation facility (All equipment located at each works area)** | | | |
| 45T Excavator | 100 | 1 | 106 |
| D7 Dozer | 100 | 1 | 110 |
| Water Truck | 100 | 1 | 115 |
| Cat 14 Grader | 100 | 1 | 110 |
| 50T All Terrain Crane | 100 | 1 | 112 |
| **Accommodation Camp (Operation)** | | | |
| Air Conditioners - Small | 100 | 150 | 84 |
| **Portal Entrance and Decline** | | | |
| 20T Excavator | 100 | 1 | 103 |
| 45T Excavator | 100 | 1 | 103 |
| 40T ADT | 100 | 2 | 108 |
| Dynamic Compaction (4WD Tractor) | 100 | 1 | 107 |
| D7 Dozer | 100 | 1 | 107 |
| Cat 14 Grader | 100 | 1 | 102 |
| Water Truck | 100 | 1 | 112 |
| Cat 825 Compactors | 100 | 1 | 107 |
| 12T Flat Drum Roller | 100 | 1 | 107 |
| **Onsite Power Generation** | | | |
| Standby Diesel Generators | 100 | 20 | 139 |
| **Batch Plants** | | | |
| Batch Plant | 100 | 2 | 121 |
| **Borrow Pit Operations (Migiki)** | | | |
| Sandvik DX 800 Quarry Drill | 100 | 1 | 113 |
| D8 Dozer | 100 | 1 | 107 |
| 45T Excavator | 100 | 1 | 106 |
| 40T ADT | 100 | 1 | 105 |
| Crushing & Screening Plant | 100 | 1 | 115 |
| Cat 966 Loader | 100 | 1 | 106 |
| Tipper Truck | 100 | 1 | 106 |
| **General Vehicle Movements** | | | |
| Truck | 100 | 20 | 108 |
| Light vehicles | 100 | 10 | 108 |
| **Construction Of Support Facilities – Preliminary Process Facility** | | | |
| 45T Excavator | 100 | 1 | 106 |
| D7 Dozer | 100 | 1 | 110 |
| Water Truck | 100 | 1 | 115 |

SOURCE SOUND POWER LIST

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level For All Noise Sources (dBA $L_{Aeq}$) |
|---|---|---|---|
| Cat 14 Grader | 100 | 1 | 110 |
| 50T All Terrain Crane | 100 | 1 | 112 |
| **Construction Of Ventilation Shaft** | | | |
| Cat 40T ADT | 100 | 1 | 105 |
| Cat 966 Loader | 100 | 1 | 106 |
| Water Truck | 100 | 1 | 112 |
| Jacon TMX10 Metre AGI Truck | 100 | 1 | 110 |
| Jacon TMX5 Metre AGI Truck | 100 | 1 | 110 |
| 50T All Terrain Crane | 100 | 1 | 109 |
| **Waste Rock Dump Operation – Nambonga decline** | | | |
| 20T Excavator | 100 | 1 | 103 |
| 45T Excavator | 100 | 1 | 103 |
| 40T ADT | 100 | 2 | 108 |
| Dynamic Compaction (4WD Tractor) | 100 | 1 | 107 |
| D7 Dozer | 100 | 1 | 107 |
| Cat 14 Grader | 100 | 1 | 102 |
| Water Truck | 100 | 1 | 112 |
| Cat 825 Compactors | 100 | 1 | 107 |
| 12T Flat Drum Roller | 100 | 1 | 107 |
| **Portal Ventilation Fans And Refrigeration** | | | |
| Portal Surface Fan – (85dba @1m) | 100 | 2 | 99 |
| Portal Refrigeration - (85dba @1m) | 100 | 4 | 102 |

**Table B2: Construction of the Infrastructure Corridor and Access Roads**

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level For All Noise Sources (dBA $L_{Aeq}$) |
|---|---|---|---|
| **Construction of Roads and Concentrate, Tailings and Fuel Pipelines** | | | |
| 45T Excavator | 100 | 1 | 103 |
| Tipper Truck | 75 | 2 | 108 |
| D7 Dozer | 100 | 1 | 107 |
| Cat 14 Grader | 100 | 1 | 107 |

**Table B3: Construction of the Coastal Area**

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level for All Noise Sources (dBA $L_{Aeq}$) |
|---|---|---|---|
| **Construction of the Port Facilities Area** | | | |
| 50T All Terrain Crane | 100 | 1 | 109 |
| Tipper Truck | 100 | 2 | 109 |
| Concrete Truck | 100 | 1 | 106 |

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level for All Noise Sources (dBA LAeq) |
|---|---|---|---|
| D7 Dozer | 100 | 1 | 107 |
| 45T Excavator | 100 | 1 | 103 |
| Cat 14 Grader | 100 | 1 | 107 |
| **Construction of Outfall Area** | | | |
| 50T All Terrain Crane | 100 | 1 | 109 |
| Tipper Truck | 100 | 2 | 109 |
| Concrete Truck | 100 | 1 | 106 |
| D7 Dozer | 100 | 1 | 107 |
| 45T Excavator | 100 | 1 | 103 |
| Cat 14 Grader | 100 | 1 | 107 |

**Table B4: Operational Power Generation Facilities Only Scenario**

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level for All Noise Sources (dBA LAeq) |
|---|---|---|---|
| **Power Generation Facilities** | | | |
| Engine – Internal SWL level | 100 | 12 | 143 |
| Ventilation Air outlet with silencer | 100 | 12 | 98 |
| Ventilation Air intake | 100 | 12 | 98 |
| Engine Exhaust Stack with silencer | 100 | 12 | 108 |
| Cooling Radiators | 100 | 24 | 121 |
| Engine Air Intake with silencer | 100 | 24 | 109 |

**Table B5: Operational 16.8Mtpa Scenario**

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level for All Noise Sources (dBA LAeq) |
|---|---|---|---|
| **Process Plant Operating** | | | |
| Stockpiling and Milling - SAG MILL | 100 | 1 | 123 |
| Stockpiling and Milling - BALL MILL A | 100 | 1 | 123 |
| Stockpiling and Milling - BALL MILL B | 100 | 1 | 123 |
| Stockpiling and Milling - Conveyors | 100 | 1 | 83 |
| Course Ore stockpile pump | 100 | 1 | 0 |
| Air Services - Blowers | 100 | 7 | 108 |
| Air Services - Compressor | 100 | 3 | 106 |
| Copper Rougher Flotation and First Cleaning - Flotation Cell | 100 | 14 | 105 |
| Copper Rougher Flotation and First Cleaning - Pumps | 100 | 10 | 106 |
| Copper Regrind - Mill | 100 | 1 | 107 |

SOURCE SOUND POWER LIST

| **Equipment** | **Duty %** | **Total Qty Of Noise Sources** | **Resultant Sound Power Level for All Noise Sources (dBA $L_{Aeq}$)** |
|---|---|---|---|
| Copper Regrind - Cyclone | 100 | 2 | 96 |
| Copper Regrind - Pumps | 100 | 2 | 99 |
| Copper Cleaner and Copper Scavenger - Flotation Cell | 100 | 6 | 102 |
| Copper Cleaner and Copper Scavenger - Pumps | 100 | 5 | 103 |
| Copper Cleaner Concentrate - Pumps | 100 | 2 | 99 |
| Copper Second and Third Cleaner - Flotation Cell | 100 | 12 | 105 |
| Copper Second and Third Cleaner - Pumps | 100 | 12 | 107 |
| Concentrate Thickening - Screen | 100 | 3 | 114 |
| Concentrate Thickening - Pumps | 100 | 6 | 104 |
| Concentrate Thickening - Agitator | 100 | 3 | 89 |
| Pyrite Flotation & Regrind Circuit - Blowers | 100 | 3 | 95 |
| Pyrite Flotation & Regrind Circuit - Pumps | 100 | 23 | 110 |
| Pyrite Flotation & Regrind Circuit - Flotation Cell | 100 | 15 | 106 |
| Pyrite Flotation & Regrind Circuit - Mill | 100 | 1 | 107 |
| Pyrite Flotation & Regrind Circuit - Cyclone | 100 | 1 | 93 |
| Collector: PAX Make-Up System - Agitator | 100 | 1 | 84 |
| Collector: PAX Make-Up System - Pumps | 100 | 4 | 102 |
| Collector: A3418A And AP3894 Make-Up System - Pumps | 100 | 4 | 102 |
| Flocculant #1: Make-Up System - Blower | 60 | 2 | 93 |
| Flocculant #1: Make-Up System - Agitator | 100 | 2 | 87 |
| Flocculant #1: Make-Up System - Pumps | 100 | 2 | 99 |
| Flushing & Hosing Water Pump | 100 | 2 | 99 |
| Flushing & Hosing water motor | 100 | 2 | 99 |
| Lime: Blower | 100 | 1 | 90 |
| Lime: Agitator | 100 | 3 | 89 |
| Lime: Pump | 100 | 5 | 103 |
| Lime: Make-Up System - Mill | 100 | 1 | 107 |
| Tailings Disposal - Pumps | 100 | 5 | 103 |
| Tailings Thickener - Pumps | 100 | 2 | 99 |

SOURCE SOUND POWER LIST

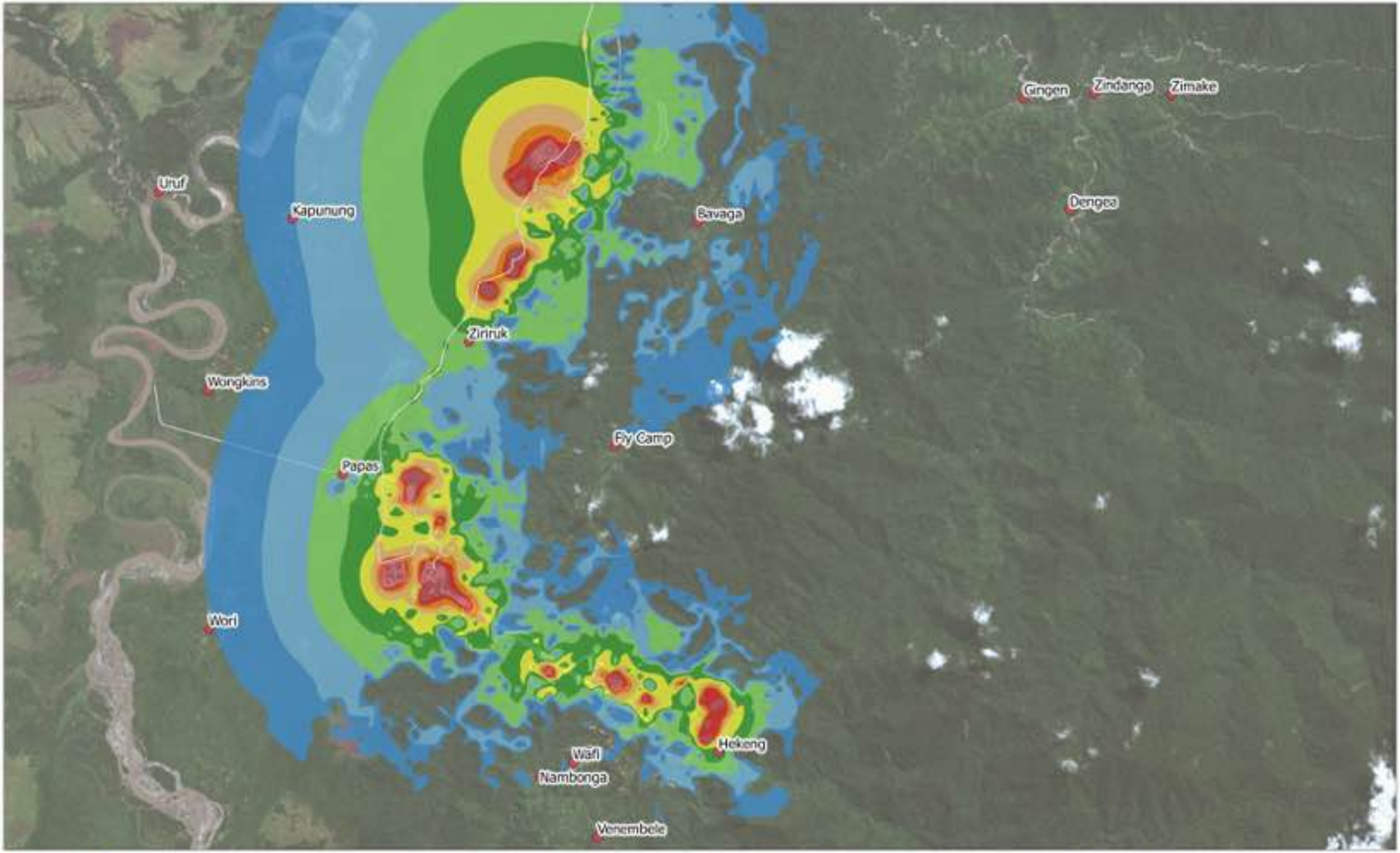
| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level for All Noise Sources (dBA $L_{Aeq}$) |
|---|---|---|---|
| **Power generation facilities** | | | |
| Engine – Internal SWL level | 100 | 12 | 143 |
| Ventilation Air outlet with silencer | 100 | 12 | 98 |
| Ventilation Air intake | 100 | 12 | 98 |
| Engine Exhaust Stack with silencer | 100 | 12 | 108 |
| Cooling Radiators | 100 | 24 | 121 |
| Engine Air Intake with silencer | 100 | 24 | 109 |
| **Borrow Pit Operations (Maliki)** | | | |
| Sandvik DX 800 Quarry Drill | 100 | 1 | 113 |
| D8 Dozer | 100 | 1 | 107 |
| 45T Excavator | 100 | 1 | 106 |
| 40T ADT | 100 | 1 | 105 |
| Crushing & Screening Plant | 100 | 1 | 115 |
| Cat 966 Loader | 100 | 1 | 106 |
| Tipper Truck | 100 | 1 | 106 |
| **Portal Terrace General Operation Activities** | | | |
| 20T Excavator | 100 | 1 | 103 |
| 45T Excavator | 100 | 1 | 103 |
| 40T ADT | 100 | 2 | 108 |
| Dynamic Compaction (4WD Tractor) | 100 | 1 | 107 |
| D7 Dozer | 100 | 1 | 107 |
| Cat 14 Grader | 100 | 1 | 102 |
| Water Truck | 100 | 1 | 112 |
| Cat 825 Compactors | 100 | 1 | 107 |
| 12T Flat Drum Roller | 100 | 1 | 107 |
| **Accommodation Camp** | | | |
| Air Conditioners - Small | 100 | 150 | 84 |
| **Ventilation Fans and Refrigeration** | | | |
| Vent Ridge Surface Fans – (85dba @1m) | 100 | 2 | 99 |
| Portal Surface Fan – (85dba @1m) | 100 | 2 | 99 |
| Portal Refrigeration - (85dba @1m) | 100 | 4 | 102 |
| **General Vehicle Movements** | | | |
| Tipper Truck | 100 | 10 | 116 |
| **Batch Plants** | | | |
| Batch Plant | 100 | 1 | 118 |

**Table B6: Operation of Secondary Borrow Pits**

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level for All Noise Sources (dBA $L_{Aeq}$) |
|---|---|---|---|
| **Borrow Pit Operations** | | | |
| Sandvik DX 800 Quarry Drill | 100 | 1 | 113 |
| D8 Dozer | 100 | 1 | 107 |
| 45T Excavator | 100 | 1 | 106 |
| 40T ADT | 100 | 1 | 105 |
| Crushing & Screening Plant | 100 | 1 | 115 |
| Cat 966 Loader | 100 | 1 | 106 |
| Tipper Truck | 100 | 1 | 106 |

**Table B7: Operation of Port Facilities Area**

| Equipment | Duty % | Total Qty Of Noise Sources | Resultant Sound Power Level for All Noise Sources (dBA $L_{Aeq}$) |
|---|---|---|---|
| **Port of Lae Operations** | | | |
| Conveyors | 100 | 1 | 83 |
| Tipper Truck | 100 | 2 | 106 |
| Compressors | 100 | 4 | 107 |
| Pumps | 100 | 6 | 103 |
| Agitators | 100 | 5 | 91 |
| Gensets | 100 | 2 | 116 |




N

0 1 2 3 4 Km

Leq - dBA

- 30 to 35
- 36 to 40
- 41 to 45
- 46 to 50
- 51 to 55
- 56 to 60
- 61 to 65
- 66 to 70
- > 70

| | |
|---|---|
| Scale: | 1:80,000 |
| Projection: | PNG94 - Zone 55 |


SLR

LANE COVE

AUSTRALIA

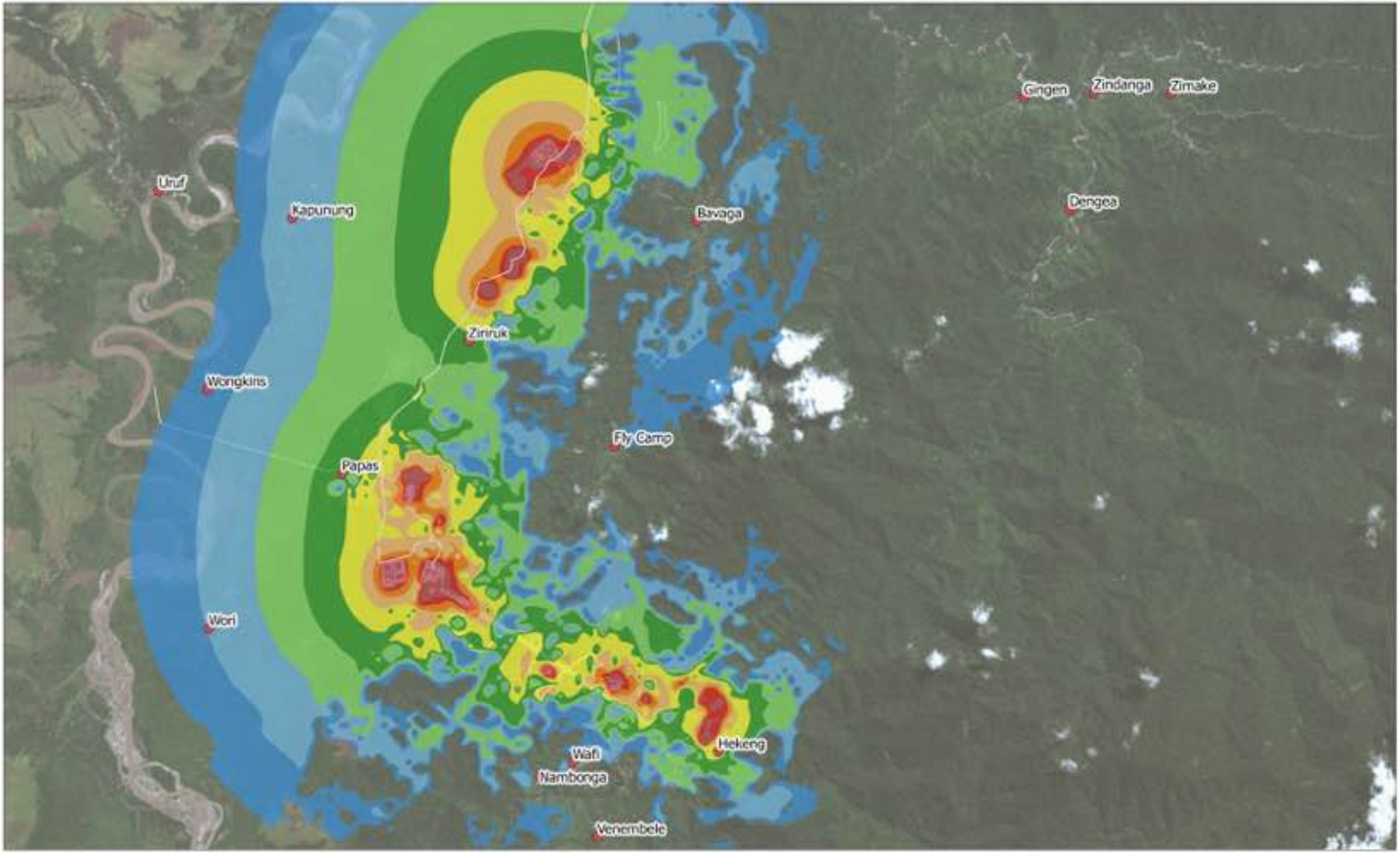


The content contained within this document may be based on third party data.
SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.


WAFI-GOLPU JOINT VENTURE

**WAFI-GOLPU PROJECT**

**Construction Noise Assessment**
**Scenario C1-NV Neutral Meteorological**
**APPENDIX MAP C MAP 1**




SLR

| | |
|---|---|
| Scale: | 1:80,000 |
| Sheet Size: | @A4 |

N

0 1 2 3 4 Km

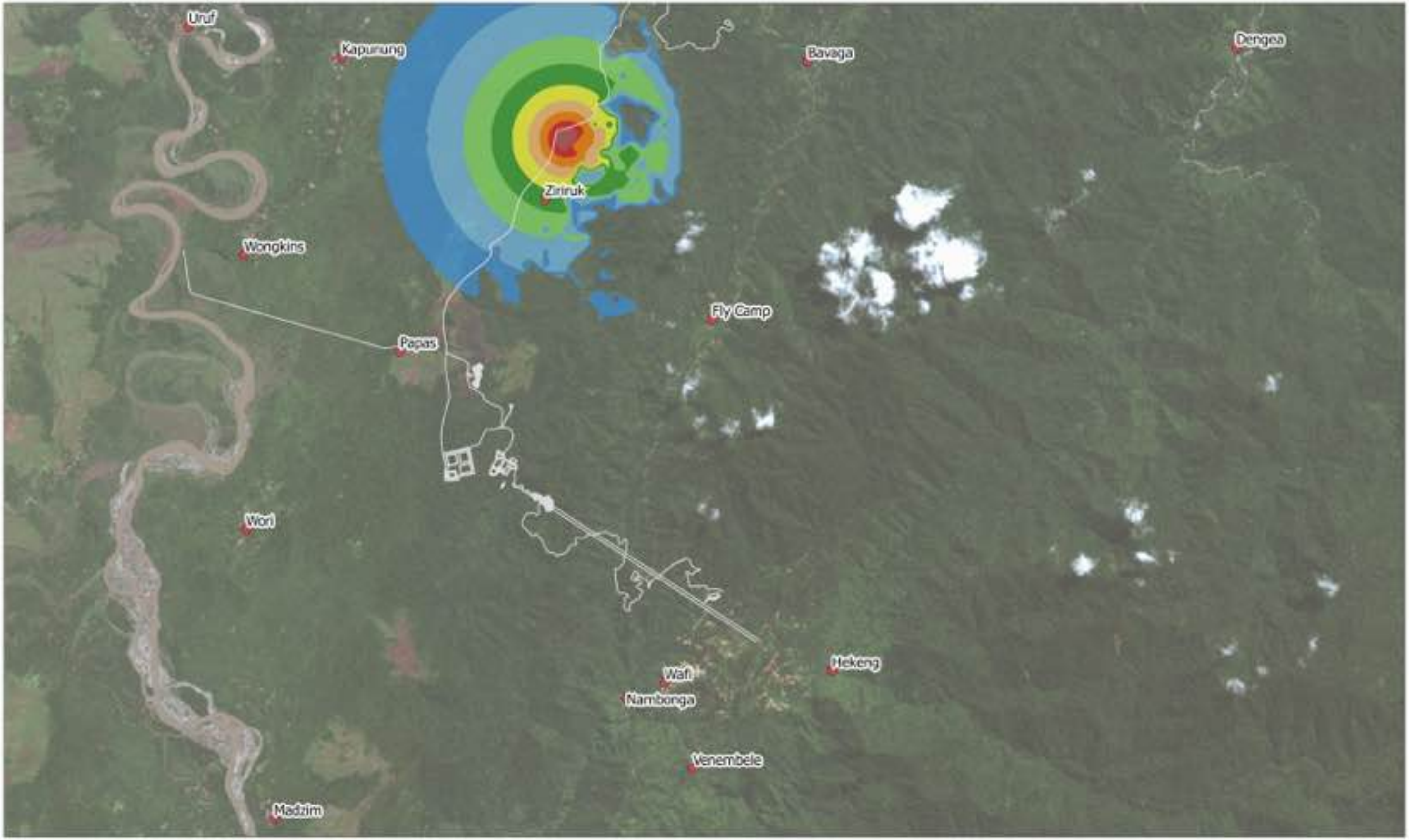
Leq - dBA

| | | |
|---|---|---|
| 30 to 35 | 41 to 45 | 61 to 65 |
| 36 to 40 | 46 to 50 | 66 to 70 |
| | 51 to 55 | > 70 |
| | 56 to 60 | |

WAFI-GOLPU JOINT VENTURE

**WAFI-GOLPU PROJECT**

**Construction Noise Assessment**
**Scenario C1-NV Enhanced Meteorological**
**APPENDIX MAP C MAP 2**




SLR

2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA

The content contained within the document may be based on third party data.
SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

| | |
|---|---|
| Project No.: | |
| Date: | |
| Drawn by: | |
| Scale: | 1:80,000 |
| Sheet Size: | |
| Projection: | |

N

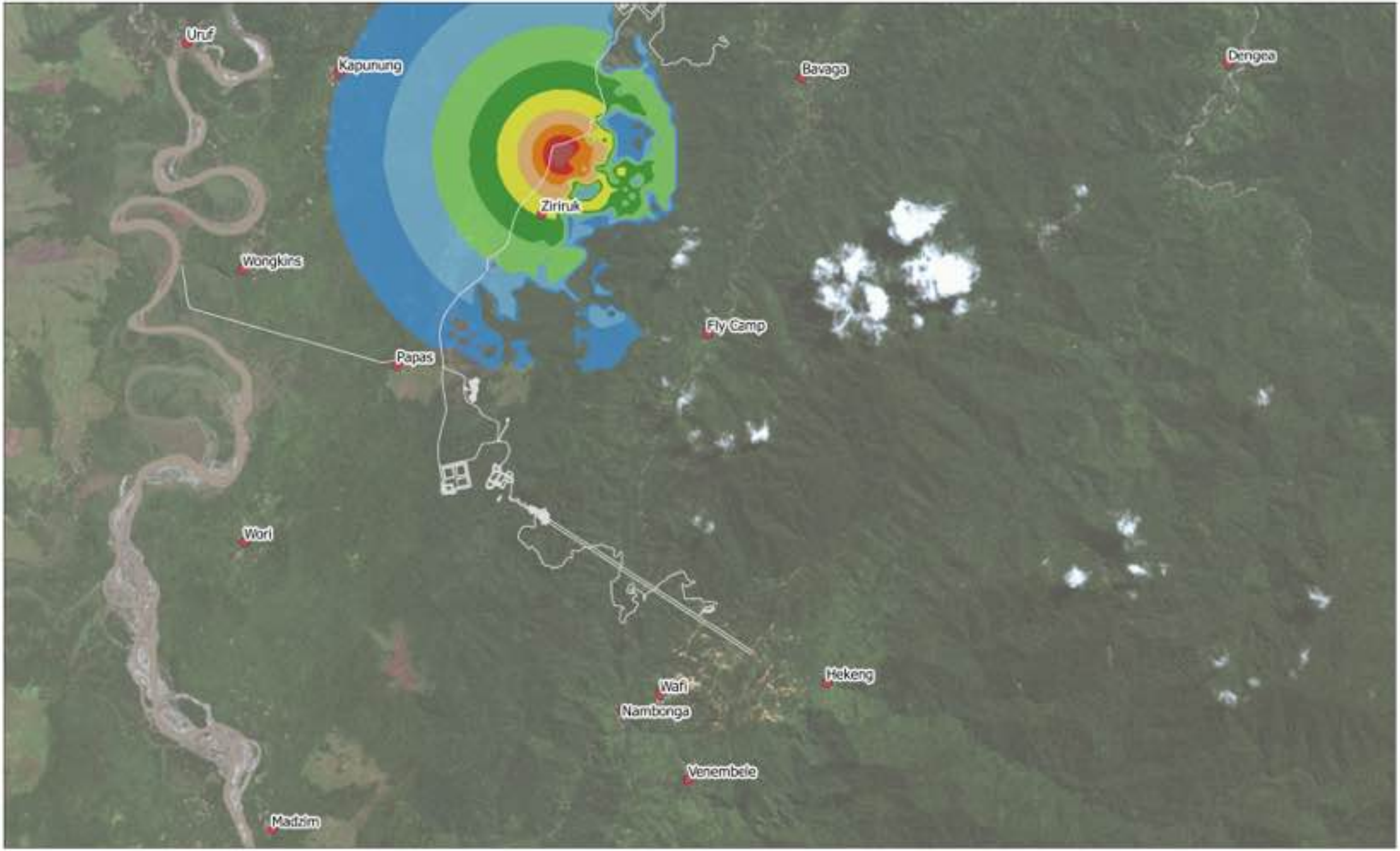
0 1 2 3 4 Km

| Leq - dBA | | |
|---|---|---|
| 30 to 35 | 41 to 45 | 61 to 65 |
| 36 to 40 | 46 to 50 | 66 to 70 |
| | 51 to 55 | > 70 |
| | 56 to 60 | |

WAFI-GOLPU JOINT VENTURE

**WAFI-GOLPU PROJECT**

**Operational Noise Assessment**
**Scenario O1-NV Neutral Meteorological**
**APPENDIX MAP D MAP 1**




SLR
2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA
T: +61 2 9427 8100
F: +61 2 0001
www.slrconsulting.com

The content contained within the document may be based on third party data.
SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

| | |
|---|---|
| Project No.: | 620.11170 |
| Date: | 31/08/2018 |
| Drawn by: | MR |
| Scale: | 1:80,000 |
| Sheet Size: | @A4 |
| Projection: | PNG94 - Zone 55 |

N

0 1 2 3 4 Km

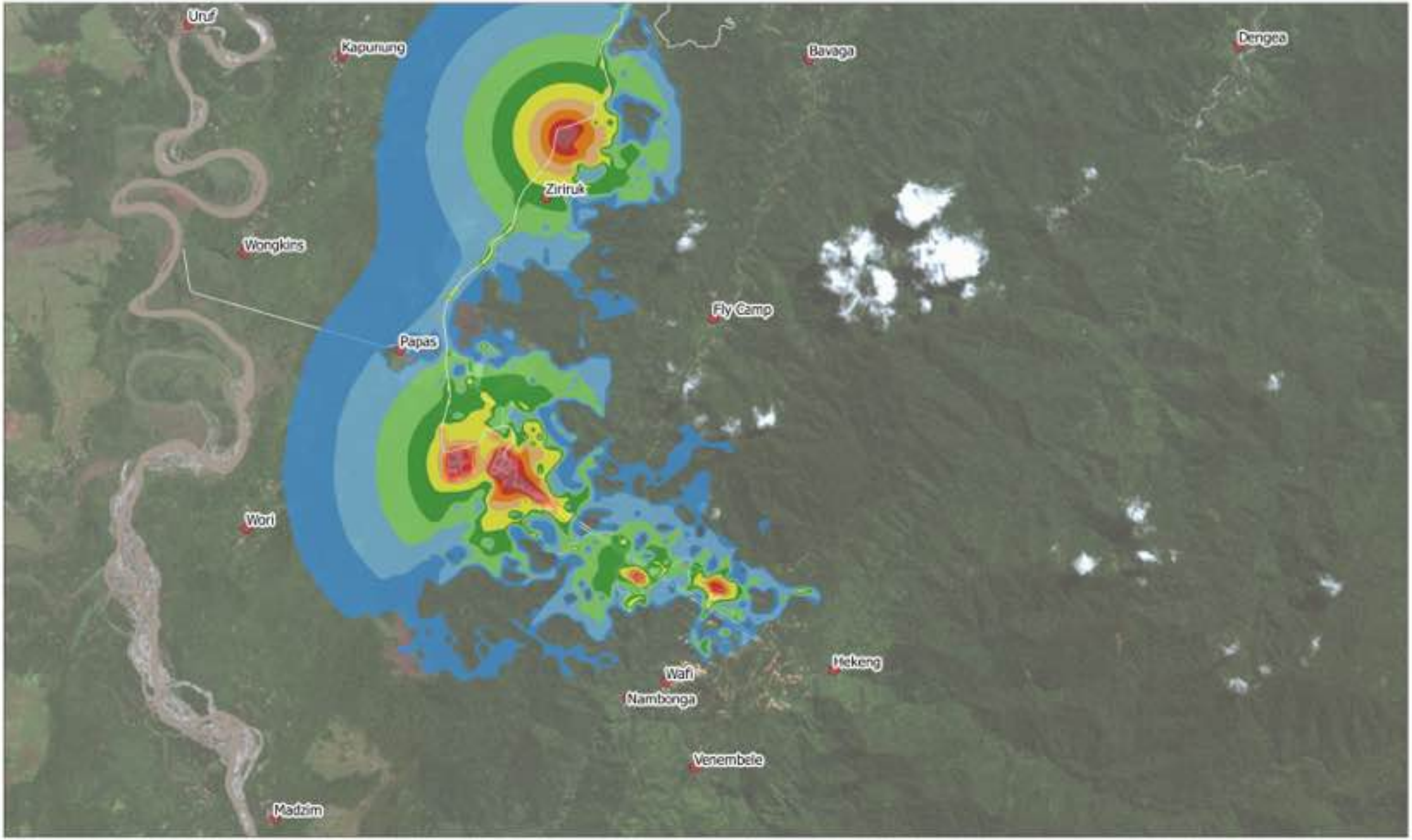
Leq - dBA

| | | |
|---|---|---|
| 30 to 35 | 41 to 45 | 61 to 65 |
| 36 to 40 | 46 to 50 | 66 to 70 |
| | 51 to 55 | > 70 |
| | 56 to 60 | |

WAFI-GOLPU JOINT VENTURE

WAFI-GOLPU PROJECT

**Operational Noise Assessment**
**Scenario 01-NV Enhanced Meteorological**
**APPENDIX MAP D MAP 2**




SLR

2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA
www.slrconsulting.com

The content contained within the document may be based on third party data.
SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

| | |
|---|---|
| Project No.: | [illegible] |
| Date: | [illegible] |
| Drawn by: | [illegible] |
| Scale: | 1:80,000 |
| Sheet Size: | @A4 |
| Projection: | [illegible] - Zone 55 |

N

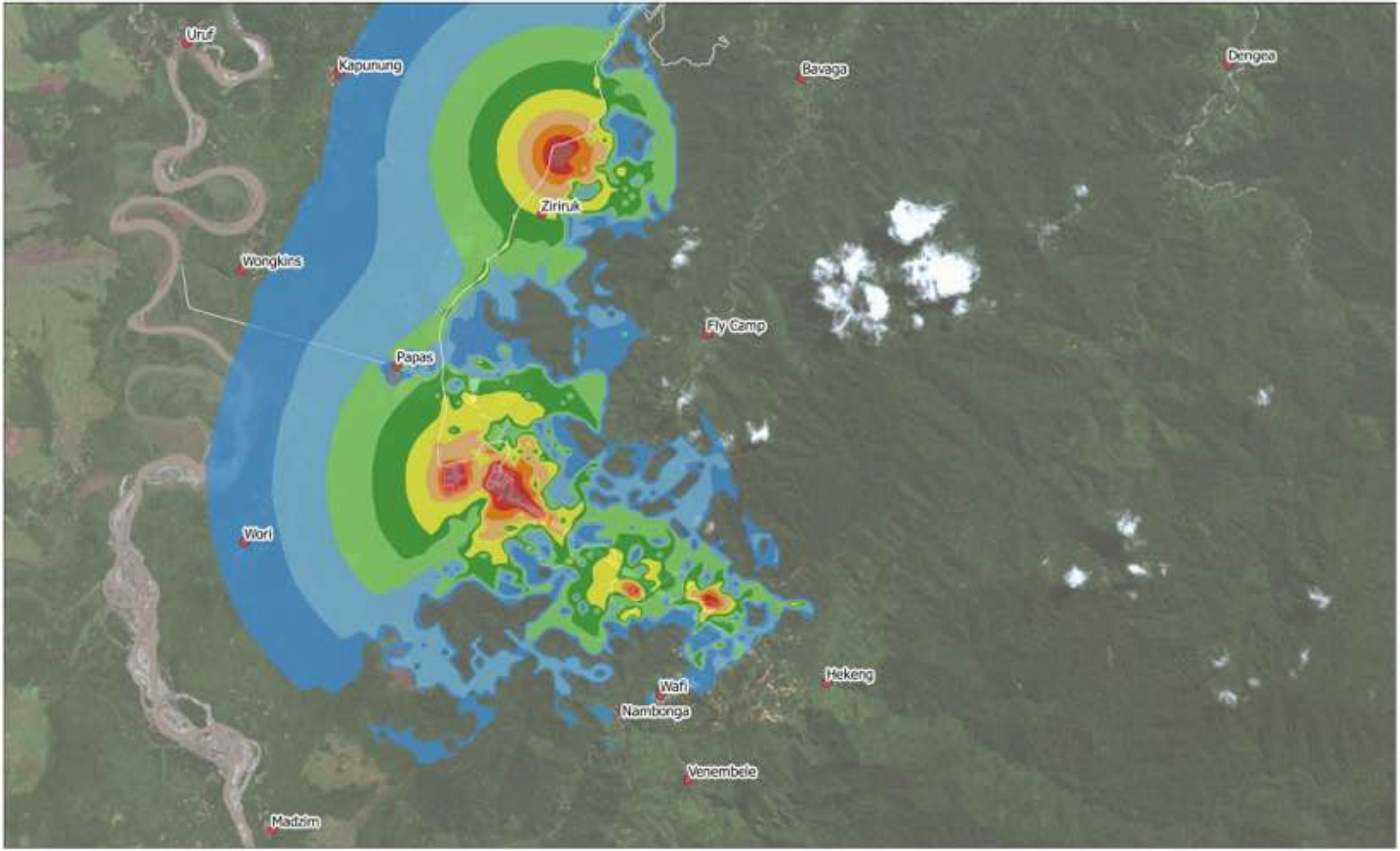
0 1 2 3 4 Km

| Leq - dBA | | |
|---|---|---|
| 30 to 35 | 41 to 45 | 61 to 65 |
| 36 to 40 | 46 to 50 | 66 to 70 |
| | 51 to 55 | > 70 |
| | 56 to 60 | |

WAFI-GOLPU JOINT VENTURE

WAFI-GOLPU PROJECT

**Operational Noise Assessment**
**Scenario O2-NV Neutral Meteorological**
**APPENDIX MAP E MAP 1**




SLR

2 LINCOLN STREET
LANE COVE
NSW 2066
AUSTRALIA
T: +61 2 9427 8100
F: +61 2 [illegible]
www.slrconsulting.com

The content contained within the document may be based on third party data.
SLR Consulting Australia Pty Ltd does not guarantee the accuracy of such information.

| | |
|---|---|
| Project No.: | 620.11170 |
| Date: | 31/08/2018 |
| Drawn by: | [illegible] |
| Scale: | 1:80,000 |
| Sheet Size: | @A4 |
| Projection: | [illegible] - Zone 55 |

N

0 1 2 3 4 Km

Leq - dBA

30 to 35
36 to 40
41 to 45
46 to 50
51 to 55
56 to 60
61 to 65
66 to 70
> 70

WAFI-GOLPU JOINT VENTURE

WAFI-GOLPU PROJECT

Operational Noise Assessment
Scenario 02-NV Enhanced Meteorological
APPENDIX MAP E MAP 2