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NEW BUGESERA INTERNATIONAL AIRPORT ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT REPORT- NOISE AND VIBRATION

RAMBOLL ENVIRON

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10. NOISE AND VIBRATION

10.1 Introduction

This chapter considers the potential impacts of the Proposed Project on noise and vibration. It predicts and evaluates the potential impacts of the Proposed Project and the associated likely impacts on noise and vibration, arising from the construction work and operation of the Proposed Project.

Noise disturbance is often raised as a significant issue by local communities concerned about developments of new roads, airports and other infrastructure projects. The noise from infrastructure is often the focus of complaints.

Noise is defined as unwanted sound, and the normal unit of measurement is the decibel (dB(A)). Sound pressure levels range from the threshold of hearing at 0 dB(A) to levels of over 130 dB(A) at which point, noise becomes painful.

The sensitivity of the human ear varies with frequency. To allow for this phenomenon, sound level meters are often equipped with a set of filters that modify the response of the sound level meter in a similar way to the human ear; these filters are referred to as the 'A-weighting network'. The dB(A) notation is used to indicate when noise levels are adjusted to the human ear. Environmental noise is, unless otherwise specified, always expressed as dB(A), even if the "(A)" is missing.

The human ear can perceive a very wide range of sound pressures, and it is convenient to use a logarithmic scale, which ensures that the numbers are manageable. The dB scale is therefore used to provide a measure of the loudness of sound in relation to the threshold of human hearing (0 dB is the threshold of sound).

Some common levels of noise on the A-weighted scale are given in Table 10-1.

Table 10-1: Common Levels of Noise

Sound Pressure Level (dBA)	Typical Environment	Average Subjective Description
140	Military aircraft take-off, 30 m distance	Intolerable
100	Outdoor rock concert or take-off of a turboprop passenger aircraft, 30 m distance	Very noisy
90	Heavy lorries by-pass, 6 m distance	Very noisy
80	Noise level inside passenger car at 80 km/hr	Noisy
60	Normal speech, distance 1 m or wind in trees, 8 m/s	Noisy
50	General office	Quiet
40	Whispering, distance 0.3 m	Quiet
20	Quiet bedroom or quiet forest	Very quiet

The subjective response to noise is dependent not only upon the noise level but also on its character, its duration and the time of day it occurs. Noise levels fluctuate, for instance during an aircraft passing overhead or changes in traffic flow on a nearby road. Scientific surveys have shown that there is a strong correlation between average noise levels and human response to the noise. During night time hours, sleep disturbance is related to the potential risk of adverse health effect of noise. For this reason, environmental noise is normally described in terms of average noise levels (equivalent continuous sound pressure levels), which can be thought of as

a constant noise level over a time period (T) that contains the same sound energy as the fluctuating noise level. In addition, a maximum noise level can be introduced. The notation for the noise descriptors is L_{Aeq} for average noise levels and L_{Amax} for maximum noise levels. The concept is shown graphically in Figure 10-1.

For this ESIA Report, average noise levels for daytime and night hours (L_{Aeq}) were used to assess the noise impact on humans and the maximum noise level, L_{Amax}, to assess noise impact on wildlife.

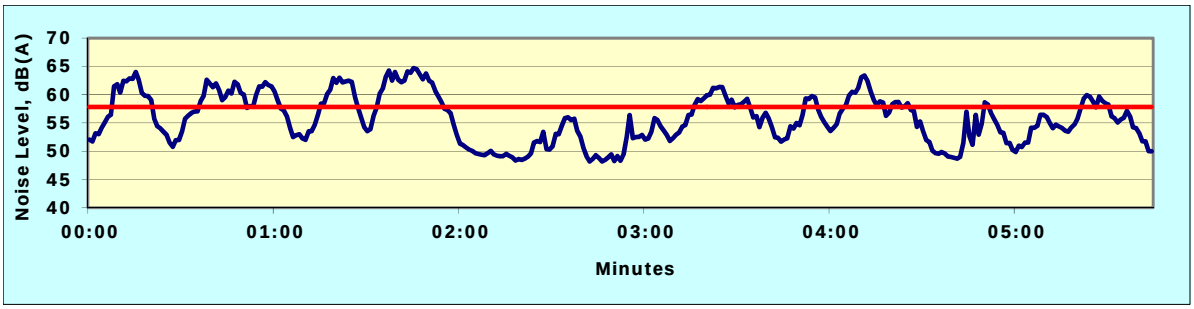

Figure 10-1: Illustration of Noise along a Road during a Period of Six Minutes[1]

If the noise level along a road as illustrated in Figure 10-1 above during a whole day is averaged in 1 hour periods, the situation could look as illustrated in Figure 10-2. It demonstrates how the noise is changing through a typical day. A similar view can be observed near an airport with typically less air traffic operations during night time hours than during daytime hours.

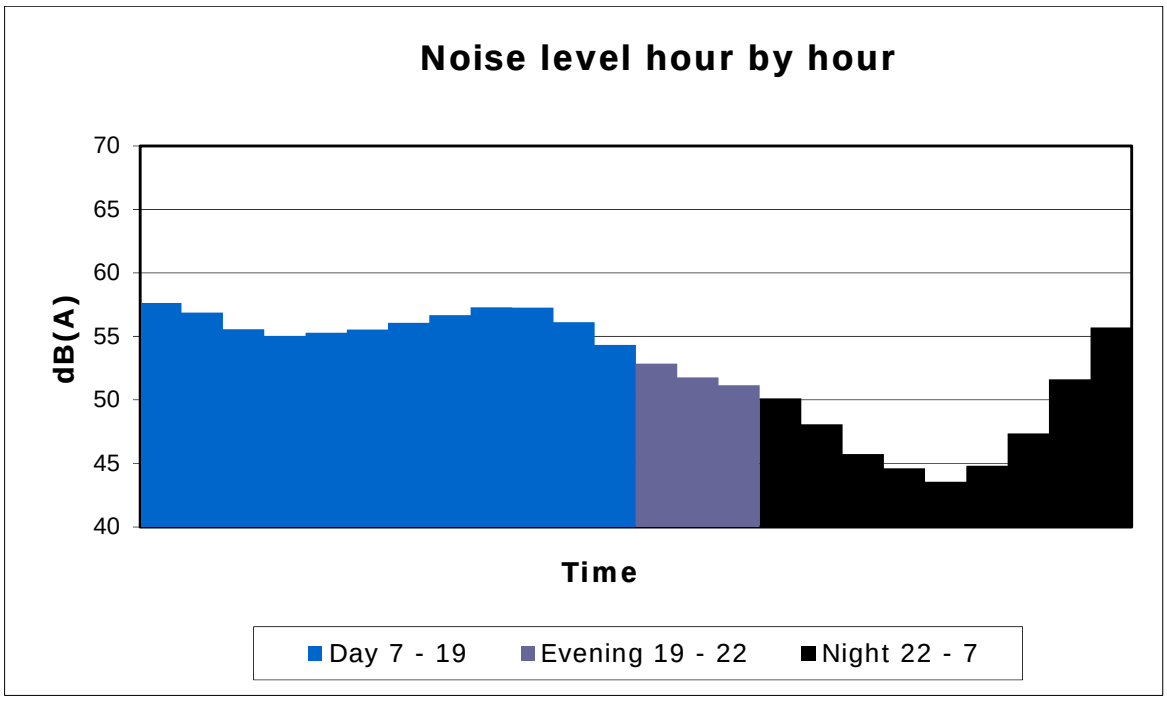

Figure 10-2: Example on Noise Level along a Road Hour by Hour during a Whole Day[2]

[1] The noise level is fluctuating and changes as vehicles passes by. The average noise level (LAeq) in this example is 58 dB(A) as shown by the red line. The maximum noise level (L_{Amax}) is 65 dB(A)

[2] 24 hours, from 07:00 in the morning until 07:00 in the morning of the next day. The noise levels are shown as 1 hour average levels (L_{Aeq} 1 hr). The average noise level (L_{Aeq}) during daytime (including evening) is in this example 56 dB(A) and during night hours 50 dB(A).

10.2 Human Sensitivity to Change in Noise Levels

Generally, a change of 3 dB(A) in fluctuating environmental noise is the minimum change perceptible to humans. A 5 dB change will normally be perceived as a significant change and a change of 10 dB either a halving or doubling of the noise level.

Table 10-2: Perceived Changes in Noise Levels

Change in noise level	Perceived change	Change can be the result of:
1 dB	A very small change	25% increase in number of noise sources
3 dB	An audible, but small change	Doubling of number of noise sources
5 dB	A significant change	Three times increase in number of noise sources
10 dB	Sounds like a halving or doubling of the noise level	10 times increase in number of noise sources

Note: This table demonstrates the perceived changes in noise levels illustrated by possible changes in number of noise sources, for example traffic flow on a road or airport (on the precondition that the mix of vehicles or aircraft is unchanged). It could also be the number of similar machinery working on a construction site.

10.3 Policy, Legal and Administrative Framework

10.3.1 Rwandan Policy

10.3.1.1 The Rwanda Environment Policy, 2003

Part of the Rwanda Environment Policy[3] 2003 is dedicated to *"Transport and Communications"* (Section 5.3.2) and includes 'strategic actions' related to noise pollution. The strategic actions include consideration for the protection of the population against noise nuisances and dangers from air, lake and land transport.

10.3.2 Legal Framework

10.3.2.1 The Organic Law No. 04/2005

The Organic Law No. 04/2005[4] determines the modalities of protection, conservation and promotion of environment in Rwanda.

In Article 4 of the Law, the human environment is defined as the organisation of an area relating to his or her social welfare. It is comprised of those that are destructive and those that are not. Those that are destructive, among others, are pollutants including *"excessive automobile noise, unbearable music noise, echo, radiation or combination of all that are likely to be destructive."*

According to Article 37 *"Competent authorities may take a decision aimed at stopping any emission of noise that is harmful to health of biodiversity, disrupts the neighbourhood or damages the property."*

According to Article 108 it is prohibited to cause noise that may be harmful to the health of biodiversity and in an intolerable manner disrupts the neighbourhood and damages property.

[3] Republic of Rwanda, 2003. Ministry of Lands, Resettlement and Environment, "Rwanda Environment Policy".

[4] Official Gazette of the Republic of Rwanda. Organic Law no. 04/2005 OF 08/04/2005. Determining the Modalities of Protection, Conservation and Promotion of the Environment in Rwanda.

10.3.3 International Standards

10.3.3.1 International Finance Corporation Performance Standards

The potential noise and vibration impacts from the Proposed Project during construction and operation have been assessed using IFC guidelines which include a general guideline on environmental noise[5] and a guideline on environment, health, and safety for airports[6].

The assessment includes potential noise and vibration impacts from construction and operation of the Expressway and construction and operation of the airport. The impact during construction takes into consideration that construction work at the airport will commence up to 2045 with the major activities up to 2020.

The IFC Guidelines do not stipulate any environmental vibration criteria. The assessment of this potential impact is therefore based on general experience and judgement.

The IFC EHS guidelines present examples of noise reduction options that should be considered where noise levels exceed these guideline values, along with recommendations for noise monitoring to be carried out either to establish existing ambient noise levels or to verify operational noise levels.

The guidelines do not include noise impacts on natural habitats and wildlife. As there are wetland habitats in the vicinity of the airport there is a need for assessment of noise disturbance to birds. This issue is assessed in Chapter 11: Biodiversity.

Table 10-3: IFC Noise Level Guidelines (dB) (Noise Levels Outside Buildings)

Receptors	**Daytime 07:00 – 22:00 hrs ($L_{Aeq\ 1hr}$)**	**Night Time 22:00 – 07:00 hrs ($L_{Aeq\ 1hr}$)**
Residential; institutional; educational	55	45
Industrial; commercial	70	70

The IFC Noise Level Guidelines address noise impacts at any point on offsite premises occupied by persons where extraneous noise and/or vibration are perceived. Examples of receptor locations may include: permanent or seasonal residences; hotels/motels; schools and day care centres; hospitals and nursing homes; places of worship; or parks and campgrounds.

The IFC guidelines do not include criteria for construction works, therefore the guidelines are relevant for the long term operational noise emission from the Proposed Project and the Expressway, rather than the short term construction noise emissions. As the noise impacts during construction activities occur within limited timeframes, it is Good International Industry Practice (GIIP) to use noise criteria that are less stringent than the criteria for the long term operation phase. Based on GIIP, the following criteria for noise sensitive neighbours (residential, institutional and educational) were adopted:

- Daytime 07:00 – 18:00: Average noise level $L_{Aeq,\ 11\ hr}$ = 70 dB
- Daytime 18:00 – 22:00: Average noise level $L_{Aeq,\ 1\ hr}$ = 70 dB
- Night time 22:00 - 07:00: Average noise level $L_{Aeq,\ 1\ hr}$ = 45 dB.

The noise levels apply outside buildings. The daytime criterion is an average noise level (L_{Aeq}) through the whole working day, giving the contractor the possibility of generating higher noise

[5] [5] IFC guidelines (Environmental, Health, and Safety (EHS) Guidelines, General EHS Guidelines: Environmental. Noise Management. 1.7 Noise. IFC April 30, 2007

[6] [6] IFC guidelines (Environmental, Health, and Safety Guidelines for Airports. IFC April 30, 2007

levels for shorter periods of time during a single day, as long as there are other periods with lower noise levels during the same day.

The proposed criteria take into account that a relatively high noise level is acceptable for most people during the daytime as construction activities take place within relatively limited timeframes. During the night time, sleep disturbance can lead to major annoyance even for a short period of time. This is the argument for adopting a relatively high daytime criterion and a relatively low night time criterion.

10.3.3.2 African Development Bank Group's Integrated Safeguards System

The African Development Bank Group[7] sets out requirements for the Operational Safeguards (OS) for a project. During the scoping phase of a project, an assessment should determine the range of likely potential risks and impacts and also determine whether specific requirements of the Bank's Operational Safeguards apply. The assessment should cover, in an integrated way, all relevant direct and indirect environmental and social risks and impacts, including those specifically covered in OS 2-5. Potential impacts include noise and vibration.

The Operational Safeguards also outlines the main pollution prevention and control requirements for borrowers or clients to achieve high quality environmental performance. One of the specific objectives are to manage and reduce pollutants (including noise and vibration) resulting from the project. This OS draws on and aligns Bank operations with existing international conventions and standards related to pollution. It also requires compliance with internationally accepted environmental standards.

10.3.4 Other Guidance

10.3.4.1 International Civil Aviation Organisation

The International Civil Aviation Organisation (ICAO) Annex 16[8] provides recommendations on a balanced approach to noise management at airports. These recommendations have been used to evaluate potential possibilities for mitigation of noise from the Proposed Airport.

10.4 Assessment Methodology

10.4.1 Scope

This chapter considers the following noise emissions arising from the earthworks and construction activities in relation to the Proposed Project:

- Construction traffic noise: noise due to heavy goods vehicle (HGV) movements as they move to and from the Proposed Project Area; and
- Construction plant and activity noise: noise due to plant and equipment associated with the earthworks/construction phase of the Proposed Project.

This chapter also considers the following noise emissions arising from the operation of the Proposed Project:

- Airborne aircraft noise: this is the noise due to aircraft as they depart from and land on the runways;

[7] African Development Bank Group's Integrated Safeguards System (December 2013). Policy statement and operational safeguards. Safeguards and Sustainability Series, Volume 1 - Issue 1.

[8] The International Civil Aviation Organisation (ICAO), July 2011. Annex 16 to the Convention on International Civil Aviation. Environmental Protection. Volume 1 – Aircraft Noise. Sixth Edition, and ICAO, 2008. Guidance on the Balanced Approach to Aircraft Noise. Management. Second Edition. Doc 9829.

- Ground noise: this is the noise due to aircraft taxiing and manoeuvring on the runways and aprons, and other ground-side noise sources, including aircraft auxiliary power units, aircraft engine ground running, ground support vehicles, and engine test facilities;
- Fixed plant noise: this is noise due to static plant and equipment associated with the Proposed Project, such as the proposed Combined Heat and Power (CHP) unit and other buildings services equipment (e.g. chillers, condensers, fans and pumps); and
- Operational traffic noise: this is the vehicle movements along the Expressway.

10.4.2 Scenarios Considered

10.4.2.1 Construction Phase

Assessment of noise from construction includes:

- Construction of the airport;
- Construction work related to the development and expansion of the airport during 2020 – 2045;
- Construction of the Expressway; and
- Transport on the quarry road.

10.4.2.2 Operation Phase

The considered scenarios during the operation phase are noise from airport operations and traffic on the Expressway in 2020 and 2045 to include the following:

- Operations following the completion of Phase 1, planned in 2020, which will provide a 29,900 m^2 Passenger Terminal with a processing capacity of 1.77 million annual passengers, a 3,000 m^2 Presidential Terminal, a 1,200 m^2 general aviation (GA) building, a runway, which will be 3,750 m long and 45 m wide, a runway end safety area (RESA) of 180 m length and 160 m width, a 180 space parking area and ancillary facilities. This scenario includes the presumed traffic increase, especially around the airport on the new Expressway; and
- Operations following the completion of Phase 5, planned in 2045, which will extend the passenger terminal up to 39,400 m^2 providing the airport a total processing capacity of 5.72 million annual passengers. This scenario also includes the presumed traffic increase, especially around the airport on the new Expressway.

The development of the Proposed Project introduces environmental noise from aircraft operations and related activities as well as noise from road traffic on the Expressway. The planned expansion of the capacity of the airport from 2020 through 2045 will lead to an increase in aircraft operations and the number of vehicles on the Expressway resulting in a potential increase in environmental noise emissions.

10.4.3 Baseline Characterisation

The baseline situation is based on onsite observations and digital map surveys. It includes the areas along the proposed Expressway connecting to the Airport Area and areas expected to be exposed to noise from aircraft operations.

Noise surveys were not undertaken given the present background noise levels in the area are low as there are no existing major roads, railways or industry. The baseline is therefore dominated by natural sounds and not mechanical noise. It is therefore not relevant for the assessment to compare natural sounds or sound from non-mechanical human activities with noise from traffic and other mechanical or technical sources.

The Expressway will link to the existing KK-15 road, which generates road traffic noise. A baseline has been established through calculation of noise from the existing roads with the assumption that present traffic on KK-15 is approximately 1,021 vehicles per day (annual average daily traffic (AADT) as outlined in Chapter 8: Traffic and Transportation).

10.4.4 Construction Phase Method of Assessment

The noise emissions from all significant noise sources have been estimated based on experience from other similar construction activities and information provided by BAC.

It is not possible to calculate vibration transmission through the ground in the same way as noise transmission through the air. This is because vibration transmission is highly influenced by local ground conditions. But vibration levels are reduced much more significantly with distance than noise. This means that vibration that can lead to annoyance will occur within short distances from the vibration source. The possible impacts have therefore been evaluated based on experience from similar projects including construction of roads (which is similar to runway construction) and buildings planned for the Proposed Project.

The main activities with respect to noise during the construction of the airport and the Expressway include:

- Vegetation clearing and removal of topsoil using bulldozers, tipper trucks, dump trucks, excavators, front loaders and motor scrapers;
- Construction of Expressway, airport runway and other paved areas (taxiways, terminal areas, parking lots, etc.) using graders, road rollers, paving machinery, vibrators and tipper trucks;
- Airport building construction using tipper trucks, excavators and cranes; and
- Transport on the quarry road using tipper trucks.

The individual noise emissions from the machinery used for construction will vary because of specific type and model, age, driver conduct and specific tasks. Based on experience from similar projects, it is estimated that the typical worst-case noise emissions from the individual machinery (sound power level, L_{WA} in dB) during operation is as follows:

- Type 1: Bulldozers, dump trucks, excavators, front loaders, motor scrapers, road rollers, vibrators, graders, paving machinery and cranes: L_{WA} = 103 dB.
- Type 2: Tipper trucks: L_{WA} = 101 dB.

It is understood that 20 bulldozers, 13 graders and 85 heavy goods vehicles (tipper trucks, concrete mixing and pouring, crane trucks, service trucks, bitumen distributors, etc.) will be utilised during construction of Phase 1. However, these heavy goods vehicles will not operate at a single location concurrently. Noise from the quarry road is expected to be dominated by tipper trucks and dump trucks. Therefore, assumptions listed in Table 10-4 have been made for the construction noise assessment in relation to the groups of machinery that can be in operation within the Proposed Project Area during this period.

Table 10-4. Expected Number of Construction Machinery in Operation During Construction Work

Construction work	Expected number of machinery	
	Machinery Type 1	Machinery Type 2
Vegetation clearing and removal of topsoil	3 - 4	3 - 4
Working areas, borrow pits	2 - 3	3 – 4
Road and runway construction	5 - 7	3 - 4
Buildings and other small structure construction	3	1

It should be noted that the construction work will include other types of machinery, such as hand tools and compressors, but the machinery listed above will be the dominating noise sources and the figures presented are aimed at representing typical situations.

Based on the estimated number of machinery working in groups at individual work sites, the total sound power level of the machinery has been used to calculate the distance from the boundaries of individual work sites where noise levels are reduced to the criteria values.

In order to commence with Phase 1 operation of the airport in 2020, construction activities will be conducted 24-hours per day.

For the quarry road, it has been estimated that the number of heavy goods vehicles on the road is calculated to be approximately 48 per day based on two-way trips; however, according to BAC, could be up to 60 with an average speed of 20 km/h. Based on this estimate, the distances from the road where the noise levels are reduced to the criteria values have been calculated.

Noise from construction works has been calculated using ISO 9613 Acoustics — Attenuation of Sound during Propagation Outdoors, Parts 1 and 2[9].

The risk of vibration impact on dwellings is based on experience from similar projects. Normally it can be expected that vibrations from road construction and similar is negligible. Some vibrations may be sensed by humans within a distance of 25 – 40 m.

10.4.5 Operation Phase Method of Assessment

The fixed noise level guidelines set out in Table 10-3 have been used to assess the noise impact from NBIA and the Expressway as opposed to an approach based on an increase in background noise levels. The basis for this approach is that the present background noise levels in the Proposed Project Area are low as there are no existing major roads, railways or industry. If the noise limits for the impact assessment are based on a low background noise level, which would be the result of a baseline survey, + 3 dB would result in unrealistically low and unachievable noise level guidelines. Instead, the noise limits in the table are deemed to be a more appropriate approach. These limits are not related to the background noise level.

10.4.5.1 Road Traffic Noise

Noise emissions have been assessed based on the expected traffic flows (Chapter 8: Traffic and Transport). The assumptions used are listed in Table 10-5 . It has been assumed that the daily traffic flow is distributed with 90% during daytime and 10% during night hours and that the road pavement is standard asphalt.

[9] International Standard Organisation, ISO 9613 Acoustics — Attenuation of Sound during Propagation Outdoors, Parts 1 and 2.

Noise from road traffic is calculated using the common European Calculation Model, CNOSSOS-EU Road[10].

Table 10-5. Expected Traffic Flow on the Proposed Expressway

Scenario / Year	Traffic flow Number of vehicles / day (24 hours), yearly average	Traffic Speed Limit	Heavy Goods Vehicles (HGVs)* Fraction of total number of vehicles
2020	4,661	80 km/h	13%
2045	22,563	80 km/h	13%
*HGVs include trucks, buses etc.			

10.4.5.2 Air Traffic Noise

The dominating noise source during airport operations will be aircraft taking off and landing, including runway operations and when the aircraft are airborne during approach and landing.

Flight operations involve preparing and moving aircraft, passengers, crew, cargo and baggage through controlled airspace to a destination. The number of aircraft operations used for this assessment were based on the Master Plan[11] which specifies three aircraft types as typical of those to be used when the Proposed Project is operational along with helicopters. These are as follows:

- Beechcraft C99;
- Boeing B737-800;
- Airbus A330-200; and
- Helicopters.

The aircraft types have been used as representative for the total flight operations in 2020 and 2045. Based on the anticipated number of helicopters and the noise generating from them, it is not expected that they will significantly influence the total noise emissions from flight operations. They have therefore not been considered further within the assessment.

It was assumed, based on the historic data for Kigali Airport presented in the Master Plan, that 70% of all operations will take place during daytime (07:00 – 22:00) and 30% during night hours (22:00 – 07:00).

According to the Master Plan, the prevailing wind direction is from the south and southeast. It is therefore assumed that 70% of all landings and take-offs will take place in the direction southeast (Runway 14) and 30% in the direction northwest (Runway 32).

The total number of flight operations is based on the Master Plan to be the following (one operation is a landing or a take-off):

- 2020: 25,581 landings and take-offs; and
- 2045: 62,701 landings and take-offs.

50% of all operations are landings and 50% are take-offs.

The overall distribution of the aircraft operations is listed in Table 10-6.

[10] European Calculation Model, CNOSSOS-EU Road issued by the European Commission. The software used for the calculations is Soundplan version 8.
[11] Masterplan. Bugesera Greenfield Airport – Rwanda. Volume 5 – Traffic Forecast. Final report. Version 4.0. February 2017.

Table 10-6: Overall Distribution of Aircraft Operations Used for Noise Assessment for Scenario 2020 and 2045		
Aircrafts	**Distribution of aircraft operations: Landings and take-offs**	
	Scenario 2020	**Scenario 2045**
Beechcraft C99	9%	8%
Boeing B737-800	70%	70%
Airbus A330-200	7%	12%
Helicopters	14%	10%

Based on the assumptions listed above, the daily number of operations for fixed wind aircraft has been calculated as a yearly average. The results are listed in Table 10-7 and Table 10-8.

Table 10-7: Scenario 2020. Yearly Average Number of Aircraft Operations Used for Noise Assessment								
Runway	**Runway 14 (direction southeast)**				**Runway 32 (direction northwest)**			
Operation	Arrival		Departure		Arrival		Departure	
Time	Day	Night	Day	Night	Day	Night	Day	Night
Beechcraft C99	1.5	0.7	1.5	0.7	0.7	0.3	0.7	0.3
Boeing B737-800	12.0	5.2	12.0	5.2	5.2	2.2	5.2	2.2
Airbus A330-200	1.2	0.5	1.2	0.5	0.5	0.2	0.5	0.2
Day: 07:00 – 22:00; Night: 22:00 – 07:00								

Table 10-8: Scenario 2045. Yearly Average Number of Aircraft Operations Used For Noise Assessment								
Runway	**Runway 14 (direction southeast)**				**Runway 32 (direction northwest)**			
Operation	Arrival		Departure		Arrival		Departure	
Time	Day	Night	Day	Night	Day	Night	Day	Night
Beechcraft C99	3.4	1.4	3.4	1.4	1.4	0.6	1.4	0.6
Boeing B737-800	29.5	12.6	29.5	12.6	12.6	5.4	12.6	5.4
Airbus A330-200	5.1	2.2	5.1	2.2	2.2	0.9	2.2	0.9
Day: 07:00 – 22:00; Night: 22:00 – 07:00								

Calculations of noise levels during peak hours have not been performed as average levels for daytime and night hours are more relevant for assessing the noise impact. The Master Plan includes an estimated peak hour as a parameter for designing the terminal capacity. If the flight operation numbers in Table 10-7 and Table 10-8 are recalculated to an average hourly number of operations during daytime and night hours, the design peak hour flight operation numbers

are six to eight times higher for daytime and 14 – 18 times higher for night hours. Noise from air traffic has been calculated using the Aviation Environmental Design Tool (AEDT), version 2c. AEDT issued by the U.S. Department of Transportation, Federal Aviation Administration[12].

Due to the significant distance (more than 1 km) from the airport ground operations to the nearest dwellings outside the Airport Area, it has been estimated that noise from aircraft ground operations will not be significant at these receptors and that the noise from the airport will be dominated by the aircraft landings and take-offs. Ground operations have therefore not been considered further.

The distance from the runway ends to the Airport Area boundary is approximately 2 km. This means that passing aircraft will normally be at a height above the ground of at least 100 m during approach and at least 300 m above the ground during take-off. This information is based on standard approach and departure profiles defined by the Aviation Environmental Design Tool (AEDT)[13] for the aircrafts used in this assessment. In this case, it is evaluated that a vibration impact from passing aircraft will not occur and has not been considered further.

10.4.5.3 Airport Fixed Plant

Due to the significant distance (more than 1 km) from the major airport facilities to the nearest dwellings outside the Airport Area, it has been evaluated that noise from fixed plants is insignificant compared to take-offs and landings and has therefore not been considered further.

10.4.6 Significance Criteria

The introduction of the airport and the Expressway has the potential to introduce noise impacts on residents and construction and operation phase workers, and potentially wildlife, in the vicinity of the airport and along the Expressway. The level of the change experienced by the residents will depend on the traffic intensity on the road and at the airport, as well as the distance between the receptor and the new noise sources. In particular, noise levels during night time will be an important parameter for the possible level of annoyance and potentially sleep disturbance.

The significance of noise impacts during operation of the Expressway and the airport has been determined through the comparison of predicted noise levels with the values set out in by IFC (Table 10-3).

The significance of noise from construction has been determined through the comparison of the predicted noise levels with the values set out in Section 10.2.3.1.

The following significance criteria have been used for the assessment:

Table 10-9: Significance Criteria

Receptor Sensitivity	
High	Locations used for rest, sleep, and quiet reflection such as residential properties, hospitals, cemeteries, educational establishments and places of worship
Medium	Locations used for work requiring concentration, such as offices
Low	Locations used for recreation and industrial activities, such as industrial units, workshops etc.

[12] Aviation Environmental Design Tool (AEDT), Federal Aviation Administration, FAA's Office of Environment and Energy. https://aedt.faa.gov/

[13] Aviation Environmental Design Tool (AEDT), Federal Aviation Administration, FAA's Office of Environment and Energy. https://aedt.faa.gov/

Table 10-9: Significance Criteria	
Impact Magnitude	
High	Noise levels greater than 10 dB above values
Medium	Noise levels 5 – 10 dB above guideline values
Low	Noise levels up to 5 dB above guideline values
Very Low	Noise levels below guideline values.

The assessment of the impacts takes into consideration the human perception of changes in noise levels as described in Section 10.2.

10.4.7 Assumptions and Limitations

It is assumed that construction activities will continue on a 24 hour basis to ensure airport is operational by 2020.

For the quarry road, it has been estimated that the number of trucks on the road is calculated to be 48 per day; however, according to BAC, could be up to 60 during daytime (07:00 – 22:00) in each direction with an average speed of 20 km/h.

Noise from aircraft operations has been calculated using representative aircraft types i.e. Beechcraft C99, Boeing B737-800 and Airbus A330-200.

It has been assumed, based on the historic data for Kigali Airport presented in the Master Plan, that 70% of all aircraft operations will take place during daytime (07:00 – 22:00) and 30% during night hours (22:00 – 07:00).

According to the Master Plan, the prevailing wind direction is from the south and southeast. It is therefore assumed that 70% of all landings and take-offs will take place in the direction southeast (Runway 14) and 30% in the direction northwest (Runway 32).

It has been estimated that noise from aircraft ground operations will not be significant at the closest receptors and that the noise from the airport will be dominated by the aircraft landings and take-offs. Ground operations have therefore not been considered further.

It has been evaluated that noise from fixed plant is insignificant compared to take-offs and landings and has therefore not been considered further.

10.5 Baseline Conditions

The areas around the Proposed Project Area, which include the Airport Area and the Expressway, are rural farmland with scattered dwellings along local roads with limited motorised traffic. This means that the baseline noise environment is characterised by low noise levels with no, or very limited, impact from infrastructure, industry, etc.

The Expressway will be linked to an existing road (KK-15). The present traffic flow has been estimated to be approximately 1,021 vehicles/day AADT) – see Chapter 8: Traffic and Transportation). Based on this information, it is estimated that the baseline average road traffic noise level is:

- Daytime 07:00 – 22:00, average noise level (L_{Aeq}): 55 dB(A) at a distance of approximately 15 m from the road.
- Night hours 22:00 – 07:00, average noise level (L_{Aeq}): 45 dB(A) at a distance of approximately 20 m from the road.

This estimate is based on the following assumptions:

- A traffic flow distribution of 90% during daytime and 10% during night hours; and
- A traffic speed of less than 60 km/h.

This means that dwellings located at a distance of less than 15 – 20 m from the area will be exposed to road traffic noise (baseline situation) above the IFC Noise Guidelines (Table 10-3).

Sensitive Receptors

The sensitive receptors are the dwellings located along the Expressway, those around the Airport Area and dwellings located under and near the future flight paths of the airport. Locations used for rest, sleep and quiet reflection such as residential properties have a high sensitivity to noise (see Section 10.4.6).

As construction work near individual receptor locations will occur within intermittent timeframes during Phase 1 construction (up to 2020) and individual smaller construction activities up to 2045, it is estimated that the sensitivity to noise from associated construction activities is low.

10.6 Potential Impacts Prior to Mitigation

10.6.1 Construction Phase Impacts

The main noise impact from during the construction period will be related to use of heavy machinery and HGVs during:

- Vegetation clearance and removal of topsoil using bulldozers, tipper trucks, dump trucks, excavators, front loaders and motor scrapers;
- Construction of the Expressway, airport runway and other paved areas (taxiways, terminal areas, parking lots, etc.) using graders, road rollers, paving machinery, vibrators and tipper trucks;
- Airport building construction using tipper trucks, excavators and cranes; and
- Transport on the quarry road using tipper trucks.

10.6.1.1 Design Controls

The assessment of potential construction phase noise impacts has been carried out assuming the following design controls are in place:

- Trucks and other machinery will be of good working condition and submitted to routine maintenance and repair; and
- Quarry equipment and machinery such as crushes are to be enclosed to minimise noise within the area.

10.6.1.2 Impact Assessment

Noise associated with construction activities has been calculated taking cognisance of the distances from individual working areas/sites, where the noise levels are reduced to the criteria values for construction work, provided in Section 10.3.4. Results are listed in Table 10-10.

Table 10-10: Calculated Distances from Individual Construction Sites Where Noise Levels Are Reduced to the Criteria Values

Construction activity	Distance from individual construction site boundary until noise is reduced to:	
	70 dB(A)	45 dB(A)
Vegetation Clearing and removal of topsoil	25 m	250 m
Working areas, borrow pits	25 m	250 m
Road and runway construction	45 m	450 m
Buildings and other small structure construction	25 m	250 m
Transport on the quarry road	<10 m from road side	150 m from road side
Quarry crushing activities	25 m	450 m

The calculated distances for the quarry road is less than calculated for the Expressway because the number of vehicles on the Expressway is higher than the assumed number of vehicles on the quarry road, during operation phase.

In general, construction work within the Airport Area is expected to take place at distances further than 25 m or 45 m from the Airport Area boundary, and in most cases also more than 250 m or 450 m, which is the minimum distance from the main construction activities within the Airport Area to the Airport Area boundary. This assumption is based on the future location of the runway, buildings and other facilities within the Airport Area. It is assumed that construction work will take place mainly at these locations with is further away from the Airport Boundary than the mentioned distances.

It is therefore expected that no dwellings will be exposed to noise from construction work from the Airport Area above 70 dB(A), as communities within the Airport Area have been relocated off-site. Furthermore, closest dwellings are located further than 450 m from the construction areas. This also implies that dwellings will not be exposed to noise above 45 dB(A) during night hours. In most cases the noise will be significantly lower. The only exception from this will be when construction activities are conducted closer to the Airport Area boundary in closer proximity to nearby dwellings. In this instance, dwellings located closer to the actual construction work within 25 m or 45 m could be exposed to noise levels above 70 dB(A), although this would be short term.

It is also estimated that there is no, or very limited risk will be caused from construction activities. This is due to the fact that the distance from the construction work will be more than the critical distance mentioned in Table 10-10.

It should be noted that the main construction activities will take place during Phase 1, which is anticipated to conclude in 2020. Phases 2-5 (from 2020 to 2045) will demonstrate a lower activity level associated with further development and extension of the airport facilities. However, as the key construction activities near individual receptors will take place within limited timeframes, it is estimated that the receptor sensitivity to noise from all construction works is low. Based on the assumption that construction work will continue for 24 hours per day, the impact significance of noise impact and vibration from construction of the airport on dwellings is expected to be **Negligible** based on a receptor sensitivity of low and an impact magnitude of low.

The Construction Camp is located within the Airport Area close to the future airport facilities. It is therefore expected that the Construction Camp can be exposed to noise above the criteria values during daytime.

There are up to approximately 50 dwellings located within 45 m of the Expressway, which is the critical distance for noise from road construction (see Table 10-10). These dwellings can be exposed to noise above 70 dB(A) when construction work commenced for the Expressway.

As the noise impact during construction of the Expressway and quarry road upgrade on each individual dwelling will be limited to shorter periods of time, and only during daylight hours, it is concluded that the impact significance is expected to be **Minor Adverse** based on a receptor sensitivity of low and an impact magnitude of medium.

There is a risk that vibration from the construction of the Expressway and quarry road upgrade can cause annoyance in dwellings at distances closer than 25 – 45 m from the construction work, although this will be for shorter periods of time. As the impact on each individual dwelling will be limited to shorter periods of time and only during daylight hours, it is concluded that the impact significance of construction of the Expressway on dwellings is expected to be **Negligible** based on a receptor sensitivity of low and an impact magnitude of low.

With the assumption that construction work and traffic on the quarry road will continue for 24 hours per day, it is estimated that a number of dwellings will be exposed to noise above 70 dB(A). It is therefore concluded that noise impact from the quarry road is **Minor Adverse** based on a receptor sensitivity of low and an impact magnitude of medium.

It is understood that the quarry will not operate continually; however, crushing activities will continue over 24 hours. Dwellings are located on the boundary of the quarry, at a distance of more than 25 m from the crushing operations. These dwellings will be exposed to noise of 70 dB(A) and noise from the crushing activities will therefore be considered a **Minor Adverse** impact based on a receptor sensitivity of high and an impact magnitude of low.

10.6.2 Operation Phase Impacts

The main noise impacts during the operation phase of the airport and the Expressway will be related to:

- Noise from the airport including aircraft during take-offs and landing; and
- Vehicle movements along the Expressway.

Ground operations and fixed plant operations are considered to not be significant at the closest receptors. Noise from ground operations and fixed plants have therefore not been considered further.

Although not assessed in this ESIA Report, the transfer of the civilian passenger traffic from Kigali International Airport will reduce noise impacts from aircraft operations from densely populated areas in Kigali.

10.6.2.1 Design Controls

The assessment of operation phase noise impacts has been calculated prior to implementation of design measures and mitigation commitments. In terms of design controls, the embankments at the boundary at the Airport Area will provide noise attenuation. The speed limit on the Expressway will be 80 km/h; however, design controls such as noise barriers will not be required due to the distance of sensitive receptors to the Expressway (>25 m) and will not minimise the impact. Furthermore, the Expressway will be surfaced with bitumen as opposed to concrete, resulting in a reduction of noise. The speed of the Expressway must be

restricted to 60 km/h to reduce noise impacts during the night and speed limiting structures such as speed humps and stop signs will lower vehicle speed resulting in lower noise generation.

10.6.2.2 Impact Assessment Prior to Mitigation

Road Traffic Noise

The noise impact from the Expressway during operation has been calculated as a corridor along the road in which the noise levels is expected to be above the criteria values. The results are listed in Table 10-11. This means that dwellings located closer to the Expressway than 40 m in 2020 can be exposed to a noise level from road traffic above 45 dB(A) during night hours. In 2045, it is expected that dwellings located closer than 75 m can be exposed to noise above 45 dB(A) as a result of the increased traffic flow and consequently higher noise emissions from the road.

When considering the noise impact on dwellings, every time the distance to the road is halved, the noise level will be 3 dB higher. Every time the distance is doubled, the noise level will be reduced by 3 dB. This means that a dwelling located at a distance of 75 m in 2045 can be exposed to 45 dB(A) during night hours. Another dwelling located at a distance of 150 m can be exposed to 42 dB(A).

The specific distances from the road will vary to some extent due to local terrain. For example, if the road is below the surrounding terrain (lower noise level). Within the distances listed in Table 10-11, the influence of local variations will normally be limited to less than 3 dB.

Table 10-11: Corridors Along Expressway with Noise Levels Above the Criteria Values

Scenario	Indicator Time period	Criteria value Average noise level, L_{Aeq}	Distance from the road where noise level is exceeded
2020	L_{Aeq}, daytime (07:00 – 22:00)	55 dB	30 m
	L_{Aeq}, night hours (22:00 – 07:00)	45 dB	40 m
2045	L_{Aeq}, daytime (07:00 – 22:00)	55 dB	55 m
	L_{Aeq}, night hours (22:00 – 07:00)	45 dB	75 m

The number of existing individual dwellings along the Expressway to be exposed to road traffic noise above the criteria values is estimated to be less than 25 in 2020 and less than 50 in 2045. These numbers are based on the exposure during night hours. It is also estimated that the exceedance of the criteria values will be less than 5 dB. It is therefore the conclusion that the impact significance on dwellings from road traffic noise is expected to be **Moderate Adverse** based on a receptor sensitivity of high and an impact magnitude of low.

Air Traffic Noise

The predicted noise impacts from air traffic operations to and from the airport and on the runway are shown as noise contours on Figure 10-3 to 10-7, which present the following:

- The average noise levels during daytime (07:00 – 22:00) based on a yearly average;
- The average noise levels during night hours (22:00 – 07:00) based on a yearly average; and

- The maximum noise level.

The maximum noise level is a result of the highest noise level that is emitted from any of the three aircraft types in any location around the airport during take-off or landing. As all three aircraft types are assumed to be operating during both daytime and night hours, and in both scenarios (2020 and 2045), the maximum noise levels are the same assuming that the utilised aircraft are the same in 2020 and in 2045.

There is 5 dB difference between each contour line. The markings “R” indicate the runway ends.

The flight paths into and out of the new airport will cross what is likely to be a substantial number of dwellings located in an essentially rural environment.

It is therefore the conclusion that the impact significance on dwellings from air traffic noise is likely to be **Major Adverse** based on a receptor sensitivity of high and an impact magnitude of medium. The assessment is based on the relatively low numbers of dwellings that will be exposed to noise with a high impact magnitude, according to the significance criteria set out in Section 10.4.6 (more than 10 dB above guideline values).

The noise contours on maximum noise levels are used for assessing potential impacts on wildlife.

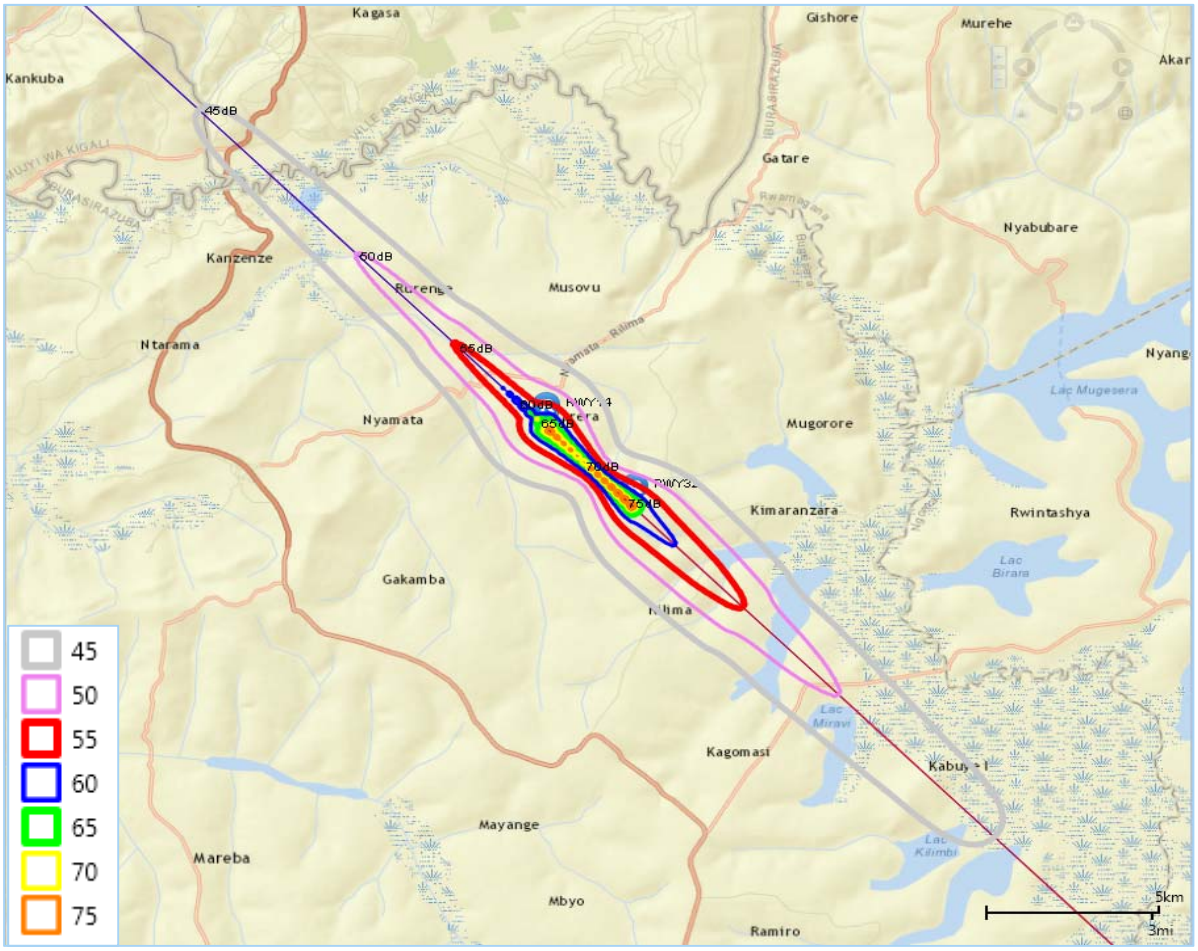

Figure 10-3: Scenario 2020. Noise from Air Traffic: Average Noise Level, L_{Aeq}, dB, During Daytime 07:00 – 22:00

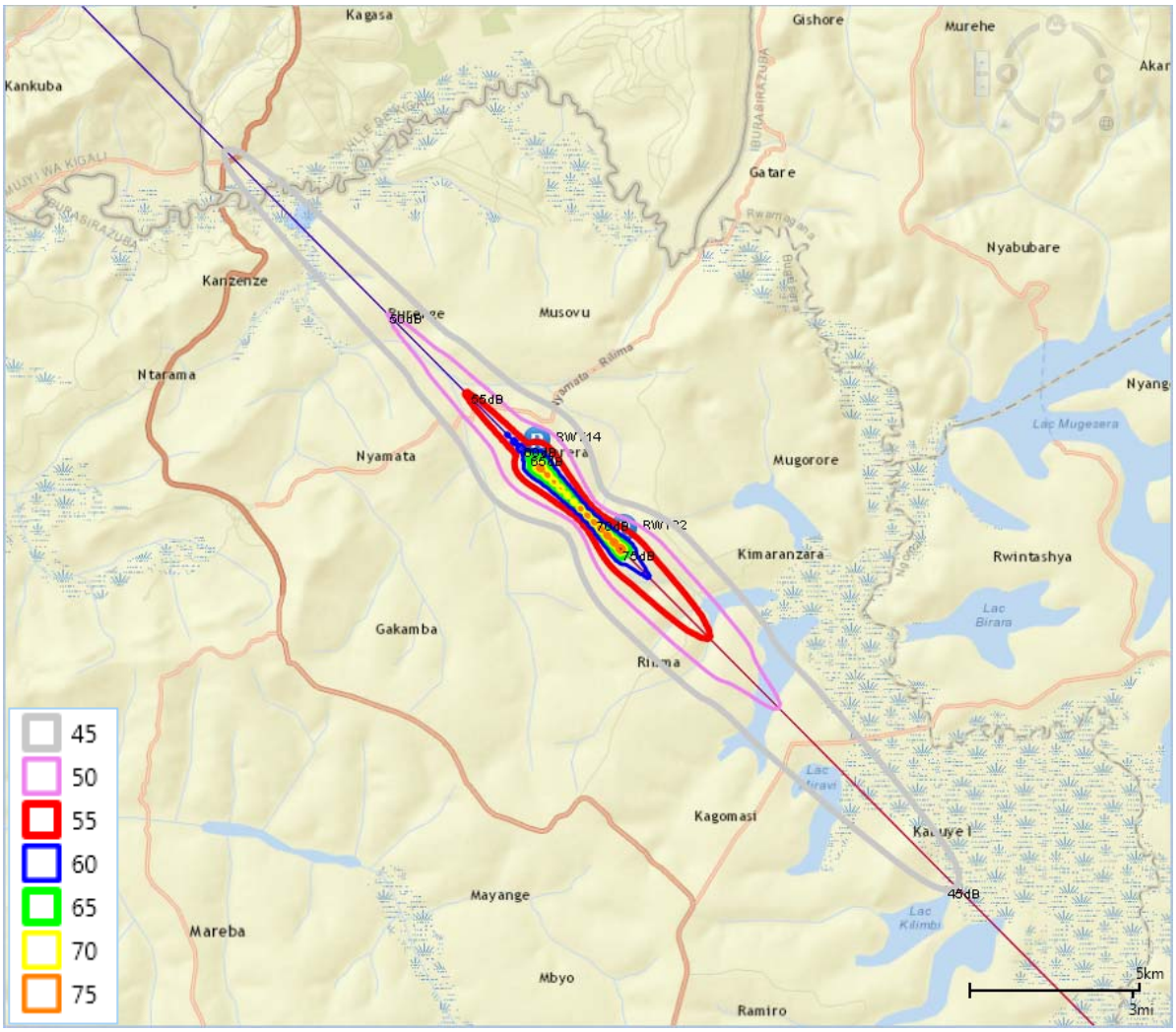

Figure 10-4: Scenario 2020. Noise from Air Traffic. Average Noise Level, L_{Aeq}, dB, During Night Hours 22:00 – 07:00

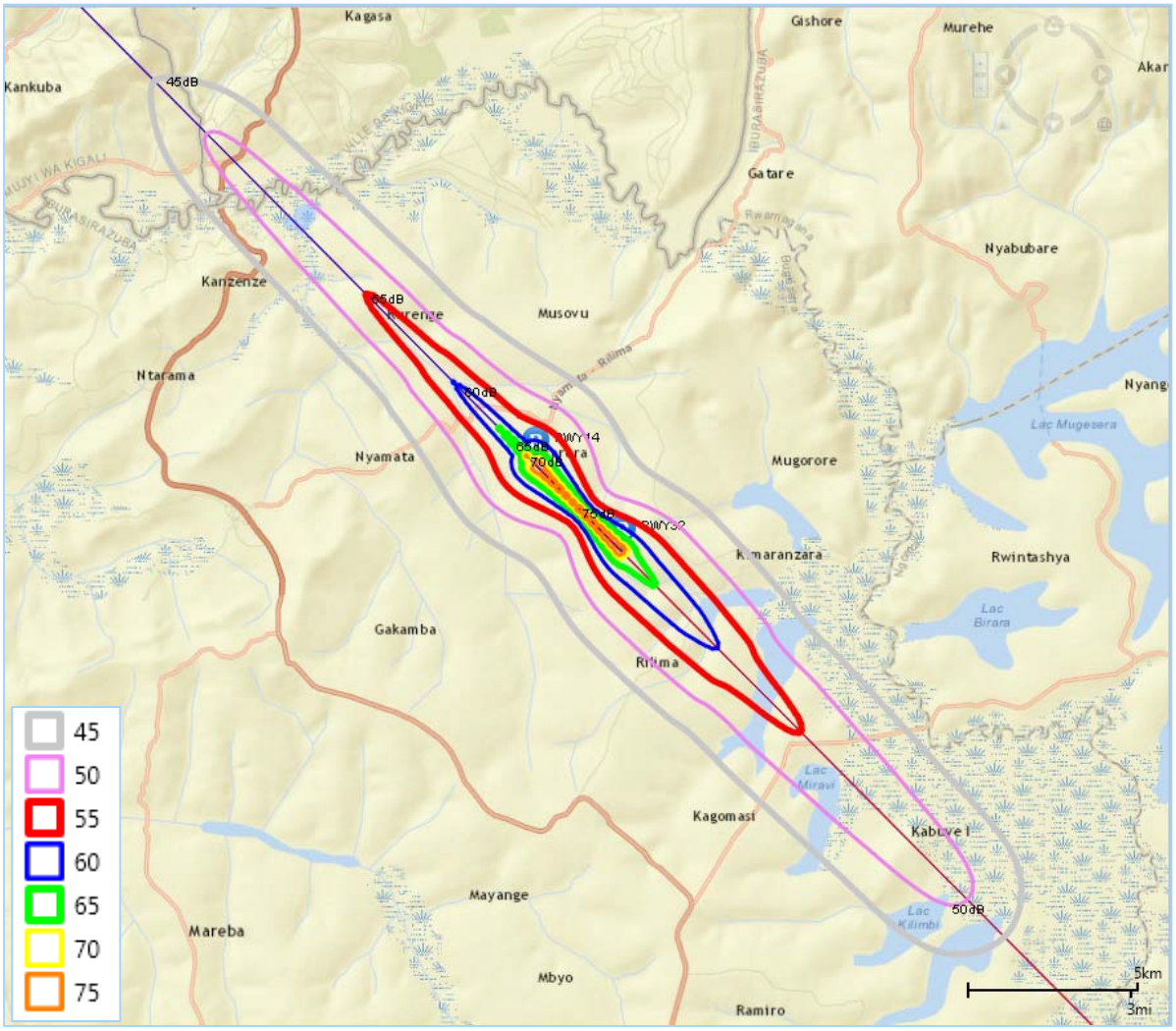

Figure 10-5. Scenario 2045. Noise from Air Traffic. Average Noise Level, L_{Aeq}, dB, During Daytime 07:00 – 22:00

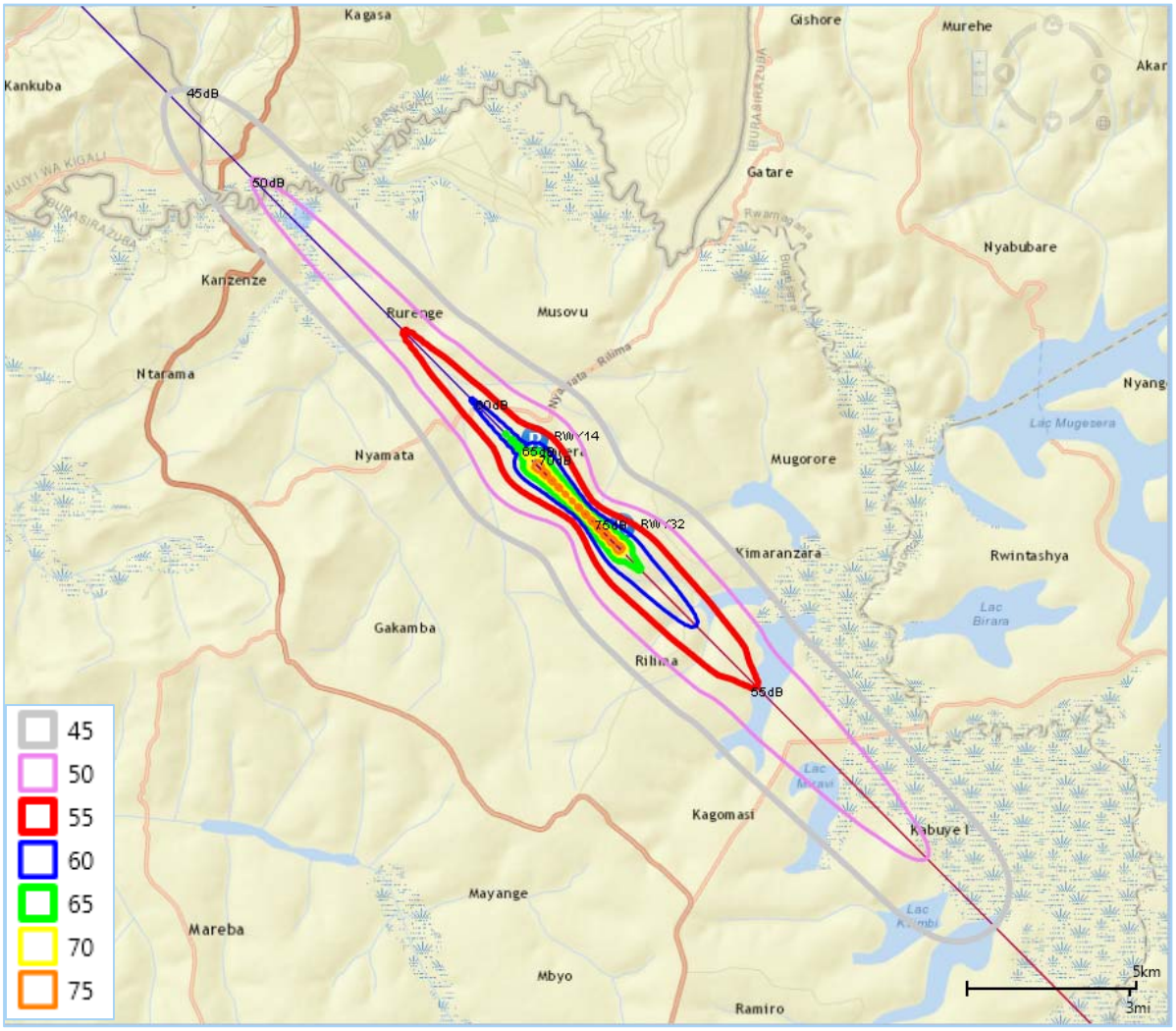

Figure 10-6. Scenario 2045. Noise from Air Traffic. Average Noise Level, L_{Aeq}, dB, During Night Hours 22:00 – 07:00

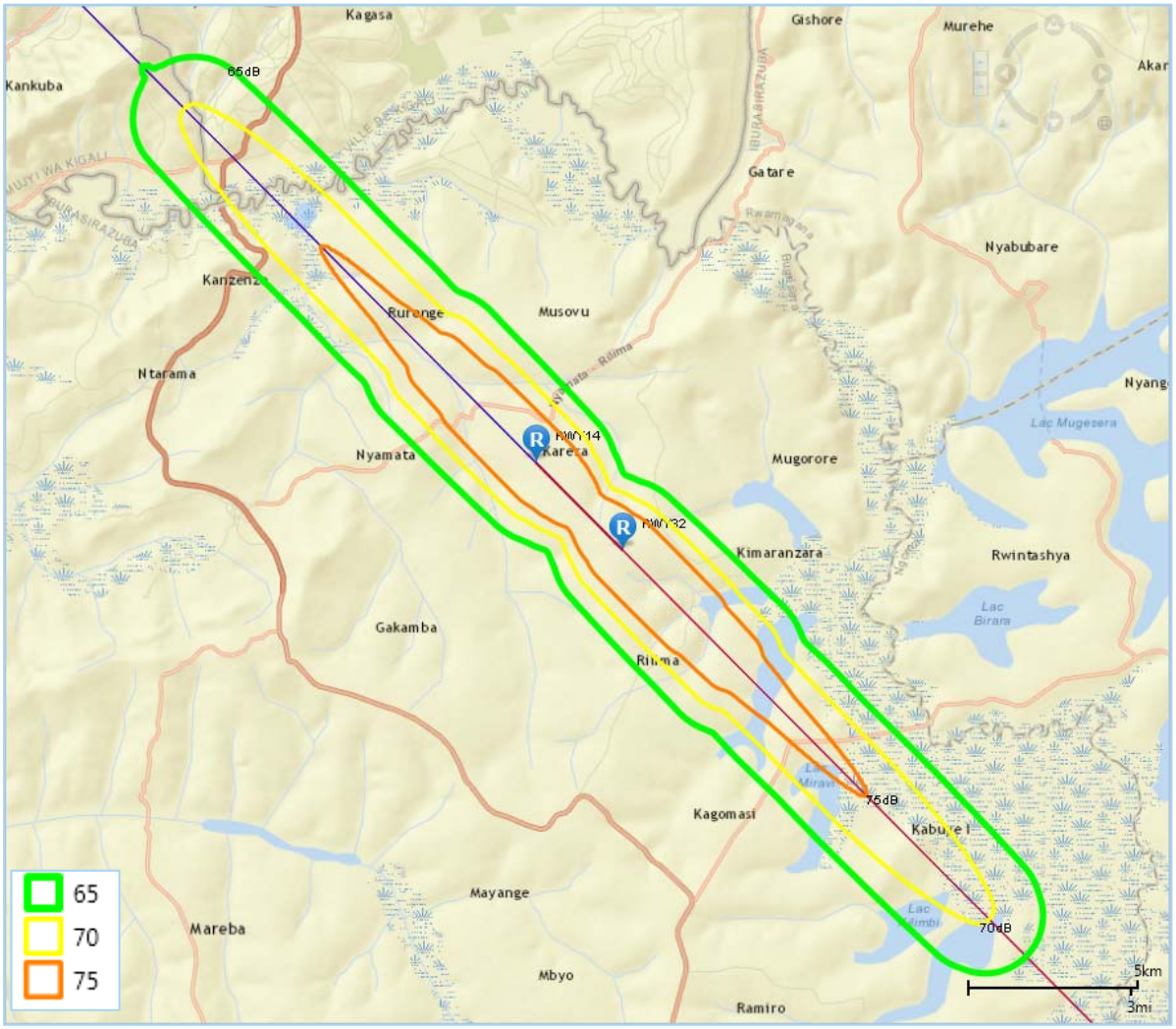

Figure 10-7. Scenario 2020. Noise from Air Traffic. Maximum Noise Level, L_{Amax}, dB.

10.7 Mitigation Measures

10.7.1 Road Traffic Noise

As the noise impact magnitude from road traffic noise on the Expressway has been assessed to be **Moderate Adverse** and exceedances of the criteria values to be within 5 dB, it is evaluated that no mitigation measures are needed. It should be noted that the noise impact will not be constant.

10.7.2 Air Traffic Noise

It is recommended that future land-use planning ensures that future noise sensitive developments are not located in areas exposed to noise levels above the criteria values.

ICAO Annex 16[14] provides recommendations on balanced approach to noise management at airports. The IFC Guidelines on Environment, Health and Safety for Airports includes recommendations on possible mitigation measures. The relevant possibilities to reduce noise impact from NBIA include:

- New engine technologies developed by aircraft manufacturers and general noise requirements set out by the ICAO have produced significant reductions of noise from

[14] Convention on International Civil Aviation, July 2011. Environmental Protection. Volume 1 – Aircraft Noise. Sixth Edition and ICAO, 2008. Guidance on the Balanced Approach to Aircraft Noise. Management. Second Edition. Doc 9829.

aircrafts that can be further utilised through regulations on the aircraft type that is allowed to use an airport, for example during night hours;

- Departure and approach procedures, including noise preferential routes/runways; and
- Use of night time or other operating restrictions.

The IFC guidelines outline that operating restrictions should be applied as a last resort and only after consultation and approval by the local authorities as the use of operating restrictions on existing aircraft may not be financially feasible or cost-effective.

Departure and approach procedures could include implementation of preferred procedures and routes for landing and take-off to minimise potential noise from approaching and departing aircraft for noise-sensitive areas. These procedures may include instructions on the use of descent profiles or "noise preferential" routes, such as the "continuous descent approach" to avoid noise-sensitive areas, the use of "Low Power/Low Drag" procedure, as long as possible to minimise airframe noise, and instructions on minimising reverse thrust on landing[15].

As dwellings are scattered in the area surrounding the airport, the use of preferred flight paths will move the noise impact to other dwellings and cause no change in the number of dwellings exposed to air traffic noise.

If the actual flight operation during take-offs can be distributed on several flight paths it will lead to a reduced noise impact on dwellings, but an increase in the number of dwellings exposed as the noise will be distributed over a larger area. This could be achieved if aircraft, shortly after take-off, make a turn away from the main flight path used in this assessment. This will mainly have an effect for dwellings exposed to relatively low noise levels as the turn can only be performed at some distance from the runway. It is estimated that this type of noise management in total will have very limited effect on the total noise impact.

10.8 Residual Impact Assessment Conclusions

10.8.1 Construction Phase Residual Impacts

Assuming that the mitigation measures outlined in Section 10.6.1.1 have been applied, the overall significance for each of the identified adverse construction phase impacts will remain as **Minor Adverse** or **Negligible**.

10.8.2 Operation Phase Residual Impacts

As the noise impact magnitude from road traffic noise on the Expressway has been assessed to be **Moderate Adverse** and exceedances of the criteria values to be within 5 dB.

International developments in aircraft regulation will assist to reduce the noise impact in the longer term but it will depend on the implementation time schedules of new aircraft with lower noise emission in the region, and in Africa as a whole.

Local operational procedures can move noise impact from some areas and possibly reduce the general noise impact, but will most likely simply move or spread the noise to other noise receptor areas.

In the medium to longer term, the future land-use planning should consider that noise sensitive developments are not located in areas exposed to noise levels above the criteria values.

[15] IFC, April 30 2007. Guidelines: Environmental, Health, and Safety Guidelines for Airports.

However, as the Proposed Project is located in a rural area void of significant noise generators, the noise impact from aircraft take-off and landing will remain **Major Adverse**.

10.9 Summary of Mitigation and Residual Impacts

10.9.1 Summary of Findings

10.9.1.1 Construction Phase

Noise from construction work will have **Minor Adverse** noise impact on dwellings. This is assumed that although construction will continue 24 hours per day, activities will not be undertaken at a single location concurrently and timeframes of construction will be limited near individual dwellings along the Expressway, the Airport Area and the quarry road. Dwellings located closer than 25 – 45 m can be exposed to high noise levels but it will be for shorter periods of time.

10.9.1.2 Operation Phase

Whilst not quantitatively assessed as part of this ESIA Report, the movement of aircraft operations from Kigali International Airport to NBIA will reduce noise impacts from aircraft operations from densely populated areas in Kigali.

The main impact from the Proposed Project will be noise from aircraft operations and road traffic on the Expressway.

It is assessed that the road traffic noise will have a **Moderate Adverse** impact as the number of dwellings exposed to noise levels above the guidelines is estimated to be less than 25 households in 2020 and less than 50 households in 2045.

Aircraft operations are expected to cause a noise impact above the noise guideline at a large number of dwellings in a predominantly rural environment along the flightpaths into and out of the new airport.

It is therefore the conclusion that the impact significance on dwellings from air traffic noise along flight paths into and out of the new airport is anticipated to be **Major Adverse**.

Possible mitigation measures to reduce noise impact from aircraft operations could be departure and approach procedures, including noise preferential routes/runways, and use of night time or other operating restrictions, as well as ensuring that, in the medium to longer term, development planning ensures that noise sensitive receptors such as further dwellings are positioned outside of the unavoidable noise impact envelopes identified in this assessment.

10.10 Monitoring

No noise monitoring is recommended during construction; however, a complaints register will be made available at the security gate at the Construction Camp to provide sensitive receptors an opportunity to raise complaints or concerns that BAC will consider and close out.

During operation of the airport, a permanent noise monitoring system to assess noise from aircraft during take-off and landing will be implemented and results evaluated against Rwandan regulatory requirements and IFC standards. Noise monitoring, combined with radar tracking, will enable the airport operator to identify any irregularities from flight procedures. Furthermore, this will assist in responding to complaints received from surrounding communities on unusual noise events and identify if the complaint is related to a single event, to a specific aircraft type or airline operator. This will be included in a Pollution Prevention Plan (which include noise emissions).

Table 10-12: Summary of Findings

Impact	Receptor	Phase	Impact Magnitude	Receptor Sensitivity	Pre-Mitigation Impact Significance	Design, Enhancement or Mitigation Measures	Management Plan	Residual Significance
Noise annoyance	Existing dwellings along Proposed Expressway	Construction	**Impact Magnitude:** Medium **Nature:** Adverse **Type:** Direct **Extent/ Scale:** Local **Duration:** Short Term **Frequency:** Periodic **Reversibility:** Irreversible	Low	**Minor Adverse**	• Vehicles, machinery and equipment will be of good working condition and submitted to routine maintenance and repair.	• Construction ESMP	**Minor Adverse**
Noise annoyance	Existing dwellings outside Airport Area boundary Existing dwellings along quarry road	Construction	**Impact Magnitude:** Low **Nature:** Adverse **Type:** Direct **Extent/ Scale:** Local **Duration:** Short Term **Frequency:**	Low	**Negligible**		• Construction ESMP	**Negligible**

Table 10-12: Summary of Findings

			Periodic **Reversibility:** Irreversible					
Vibration annoyance	Existing dwellings outside Airport Area boundary Existing dwellings along quarry road Existing dwellings along Proposed Expressway	Construction	**Magnitude:** Low **Nature:** Adverse **Type:** Direct **Extent/Scale:** Local **Duration:** Short Term **Frequency:** Periodic **Reversibility:** Irreversible	Low	**Negligible**	• Vehicles, machinery and equipment will be of good working condition and submitted to routine maintenance and repair.	• Construction ESMP	**Negligible**
Noise	Dwellings adjacent to the quarry area	Construction	**Impact Magnitude:** Low **Nature:** Adverse **Type:** Direct **Extent/ Scale:** Local **Duration:** Short Term	High	**Minor Adverse**	• Quarry equipment and machinery such as crushes are to be enclosed to minimise noise within the area.	• Construction ESMP	**Negligible**

Table 10-12: Summary of Findings

			Frequency: Periodic **Reversibility:** Reversible					
Noise annoyance	Existing dwellings along Proposed Expressway	Operation	**Impact Magnitude:** Low **Nature:** Adverse **Type:** Direct **Extent/Scale:** Local **Duration:** Long Term **Frequency:** Constant **Reversibility:** Irreversible	High	**Moderate Adverse**	• Speed limiting structures such as speed humps and stop signs will lower vehicle speed resulting in lower noise generation.	• Operation ESMP	**Moderate Adverse**
Noise annoyance	Existing dwelling under and near airport flight paths	Operation	**Impact Magnitude:** Medium **Nature:** Adverse **Type:** Direct **Extent/Scale:** Local **Duration:** Long Term	High	**Major Adverse**	• New engine technologies, general noise requirements and regulations on the aircraft type that is allowed to use an airport; • Departure and approach	• IFC Guidelines on Environment, Health and Safety for Airports.	**Major Adverse**

Table 10-12: Summary of Findings

			Frequency: Constant **Reversibility:** Irreversible			procedures, including noise preferential routes/runways; and • Use of night time or other operating restrictions.	• Pollution Prevention Plan. • Noise Monitoring System.	