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Project: Aqaba-Amman Water Desalination and Conveyance (AAWDC)

2025 Environmental and Social Impact Assessment

Appendix 9A.2 Underwater sound modelling

Energies Group

ESIA Support

Underwater sound assessment - Pecker dredging

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1 INTRODUCTION

Energies Group have requested that Xodus Group Ltd (Xodus) undertake an underwater noise impact assessment of the potential impact to marine mammals and fish during the construction phase of the project and a lesser extent during operations. The sound assessment specifically considers the use of a pecker during dredging operations. This modelling undertaken was based on reference data obtained during a desk-based review of similar equipment and operations.

2 BACKGROUND

2.1 Underwater Sound and Assessment Metrics

Sound is transmitted through liquids as longitudinal waves, or compression waves. These are waves of alternating pressure deviations from the equilibrium pressure, causing local regions of compression and rarefaction. Sound pressure (p) is therefore the average variation in pressure caused by the sound. By convention, sound levels are expressed in decibels (dB) relative to a fixed reference pressure commonly 1 micropascal (μPa) for underwater measurements, as measurements typically cover a very wide range of pressure values.

Peak Sound Pressure Level (SPL)

The Peak Sound Pressure Level (SPL), also referred to as the zero-to-peak SPL (SPL_{0-PK}), is the maximum sound pressure during a stated time interval. A peak sound pressure may arise from a positive or negative sound pressure, and the unit is the pascal (Pa). This quantity is typically useful as a metric for a pulsed waveform, though it may also be used to describe a periodic waveform.

Root Mean Square (RMS) sound pressure

The Root Mean Square (RMS) Sound Pressure Level (SPL_{RMS}) is the mean square pressure level measured over a given time interval. Therefore, it represents a measure of the average sound pressure level over the time interval. The SPL_{RMS} sound pressure is expressed in pascals (Pa).

When the SPL_{RMS} is used to quantify a transient sound source the time period over which the measurements are averaged must be given, as the SPL_{RMS} value will vary with the averaging time period.

Sound Exposure Level (SEL)

The Sound Exposure Level (SEL) is the time integral of the square pressure over a time window long enough to include the entire pressure pulse. The SEL is therefore the sum of the acoustic energy over a measurement period, and effectively takes account of both the level of sound, and the duration over which the sound is present in the environment.

3 MARINE MAMMAL IMPACT CRITERIA

Underwater noise has the potential to affect marine life in different ways depending on its level and characteristics. Richardson *et al.* (1995) defined four zones of noise influence which vary with distance from the source and level.

These are:

The zone of audibility: this is the area within which the animal can detect the sound. Audibility itself does not implicitly mean that the sound will have an effect on the marine mammal.

The zone of responsiveness: this is defined as the area within which the animal responds either behaviourally or physiologically. The zone of responsiveness is usually smaller than the zone of audibility because, as stated previously, audibility does not necessarily evoke a reaction.

The zone of masking: This is defined as the area within which sound can interfere with detection of other sounds such as communication or echolocation clicks. This zone is very hard to estimate due to a paucity of data relating to how marine mammals detect sound in relation to masking levels (for example, humans are able to hear tones well below the numeric value of the overall noise level).

The zone of injury / hearing loss: this is the area where the sound level is high enough to cause tissue damage in the ear. This can be classified as either a Temporary Threshold Shift (TTS) or Permanent Threshold Shift (PTS) of hearing. At even closer ranges, and for very high intensity sound sources (e.g. underwater explosions), physical trauma or even death are possible.

For this study, it is the zones of injury and disturbance (i.e. responsiveness) that are of concern (there is insufficient scientific evidence to properly evaluate masking). To determine the potential spatial range of injury and disturbance, a review has been undertaken of available evidence, including international guidance and scientific literature. The following sections summarise the relevant thresholds for onset of effects and reference the evidence base used to derive them.

3.1 Injury (Physiological Damage)

The Joint Nature Conservation Committee (JNCC) (2010) recommends using the injury criteria proposed by Southall *et al.* (2007), which are based on a combination of linear (i.e., un-weighted) peak pressure levels and mammal hearing weighted (M-weighted) SEL.

In 2018, the National Marine Fisheries Service (NMFS) (2018) provides details of the acoustic thresholds at which individual marine mammals are predicted to experience changes in their hearing sensitivity for acute, incidental exposure to all underwater anthropogenic sound sources. These new thresholds reflect new/updated scientific formation that has demonstrated differences between the marine mammal hearing groups first categorised in Southall *et al.* (2007).

The work undertaken by Southall *et al.* (2007) was revaluated in light of subsequent scientific advances and as a result revised sound exposure criterion to predict the onset of auditory effects in marine mammals have been published (Southall *et al.*, 2019). The only significant difference between Southall *et al.* (2019) and NMFS (2018) was the renaming of the mid-frequency and high frequency groups to high frequency and very high frequency respectively.

This study uses the Southall *et al.* (2019) hearing group frequency categories which are relevant to marine mammals in the project area in the Gulf of Aqaba:

- Low-Frequency (LF) cetaceans i.e. marine mammal species such as Bryde's whale with an estimated functional hearing range between 7 Hz and 35 kHz;
- HF cetaceans i.e. marine mammal species such as dolphins, sperm whales, and killer whales with an estimated functional hearing range between 150 Hz and 160 kHz;
- VHF cetaceans, although not present in the Gulf of Aqaba region, include marine mammal species such as true porpoises, river dolphins with an estimated functional hearing range between 275 Hz and 160 kHz; and
- Pinnipeds in Water (PW) are not native to the Gulf of Aqaba or surrounding Red Sea, they comprise a suborder of carnivorous aquatic mammals that includes seals, walruses and other similar animals having finlike flippers with an estimated functional hearing range between 50 Hz and 86 kHz (for underwater).

These are presented pictorially in Figure 3.1.

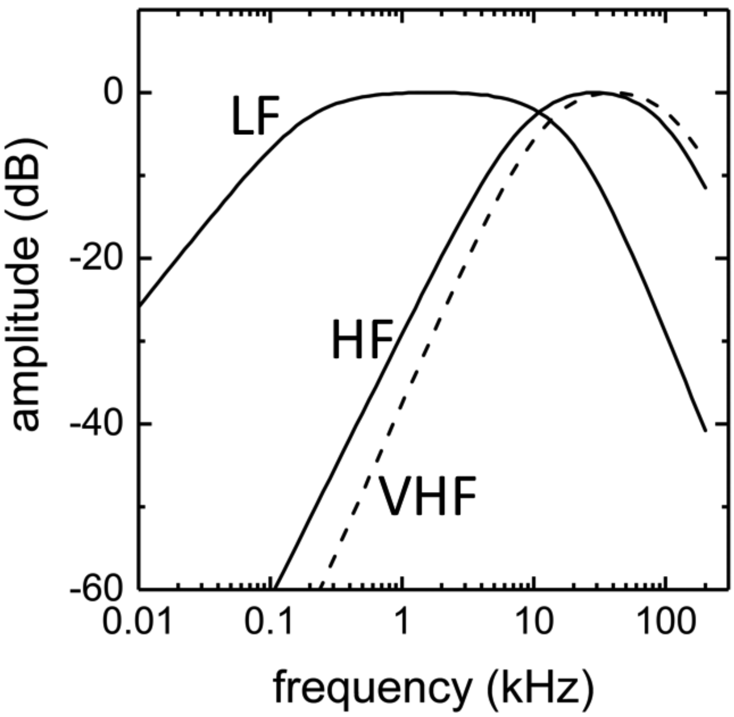

Figure 3.1 Auditory Weighting Functions for LF, HF and VHF (dashed line) Cetaceans (Southall et al., 2019).

3.2 Disturbance

The JNCC guidance (JNCC, 2010) proposes that a disturbance offence may occur when there is a risk of a significant group of animals incurring sustained or chronic disruption of behaviour or when a significant group of animals are displaced from an area, with subsequent redistribution being significantly different from that occurring due to natural variation.

There is much intra-hearing group and intra-species variability in behavioural response. Therefore, this assessment adopts a simplified approach in the absence of further scientific information and uses the US National Marine Fisheries Service (NMFS) Level B harassment threshold of 160 dB re 1 µPa RMS for impulsive sound.

Level B Harassment is defined as having the potential to disturb a marine mammal or marine mammal stock in the wild by causing disruption of behavioural patterns, including, but not limited to, migration, breathing, nursing, breeding, feeding, or sheltering but which does not have the potential to injure a marine mammal or marine mammal stock in the wild. This is similar to the JNCC (2010) description of non-trivial disturbance and has therefore been adopted as the basis for onset of behavioural change in this assessment.

Exposure to sound levels in excess of the behavioural change threshold stated above does not necessarily imply that the sound will result in significant disturbance as defined in the legislation. Whether or not a behavioural response might occur is widely recognised as being highly context specific (Southall *et al.*, 2007; Southall *et al.*, 2019; Southall *et al.*, 2021). As noted previously, it is also necessary to assess the likelihood that the sensitive receptors will be exposed to that sound and whether the numbers exposed are likely to be significant at the population level.

3.3 Criteria Summary

3.3.1 Marine Mammals

The hydraulic pecker/hammering activities have been assessed as an impulsive noise source as consistent with the considered thresholds and guidelines. The marine mammal impact criteria applied in this study are as described by Southall *et al.* (2019) and the National Oceanic and Atmospheric Administration (NOAA) (2019), for auditory threshold shifts or hearing loss and behavioural respectively.

The Southall *et al*. (2019) underwater acoustic thresholds for the onset of TTS and PTS for cetaceans, as well as the NOAA (2019) behavioural response threshold, are presented in Table 3-1.

Table 3-1 Summary of Weighting Function Parameters for Impulsive Noise Sources, Southall et al. (2019).

Hearing group	Southall *et al.* (2019)				NOAA (2019)
	PTS Onset thresholds (received level)		TTS onset thresholds (received level)		Behaviour
	SEL (dB re 1 µPa2·s)	SPL (dB re 1 µPa)	SEL (dB re 1 µPa2·s)	SPL (dB re 1 µPa)	SPL (dB re 1 µPa)
Low Frequency (LF) cetaceans	183	219	168	213	160
High Frequency (HF) cetaceans	185	230	170	224	
Very High Frequency (VHF) Cetaceans	155	202	140	196	

3.3.2 Fish

The Sound Exposure Guidelines for Fishes and Sea Turtles (Popper *et al.*, 2014) guidelines sets out criteria for injury and other impacts for various man-made sources . Whilst these sources does not specifically include hydraulic pecker/hammering it does include pile driving, which has been used in this assessment as a proxy for the use of a hydraulic pecker. The criteria include a range of indices; SEL, RMS and peak sound pressure levels. Where insufficient data exist to determine a quantitative guideline value, the risk is categorised in relative terms as "high", "moderate" or "low" at three distances from the source: "near" (i.e., in the tens of metres), "intermediate" (i.e., in the hundreds of metres) or "far" (i.e., in the thousands of metres). It should be noted that these qualitative criteria cannot differentiate between exposures to different levels of sound and therefore all sources of sound, independent of source level, would theoretically elicit the same assessment result.

The Popper *et al.* (2014) criteria presented for dredging are reproduced in Table 3-2.

Table 3-2 Threshold criteria for potential impacts to fish due to pile driving activities (Popper et al., 2014).

Type of animal	Parameter	Mortality and potential mortal injury	Impairment		Behavioural response
			Recoverable Injury	TTS	
Fish: no swim bladder (particle motion detection)	Peak, dB re 1 µPa	>213	>213	-	(*Near*) High (*Intermediate*) Mod. (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	>219	>216	>>186	
Fish: where swim bladder is not involved in hearing (particle motion detection)	Peak, dB re 1 µPa	>207	>207	-	(*Near*) High (*Intermediate*) Mod. (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	210	203	>186	
Fish: where swim bladder is involved in hearing (primarily pressure detection)	Peak, dB re 1 µPa	>207	>207	-	(*Near*) High (*Intermediate*) Mod. (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	207	203	186	
Eggs and larvae	Peak, dB re 1 µPa	>207	(*Near*) Mod (*Intermediate*) Low (*Far*) Low	(*Near*) Mod (*Intermediate*) Low (*Far*) Low	(*Near*) Mod (*Intermediate*) Low (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	>210			

4 MODEL INPUTS

A desktop review of available data pertaining to pecker dredging operations was undertaken by Xodus. The data selected for the modelling study was based on a paper describing trenching operations using a hydraulic hammer (JASCO, 2023). Having reviewed the available equipment description it was considered that the values provided were also appropriate for a hydraulic pecker. The SPL value derived by Xodus from the SEL value where also similar to the upper range provided by Wyatt *et al.* (2008) for a backhoe dredger with a percussion tool (180 – 190 dB @ dB re 1 µPa).

The model input data used within assessment is summarised in Table 4-1.

Table 4-1 Dredging equipment input data.

Equipment type	Hydraulic hammer
SPL (@ 1 m: dB re 1 µPa)	195[1]
SEL (@ 1 m: dB re 1 µPa^{2}s)	192
Duration (hrs)	12
Water depth (m)	5

[1] *Calculated by Xodus from the SEL value*

5 RESULTS

5.1 Marine Mammals

The source SPL value of 195 dB @ 1 m: dB re 1 µPa is below the threshold values for both PTS for all marine mammal hearing groups (Table 3-2) and therefore no impacts from SPLs are predicted. This section focuses only on the potential impacts of the cumulative SEL, based on a 12h exposure period (SEL_{12hr}).

The predicted impact distances for the SELs propagation are shown in Table 5-1.

Table 5-1 Predicted radius of exceedance of the SEL_{12hr} PTS threshold (m).

Situation	Radius of potential injury zones (m)		
	VHF Cetaceans	HF Cetaceans	LF Cetaceans
PTS	139	15	76
TTS	495	55	430
Strong behavioural distance	153		

Based on the acoustic characteristics of the dredging equipment the calculated SEL_{12hr} values indicate potential onset of PTS at distances of up to 139 m for VHF cetaceans, 75 m for LF cetaceans, and 15 m for HF cetaceans. These thresholds are based on the auditory criteria established by Southall *et al.* (2019). The SEL values were derived using measured SPL data and exposure duration, in accordance with standard acoustic assessment protocols.

The assessment indicated that TTS impacts (i.e. recoverable injury) are limited to approximately 500 m from the source for all marine hearing groups.

In the Gulf of Aqaba, marine mammal species such as Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) and spinner dolphins (*Stenella longirostris*) are commonly observed. Both species fall under the HF cetacean hearing group, for which Southall *et al.* (2019) defines impulsive SEL thresholds of 170 dB re 1 µPa^2s for TTS and 185 dB re 1 µPa^2s for PTS. The TTS threshold for this species would be exceeded within 55 m of the source location. Occasional sightings of LF cetaceans, such as Bryde's whales (*Balaenoptera edeni*), have also been documented in the region. The predicted distance of TTS threshold exceedance is approximately 430 m for LFC.

The behavioural impact assessment was conducted using the Level B harassment threshold of 160 dB re 1 µPa (rms) proposed by NMFS (2013). As a worst-case the results presented corresponds to a static marine mammal. This resulted in a predicted radial distance of approximately 153 m for all marine mammal hearing groups, however this is based on the SPL_{rms} metric. If we assume that TTS (recoverable injury) is also likely to produce a behavioural change (e.g. area avoidance) then this would equate to a behavioural limit of approximately 500 m.

Behavioural changes such as moving away from an area for short periods, reduced surfacing time, masking of communication signals or echolocation clicks, vocalisation changes and separation of mothers from offspring for short periods, do not necessarily imply that detrimental effects will result for the animals involved. In addition, the pulses will be intermittent rather than a continuous sound, which will reduce the period over which sound is experienced and allow animals to echolocate and communicate between pulses. Some whales are known to continue calling in the presence of pulses since the vocalisations can be heard between pulses (e.g., Greene & McLennan, 2000, Madsen *et al.*, 2002). It is therefore considered that the zone of behavioural change will not be a zone from which animals are necessarily excluded, but rather one in which normal behaviour might be affected across a range of potential responses, from a simple noticing of the sound to a startle response and return to normal behaviour, through to exclusion from an area. The fact that an animal is within this area does not necessarily mean that disturbance will occur. Mitigation of the potential impacts of anthropogenic sound on cetaceans focuses on reducing near field injuries, and risk assessments assumes that the animals move away from loud sources of sound. While this is supported by various studies, observations also show a decline in response to airgun sound during the seismic survey. The findings of Thompson *et al.* (2013) suggest that broader-scale exclusion from preferred habitats is unlikely. Instead, individual's fitness and demographic consequences are likely to be subtle and indirect, highlighting the need to develop frameworks to assess the population consequences of sub-lethal changes in foraging energetics of animals occurring within affected sites.

5.2 Fish

The distances at which sound level decreases to below the various threshold values for the different types of fish due to the proposed dredging activities are presented in Table 5.2. As with the marine mammals the source SPLs (Table 4-1) are below the threshold criteria for potential impacts to fish proposed by Popper *et al*. (2014)

The results indicate that for the pecker drilling operations, SEL_{12hr} will decrease to below threshold values for potential mortality beyond approximately 64 m from the source for fish, eggs and larvae; for temporary threshold shifts the distance is 684 m for all fish categories.

Adult fish not in the immediate vicinity of the sound generating activity are generally able to move away and avoid the likelihood of physical injury. However, larvae are not highly mobile and are therefore more likely to incur injuries from the sound energy, including damage to their hearing, kidneys, hearts and swim bladders. Damage from shock to eggs and developing embryos consist of deformation and compression of the membrane, spiral curling of the embryo, displacement of the embryo, and disruption of the vitelline membrane. Although, such effects are unlikely to happen outside of the immediate vicinity of the dredging activities. Popper *et al*. (2014) recognises the need for more data to help determine the effects of anthropogenic sound on eggs and larvae.

In terms of disturbance (or behavioural response) the impacts from dredging activities are presented in qualitative terms rather than quantitatively. Based on these qualitative criteria, there is a high level of risk of disturbance up to 'tens of metres' from the source and low at distances of 100s of metres. For eggs and larvae, the risk is high close to the centre of activity (tens of metres) and low beyond this point.

In summary, using the approach adopted by Popper *et al.* (2014), the area of behavioural change will extend beyond 10 m from the source, but the risk of disturbance will be moderate and is unlikely to be significant beyond 684 m.

Table 5.2 Impact assessment on fish and sea turtles from the dredging activities.

Type of Animal	Parameter	Mortality and Potential Mortal Injury (m)	Impairment		Behavioural Response
			Recoverable Injury (m)	TTS	
Fish: no swim bladder (particle motion detection)	Peak, dB re 1 µPa	-	-	-	(*Near*) High (*Intermediate*) Mod. (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	16	24	684	
Fish: where swim bladder is not involved in hearing (particle motion detection)	Peak, dB re 1 µPa	-	-	-	(*Near*) High (*Intermediate*) Mod. (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	44	104	684	
Fish: where swim bladder is involved in hearing (primarily pressure detection)	Peak, dB re 1 µPa	-	-	-	(*Near*) High (*Intermediate*) Mod. (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	64	104	684	
Eggs and larvae	Peak, dB re 1 µPa	-	(*Near*) Mod (*Intermediate*) Low (*Far*) Low	(*Near*) Mod (*Intermediate*) Low (*Far*) Low	(*Near*) Mod (*Intermediate*) Low (*Far*) Low
	SEL_{cum} dB re 1 µPa ^{2}·s.	44			

6 CONCLUSIONS

Based on the acoustic characteristics of the equipment, which generates non-impulsive noise, the calculated SEL values indicate potential onset of PTS at distances of up to 139 m for VHF cetaceans, 76 m for LF cetaceans, and less than 15 m for HF cetaceans.

The potential impacts to fish have been assessed using the threshold criteria for dredging activities presented by Popper *et al*. (2014). The fish impact assessment indicated that the distances at which the sound level exceeds the threshold values during the proposed operations are small, with the maximum potential for mortality being no greater than 64 m from the source for all fish types, eggs and larvae. The predicted maximum range for the onset of TTS in fish is approximately 684 m.

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Project: Aqaba-Amman Water Desalination and Conveyance (AAWDC)

2025 Environmental and Social Impact Assessment

Appendix 9B.1 Noise and vibration screening assessment

NOISE AND VIBRATION ASSESSMENT

Aqaba-Amman Water Desalination and Conveyance Project (AAWDCP)

November 2025

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1 INTRODUCTION

This report presents the findings of an assessment of the likely effects from noise and vibration as a result of the Aqaba-Amman Water Desalination and Conveyance Project, Jordan (the Project). Where required, this report describes recommended measures to address potential impacts of the scheme in terms of noise and vibration during the construction and operational phases.

This report has been authored by Martin Stevenson, Director at Metrica Environmental Consulting Ltd (Metrica). Metrica are a specialist noise and vibration consultancy based in the UK. Martin has over 15 years' experience undertaking noise and vibration impact assessments for projects in both the UK and internationally. Martin is a full member of the Institute of Acoustics.

The scope of this assessment is focused on noise and vibration disturbance to community receptors.

2 LEGAL AND ADMINISTRATIVE FRAMEWORK

This section provides a summary of the relevant legal and administrative framework for the assessment of noise and vibration.

2.1 PREVENTION AND ELIMINATION OF NOISE (2003)

The Jordanian *Instruction for the Prevention and Elimination of Noise* (2003) specifies the maximum allowable noise limits that noise-emitting Projects should comply with. Regarding construction noise, the Instruction states:

- All construction activities using noise producing plants and equipment (e.g., mixers and vibrators) must cease between 8:00 p.m. and 6:00 a.m., unless a permit is granted by the MoE; and
- Work activities within light industrial areas with residential dwellings are prohibited to continue between 9:00 p.m. and 7:00 a.m. (summer) and between 8:00 p.m. and 6:00 a.m. (winter).

Article 6 of the Instruction specifies the maximum allowable noise level (in dBA) for specific times and areas. The limits are presented in Table 1 below.

Table 1: Maximum Allowable Noise Limits

Area	Allowable Limits for Noise Levels (dBA)	
	Day	Night
Residential areas in cities	60	50
Residential areas in suburbs	55	45
Residential areas in villages	50	40
Residential areas with some business / commercial areas	65	55
Industrial areas	75	65
Tuition, worshiping and hospitals	45	35

It should be noted that the Instruction does not provide explicit definitions for areas where the allowable noise levels are specified e.g. cities, suburbs etc.

2.2 IFC EHS GUIDELINES – ENVIRONMENTAL NOISE MANAGEMENT

IFC EHS Guidelines 1.7 Noise (IFC Noise 1.7)[1] contains information for the assessment and management of noise.

IFC Noise 1.7 provides a number of noise prevention and mitigation measures which can be implemented to reduce impacts at receptors. The document states that noise impacts should not exceed the levels summarised in Table 2 below or result in a maximum increase in background levels of 3 dB at the nearest receptor.

Table 2: IFC Noise Level Guidelines

Receptor	Noise Level Guidelines ($L_{Aeq,1hr}$)	
	Day (0700 – 2200)	Night (2200 – 0700)
Residential, institutional and educational	55	45
Industrial / commercial	70	70

3 INDUSTRY BEST PRACTICE

While Jordanian and IFC Guidance provides noise limits, neither document provides information on the prediction of construction noise or vibration. As such the following appropriate international technical standards have been used to supplement the Jordanian and IFC guidance, as set out below.

3.1 BS 5228:2009+A1:2014 CODE OF PRACTICE FOR NOISE AND VIBRATION CONTROL ON CONSTRUCTION AND OPEN SITES – PART 1 (NOISE)

BS 5228:2009:A1:2014-1 Noise ('BS 5228-1')[2] is a UK guidance document, the principles of the assessment of provides example criteria for the assessment of the significance of noise effects. Whilst this a standard specific to the United Kingdom, it is widely adopted for the assessment of construction-specific noise and vibration impacts on infrastructure projects across the world.

With regards to the assessment of construction noise, BS 5228 presents several assessment methodologies, of which Example Method 2: 5 dB(A) change, states:

"Noise levels generated by site activities are deemed to be potentially significant if the total noise (pre-construction ambient plus site noise) exceeds the pre-construction ambient noise by 5 dB or more, subject to lower cut off values of 65 dB, 55 dB and 45 dB $L_{Aeq,T}$ from site noise alone, for the daytime , evening and night-time periods, respectively; and a duration of one month or more, unless works of a shorter duration are likely to result in significant effect".

[1] Environmental, Health, and Safety (EHS) Guidelines, General EHS Guidelines: Environmental Noise, International Finance Corporation, 2007

[2] British Standard 5228:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – part 1 (Noise), BSI, 2014

The standard also provides methods for calculating the levels of noise resulting from construction activities, as well as source levels for various types of plant, equipment and activities.

3.2 BS 5228:2009+A1:2014 CODE OF PRACTICE FOR NOISE AND VIBRATION CONTROL ON CONSTRUCTION AND OPEN SITES – PART 2 (VIBRATION)

Section B2 of BS 5228:2009:A1:2014 Part 2 Vibration ('BS 5228-2')[3] sets out guidance on the effects of vibration, including vibration levels at which effects are perceptible to human receptors. Table 3 summarises this guidance.

Table 3: BS 5228-2 Guidance on Effects of Vibration

Vibration Level (Peak Particle Velocity (PPV) mm/s)	Effect
0.14	Vibration might be just perceptible in the most sensitive situations for most vibration frequences associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3	Vibration might be just perceptible in residential environments.
1.0	It is likely that vibration of this level in residential environments will cause complaint but can be tolerated if prior warning and explanation has been given to residents.
10	Vibration is likely to be intolerable for any more than a very brief exposure to this level in most building environments.

With regards to structural damage, BS 5228-2 states that the response of a building to ground borne vibration is affected by the type of foundation, underlying ground conditions, building construction and condition of the building.

Table 4 below provides vibration guide values for cosmetic damage to buildings.

Table 4: Transient Vibration Guide Values for Cosmetic Damage

Type of Building	Peak component particle velocity in frequency range of predominant pulse	
	4 Hz to 15 Hz	15 Hz and above
Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	
Unreinforced or light framed structures Residential or light commercial buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

BS 5228-2 states that minor damage is possible at vibration magnitudes which are greater than twice the values provided in Table 4, and major damage can occur at values four times greater.

[3] British Standard 5228:2009+A1:2014 Code of practice for noise and vibration control on construction and open sites – part 2 (Vibration), BSI, 2014

3.3 DESIGN MANUAL FOR ROADS AND BRIDGES (DMRB) VOLUME 11

DMRB[4] sets out the requirements for assessing and reporting the effects of highways noise from the construction and operation of highway project. Whilst DMRB relates to UK infrastructure, the principles of DMRB represent the industry best practice for the assessment of road noise and vibration.

With regards to construction activity noise assessment methodology and criteria, DMRB references the methodology and criteria in BS 5228-1 (Section 3.2).

Table 3.17 of DMRB (summarised in Table 5 below) provides the magnitude of impact at receptors due to construction traffic, based on the increase in Basic Noise Level (BNL). The BNL is calculated at a reference distance of 10 m to define to the change in noise level.

Table 5: Impact due to Construction Traffic Noise

Level of Impact	Increase in BNL of Closest Public Road used for Construction Traffic (dB)
Major	Greater than or equal to 5.0
Moderate	Greater than or equal to 3.0 and less than 5.0
Minor	Greater than or equal to 1.0 and less than 3.0
Negligible	Less than 1.0

Tables 3.31 and 3.33 of DMRB provide magnitude criteria for the assessment of vibration due to construction activities. These are summarised in Table 6 below.

Table 6: Impact due to Construction Activity Vibration

Impact	Vibration Level
Major	Above or equal to 10 mm/s Peak Particle Velocity (PPV)
Moderate	Above or equal to 1.0 mm/s PPV and below 10 mm/s PPV
Minor	Above or equal to 0.3 mm/s PPV and below 1.0 mm/s PPV
Negligible	Below 0.3 mm/s

3.4 CALCULATION OF ROAD TRAFFIC NOISE (CRTN)

The Control of Road Traffic Noise[5] was published by the UK's Department of Transport, and provides a widely recognised procedure for calculating the propagation of noise from road traffic based on traffic flows and road speed. CRTN is used to calculate road traffic noise levels before and during construction, to allow an assessment in line with the criteria specified in DMRB (see Section 3.3 for details).

[4] Design Manual for Roads and Bridges, Volume 11, Highways England, 2020

[5] Calculation of Road Traffic Noise (CRTN), Department of Transport and Welsh Office, HMSO, 1988

4 BASELINE NOISE LEVELS

Various published data sources have been used to characterise the baseline acoustic environment at the following key locations:

- Sahab district and Ras Al-Ain Area in Amman governorate;
- Al-Husayneyah and Jaya villages in Ma'an governorate; and
- Aqaba City and Wadi Rum in Aqaba governorate.

Full details of the data sources and associated references are presented in Chapter 6 of the ESIA. For clarity, a summary of the relevant existing noise levels in each area are presented in the following sections.

4.1 AMMAN GOVERNATE BASELINE NOISE MEASUREMENTS

Noise monitoring was conducted in September 2021 in the Sahab district as part of the baseline study for the 2022 AAWDC Project ESIA. The measurements were performed over a 72-hour monitoring period, with data recorded at 1-hour intervals.

The monitoring was undertaken in a predominantly residential area that includes some commercial facilities. Consequently, it can be considered representative of the other regions along the proposed pipeline route, such as Rajm Al-Shami Suburb in Mowaqqar district. Although Rajm Al-Shami is not a major urban centre like Sahab, it shares similar residential characteristics and is located closer to the King Abdullah II Industrial City.

The average noise levels measured in the Sahab district are presented in Table 7 below.

Table 7: Summary of Sahab District Baseline Noise Level

Period	Result, dBA (Daily average)		
	Day 1	Day 2	Day 3
Daytime	55	55	53
Night-time	37	46	46

Noise data for the Ras Al-Ain area was collected during a 2017 monitoring campaign at the Greater Amman Municipality building as part of the ESIA for the Amman and Amman-Zarqa Bus Rapid Transit Systems (Engicon, 2017).

The Ras Al-Ain baseline noise survey recorded the following noise levels:

- 76 dBA during daytime periods; and
- 59 dBA during night-time periods.

The acoustic environment in this area is dominated by noise from the densely populated residential area and proximity to major roads. These survey results from the Ras Al-Ain area may also be representative of sensitive receptors located along the pipeline route, such as the Abu Alanda area, which shares similar conditions of dense residential development and proximity to major roads.

4.2 MA'AN GOVERNATE BASELINE NOISE MEASUREMENTS

Noise data is available from a baseline survey conducted in August 2018 in Al-Husayneyah village for the 50 MW Solar Power Project ESIA (ECO Consult, 2018). Noise data from Al-Husayneyah village can be regarded as representative of multiple locations along the proposed Project pipeline route within Ma'an governorate, where the route passes mainly through vacant lands with some agricultural use activities.

The Al-Husayneyah baseline noise survey recorded the following noise levels:

- 61 dBA during daytime periods; and
- 51 dBA during night-time periods.

Another source of noise data for Ma'an governorate is the 2017 baseline survey for the Shobak 45 MW Wind Power Project ESIA (ECO Consult, 2017) near the Jaya Village. The survey was conducted over a 24-hour period. The monitoring location can be characterised as a rural residential / agricultural area, consisting of a village with a typical concentration of residential buildings alongside surrounding agricultural land. Similar to the monitoring location at Al-Husayneyah village, the Jaya village monitoring location can be regarded as representative of several locations along the proposed Project pipeline route, such as Jafr and Hasa, due to their similar characteristics in terms of land use, residential and agricultural mix, and absence of major noise sources.

The Jaya Village baseline noise survey recorded the following noise levels:

- 44 dBA during daytime periods; and
- 43 dBA during night-time periods.

4.3 AQABA GOVERNATE BASELINE NOISE MEASUREMENTS

Within the Aqaba governorate, noise monitoring was conducted for 72 hours in September 2021 in Wadi Rum as part of the baseline surveys for the 2022 AAWDC Project ESIA.

The area around the monitoring location consists of several farms with scattered residential houses, except for the Rum Agriculture Company workshops and vehicle movements on a nearby secondary road, which are the primary sources of noise. The monitoring location is considered a suitable representation of the typical baseline noise conditions in the surrounding villages of Wadi Rum, such as Shakriyye Village. The measured levels are summarised in Table 8 below.

Table 8: Summary of Wadi Rum District Baseline Noise Level

Period	Result, dBA (Daily average)		
	Day 1	Day 2	Day 3
Daytime	43	40	42
Night-time	40	38	39

Noise data for Aqaba city and surrounding areas is available from the baseline environmental assessment carried out by Japan International Cooperation Agency (JICA) in January 2024 as part of the Urban Development Master Plan Update Study, aimed to assess existing environmental conditions and to provide reference data for sustainable urban and industrial planning. Ambient noise measurements were conducted at four representative locations in Aqaba, including residential areas, main roads, and resort zones.

Table 9 overleaf presents the results of the noise measurements.

Table 9: Summary of Aqaba Baseline Noise Levels

Monitoring Location	Area Type	Period	Baseline Noise Level, dB(A)
1 Aqaba City	Mixed commercial and tourism area	Daytime	67
		Night-time	56
2 Aqaba City	Residential area	Daytime	66
		Night-time	51
3 Main Road	Mixed commercial and residential area	Daytime	73
		Night-time	70
4 Tala Bay	Tourism and recreational area	Daytime	50
		Night-time	49

5 SCOPE OF ASSESSMENT

5.1 CONSTRUCTION PHASE

The assessment of noise and vibration during the construction phase of the Project is focused on the potential disturbance as a result of construction related activities along the conveyance pipeline route and at the conveyance Above Ground Installations (AGIs).

The Intake Pumping Station (IPS) and desalination plant sites are located within the Aqaba Industrial Zone, adjacent to the Aqaba Thermal Power Station (east of the desalination plant) and the phosphate loading jetty (east of the IPS). As a result, both sites are already surrounded by heavy industry. The IPS and desalination plant are also located approximately 2 km from the nearest community / residential receptors.

The renewable facility site is located 5 km east of Al-Quwayrah; the nearest community receptors are located approximately 3 km from the site.

Given the substantial distance (i.e. at least 2 km) between construction activities and nearest community receptors, noise and vibration associated with construction activities at the IPS, desalination plant and renewable facility sites have been scoped out of the assessment.

Installation of OHL transmission towers will occur relatively quickly, and in general, the OHL route does not pass close to receptors. As such noise and vibration impacts from installation of the OHL are anticipated to be minimal and are therefore not considered further as part of this assessment

The construction noise and vibration assessment therefore considers the following:

- Installation of Above Ground Infrastructure (AGI), including Pumping Stations, Regulating Tank Facilities and Break Pressure Tanks.
- Installation of Conveyance Pipeline, including:
    - Trenching;
    - Pipe Installation and Welding;
    - Backfilling and Road Maintenance; and
    - Crushing and Screening.
- Construction Traffic (on site and on public roads).

5.2 OPERATIONAL PHASE

While the conveyance pipeline itself will not generate operational noise, the IPS, desalination plant, pumping stations, regulating facilities and renewable facility will all include noise-emitting equipment such as pumps, generators, fans, inverters and transformers.

As noted in Section 5.1, the IPS, desalination plant and renewable facilities are located approximately 2 km from the nearest community / residential receptor. At this distance, there is no reasonable prospect of operational noise from these facilities impacting the nearest receptors.

Equipment associated with conveyance AGIs (i.e. pumping stations and regulating facilities) will be housed within buildings. The Conceptual Design Report for the Conveyance Project[6] confirms that AGI building walls will consist of double concrete masonry with 80 mm thermal insulation, and roofs will comprise reinforced concrete slabs. As such, noise breakout from these buildings is expected to be minimal. In addition, the Conceptual Design Report provides the maximum sound power level for the HVAC equipment associated with all buildings. The highest sound power level reported is 80 dBA. At a distance of 20 m, an HVAC noise level of 80 dB(A) would be lower than 45 dB, L_{Aeq}, which is the most stringent noise limit in the Jordanian Guidelines (Section 2.1). Given that AGI buildings are located substantially more than 20 m from the nearest receptors, no further assessment of operational noise from conveyance AGIs is required.

Some additional operational traffic will be generated through workers movements to and from the facilities, however these increases will be negligible relative to existing traffic volumes and will not result perceptible noise increases at the nearest receptors.

Based on the above, all operational noise will not result in adverse impacts at the nearest receptors, and as such no further assessment of operational noise is required.

6 ASSESSMENT METHODOLOGY

6.1 RECEPTOR CATEGORIES AND NOISE LIMITS

The key receptors sensitive to noise and vibration generated from the construction of the conveyance pipeline and AGIs comprise residential dwellings, occupants of places of worship, medical facilities and hospitals and places of education. To a lesser extent, industrial and commercial areas may also be impacted by noise receptors.

An assessment of the conveyance pipeline and AGIs route has been completed based on the presence of communities and infrastructure adjacent to the pipeline route. The majority of the route (over 75%) passes through areas that are generally rural in character, with fewer than 10 dwellings, little or no industry or businesses, and no intensive agricultural land in the vicinity.

Towns and villages within 1 km of the conveyance pipeline route or AGIs include:

[6] Aqaba-Amman Water Desalination and Conveyance Project, Conceptual Design Report for Conveyance Project, ILF Consulting Engineers, 2023

- Diesah, Sallheiah, Mezfer, Rashdyah and Shakriyyeh within Aqaba Governorate;
- Hasa within Tafiela Governorate; and
- Qatraneh and Sad El-Soltani within Karak Governorate.

These are the most sensitive settlements to noise impacts, based on their proximity to the works. Within the Amman Governorate, the pipeline passes through numerous less sensitive communities in the suburbs of Amman city.

Community facilities, including places of worship, medical centres, and educational institutions, are located within the towns and villages listed above, with the highest provision in Amman. The closest educational facilities at the southern end of the route include the Aqaba Medical Sciences University and Aqaba University of Technology, which are located within 150 m of the conveyance route and within 300 m of the nearby Break Pressure Tank (BPS2) site.

On the basis that the Project does not plan to undertake night-time construction works, and taking into account the most stringent noise limits presented in the Jordanian Instruction (Section 2.1) for each receptor type/category and IFC limit values, the following noise limits have been adopted for the assessment:

- All residential areas except villages (55 dB(A) daytime limit);
- Residential areas in villages (50 dB(A) daytime limit); and
- Places of education, hospitals and places of worship (45 dB(A) daytime limit).

6.2 CONSTRUCTION NOISE ASSESSMENT METHODOLOGY

Indicative details of the type and number of construction plant items to be used during construction of the conveyance system have been provided by the EPC contractor. The type and number of plant items used during construction of the AGI is based on the author's prior experience working on other infrastructure projects.

In order to predict noise from activities associated with the construction of the AGI and conveyance pipeline, typical noise levels for plant / equipment items have been sourced from Annex C of BS 5228-1. As a worst case, predictions of construction noise are based on the following assumptions:

- All plant operational simultaneously;
- No reduction in noise due to barrier effects through existing buildings; and
- No reduction in noise as a result of topographical screening.

Table 10 presents the modelling inputs for construction and installation of the AGI, including Pumping Stations, Regulating Tank Facilities and Break Pressure Tanks.

Table 10: Construction and Installation of AGI

BS 5228 Ref.	Plant / Equipment	Quantity	On-time (%)	Sound Pressure Level at 10 m, dB L_{Aeq}
C.4 ref 63	Excavator	2	75	77
C.6 ref 32	Front Loader	2	75	75
C.5 Ref 12	Dozer	1	75	77
C.4 ref 66	Back hoe loader	1	75	69
C.2 ref 30	HGVs	2	100	79
C.4 ref 38	Mobile Crane	1	25	78
C.4 ref 76	Generators	1	100	61
C.4 ref 93	Angle grinder	1	25	80
C.4 Ref 95	Impact Wrench	1	100	73
Resulting overall Sound Pressure Level at 10 m				86

Tables 11 to 15 below present the modelling inputs for the construction of the conveyance.

Table 11: Conveyance Trenching

BS 5228 Ref.	Plant / Equipment	Quantity	On-time (%)	Sound Pressure Level at 10 m, dB L_{Aeq}
C.4 ref 63	Excavator	8	75	77
C.6 ref 32	Front Loader	4	75	75
C.4 ref 66	Back hoe loader	1	75	69
C.4 ref 2	Dump Truck	4	75	78
C.2 ref 30	HGVs	2	100	79
C.6 ref 37	Water Truck	2	50	81
C.3 Ref 19	Air compressor	2	100	75
Resulting overall Sound Pressure Level at 10 m				90

Table 12: Sheet Pile Conveyance Trenching

BS 5228 Ref.	Plant / Equipment	Quantity	On-time (%)	Sound Pressure Level at 10 m, dB L_{Aeq}
C.4 ref 63	Excavator	8	75	77
C.6 ref 32	Front Loader	4	75	75
C.4 ref 66	Back hoe loader	1	75	69
C.4 ref 2	Dump Truck	4	75	78
C.2 ref 30	HGVs	2	100	79
C.6 ref 37	Water Truck	2	50	81
C.3 Ref 19	Air compressor	2	100	75
C3 Ref 8	Vibratory rig	2	50	88
Resulting overall Sound Pressure Level at 10 m				92

Table 13: Pipe Welding and Installation

BS 5228 Ref.	Plant / Equipment	Quantity	On-time (%)	Sound Pressure Level at 10 m, dB L_{Aeq}
C.4 ref 66	Back hoe loader	1	75	69
C.3 Ref 19	Air compressor	1	100	75
C.4 ref 38	Mobile Crane	4	50	78
C.4 ref 76	Generators	4	100	61
C.2 ref 30	HGVs	2	100	79
Resulting overall Sound Pressure Level at 10 m				85

Table 14: Backfilling and Road Maintenance

BS 5228 Ref.	Plant / Equipment	Quantity	On-time (%)	Sound Pressure Level at 10 m, dB L_{Aeq}
C.4 ref 63	Excavator	4	75	77
C.6 ref 32	Front Loader	4	75	75
C.5 Ref 12	Dozer	1	75	77
C.4 ref 66	Back hoe loader	1	75	69
C.5 Ref 19	Roller	2	50	80
C.6 ref 31	Grader	1	50	86
C.6 ref 37	Water Truck	3	50	81
C.2 ref 30	HGVs	2	100	79
Resulting overall Sound Pressure Level at 10 m				90

Table 15: Crushing and Screening

BS 5228 Ref.	Plant / Equipment	Quantity	On-time (%)	Sound Pressure Level at 10 m, dB L_{Aeq}
C.1 Ref 15	Crusher	1	100	84
C.4 ref 66	Backhoe loader	1	100	69
C.6 ref 37	Water Truck	1	100	81
C.1 ref 13	Screening equipment	1	100	86
C.2 ref 30	HGVs	2	100	79
Resulting overall Sound Pressure Level at 10 m				90

6.3 CONSTRUCTION VIBRATION ASSESSMENT METHODOLOGY

Some construction activities can generate vibration in close proximity to the activity in question. As part of this assessment, both vibratory piling and vibratory compaction have been considered.

The formulae presented in BS 5228-2 (as discussed in Section 3.2) have been used to predict vibration from vibratory piling (the method most likely to be adopted for the installation of sheet piles) and vibratory compaction, based on the following inputs:

- 85 kJ hammer energy for piling rig; and
- 0.86 mm maximum drum vibration amplitude, based on CAT CB10 Vibratory Roller for vibratory compaction of road surfaces.

6.4 CONSTRUCTION TRAFFIC ASSESSMENT METHODOLOGY

Road traffic noise levels along Highway 15 have been calculated using the CRTN method (Section 3.4) which contains a method for calculating the Basic Noise Level (BNL) from road usage in terms of the 18-hour average Annual Average Weekday Traffic (AAWT) flow. The temporary changes in road traffic noise are then assessed by comparing the calculated Baseline BNL (i.e., existing vehicle movements) with the Baseline with Construction Traffic (i.e., existing vehicle movements plus construction movements). Both the Baseline BNL and Baseline with Construction Traffic BNL are calculated at a reference distance of 10 m to define the change in noise level.

In order to calculate the Baseline BNL, the existing levels of road traffic at three locations along Highway 15 have been provided by the Client[7]. For each location, the AAWT for 2025 (i.e. the Baseline BNL) has been calculated, of which between 20 – 30 % are understood to be HGV movements.

With regards to construction traffic, it is understood that there will be a total of approximately 1,460,000 HGV movements required over the two-year construction period of the Project. Assuming 5-day working weeks, this results in approximately 2800 HGV movements per day, in total.

[7] Base Case: Summary of assets characteristics, ALG Transportation, Infrastructure and Logistics

Once the Baseline BNL and Baseline with Construction Traffic BNL have been calculated, the change in BNL has then been compared to the impact levels as summarised in Table 5 of this report.

The above methodology is applicable to construction traffic travelling to / from site on public roads. Noise from HGVs operating in areas of active construction are inherently included as part of the assessment of construction activity, as shown in Tables 10 – 15 of Section 6.2.

7 RESULTS OF CONSTRUCTION NOISE AND VIBRATION MODELLING

7.1 CONSTRUCTION NOISE MODELLING RESULTS

Based on the criteria in Section 6.1, the distances beyond which the noise criteria are met have been calculated. These distances are worst case and assume no attenuation due to intervening structures or topography.

As can be seen from Tables 11, 14 and 15, trenching (non-sheet piling), backfilling and road maintenance and crushing and screening result in the same level of overall construction noise. As such the distances at which the noise criteria are achieved is the same for each of these construction activities.

Table 16 presents the area category, the respective noise criterion and the calculated distance beyond which the noise criterion is met.

Table 16: Distance Beyond Which Applicable Noise Criteria are Met

<table>
<tr><th>Area / Category Type</th><th>Construction Activity</th><th>Noise Criterion, dB(A)</th><th>Distance beyond which Noise Criterion is met, m</th></tr>
<tr><td rowspan="4">All residential areas except villages</td><td>Construction and Installation of AGI</td><td rowspan="4">55</td><td>210</td></tr>
<tr><td>Trenching, Backfill and Road Maintenance, Crushing and Screening</td><td>300</td></tr>
<tr><td>Sheet Pile Trenching</td><td>360</td></tr>
<tr><td>Pipe Installation and Welding</td><td>200</td></tr>
<tr><td rowspan="4">Residential areas in villages</td><td>Construction and Installation of AGI</td><td rowspan="4">50</td><td>325</td></tr>
<tr><td>Trenching, Backfill and Road Maintenance, Crushing and Screening</td><td>460</td></tr>
<tr><td>Sheet Pile Trenching</td><td>575</td></tr>
<tr><td>Pipe Install and Welding</td><td>310</td></tr>
<tr><td>Places of education, hospitals and places of worship</td><td>Construction and Installation of AGI</td><td>45</td><td>525</td></tr>
</table>

	Trenching, Backfill and Road Maintenance, Crushing and Screening		750
	Sheet Pile Trenching		925
	Pipe Install and Welding		500

It is important to note that the above distances assume a clear line of sight between the construction area and receptor. In practice, any receptor located behind a building or other intervening structure is likely to experience noise levels substantially below those buildings directly fronting construction works.

7.2 CONSTRUCTION VIBRATION MODELLING RESULTS

In order to identify receptors which may experience adverse construction vibration effects, the distances at which vibration from vibratory piling and vibratory compaction would fall below 1 mm/s PPV (i.e. the level at which a medium impact would be experienced) and 15 mm/s PPV (i.e. the minimum level at which cosmetic damage could occur in light / residential buildings) have been calculated, as detailed in Table 17.

Table 17: Distance Beyond Which Applicable Vibration Criteria are Met

	Distance beyond which Vibratory Piling Criterion is met, m	Distance beyond which Vibratory Compaction Criterion is met, m
Human annoyance Distance at which vibration PPV is equal to 1 mm/s	25	20
Cosmetic Damage Distance at which vibration PPV is equal to 15 mm/s	4	4

7.3 CONSTRUCTION TRAFFIC MODELLING RESULTS

As discussed in Section 6.4, the Baseline BNL along with the Baseline with Construction Traffic BNL have been calculated using the method specified in CRTN, based on existing traffic data provided by the Client.

Table 18 below presents the calculated Baseline BNL along with the Baseline with Construction Traffic BNL.

Table 18: Construction Traffic Predicted Levels

Road Segment Name	Baseline BNL, dB	Baseline with Construction Traffic BNL, dB
Swaqa Prison	79.2	80.1
Al Husainyah Medical Center	77.4	78.7
Knowledge DBP Shop Station	76.7	78.2

8 CONSTRUCTION NOISE MANAGEMENT BEST PRACTICE

Prior to the start of construction works being undertaken, it is recommended that a detailed Construction Noise and Vibration Management Plan (CNVMP) be developed by the EPC contractor, based on the finalised construction methods, programme, and plant to be used on site.

It is recommended that any CNVMP should establish procedures for community liaison, monitoring, communication, and compliance management, and include details of the following:

- Roles and Responsibilities
  - Identification of the person responsible on site for noise and vibration management and community liaison; and
  - Definition of roles for contractors, subcontractors, and environmental specialists.
- Baseline Levels and Noise Criteria
  - A summary of baseline ambient noise and vibration levels at representative receptors;
  - Identification of any areas requiring baseline noise or vibration monitoring; and
  - Applicable noise limits at each receptor.
- Requirement for Monitoring and Reporting Protocols
  - Consideration of any areas which require noise or vibration monitoring locations during construction i.e. sensitive receptors close to construction activities;
  - Trigger/action levels and response procedures if thresholds are exceeded; and
  - Record-keeping, reporting, and review mechanisms.
- Communication and Community Engagement
  - Procedures for informing nearby residents and stakeholders of upcoming works (especially noisy operations such as piling);
  - A complaints procedure including response times and corrective action protocols; and
  - Provision of contact details for a dedicated community liaison officer.
- Training and Awareness
  - Induction and toolbox talks for all site personnel regarding noise and vibration good practice.
- Review and Continuous Improvement
  - Procedures for reviewing performance against noise/vibration targets; and
  - Updating the CNVMP as methods or programme change.

In addition to the above, it is recommended that the following best practice noise and vibration control measures should be included in any CNVMP:

- Construction working hours should be restricted to times agreed with the relevant authority.
- Deliveries of plant and materials by HGV to site should only take place via designated routes and within times agreed with relevant stakeholders.
- Non-tonal and/or directional reversing alarms should be considered.
- Plant and engines should be switched off when not in use.

- Where necessary and practicable, noise from fixed plant and equipment should be contained within suitable acoustic enclosures or behind acoustic screens.
- All plant and equipment should be properly maintained and operated to prevent excessive noise and vibration and will be switched off when not in use.
- Where practicable, noisy equipment should be orientated to face away from the nearest noise-sensitive receptors.
- On-site chutes and bins should be lined with damping material.

The above mitigation measures should be applied to all areas of the Project where possible.

In order to minimise noise and vibration impacts from construction traffic, any CNVMP should require that the contractor undertake a pre-commencement condition survey of the routes to each site access to identify defects in the road surface. Where required the contractor should undertake remedial measures to ensure roads are smooth to minimise noise and vibration impacts from HGVs driving over potholes etc.

9 ASSESSMENT OF PREDICTED CONSTRUCTION NOISE AND VIBRATION

9.1 CONSTRUCTION ACTIVITY NOISE

Distances at which the noise criteria could be exceeded have been presented in Section 7.1. These distances are based on a number of worst-case assumptions, including all plant operating simultaneously and no attenuation from buildings or topography.

The following sections discuss the predicted construction noise levels from the modelling assessment taking into account baseline characteristics, the nature and duration of the proposed project activities and the best practice noise management measures presented in Section 8 above.

9.1.1 Installation of Above Ground Infrastructure

In general, the AGI facilities are located in rural areas, with very limited receptors in close proximity e.g. a single petrol station adjacent to BPS3 site, a single industrial facility opposite the RGT3 and BPT sites and an office and commercial area adjacent to the RGT1 site. PS ADC is located in an area of developed agricultural land with the nearest communities located approximately 500 m to the south.

Within these rural areas, receptors located within 325 m of the AGI could exceed the relevant 50 dBA noise limit (applicable to residential areas in villages), as per Table 16. Based on a review of the AGI locations, there are very few receptors located with 325 m of the AGIs, and as such construction activities associated with the installation of the of the AGIs is unlikely to exceed the noise criteria.

BPS2 is located close to the Aqaba Medical Sciences University and Aqaba University of Technology campuses which are located approximately 300 m from the BPS2 site boundary. As such, the University buildings are within the 525 m distance at which the 45 dBA limit for places of education could be exceeded. As such, during construction of the BPS2, in addition to the general noise management measures identified in Section 8, it is recommended that the EPC contractor consider specific mitigation measures in Section 10 to ensure noise from construction activities at the Aqaba Medical Sciences University and Aqaba University of Technology campuses is reduced as much as practicable.

9.1.2 Conveyance Route Installation – All Residential Areas Except Villages

As specified in Section 7, within all residential areas except villages, the worst-case distance at which construction noise could exceed the 55 dB(A) noise criteria is 360 m during sheet piling activities.

Towns and villages within 360 m of the conveyance pipeline route include:

- Diesah, Sallheiah, Mezfer, Rashdyah and Shakriyyeh within Aqaba Governorate;
- Hasa within Tafiela Governorate; and
- Qatraneh and Sad El-Soltani within Karak Governorate.

It is important to note that due to shielding provided by buildings which directly face construction works, any receptors located behind those buildings will likely experience noise levels below the noise criteria presented in Section 6.1. As such, only those receptors which directly face the conveyance route are likely to experience noise levels above the 55 dB(A) noise criterion. This is particularly relevant for urban areas, where building density will be higher, increasing shielding provided to receptors located behind those closest to the conveyance route.

In addition, it is important to note that existing baseline noise levels within Amman are between 55 dB(A) and 76 dB(A), as summarised in Section 4. It is notable that this range in background noise levels is above the 55 dB(A) noise criteria specified in Section 6.1, without any contribution form the Project construction works. As such, in many urban areas, the existing level of noise is likely to mask noise from construction activities.

It should also be noted that sheet piling is anticipated as an alternative to conventional trenching in constrained areas, specifically within urban and built-up areas. Where sheet piling can be avoided, only receptors within 300 m would be likely to exceed the criteria in practice.

With regards to the duration, it is notable that BS 5228-1 states that adverse impacts are only likely where noise criteria are exceeded for a period of one month or more, as short-term impacts can typically be tolerated by residents, particularly when previously informed about upcoming works, as per Section 8). It is understood that the conveyance works will progress at a rate of 300 - 500 m per day. While construction activities in any one area will last more than one day, it is highly likely that peak construction activity (particularly any piling works) will only last for 2 – 3 days during trenching works, then again for similar duration during the installation of the pipeline itself. As such, while there may be several periods when the noise criteria are temporarily exceeded, effects will be greatly mitigated by the short duration.

Given the noise criteria is likely to be exceeded at a number of residential receptors, in addition to the general noise management measures identified in Section 8, it is recommended that the contractor consider specific mitigation measures in all areas where conveyance installation will take place within 360 m of residential receptors. Specific mitigation measures which should be considered are presented in Section 10.

9.1.3 Conveyance Route Installation – Residential areas in villages

As specified in Section 7, within residential areas in villages, the worst-case distance at which construction noise could exceed the 50 dB(A) noise criteria is 575 m during sheet piling activities.

Towns and villages within 575 m of the conveyance pipeline route include:

- Diesah, Sallheiah, Mezfer, Rashdyah and Shakriyyeh within Aqaba Governorate;

- Hasa within Tafiela Governorate; and
- Qatraneh and Sad El-Soltani within Karak Governorate.

While there may be a number of village receptors within 575 m of the conveyance route, it is important to note that due to shielding provided by buildings which directly face construction works, any receptors located behind these buildings will likely experience noise levels below the noise criteria presented in Section 6.1. As such, only those receptors which directly face the conveyance route are likely to experience noise levels above the 55 dB(A) noise criteria.

It should also be noted that sheet piling is anticipated as an alternative to conventional trenching in constrained areas, specifically within urban and built-up areas. Where sheet piling can be avoided, only receptors in villages within 460 m of construction works would be likely to exceed the criteria in practice.

With regards to duration, it is notable that BS 5228-1 states that adverse impacts are only likely where noise criteria are exceeded for a period of one month or more, as short-term impacts can typically be tolerated by residents. It is understood that the conveyance system will progress at a rate of 500 m per day in rural locations. While construction activities in any one area will last more than one day, it is highly likely that peak construction activity (particularly any piling works) will only last for 1 – 2 days during trenching works, then again for similar duration during the installation of the pipeline itself. As such, while there may be several periods when the noise criteria are temporarily exceeded, effects will be greatly mitigated by the short duration.

Given the noise criteria is likely to be exceeded at a number of residential receptors, in addition to the general noise management measures identified in Section 8, it is recommended that the contractor consider specific mitigation measures in all areas where conveyance installation will take place within 575 m of residential receptors. Specific mitigation measures which should be considered are presented in Section 10.

9.1.4 Conveyance Route Installation – Places of education, hospitals and places of worship

As a worst case, places of education, hospitals and places of worship would exceed the noise criteria of 45 dB(A) where conveyance route passes within 925 m, during sheet piling activities.

While there may be several places of education, hospitals and places of worship within 925 m of the conveyance route, it is important to note that any other building located between the receptor and the conveyance route will reduce the level of noise at these receptors in practice. This is particularly relevant in the more densely built-up areas in Amman. The closest educational facilities at the southern end of the route include the Aqaba Medical Sciences University and Aqaba University of Technology, which are located within 150 to 200 m of the conveyance route.

The worst-case noise levels are generated by sheet piling, which is only anticipated as an alternative to conventional trenching in constrained areas, specifically within urban and built-up areas. As such, for most of the conveyance route only sensitive receptors within 750 m would be likely to exceed the criteria in practice.

In addition, it is notable that BS 5228-1 states that adverse impacts are only likely where noise criteria are exceeded for a period of one month or more, as short-term impacts can typically be tolerated by residents. It is understood that the conveyance system will progress at a rate of 500 m per day in rural locations. While construction activities in any one area will last more than one day, it is highly likely that peak construction activity (particularly any piling works) will only last for 1 – 2 days during trenching works, then again for similar duration during the installation of the pipeline itself. As such, while there may be several periods when the noise criteria are temporarily exceeded, effects will be greatly mitigated by the short duration.

Given the noise criteria is likely to be exceeded at a number of places of education, hospitals and places of worship, in addition to the general noise management measures identified in Section 8, it is recommended that the contractor consider specific mitigation measures in all areas where conveyance installation will take place within 925 m of residential receptors. Specific mitigation measures which should be considered are presented in Section 10.

9.2 CONSTRUCTION VIBRATION

Vibratory piling is anticipated to occur during the installation of the AGI. In addition, sheet piling could occur in urban areas during installation of conveyance system, particularly where space is limited. Vibratory compaction is likely to occur as roads are repaired / made good following installation of the conveyance system.

As can be seen in Table 17, receptors within 20 m of any vibratory compaction or 25 m of any vibratory piling work could experience vibration levels above 1 mm/s, which is the level above which complaints are likely.

However, as discussed in Section 3.3, vibration levels of above 1 mm/s can be tolerated providing prior warning has been given the residents. As such, where construction works are likely to take place within 20 m of a residential receptors, it is recommended that the contractor contact the residents prior to works being undertaken to advise them of upcoming construction works. The contractors should provide an estimate of the duration of works. On the basis that any vibration effects would be short term, and any receptors within 20 m warned prior to works being undertaken, it is considered that no adverse vibration impacts will occur.

With regards to cosmetic or structural damage to buildings, cosmetic damage is only likely to occur where vibratory piling or compaction is undertaken within 4 m of lightweight buildings. It is therefore recommended that construction activities likely to result in substantial levels of vibration (i.e. pilling and compaction) are not undertaken within 4 m of any existing building. If it is found that such works are unavoidable, a structural survey by a qualified engineer should be undertaken prior to construction being undertaken to investigate the risk of cosmetic / structural damage in practice and where require specify mitigation measures to ensure damage is avoided.

9.3 CONSTRUCTION TRAFFIC

The potential changes in road traffic noise along Highway 15 (i.e. the primary construction route) as a result of construction traffic have been assessed by calculating the baseline and construction year BNL (as calculated in Section 7.3) and comparing the change to the criteria specified in DMRB (Section 3.3).

Table 19 overleaf presents the results of the assessment.

Table 19: Construction Traffic Noise Assessment

Road Segment Name	Baseline BNL, dB	Baseline with Construction Traffic BNL, dB	Change in BNL, dB	Impact
Swaqa Prison	79.2	80.1	0.9	Negligible
Al Husainyah Medical Center	77.4	78.7	1.3	Minor
Knowledge DBP Shop Station	76.7	78.2	1.5	Minor

As can be seen, the predicted noise levels from construction traffic at all points along the main access route (Highway 15) would result in Negligible / Minor impacts at worst.

As discussed in Section 6.4, noise from HGVs operating in areas of active construction are inherently included as part of the assessment of construction activity, as shown in Tables 10 – 15 of Section 6.2.

10 SPECIFIC NOISE AND VIBRATION MITIGATION

As noted in Section 9, there are a number of areas where the noise criteria are likely to be exceeded. While exceedances are anticipated to be short-term and limited to those receptors which directly face construction activities, it is recommended that where receptors are likely to exceed the assessment criteria, additional mitigation is considered and implemented where possible / practicable.

It is recommended that as part of the CNVMP, the contractor should identify all areas which are likely to exceed the noise limits based on the finalised location and construction methods. Within these areas, the contractor should assess the feasibility of implementing the following noise mitigation measures:

- Alternative Support Systems (to minimise / avoid the use of sheet piling);
- Lower-noise piling techniques;
- Notification / engagement of stakeholders; and
- Additional noise barriers.

In each case, the contractor should balance the advantages of any reduction in noise level against any subsequent increase in duration. For example, the contractor may conclude that while press piling techniques may result in a lower overall noise level at nearby receptors, in practice vibratory piling should be used as construction works can progress substantially quicker, resulting in a reduced impact.

Each of the above have been considered in detail in the following sections:

Alternative Support Systems (Avoiding Sheet Piling)

In accordance with the principles of Best Practicable Means (BPM), alternative construction methodologies should be reviewed with the objective of minimising noise and vibration impacts during trenching and associated temporary works.

In particular, the following methods should be considered:

- Trench boxes / hydraulic trench supports
    - ◊ **Description:** Prefabricated steel or aluminium boxes lowered into the excavation to support trench walls;

- ◊ **Noise advantage:** No piling required — installation uses an excavator;
- ◊ **Suitable for:** Relatively short or shallow trenches (e.g. utilities);
- ◊ **Limitation:** Not ideal for very deep or wide excavations or where groundwater inflow is significant

- ♦ **Hydraulic or mechanical shoring systems**
  - ◊ **Description:** Hydraulic rams or mechanical braces press against trench walls, often used with timber or steel walers.
  - ◊ **Noise advantage:** No percussive or vibratory driving; installation is low-noise.
  - ◊ **Limitation:** Requires careful design; slower to install than sheet piles for long runs.
- ♦ **Contiguous or secant-bored piles**
  - ◊ **Description:** Cast-in-place concrete piles formed by auger drilling rather than driving.
  - ◊ **Noise advantage:** Much quieter than sheet piling (rotary drilling is typically 10–20 dB quieter than impact piling).
  - ◊ **Limitation:** More expensive; requires larger plant and more space.
  - ◊ **Best for:** Deeper, more permanent retaining structures in constrained environments.

Lower-Noise Sheet Piling Techniques

Where sheet piling is unavoidable, the following should be considered:

- ♦ **Press-in piling systems**
  - ◊ **Description:** Hydraulic jacking system that "presses" piles into the ground using static force.
  - ◊ **Noise advantage:** Up to 20 dB quieter than vibratory piling, with very low vibration.
  - ◊ **Limitation:** Requires suitable reaction force (previously installed piles or weight system); slower progress rate.
- ♦ **Vibratory piling instead of impact driving**
  - ◊ **Description:** Uses high-frequency vibration to fluidise soil around pile, allowing insertion/removal.
  - ◊ **Noise advantage:** About 10–15 dB quieter than impact driving; lower impulsivity.
  - ◊ **Limitation:** Can still produce vibration issues in sensitive areas (e.g. near historic structures).
- ♦ **Pre-auguring before sheet pile installation**
  - ◊ **Description:** Pre-drill a pilot hole to loosen dense ground before vibrating or pressing piles.
  - ◊ **Noise advantage:** Reduces required energy and time per pile, cutting both noise and vibration.

Notification / Engagement of Stakeholders

It is recommended that receptors within the areas likely to exceed the noise criteria are engaged prior to construction to set expectations around noise. In particular, it is important that the benefit of the Project (i.e. providing fresh water to Amman) is communicated.

It is recommended that the following actions are implemented into the CNVMP, which the contractor will then be legally obligated to action:

- Before works start, identify local sensitive receptors (homes, schools, hospitals) and baseline ambient noise levels. Use that to inform the community engagement strategy;
- Establish a community communication plan
  - Provide a project overview letter or briefing to neighbours explaining what works will happen, expected noise / practical mitigation measured, times of highest noise levels (e.g., piling, trenching etc.);
  - Provide a named contact (phone/email) for neighbour concerns/complaints; and
  - Update neighbours when particularly noisy operations are planned (e.g., piling, large plant mobilisation, testing) so they aren't surprised.
- Maintain good relationships during works
  - Hold periodic updates (if project is long) or newsletters;
  - Consider a liaison committee if many stakeholders; and
  - Document and respond to complaints promptly, investigate and where possible mitigate (e.g., change working hours, quieter equipment, barrier location, plant location).
- Set expectations around noise: Use clear language about what noise levels might be, what mitigation will be in place, when noisy operations will occur, and expected duration.
- Mitigation planning: communicate how mitigation will be used to minimise noise and how neighbours will be affected.
- Monitoring and feedback: If noise monitoring is undertaken, consider sharing summarised results or confirming that noise levels are within agreed limits, reinforcing transparency and trust.

Additional Noise Barriers

Where possible, noise barriers and mobile screens should be used to reduce noise levels and minimise noise impacts. Where noise barriers and/or mobile screens are used, the following general design requirements should be met:

- Construction management to schedule construction of barriers/walls/berms so that they are installed on site as early as possible and prior to high noise level generating activities.
- Barriers or walls to be constructed of typical construction hoarding or plywood cladding (e.g. 18 to 25 mm) and at least 2.4 m in height (typically the standard height for construction hoarding). Materials of equivalent acoustic performance may be used. If possible, acoustic absorptive material should be fixed to the inside of the screen (facing the site) to minimise reflected noise.
- Barriers/walls/berms should be continuous and extend to the ground (as far as is practicable), have no gaps, cracks or any penetrations that are likely to adversely affect the acoustic performance of the screen.

11 SUMMARY

Metrica was commissioned to undertake an assessment of noise and vibration impacts during the construction and operation of the Aqaba-Amman Water Desalination and Conveyance Project.

Appropriate noise and vibration criteria have been specified based on both Jordanian and International guidelines.

With regards to construction noise and vibration, various receptors have been identified within the distance at which the criteria could be exceeded, although exceedances will be short term in duration. Where criteria is exceeded, it is recommended that the additional mitigation measures specified in Section 10 should be applied to ensure impacts are minimised as far as possible.

12 GLOSSARY OF TERMS

Background Noise: The background noise level is the underlying level of noise present at a particular location for the majority (usually 90%) of a period of time.

Decibel (dB): The decibel is the basic unit of noise measurement. It relates to the cyclical changes in pressure created by the sound and operates on a logarithmic scale, ranging upwards from 0 dB. 0 dB is equivalent to the normal threshold of hearing at a frequency of 1000 Hertz (Hz). Each increase of 3 dB on the scale represents a doubling of the Sound Pressure, and is typically the minimum noticeable change in sound level under typical listening conditions.

dB(A): Environmental noise levels are usually discussed in terms of dB(A). This is known as the A-weighted sound pressure level, and indicates that a correction factor has been applied, which corresponds to the human ear's response to sound across the range of audible frequencies. The ear is most sensitive in the middle range of frequencies (around 1000-3000 Hz), and less sensitive at lower and higher frequencies. The A weighted noise level is derived by analysing the level of a sound at a range of frequencies and applying a specific correction factor for each frequency before calculating the overall level. In practice this is carried out automatically within noise measuring equipment by the use of electronic filters, which adjust the frequency response of the instrument to mimic that of the ear.

Frequency: The frequency of a sound is equivalent to its pitch in musical terms. The units of frequency are Hertz (Hz), which represents the number of cycles (vibrations) per second.

$L_{A90,t}$: This term is used to represent the A-weighted sound pressure level that is exceeded for 90% of a period of time, t. This is used as a measure of the background noise level.

$L_{Aeq,t}$: This term is known as the A-weighted equivalent continuous sound pressure level for a period of time, t. It is similar to an average, and represents the sound pressure level of a steady sound that has, over a given period, the same energy as the fluctuating sound in question.

Sound pressure (P): The fluctuations in pressure relative to atmospheric pressure, measured in Pascals (Pa).

Sound pressure level (L_p): Sound pressure measured on the decibel scale, relative to a sound pressure of 2 x 10-5 Pa.

Project: Aqaba-Amman Water Desalination and Conveyance (AAWDC)

2025 Environmental and Social Impact Assessment

Appendix 9B.2 Air quality and dust screening assessment

AIR QUALITY AND DUST ASSESSMENT

Aqaba-Amman Water Desalination and Conveyance Project (AAWDCP)

November 2025

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1 INTRODUCTION

This report provides an assessment of air quality and dust risks and impacts associated with the Aqaba-Amman Water Desalination and Conveyance (AAWDC) Project (hereafter referred to as 'the Project').

This assessment has been undertaken by Adam Price, member of the UK Institute of Air Quality Management (IAQM), and who holds over nine years of experience in air quality assessments and atmospheric science.

2 LEGAL AND ADMINISTRATIVE FRAMEWORK

This section provides a summary of the relevant legal and administrative framework for the assessment of ambient air quality and construction dust.

2.1 AMBIENT AIR QUALITY

2.1.1 Jordanian Standard 1140/2006[1]

The Jordanian Standard No. 1140/2006 presents the permissible limits for emissions of gases and particulate matter to the ambient air for the protection of human health. The limits are presented in Table 1 below. For clarity, limits presented in the Jordanian Standard in parts per million (ppm) have been converted to micrograms per meter cubed (μg/m^3) to bring them in line with international guidance.

Table 1: Jordanian Standard for Ambient Air Quality

Pollutant	Sample Duration	Maximum Allowable Limit (μg/m^3)	Number of Allowable Exceeded Events
Sulphur Dioxide (SO_2)	1-hour	800	3 times in any 12-month period per year
	24-hour	400	Once per year
	1-year	100	-
Carbon Monoxide (CO)	1-hour	300	3 times in any 12-month period per year
	8-hours	100	3 times in any 12-month period per year
Nitrogen Dioxide (NO_2)	1-hour	400	3 times in any 12-month period per year
	24-hour	150	3 times in any 12-month period per year
	1-year	95	-
Ozone (O_3)	1-hour	240	-
	8-hours	160	-
Particulate Matter (PM_{10})	24-hour	120	3 times in any 12-month period per year
	1-year	70	-
Particulate Matter ($PM_{2.5}$)	24-hour	65	3 times in any 12-month period per year
	1-yearly	15	-

[1] Jordanian Standard 1140/2006, Jordanian Ministry of Environment, 2006

2.1.2 IFC EHS Guidelines – Air Emissions and Ambient Air Quality[2]

IFC EHS Guidelines 1.1 *Air Emissions and Ambient Air Quality* ('IFC Air Quality 1.1') contains information for the assessment and management of air quality. IFC Air Quality 1.1 states that:

"Projects should … prevent or minimize impacts by ensuring that:

- *Emissions do not result in pollutant concentrations that reach or exceed relevant ambient air quality guidelines and standards by applying national legislated standard, or in their absence the current WHO Air Quality Guidelines or other internationally recognized sources;"*

IFC Air Quality 1.1 provides Air Quality Assessment Levels (AQALs) for a range of pollutants based upon World Health Organisation (WHO) ambient air quality guidelines[3], as presented in Table 2 below. Guideline values include interim targets for use during the implementation of new air quality regimes.

Table 2: IFC Air Quality Assessment Levels

Pollutant	**Averaging Period**	**Guideline Values, µg/m³**
Sulphur Dioxide (SO_2)	24-hour	125 (interim target 1)
		50 (interim target 2)
		20 (guideline)
	10-minute	500 (guideline)
Nitrogen Dioxide (NO_2)	1-Year	40
	1-hour	200
Particulate Matter PM_{10}	1-year	70 (Interim target 1)
		50 (interim target 2)
		30 (Interim target 3)
		20 (guideline)
	24-hour	150 (Interim target 1)
		100 (Interim target 2)
		75 (Interim target 3)
		50 (Guideline)
Particulate Matter $PM_{2.5}$	1-Year	35 (Interim target 1)
		25 (Interim target 2)
		15 (Interim target 3)
		10 (guideline)
	24-hour	75 (Interim target 1)
		50 (Interim target 2)
		37.5 (Interim target 3)
		25 (Guideline)
Ozone (O_3)	8-hour daily maximum	160 (Interim target 1)
		100 (Guideline)

[2] International Finance Corporation Environmental, Health and Safety Guidelines, World Bank Group, April 2007

[3] World Health Organisation Global Air Quality Guidelines, World Health Organization, 2021

2.1.3 Institute of Air Quality Management (IAQM) Land-Use Planning & Development Control: Planning For Air Quality Guidance (2017)[4]

There are no Jordanian, or internationally recognized construction dust emissions guidelines. As such, UK guidance has been applied which is considered appropriate for use in other regions.

The Institute of Air Quality Management (IAQM) *Planning for Air Quality Guidance* sets out the industry best practice criteria for the assessment of Air Quality impacts from development projects.

The guidance suggests expressing the magnitude of incremental change in concentrations as a proportion of an Air Quality Assessment Level (AQAL), such as the Air Quality Objectives (AQOs) set out in Tables 1 and 2, above.

The magnitude of change is then identified based on the change in pollutant concentrations as a result of the Project. The criteria suggested for assigning significance is set out in Table 3 below.

Table 3: Magnitude of Change

Average Concentration at Receptor	% Change in concentration relative to AQAL			
	1	2 - 5	6 - 10	>10
75% or less of AQAL	Negligible	Negligible	Slight	Moderate
76-94% of AQAL	Negligible	Slight	Moderate	Moderate
95-10% of AQAL	Slight	Moderate	Moderate	Substantial
103-109% of AQAL	Moderate	Moderate	Substantial	Substantial
110% or more of AQAL	Moderate	Substantial	Substantial	Substantial

2.2 CONSTRUCTION DUST

2.2.1 IAQM Assessment of Dust from Construction & Demolition (2024)

Construction dust emissions consist of solid particles that have been agitated into the air by on-site activities. Whilst this includes particulate matter of a suitable aerodynamic size to cause human health issues (PM_{10} and $PM_{2.5}$) the main focus of a construction dust assessment is on the airborne particulates of greater aerodynamic size that present an amenity issue to sensitive receptors in the Project surroundings by means of visible dust soiling.

There are no national or international standards or objectives for the emissions of dust from construction activities, however guidance produced by the IAQM provides a best practice approach to assessing impacts from construction and demolition activities and includes a source-pathway-receptor methodology for identifying the risk magnitude of potential dust sources. The guidance seeks to identify major dust emissions sources, the relevant vectors by which these emissions will be transmitted and the most appropriate mitigation measures to prevent local harm to amenity and health as a result of construction activities.

[4] Institute of Air Quality Management Guidance on land-use planning and development control: Planning for air quality, 2017

3 BASELINE

Monitoring data and local background information has been taken from the Jordanian Ministry of Environment (MoEnv) Ambient Air Quality Monitoring Report 2024[5].

Monitoring was undertaken at 14 locations across four Governorates for all pollutants of concern as identified in Jordanian Standard 1140/2006. The results of the Jordanian ambient air quality monitoring programme are presented within Chapter 6 of the AADWC Project Updated ESIA (2025).

Monitoring showed that AQOs were being met at all monitoring locations across Jordan for all pollutants with the exception of $PM_{2.5}$ which was found to be exceeding AQO levels at 12 of the 14 monitored locations. The worst recorded annual mean $PM_{2.5}$ concentrations, as a proportion of the AQAL, were recorded at the Hashemite Hall monitoring station in Zarqa' Governorate with annual mean concentrations of 33.9 μg/m^3 equivalent to 226 % of the relevant Jordanian Standard AQAL.

Exceedance of the $PM_{2.5}$ annual objective has been attributed by the MoEnv to the emissions from sources related to human activities, especially in the transportation, industrial and energy sectors as well as some natural airborne pollutants from dust storms.

Monitoring of environmental dust, i.e., non-respirable particulate matter, is not undertaken by the MoEnv. Given the physical geography of the Project surroundings, principally the predominantly desert soil conditions, it is expected that there will be a high baseline level of environmental dust.

4 ASSESSMENT METHODOLOGY

4.1 SCOPE OF ASSESSMENT

4.1.1 Construction Phase

The assessment of air quality in the construction phase of the Project considers human health and dust soiling as a result of construction related activities at the IPS, desalination plant, renewable facility, along the conveyance route and at the conveyance Above Ground Installations (AGIs).

4.1.1.1 Ambient Air Quality

The impact on ambient air quality and human health as a result of construction plant has been predicted for the construction phase of the Project using industry-standard software *ADMS Roads Extra dispersion model* (version 5.1.0.2, released March 2020 updated July 2025).

Given that the construction programme for the Project is relatively long-term (approximately 2 years), the impact on ambient air quality and human health as a result of Project construction traffic has also been predicted using ADMS dispersion modelling software.

[5] Ambient Air Quality Monitoring Report 2024, Jordanian Ministry of Environment, 2025

4.1.1.2 *Construction Dust*

An assessment of the potential dust emissions arising from the construction phase of the Project has been undertaken based upon IAQM *Guidance on the Assessment of Dust from Demolition and Construction* (see Section 2.2.1 for details).

4.1.2 Operational Phase

Once operational, the Project will generate a very small number of additional traffic movements, which will be widely dispersed across the existing road network. As such, an assessment of operational phase traffic emissions is scoped out as there is no reasonable prospect of a significant effect.

Emergency generators are proposed at the desalination facilities and the conveyance AGIs. At the time of writing, the size and location of these generators is not known, however it is understood that they are to be used to provide critical power only in the event of an emergency, on a temporary basis (i.e. they will not provide power for process demands) - as such they are scoped out of this assessment.

4.2 CONSTRUCTION PHASE METHODOLOGY

4.2.1 Ambient Air Quality

A quantitative assessment of local air quality associated with construction plant and road traffic emissions as a result of the Project has been completed and assessed against the objectives set out in Table 1 for $PM_{2.5}$.

$PM_{2.5}$ has been selected as the air quality assessment level for the Project as the baseline concentrations for all other pollutants of concern are considerably below their respective assessment objectives at all locations where they were monitored.

Details regarding the type and number of construction plant items used during conveyance activities are sourced from the construction contractor. The types and number of plant items used during construction of the AGIs (renewable facility, desalination plant etc.) are based on the author's prior experience working on similar infrastructure projects.

Data for plant emissions to air have been taken from the United States Environmental Protection Agency's Fleet Average Emissions Factors[6] for plant of the appropriate power, based on the supplied information. As a conservative assessment, it has been assumed that 100% of Total Suspended Particulate emitted is $PM_{2.5}$.

In order to provide distances for the emissions to air from construction phase traffic, a representative 50 m section of road representing Highway 15 (the primary construction traffic route) has been modelled.

Baseline Annual Average Daily Traffic (AADT) numbers for the Highway 15 have been taken from toll booth transit numbers provided by the Jordanian Ministry of Public Works & Housing at the Swaqa Prison Toll Plaza. This was selected as the worst case traffic count of those available for Highway 15. Project construction traffic numbers have been provided by the pipeline construction contractor.

[6] United States Environmental Protection Agency: GHG Emission Factors Hub (online). Available from: https://www.epa.gov/climateleadership/ghg-emission-factors-hub

Hourly sequential meteorological data for 2020 – 2024 for Aqaba King Hussein International Airport has been used in all modelling scenarios.

Background pollutant concentrations have been taken from MoEnv annual monitoring sites. Representative monitoring sites have been chosen for each Governorate within which Project construction work will take place. Where monitoring is not undertaken in a Governorate, monitoring from an adjacent Governorate at a representative site has been substituted.

$PM_{2.5}$ concentrations have been predicted for a 100 m x 100 m grid square around each construction activity and road segment at a 1-metre resolution. These concentrations have been added to the respective background concentration to provide the total environmental concentration. The criteria in Table 3 have then been used to determine the range from each construction activity and road segment at which each level of effect would be expected.

Tables 4 to 13 below present the modelling inputs for each of the five individual construction crews working on at any one time.

Table 4: Installation of IPS

Plant / Equipment	Quantity	On-time (%)
Excavator	2	75
Front Loader	2	75
Dozer	1	75
Backhoe loader	1	75
Truck (tipping fill)	2	100
Mobile Crane	1	25
Generators	1	100
Angle grinder	1	25

Table 5: Installation of Desalination Plant

Plant / Equipment	Quantity	On-time (%)
Excavator	4	75
Front Loader	4	75
Dozer	2	75
Backhoe loader	2	75
Truck (tipping fill)	4	100
Mobile Crane	2	25
Generators	2	100
Angle grinder	2	25

Table 6: Pipeline Trenching

Plant / Equipment	Quantity	On-time (%)
Excavator	8	75
Front Loader	4	75
Backhoe loader	1	75
Dump Truck	4	75
Truck (tipping fill)	2	100
Water Truck	2	50
Air Compressor	2	100

Table 7: Pipeline Installation

Plant / Equipment	Quantity	On-time (%)
Backhoe loader	1	75
Truck (tipping fill)	2	100
Mobile Crane	4	50
Generators	4	100
Air Compressor	1	100

Table 8: Pipeline Backfilling

Plant / Equipment	Quantity	On-time (%)
Excavator	4	75
Front Loader	4	75
Dozer	1	75
Backhoe loader	1	75
Truck (tipping fill)	2	100
Grader	1	50
Roller	3	50
Water Truck	2	50

Table 9: Crushing/Screening

Plant / Equipment	Quantity	On-time (%)
Crusher	1	100
Backhoe loader	1	100
Water Truck	1	100
Screening Equipment	1	100
Truck (tipping fill)	2	100

Table 10: Installation of Pumping Station

Plant / Equipment	Quantity	On-time (%)
Excavator	2	75
Front Loader	2	75
Dozer	1	75
Backhoe loader	1	75
Truck (tipping fill)	2	100
Mobile Crane	1	25
Generators	1	100
Angle grinder	1	25

Table 11: Installation of Regulating Tank Facility

Plant / Equipment	Quantity	On-time (%)
Excavator	2	75
Front Loader	2	75
Dozer	1	75
Backhoe loader	1	75
Truck (tipping fill)	2	100
Mobile Crane	1	25
Generators	1	100
Angle grinder	1	25
Impact Wrench	1	100

Table 12: Installation of Renewables Facility

Plant / Equipment	Quantity	On-time (%)
Excavator	2	75
Front Loader	2	75
Dozer	1	75
Backhoe loader	1	75
Truck (tipping fill)	2	100
Mobile Crane	1	25
Generators	1	100
Angle grinder	1	25
Impact Wrench	1	100

Table 13: Installation of Overhead Lines

Plant / Equipment	Quantity	On-time (%)
Excavator	2	75
Front Loader	2	75
Dozer	1	75
Backhoe loader	1	75
Truck (tipping fill)	2	100
Mobile Crane	1	25
Generators	1	100
Angle grinder	1	25
Impact Wrench	1	100

4.2.2 Assessment Criteria

The guidance issued by IAQM sets criteria by which to identify the magnitude of change of any pollutant concentration by expressing this as the magnitude of the incremental change in concentrations as a proportion of an AQAL.

A range of distances corresponding to the level of impact predicted using the Jordanian Standard AQAL have been derived.

As a range of pollutants are emitted by construction plant, the distances have been determined based upon the worst case pollutant for each activity. Additional distances for common pollutants have been included in Annex 1. As pollutant dispersion is heavily windinfluenced, the results are asymmetrical due to the presence of prevailing wind conditions. In order to ensure a worse case assessment, it has been assumed that the distance downwind of the prevailing wind is to be used in all directions.

4.2.3 Construction Dust

An assessment of Project construction dust has been undertaken giving consideration to the IAQM *Guidance on the Assessment of Dust from Demolition and Construction'* to determine the potential air quality impacts associated with construction activity for the Project.

The assessment has been based on the underlying environmental concept of 'Source-Pathway-Receptor', with a risk assessment approach taken to assessing the both construction activity to be undertaken and the receiving environment, in order to put forward appropriate mitigation measures.

The potential for dust emissions is assessed taking into consideration three separate vectors for potential impacts:

- Annoyance due to dust soiling;
- The risk of health effects due to an increase in exposure to PM_{10}; and
- Harm to ecological receptors.

IAQM guidance has been used as the basis for establishing the potential risks of dust emissions during project construction work. The sensitivity of the area surrounding the Project has been determined and is provided in Chapter 6 of the ESIA. This highlights the Urban areas where sensitivity to dust-related issues is higher, and rural areas where sensitivity is lower. Consideration has also been given to areas of ecological sensitivity including agricultural and pastoral areas.

5 ASSESSMENT OF EFFECTS

5.1 CONSTRUCTION PLANT EMISSIONS

Distances at which air quality effects are forecast to occur, as a result of construction plant emissions, are presented in Table 14 to 18 below for each Governorate, for each construction activity for $PM_{2.5}$ concentrations.

$PM_{2.5}$ has been selected as the air quality assessment level for the Project as the baseline concentrations for all other pollutants of concern are considerably below their respective assessment objectives at all locations where they were monitored.

Based on IAQM guidance, there are no effects expected at distances beyond the lowest effect band detailed in the below tables. Furthermore there are no substantial effects recorded at some Governorates as the development does not increase the ambient pollutant concentration by a sufficient amount to trigger that level of effect.

Table 14: Distances from Construction Activities at which effects occur – Amman

Construction Activity	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
Trenching	10	20	N/A	N/A
Pipe Installation and Welding	5	15	N/A	N/A
Backfill and Road Maintenance	15	30	N/A	N/A
Crushing and Screening	25	45	N/A	N/A
Pumping Station Installation	5	15	N/A	N/A
Regulating Tank Facility Installation	5	15	N/A	N/A

Table 15: Distances from Construction Activities at which effects occur – Karak

Construction Activity	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
Trenching	N/A	5	10	20
Pipe Installation and Welding	N/A	1	5	15
Backfill and Road Maintenance	N/A	5	15	30
Crushing and Screening	N/A	10	25	45

Table 16: Distances from Construction Activities at which effects occur – Tafilah

Construction Activity	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
Trenching	N/A	5	10	20
Pipe Installation and Welding	N/A	1	5	15
Backfill and Road Maintenance	N/A	5	15	30
Crushing and Screening	N/A	10	25	45

Table 17: Distances from Construction Activities at which effects occur – Ma'an

Construction Activity	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
Trenching	N/A	5	10	20
Pipe Installation and Welding	N/A	1	5	15
Backfill and Road Maintenance	N/A	5	15	30
Crushing and Screening	N/A	10	25	45
Pumping Station Installation	N/A	1	5	15
Regulating Tank Facility Installation	N/A	1	5	15

Table 18: Distances from Construction Activities at which effects occur – Aqaba

Construction Activity	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
IPS Construction	N/A	10	15	25
Desalination Plant Installation	N/A	5	10	25
Trenching	N/A	5	10	20
Pipe Installation and Welding	N/A	1	5	15
Backfill and Road Maintenance	N/A	5	15	30
Crushing and Screening	N/A	10	25	45
Pumping Station Installation	N/A	1	5	15
Regulating Tank Facility Installation	N/A	1	5	15
Renewable Facility Installation	N/A	1	5	15
OHL Installation	N/A	1	5	15

5.1.1 Road Traffic

Buffer distances at which air quality effects are forecast to occur, as a result of emissions from Project construction traffic, are presented in Table 19 below for each Governorate.

Table 19: Distances for Project Construction Traffic at which effects occur

Governorate	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
Amman	5	15	N/A	N/A
Karak	N/A	N/A	5	15
Tafilah	N/A	N/A	5	15
Ma'an	N/A	N/A	5	15
Aqaba	N/A	N/A	5	15

Given that the background concentration in Amman Governorate is above the AQO for PM2.5, AQO is expected to be exceeded at all Project locations within this Governorate once emissions from the Project are considered.

At all other Project construction locations there is not predicted to be any exceedances of the AQO for $PM_{2.5}$.

5.1.2 Mitigation Measures

In order to minimise effects, all Project combustion plant and road traffic will be operated in line with manufacturer's best practice with regards to fuelling and operating conditions to reduce emissions. Combustion plant should also be switched off when not in use and vehicle idling avoided wherever possible.

5.2 CONSTRUCTION DUST

5.2.1 Dust Risk Prior to Mitigation

Construction work associated with the Project has the potential to generate substantial levels of dust. IAQM guidance identifies the likely stages of construction work that will lead to dust emissions and recommends assigning each a dust emissions risk. Given the large scale of the Project and the inherently dusty nature of the working environment it has been considered that all stages of construction work are likely to present an elevated risk of dust emissions.

As such, using the source-pathway-receptor approach, there will be a large dust emissions source wherever the Project will be under construction. As the airborne pathway for the conveyance of dust emissions is generally considered to be effective, the levels of mitigation required will be determined by the receiving environment.

5.2.2 Mitigation Measures

Based upon the above risks, appropriate, specific mitigation is to be adopted with regard to dust impacts based upon the receiving environment. The IAQM guidance provides example mitigation measures to reduce dust impacts; these have been added to additional, region-specific best practice control measures and are suitable to be included in a Construction Environmental Management Plan (CEMP), as required.

Mitigation is provided for localities where the effects of dust have been identified as a key concern as well as for areas of work at which the receiving environment is of lower concern.

It should be noted that water-suppression features prominently in the below mitigation however it is acknowledged that, due to the practicalities of the construction environment and the particular scarcity of water in Jordan, this may not always be possible. A greater focus should therefore be placed on covering potential sources of dust and careful management to minimise the generation of dust to compensate for for the inherent water scarcity.

Mitigation measures are summarised in tables 20 and 21 overleaf.

Table 20: Proposed Urban and Agricultural Dust Mitigation Measures

Issue	Control Measure
Communication	• Develop and implement a stakeholder communications plan that includes community engagement before work commences on site; • Display the name and contact details of person(s) accountable for dust issues on the site boundary; • Display the head or regional office contact information; and • Develop and implement a Dust Management Plan (DMP) which may be incorporated into the overall CEMP.
Site Management	• Record all dust complaints, identify causes(s), take appropriate measures to reduce emissions in a timely manner and record the measures taken; • Make the complaints log available to the relevant authority when asked; and • Record any exceptional incidents that cause dust emissions either on or off-site and the action taken to resolve the situation in the logbook.
Monitoring	• Undertake daily on-site and off-site inspection, where receptors (including roads) are nearby, to monitor dust, record inspection results, and make the log available to the relevant authority when asked. This should include regular dust soiling checks of surfaces such as street furniture, cars and windowsills within 100 m of site boundary, with cleaning to be provided if necessary; • Carry out regular site inspections to monitor compliance, record inspection results and make an inspection log available to the relevant authority when asked; • Increase the frequency of site inspections when activities with a high potential to produce dust are being carried out and during prolonged dry or windy conditions; and • Agree dust deposition, dust flux, or real-time PM10 continuous monitoring locations at long term construction sites. Where possible, commence baseline monitoring at least three months before work commences at that site.
Preparing and Maintaining the Site	• Plan site layout so that machinery and dust-causing activities are located away from receptors, as far as is possible; • Erect solid screens or barriers around dusty activities or the site boundary that are at least as high as any stockpiles on site; • Where possible / practicable, fully enclose site or specific operations where there is a high potential for dust production and the site is expected to be active for a prolonged period; • Keep site fencing, barriers and scaffolding clean using wet methods where feasible to do so. • Remove materials that have the potential to produce dust from site as soon as possible unless being re-used on site. If they are being reused on-site, cover as described below; and • Cover, seed or fence stockpiles to prevent wind whipping.
Operating Vehicles/Machinery	• Ensure all vehicles switch off engines when stationary - no idling vehicles; and • Impose and signpost a maximum-speed-limit of 15 mph on surfaced and 10 mph on unsurfaced haul roads and work areas.

Operations	• Only use cutting, grinding or sawing equipment fitter or in conjunction with suitable dust suppression techniques such as water sprays or local extraction; • Ensure an adequate water supply on the site for effective dust suppression using non-potable water where possible and appropriate; • Use enclosed chutes and conveyors and covered skips; • Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate; and • Ensure equipment is readily available on site to clean any dry spillages and clean up spillages as soon as reasonably practicable after the event.
Waste Management	• Avoid bonfires and burning of waste materials.
Earthworks	• Where applicable, re-vegetate earthworks and exposed areas / soil stockpiles to stabilise surfaces as soon as practicable; • Use Hessian, mulches or tackifiers where it is not possible to re-vegetate or cover with topsoil, as soon as practicable; and • Only remove the cover in small areas during work and not all at once.
Construction	• Avoid scabbling (roughening of concrete surfaces) if possible; • Ensure sand and other aggregates are stored in bunded areas and are not allowed to dry out, unless this is required for a particular process, in which case ensure that appropriate additional control measures are in place; • Ensure bulk cement and other fine powder materials are delivered in enclosed tankers and stored in silos with suitable emission control systems to prevent escape of material and overfilling during delivery; and • For smaller supplies of fine power materials ensure bags are sealed after use and stored appropriately to prevent dust.
Vehicle Management	• Use dust sweepers on the access and local roads (water-assisted where feasible to do so); • Avoid dry sweeping of large areas; • Ensure vehicles entering and leaving site are covered to precent escape of materials during transport; and • Implement a wheel washing system.

Table 21: Proposed Rural Sensitivity Dust Mitigation Measures

Issue	Control Measure
Communication	• Display the name and contact details of person(s) accountable for dust issues on the site boundary; • Display the head or regional office contact information; and • Develop and implement a Dust Management Plan (DMP) which may be incorporated into the overall Construction Environmental Management Plan.
Site Management	• Record all dust complaints, identify causes(s), take appropriate measures to reduce emissions in a timely manner and record the measures taken; • Make the complaints log available to the relevant authority when asked; and • Record any exceptional incidents that cause dust emissions either on or off-site and the action taken to resolve the situation in the logbook.
Monitoring	• Carry out regular site inspections to monitor compliance, record inspection results and make an inspection log available to the relevant authority when asked; and • Increase the frequency of site inspections when activities with a high potential to produce dust are being carried out and during prolonged dry or windy conditions.
Preparing and Maintaining the Site	• Plan site layout so that machinery and dust-causing activities are located away from receptors, as far as is possible; • Erect solid screens or barriers around dusty activities or the site boundary that are at least as high as any stockpiles on site; • Where possible / practicable, fully enclose site or specific operations where there is a high potential for dust production and the site is expected to be active for a prolonged period; • Keep site fencing, barriers and scaffolding clean using wet methods where feasible to do so. • Remove materials that have the potential to produce dust from site as soon as possible unless being re-used on site. If they are being reused on-site, cover as described below; and • Cover, seed or fence stockpiles to prevent wind whipping.
Operations	• Only use cutting, grinding or sawing equipment fitter or in conjunction with suitable dust suppression techniques such as water sprays or local extraction; • Ensure an adequate water supply on the site for effective dust suppression using non-potable water where possible and appropriate; • Use enclosed chutes and conveyors and covered skips; • Minimise drop heights from conveyors, loading shovels, hoppers and other loading or handling equipment and use fine water sprays on such equipment wherever appropriate; and • Ensure equipment is readily available on site to clean any dry spillages and clean up spillages as soon as reasonably practicable after the event.
Waste Management	• Avoid bonfires and burning of waste materials.
Vehicle Management	• Use dust sweepers on the access and local roads (water-assisted where feasible to do so); • Avoid dry sweeping of large areas; • Ensure vehicles entering and leaving site are covered to precent escape of materials during transport; and

	• Implement a wheel washing system.

5.2.3 Dust Risk Post Mitigation

Providing the mitigation measures summarised in Tables 23 and 24 are implemented, the residual effect is deemed to be not significant in accordance with the IAQM guidance.

6 CONCLUSION

Metrica was commissioned to undertake an assessment of air quality and dust impacts during the construction and operation of the Aqaba-Amman Water Desalination and Conveyance Project.

Appropriate air quality objective for assessment have been specified based on Jordanian, IFS, WHO, and appropriate international guidance.

Predicted $PM_{2.5}$ concentrations are expected to be in exceedance of existing international and national AQAL's however this is as a result of background pollutant concentrations already being in breach of the AQAL prior to any Project work. Predicted pollutant concentrations are expected to be below the relevant national and international AQAL's for NO_2 and PM_{10}.

Additional pollutants with existing AQAL's have not been modelled due to a combination of a lack of reliable emissions data and the measured background levels being considerably below the AQO, however, based on very low background levels and using professional judgment it is expect there would not be any exceedances of the relevant AQO as a result of the Project construction activities

With regards to construction effects, various receptors have been identified within the distance at which the criteria could be exceeded, although exceedances will be short-term in duration. Where criteria are exceeded, additional mitigation measures specified in Section 5 should be applied to ensure impacts minimised as far as possible.

7 GLOSSARY OF TERMS

Annual Average Daily Traffic (AADT): The total volume of vehicle traffic on a road link divided by 365 to provide the average traffic flow per day.

Air Quality Objective (AQO)/Air Quality Assessment Level (AQAL): An objective or limit value for a given pollutant defined by national or international guidance.

Heavy duty Vehicle (HDV): Goods vehicles and buses >3.5t gross vehicle weight.

Institute of Air Quality Management (IAQM): The professional body for air quality professionals in the United Kingdom.

Light Duty Vehicle (LDV): Cars and small vans <3.5t gross vehicle weight.

Nitrogen Dioxide (NO_2): Pollutant formed from Nitrogen and Oxygen in the atmosphere as a bi-product of the combustion of fossil fuels in internal combustion.

Oxides of Nitrogen (NO_X): The combination of Nitrogen Dioxide (NO_2) and nitric acid (NO) in the atmosphere.

PM_{10} and $PM_{2.5}$: Particulate matter with an aerodynamic diameter of less than 10 microns or less than 2.5 microns.

Total Suspended Particulate (TSP): All airborne particles (including dust), that are less than 100 microns in diameter and able to be suspended in the atmosphere.

ANNEX 1 – FULL DISPERSION MODELLING DISTANCE TABLES

Construction Plant Emissions – PM_{10}

Distances at which air quality effects are forecast to occur, as a result of construction plant emissions, are presented in Table 1 to 5 below for each Governorate, for each construction activity.

Table 1: Distances for Construction Activities – Amman

Construction Activity	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
IPS Construction	N/A	N/A	N/A	5
Desalination Plant Installation	N/A	N/A	N/A	5
Trenching	N/A	N/A	N/A	5
Pipe Installation and Welding	N/A	N/A	N/A	5
Backfill and Road Maintenance	N/A	N/A	N/A	5
Crushing and Screening	N/A	N/A	N/A	5
Pumping Station Installation	N/A	N/A	N/A	5
Regulating Tank Facility Installation	N/A	N/A	N/A	5
Renewable Facility Installation	N/A	N/A	N/A	5
OHL Installation	N/A	N/A	N/A	5

Table 2: Distances for Construction Activities – Karak

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	N/A	N/A	5
Desalination Plant Installation	N/A	N/A	N/A	5
Trenching	N/A	N/A	N/A	5
Pipe Installation and Welding	N/A	N/A	N/A	5
Backfill and Road Maintenance	N/A	N/A	N/A	5
Crushing and Screening	N/A	N/A	N/A	5
Pumping Station Installation	N/A	N/A	N/A	5
Regulating Tank Facility Installation	N/A	N/A	N/A	5
Renewable Facility Installation	N/A	N/A	N/A	5
OHL Installation	N/A	N/A	N/A	5

Table 3: Distances for Construction Activities – Tafilah

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	N/A	N/A	5
Desalination Plant Installation	N/A	N/A	N/A	5
Trenching	N/A	N/A	N/A	5
Pipe Installation and Welding	N/A	N/A	N/A	5
Backfill and Road Maintenance	N/A	N/A	N/A	5
Crushing and Screening	N/A	N/A	N/A	5
Pumping Station Installation	N/A	N/A	N/A	5
Regulating Tank Facility Installation	N/A	N/A	N/A	5
Renewable Facility Installation	N/A	N/A	N/A	5
OHL Installation	N/A	N/A	N/A	5

Table 4: Distances for Construction Activities – Ma'an

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	N/A	N/A	5
Desalination Plant Installation	N/A	N/A	N/A	5
Trenching	N/A	N/A	N/A	5
Pipe Installation and Welding	N/A	N/A	N/A	5
Backfill and Road Maintenance	N/A	N/A	N/A	5
Crushing and Screening	N/A	N/A	N/A	5
Pumping Station Installation	N/A	N/A	N/A	5
Regulating Tank Facility Installation	N/A	N/A	N/A	5
Renewable Facility Installation	N/A	N/A	N/A	5
OHL Installation	N/A	N/A	N/A	5

Table 5: Distances for Construction Activities – Aqaba

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	N/A	N/A	5
Desalination Plant Installation	N/A	N/A	N/A	5
Trenching	N/A	N/A	N/A	5
Pipe Installation and Welding	N/A	N/A	N/A	5
Backfill and Road Maintenance	N/A	N/A	N/A	5
Crushing and Screening	N/A	N/A	N/A	5
Pumping Station Installation	N/A	N/A	N/A	5
Regulating Tank Facility Installation	N/A	N/A	N/A	5
Renewable Facility Installation	N/A	N/A	N/A	5
OHL Installation	N/A	N/A	N/A	5

Road Traffic – PM_{10}

Buffer distances at which air quality effects are forecast to occur, as a result of emissions from Project construction traffic, are presented in Table 6 below for each Governorate.

Table 6: Distances for Project Construction Traffic

Governorate	Distance			
	Substantial	Moderate	Slight	Negligible
Amman	N/A	N/A	N/A	N/A
Karak	N/A	N/A	N/A	N/A
Tafilah	N/A	N/A	N/A	N/A
Ma'an	N/A	N/A	N/A	N/A
Aqaba	N/A	N/A	N/A	N/A

Construction Plant Emissions – NO_2

Distances at which air quality effects are forecast to occur, as a result of construction plant emissions, are presented in Table 7 to 11 below for each Governorate, for each construction activity.

Table 7: Distances for Construction Activities – Amman

Construction Activity	Distance From Source at Which Effect Occurs, m			
	Substantial Effect	Moderate Effect	Slight Effect	Negligible Effect
IPS Construction	N/A	5	15	30
Desalination Plant Installation	N/A	15	35	50
Trenching	N/A	15	20	35
Pipe Installation and Welding	N/A	5	15	30
Backfill and Road Maintenance	N/A	10	40	50
Crushing and Screening	N/A	5	15	25
Pumping Station Installation	N/A	5	15	35
Regulating Tank Facility Installation	N/A	5	15	35
Renewable Facility Installation	N/A	5	15	35
OHL Installation	N/A	5	15	35

Table 8: Distances for Construction Activities – Karak

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	5	15	30
Desalination Plant Installation	N/A	15	35	50
Trenching	N/A	15	20	35
Pipe Installation and Welding	N/A	5	15	30
Backfill and Road Maintenance	N/A	10	40	50
Crushing and Screening	N/A	5	15	25
Pumping Station Installation	N/A	5	15	35
Regulating Tank Facility Installation	N/A	5	15	35
Renewable Facility Installation	N/A	5	15	35
OHL Installation	N/A	5	15	35

Table 9: Distances for Construction Activities – Tafilah

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	5	15	30
Desalination Plant Installation	N/A	15	35	50
Trenching	N/A	15	20	35
Pipe Installation and Welding	N/A	5	15	30
Backfill and Road Maintenance	N/A	10	40	50
Crushing and Screening	N/A	5	15	25
Pumping Station Installation	N/A	5	15	35
Regulating Tank Facility Installation	N/A	5	15	35
Renewable Facility Installation	N/A	5	15	35
OHL Installation	N/A	5	15	35

Table 10: Distances for Construction Activities – Ma'an

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	5	15	30
Desalination Plant Installation	N/A	15	35	50
Trenching	N/A	15	20	35
Pipe Installation and Welding	N/A	5	15	30
Backfill and Road Maintenance	N/A	10	40	50
Crushing and Screening	N/A	5	15	25
Pumping Station Installation	N/A	5	15	35
Regulating Tank Facility Installation	N/A	5	15	35
Renewable Facility Installation	N/A	5	15	35
OHL Installation	N/A	5	15	35

Table 11: Distances for Construction Activities – Aqaba

Construction Activity	Distance, m			
	Substantial	Moderate	Slight	Negligible
IPS Construction	N/A	5	15	30
Desalination Plant Installation	N/A	15	35	50
Trenching	N/A	15	20	35
Pipe Installation and Welding	N/A	5	15	30
Backfill and Road Maintenance	N/A	10	40	50
Crushing and Screening	N/A	5	15	25
Pumping Station Installation	N/A	5	15	35
Regulating Tank Facility Installation	N/A	5	15	35
Renewable Facility Installation	N/A	5	15	35
OHL Installation	N/A	5	15	35

Road Traffic – NO_2

Buffer distances at which air quality effects are forecast to occur, as a result of emissions from Project construction traffic, are presented in Table 12 below for each Governorate.

Table 12: Distances for Project Construction Traffic

Governorate	Distance			
	Substantial	Moderate	Slight	Negligible
Amman	N/A	N/A	N/A	N/A
Karak	N/A	N/A	N/A	N/A
Tafilah	N/A	N/A	N/A	N/A
Ma'an	N/A	N/A	N/A	N/A
Aqaba	N/A	N/A	N/A	N/A

Project: Aqaba-Amman Water Desalination and Conveyance (AAWDC)

2025 Environmental and Social Impact Assessment

Appendix 9B.3 Glint and glare review

GLINT & GLARE SCREENING ASSESSMENT

Aqaba-Amman Water Desalination and Conveyance Project (AAWDCP)

November 2025

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ANNEX 2: LOCATION PLAN

1 INTRODUCTION

This report provides an assessment of the glint and glare impacts associated with the Aqaba-Amman Water Desalination and Conveyance (AAWDC) Project (hereafter referred to as 'the Project'). It should be noted that assessment is independent of the Project's visual amenity impacts, which have been assessed by others.

2 GLINT AND GLARE DEFINITION

'Glint' and 'Glare' are the effects caused by the reflection of sunlight from reflective surfaces such as glazing or solar photovoltaic (PV) panels, with the following definition:

- Glint: a momentary flash of light that may be produced as a direct reflection of the sun in the solar panel; and
- Glare: a continuous source of excessive brightness experienced by a stationary observer located in the path of reflected sunlight from the face of the panel.

The UK Government's National Policy Statement for Renewable Energy Infrastructure[1] states that…*"commercially available solar panels are designed with anti-reflective glass or are produced with anti-reflective coating and have a reflective capacity that is generally equal to or less hazardous than other objects typically found in the outdoor environment, such as bodies of water or glass buildings."*

3 PROJECT OVERVIEW

The Project's renewable energy facility consists of a Solar Photovoltaic (PV) array and associated infrastructure:

- Single-axis tracking PV panels;
- Maximum panel tilt angle of 55 degrees;
- North-south tracking axis (i.e. array azimuth will track east-west); and
- Standard anti-reflective panel coating (ARC).

It is important to note that as proposed solar panels will not focus light in any way, there is no potential for physical injury (retinal burn) to occur. As such, all effects referred to in this assessment relate to distraction and / or annoyance, rather being directly injurious to health.

A drawing showing the facility's indicative design is provided in Annex 1 of this report.

4 LEGAL AND ADMINISTRATIVE FRAMEWORK

The following guidance and standards are pertinent to this assessment:

4.1 IFC UTILITY-SCALE SOLAR PHOTOVOLTAIC POWER PLANTS

The International Finance Corporation (IFC)'s guide on *Utility-Scale Solar Photovoltaic Power Plants* [2] states:

"Solar panels are designed to absorb, not reflect, irradiation. However, glint and glare should be a consideration in the environmental assessment process to account for potential impacts on landscape/visual and aviation aspects."

[1] UK Government (November 2023). National Policy Statement for Renewable Energy Infrastructure.

[2] IFC World Bank Group (2025) Utility-Scale Solar Photovoltaic Power Plants: A Project Developer's Guide.

"There may be restrictions to development within historic districts to preserve aesthetic harmony, which should be investigated prior to any project development. Similarly, installers should note the impact of glare from PV modules on neighbouring businesses or residences."

Whilst not prescriptive, IFC guidance requires developers to adhere to its Performance Standards on Environmental and Social Sustainability and follow Good International Industry Practices (GIIP), as encompassed by the general approach described above.

4.2 INDUSTRY BEST PRACTICE GUIDANCE

It should be noted that neither the IFC nor Jordanian planning guidance provides a specific methodology for assessing the impact of glint and glare. However, the following guidance is regularly applied to assessments internationally, and is considered to provide a reasonable and robust approach:

- Measurement and Assessment of Light Immissions[3];
- Renewable Energy Developments: Solar Photovoltaic Developments[4]; and
- Review of Solar Energy System Projects on Federally-Obligated Airports[5].

4.2.1 Measurement and Assessment of Light Immissions

The German Ministry for Environment, Health and Consumer Protection published the *Measurement and Assessment of Light Immissions* in 1993, which was most recently updated in 2014. Paragraph 8 of the most recent version of the guidelines is dedicated to the assessment of reflections from solar PV panels.

The guidelines state that… [translated from German] *"experience has shown that immission locations that are more than approximately 100 m away from a photovoltaic system only experience short-term glare effects. Only in the case of extensive photovoltaic parks could more distant immission locations still be relevant."*

In addition, the guidelines note that where a reflection source is located in the same direction (+/- 10 degrees) as the sun itself, the direct glare from the sun masks any reflections, and can therefore be scoped out of further assessment.

For those receptors within the study area described above, the guidelines state that effects are acceptable when glare is experienced for no more than 30 minutes on any given day, or 30 hours per year.

4.2.2 Renewable Energy Developments: Solar Photovoltaic Developments

The UK Civil Aviation Authority (CAA) issued a guidance note, Renewable Energy Developments, most recently updated in April 2024. This guidance note was prepared by the Combined Aerodrome Safeguarding Team (CAST), supported by the CAA, and aims to provide safeguarding advice in relation to solar photovoltaic developments on a range of matters, including glint and glare.

With specific reference to glint and glare effects, Section 2 of the guidance note states that:

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[3] Ministry for the Environment, Health and Consumer Protection (2014). Light Guidelines (Leitlinie des Ministeriums für Umwelt, Gesundheit und Verbraucherschutz zur Messung und Beurteilung vonm Lichtimmissionen)

[4] CAA (2024). Solar photovoltaic Developments CAST Aerodrome Safeguarding Guidance Note

[5] Federal Aviation Administration (2021) Review of Solar Energy System Projects on Federally-Obligated Airports.

"In most cases, an assessment should be undertaken for a solar PV development which is being proposed within a specific distance (indicated by the aerodrome authority) from an aerodrome. For many aerodromes, 5 km is the distance of choice but it could be considered out to 10 km. In exceptional circumstances, assessments may be required beyond 10 km."

No specific methodology or assessment criteria are defined for assessing the impact of glint and glare on aviation infrastructure.

4.2.3 Review of Solar Energy System Projects on Federally-Obligated Airports

In 2013, the United States' Federal Aviation Administration (FAA) published interim guidance which stated that for a solar PV development to obtain FAA approval or to receive no objection, there should be no more than a "low potential for after-image" along the final 2-mile approach path for any existing or proposed runway, as defined by Sandia Laboratories' Solar Glare Hazard Analysis Tool (SGHAT).

SGHAT categorises glint and glare into three tiers of severity (ocular hazards) that are referred to as different colours in the model output. It should be noted that these categories relate to the intensity of the reflection, rather than being duration dependant:

- Red glare: Glare predicted with a potential for permanent eye damage (retinal burn);
- Yellow glare: Glare predicted with a potential for temporary after image; and
- Green glare: Glare predicted with a low potential for temporary after image.

It also notes that no significant impacts are possible for reflections located more than 50 degrees either side of the direction of travel.

Page 2 of the Interim guidance stated that "the FAA expects to continue to update these policies and procedures as part of an iterative process as new information and technologies become available."

4.2.3.1 2021 Update

In accordance with the above, the Interim FAA guidance was updated in 2021 to reflect the state of knowledge at the time.

As part of the update, the FAA withdrew the requirement to undertake glint and glare analysis using SGHAT as the software is no longer available. The assessment of glint and glare impacts due to the Development therefore uses alternative industry standard modelling software which utilises the same methodology as SGHAT.

With regard to the potential for solar glint and glare impacts in general, the 2021 update states the following in the section entitled 'Developments Since Interim Policy':

"Initially, the FAA believed that solar energy systems could introduce a novel glint and glare effect to pilots on final approach. FAA has subsequently concluded that in most cases, the glint and glare from solar energy systems to pilots on final approach is similar to glint and glare pilots routinely experience from water bodies, glass-façade buildings, parking lots, and similar features. However, FAA has continued to receive reports of potential glint and glare from on-airport solar energy systems on personnel working in ATCT [Air Traffic Control Tower] cabs. Therefore, FAA has determined the scope of agency policy should be focused on the impact of on-airport solar energy systems to federally-obligated towered airports, specifically the airport's ATCT cab."

Given the above, it is clear that the FAA consider that with the exception of ATCTs, no unacceptable glint and glare impacts are expected from solar PV panels in terms of aviation safety.

5 BASELINE

Sensitive receptors are those for which solar glare may either reduce the level of amenity at that location (such as residential dwellings), or be of sufficient intensity to pose a potential safety risk through reduced visibility (such as car or train drivers, aircraft pilots and air traffic controllers). As stated in Section 3, It is important to note that as proposed solar panels will not focus light in any way, there is no potential for any glare to result in direct physical injury in any circumstance.

In order identify any potential sensitive receptors and any other solar PV projects in the local area, a search was undertaken through study of aerial imagery, online mapping, and information provided by the Project's applicant. Annex 2 presents a figure showing the general footprint of the renewable energy facility, and the local context. It should be noted that three alternative locations for the renewable energy facility are shown in Annex 2. Option 2 (Al -Quweira) is the selected option for the Project, and is therefore the location assessed in this report.

6 ASSESSMENT METHODOLOGY

6.1 STUDY AREAS

6.1.1 RESIDENTIAL RECEPTORS

As stated in Section 4.2.1, glint and glare effects are unlikely to be an issue for residential receptors more than approximately 100 m from PV panels, due to the reduced intensity and short duration of effects beyond this distance. However, as this distance is approximate and dependent upon the extent of a given development, the residential receptor study area for this assessment has been based upon a 200 m buffer distance in order to ensure a robust approach.

6.1.2 ROAD AND RAIL INFRASTRUCTURE

The assessment criteria for road and rail infrastructure relate purely to glare intensity, rather than duration of effects. In line with FAA guidance (see Section 4.2.3), whilst low-intensity 'green' glare is acceptable, any incidence of 'yellow' or 'red' glare is considered an adverse impact, regardless of duration.

An appropriate study area for road and rail infrastructure has been determined through modelling undertaken by Metrica. It was found that for typical large-scale solar developments in the UK, 'yellow glare' is unlikely to occur beyond approximately 375 m, based on a number of worst-case parameters i.e. a 2 km^2 (2 km x 1 km) PV array with no anti-reflective coating, tilt angles of between 20 and 30 degrees, and receptors located along the longer array boundary, at heights between 1.5 m and 50 m above ground level (AGL).

Taking the above into account, a study area of 1 km for road infrastructure has been adopted and is considered a highly conservative approach. In line with widely accepted best practice, local / minor roads within the 1 km study area are not typically assessed; this is due to local roads having reduced traffic densities and speeds, meaning any potential impact due to a temporary reflection is low.

6.1.3 AIRPORTS AND AVIATION INFRASTRUCTURE

The study area for aerodromes as defined in FAA guidance is as follows:

- 10 km for safeguarded civil or military aerodromes[6]; and
- 5 km for other / non-safeguarded aerodromes.

It should be noted that any approach paths within the respective study area have been included, regardless of whether the aerodrome itself is located within that study area. To inform this process, additional screening was undertaken to a distance of 13 km, thereby ensuring any such flight paths are captured.

6.1.4 HISTORIC DISTRICTS

As noted in Section 4.1, IFC guidance recommends that consideration is given to the potential for glare to adversely affect nearby historic districts, or areas which are particularly valued for their cultural importance.

There is no specific guidance on the assessment of glare affecting such areas. Therefore, a study area of 1 km has been adopted for the purposes of this assessment. This distance is based upon the study area for roads, beyond which there is no reasonable prospect of glint or glare resulting in adverse impacts.

6.2 ASSESSMENT CRITERIA

For those receptors identified within the above study areas, the following assessment criteria apply:

6.2.1 RESIDENTIAL RECEPTORS

The assessment criteria for residential receptors are those described in Section 4.2.1, i.e., that the glint and glare effects are acceptable providing such effects occur for no more than 30 minutes per day, or 30 hours (equivalent to 1,800 minutes) per year.

6.2.2 ROAD, RAIL AVIATION AND HISTORIC DISTRICT RECEPTORS

The assessment criteria for road, rail aviation and historic district receptors are those described in Section 4.2.3, i.e., that the glint and glare effects are acceptable providing there is found to be no more than a low potential for after-image (i.e., 'green glare') when assessing in accordance with the SGHAT methodology. As previously stated, the SGHAT methodology is based purely upon the intensity of the reflection and the viewing angle and is not duration-dependant.

With specific regard to Air Traffic Control Towers (ATCT), United States Federal Aviation Administration (FAA) guidance requires that…*"a proposed solar project will not result in ocular (i.e. glint or glare) impacts to the airport's ATCT".* In the absence of more detailed guidance, the glint and glare threshold for ATCTs is therefore zero (i.e. no glint and glare is acceptable, regardless of intensity).

[6] As defined in UK Government (2016) 'Town and country planning (safeguarded aerodromes, technical sites and military explosives storage areas) direction 2002 (last updated December 2016)

7 ASSESSMENT OF IMPACTS

7.1 RESIDENTIAL RECEPTORS

Based on a review of online mapping, aerial imagery and feedback from the Project team there are no residential receptors within close proximity to the proposed solar facility site. The closest residential receptor has been identified as being located approximately 3 km west of the renewable energy facility, and therefore well beyond the respective study area; As such, no adverse impacts on residential receptors are anticipated.

7.2 ROAD AND RAIL RECEPTORS

The closest road or rail line to the renewable energy facility is Highway 47, located approximately 6 km to the west, and therefore well beyond the respective study area; as such, no adverse impacts on roads or rail lines are anticipated.

7.3 AIRPORTS AND AVIATION RECEPTORS

The closest airport or aviation asset to the renewable energy facility is King Hussein International Airport, located approximately 36 km southwest at the closest point, and therefore well beyond the respective study area; as such, no adverse impacts on airports or aviation are anticipated.

7.4 HISTORIC DISTRICT RECEPTORS

The closest historic district to the renewable energy facility is Wadi Rum, a UNESCO Protected Area. The core Protected Area boundary is located approximately 5 km south of the Project's renewable energy facility at the closest point, and therefore well beyond the respective study area.

Notwithstanding the above, the renewable energy facility is located within the wider buffer zone for Wadi Rum, classified by UNESCO as 'Medium Development: Limited to Non-Consumptive Tourism'. The primary purpose of the buffer zone is to allow moderate economic and infrastructure growth while prioritizing non-consumptive tourism activities. The renewable energy facility provides no draw or interest in terms of tourism, and is located in an area with other existing solar PV facilities (see Section 7.5). Given this, along with the facility's purpose (i.e. providing a source of clean, zero-emission energy generation), no adverse impacts are anticipated in terms of glint and glare.

7.5 CUMULATIVE EFFECTS

For those receptors where the assessment criteria are based purely on intensity (i.e. all receptor types other than residential dwellings), any additional glare experienced from other developments would need to occur at precisely the same time as the glare from the Development, at the same point along the route (for linear receptors), and from the same direction in order to result in a cumulative effect. There is no reasonable prospect of this occurring in practice and as such, the assessment of cumulative effects for these receptor types has been scoped out.

Notwithstanding the above, cumulative effects are a potential consideration for receptors where the total duration is a factor (i.e., residential dwellings). Therefore, and in line with the study areas described in Section 5.1, the potential for cumulative impacts is limited to other solar facilities located within 400 m of both the Project's renewable energy facility (beyond which there is no possibility of the residential 200 m study areas of both facilities overlapping).

The closet cumulative development is Quweira Solar Power Plant, located approximately 1 km to the southwest; as such, no material cumulative effects can occur.

8 MITIGATION

No receptors have been identified within their respective study areas. As such, no adverse impacts are anticipated, and no mitigation measures are required.

9 SUMMARY

Metrica was commissioned to undertake a Glint and Glare Impact Assessment for the Project's renewable energy facility.

This assessment has been carried out in accordance with best practice international guidance. The results confirm that the Project complies with all relevant glint and glare criteria, and no adverse impacts are anticipated.

10 GLOSSARY OF TERMS

After-Image: An image that continues to appear in the eyes after exposure to the original image has ceased.

Axis Tracking: Motorised PV array modules which are able change their tilt and / or azimuth angle in order to face the sun as it tracks across the sky.

Azimuth: A direction or bearing defined a horizontal angle between 0° and 359° measured clockwise from North.

Elevation: height above mean sea level.

Elevation Angle: An angle that is formed between the horizontal line (0°) and the line of interest.

Field of View: The angular extent of the observable world that is seen at any given moment. For the assessment of glint and glare effects, this is typically taken as being 50° either side of the direct line of sight.

Glare: A continuous source of bright light typically received by static receptors or from large reflective surfaces.

Glint: A momentary flash of bright light typically received by moving receptors or from moving reflectors.

Green Glare: Glare predicted with a low potential for temporary after-image.

Local Road: Minor roads typically linking residential areas to the primary road network.

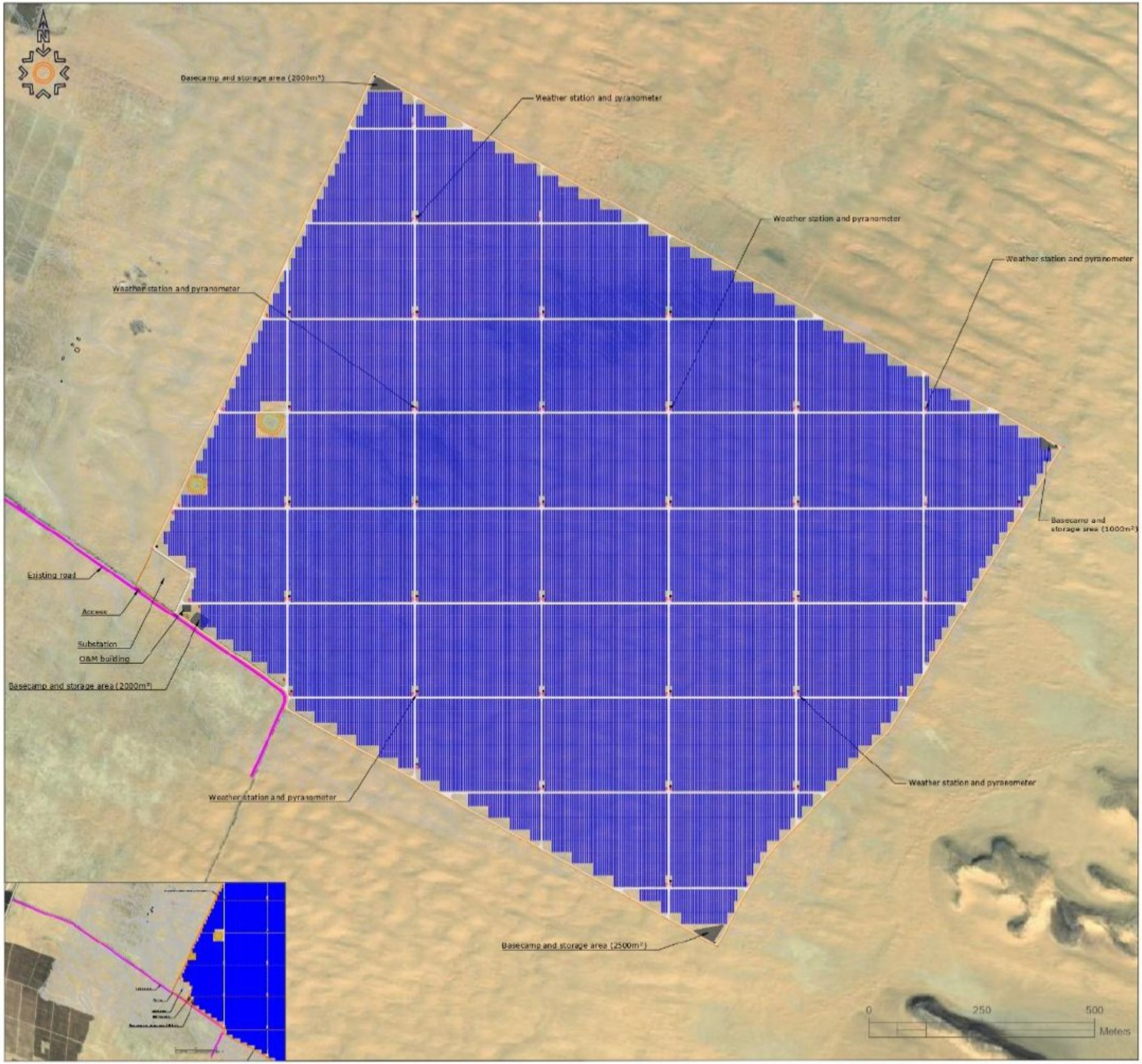
National Road: Major roads intended to provide large-scale transport links within or between geographical areas.

Receptor: In this context, a receptor is a potential viewer of glint and glare effects, either static or mobile.

Red Glare: Glare predicted with a potential for permanent eye damage (retinal burn),

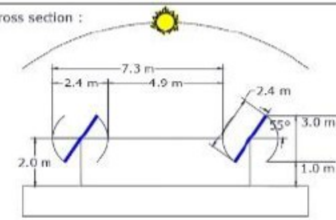
Yellow Glare: glare predicted with a potential for temporary after-image.

ANNEX 1: INDICATIVE LAYOUT



Meridiam	MER-2024-03-JordanieOE PV plant - AAWDC project 312.41 MWp Detailed design			
Fenced area	Surface : 485.98 ha		Perimeter : 8831.03 m	
Equipment	Module : TSM-NEG21C.20 710Wc Dimensions : 2384 x 1303 x 33 mm			440 020u
	Inverter : Sungrow-SG320HX			947u
	Transformer : Sungrow MVS4500-LV Dimensions : 6058 x 2438 x 2896 mm			68u
Connection	Ratio DC/AC : 1.10			
	Total AC power : 284 100 kW			
	Connection : 132 kV			
Structures	Table type : 1V Trackers			
	Table configuration	1V56	1V28	-
	Number of tables	7623	469	-
Implantation	Azimuth : 0°	Tilt : +-55°	GCR : 33%	
	☐Shading angle : -		Average space : -	
	☒Fixed space : 4.90 m			

Cross section :



Legend : Photovoltaic elements

Photovoltaic elements		
	1V56 Trackers	76.05 x 2.38 m
	1V28 Trackers	39.00 x 2.38 m
Electrical elements		
	PV Transformer Station	6.04 x 2.44 m
	Collector	6.04 x 2.44 m
Civil elements		
	Contour line	
	Internal track	3.00 m
	Existing road	5.00 m
	Access track to be created	
	Gate	7.00 m
	Fence	
Exclusion zones		
	Topography	10.00 m
Other elements		
	Crane operation	7.50 x 7.50 m
	Weather station	6 u.
	Pyranometer (horizontal plane)	18 u.
	Pyranometer (plane of array)	18 u.
	Watertank	60 m3
	Camera	200 m (field of view)
	Spare parts container	12.19 x 2.44 x 2.59 m
	Basecamp	2000 m²
	O&M building	

Index	Date	Changes	Author	Checker
A	27/11/24	Basic design	MFE	BAL
B	13/12/24	Detailed design	MFE	BAL
C	24/12/24	Mise à jour zone d'implantation	ABF	BAL

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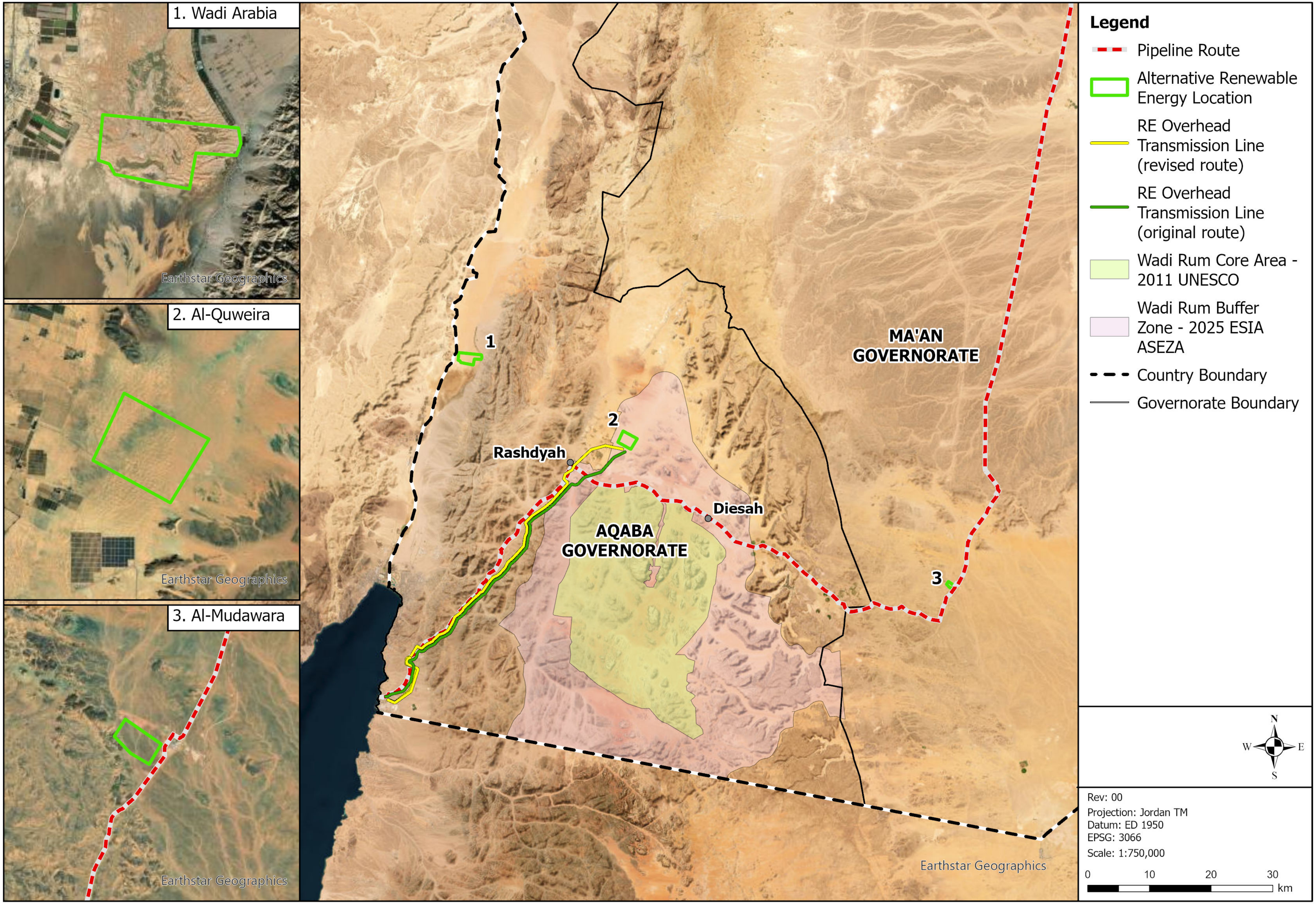
A3

Scale : 1:12000

MER-2024-03-JordanieOE-DetailedDesign-Trackers-1V-RD4.9-C

ANNEX 2: LOCATION PLAN



1. Wadi Arabia
2. Al-Quweira
3. Al-Mudawara
Earthstar Geographics
1
2
3
Rashdyah
Diesah
AQABA GOVERNORATE
MA'AN GOVERNORATE
Legend
Pipeline Route
Alternative Renewable Energy Location
RE Overhead Transmission Line (revised route)
RE Overhead Transmission Line (original route)
Wadi Rum Core Area - 2011 UNESCO
Wadi Rum Buffer Zone - 2025 ESIA ASEZA
Country Boundary
Governorate Boundary
N
E
S
W
Rev: 00
Projection: Jordan TM
Datum: ED 1950
EPSG: 3066
Scale: 1:750,000
0
10
20
30
km