Ecoline International

ENVIRONMENTAL AND SOCIAL IMPACT ASSESSMENT (ESIA)
SISIAN-KAJARAN
(NORTH-SOUTH CORRIDOR)
ROAD PROJECT,
ARMENIA

Volume 3. Physical Environment

Source: projections of the proposed road collated from the '3D description of the Sisian-Kajaran Road', Armenian Road Department, 2022 [https://www.youtube.com/watch?v=fu-dgAwjSsU

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Ecoline International Ltd. 1 Racho Dimchev Str., Sofia, 1000, Bulgaria www.ecoline-int.org

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Prepared by:

Ecoline International Ltd.
(Sofia, Bulgaria)

Director: Dr. Maia Gachechiladze-Bozhesku
Mobile: +380 951 100 727 / +359 876 63 0522
E-mail: mgachechiladze@ecoline-int.org

SE Solutions (Pty) Ltd.
(South Africa)
Director: Sean O'Beirne
Tel: +27 (0)12 643 0190
Mobile: +27 (0)82 903 9751
E-mail: sobeirne@tiscali.co.za

ATMS Solutions Ltd.
(Yerevan, Armenia)
Director: Artak Ter-Torosyan
Tel.: +37410 58 36 43
Mobile: +37499 10 94 95
E-mail: artak.ter-torosyan@atms.am

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DISCLAIMER

An Environmental and Social Impact Assessment (ESIA) is necessarily predictive in that it gets completed well before the project being assessed is actually implemented. The information on which the assessment is based comes from multiple sources including the feasibility report, the detailed design document, reports on studies that were conducted as part of the feasibility investigations, records of meetings, other publications, various databases, data that is collected by the team conducting the ESIA, anecdotal information and others. It is extremely difficult to verify the information that is used other than through testing the logic of that information as well as that can be done. In preparing this document, care has been taken to ensure that whatever information has been available has been accurately reproduced in the ESIA. Should information be found in this document that is incorrect then it is respectively requested that the incorrect information be brought to our attention so that the ESIA can be updated accordingly. We cannot be held accountable for information that we have accepted and reproduced in good faith regardless of the consequences of such information being incorrect. Anyone reproducing information contained in this ESIA does so entirely at their own risk.

LIST OF ABBREVIATIONS

ACL	Admissible Concentration Limit
ADB	Asian Development Bank
AoI	Area of Impact
AQG	Air Quality Guidelines
ARD	Acid rock drainage
BAP	Biodiversity Action Plan
BOD	Biochemical Oxygen Demand
CadnaA	Computer Aided Noise Abatement (software)
cm	centimetre
CMIP5	Coupled Model Inter-Comparison Project Phase 5
CMIP6	Coupled Model Inter-Comparison Project Phase 6
CO	Carbon monoxide
COD	Chemical Oxygen Demand
dB	decibel
DD	Detailed Design
DTM	Digital Terrain Model
E&S	Environmental and social
EC	European Commission
EBRD	European Bank for Reconstruction and Development
EIA	Environmental Impact Assessment
EIB	European Investment Bank
ESAP	Environmental and Social Action Plan
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
ESP	Environmental and Social Policy (of the EBRD)
ESS	Environmental and Social Standard (of the EIB)
EU	European Union
GCM	General Circulation Model
GHG	Greenhouse Gas
GRAL	Graz Lagrangian Model
ha	hectare
ISO	International Organisation for Standardization
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
LAeq	Equivalent Continuous Sound Pressure Level
Lw	sound power level
m	metre
mm	millimetre
MAC	Maximum Acceptable Concentration
MASL	Meters Above Sea Level
MoE	Ministry of Environment of Armenia
MPC	Maximum Permissible Concentration
NGO	Non-governmental organization
NO_2	nitrogen dioxide
NTS	Non-Technical Summary
O_3	Ozone
OHS	Occupational Health and Safety
PGA	Peak Ground Acceleration
PM	Particulate Matter
PR	Performance Requirement (of the EBRD)
RA	Republic of Armenia
RCM	Regional Climate Model
RCP	Representative Concentration Pathway
RD	Road Department

SEP	Stakeholder Engagement Plan
SHPP	Small Hydro Power Plant
SLM	Sound Level Meter
SNCO	State Non-Commercial Organization
SO_2	sulphur dioxide
SSP	Shared Socio-Economic Pathway
TLV	Threshold Limit Value
TSP	Total Suspended Particulates
TSS	Total Suspended Solids
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
US EPA	United States Environmental Protection Agency
VOC	Volatile Organic Compound
WB	World Bank
WHO	World Health Organisation
WRF	Weather Research and Forecasting

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PREAMBLE

This document is the **Physical Environment** report for the proposed greenfield Armenian Sisian-Kajaran section of the North-South Road Corridor (the Project). It forms **Volume 3** of the Environmental and Social Impact Assessment Report (ESIA) for the Project.

The ESIA Report consists of several volumes with related annexes, as follows:

- Volume 1 – Project Definition including Project introduction, context and rationale, project description, alternatives, legal framework, and ESIA methodology;
- Volume 2 – Biodiversity including baseline analysis, impact / risk assessment (including Critical Habitat Assessment and Appropriate Assessment) and mitigation;
- **Volume 3 – Physical Environment including baseline analysis, impact/risk assessment and mitigation measures in relation to air quality and climate, noise and vibration, landscape, etc. (this Report);**
- Volume 4 – Social Environment including socio-economic, gender and cultural heritage baseline analysis, impact / risk assessment and mitigation, as well as stakeholder engagement;
- Volume 5 – Cumulative Impact Assessment;
- Volume 6 – Environmental and Social Management Plan (ESMP);
- Volume 7 – Conclusions and Recommendations.

The ESIA was publicly disclosed for the period of over 120 days according to international lender requirements (from 21 July to 1 December 2023). In addition to the ESIA report, the ESIA disclosure package includes:

- Non-technical Summary (NTS) which is a concise and over-arching document summarising the results of the ESIA in non-technical language;
- Stakeholder Engagement Plan (SEP) that guides information disclosure and meaningful engagement with Project stakeholders, as well as a grievance mechanism;
- Resettlement Framework that guides issues related to Project-induced physical and economic displacement, land acquisition, compensations and livelihood restoration;
- Biodiversity Action Plan (BAP) that articulates actions that can help ensure the conservation or enhancement of potentially affected habitats and species considered of particular conservation value; and
- Environmental and Social Action Plan (ESAP) that contains actions required to implement the Project in compliance with international lender requirements.

Following the public disclosure, the ESIA Disclosure and Consultation Report was prepared to document and summarise the feedback from stakeholders received and engagement activities completed during the ESIA disclosure period.

The current version of the ESIA package captures the feedback from stakeholders collected during the ESIA disclosure and it will be re-disclosed, together with the ESIA Disclosure and Consultation Report, for the Project life-cycle.

1 INTRODUCTION

This report (Volume 3) presents the Physical Environment baseline in relation to the Project area of Influence and assesses the impacts of the Project on the Physical Environment. It comprises:

- Climate,
- Climate change,
- Ambient air quality,
- Topography,
- Geology, geological hazards and processes, and seismicity,
- Soil,
- Noise and vibration,
- Radioactivity,
- Surface water,
- Groundwater resources,
- Waste and spoil, and
- Landscape and visual amenity.

Where adverse impacts have been predicted, mitigation measures are presented. Enhancement measures are proposed where relevant to allow for a greater coverage of positive impacts. These mitigation measures are taken forward into the Environmental and Social Management Plan (ESMP) for the Project (Volume 6).

The photos and the maps in this Volume are taken or created by the Consultant unless indicated otherwise.

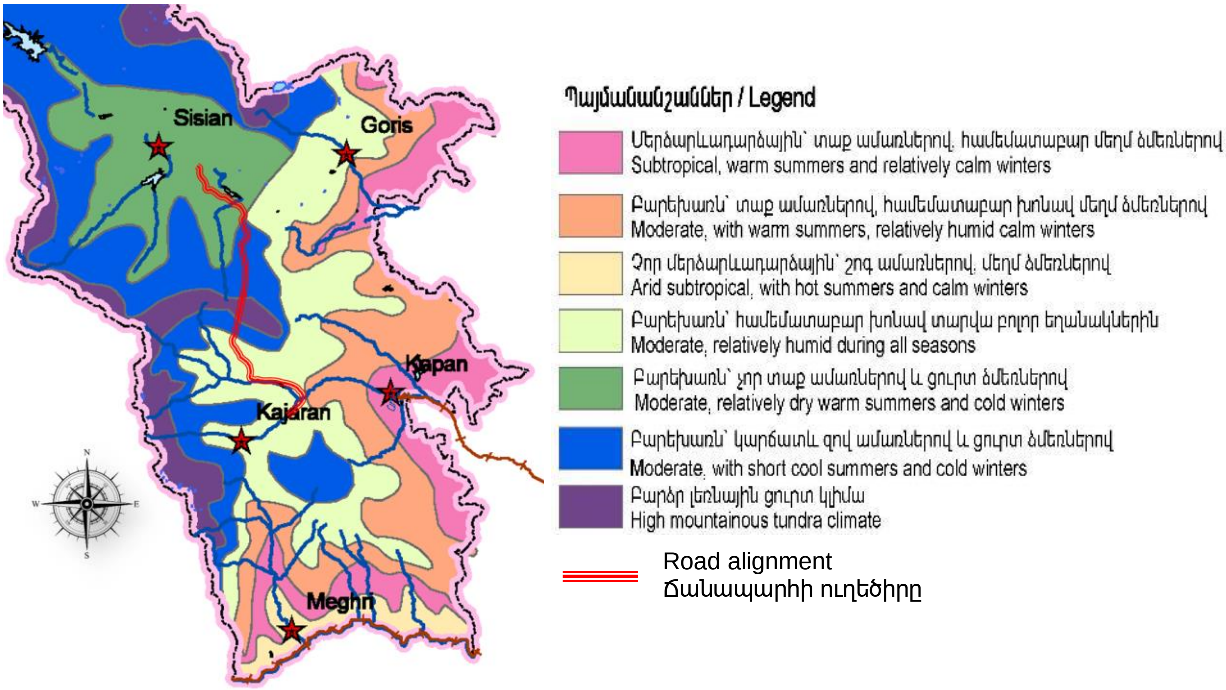
The maps in this Volume are drawn by the Consultant unless indicated otherwise.

2 PHYSICAL ENVIRONMENT: BASELINE

2.1 Climate

The Project is situated in Syunik Region within the administrative boundaries of Sisian and Kajaran Communities. The climate of Syunik Region is influenced by eastern air masses from the Caspian Sea and the dry Iranian plateau and is accordingly defined as continental. Humid air masses are highly transformed and dried as they pass over the Zangezur Mountain Range. However, the extreme diversity of the relief creates climate diversity too. In general, temperature decreases with height and rainfall increases with height. The climatic map of Syunik Region including the Project area is presented in **Figure 1**.

Mean annual temperatures in the Sisian and Kajaran regions are 8.5°C and 6.9°C, with mean annual rainfall of 532 mm and 686 mm, respectively[1]. The annual distribution of precipitation is highly variable. Most precipitation occurs in the period of March-June with the Sisian region, experiencing mostly clear weather with a high radiation balance - 60-62 kcal/cm[2]. The longest multi-year annual average sunshine period observed in Sisian was 2,660 hours.



Source: adjusted from the Water Resources Atlas of Armenia, Yerevan, 2008

Figure 1. Climatic Map of Syunik Region

Snow cover starts at altitudes of 1,200 MASL. The depth of snow cover is 15-20 cm at altitudes of 1,300-1,500 m and 120-180 cm at 3,000 m and higher. The snow remains for 1-1.5 months (January-February) a year at altitudes of up to 1,500 m, and 6.5-7 months (predominantly November-May) a year at altitudes of 3,000 m and higher.

The average annual relative humidity is 60% for Sisian and 70% for Kajaran, with less than 30% at low altitudes (up to 1,000 m) and 60- 80% at higher altitudes - 2,600 m[2].

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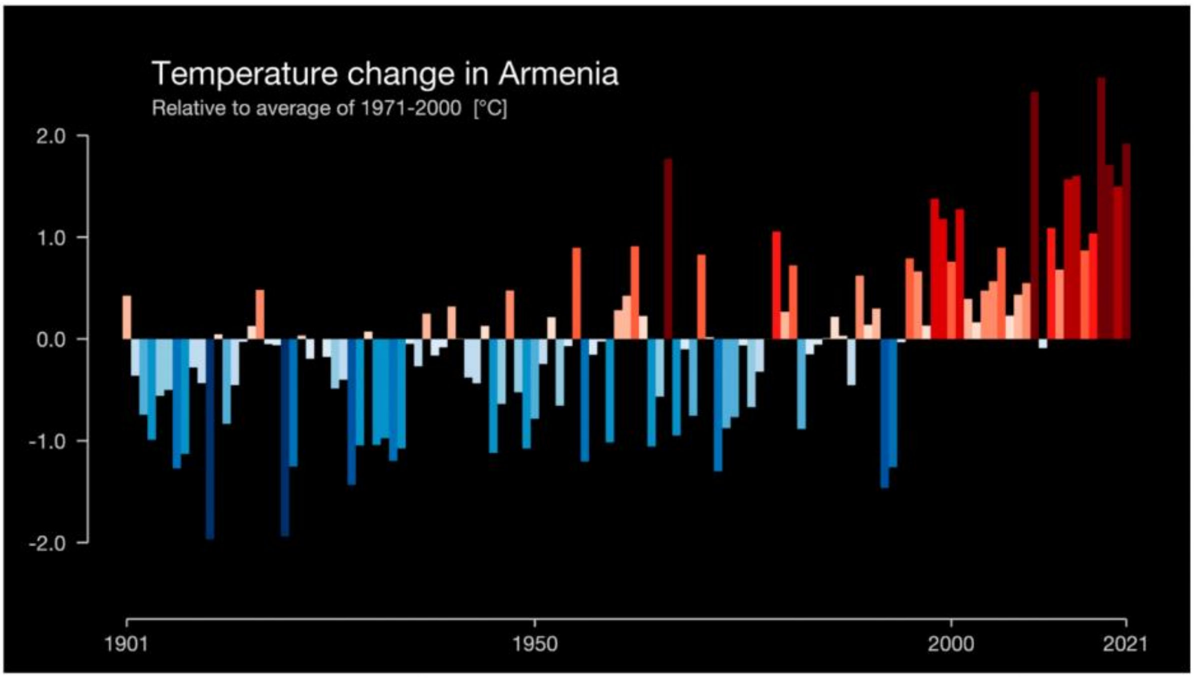
[1] Source: North-South Road Corridor Investment Program, Tranche 4: Section Sisian-Kajaran, Detail Design, Final Environmental Impact Assessment Report and Environmental Management Plan, November 2019.

[2] RA Construction Norms II-7.01-2011 "Construction Climatology" (HHShN).

2.2 Climate Change in Armenia[3]

2.2.1 Observed Climate Change

Global warming effects are already evident in Armenia. Mean annual air temperature increased by 1.23°C between 1929 and 2016 (Armenia's 4th National Communication on Climate Change (RA, 2020)). The temperature increase has been more pronounced in more recent times where nearly a third of the recorded increase (+0.38°C) occurring in the last decade alone (Republic of Armenia, 2020). Armenia's hottest years on record were recorded in this century (**Figure 2**). Between 1990 and 2019, mean annual temperature increases compared to the baseline period (1961-1991) averaged 0.9°C, BUR3 (2021). An increase of 1.5°C from annual average temperature for the period of 1961-1990 was recorded in 2019.



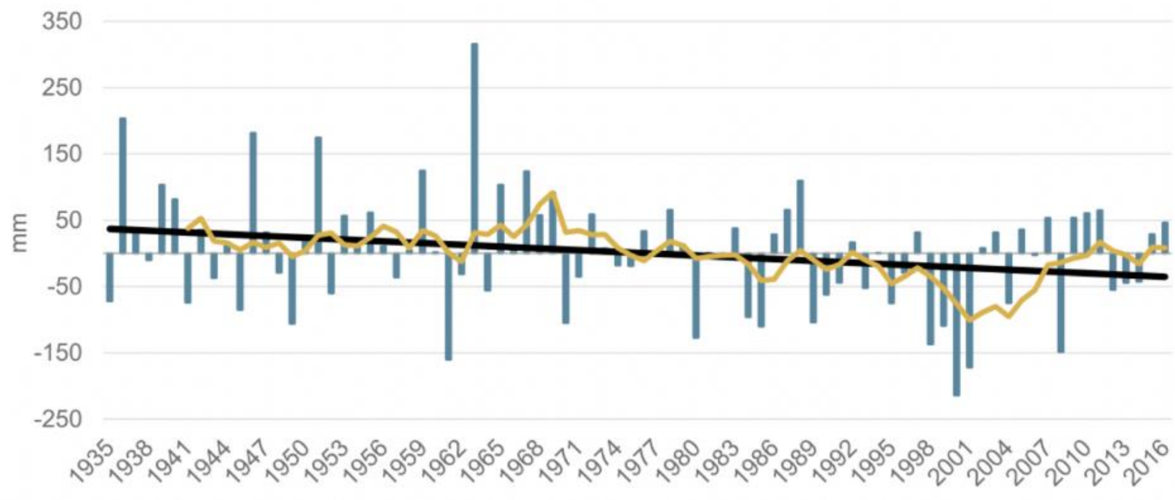
Source: https://showyourstripes.info/c/asia/armenia

Figure 2. Observed temperature change in Armenia (1901-2021) relative to the average of 1971-2000

Precipitation records show a steady decline for the same period in contrast to the temperature increases, with a 10% decline in precipitation for the period of 1935-2012 (**Figure 3**)[4]. The current average annual precipitation of 526 mm per year is 5,1% less than the average annual precipitation between 1961-1990, when it was 592 mm per year. The spatial distribution of precipitation has now also changed from region to region: Since 1935, the northern, southern and central regions of Armenia have become drier, whereas increases in precipitation in the Shirak plain, in the Lake Sevan basin, and in Aparan-Hrazdan regions are evident (RA, 2020).

[3] Much of the information presented in this section has been sourced from Bernard Gruppe, 2022, Report No. 2 Task 4 Climate Adaptation Review, P012400-PH1-GEN-203-RE.

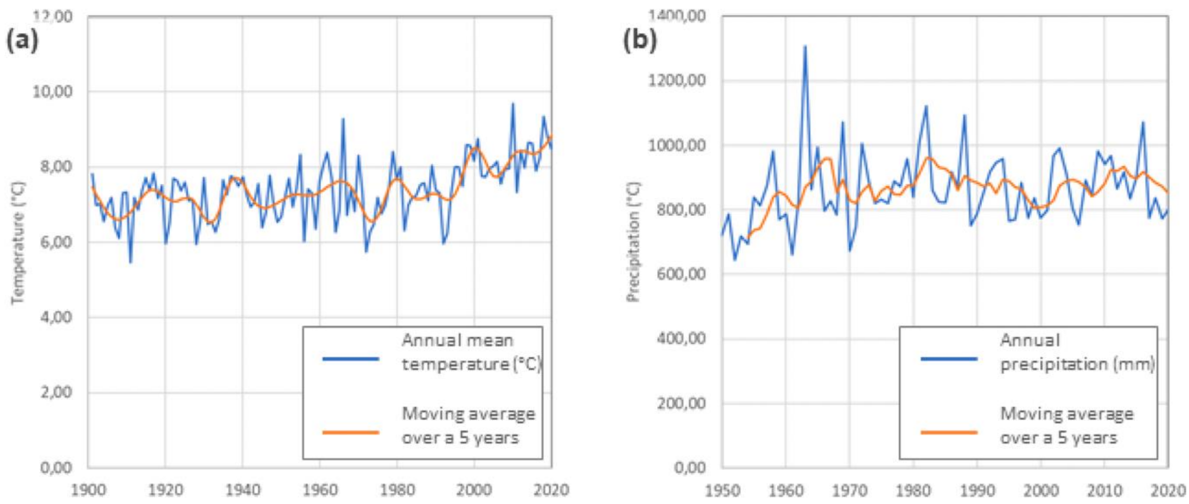
[4] Republic of Armenia. 2020. Armenia's 4th National Communication on Climate Change. https://unfccc.int/sites/default/files/resource/NC4_Armenia_.pdf



Source: RA, 2020

Figure 3. Observed precipitation change in Armenia (1935-2016)

Temperature and precipitation in the past decades for Syunik Region is shown in **Figure 4**. There is no doubt that temperature has increased progressively over the last 120 years (a), but precipitation patterns during the last 70 years are far less clear (b). Information on the largest 1-day precipitation annual trend indicates dominant natural variability and ambiguous trends over the past decades.



Source: World Bank Group 2021

Figure 4. Observed (a) annual mean air temperature and (b) annual precipitation for Syunik Region

Monthly temperature and precipitation for six meteorological stations that represent the southern part of Armenia and especially the area of the Sisian-Kajaran road section well in geographical distribution and altitude, are listed in below pictures.

Mean annual air temperature at the same meteorological stations (**Table 1**) from 1961 to 2021 is also shown. Not unexpectedly, mean temperature is related to altitude with higher elevation stations having lesser annual mean temperatures. Nonetheless, mean temperature for all meteorological stations indicates clearly increasing temperatures over the last 60 years. Annual precipitation at the six meteorological stations for the period of 1961 to 2021, also exhibits an association between annual precipitation and station altitude. Low-altitude stations experience less precipitation while higher-altitude stations experience more precipitation. There is pronounced natural variability and no clear trends at any of the stations.

Table 1. Meteorological stations located in the southern part of Armenia

Station name	Altitude (MASL)	Coordinates (WGS 84)	
		Latitude	Longitude
Vorotan Pass	2 387	39°41’35’’	45°42’42’’
Goris	1 403	39°31’5’’	46°20’18’’
Sisian	1 580	39°31’13’’	46°1’47’’
Kajaran	1 843	39°9’10’’	46°9’33’’
Kapan	705	39°12’15’’	46°27’44’’
Meghri	627	39°53’52’’	46°14’33’’

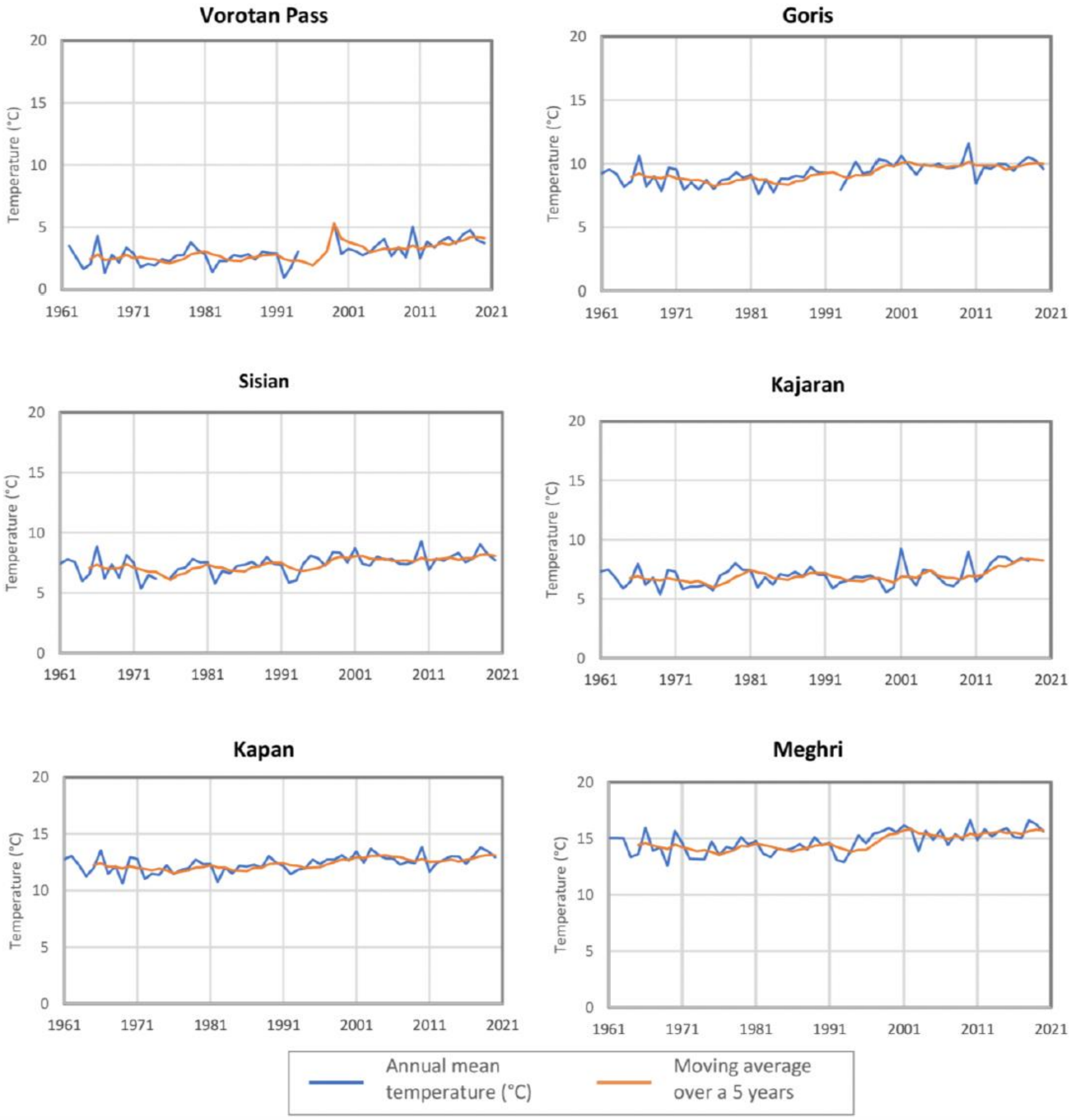


Figure 5. Observed annual mean temperature at selected meteorological stations located in the southern part of Armenia (details regarding location and altitude of stations can be found in Table 1).

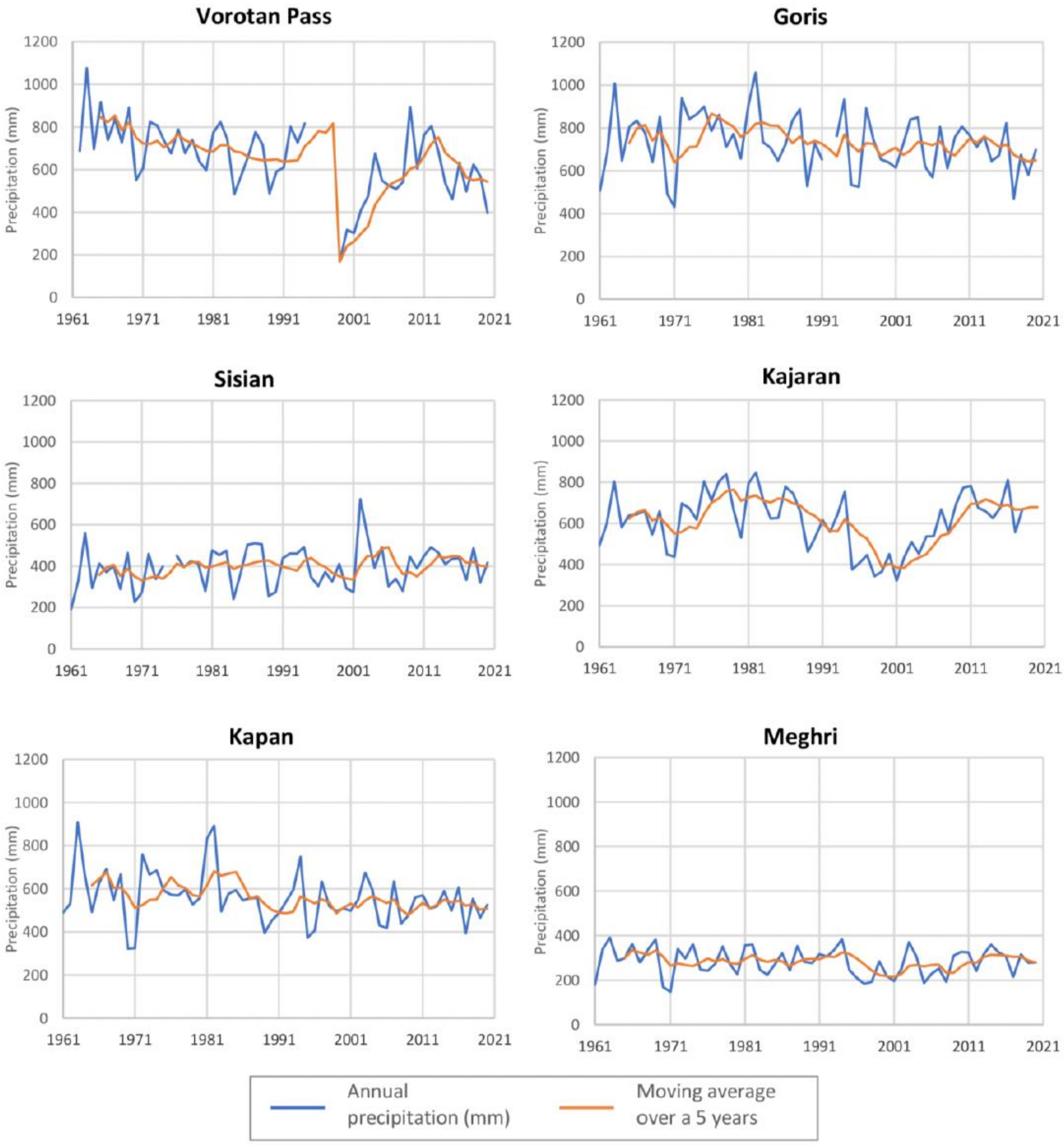


Figure 6. Observed annual mean precipitation at selected meteorological stations located in the southern part of Armenia (details regarding location and altitude of stations can be found in Table 1).

2.2.2 Projected Climate Change

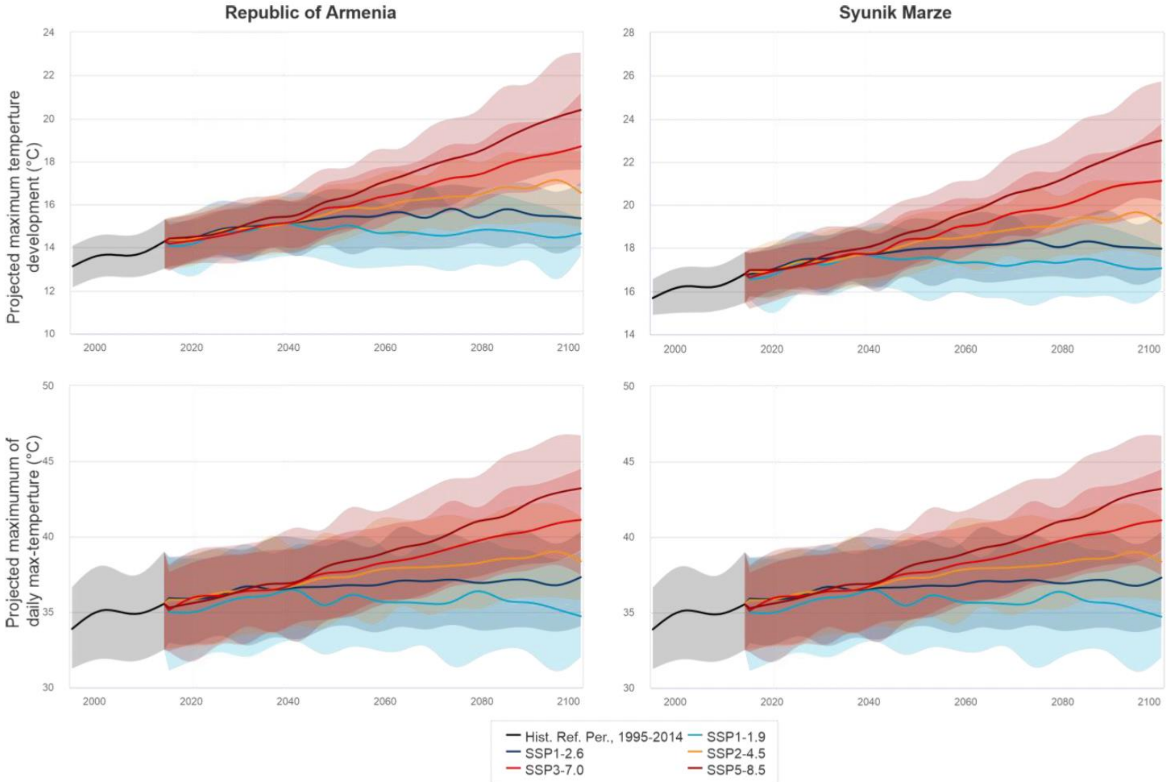
Projected climate change is based on various assumed scenarios that combine so-called shared socio-economic pathways (SSPs) and representative concentration pathways (RCPs). The SSPs characterise how socio-economic circumstances may unfold into the future and the likely associated greenhouse gas emissions while the RCPs indicate the resultant likely greenhouse gas concentrations (bearing in mind that it is the greenhouse gas *concentrations* that are the direct cause of global warming). In combination the two provide future possible climate change scenarios as follows:

- SSP1: Sustainability (taking the green road)
  - SSP1-1.9: Very low GHG emissions (net zero CO_2 emissions around 2050)
  - SSP1-2.6: Low GHG emissions (net zero CO_2 emissions around 2075)
- SSP2: Middle of the road
  - SSP2-4.5: Intermediate GHG emissions (CO_2 emissions around current levels until 2050 and then falling, but not reaching, net zero by 2100)

- SSP3: Regional rivalry (a rocky road)
    - SSP3-7.0: High GHG emissions (CO_2 emissions doubling by 2100)
- SSP4: Inequality (a road divided)
- SSP5: Fossil-fuelled development (taking the highway)
    - SSP5-8.5: Very high GHG emissions (CO_2 emissions triple by 2075)

Despite advances in the accuracy of climate models, they are always simplifications of very complex processes that have significant day to day variability either human induced or naturally driven. As such the focus is the likely exacerbation of natural hazards and within the context of the project, climate extremes, notably heavy or extreme precipitation. Predicting site-specific changes in heavy precipitation patterns due to climate change would require high-quality and high-resolution measurements.

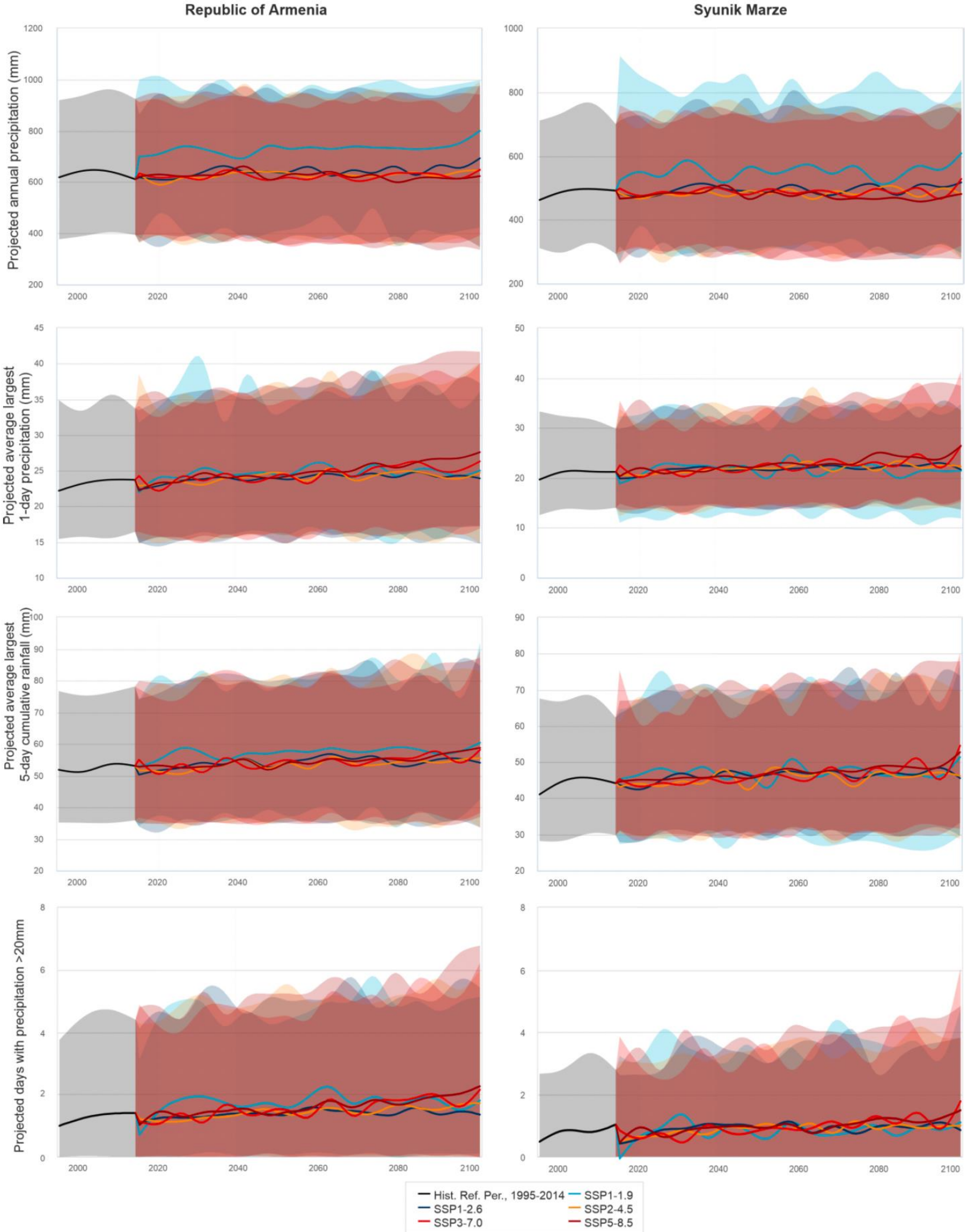
Such measurements are not available in the area for site-specific climate forecasting and so the results presented here rely on results of the GCM-RCM multi-model ensemble. The surface temperature in Armenia, including in Syunik Region, is predicted to increase at least until mid-century and will further increase for most of the climate scenarios (except SSP1-1.9) (**Figure 7**). The high-emission pathways SSP5-8.5, result in unabated temperature increases of almost 6°C by the end of the century (**Figure 7** and **9**). By mid-century (2040-2059), (the planned project lifetime), the projected maximum of daily max temperature is expected to be 33.5 °C (31.9 °C to 35.9 °C) and 35 °C (33.8 °C to 36.6 °C) for SSP1-1.9 ensemble and SSP3-7.0 ensemble, respectively (World Bank Group 2021).



Source: World Bank Group 2021.

Figure 7. Projected temperature development for Armenia (left panel) and Syunik Region (right panel) for different socio-economic pathways. Top panel: projected maximum temperature development; bottom panel: projected maximum of daily max-temperature

The projected annual, mean maximum 1-day, mean maximum 5-day cumulative rainfall, and days with more than 20 mm are shown in **Figure 8**. These projections are especially important for this project as heavy precipitation would increase the magnitude and frequency of gravitational hazards, such as mudflow, rockfall and landslides. Projected annual precipitation exhibits no significant trend, in either Syunik Region (**Figure 8**, top panel) nor the rest of the country. Variability within the ensembles is, however, large. The projected average largest 1-day and 5-day precipitation (**Figure 8**, middle panels) increase over time for all climate pathways as do forecast days with more than 20 mm precipitation (also country-wide and for Syunik Region). Extreme rainfall days (defined as annual total precipitation when daily precipitation exceeds the 99th percentile of wet day) are forecast to increase from 22 to 32% by 2050 (USAID 2017). Heavy precipitation is likely to be more frequent and intense under future climatic conditions in Armenia and Syunik Region specifically.

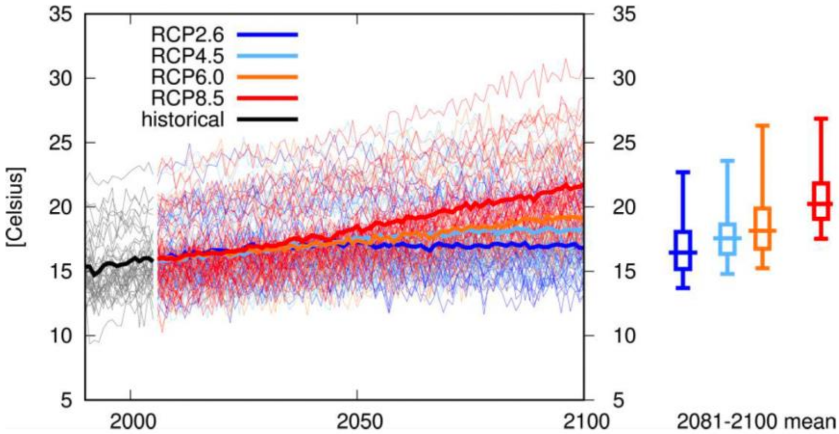


Source: World Bank Group 2021

Figure 8. Projected precipitation development for Armenia (left panel) and Syunik Marze (right panel) for different socio-economic pathways. Top panel: projected annual precipitation; 2nd panel from top: projected average maximum 1-day

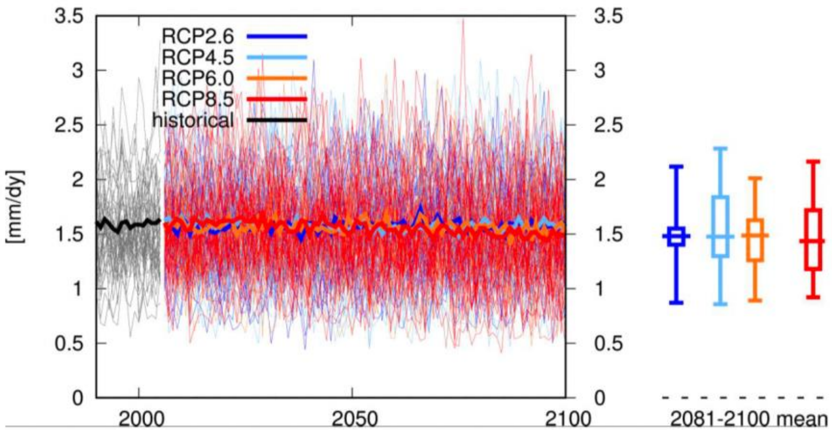
precipitation; 3rd panel from top: projected average maximum 5-day precipitation; bottom panel: projected days with precipitation >20 mm

Forecast future temperature and precipitation at the southern portal of the Bargushat tunnel are illustrated in **Figures 9** and **10.** Maximum near surface temperatures for all RCPs increase over time, with RCP8.5 exhibiting a some 5 °C increase by the end of the century. Precipitation changes over the next decades are highly variable (**Figure 10**). A key finding of the 6th IPCC report confirms the modelling data shown in **Figure 10**. Forecast changes in extreme precipitation intensity and frequency indicate a 1-day precipitation event that occurred once in 10 years on average would now occur once in a 3-year event) in a world 4°C-warmer than pre-industrial averages (+30.2 % at 4°C of warming) (IPCC, 2021).



Source: KNMI Climate Change Atlas

Figure 9. Projected maximum near surface temperature changes in the project region (Lat. 39°17’35’’ (N), Lon. 46°6’46’’ (E)) based on an ensemble of CMIP5[5] scenarios (left part of figure). The boxplots show average temperature over full CMIP5 ensembles for the period 2081-2100 (right part of the figure)



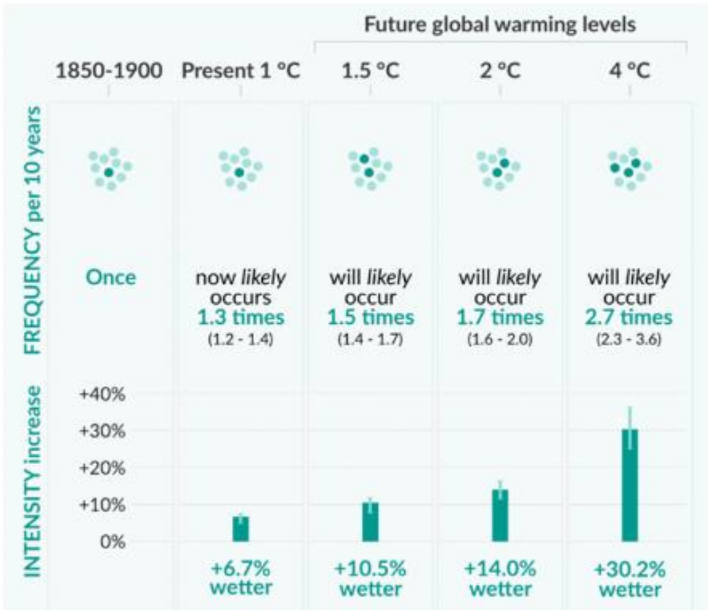
Source: KNMI Climate Change Atlas

Figure 10. Projected precipitation in the project region (Lat. 39°17’35’’ (N), Lon. 46°6’46’’ (E)) based on an ensemble of CMIP5 scenarios (left part of figure). The boxplots show average precipitation over full CMIP5 ensembles for the period 2081-2100 (right part of the figure)

[5] Coupled Model Intercomparison Project 5 is a collaborative framework designed to improve knowledge of climate change.

2.2.3 Climate Change Impacts

The projected increase in mean annual temperature of between 1.6°C and 2.2°C by 2050, would see significant changes to several hydrometeorological phenomena. In addition to the increase in intense daily rainfall events, increased storminess or more prolonged droughts could also be expected for Armenia (**Figure 11**). A changed climate will see quite different day to day weather patterns with negative effects such as reduced crop yields, damage to crops and livestock and increased soil erosion through extreme weather events. Reduced water supply (including reduced hydropower potential) and reduced water quality will provide additional challenges for water resources management in Armenia. Increases in extreme weather events causing flood and mudslide damage to roads, power lines, human settlements and other infrastructure can also be expected (e. g. USAID 2017; WB and ADB 2021).

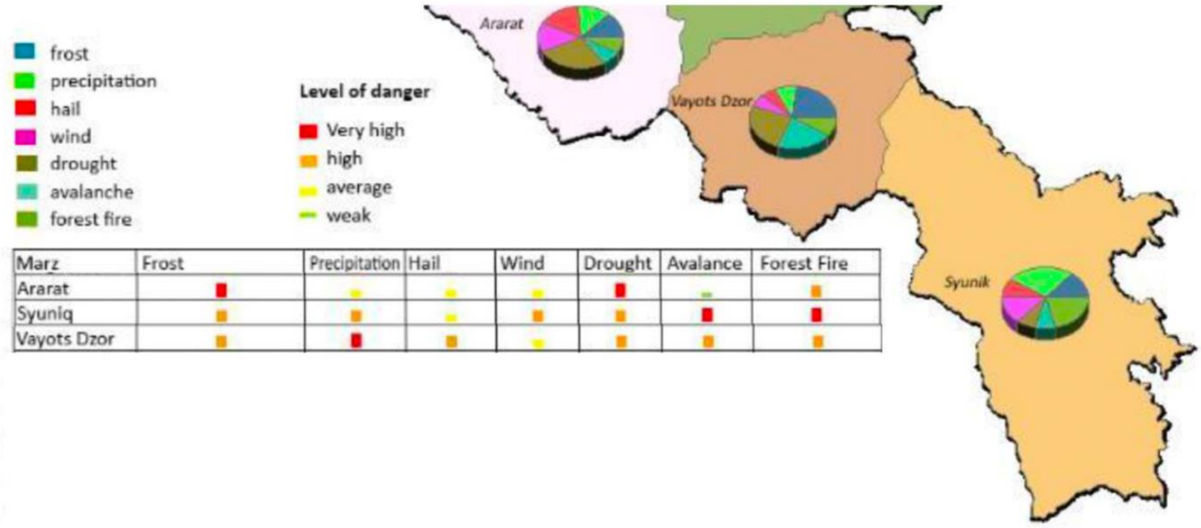


Source: IPCC 2021, p. 18

Figure 11. Projected changes in the intensity and frequency of extreme precipitation over land for global warming level 1°C, 1.5°C, 2°C, and 4°C compared to the baseline 1850-1900[6]

Armenia's fourth national communication on climate change to the UNFCCC details expected changes to frost, precipitation, hail, wind, drought, avalanches, and forest fires. Precipitation will be a key climate impact with significant risk, for Syunik Region. Avalanches and forest fires are similarly risky for road infrastructure in mountainous territory (**Figure 12**).

[6] Note to the figure: An extreme precipitation event is defined as the daily precipitation amount over land that was exceeded on average once in 10 years during the baseline period. 'Frequency' section: Each year is represented by a dot, whereas dark dots indicate years in which the extreme threshold is exceeded, while light dots are not. Bold values represent the medians and the values in parenthesis represent 5-95% range of the multi-model ensemble from simulations of CMIP6. The bars and the ranges displayed in the 'Intensity' section are based on medians and 5-95% range of the multi-model ensemble from simulations of CMIP6

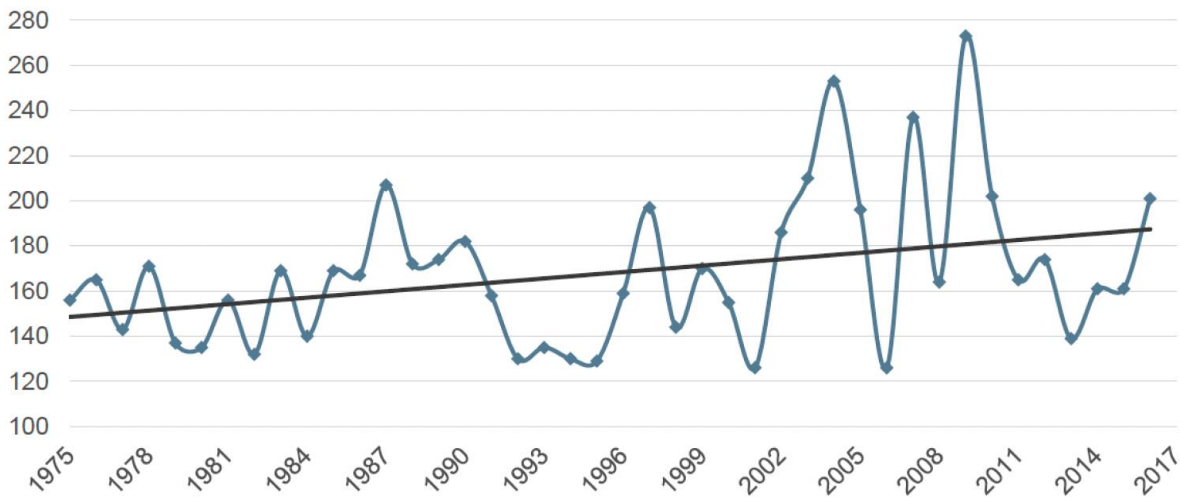


Source: adapted from the RA, 2020

Figure 12. Vulnerability of Armenia's southern regions to hazardous hydrometeorological phenomena

2.2.4 Climate Change-related Natural Hazards

In general, Armenia is characterized by a high frequency and magnitude of hazardous hydrometeorological phenomena that can result in natural disasters with potentially significant damage to both people and the economy. Such extreme weather events in Armenia have increased by 23.5% in the period 1975-2016 compared to the period 1961-1990 (RA, 2020) (**Figure 13**). These extreme weather events cause mudflows, floods, landslides and other natural hazards with negative impacts on the different economic sectors of Armenia. Such risks are further exacerbated in mountain areas. Some 4.1% of the country has landslide risk, with direct risks to communities and infrastructure. Between 1998 and 2010, weather-related natural hazards caused losses of some $2.8 billion, averaging $450 million per year (USAID 2017). Climate change is heightening Armenia's vulnerability, with increased frequencies of severe weather, worsening desertification and land degradation. The most vulnerable economic sectors are agriculture, human health, water resources, forestry, transport and energy infrastructure (NC4, 2020).



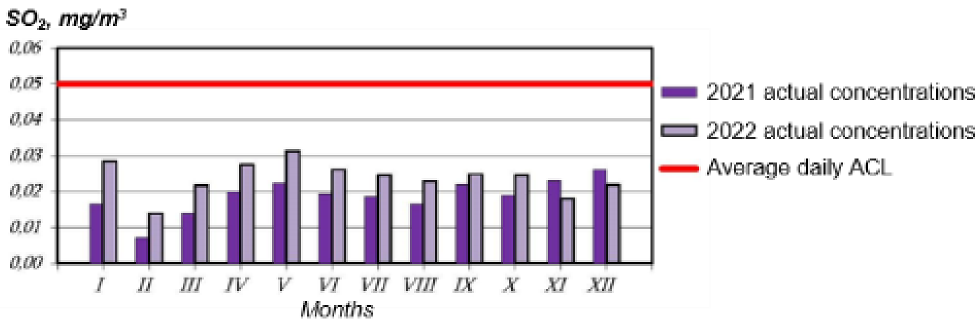
Source: RA, 2020

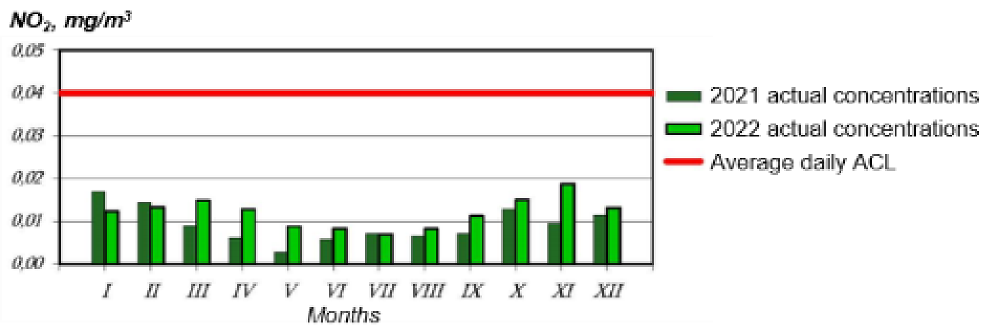
Figure 13. Cumulative number of cases of hazardous hydrometeorological phenomena, such as frostbite, hail, strong wind and heavy precipitation, observed during the period of 1975-2016 in Armenia

2.3 Ambient Air Quality

Ambient air quality in the Project area is considered to be relatively good, as it is located largely away from major industrial enterprises, such as the Zangezur Copper-Molybdenum Combine (a mine in Kajaran Town, see **Figure 22**). Darbas area of Sisian Community hosts small polluters including “Tatni” mineral water bottling plant, “Darbas” carbonated drinks plant and Shamb hydropower plant. Five small hydropower plants (SHPPs) are located within Lernadzor administrative area of the Kajaran community, far from the Project site. Vehicle emissions are small in the road’s southern part (Kajaran) because of the very small population and low traffic volumes. Vehicle emissions are considered to be larger in the northern section, due to a bigger population, traffic volumes and economic activities.

Ambient concentrations of sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) in Kajaran are monitored by the Hydrometeorology and Monitoring Centre State Non-Commercial Organization (SNCO)[7]. Concentrations measured during 2021-2022 in Kajaran were below the 0.05 mg/m^3 and 0.04 mg/m^3 average daily Admissible Concentration Limits (ACLs) respectively, set by the RA Government Decree No. 160-N[8]. The results of SO_2 and NO_2 monthly monitoring performed by the Hydrometeorology and Monitoring Centre in 2021-2022 are presented in their annual bulletins[9]. The diagrams extracted from the 2022 annual bulletin showing the SO_2 and NO_2 actual concentrations compared with the ACLs are presented below:





For the current ESIA, ambient SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10} concentrations were measured at 22 receptors identified during the Project’s ESIA Scoping (see the map in **Annex 1**). Potential receptors were selected from socially important facilities such as residential houses, schools, shops, churches, museums or other buildings used locally in each village along the road that could be affected by air emissions and might be sensitive to air quality impacts. Each location is described in **Annex 1.** Several measurement points were selected along/near the

[7]Annual information bulletin on environmental conditions in the Republic of Armenia. Note that no air quality monitoring is carried out by the state Hydrometeorology and Monitoring Centre in other settlements of the Project area.
[8]RA Government Decree No. 160-N, 02.02.2006 (https://www.arlis.am/documentview.aspx?docid=86441)
[9]http://armmonitoring.am/page/69.

existing roads that could be affected negatively by construction and/or operations of the proposed roadway.

Ambient CO, $PM_{2.5}$ and PM_{10} concentrations were measured using continuous samplers from 3-9 June 2022. To determine the average ambient CO, $PM_{2.5}$ and PM_{10} concentrations, three measurements were conducted at each sensitive point at different times of the day and an average daily concentration calculated. Ambient SO_2 and NO_2 concentrations were determined using passive samplers (that absorb ambient SO_2 and NO_2 over the period for which they are exposed), which were installed at selected locations for 10-12 days in June 2022. The passive samplers were analysed in the state laboratory of the Hydrometeorology and Monitoring Centre, SNCO. The measurement results were compared with the ACLs for SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10} that are set out in the RA Government Decree No.160-N and the WHO Air Quality Guidelines (AQG) (**Figure 14** to **Figure 17**) (please see Box 2 for an explanation on the validity of these campaign measurements).

Table 2. Locations of the air quality sampling points

Sisian-Shenatagh section	
S1	Intersection of the M2 road with the starting point of the proposed Project Road, Ojax restaurant
S2	Aghitu village
S4	Vaghatin village
S7	In front of Shamb HPP
S10	Darbas village
S12	Lor village
S14	Shenatagh village
ER1*	Aghitu village, near the school
ER2	Noravan village, near the school
ER3	Darbas village, near St. Stephan Church
ER4	Getatagh village, near Holy Mother Church
ER5	Lor village, near St. Gevorg church and residential houses
ER6	Shenatagh village, near the Memorial to R. Vasiryan
K1	Unpopulated area located at the distance of approx. 1.5km to the north from the crossing point of the existing road with the road to Nor Astghaberd
Qirs-Kajaran section	
K3	Geghi settlement
K5	Geghi (Verin Geghavank) settlement
K8	Geghi (Geghavank) settlement. After the dam of Geghi Reservoir
K9	Kavchut settlement
K10	Lernadzor settlement
K11	Lernadzor settlement area. Near Electrical substation / Pump station
ER7	Kavchut settlement, near the 3-storey multi-residential buildings
ER8	Near the commercial facility located at the crossing point of M-2 road and the existing road to Qirs settlement

**ER - sensitive points located along/near the Existing Roads that could be affected negatively by construction and/or operations of the proposed roadway.*

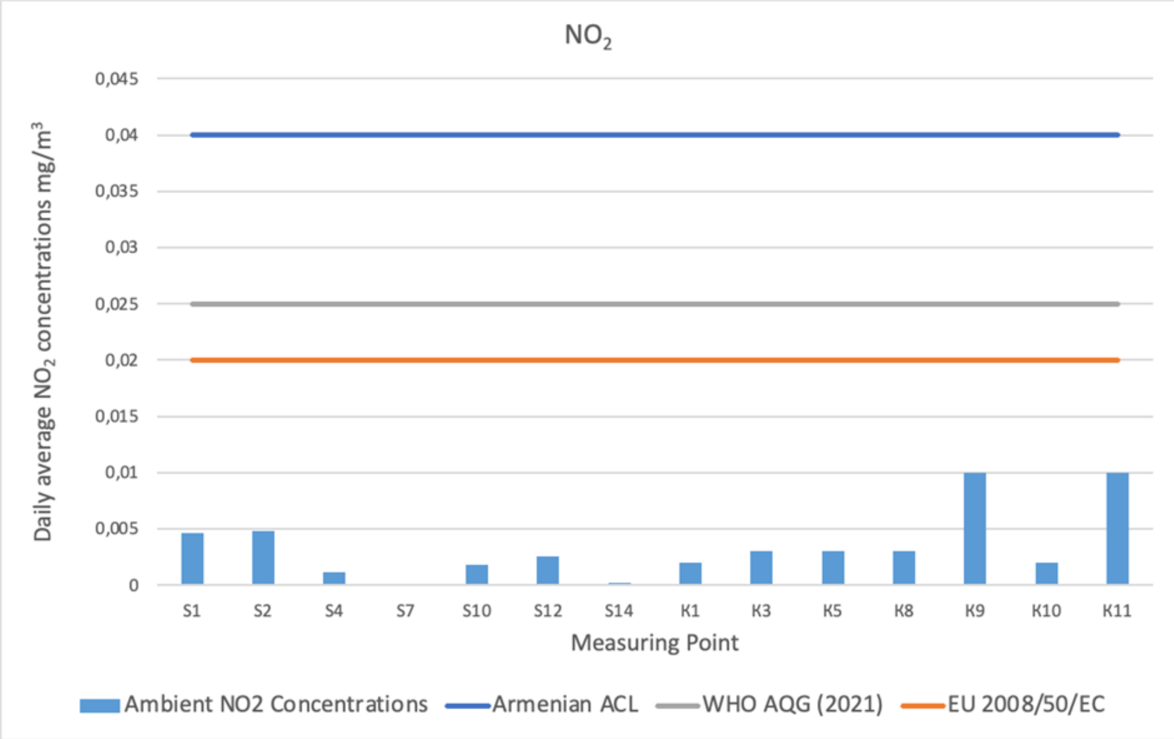


Figure 14. Ambient daily average NO_2 concentrations as measured during the ESIA campaign, for various points along the road routing compared to the Armenian ACL, and WHO Air Quality Guidelines (2021). Note that there is no hourly limit for NO_2 in the 2005 guidelines. The sampling points are summarised in Table 2

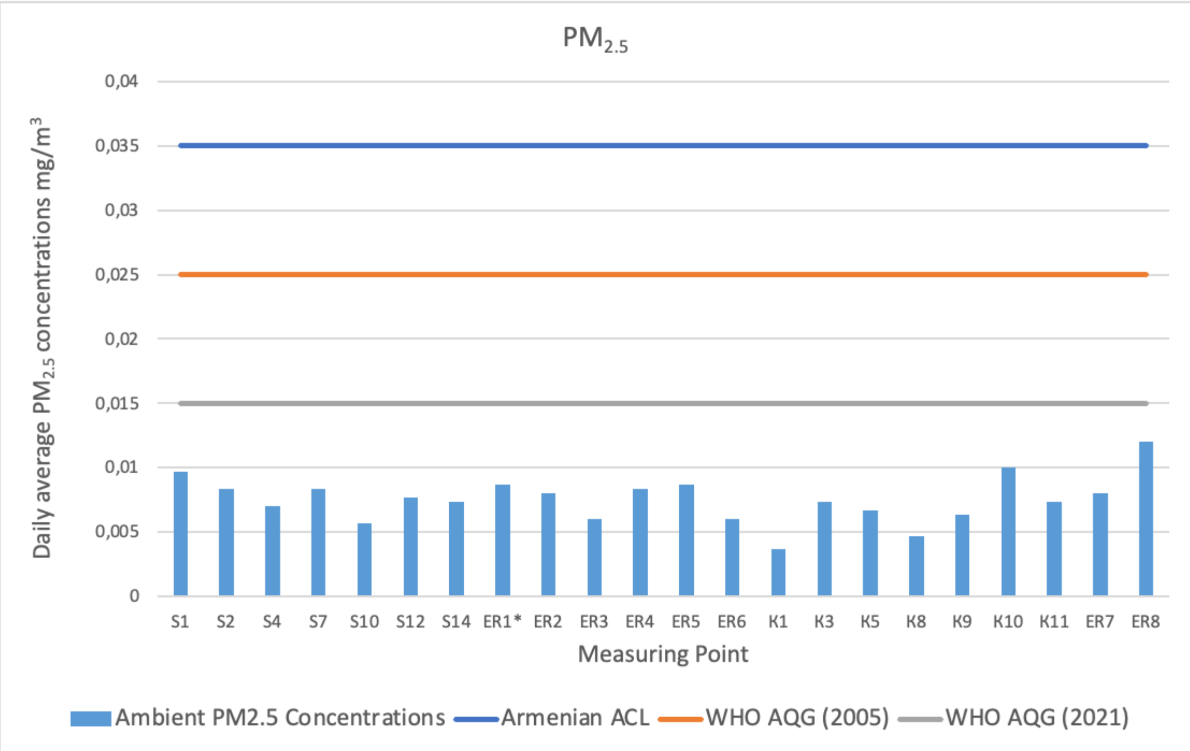


Figure 15. Ambient daily average $PM_{2.5}$ concentrations as measured during the ESIA campaign, for various points along the road routing compared to the Armenian ACL and WHO Air Quality Guidelines (2005 and 2021). The sampling points are summarised in Table 2

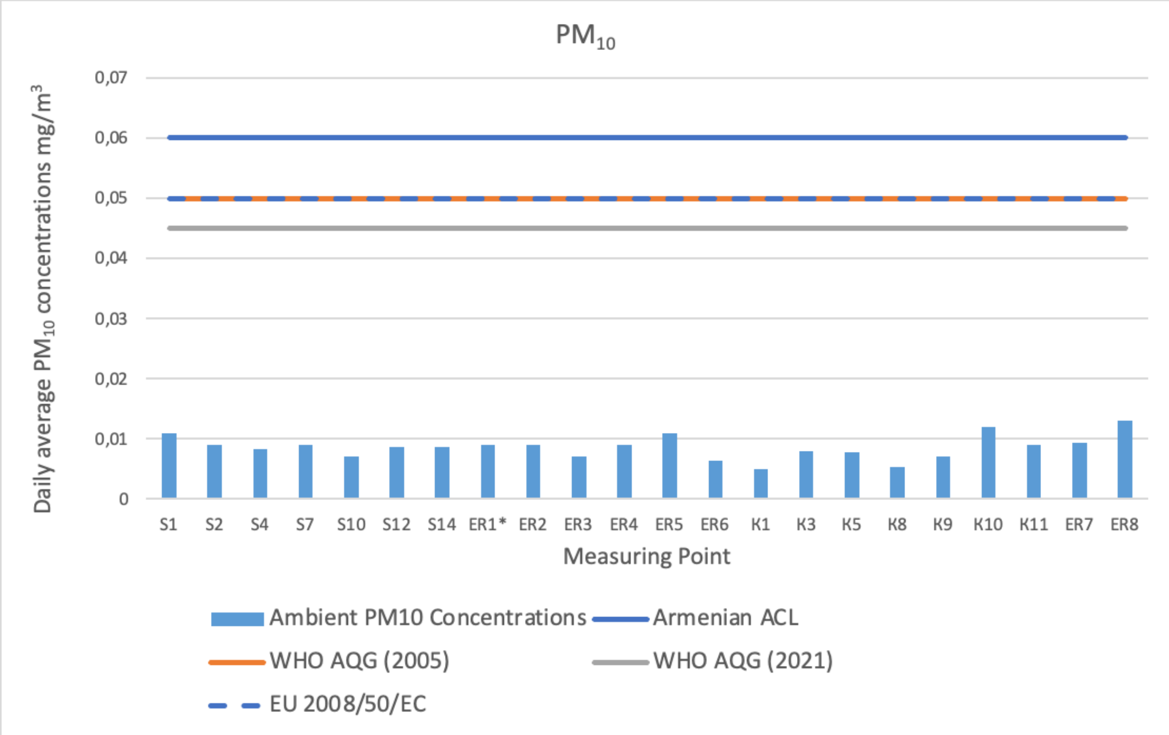


Figure 16. Ambient daily average PM_{10} concentrations as measured during the ESIA campaign, for various points along the road routing compared to the Armenian ACL and EU 2008/50/EC standards and WHO Air Quality Guidelines (2005 and 2021). The sampling points are summarised in Table 2

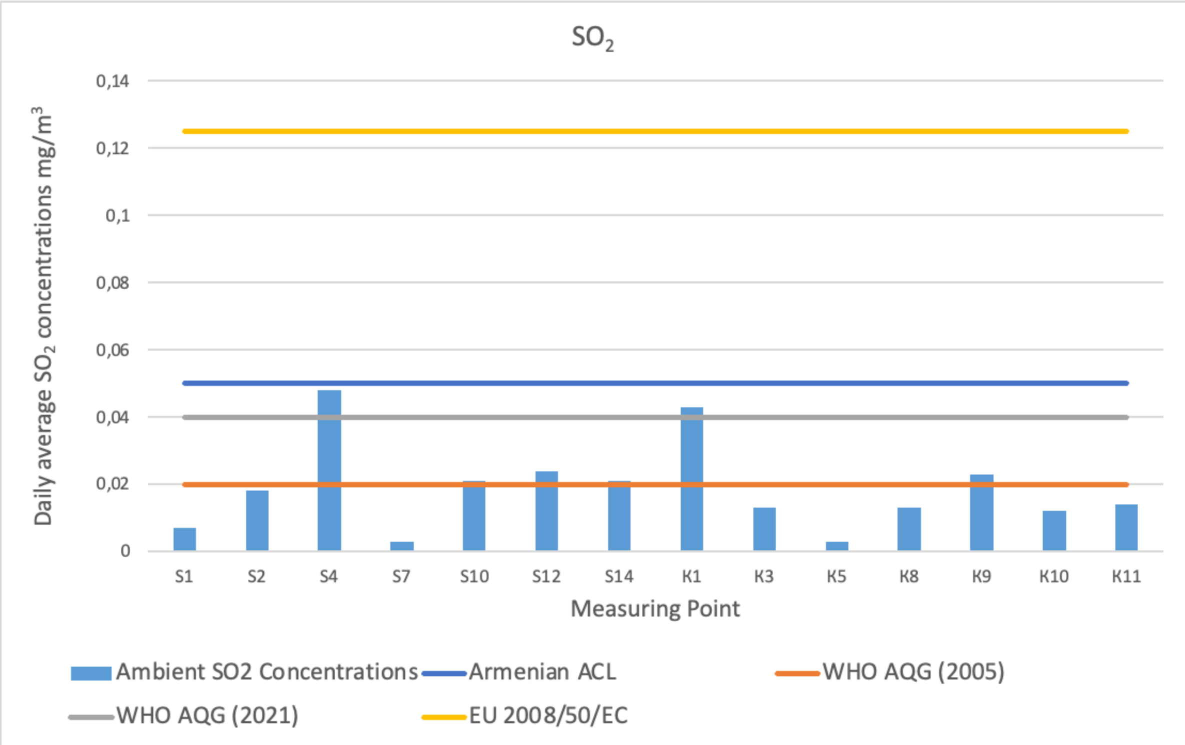


Figure 17. Ambient daily average SO_2 concentrations as measured during the ESIA campaign, for various points along the road routing compared to the Armenian ACL and EU 2008/50/EC standards and WHO Air Quality Guidelines (2005 and 2021). The sampling points are summarised in Table 2

The measured ambient SO_2, NO_2, CO, $PM_{2.5}$ and PM_{10} concentrations at all measurement points are within the ACLs set by the national regulations and in most instances comfortably so. The measured concentrations are also seen to comply with the 2005 WHO guidelines but not with the slightly more stringent 2021 guidelines (see these in **Section 3.1**). Measured ambient SO_2, concentrations exceed the WHO guidelines in two locations, namely, in Vaghatin village and at K1 (an unpopulated area located approximately 1.5km north of the crossing point of the existing road with the road to Nor Astghaberd). Measured concentrations of CO in Kavchut are more than three times the WHO AQG.

The results suggest that the prevailing air quality is generally good with some localised pollution sources such as domestic (household) fuel use, resulting in elevated SO_2 concentrations at some points along the roadway (although most of the measured concentrations are no more than half the 2021 AQG). The air quality data presented here must be used with caution, however, as it is a very limited sample representing a particular time and place and not necessarily representative of the air quality that may prevail for the entire year. The logistics and costs of obtaining a fully representative years' worth of air quality monitoring data, precludes obtaining such data. The monitoring data must be seen as no more than indicative for the purposes of the assessment.

2.4 Topography

The Sisian-Kajaran road section is entirely located within Syunik Region. The terrain along the proposed road is highly complex with diverse topography (Figure 18). The topography combines fold, coulisse-shaped and linearly stretched mountain ranges, volcanic massifs, upland plateaus, intermountain concavities, and river valleys. Mountain slopes are intensively weathered (eroded) with steep slopes (35° and more) and fragmented by the Vorotan, Voghji and Geghi River Valleys. The Bargushat ridge (which will be traversed by the road section) is located on the hillside of the Zangezur Mountain Range and extends for 42 km amid the Vorotan and Voghji River Basins. Peaks reach over 3,000 m, particularly Aramazd – 3,392 m, Geghaqar – 3,343 m, and Tarkatar – 3,277 m. The mountain Range descends in the south-east (near Kapan).

Greater Ishkhanasar, located 9 km northeast of the village of Noravan, is the highest point of the Project region (3,549 m). The Noravan River, the Metsdzor and Vaghatin tributaries of the Vorotan River and the Shamb River flow from the slopes of this mountain. The mountain is of volcanic origin and its steep slopes are dissected by deep gorges and crevasses. The relief of the Project region is shown in **Figure 18** and briefly described below:

a) slopes and plateaus (1,500-2,800 m) "armoured" with lava sheets; folded structures slightly dissected in the base and rugged with disturbances (section of the southern foot of Mount Ishkhanasar),

b) lava-covered marginal plateaus (1,100-2,200 m) on slightly sloped, folded structures (from highway M2-Meghri to Vorotan river gorge),

c) wide valleys with gully and terraces (wide valley of the Vorotan river, a section adjacent to Shamb reservoir),

d) V-shaped narrow valleys (valley and tributaries of the Shenatagh and Geghi rivers),

e) transverse and oblique mountain ranges and plateaus that are sedimentary-volcanogenic, with carbonate intensive folded base (the northern mountain slope of the Bargushat ridge beginning from Aramazd mountain summit),

f) structural erosive relief, high mountains (over 2,800 m), represented by forms of snow-glacial relief, severely dissected, sharp and rocky crests, sloping sides up to 350m (the southern mountain slope of the Bargushat ridge beginning from Aramazd mountain summit),

g) with steep slopes (up to 250-350m), slightly wavy watershed, northern, eastern and southern mountain slopes of the eastern mountain arm of the Zangezur ridge (to the north of Kajaran).

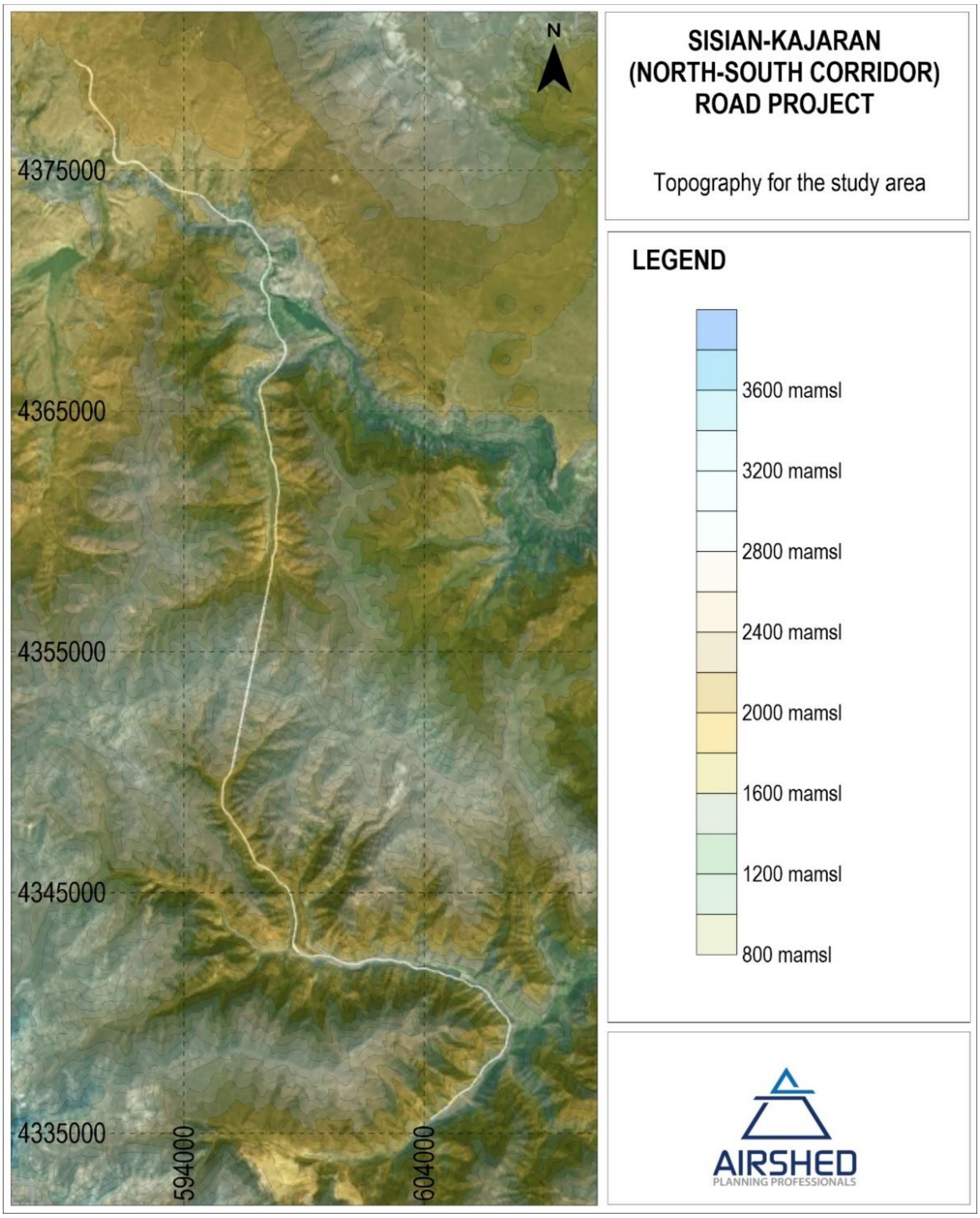


Figure 18. The topography of the proposed roadway

2.5 Geology, Geological Hazards and Processes, and Seismicity

The starting (northern) section of the planned road is characterized by volcanic rocks of the Greater Ishkhanasar volcanic massif: Upper Pliocene - Eo-pleistocene period represented by basalt, andesite, dacite, rhyolite, obsidian, perlite, tuff-breccia, travertine (3.3-0.85 the absolute age in million years)[10]. There are numerous volcanic centres. The above-mentioned rocks are mainly covered with quaternary loose deposits: deluvial, proluvial, alluvial, eluvial colluvial. The bed and washout of the Vorotan River, as well as the terraces are lacustrine,

[10] For the geological map of Armenia (2015) refer to Republican Geological Fund of Armenia at https://www.geo-fund.am/filemanager/maps-02.pdf.

fluvial proluvial and slope deposits of Upper pliocene - pleistocene age (3.3-0.01 the absolute age in million years).

Within the section between the Vorotan River valley and the Bargushat mountain slope, the volcanic - sedimentary rocks, such as andesites, tuff-breccias, tuff sandstones, marl stones, limestones, clays, argillaceous sandstones, aleurolites and olivine basalts occur. The Bargushat ridge has comparably large and small granitoid bodies, which become exposed between the Voghji and Vorotan Rivers, in the central and western boundaries of the mountain range.

The road section passes through the Shenatagh (northern slope of the mountain range) and Karut (southern slope of the mountain range) intrusions or their middle part (tunnel section). The Shenatagh intrusion occupies a larger area (100-120 km^2) than the Qirs - Karut intrusion (about 50km^2).

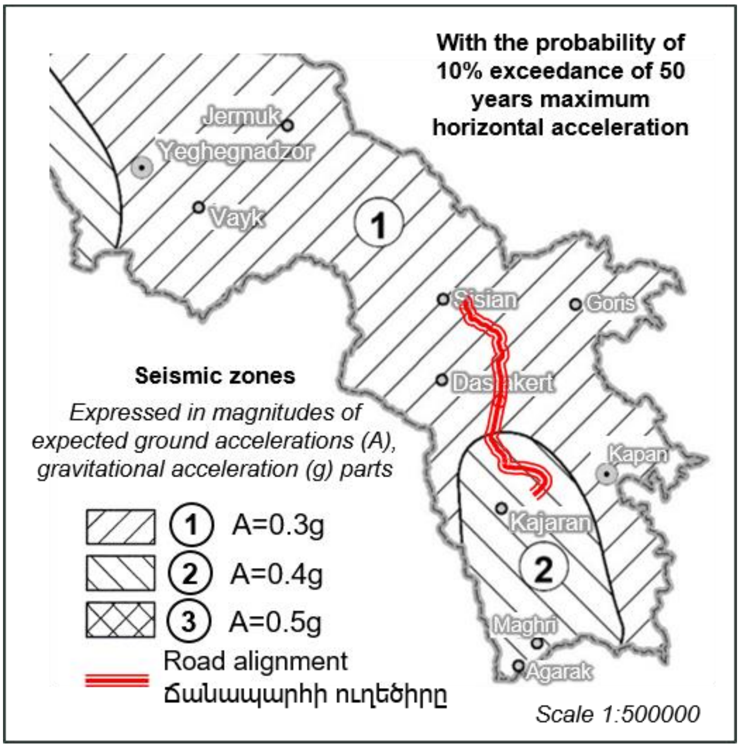
These two intrusions contain similar rocks: gabbro, pyroxenite, gabbrodiorite, monzonite, granodiorite and pink syenites. Two other intrusions (50-60 km^2), Kazangel and Geghi, are prominent on the southern slope of the Bargushat ridge. They contain porphyrites and limestones of Lower Jurassic age located in the contacting part of powerful normal granite and granodiorite massif. The Kazangel intrusion also contains Lower Jurassic porphyrites and pink porphyrite granodiorites. The valley of the Geghi River contains basalts, andesites, tuff sandstones, tuff-aleurolites, limestones and alluvial (fluvial) deposits of Upper Jurassic - Lower Cretaceous age. The right-bank slope of the Geghi river and the left-bank slope of the Voghji river up to the entrance to Kajaran contains Lower Cretaceous limestones, aleurolites, metamorphic laminated limestones, tuff sandstones, basalts, andesite basalts (135-96 million years), as well as limestones, sandstones, quartz sandstones, clay shales of Devonian - Lower Carbon age (385-315 million years). Near the entrance to Kajaran, gabbroes, granodiorites, quartz diorites, monzonites, nephelinic syenites, leucogranites of Upper Eocene age (42-38 million years) also appear.

As per the RA Construction Norms (HHShN) 20.04 “Earthquake-resistant construction and design norms”[11], Armenia is divided into 1st, 2nd and 3rd seismic zones, with the last the most seismically hazardous. The magnitudes of expected ground horizontal accelerations per seismic zones are:

Seismic zones	**1st**	**2nd**	**3rd**
Ground horizontal accelerations magnitudes **a**, cm/sec^2	300	400	500

The road alignment will run through only the 1st (Sisian-Shenatagh section and Bargushat tunnel) and 2nd (Qirs-Kajaran section) seismic zones (**Figure 19**). **Thus, the Project is not within the most seismic zones of Armenia.**

[11] https://www.arlis.am/documentview.aspx?docid=148897



Source: RA Construction Norms (HHShN) 20.04

Figure 19. Extract from the map of zoning of probable seismic risks in the RA territory

The seismic zones of settlements located along the proposed road alignment are given in Table 3. The design refers to national standards that guide earthquake resistant construction and design, and specific measures required for developments in each seismic zone were used in the Project design. According to the independent technical assessment of the Project's detailed design, additional improvements are recommended to increase the stability of two retaining walls[12].

Table 3. Seismic zones of settlement located along the proposed road alignment
(Extract from Annex 2 of RA Construction Norms (HHShN) 20.04)

Settlement	Seismic zone	Settlement	Seismic zone
Sisian Community		Kajaran Community	
Sisian town	1	Kitsk (Qirs) village	1
Noravan village	1	Geghi village	2
Aghitu village	1	Geghavank village	2
Uyts village	1	Nor Astghaberd village	2
Vaghatin village	1	Kavchut village	2
Vorotan village	1	Babikavan village	2
Shamb village	1	Zagikavan	2
Darbas village	1	Lernadzor	2
Lor village	1	Kajaran town	2
Getatagh village	1		
Shenatagh village	1		

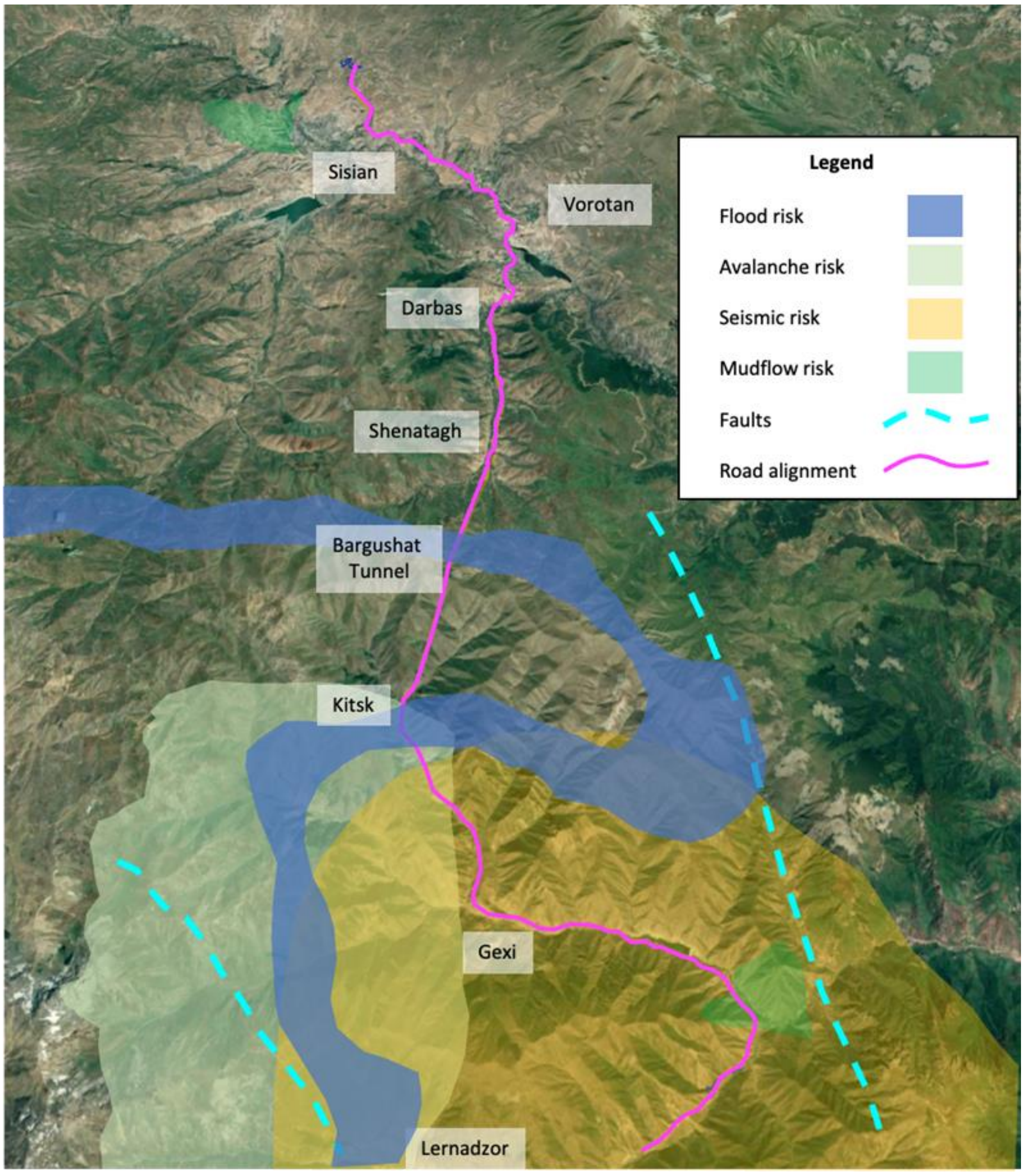
[12] Bernard Gruppe. 15.09.2022. Sisian-Kajaran (North-South Corridor) Road Project. Report No.2. Task 7 review of Detailed Design.

Erosion is mainly anthropogenic due to mine operations around Kajaran and Ajabaj village in the Geghi River basin as well as the Loradzor River basin. The slopes surrounding Shenatagh village are subject to erosion due to the density of earth roads. Soils are highly erodible in the proposed road's southern section and perhaps to a slightly lesser degree on the northern side.

Erosion caused by livestock husbandry, uncontrolled establishment of earth roads, and use of fallow agricultural lands are observed on slopes close to almost all settlements within the Project region. Avalanches are observed upstream the Voghji and Geghi Rivers, at altitudes of 1,400- 3,400 m. The most damaging avalanche occurred in the Vorotan River basin in 1988, at a volume of 96,000 m^3. The Project is situated in medium and low natural hazards risk areas in the RA[13]. Part of the Sisian-Shenatagh road section runs through medium mudflow risk areas (see the map below).

A stylized map is shown of geohazards known to exist along the prosed road alignment including flooding, avalanche, seismic and mudflow risks. Two major faults are also shown. These geohazards prevail in the southern part of the alignment. The mudflow risk evident in the northern part of the alignment is too far away from the road to be considered a risk in its own right.

[13] Water Resources Atlas of Armenia, Yerevan, 2008.



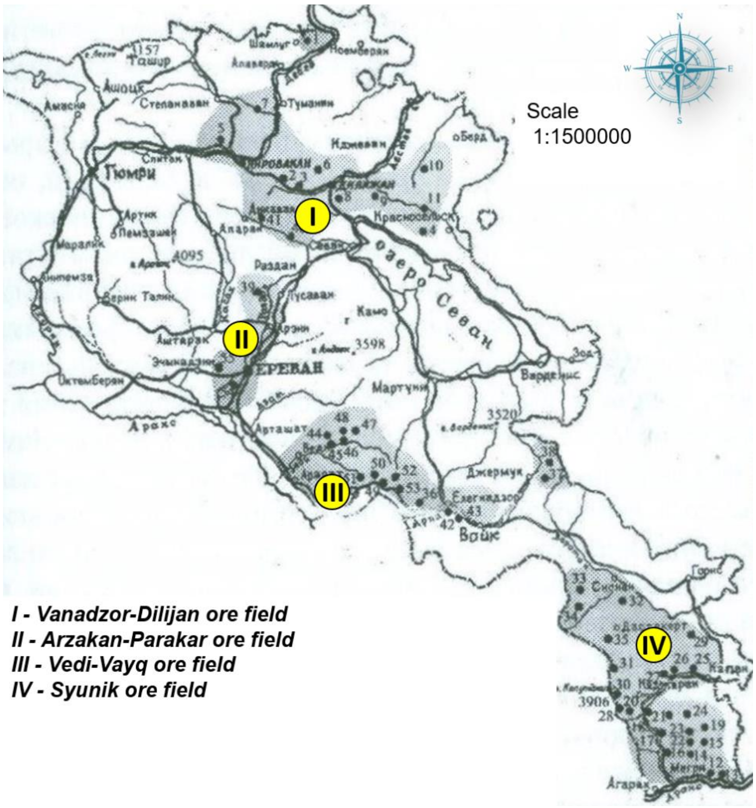
Source: Drawn based on the information provided by Technical Consultant (Bernard's team) in January 2023

Figure 20. Stylised map of geohazards along the proposed roadway

2.6 Radioactivity and Uranium-Bearing Formations of the Region

According to previous geological exploration[14], Armenia can be conditionally divided into four ore fields with radioactive elements (see **Figure 21**).

[14] P.G. Alayan, Uranium-containing geological formations in Armenia. Engineering Academy of Armenia, Yerevan 2010



Source: P.G. Alayan, Uranium-containing geological formations in Armenia. Engineering Academy of Armenia, Yerevan 2010

Figure 21. Uranium-bearing ore fields and districts

The Syunik (Zangezur) ore field is situated in the interfluve area of the Vorotan, Vogchi and Araks Rivers, in a deep fault zone with several regional disturbances (Debakli-Ayriget and Khustup-Giratagh) trending northwest. The uranium-bearing ore districts in the vicinity of the Project area are No. 25 (Pakhrut) and No. 26 (Hand).

The Pakhrut fault is located 5-6 km to the east of the Kajaran copper-molybdenum mine, on both slopes of the Vogchi River's canyon. The exo-contact stripe of intrusion is more than 1.5km long and 0.6km wide, and stretches northwest, in parallel to the Lernadzor fault. The ore district has been explored through several horizons using boreholes and underground drilling. The Vogchi, Lernadzor and Pakhrut deposits were identified in these studies. The ores of Pakhrut deposit are uranium-molybdenum and silica-carbonated by the content of non-metallic components and of uranium type by and the nature of their radioactivity. Initial calculations[15], indicate uranium reserves of the Pakhrut deposit around 20,000 tonnes including 12,000 tonnes of forecast resources. The average content of uranium in ore is around 0.2%.

The Hand fault neighbours the Pakhrut-Lernadzor ore field and contains 22 ore bodies with only one explored in detail. The fault stretches northeast and has a steep slope. Average uranium content is 0.2-0.3% reaching 1.0% at some locations. The uranium content ranges from0.056-0.53% at the other ore bodies.

Faults of the Syunik ore field are hydrothermal uranium-molybdenum types and represented by veins, column-shaped and nest-shaped bodies with the average uranium content of 0.1-0.3%. The uranium-bearing deposit nearest to the Project road is the Pakhrut deposit, which

[15]Ibid

is 5-6km from the Kajaran copper-molybdenum mine. The location of the Pakhrut and Hand uranium-bearing deposits relative to the planned road is shown in **Figure 22**.

Figure 22. Location of the uranium-bearing deposits relative to the Project road

2.7 Soil

The Project region has the following soil types (see also **Figure 23**), as per the Water Resources Atlas of Armenia:

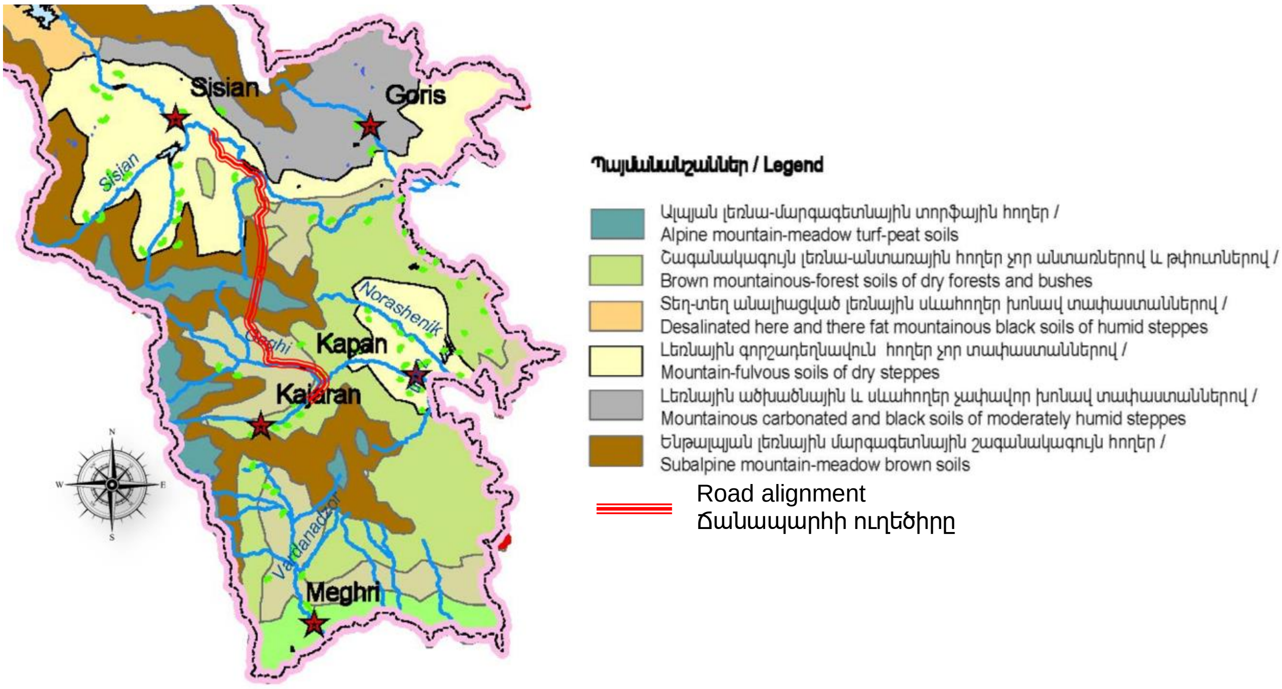
a) Mountain-fulvous soils of dry steppes,

b) Brown mountainous-forest soils of dry forests and bushes,

c) Subalpine mountain-meadow brown soils,

d) Mountainous-forest steppe soils, and

e) Alpine mountain-meadow turf-peat soils.



Source: Water Resources Atlas of Armenia, Yerevan, 2008

Figure 23. Map of Soil Types in Syunik Region and Project Area

The previous EIA of 2019 contained no data on soil quality and composition for the Project within the study area.

During the ESIA Scoping, ten soil sampling points were identified (see the maps in **Annex 1**) of which six were located in Sisian-Shenatagh and four in Qirs-Kajaran sections. The points were selected as they are located within the settlements (next the residential houses and commercial buildings (such as Ojax restaurant)), that will be crossed by the proposed road, hence potentially contaminated during Project construction and operations. Soil sampling was conducted on 4 and 15 May 2022. Soil samples were analysed using the ISO 17294-2:2016 standard method in the state laboratory of the Hydrometeorology and Monitoring Centre, SNCO.

Results of the soil analyses compared to the ACLs for chemical elements in soil set out in the Sanitary Rules and Norms No. 2.1.7.003-10 "Hygienic requirements for soil quality"[16] are given in **Table 4** for the soil samples for the Sisian-Shenatagh section, and in **Table 5** for the soil samples taken from the Qirs-Kajaran section.

Table 4. Concentrations of chemical elements in soil samples taken from the Sisian-Shenatagh section compared with the Armenian ACLs

No	Chemical elements	Unit	Results of analysis						ACL of chemicals in soil
			S1	S2	S4	S10	S12	S14	
1	Lithium	gr/kg	0.00134	0.00116	0.000813	0.00843	0.00435	0.00379	-
2	Beryllium	gr/kg	0.00205	0.00177	0.00280	0.00192	0.00119	0.00184	-
3	Boron	gr/kg	0.0395	0.0463	0.0362	0.0362	0.0330	0.0367	-
4	Sodium	gr/kg	3.56	3.23	5.16	3.11	3.34	3.70	-
5	Magnesium	gr/kg	0.0334	<0.01	<0.01	0.303	1.02	0.574	-
6	Aluminium	gr/kg	5.37	1.92	4.57	6.377	8.14	8.556	-

[16] https://www.arlis.am/DocumentView.aspx?docid=146741

No	Chemical elements	Unit	Results of analysis						ACL of chemicals in soil
			S1	S2	S4	S10	S12	S14	
7	Total phosphorus	gr/kg	1.66	3.38	2.46	1.46	2.42	2.38	-
8	Potassium	gr/kg	14.44	16.46	16.05	11.69	11.80	13.05	-
9	Calcium	gr/kg	0.699	0.713	0.334	0.818	4.15	1.43	-
10	Titanium	gr/kg	3.44	2.96	3.76	3.17	2.44	3.27	-
11	Vanadium	gr/kg	0.101	0.0860	0.127	0.122	0.105	0.146	0.15
12	Chrome	gr/kg	0.0524*	0.0380	0.0368	0.0346	0.0294	0.0152	0.006
13	Iron	gr/kg	21.16	12.64	19.95	25.53	18.81	30.40	-
14	Manganese	gr/kg	0.311	0.386	0.291	0.265	0.250	0.366	1.5
15	Cobalt	gr/kg	0.0167	0.0133	0.0162	0.0146	0.0128	0.0168	0.005
16	Nickel	gr/kg	0.0505	0.0386	0.0433	0.0304	0.0191	0.0165	0.004
17	Copper	gr/kg	0.157	0.0581	0.0636	0.0454	0.0485	0.0457	0.003
18	Zinc	gr/kg	0.0870	0.0965	0.0681	0.0509	0.117	0.0675	0.023
19	Arsenic	gr/kg	0.00955	0.00689	0.00799	0.0139	0.0163	0.127	0.002
20	Selenium	gr/kg	0.00298	0.00266	0.00167	0.00244	0.00295	0.00237	-
21	Strontium	gr/kg	0.0334	0.0929	0.0287	0.0417	0.0479	0.0293	-
22	Molybdenum	gr/kg	0.00323	0.00162	0.00212	0.00129	0.00122	0.00330	-
23	Cadmium	gr/kg	0.000416	0.00030	0.000280	0.000188	0.000303	0.000224	-
24	Tin	gr/kg	0.00151	0.00140	0.00138	0.000710	0.00240	0.00105	-
25	Antimony	gr/kg	0.000651	0.000686	0.000455	0.000358	0.00101	0.00138	0.0045
26	Barium	gr/kg	0.0553	0.0279	0.0527	0.0567	0.0644	0.0641	-
27	Lead	gr/kg	0.0190	0.0181	0.0183	0.0151	0.0439	0.0166	0.032

Values that exceed the national standards are marked in orange.

Table 5. Concentrations of chemical elements in soil samples taken from Qirs-Kajaran section compared with the Armenian ACLs

No	Chemical elements	Unit	Results of analysis				ACL of chemicals in soil
			K1	K3	K9	K10	
1	Lithium	gr/kg	0.00348	0.00381	0.00128	0.00361	-
2	Beryllium	gr/kg	0.00146	0.000119	0.00129	0.00157	-
3	Boron	gr/kg	0.0407	0.0421	0.0379	0.0424	-
4	Sodium	gr/kg	2.65	1.53	1.45	1.54	-
5	Magnesium	gr/kg	0.672	0.287	<0.01	<0.01	-
6	Aluminium	gr/kg	4.13	0.331	1.31	0.548	-
7	Total phosphorus	gr/kg	2.12	4.87	1.68	2.13	-
8	Potassium	gr/kg	13.21	9.77	12.04	11.19	-
9	Calcium	gr/kg	1.21	6.94	0.259	0.321	-
10	Titanium	gr/kg	4.39	2.46	3.24	3.81	-
11	Vanadium	gr/kg	0.165*	0.0798	0.138	0.120	0.15
12	Chrome	gr/kg	0.0518	0.0192	0.0335	0.0501	0.006
13	Iron	gr/kg	30.53	1.96	22.08	19.67	-
14	Manganese	gr/kg	0.795	0.580	0.533	0.849	1.5
15	Cobalt	gr/kg	0.0265	0.0184	0.0177	0.0203	0.005
16	Nickel	gr/kg	0.0470	0.0420	0.0296	0.0487	0.004
17	Copper	gr/kg	0.0903	0.0655	0.0854	0.151	0.003
18	Zinc	gr/kg	0.116	0.142	0.0922	0.0849	0.023
19	Arsenic	gr/kg	0.0269	0.144	0.0115	0.0122	0.002
20	Selenium	gr/kg	0.00306	0.00209	0.00250	0.00286	-
21	Strontium	gr/kg	0.0279	0.0403	0.0216	0.0326	-

No	Chemical elements	Unit	Results of analysis				ACL of chemicals in soil
			K1	K3	K9	K10	
22	Molybdenum	gr/kg	0.0026	0.0022	0.003	0.0142	-
23	Cadmium	gr/kg	0.000496	0.000399	0.000296	0.000340	-
24	Tin	gr/kg	0.00151	0.00132	0.00123	0.00163	-
25	Antimony	gr/kg	0.00262	0.00456	0.00145	0.00113	0.0045
26	Barium	gr/kg	0.0566	0.0289	0.0177	0.0224	-
27	Lead	gr/kg	0.0229	0.0233	0.0176	0.0189	0.032

**Values that exceed the national standards are marked in orange.*

Concentrations of Cr, Co, Ni, Cu, Zn and As exceed the ACLs set by national sanitary rules and norms in all ten soil samples. The Project region and specially the Qirs-Kajaran area is rich in metallic deposits, so the high concentrations of heavy metals in soil samples can be explained by natural geological processes and are not considered to have been caused anthropogenically.

No specific soil quality standards have been adopted by the EBRD or other international lenders. EBRD PR3 specifies that as a signatory to the European Principles for the Environment, the EBRD and EIB, is committed to requiring compliance with relevant EU environmental standards, including those related to soil pollution. However, there are no European Directives dealing specifically with and setting thresholds for soil quality and land contamination. The overall approach is one of risk management, which means that there are no generically defined quality standards. Owing to this critical difference between the Armenian and international approaches to soil pollution management, the Project will apply a risk-based approach while making sure that the above Armenian minimum soil quality standards are respected.

2.8 Noise and Vibration

Noise and vibration levels were measured in June 2022[17] at 22 selected points for noise and 25 selected points for vibration (see the maps in **Annex 1)**, according to the sampling strategy and methodology developed during ESIA Scoping. The points for noise and vibration measurements were selected as potential receptors in those settlements (near the residential houses, schools, shops, churches, museums or other buildings) that will be crossed by the planned road, hence potentially affected during construction and road operations. Some noise and vibration measurements were additionally conducted in villages along the existing roads that may be used during Project construction and temporarily impacted. Vibration measurements were also conducted near the nearest industrial units, mostly SHPPs.

Threshold Limit Values (TLVs) for equivalent (average) and maximum noise/sound levels set by the RA Sanitary Norms №2-III-11.3 "Noise in the workplaces, in residential and public buildings and housing in construction areas"[18] and IFC's Environmental, Health, and Safety General Guidelines (2007)[19] are summarized in **Table 6**. The Armenian noise standards for workplace and public buildings are more stringent than these of IFC/WHO and thus will be used as project standard during the impact assessment. The Armenian and IFC/WHO noise

[17] The 2019 EIA report did not contain any information on ambient noise and vibration along the proposed road and the existing; nor such information was found in the public domain. So, the measurements were undertaken during the current ESIA studies.

[18] https://www.arlis.am/documentview.aspx?docid=169599

[19] https://www.ifc.org/wps/wcm/connect/29f5137d-6e17-4660-b1f9-02bf561935e5/Final%2B-%2BGeneral%2BEHS%2BGuidelines.pdf?MOD=AJPERES&CVID=nPtguVM

limits are the same for residential areas. Where there are no IFC/WHO values, the Armenian standards will be applied and *vice versa*.

Table 6. Armenian threshold limit values (TLV) for noise and IFC/WHO noise standards

No	Premises and territories		TLV, dBA		
			National		IFC/WHO
			Equivalent to sound level	Maximum sound level	One hour equivalent to sound level
1	Workplace		80		85
2	Shops, trading halls, airport and railway stations waiting rooms, drop-off points of public service providers		60	75	
	Industrial, commercial				70 (day and night)
3	Territories adjacent to residential buildings, clinics, ambulatories, rest houses, care homes, disabled persons homes, libraries, kinder gardens, schools and other educational facilities	day-time[20]	55	70	55
		night-time[21]	45	60	45

The noise measurements at the 22 monitoring locations are shown relative to the applicable equivalent and maximum TLVs set by the national sanitary norms (as these are more stringent than the IFC guidelines) in **Figure 24 - Figure 27.** The L_{aeq} values generally exceed the Armenian TLVs and the same is true for maximum sound pressure levels which are exceeded across the entire monitoring domain with more significant exceedances for the actual sound level equivalent.

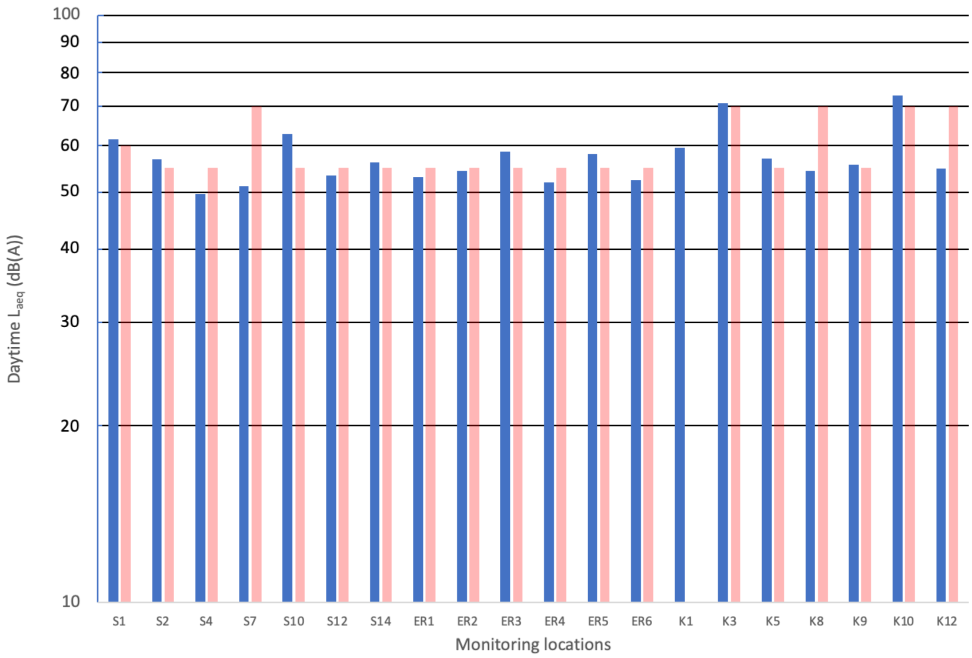


Figure 24. Daytime L_{aeq} noise measurements (blue bars) compared to the Armenian Standard (red bars)

[20]Between 07:00 and 23:00 (for IFC, 07:00 and 22:00)
[21]Between 23:00 and 07:00 (for IFC, 22:00 and 07:00)

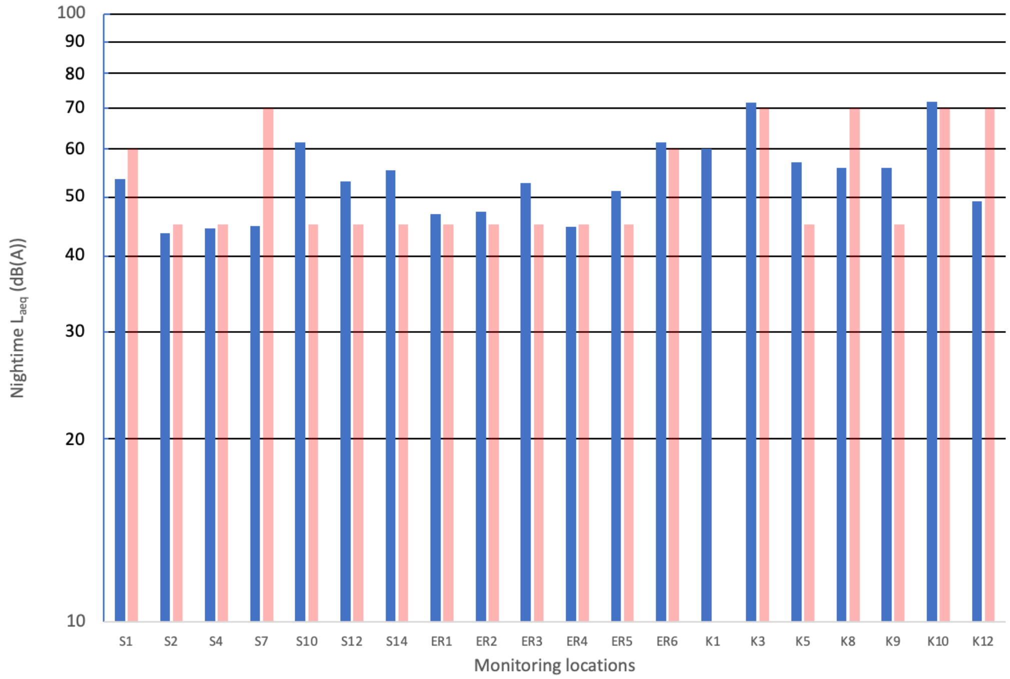


Figure 25. Night time L_{aeq} noise measurements (blue bars) compared to the Armenian Standard (red bars)

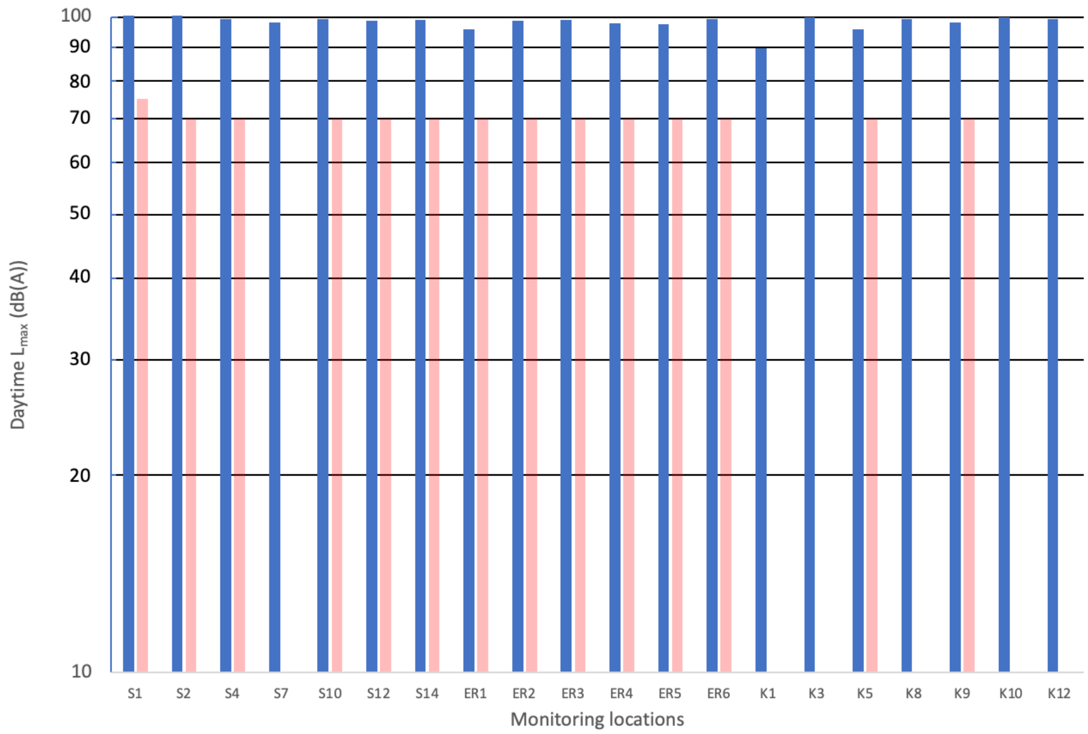


Figure 26. Daytime L_{max} noise measurements (blue bars) compared to the Armenian Standard (red bars)

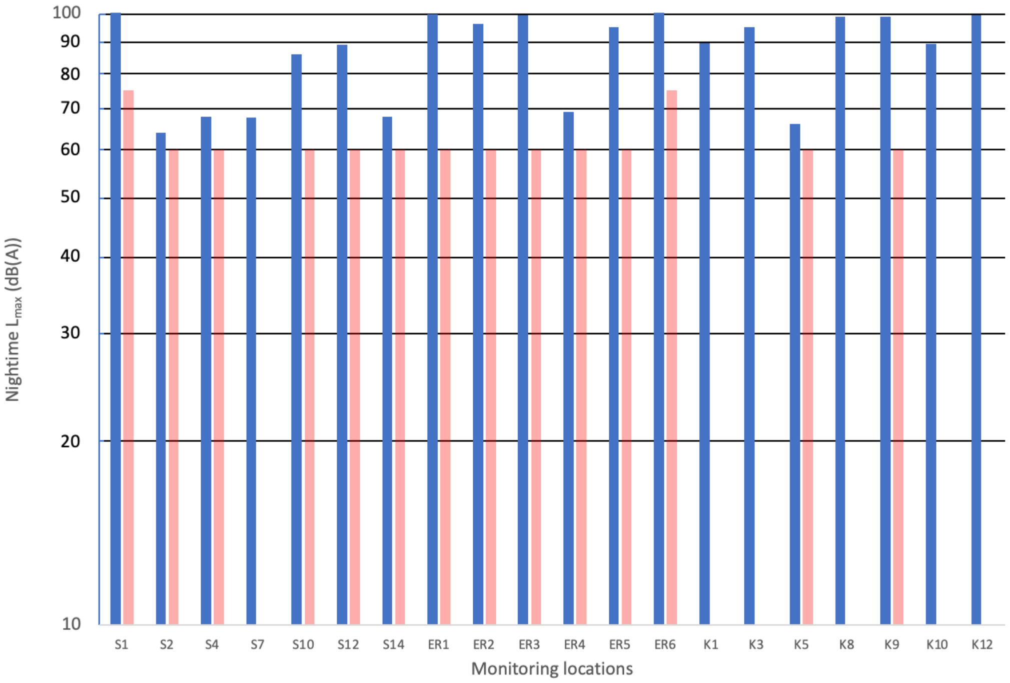


Figure 27. Night time L_{max} noise measurements (blue bars) compared to the Armenian Standard (red bars)

The noise monitoring indicates a generally rural setting but with the occasional presence of very loud noise sources most likely - agricultural vehicles, implements (**Figure 28**) and indeed motor cars and trucks. Many of these vehicles are very old and poorly maintained making them unduly noisy. The effect is further exacerbated at night with the movement of such vehicles in a generally quieter setting and with more stringent noise standards.

Figure 28. An example of many old and poorly maintained agricultural vehicles that operate in the villages and are the likely episodic noise sources

TLVs for the corrected (equivalent corrected) values for the different categories of the vibration acceleration are given in **Table 7** (based on the RA Hygienic Norms №2.2.4-009-06 "Vibration in the workplaces, in residential and public buildings"[22]). As the international lenders have no established thresholds for vibration for human and structural receptors, lender-funded developments may apply the Directive 2002/44/EC, UK British Standards BS 5228-2:2009 and BS 7385-2:1993 and ISO 4866:2010 (for details refer to **Section 3.2.2)**. However, the national thresholds and international values are not directly compatible, and thus the national standards are used in the below analysis.

Table 7. National TLVs for vibration acceleration for 'humans in buildings' receptors

No	Whole-body general vibration[23]	TLV for corrected and equivalent corrected values	
		m/s²	dB
1	Transport-technological (2nd category)	0.28	109
2	Technological (3rd category a)	0.1	100
3	Technological (3rd category b)	0.04	92
4	Technological (3rd category g)	0.014	83
5	Residential buildings, clinics, rest houses	0.004	72

The average corrected (equivalent corrected) values of vibration acceleration (average value of three instrumental measurements at the same point at different times during a day) compared with the relevant national TLVs are given in **Table 8**. The baseline vibration acceleration levels within the Sisian-Shenatagh section are mostly below national TLVs. At points S1 and ER4 the vibration acceleration levels slightly exceed the TLV (by 0.1 and 0.3 dB, respectively). At point K10, near Dzagikavan settlement, the vibration acceleration level is 77.8 dB,5.8 dB higher than the TLVs due to the high traffic density of heavy vehicles on the M2 road. At points K3, K5 and ER8, vibration acceleration levels exceed the TLVs by 1.1, 0.6 and 0.4 dB, respectively. The main sources of baseline vibration are heavy vehicles on the existing roads. At points located near rivers, the water flow also contributes to vibration levels.

Table 8. Corrected (equivalent corrected) values of vibration acceleration compared with TLVs for 'humans in buildings' receptors

No	Points	Corrected (equivalent corrected) values, dB	
		Average values (measured)	TVL
1	S1	**72.1**	**72**
2	S2	**70.0**	**72**
3	ER2	**69.2**	**72**
4	ER1	**68.4**	**72**
5	S4	**67.2**	**72**
6	S5	**64.3**	**72**
7	S7	**64.3**	**100**
8	S10	**64.9**	**72**
9	ER3	**66.6**	**72**
10	ER4	**72.3**	**72**
11	ER5	**67.7**	**72**
12	S12	**67.7**	**72**
13	S14	**62.8**	**72**
14	ER6	**67.2**	**72**

[22] https://www.arlis.am/documentview.aspx?docid=163276

[23] Transport-technological (2nd category) vibration ooccurs in the workplace from machines and mechanisms. Technological (3rd category) vibration generates from stationary machines in workplaces or can be transferred to a workplace without vibration source:
- imposes on workplaces located in production facilities (3rd category a))
- imposes workplaces in facilities without vibration sources (3rd category b))
- imposes on workplaces in administrative, office and other non-production facilities (3rd category g)).

No	Points	Corrected (equivalent corrected) values, dB	
		Average values (measured)	TVL
15	K1	**65.8**	**72**
16	K3	**73.1**	**72**
17	**K4**	**68.8**	**100**
18	**K5**	**72.6**	**72**
19	**K6**	**72.0**	**100**
20	**K8**	**66.9**	**72**
21	**K9**	**64.4**	**72**
22	K10	**77.8**	**72**
23	K11	**70.6**	**100**
24	ER7	**68.0**	**72**
25	ER8	**72.4**	**100**

2.9 Surface Water

2.9.1 River Network

The proposed road passes through the valleys of the **Vorotan, Loradzor (Shenatagh)[24], Karut, Geghi and Voghji Rivers** and crosses some of these rivers (Vorotan, Shenatagh, Karut, and Geghi) and their tributaries (Noravan, Vaghatin, Aghbashget, etc.) (**Figure 29**). The rivers are typically mountainous with fractured relief and hydrographic networks in the catchment basin. The rivers are steep and fast flowing, with narrow riverbeds at places.

Source: Water Resources Atlas of Armenia, Yerevan, 2008

Figure 29. Hydrological Map of Syunik Region[25]

The **Vorotan River** is the largest tributary of the Araks River in the Zangezur area (**Figure 30**). The river originates in the North-Eastern Syunik plateau and eastern slopes of the

[24] The Loradzor River is also called 'Shenatagh'.
[25] Some tributaries within the Project region are not shown in the map.

Zangezur Mountain Range from small lakes and springs, and flows into the Araks river beyond the Armenian border. The total length of the river is 178 km (111 km within the RA), with a 5,650 km^2 catchment area, including 2,597km^2 within the RA. The main tributaries of the Vorotan river are the **Sisian, Loradzor and Goris Rivers**. The Project's Sisian-Shenatagh section runs along the right-bank mountain slope of the **Vorotan River** for about 10 km at 100-1,000 m from the river and then crosses the Vorotan river in the northern part of the Shamb water reservoir, near Vorotan village.

The 23 km **Loradzor River** (also called Loraget, Lernashen and Shenatagh) originates in the south-west slopes of the Bargushat mountain range, flows through Shenatagh, Lor, Getatagh, Darbas, and Ltsen villages and enters the Shamb reservoir via a 2 km long tunnel. After crossing the Loradzor river, the existing Sisian-Shenatagh road section runs adjacent to the river for about 8 km.

After intersecting the Bargushat ridge, the Qirs-Kajaran section runs along the Karut tributary of the **Geghi River** for about another 8 km, crossing the upper part of the tributary. The **Geghi River** (30 km) originates in the eastern slopes of the Zangezour mountains at 3,130 m altitude and joins **the Voghji River** from the left. The 1.8 ha Gazana lake occurs in the headwaters of the Geghi River at 3,150 m. The lake was included in the list of RA Natural Monuments in 2008 and has a catchment area of 308.3 km^2.

The **Voghji River** is the second largest river in the Zangezur area. The **Kaputjugh River**, originates from the melt waters of Mount Kaputjugh (3,905 m), joins **the Kajaran River** and forms the Voghji River, a tributary of the Araks River. The Voghji River's total length is 82 km (52 km within the RA) and its catchment area is 2,337 km^2 (1,240.47 km^2 within the RA). The largest tributary is the Geghi River. Another important river in this basin is the **Tsav River**. The relief of the basin forms a dishevelled network of hills, with the surface of the basin incised by canyons, valleys and meadows. The basin of the **Voghji River** is characterized by strong fragmentation and relatively moderate water-permeability.

Vorotan River (near Shamb HPP)

Loradzor River (near Shenatagh village)

Voghji River (near M2 road)

Geghi River (near Geghi village)

Figure 30. Rivers located in the Project region

Table 9. Main rivers in the Project area[26]

№	Name of rivers	Length, km	Catchment area in the RA, km^2	Flow rate, mln. m^3/year	Crossed by the proposed road?
1	Vorotan	178	2597	716	Yes
2	Loradzor	23	118	13	Yes
3	Voghji	82	1241	366	No
4	Geghi	30	308	145	Yes

The proposed road crosses surface water courses ten times, of which six are in the Sisian-Shenatagh section and four in the Qirs-Kajaran section. Information on the rivers/tributaries crossed by the proposed road, as well as the numbers and locations of the respective bridges are given in **Table 10**. Please also see **Section 2.9.3** of this Report for maximum and average flow data for these rivers.

Table 10. Water streams to be crossed by the Project road

№	Name of rivers/ tributaries	Length, km	Number of a bridge over the river	Location of the bridges
1	Noravan (tributary of Vorotan)	20	BR002	km10+250 - km10+500
2	Vaghatin (tributary of Vorotan)	12	BR004	km11+580 - km11+750
3	Vorotan	178	BR005	km12+650 - km13+150
4	Unknown (tributary of Vorotan)	-	BR007	km15+750 - km16+000
5	Loradzor	23	BR008	km18+200 - km18+450
6	Aghbashget (tributary of Loradzor)	10	BR016	km26+250 - km26+500
7	Karut (tributary of Geghi)	~20	BR017	km36+280 - km36+500
8	Karut (tributary of Geghi)	~20	BR018	km37+430 - km37+540
9	Kiladara/Karakhan (tributary of Geghi)	-	BR020	km45+310 - km45+750
10	Geghi (tributary of Voghji)	30	BR021	km49+350 - km49+570

River flows are variable during the year as a function of snowmelt and rainfall intensity. More than half the flow occurs during spring (March-June), while the lowest flows are observed in the winter period (8-17%). About 30% of total annual river flows occur in summer-autumn.

Water from the rivers in the Project area are not used for drinking purposes. Several HPPs use the water of the Vorotan, Loradzor and Geghi Rivers and these are strictly regulated by the State regulatory bodies and MoE (including monitoring of ecological flows). Amateur fishing occurs in the Vorotan and Loradzor Rivers (refer to Volume 4, Section 3.3.4).

2.9.2 Lakes and Reservoirs

There are no natural lakes near the proposed road, tunnel, bridges and/or connecting roads. Some small mountain lakes, found at 2,300-3,500 MASL, are located far away from the proposed road.

There are two reservoirs located close to the proposed road: **Shamb and Geghi reservoirs**. The **Shamb reservoir** is fed by the Vorotan River and has a total capacity is 13.6 mln.m^3 and usable capacity of 11.8 mln.m^3, while the water table surface area is 11 ha. The reservoir is used for hydropower generation and fish production. The proposed road runs for about 2 km along the reservoir between 100 m in the north and 2,000 m in the south (see **Figure 6 in ESIA Volume 1**).

[26] "Hydrometeorology and Monitoring Centre" SNCO.

Shamb reservoir

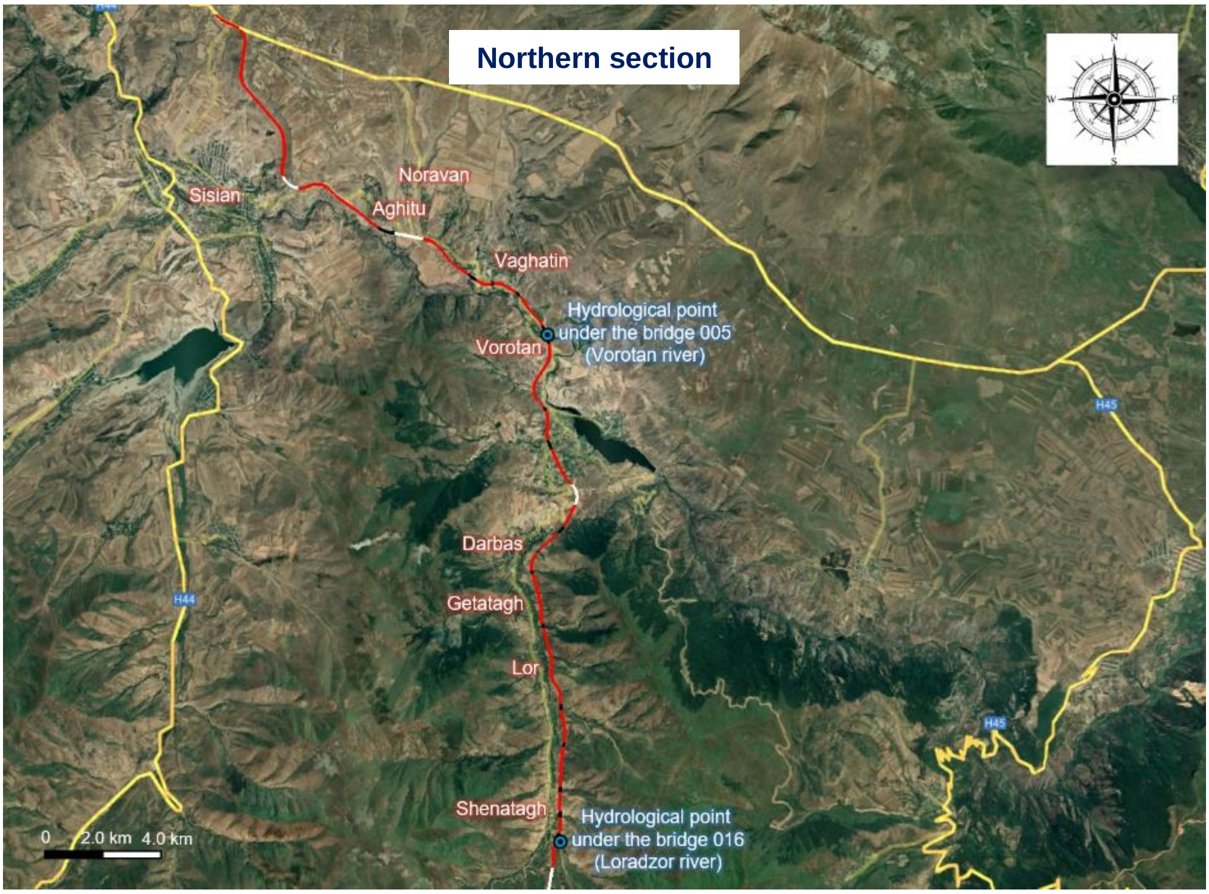
Geghi reservoir

Figure 31. Water reservoirs within the Project region

The **Geghi reservoir** is located on the Geghi River with a capacity 15 mln.m^3, with current utilisation of 12 mln.m^3, and water surface area of 35 ha. The reservoir is used for hydropower generation, fish farming and irrigation. In addition, Zangezur Copper Molybdenum Combine CJSC abstracts water from this reservoir during low flow periods. The reservoir is about 40-80 m from the proposed road (see **Figures 8 and 9 in ESIA Volume 1**).

2.9.3 Hydrological Survey

A hydrological survey using multi-year flow monitoring data was conducted on the main surface water systems (rivers) that would be crossed by the planned road alignment. These rivers are the Vorotan and Loradzor in the Northern section and the Geghi and its tributary Karut in the Southern section of the Project area. These rivers are mostly fed by snowmelt and rainfall as well as underground sources, and hence have high flooding potential, especially during spring. The hydrological surveys were conducted for all 4 rivers crossed by the Project road at points under the planned bridges 005 (Vorotan river), 016 (Loradzor river), 018 (Karut tributary) and 021 (Geghi river) that are considered as having flooding potential by the local hydrologists. The points where hydrological surveys were conducted relative to the proposed road alignment are presented in **Figure 32**.



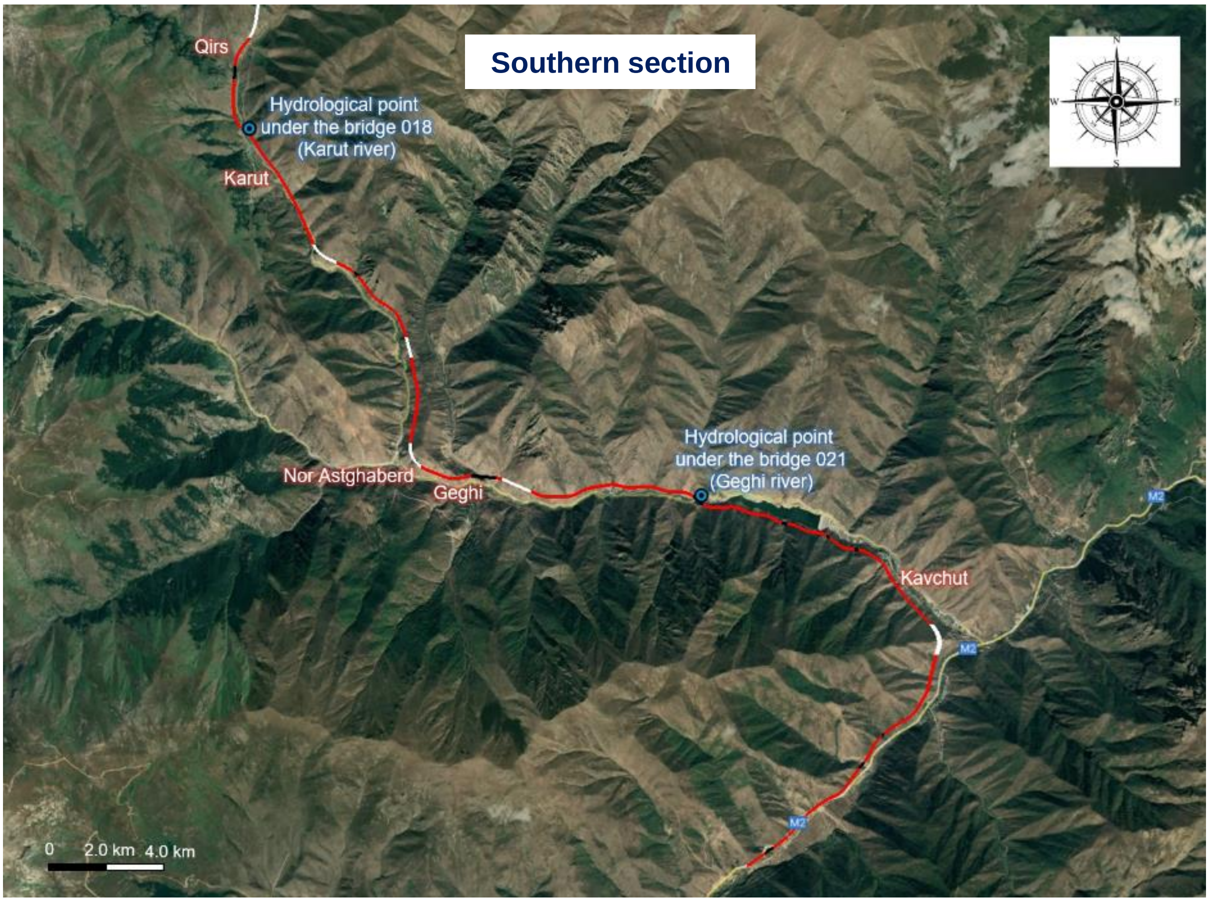


Figure 32. Maps indicating hydrological survey points

The main parameters studied during the hydrological survey are:

1) Water sources;
2) Ice period;
3) Average and maximum flows;
4) Water hydraulic calculations for spring floods (flood risk assessment).

2.9.3.1 Hydrological point - Vorotan River

The Vorotan River is a type of mountain watercourse mostly fed by snowmelt, however, groundwater and rainwater also play an important role (**Table 11**). The water regime of the river has the following phases: spring floods that also occur in early summer, rainy floods, summer-autumn and winter low levels. Annually, the upper streams of the Vorotan River are covered with a stable layer of ice, which lasts for an average of 50-60 days in winter. The thickness of the ice layer is 5-10 cm.

Table 11. Ratio of the Vorotan River water feeding sources (% of total flow) during the spring flooding season

Hydrological monitoring station	Characteristic year for	Sources, %		
		snowmelt water	rainwater	groundwater
Vorotan	Average water flow	30	57	13
	Excessive water flow	17	70	13
	Low water flow	50	41	9

Annual and monthly average water flows in the Vorotan River were sourced from multi-year monitoring data (1959-2021) from the "Vorotan" station. The data is assumed fully characteristic of the water regime at the selected hydrological point (under Bridge 005). The monthly mean flow is summarized in **Table 12**.

Table 12. Water annual and monthly average flows, m^3/sec

1959-2021 period	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Average	4.75	4.84	5.00	4.99	5.70	4.87	4.65	4.68	4.93	4.66	4.72	4.94	4.90

Source: Multi-year hydrological monitoring data from the Hydrometeorology and Monitoring Centre

The water flow in the Vorotan River basin is markedly seasonal. Some 65% of the annual water flow occurs from April to July. For the Vorotan River, 1992 was an average year, 2002 excessive, 2000 low and 1999 extremely low water flow years. Monthly water and average annual flow for the extreme years are presented in **Table 13**. Annual average flow in excessive year is 5.59 m^3/sec and in extremely low water year, 3.2 m^3/sec. The highest water flow during the excessive year occurred in May 2002 at 27.6 m^3/sec, while the lowest flow was in January 1999 at 2.95 m^3/sec.

Table 13. Annual and monthly average water flows in excessive, average, low and extremely low years

Units	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Excessive water year (2002)													
%	4.7	4.7	4.7	7.7	41.2	8.2	4.5	4.6	4.9	5.0	5.0	4.9	100
m^3/sec	3.14	3.12	3.16	5.13	27.6	5.50	3.04	3.07	3.28	3.35	3.35	3.31	5.59
mln.m^3	8.41	7.55	8.46	13.3	73.9	14.3	8.14	8.22	8.50	8.97	8.68	8.87	177.3
Average water year (1992)													
%	7.4	7.4	7.3	7.7	7.7	10.0	8.5	8.8	9.7	8.6	8.6	8.4	100
m^3/sec	3.87	3.86	3.79	4.00	4.02	5.24	4.44	4.58	5.09	4.49	4.48	4.39	4.35
mln.m^3	10.4	9.3	10.2	10.4	10.77	13.6	11.9	12.3	13.2	12.0	11.6	11.8	137.3
Low water year (2000)													
%	7.1	7.1	7.8	9.3	9.7	8.9	8.4	7.9	9.9	8.9	7.8	7.2	100
m^3/sec	3.06	3.08	3.39	4.02	4.19	3.84	3.61	3.43	4.28	3.84	3.36	3.13	3.60
mln.m^3	8.20	7.45	9.08	10.4	11.2	9.95	9.67	9.19	11.1	10.3	8.71	8.38	113.6

Extremely low water year (1999)												
%	7.7	7.9	7.9	8.4	9.9	9.7	8.6	7.8	8.1	8.1	8.1	8.0	100
m^3/sec	2.95	3.03	3.02	3.22	3.82	3.74	3.31	2.99	3.10	3.10	3.11	3.06	3.20
mln.m^3	7.90	7.33	8.09	8.35	10.2	9.69	8.87	8.01	8.04	8.30	8.06	8.20	101.1

Maximum flows in a 27-year data record (1990-2021[27]) at the "Vorotan" hydrological monitoring station occur during spring and early summer, mainly due to intensive snow melting (**Table 14**).

Table 14. Water maximum flows in the Vorotan River

Years	Q, m^3/sec	Years	Q, m^3/sec	Years	Q, m^3/sec
1990	4.26	2003	39.5	2012	17.6
1991	9.72	2004	26.0	2013	11.5
1992	12.0	2005	4.29	2014	3.97
1997	27.6	2006	4.00	2015	4.17
1998	24.5	2007	6.42	2016	4.08
1999	5.00	2008	10.8	2018	11.1
2000	5.40	2009	3.40	2019	12.1
2001	6.45	2010	5.91	2020	18.2
2002	67.2	2011	9.98	2021	14.3
Average - 13.5 m^3/sec					

Average maximum flow is 13.5 m^3/sec; however, 67.2 m^3/sec was recorded in 2022 during the spring flood. The lowest averaged maximum water flow was registered in 2009 at 3.4 m^3/sec.

Hydraulic calculations of water level increase during the spring flooding season are given in **Table 15** and shown in **Figure 32**. The 0.1% and 1.0% availability of maximum water flows using the riverbed cross-section under bridge 005 were derived.

Table 15. Maximum water flow hydraulic calculations under the planned bridge 005

Water level, MASL	Riverbed width, m	Catchment area, m^2	Velocity, m/sec	Water flow, m^3/sec
1373.10	10.00	0.50	0.29	0.14
1373.20	20.00	2.00	0.50	1.01
1373.30	30.00	4.50	0.70	3.17
1373.40	40.00	8.00	0.89	7.15
1373.50	50.00	12.50	1.07	13.4
1373.60	60.00	18.00	1.25	22.5
1373.70	70.00	24.50	1.42	34.8
1373.80	80.00	32.00	1.58	50.7
1373.90	90.00	40.50	1.75	70.8
1374.00	100.00	50.00	1.91	95.3
1374.10	103.33	60.17	2.16	130
1374.20	106.67	70.67	2.40	170
1374.30	110.00	81.50	2.63	214
1374.40	113.33	92.67	2.85	264
1374.50	116.67	104.17	3.06	318
1374.60	120.00	116.00	3.25	377

[27] Data from 1993 to 1997 are missing.

During Spring flooding, the water level in the Vorotan River under bridge 005 could increase by 1.8 m (from 1373.0 to 1374.8), which must be provided for in the bridge design and construction.

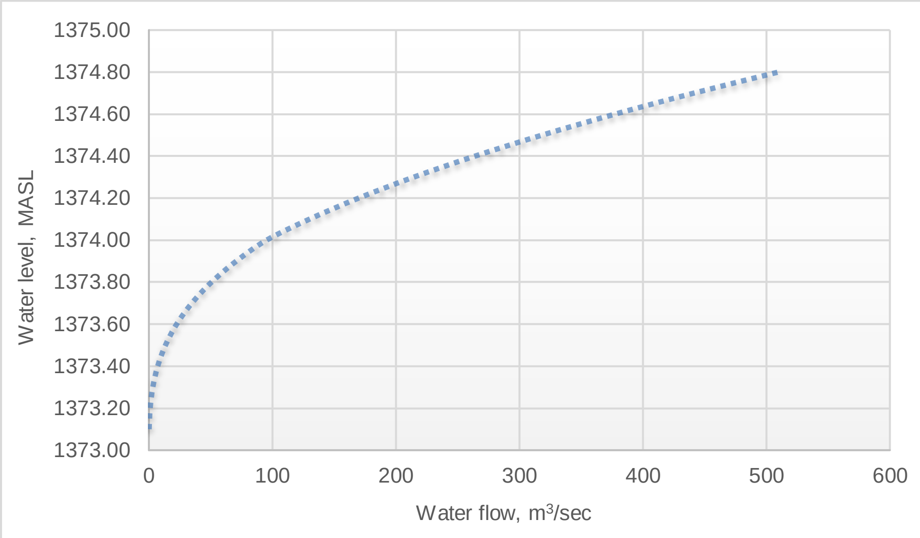


Figure 33. Calculated water level increase during the spring flooding season under the planned bridge 005

2.9.3.2 Hydrological point - Loradzor River

As with the Vorotan, the Lernadzor is a typical mountainous river fed by snowmelt, groundwater and rainwater (Table 16). Spring floods that also occur in early summer, rainy floods, summer-autumn and winter low levels characterise an annual flow cycle. The upper streams of the Lernadzor River are covered with a stable layer of ice annually, which lasts an average of 50-60 days in winter. The thickness of the ice layer is 5-10 cm.

Table 16. Ratio of the Lernadzor water feeding sources (% of total flow)

Hydrological monitoring station	Feeding sources, %	
	snowmelt and rainwater	groundwater
Ltsen	70	30

Annual and monthly water flows from the "Ltsen" monitoring station (1934-1981) have been used to calculate the cross-section (hydrological point under Bridge 016) also using data (1982-2021) from the "Gorhayk" station. The results are summarized in Table 17.

Table 17. Water annual and monthly average flows, m^3/sec

1934-2021 period	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Average	0.12	0.13	0.15	0.43	0.93	0.64	0.29	0.19	0.17	0.15	0.15	0.13	0.29

Like the Vorotan, the annual water flow in the Lernadzor River basin is strongly seasonal. Some 65% of the annual water flow occurs from April to July. The historical record shows 1984 as average, 1988 as excessive, 2011 as the low and 1961 as extremely low water flow years (Table 18). Annual average flow in an excessive water year is 0.33 m^3/sec and in extremely low water year 0.15 m^3/sec. The highest water flow during the excessive water year was in May 2002 at 0.92 m^3/sec, while the lowest flow registered in 1999 was 0.08 m^3/sec.

Table 18. Annual and monthly average water flows in excessive, average, low and extremely low years

Units	Months	Annual

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Excessive water year (1988)													
%	3.8	3.7	4.2	17.8	23.3	15.8	5.5	3.9	6.4	5.5	5.0	5.3	100
m^3/sec	0.15	0.15	0.16	0.70	0.92	0.62	0.22	0.15	0.25	0.21	0.19	0.21	0.33
mln.m^3	0.40	0.35	0.44	1.82	2.45	1.61	0.58	0.41	0.66	0.58	0.51	0.55	10.3
Average water year (1984)													
%	4.0	4.0	4.1	17.4	32.7	20.6	3.6	2.9	2.2	2.1	2.5	3.9	100
m^3/sec	0.14	0.14	0.15	0.62	1.16	0.73	0.13	0.10	0.08	0.08	0.09	0.14	0.30
mln.m^3	0.38	0.34	0.39	1.60	3.11	1.89	0.34	0.27	0.20	0.20	0.23	0.37	9.33
Low water year (2011)													
%	3.2	3.2	3.2	3.8	32.1	29.0	6.8	4.3	3.9	3.9	3.3	3.2	100
m^3/sec	0.10	0.10	0.10	0.11	0.95	0.86	0.20	0.13	0.11	0.12	0.10	0.10	0.25
mln.m^3	0.26	0.23	0.26	0.29	2.55	2.23	0.54	0.34	0.30	0.31	0.26	0.26	7.81
Extremely low water year (1961)													
%	4.9	4.6	4.7	14.2	29.0	9.8	6.8	5.8	5.8	4.9	4.7	4.6	100
m^3/sec	0.09	0.08	0.08	0.25	0.51	0.17	0.12	0.10	0.10	0.09	0.08	0.08	0.15
mln.m^3	0.23	0.20	0.23	0.65	1.38	0.45	0.32	0.27	0.27	0.23	0.22	0.22	4.67

The 48-year (1934-1981) data from the "Ltsen" hydrological monitoring station were used to determine the parameters of maximum flow in the catchment area. The maximum flows are observed during the spring-summer floods, mainly due to intensive snow melt (**Table 19**).

Table 19. Water maximum flows in the Loradzor River

Years	Q, m^3/sec	Years	Q, m^3/sec	Years	Q, m^3/sec
1934	10.1	1952	4.70	1968	15.0
1935	2.92	1953	3.16	1969	22.7
1936	2.58	1954	5.90	1970	4.07
1937	7.97	1955	4.25	1971	2.80
1938	6.25	1956	4.42	1972	6.66
1941	5.05	1957	5.35	1973	6.11
1942	14.1	1958	4.85	1974	4.58
1943	6.16	1959	8.40	1975	6.53
1944	5.25	1960	7.70	1976	10.6
1945	8.10	1961	3.48	1977	8.53
1946	7.10	1962	3.44	1978	6.78
1947	5.51	1963	6.00	1979	5.77
1948	5.40	1964	16.4	1980	2.23
1949	8.00	1965	20.6	1981	3.36
1950	5.46	1966	6.14		
Average - 7.38 m^3/sec					

Average maximum flow for the studied hydrological point is 7.38 m^3/sec, however, 22.7 m^3/sec was recorded in 1969 during the spring flood. The lowest averaged maximum water flow was registered in 1980 at 2.23 m^3/sec. Hydraulic calculations of water level increase during the spring floods are given in **Table 20** and shown in **Figure 34**. The calculations were conducted for the 0.1% and 1.0% maximum water flows taking into account the Lernadzor River bed cross-section under proposed bridge 016.

Table 20. Maximum water flow hydraulic calculations under the planned bridge 016

Water level, MASL	Riverbed width, m	Catchment area, m^2	Velocity, m/sec	Water flow, m^3/sec
1795.10	5.000	0.250	0.286	0.07
1795.20	10.000	1.000	0.507	0.51
1795.30	15.000	2.250	0.708	1.59
1795.40	20.000	4.000	0.897	3.59
1795.50	25.000	6.250	1.079	6.75
1795.60	26.500	8.825	1.368	12.1

Water level, MASL	Riverbed width, m	Catchment area, m²	Velocity, m/sec	Water flow, m³/sec
1795.70	28.000	11.550	1.634	18.9
1795.80	29.500	14.425	1.880	27.1
1795.90	31.000	17.450	2.112	36.8
1796.00	32.500	20.625	2.330	48.1
1796.10	34.000	23.950	2.538	60.8
1796.20	35.500	27.425	2.735	75.0
1796.30	37.000	31.050	2.923	90.8
1796.40	38.500	34.825	3.103	108
1796.50	40.000	38.750	3.275	127
1796.60	41.500	42.825	3.441	147
1796.70	43.000	47.050	3.599	169
1796.80	44.500	51.425	3.752	193

As per the projection given in **Figure 34**, during the spring flood, water level in the Loradzor River under the Project bridge 016 can potentially increase from 1795.0 MASL to 1796.8 MASL and must be provided for in Project design and construction.

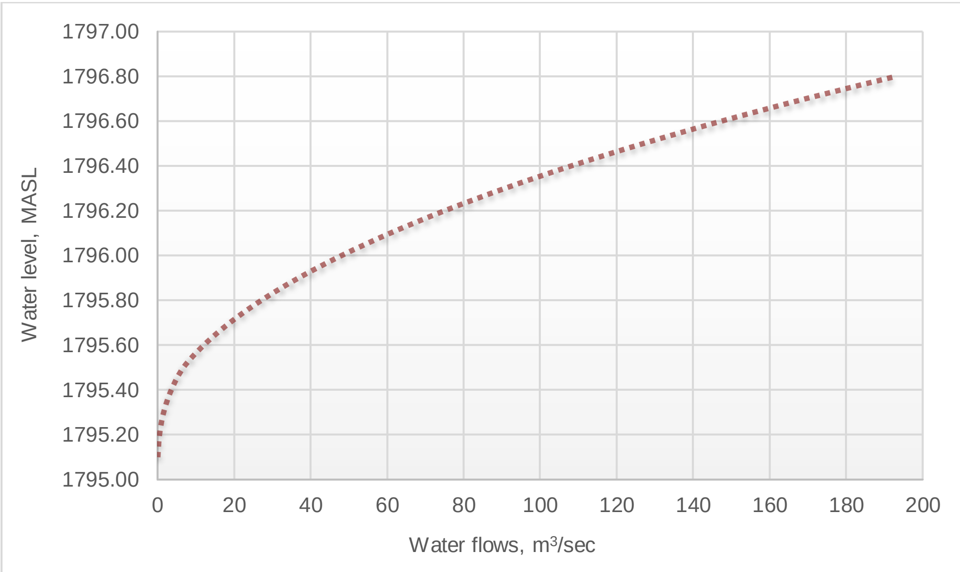


Figure 34. Calculated water level increase during the spring flooding season under the planned bridge 016

2.9.3.3 Hydrological point - Geghi River

The Geghi River is a typical mountain river with a mixed feeding, mainly from snowmelt, groundwater and rainfall (**Table 21**). The Geghi is characterized by pronounced spring-summer water abundance, caused by snowmelt and precipitation during the winter season. The peak flow occurs in the second half of May or June. In the Geghi basin, maximum flows are observed mainly during spring-summer floods. Minimum discharges occur mostly in winter and summer (end of July - August). Upper reaches of the Geghi River are covered in winter with a stable ice layer of 2-4 cm that lasts 15-20 days on average per annum..

Table 21. Ratio of the Geghi River water feeding sources (% of total flow) during the spring flooding season

Hydrological monitoring station	Year that characterizing with	Feeding sources, %		
		snowmelt water	rainwater	groundwater
Geghi	Average water flow	70	15	15

	Excessive water flow	71	13	16
	Low water flow	60	15	25

Flow data from the "Geghi" hydrological station were used for the hydrological point under the bridge 021. The cross-sections of the Geghi River's catchment area at the studied point and the "Geghi" hydrological station are similar enough for monitoring data from "Geghi" station to be acceptable for the water flow calculations.

Annual and monthly water flows (1948-1987) were sourced from the "Geghi" station, with water flows for 1988-2021 based on data from "Kapan" station. These data are summarized in the below table.

Table 22. Water annual and monthly average flows, m^3/sec

1948-2021 period	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Average	1.14	1.15	1.69	4.76	10.1	10.0	5.39	2.56	1.68	1.55	1.39	1.22	3.55

Flow in the Geghi River basin is highly seasonal. 80% of the annual water flows in the Geghi isfrom April to July. 1960 represents average, 1985 excessive, 1990 low and 2014 as extremely low water flow years **Table 23**. The annual average flow in the excessive flow year is 5.43 m^3/sec and in the extremely low water year - 1.69 m^3/sec. The highest flow during the excessive water year was in June 1985 at 17.2 m^3/sec, while the lowest flow was in January-February 2014 at 0.65 m^3/sec.

Table 23. Annual and monthly average water flows in excessive, average, low and extremely low years

Units	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Excessive water year (1985)													
%	3.4	3.5	3.9	12.4	25.9	26.4	9.4	3.9	3.2	2.8	2.7	2.6	100
m^3/sec	2.19	2.29	2.56	8.06	16.9	17.2	6.11	2.53	2.07	1.82	1.77	1.68	5.43
mln.m^3	5.87	5.54	6.86	20.9	45.3	44.6	16.4	6.78	5.37	4.87	4.59	4.50	171.5
Average water year (1960)													
%	2.9	2.9	3.3	12.3	26.8	18.8	14.0	7.1	3.1	2.8	3.1	2.9	100
m^3/sec	1.17	1.2	1.35	5.00	10.9	7.65	5.7	2.88	1.26	1.15	1.26	1.16	3.39
mln.m^3	3.13	2.90	3.62	13.0	29.2	19.8	15.3	7.71	3.27	3.08	3.27	3.11	107.3
Low water year (1990)													
%	2.3	2.4	2.9	10.2	35.6	24.6	8.4	3.7	2.3	2.6	2.6	2.5	100
m^3/sec	0.63	0.64	0.80	2.78	9.71	6.70	2.28	1.02	0.62	0.72	0.70	0.67	2.27
mln.m^3	1.68	1.56	2.13	7.2	26.0	17.4	6.10	2.72	1.61	1.93	1.83	1.79	71.9
Extremely low water year (2014)													
%	3.2	3.2	4.6	17.0	24.3	20.0	8.5	3.8	3.3	3.9	3.9	4.3	100
m^3/sec	0.65	0.65	0.93	3.44	4.92	4.04	1.72	0.76	0.67	0.79	0.80	0.86	1.69
mln.m^3	1.74	1.58	2.49	8.9	13.2	10.5	4.61	2.05	1.73	2.11	2.07	2.31	53.3

A 40-year (1948-1987) data record from the "Geghi" and "Kapan" hydrological monitoring stations shows maximum flows during spring-summer floods, mainly due to intensive snow melt (**Table 24**).

Table 24. Water maximum flows in the Vorotan River

Years	Q, m^3/sec	Years	Q, m^3/sec	Years	Q, m^3/sec	Years	Q, m^3/sec
1948	19.0	1959	21.5	1970	29.7	1980	21.7
1949	9.00	1960	33.4	1971	16.0	1981	17.8
1950	22.5	1961	9.00	1972	12.8	1982	18.4
1951	10.5	1962	13.5	1973	27.2	1983	30.9

1952	18.0	1963	30.7	1974	22.3	1984	31.6
1953	17.1	1964	21.7	1975	16.6	1985	29.9
1954	20.9	1965	20.4	1976	18.1	1986	30.9
1955	11.7	1966	21.6	1977	35.1	1987	37.3
1956	122	1967	29.5	1978	30.3	1988	35.7
1958	18.0	1968	37.7	1979	30.8		
Average - 25.7 m^3/sec							

The averaged maximum flow for the hydrological point is 25.7 m^3/sec, however, 37.3 m^3/sec was recorded in 1987 during spring flooding. The lowest averaged maximum flow was registered in 1949 and 1961 at 9.0 m^3/sec.

Water level increase during spring flooding is given in **Table 25** and shown in **Figure 35**. The calculations were conducted for 0.1% and 1.0% maximum water flows as a function of the Geghi River bed cross-section under the planned bridge 021.

Table 25. Maximum water flow hydraulic calculations under the planned bridge 021

Water level, MASL	Riverbed width, m	Catchment area, m^2	Velocity, m/sec	Water flow, m^3/sec
1414.10	1.427	0.071	0.280	0.02
1414.20	2.854	0.285	0.495	0.14
1414.30	4.280	0.642	0.691	0.44
1414.40	5.707	1.141	0.876	1.00
1414.50	7.134	1.783	1.054	1.88
1414.60	8.561	2.568	1.225	3.15
1414.70	9.987	3.496	1.392	4.87
1414.80	11.414	4.566	1.555	7.10
1414.90	12.841	5.778	1.714	9.90
1415.00	14.268	7.134	1.870	13.3
1415.10	15.694	8.632	2.023	17.5
1415.20	17.121	10.273	2.173	22.3
1415.30	18.548	12.056	2.320	28.0
1415.40	19.975	13.982	2.465	34.5
1415.50	21.401	16.051	2.607	41.8
1415.60	22.828	18.262	2.746	50.2
1415.70	24.255	20.617	2.883	59.4
1415.80	25.682	23.113	3.017	69.7
1415.90	27.108	25.753	3.149	81.1
1416.00	28.535	28.535	3.278	93.5
1416.10	29.962	31.460	3.404	107
1416.20	31.389	34.527	3.528	122
1416.30	32.815	37.738	3.649	138
1416.40	34.242	41.090	3.768	155
1416.50	35.669	44.586	3.884	173
1416.60	37.096	48.224	3.997	193
1416.70	38.522	52.005	4.108	214
1416.80	39.949	55.929	4.216	236

As per the projection given in Figure 35, it may be concluded that during the spring flooding season, water level in the Geghi River under the Project bridge 021 can potentially increase from 1414.0 MASL to 1416.8 MASL, which must be considered during the Project design and construction.

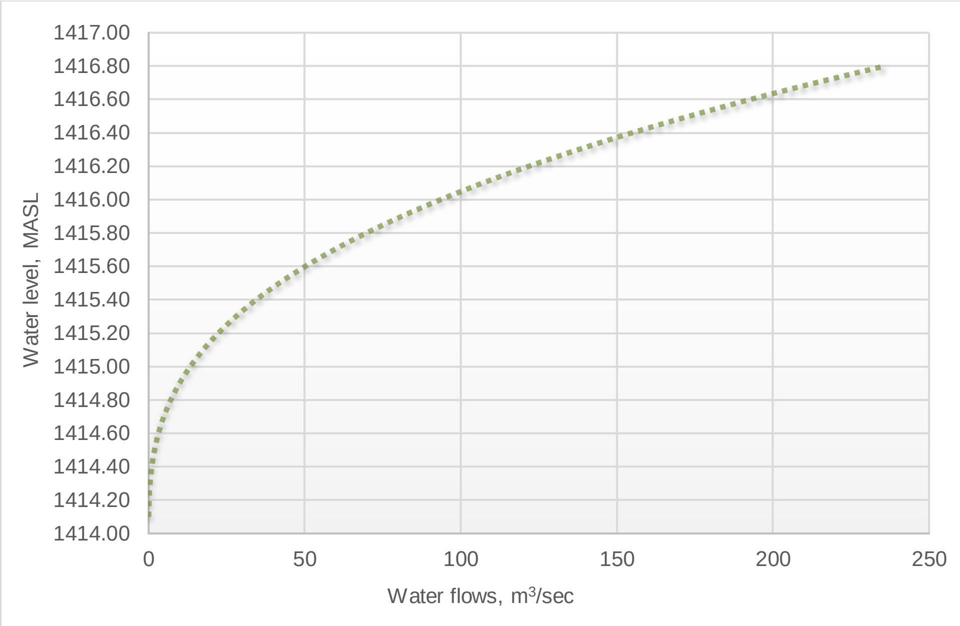


Figure 35. Calculated water level increase during the spring flooding season under the planned bridge 021

2.9.3.4 Hydrological point - Karut River

The Karut River, a tributary of the Geghi River, is also a typical mountain river with mixed sources, mainly from snowmelt, groundwater and rainfall (Table 26). The water regime of the river, unlike other watercourses of the region, is characterized by smooth, long-term flooding (March-July), caused by snow and ice melting. During winter, the upper streams of the river are covered with a stable ice layer.

Table 26. Ratio of the Karut River water feeding sources (% of total flow) during the spring flooding season

Hydrological monitoring station	Year that characterizing with	Feeding sources, %		
		snowmelt water	rainwater	groundwater
Karut	Average water flow	70	15	15
	Excessive water flow	71	13	16
	Low water flow	60	15	25

There are no hydrological monitoring stations along the Karut River, so all hydrological parameters were sourced from the "Geghi" hydrological monitoring station and adapted to the Karut. The data were available from 1950 until 1987 from the State hydrometeorological service and data from the "Kapan" monitoring station were used from 1988 to 2021 (see these summarized in the below table).

Table 27. Water annual and monthly average flows, m^3/sec

1950-1987 period	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Average	0.22	0.22	0.32	0.91	1.93	1.92	1.03	0.49	0.32	0.30	0.27	0.23	0.68

Water flow is highly seasonal with 80% of the annual water flows from April to July. 1960 represents average, 1985 excessive, 1990 low and 2014 as extremely low water flow years (Table 28). The annual average flow in an excessive water year is 1.04 m^3/sec and an extremely low water year - 0.32 m^3/sec. The highest flow during the excessive water year occurred in June 1985 at 3.29 m^3/sec, while the lowest flow was registered in January-February 2014 at 0.12 m^3/sec.

Table 28. Annual and monthly average water flows in excessive, average, low and extremely low years

Units	Months												Annual
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Excessive water year (1985)													
%	3.4	3.5	3.9	12.4	25.9	26.4	9.4	3.9	3.2	2.8	2.7	2.6	100
m^3/sec	0.42	0.44	0.49	1.54	3.24	3.29	1.17	0.48	0.40	0.35	0.34	0.32	1.04
mln.m^3	1.12	1.06	1.31	4.00	8.67	8.54	3.13	1.30	1.03	0.93	0.88	0.86	32.8
Average water year (1960)													
%	2.9	2.9	3.3	12.3	26.8	18.8	14.0	7.1	3.1	2.8	3.1	2.9	100
m^3/sec	0.22	0.23	0.26	0.96	2.09	1.47	1.09	0.55	0.24	0.22	0.24	0.22	0.65
mln.m^3	0.60	0.56	0.69	2.48	5.59	3.80	2.92	1.48	0.63	0.59	0.63	0.60	20.6
Low water year (1990)													
%	2.3	2.4	2.9	10.2	35.6	24.6	8.4	3.7	2.3	2.6	2.6	2.5	100
m^3/sec	0.12	0.12	0.15	0.53	1.86	1.28	0.44	0.19	0.12	0.14	0.13	0.13	0.44
mln.m^3	0.32	0.30	0.41	1.38	4.98	3.32	1.17	0.52	0.31	0.37	0.35	0.34	13.8
Extremely low water year (2014)													
%	3.2	3.2	4.6	17.0	24.3	20.0	8.5	3.8	3.3	3.9	3.9	4.3	100
m^3/sec	0.12	0.12	0.18	0.66	0.94	0.77	0.33	0.15	0.13	0.15	0.15	0.17	0.32
mln.m^3	0.33	0.30	0.48	1.71	2.52	2.01	0.88	0.39	0.33	0.40	0.40	0.44	10.2

Extreme spring floods occur once every 10-20 years when there is snow in the upper zones of the basin and when the sharp increase of air temperature in combination with intensive rainfall occurs over large areas of the watershed. Between 1956-1977, three very strong mudflows occurred in the Voghji River basin (the Geghi is tributary of the Voghji). The mudflow in 28.08.1956 covered the entire basin of the Voghji River, including its main tributary, the Geghi. The amount of precipitation that caused the flood was 70-80 mm. Numerous tributaries and ravines from steep slopes carried powerful limestone flows into the Voghji and Geghi rivers. The mudflow simultaneously flowed into the beds of the Voghji and Geghi rivers destroying bridges and buildings.

Massive damage was caused in Kapan. The maximum flow at the "Kapan" monitoring station was 270 m^3/sec, at the "Kajaran" station - 100 m^3/sec and at the "Geghi" station - 122 m^3/sec. The second and third mudflows occurred in the lower parts of the Voghji River in 1959 and 1960.

A 40-year (1948-1988) data record from the "Geghi" and "Kapan" hydrological monitoring stations illustrate maximum flow in the catchment area notably during the spring-summer floods, mainly due to intensive snow melt (Table 29).

Table 29. Water maximum flows in the Vorotan River

Years	Q, m^3/sec	Years	Q, m^3/sec	Years	Q, m^3/sec	Years	Q, m^3/sec
1948	19.0	1959	21.5	1970	29.7	1980	21.7
1949	9.00	1960	33.4	1971	16.0	1981	17.8
1950	22.5	1961	9.00	1972	12.8	1982	18.4
1951	10.5	1962	13.5	1973	27.2	1983	30.9
1952	18.0	1963	30.7	1974	22.3	1984	31.6
1953	17.1	1964	21.7	1975	16.6	1985	29.9
1954	20.9	1965	20.4	1976	18.1	1986	30.9
1955	11.7	1966	21.6	1977	35.1	1987	37.3
1956	122	1967	29.5	1978	30.3	1988	35.7
1958	18.0	1968	37.7	1979	30.8		
Average - 25.7 m^3/sec							

Hydraulic calculations of water level increase during spring floods are given in **Table 30** and shown in **Figure 36**. The 0.1% and 1.0% maximum water flows taking into account the Geghi River bed cross-section under the planned bridge 018, were calculated.

Table 30. Maximum water flow hydraulic calculations under the planned bridge 018

Water level, MASL	Riverbed width, m	Catchment area, m^2	Velocity, m/sec	Water flow, m^3/sec
1995.10	1.100	0.055	0.293	0.02
1995.20	2.200	0.220	0.519	0.11
1995.30	3.300	0.495	0.724	0.36
1995.40	4.400	0.880	0.919	0.81
1995.50	5.500	1.375	1.105	1.52
1995.60	6.600	1.980	1.285	2.54
1995.70	7.700	2.695	1.459	3.93
1995.80	8.800	3.520	1.630	5.74
1995.90	9.900	4.455	1.797	8.01
1996.00	11.000	5.500	1.960	10.8
1996.10	12.100	6.655	2.121	14.1
1996.20	13.200	7.920	2.278	18.0
1996.30	14.300	9.295	2.432	22.6
1996.40	15.400	10.780	2.584	27.9
1996.50	16.500	12.375	2.733	33.8
1996.60	17.600	14.080	2.879	40.5
1996.70	18.700	15.895	3.023	48.0
1996.80	19.800	17.820	3.163	56.4
1996.90	20.900	19.855	3.301	65.6
1997.00	22.000	22.000	3.437	75.6
1997.10	23.600	24.280	3.513	85.3
1997.20	25.200	26.720	3.596	96.1
1997.30	26.800	29.320	3.684	108
1997.40	28.400	32.080	3.775	121
1997.50	30.000	35.000	3.868	135
1997.60	31.600	38.080	3.963	151

During the spring flood, water level in the Karut River under the Project bridge 018 can potentially increase from 1,995.0 MASL to 1,997.8 MASL, which must be considered during design and construction (**Figure 36).**

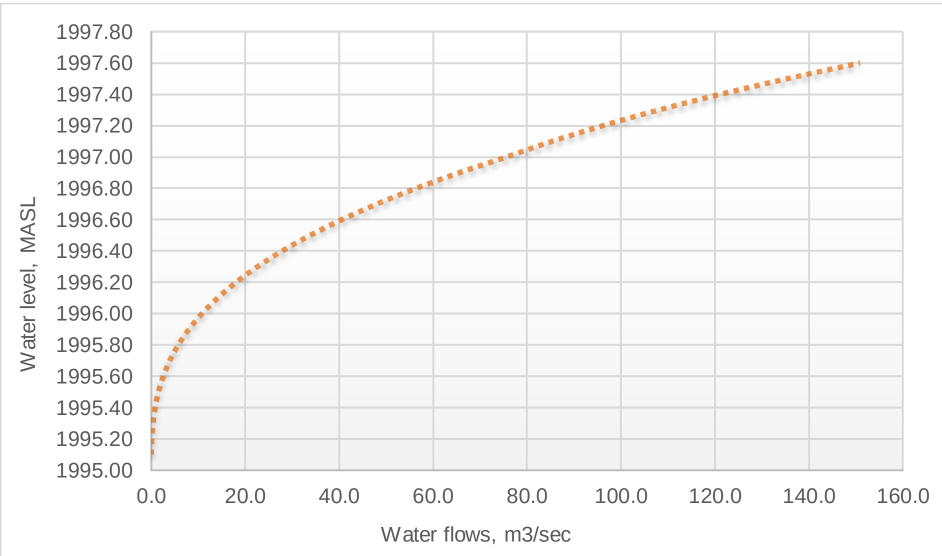


Figure 36. Calculated water level increase during the spring flooding season under the planned bridge 018

2.9.4 Surface Water Quality

The RA Government Decision №75 adopted in January 2011 specifies requirements for river water quality. That decision defines water specific criteria (environmental norms) for five water quality categories for the river basins of Armenia (Class 1 - excellent; Class 2 - good; Class 3 - fair; Class 4 - poor; and Class 5 – bad). The "Hydrometeorology and Monitoring Centre" SNCO regularly analyses water quality in the Vorotan, Loradzor and Geghi Rivers. The results show that the water quality is fair (Class 3) in the Vorotan River 3 km downstream from Sisian Town, good (Class 2) in the Loradzor River, and fair (Class 3) at the confluence of the Geghi River.

Ten water samples were taken from the rivers and their tributaries potentially affected by the Project, i.e., flow under the bridges (points S3, S6, S8, S9, S11, S14 and K7), near the tunnel (point K2) and along the planned road (points K10 and K12). Six samples were from streams along the Sisian-Shenatagh section and four samples along the Qirs-Kajaran section (see the maps in **Annex 1**). The water samples were analysed in the state laboratory of the Hydrometeorology and Monitoring Centre. The streams of the Sisian-Shenatagh section belong to the Vorotan River Basin, hence, the environmental norms set for the Vorotan River[28] were used for the assessment of the quality of the respective six water samples (bodies). Similarly, the environmental norms set for the Geghi River[29] were used for the assessment of the quality of the four water samples (bodies) along the Qirs-Kajaran section as all four water bodies belong to the Geghi River basin. The quality of water in the water bodies along the Sisian-Shenatagh and Qirs-Kajaran sections are presented in **Table 31** and **Table 32,** respectively.

Table 31. The results of water quality analysis of six water samples taken along the Sisian-Shenatagh section

No	Analysed parameters	Unit	S3		S6		S9		S11		S13		S14	
			Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category
1	Colour	rank	15	3	10	3	15	3	15	3	15	3	20	3
2	Smell	points	0	1	0	1	0	1	0	1	0	1	0	1
3	Transparency	cm	31	*	31	*	31	*	31	*	31	*	31	*
4	Suspended solids	mg/l	19.7	2	13.6	2	24.7	2	14.7	2	21.7	2	22.0	2
5	pH	-	8.3	1	8.1	1	8.1	1	8.2	1	7.9	1	7.8	1
6	Mineralization	mg/l	412	*	212	*	157	*	143	*	172	*	82	*
7	El.conductivity	μs/cm	634	2	327	2	241	2	219	2	264	2	126	2
8	BOD_5	mgO_2/l	2.38	1	2.76	1	2.25	1	2.57	1	2.31	1	2.22	1
9	COD	mgO/l	5	1	10	1	5	1	5	1	10	1	15	2
10	Phosphate ion	mg/l	0.173	2	0.449	3	0.0612	1	0.0401	1	0.0745	1	0.00972	1
11	Sulphate ion	mg/l	103.75	3	63.71	2	19.57	2	18.30	2	21.68	2	9.95	2
12	Chloride ion	mg/l	7.46	2	5.75	2	4.12	2	3.74	1	4.60	2	2.71	1
13	Nitrate ion	mg/l	1.4247	2	4.031	3	1.08	2	0.74	2	0.81	2	0.96	2
14	Fluoride ion	mg/l	0.296	*	0.128	*	0.0870	*	0.0890	*	0.103	*	0.0846	*
15	Bromide ion	mg/l	0.0435	*	<0.03	*	<0.03	*	<0.03	*	<0.03	*	<0.03	*
16	Nitrite ion	mg/l	0.0179	2	0.0345	2	0.0291	2	0.0220	2	0.0275	2	0.0200	2
17	Ammonium ion	mg/l	0.116	1	0.084	1	0.089	1	0.109	1	0.266	1	0.066	1
18	Silicate ion	mg/l	19.87	2	25.08	3	6.98	1	5.64	1	6.61	1	4.26	1
19	Carbonate ion	mg/l	21.0	*	15.0	*	10.5	*	10.5	*	10.5	*	6.0	*
20	Lithium	mg/l	0.0271	5	0.0183	5	0.0111	4	0.0107	4	0.0184	5	0.000408	1
21	Beryllium	mg/l	<0.0001	1	<0.0001	1	<0.0001	1	<0.0001	1	<0.0001	1	<0.0001	1

[28] Annex 20 of the RA Government decision No 75
[29] Ibid

No	Analysed parameters	Unit	S3		S6		S9		S11		S13		S14	
			Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category
22	Boron	mg/l	0.264	2	0.101	2	0.118	2	0.115	2	0.192	2	0.0153	2
23	Sodium	mg/l	33.70	2	11.83	2	5.13	2	4.64	2	5.87	2	2.20	1
24	Magnesium	mg/l	18.46	2	8.43	2	5.03	2	4.55	2	5.54	2	2.36	2
25	Aluminium	mg/l	<0.01	1	0.034	1	0.079	1	0.069	1	0.053	1	0.090	1
26	Total phosphorus	mg/l	0.123	2	0.274	3	0.0454	1	0.0239	1	0.0780	1	0.00608	1
27	Potassium	mg/l	7.13	2	5.39	2	1.58	1	1.39	1	1.69	1	0.786	1
28	Calcium	mg/l	52.07	2	26.45	2	29.28	2	28.08	2	33.32	2	16.40	2
29	Titanium	mg/l	0.00582	*	0.00622	*	0.00414	*	0.00360	*	0.00302	*	0.00372	*
30	Vanadium	mg/l	0.0443	4	0.0350	4	0.00115	1	0.000836	1	0.000814	1	0.000659	1
31	Chrome	mg/l	0.000673	2	0.000445	1	0.000187	1	0.000103	1	0.000130	1	<0.0001	1
32	Iron	mg/l	0.0258	1	0.0482	1	0.0878	2	0.0663	1	0.0765	1	0.0734	1
33	Manganese	mg/l	0.0286	4	0.0144	3	0.00735	2	0.00476	2	0.00980	3	0.00400	1
34	Cobalt	mg/l	0.000173	2	<0.0001	1	0.000165	2	0.000123	1	0.000160	2	0.000102	1
35	Nickel	mg/l	0.00179	2	0.000670	2	0.000839	2	0.000806	2	0.000905	2	0.000508	2
36	Copper	mg/l	0.00127	1	0.00166	1	0.00223	2	0.00212	2	0.00249	2	0.00169	1
37	Zinc	mg/l	0.00145	1	0.0108	2	0.00228	2	0.00202	2	0.00400	2	0.00299	2
38	Arsenic	mg/l	0.00659	2	0.00387	2	0.00215	2	0.00190	2	0.00264	2	0.000312	1
39	Selenium	mg/l	0.000273	1	0.000240	1	0.000142	1	0.000333	1	0.000692	2	0.000598	2
40	Strontium	mg/l	0.355	*	0.157	*	0.209	*	0.195	*	0.245	*	0.0847	*
41	Molybdenum	mg/l	0.00777	4	0.00260	3	0.00151	2	0.00150	2	0.00155	2	0.000865	1
42	Cadmium	mg/l	<0.0001	2	<0.0001	2	<0.0001	2	<0.0001	2	<0.0001	2	<0.0001	2
43	Tin	mg/l	<0.001	1	<0.001	1	<0.001	1	<0.001	1	<0.001	1	<0.001	1
44	Antimony	mg/l	0.000116	1	<0.0001	1	<0.0001	1	<0.0001	1	<0.0001	1	<0.0001	1
45	Barium	mg/l	0.0164	3	0.0114	2	0.0231	3	0.0236	3	0.0266	4	0.0157	3
46	Lead	mg/l	<0.0001	1	0.000268	2	0.000232	2	0.000141	2	0.000166	2	0.000267	2

*no water quality criteria are set for these parameters

Table 32. The results of water quality analysis of four water samples taken along the Qirs-Kajaran section

No	Analysed parameters	Unit	K2		K7		K10		K12	
			Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category
1	Colour	rank	5	3	15	3	15	3	15	3
2	Smell	points	0	1	0	1	0	1	0	1
3	Transparency	cm	31	*	31	*	31	*	31	*
4	Suspended solids	mg/l	6.5	1	10.9	2	31.0	3	24.8	2
5	pH	-	8.3	1	8.2	1	8.3	1	8.2	1
6	Mineralization	mg/l	150	*	97	*	243	*	171	*
7	Electrical conductivity	µs/cm	230	2	149	1	375	2	263	2
8	BOD_5	mgO_2/l	1.61	1	1.84	1	1.95	1	1.85	1
9	COD	mgO/l	15	2	15	2	15	2	20	2
10	Phosphate ion	mg/l	0.00527	1	0.00770	1	0.0555	1	0.0130	1
11	Sulphate ion	mg/l	18.10	2	10.66	1	71.00	2	35.36	2
12	Chloride ion	mg/l	1.97	1	2.01	1	7.93	2	4.50	1
13	Nitrate ion	mg/l	0.0807	1	0.502	2	4.01	3	2.18	2
14	Fluoride ion	mg/l	0.0910	*	0.0860	*	0.0940	*	0.0910	*
15	Bromide ion	mg/l	<0.03	*	<0.03	*	<0.03	*	<0.03	*
16	Nitrite ion	mg/l	0.00770	2	0.0182	2	0.0957	3	0.0500	2

No	Analysed parameters	Unit	K2		K7		K10		K12	
			Result of analysis	Category	Result of analysis	Category	Result of analysis	Category	Result of analysis	Category
17	Ammonium ion	mg/l	0.0509	2	0.0951	2	0.370	2	0.252	2
18	Silicate ion	mg/l	3.40	1	3.86	1	5.08	1	4.36	1
19	Carbonate ion	mg/l	13.5	*	10.5	*	15.0	*	13.5	*
20	Lithium	mg/l	0.00404	1	0.00295	1	0.0113	3	0.00648	2
21	Beryllium	mg/l	<0.0001	1	<0.0001	1	<0.0001	1	<0.0001	1
22	Boron	mg/l	0.0157	2	0.0268	3	0.106	4	0.0634	4
23	Sodium	mg/l	4.03	1	3.20	1	7.89	2	5.78	2
24	Magnesium	mg/l	5.35	2	3.38	1	11.64	2	6.93	2
25	Aluminium	mg/l	<0.01	1	0.039	1	0.097	1	0.078	1
26	Total phosphorus	mg/l	0.0116	1	0.00813	1	0.0375	2	0.0203	2
27	Potassium	mg/l	0.870	2	0.748	2	1.947	2	1.328	2
28	Calcium	mg/l	34.79	2	20.73	1	42.72	2	30.94	2
29	Titanium	mg/l	0.000890	*	0.00176	*	0.00725	*	0.00678	*
30	Vanadium	mg/l	0.000408	1	0.000545	1	0.00129	3	0.00105	3
31	Chrome	mg/l	0.000196	1	0.000308	1	0.000685	2	0.000525	2
32	Iron	mg/l	0.0189	1	0.0467	1	0.177	3	0.150	3
33	Manganese	mg/l	0.00185	1	0.00279	1	0.0147	3	0.0124	3
34	Cobalt	mg/l	<0.0001	1	<0.0001	1	0.0003142	1	0.0002157	1
35	Nickel	mg/l	0.000416	1	0.000258	1	0.00108	2	0.000640	1
36	Copper	mg/l	0.00101	1	0.00191	1	0.0173	2	0.0111	2
37	Zinc	mg/l	0.00160	2	0.00149	1	0.00303	2	0.00186	1
38	Arsenic	mg/l	0.000264	1	0.000392	2	0.00226	2	0.00126	2
39	Selenium	mg/l	0.000181	1	0.000272	2	0.00608	2	0.00243	2
40	Strontium	mg/l	0.235	*	0.125	*	0.436	*	0.263	*
41	Molybdenum	mg/l	0.148	5	0.0158	3	0.0931	4	0.0540	3
42	Cadmium	mg/l	0.000457	2	<0.0001	2	0.000302	2	0.000178	2
43	Tin	mg/l	<0.001	1	<0.001	1	<0.001	1	<0.001	1
44	Antimony	mg/l	0.00254	4	0.000176	1	0.000293	1	0.000262	1
45	Barium	mg/l	0.0335	2	0.0185	1	0.0232	2	0.0221	2
46	Lead	mg/l	0.000348	2	0.000843	2	0.00106	2	0.00131	2

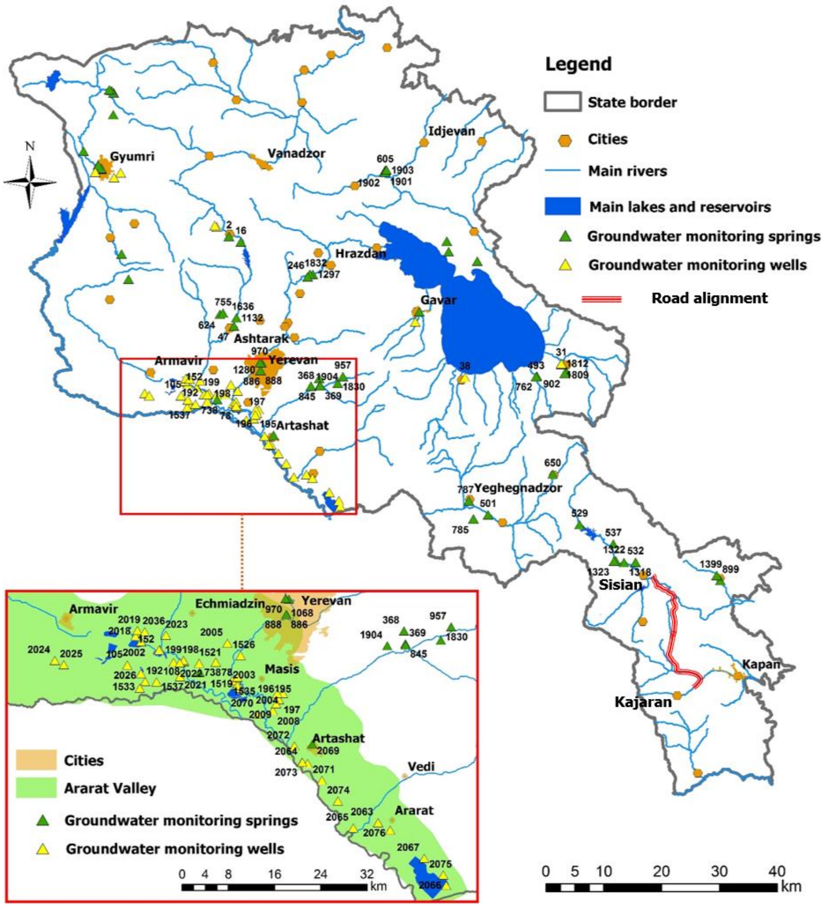
*no water quality criteria are set for these parameters

The results of the chemical analyses of water samples taken from the Vorotan, Loradzor, Geghi and Voghji rivers indicate that water quality in the streams mostly complies with the criteria of 1st (excellent) and 2nd (good) classes, with the exception of some metals' concentrations. In terms of lithium, vanadium, manganese and molybdenum content in samples from the Vorotan River, the water quality is related to the bad and poor classes. The concentration of molybdenum and antimony in the Geghi River is relatively high (bad and poor classes) and in terms of Mo and Sb content the water quality there is classified as bad and poor. This may be related to the abundance of ore deposits in the area (see **Section 2.6**).

2.10 Groundwater Resources

2.10.1 Overview

As per the map of the groundwater resources monitoring network in Armenia[30] there is no groundwater resource monitoring in the Project area (**Figure 37**). Groundwater occurs in the weathering crust of various rocks and deep cracks, as well as in the pores of alluvial-prolluvial formations along riverbeds. The groundwater reserve of 429 mln.m^3/year exists for the Vorotan River and 185.1 mln.m^3/year for the Voghji River Basin, according to the multi-year average values (**Table 33**). The major springs are spread in the Vorotan River valley and slopes of the Syunik volcanic plateau, in the upper and middle reaches of the Voghji and Geghi Rivers.



Source: Water Resources Atlas of Armenia, Yerevan, 2008

Figure 37. Groundwater resources monitoring network

Table 33. Groundwater Resources[31]

№	River basin	Groundwater resources by flow components, mln.m^3/year			Ground water level, m
		Total	Spring	Drainage flow	
1	Vorotan	429	118	208	107
2	Voghji	185.1	72.2	26.5	86.4

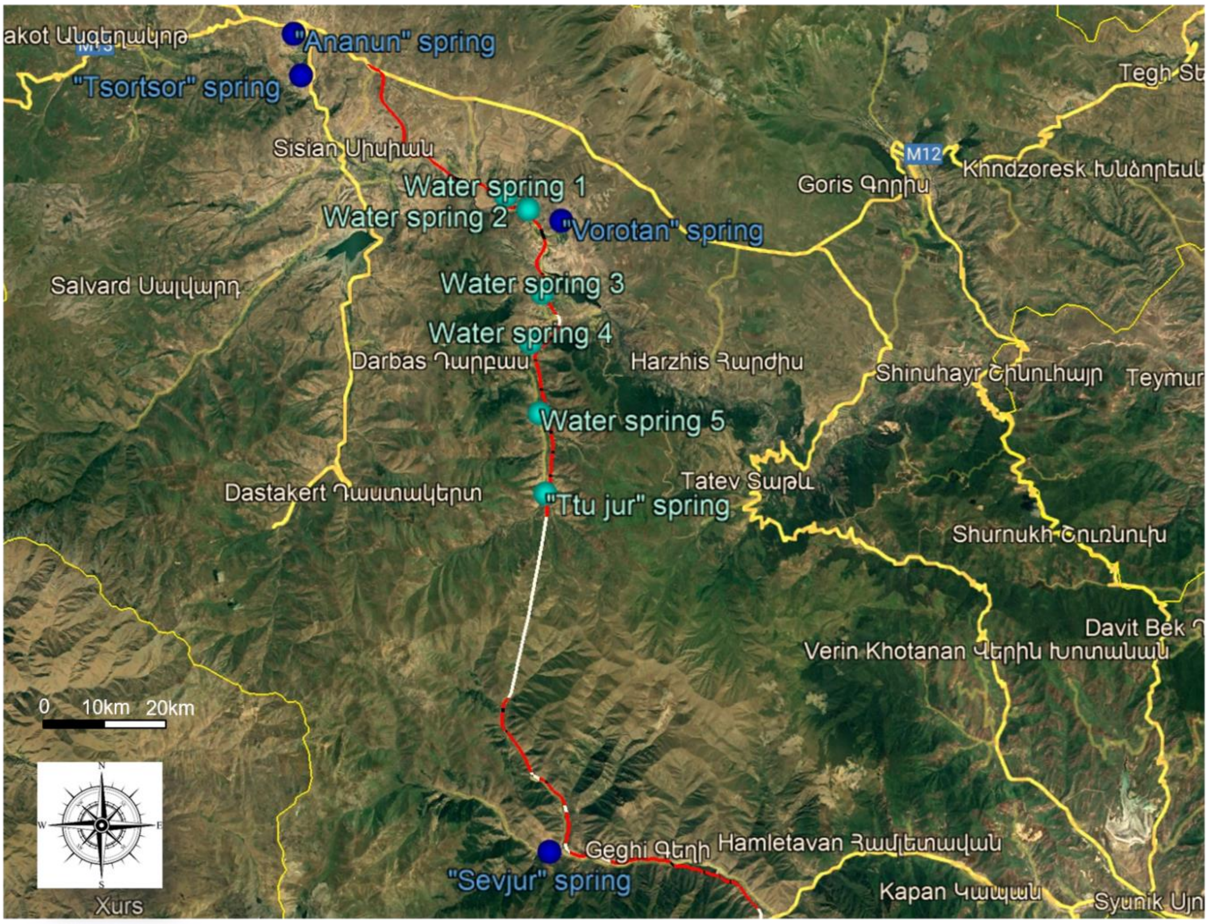
[30]Water Resources Atlas of Armenia, Yerevan, 2008

[31]North-South Road Corridor Investment Program, Tranche 4: Section Sisian-Kajaran, Detail Design, Final Environmental Impact Assessment Report and Environmental Management Plan, November 2019

2.10.2 Springs

The RA Government Decision №967-N[32] included 16 springs in Syunik Region into the RA list of nature monuments (so-called "water springs of national significance"). Two of the springs are within the administrative boundaries of Project-affected settlements (**Figure 38.**, dark blue points):

- "Vorotan" spring, in the northern part of Vorotan village, 1,000 m from the planned road,
- "Sevjur" spring, within the administrative boundaries of Geghi village, 800 m west of the planned road,



Spring	GPS cooridanates		Spring	GPS cooridanates	
"Ananun"	39°34'20.17"N	45°59'41.95"E	"Tsortsor"	39°33'18.15"N	45°59'56.06"E
"Vorotan"	39°29'37.97"N	46° 8'29.60"E	"Sevjur"	39°13'38.17"N	46° 8'5.32"E

Figure 38. Springs in the Project region

Two other springs are within the administrative boundaries of Sisian Community, in the vicinities of Shaqi village. Both are located 3.8 km west of the starting point of the planned road.

Almost all villages in the northern (Sisian-Shenatagh) section of the proposed road have at least 1-2 springs of local significance that were observed during site visits to the Project region

[32] https://www.arlis.am/documentview.aspx?docid=157090

(**Figure 38**, light blue points). Most of these springs occur along the existing road, are marked by cross-stones and are considered by local people as spiritual sites.

Springs 1 and 2 (, a) and b)) are situated within the administrative area of Vaghatin settlement, water springs 3, 4 and 5 (**Figure 39**, c), d) and e)) in Shamb, Darbas and Lor settlements, respectively, and "Ttu jur" spring (**Figure 39**, f)) in Shenatagh village. All springs of local significance are 200-300 m from the proposed road alignment. The water from the springs is used only occasionally for drinking by the population of Vaghatin, Shamb, Darbas, Lor, Getatagh and Shenatagh settlements and by visitors / drivers, approx. 2,500-3,000 people. These are not the main water source in the villages but rather places of gatherings and occasional collection of water in bottles.

a) Spring 1 (Vaghatin)

b) Spring 2 (Vaghatin)

c) Spring 3 (Shamb)

d) Spring 4 (Darbas)

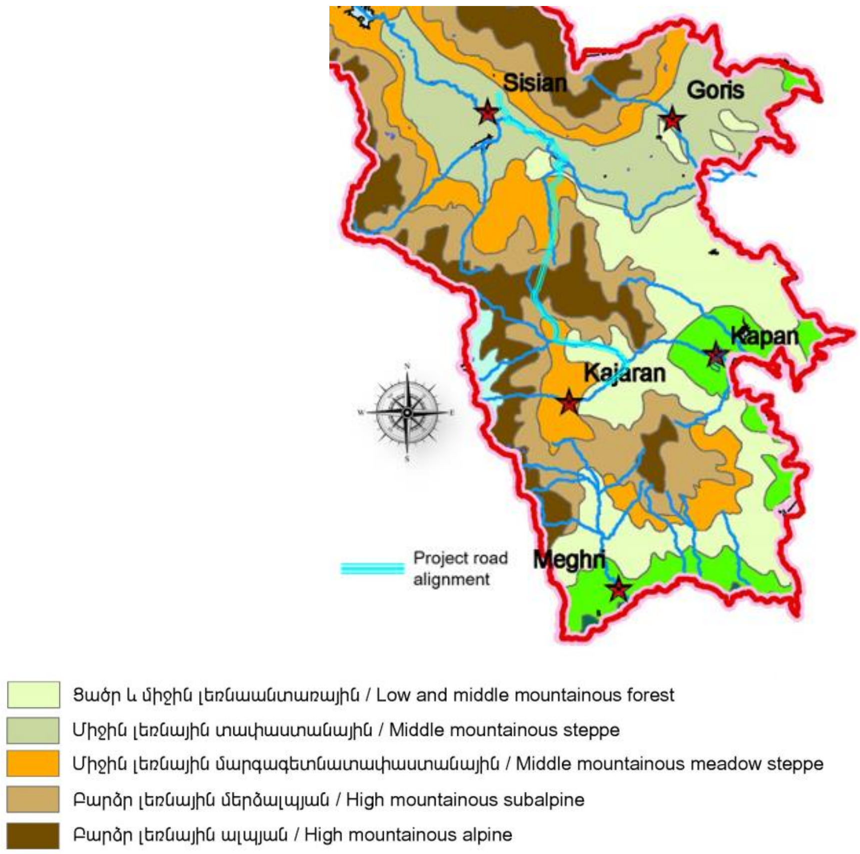
e) Spring 5 (Lor)

f) "Ttu jur" spring 6 (Shenatagh)

Figure 39. Photos of the springs in the Project region

2.11 Landscape and Visual Amenity

The planned road passes through six vertical landscape zones: low and middle mountain below forest level, low and middle mountain forest, middle mountain steppe, middle mountain meadow steppe, high mountain subalpine, high mountain alpine and will have direct and indirect impacts on the physical and biological resources of the environment, archaeological/historical sites and cultural monuments. The landscapes of the project area are described in the following section and illustrated using photographs below. Cultural landscapes (viz. where the visual amenity of the landscape includes human made structures) are discussed in **Volume 4 of the ESIA**.



Source: Water Resources Atlas of Armenia, Yerevan, 2008

Figure 40. Landscape zones of Syunik Region

The first 15 km of the Project road passes along the middle mountain steppe. It starts from the 1780 MASL (km 0+000) and gradually descends to approx. 1380 MASL (km 12+800 - km 15+000 section). The beginning section of the planned road runs through the administrative area of Sisian Community and then starting from the chainage km 5+000 and up to the Shamb HPP and Shamb reservoir area (km 15+000) passes along the valley of Vorotan River (**Figure 41** and **Figure 42**).

From chainage km 15+000 the landscape around the planned road changes to middle mountain meadow steppe. Starting from Darbas village and up to the Bargushat tunnel (Shenatagh village) the planned road runs along the left slope of the Loradzor River gradually climbing from 1500 MASL to 1800 MASL. The landscape here is characterized by a combination of middle mountain meadow steppe and high mountainous sub-alpine (**Figure 43** and **Figure 44**). Near the northern portal of Bargushat tunnel the planned road reaches around 1880 MASL altitude and is surrounded by high mountainous sub-alpine landscape (**Figure 45** and **Figure 46**). The 8.6 km long Bargushat tunnel mostly passes through the high mountainous alpine zone.

The southern portal of the Bargushat tunnel (near Qirs village) is situated at 2100 MASL surrounded by high mountainous alpine landscape (**Figure 47** and **Figure 48**). Between Qirs (km 36+000) and Karut (km 39+000) villages the landscape gradually changes from high mountainous alpine into high mountainous sub-alpine (**Figure 49, Figure 50** and **Figure 51**). Near Geghi village the landscape changes to middle mountain meadow steppe. Between km 44+500 and km 54+600, the planned road runs along the Geghi River valley (**Figure 52,**

Figure 53, Figure 54 and **Figure 55**) characterized by low and middle mountainous forest zone. The section between km 54+600 and km 60+000 (ending point of Sisian-Kajaran road) is passing along the M2 road.

Figure 41. Landscape of the beginning part of the road alignment (km 0+000 - km 2+000), view from Zorats Qarer

Figure 42. Landscape of the valley of Vorotan River, view from Vorotnavank Monastery (km 11+900), the road alignment shall pass along the left slope

Figure 43. Landscape of the valley of the Vorotan River, view from Shamb HPP (km 14+900)

Figure 44. View from the existing road to Darbas village and valley of the Loradzor River (km 18+000), the road alignment shall pass along the left slope

Figure 45. View of the slope where the planned road will be constructed (km 23+100)

Figure 46. View looking south from the northern portal of the Bargushat tunnel

Figure 47. View looking north from the northern portal of the Bargushat tunnel

Figure 48. Position of the northern portal of the Bargushat tunnel

Figure 49. Landscape of the southern part of the road alignment looking north

Note the scar on the left-hand side of the picture created by the Iran-Yerevan gas pipeline.

Figure 50. View looking north close to the southern portal of the Bargushat tunnel.

Figure 51. Landscape in the southern part of the road alignment looking north.

Figure 52. Landscape in the southern part of the road alignment looking south, Qirs-Karut section

Figure 53. Valley of Geghi River (before the Geghi reservoir), the road alignment will pass along the left slope

Figure 54. Landscape in the southern part of the road alignment after Karut village.

Figure 55. Low and middle mountainous forest landscape near Kavchut village.

3 ASSESSMENT OF POTENTIAL ENVIRONMENTAL IMPACTS AND RISKS AND MITIGATION MEASURES

3.1 Air Quality and GHG Emissions

3.1.1 Air Quality

3.1.1.1 Introduction and AoI

In this section of the ESIA potential air quality impacts associated with the Project are described and assessed. The assessment was undertaken with reference to relevant national and international standards and reference criteria (see below). Both the construction and operations of the proposed roadway will generate atmospheric emissions which will impact on local air quality along the length of the roadway. During construction the principal emission of concern is dust that may be generated by construction activities such as excavations, transport of excavated material, vehicle movement on unpaved roads and so forth, but during road operations it is principally exhaust emissions (from combustion) that are of greatest concern.

A site-specific baseline survey was carried out in June 2022 to determine baseline air quality and presented in **Section 2.3**. The data from that assessment indicated that air quality is generally good along the length of the proposed roadway with localised pollution sources resulting in two areas where the 2005 WHO SO_2 AQG were exceeded. At the same time, the 2021 WHO AQG are slightly less stringent than the 2005 AQG and the measured concentrations comply with the 2021 guidelines. In addition, the WHO AQG are very exacting for many countries and regions where there are pollution sources and as such the WHO details interim target values which are even less stringent than the AQG. The measured concentrations comfortably comply with the interim target values.

The AoI for the air quality assessment was identified to incorporate the nearest receptors to the proposed Project construction and operation activities. The potential AoI is a band of approximately 500 m either side of the centreline of the proposed roadway but more importantly is the specific residential areas that occur along the existing road especially, but not exclusively, on the northern side of the road alignment. Specific receptors have been defined as detailed in **Table 34** (where campaign ambient air quality monitoring took place during the baseline assessment). All other settlements are seen as receptors that could potentially be affected during either construction or operations of the proposed roadway (see the maps in **Annex 1**).

Table 34. Listing of specific potentially sensitive receptors along the roadway where campaign air quality monitoring was conducted during the baseline (sensitive receptors are shown in a series of maps in Figure 65 and Figure 66)

Note: In addition to these sensitive receptors, all inhabited settlements as well as agriculture activities on either side of the proposed roadway within an approximately 500 m buffer are deemed to be sensitive receptors too.

Point	Sensitive Receptor
ER1	Aghitu village, near the school
ER2	Noravan village, near the school
ER3	Darbas village, near St. Stephan Church
ER4	Getatagh village, near Holy Mother Church
ER5	Lor village, near St. Gevorg church and residential houses
ER6	Shenatagh village, near the Memorial to R. Vasiryan
ER7	Kavchut settlement, near the 3-storey multi-residential buildings
ER8	Near the commercial facility located at the crossing point of M-2 road and the existing road to Qirs settlement

3.1.1.2 Reference Criteria

The RA Law on Atmospheric Air Protection provides legislation for air protection and quality. Daily average and maximum one-time Admissible Concentration Limits (ACLs) for ambient air quality in residential areas are set by the RA Government Decree No. 160-N (**Table 35**). In addition, provisions of the IFC Environmental, Health and Safety General Guidelines (2007) which reference the WHO Air Quality Guidelines (2005), were applied. The WHO published revised guidelines in 2021 and these guidelines were used for the assessment. The principle of using the strictest standards (whether locally or internationally defined) was also applied (**Table 35**) although it should be recognised that the 2021 WHO AQG have superseded the 2005 AQG even though, in the case of SO_2, less stringent than the 2005 AQG.

Table 35. Air Quality Standards highlighting (in red) the most stringent

Pollutant	Averaging period	EU 2008/50/EC		WHO		Armenian stds
		Concentration	Permitted exceedances per year	2005	2021	
$PM_{2.5}$	24-hour			25	15	35
	Annual	25			10	
	Maximum					160
PM_{10}	24-hour	50	35	50	45	60
	Annual	40	n/a	20	15	
	Maximum					300
Sulphur dioxide	1-hour	350	24			
	24-hour	125	3	20	40	50
	Maximum					500
Nitrogen dioxide	1-hour	200	18			
	24-hour				25	40
	Annual	40	n/a	40	10	
	Maximum					200
Carbon monoxide	Maximum Daily 8hour	10 000	n/a			
	24-hour				4 000	3 000
	Maximum					5 000

µg = microgram
[a] 99th percentile (i.e., 3–4 exceedance days per year).
[b] Average of daily maximum 8-hour mean O_3 concentration in the six consecutive months with the highest six-month running- average O_3 concentration.

3.1.1.3 Method, Assumptions and Limitations

For the assessment, atmospheric emissions were derived for the construction and operations phases of the project. Thereafter, the impact of those emissions on prevailing air quality was determined using a dispersion model that simulates the dispersion of emissions through the atmosphere. The model output is predicted ambient concentrations that are likely to occur because of the proposed roadway activities relative to potentially sensitive receptors. Finally, predicted concentrations were compared to defined standards to be able to assess the significance of the impacts.

Dispersion Modelling[33]

Meteorological processes direct the dispersion, transformation and eventual removal of pollutants from the atmosphere. The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer (the layer of atmosphere closes to the earth). This dispersion comprises vertical and horizontal components of motion. The stability of the atmosphere and

[33] The emissions calculations and dispersion modelling that underpins this assessment was conducted by Airshed Planning Professionals, and authored by Ms. Gillian Petzer.

the depth of the surface-mixing layer define the vertical component. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field namely the direction in which the wind is blowing.

For the dispersion modelling it is necessary to determine the atmospheric characteristics both at the earth's surface, but also in the upper air. The modelling requires various atmospheric parameters such as temperature, wind velocity, mixing height and others to be defined in a three-dimensional grid that encompasses the modelling domain. Due to the great difficulty of sourcing upper air meteorological data, a three-dimensional grid was modelled for the roadway using data from the Weather Research and Forecasting (WRF) Model. The WRF is a state-of-the-art mesoscale numerical weather prediction system for both atmospheric research and operational forecasting. WRF data over a three-year period (2019 to 2021) were sourced for the modelling.

Air Quality Dispersion Simulations

The dispersion modelling of traffic emissions was done using the Graz Lagrangian Model (GRAL) (Graz University of Technology, 1999). The high-resolution model system GRAMM/GRAL, developed at the Institute of Thermodynamics and Sustainable Propulsion Systems at Graz University of Technology, is well-suited to dispersion modelling in urban areas, both in scientific research and regulatory assessments. The model is especially suitable for low-wind speed conditions and complex terrain. An integrated micro-scale flow-field model takes the effect of buildings on pollutant dispersion into account. The initial driver for the development of GRAL was the need for a model that could deal with the frequent low-wind-speed conditions (< 1.5 m/s for up to 90 per cent of the time) in the inner-Alpine basins of Austria. Another important feature of GRAL is the ability to deal with the dispersion of pollutants emitted from road tunnel portals.

The simulations covered an area of 22 km east-west by 45 km north-south and encompassed the project area. The area was divided into a grid matrix with a 50 m resolution. The model was set to calculate concentrations at each grid and discrete receptor point (more than 396 000 points) at a height of 1.5 m above ground level. Two operational scenarios were modelled for years 2029 (early operations) and 2048.

Emissions inventory

The main atmospheric emissions from road construction and operation are Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Carbon Monoxide (CO) and particulate matter (PM_{10} and $PM_{2.5}$).

Construction

Heavy construction is a source of dust (see **Box 1**) that may have a substantial but typically temporary impact on local air quality. Road construction activities may have large atmospheric emissions potential associated with land clearing, drilling and blasting, ground excavation, cut and fill operations (i.e., earth moving), and so forth. Although there are important emissions from the tailpipes of construction vehicles and machinery (combustion emissions) in relative terms these emissions are not as significant as those from an operational roadway. For road construction it is dust that is the major concern. Dust emissions often vary substantially from day to day, depending on the level of activity, the specific operations, and the prevailing meteorological conditions. A large portion of the emissions result from equipment and traffic over temporary unpaved roads at the construction site.

Box 1: What is dust?

The term 'dust' refers to airborne particles (or particulates) of solid matter such as fine sand. Dust is quite different from other atmospheric pollutants in that it is a solid while they are generally gasses. Dust is made up of a large spectrum of particle sizes from large to very small. In general terms larger particles are generated mechanically (vehicle driving on an unpaved road) while the smallest particles are generated by combustion (ash). The standards set to ensure human health and environmental protection are packaged according to the different particulate sizes. All dust is referred to as Total Suspended Particulates (TSP). Again, in general terms, the larger dust particulates are less of a concern as they generally settle out of the atmosphere quite quickly and are too large to be inhaled.

Human health concerns derive from the smaller particulates that can potentially penetrate deep into the human lung. Particulate matter smaller than 10 microns are referred to as PM_{10} and particulate matter smaller than 2,5 microns referred to as $PM_{2,5.}$ It is this latter size category that poses the greatest risk of adverse human health effects from dust due to the depth that such particulates can penetrate the lung.

There is simply inadequate specificity regarding construction activities, locations and timing at this stage and so it is prudent to use a generally recognised dust emissions factor for road construction. Approximate emission factors for total suspended particulate (TSP) concentrations for construction are:

E = 2.69 megagrams (Mg)/hectare/month of activity (US EPA, 1995)

It is extremely difficult to determine the ratio of the different dust size particles in the absence of direct physical measurements. The above emission factor is given in TSP (i.e. all dust). For this study, where the smaller particulates are the concern, it is conservatively assumed that all the dust is in fact PM_{10}. This assumption means that the predicted concentrations of PM_{10} will be overstated and applying a safety factor to the modelling. In general terms $PM_{2.5}$ is more typically derived from combustion whereas mechanically generated dust from construction is typically coarser (PM_{10} and larger). As such only PM_{10} was modelled (already conservatively) as assuming all TSP was $PM_{2.5}$ would be an unrealistically exaggerated worst case. Also, the emissions factor is based on 30 days of construction a month, meaning an additional safety factor in the modelling. Assuming an area of 26 hectares and 1 month of activity at any given site along the roadway, emissions equate to 96 kg/hr.

Operations

Vehicles numbers on the Sisian-Kajaran corridor were projected at 3 692 per day (for the year 2029) and 8 194 per day (for the year 2048). The vehicle split was assumed to be 52% cars and minibuses, 5.5% buses and 42.5% trucks. The traffic on the road was assumed to be continuous with an even distribution of vehicle numbers per hour (for day- and night-time). Vehicle speeds were assumed to be 100 km/hr (the design speed of the roadway). Road slopes were estimated for the various sections of the road and chosen to be either 0, 0.02, 0.04 or 0.06.

Other assumptions are provided in **Table 36** for 2029 and **Table 37** for 2048. The 8.64 km Bargushat tunnel exhaust ducts are assumed to be located at each of the two tunnel portals with emissions assumptions detailed in **Table 38**. All vehicle emissions within the tunnels are released at the portals. The smaller tunnels are assumed not to have ventilation systems.

Table 36. Assumptions used in the estimation of vehicle emissions - 2029

Type	Fuel type	Vehicle numbers per hour	Type car/truck/bus	Euro
Passenger cars	Petrol	62	40 %: small	20%: Euro 1
			40 %: medium	20%: Euro 2
			20%: large	20%: Euro 3
				20%: Euro 4
				16%: Euro 5
				4%: Euro 6
	Diesel	5	20 %: small	20%: Euro 1
			30 %: medium	20%: Euro 2
			50%: large	20%: Euro 3
				20%: Euro 4
				16%: Euro 5
				4%: Euro 6
	Liquified petroleum gas (LPG)	2	20 %: small	20%: Euro 1
			30 %: medium	20%: Euro 2
			50%: large	20%: Euro 3
				20%: Euro 4
				16%: Euro 5
				4%: Euro 6
	Compressed natural gas (CNG)	12	20 %: small	80%: Euro 4
			30 %: medium	20%: Euro 5
			50%: large	
Trucks	Petrol	40	100%: >3.5t	100%: Conventional
	Diesel	25	1%: Rigid <=7,5 t	22.5%: Euro I
			32%: Rigid 7,5 - 12 t	22.5%: Euro II
			6%: Rigid 12 - 14 t	22.5%: Euro III
			6%: Rigid 14 - 20 t	22.5%: Euro IV
			6%: Rigid 20 - 26 t	7%: Euro V
			6%: Rigid 26 - 28 t	3%: Euro VI
			6%: Rigid 28 - 32 t	
			9%: Rigid >32 t	
			9%: Articulated 34 - 40 t	
			9%: Articulated 40 - 50 t	
			9%: Articulated 50 - 60 t	
Buses	Diesel	1	50%: Urban <=15 t	22.5%: Euro I
			40%: Urban 15 - 18 t	22.5%: Euro II
			10%: Coaches <=18 t	22.5%: Euro III
				22.5%: Euro IV
				7%: Euro V
				3%: Euro VI
	CNG	7	100%: Urban CNG buses	15%: Euro I
				35%: Euro II
				50%: Euro III
Total		**154**		

Table 37. Assumptions used in the estimation of vehicle emissions - 2048

Type	Fuel type	Vehicle numbers per hour	Type car/truck/bus	Euro
Passenger cars	Petrol	137	40 %: small	20%: Euro 1
			40 %: medium	20%: Euro 2
			20%: large	20%: Euro 3
				20%: Euro 4
				16%: Euro 5
				4%: Euro 6
	Diesel	11	20 %: small	20%: Euro 1
			30 %: medium	20%: Euro 2
			50%: large	20%: Euro 3

Type	Fuel type	Vehicle numbers per hour	Type car/truck/bus	Euro
				20%: Euro 4
				16%: Euro 5
				4%: Euro 6
	LPG	3.5	20 %: small	20%: Euro 1
			30 %: medium	20%: Euro 2
			50%: large	20%: Euro 3
				20%: Euro 4
				16%: Euro 5
				4%: Euro 6
	CNG	26.5	20 %: small	80%: Euro 4
			30 %: medium	20%: Euro 5
			50%: large	
Trucks	Petrol	88	100%: >3.5t	100%: Conventional
	Diesel	56.5	1%: Rigid <=7,5 t	22.5%: Euro I
			32%: Rigid 7,5 - 12 t	22.5%: Euro II
			6%: Rigid 12 - 14 t	22.5%: Euro III
			6%: Rigid 14 - 20 t	22.5%: Euro IV
			6%: Rigid 20 - 26 t	7%: Euro V
			6%: Rigid 26 - 28 t	3%: Euro VI
			6%: Rigid 28 - 32 t	
			9%: Rigid >32 t	
			9%: Articulated 34 - 40 t	
			9%: Articulated 40 - 50 t	
			9%: Articulated 50 - 60 t	
Buses	Diesel	2.5	50%: Urban <=15 t	22.5%: Euro I
			40%: Urban 15 - 18 t	22.5%: Euro II
			10%: Coaches <=18 t	22.5%: Euro III
				22.5%: Euro IV
				7%: Euro V
				3%: Euro VI
	CNG	16	100%: Urban CNG buses	15%: Euro I
				35%: Euro II
				50%: Euro III
Total		**341**		

Table 38. Assumptions used in the vent (portal) emissions at the Bargushat tunnel

Type	Vent height (m)	Vent diameter (m)	Vent temperature (°C)	Vent flow (m^3/s)
Vent	10	2	15	160

The relationship between physical baseline measurements and modelled scenarios for the impact assessment are explained in **Box 2** below.

Box 2: The relationship between physical baseline measurements and modelled scenarios for the impact assessment

For the baseline specific measurements were conducted for air quality, noise and vibration and water quality. These measurements can only ever be seen as indicative as the sampling was of limited duration. The cost of conducting at least a full year's worth of baseline data is prohibitive especially air quality data where continuous gas analysers would be required for different pollutants, requiring ongoing calibration and maintenance and then only at a single point. The baseline measurements conducted for this ESIA simply provide an indication and nothing more and need to be used with caution in conducting the further assessment.

For noise, air quality and vibration, the assessment was based on modelling the likely off-site conditions as a function of the on-site sources that are expected during construction and operations of the road. The modelling of air quality and noise is based on at least a full year and in the case of air quality, three years' worth of input data. It is therefore very difficult if not impossible to directly relate the modelled outputs to the baseline outputs. In addition, the modelled data is based on sources of impact that do not exist currently but will exist when the project is implemented.

The measurements conducted for the baseline provide a 'peg in the sand' that can be used qualitatively in the assessment but not quantitatively and there should not be an expectation of anything more than that.

3.1.1.4 Impact Assessment: Construction

The potential impacts during construction activities derive from:

- Dust (e.g., from quarrying, batching plants, earth moving or transport of dry materials) for construction and new access roads, potentially having an adverse impact on sensitive nearby receptors; and
- Exhaust emissions from construction traffic and machinery may result in a deterioration of local ambient concentrations of nitrogen dioxide (NO_2), VOCs, sulphur dioxide (SO_2) and particulate matter ($PM_{2.5}$ and PM_{10}). At the outset this potential impact was not modelled as the same pollutants would be generated during road operations but from an obviously much larger vehicle fleet.

Mechanically generated dust emitted by construction activities may cause impacts on nearby receptors, such as natural habitats, residential properties, agriculture and people through:

- Dusting / soiling of surfaces, crops, natural vegetation, water bodies, and others; and,
- Human health effects through exposure to airborne fine particulate matter.

For the modelling and assessment, the entire roadway with the proposed SDAs, was divided into six sites and dust modelled for one site deemed representative of the others (**Figure 56**). The site chosen (Site 6) includes a possible spoil disposal area, which is obviously a key source of dust in its own right

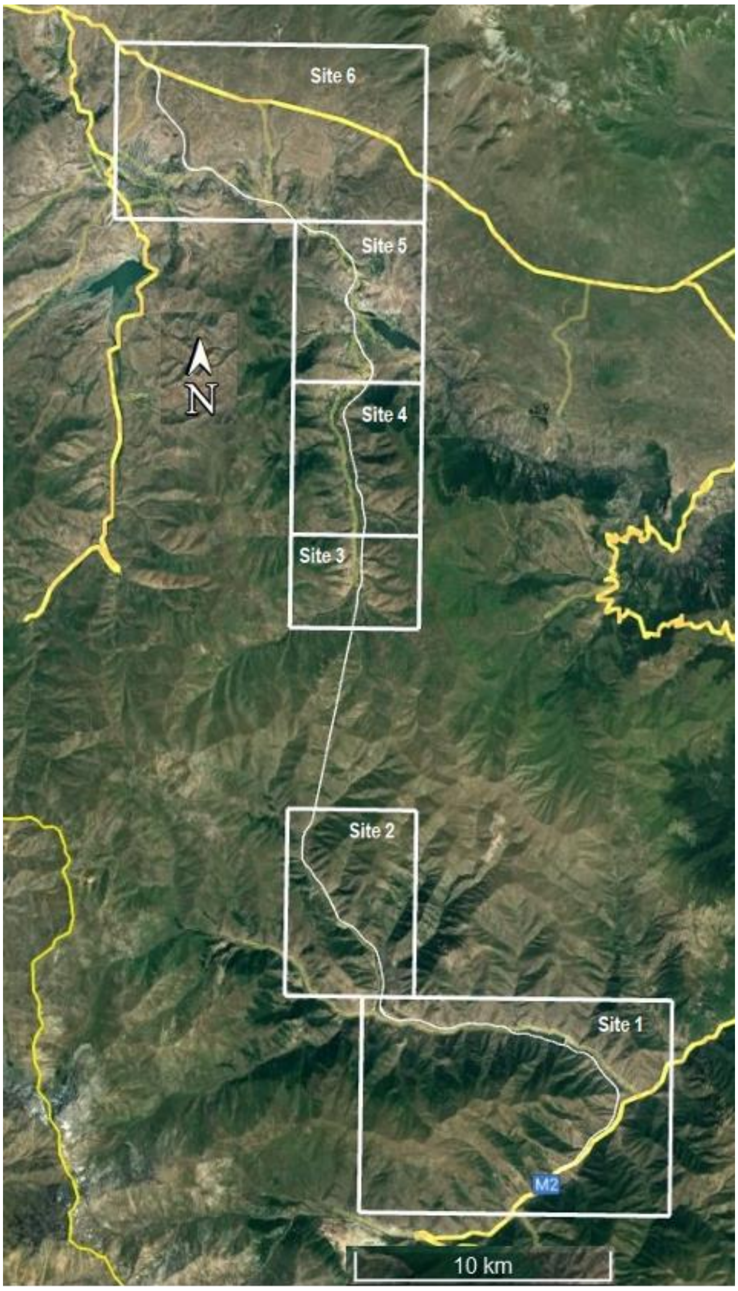


Figure 56. Impact areas selected for assessment due to location of potential receptors. Note that Site 6 was considered representative of the likely air quality impacts as a result of construction[34]

The spatial distribution of predicted pollution concentrations is shown as isopleth (lines joining equivalent pollution concentrations) maps. It is very difficult to present dispersion modelling results for an extended section of roadway due to scale and so it is necessary to divide up the roadway into sections so that the detail of the dispersion modelling can be seen. At the same time, there are multiple permutations for every pollutant, every averaging period and the three

[34] Due to the extremely limited information on the construction process construction emissions are assumed to be the same along the entire roadway. As such the dispersion modelling will reflect largely the same dispersion patterns for all the sites with small differences related to topography. This is why one site can be representative of the entire roadway. Specific predicted concentrations at each of the defined receptors along the entire length of the roadway are presented later in this section.

scenarios of construction, operations 2029 and 2048, implying just less than 200 isopleth maps. As such the information is presented here selectively and only on the pollutants that are potentially significant. For example, the Armenian daily CO standard is 3 000 µg/m^3 and yet the maximum modelled concentrations are <5 µg/m^3 and so CO modelling is not presented in this document.

The simulated highest daily average PM_{10} concentrations are shown in **Figure 57** and the annual average concentrations in **Figure 58**. It can be seen from the maps that all the specified standards are exceeded at various distances from the source of the dust.

Modelled maximum daily average PM_{10} concentrations due to project construction exceeds the Armenian standard up to ~1.5 km from the construction site, and the WHO AQG value up to ~2 km from the site (**Figure 57**). It should be noted that the isopleth map brings together the highest concentrations modelled for each receptor, regardless of when they occurred in the year. Even though this is a daily model outcome the simulated annual average PM_{10} concentrations due to project construction operations exceeds the WHO AQG value up to ~1.2 km from the construction site (**Figure 58**).

Because the emission factor used is referenced to TSP, use of this factor to estimate particulate matter (PM) no greater than 10 µm in aerodynamic diameter (PM_{10}) will result in conservatively high estimates. With actual activities and mitigation measures, it is anticipated that this impact would be reduced.

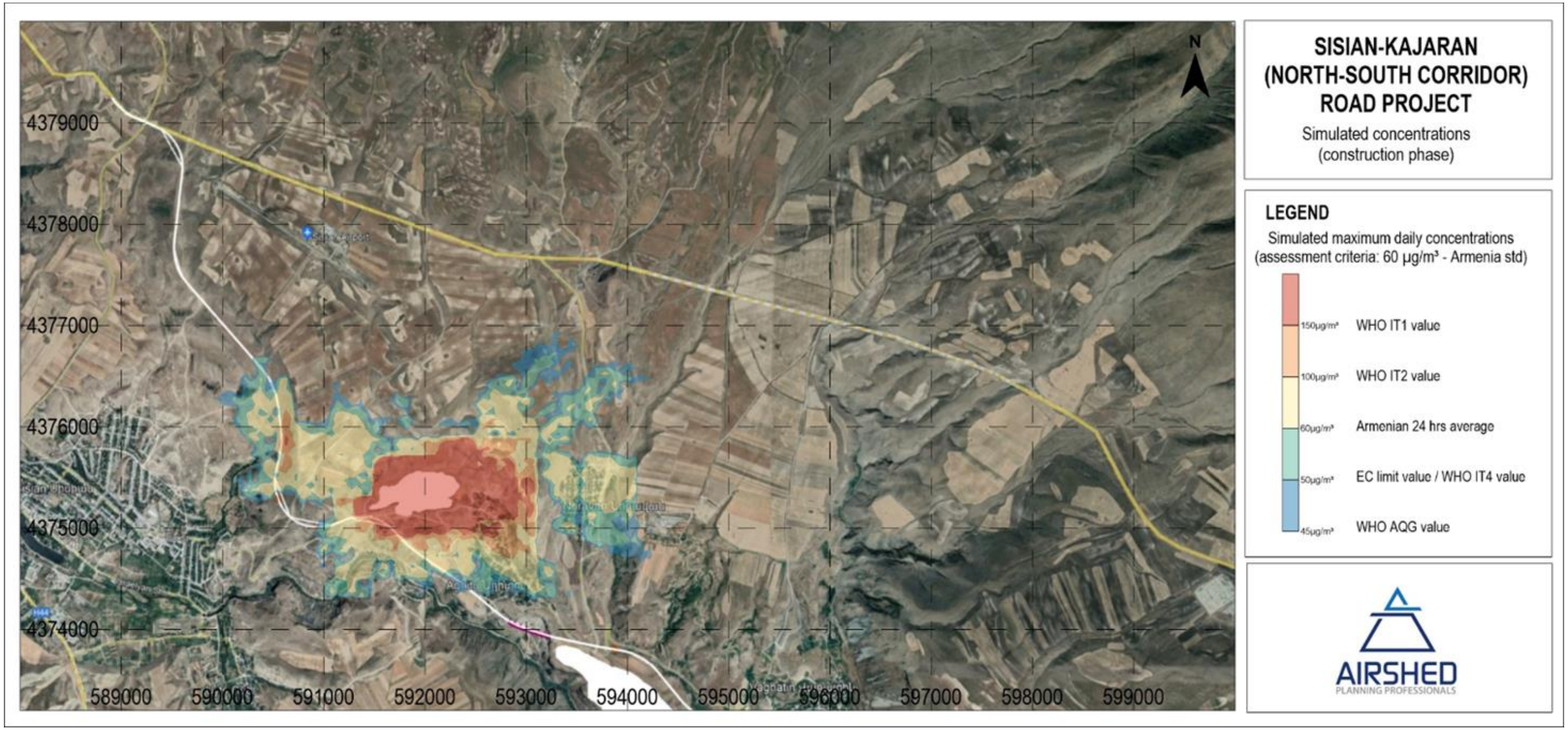


Figure 57. Simulated highest daily average ambient PM_{10} concentrations at Site 6 due to proposed project construction activities

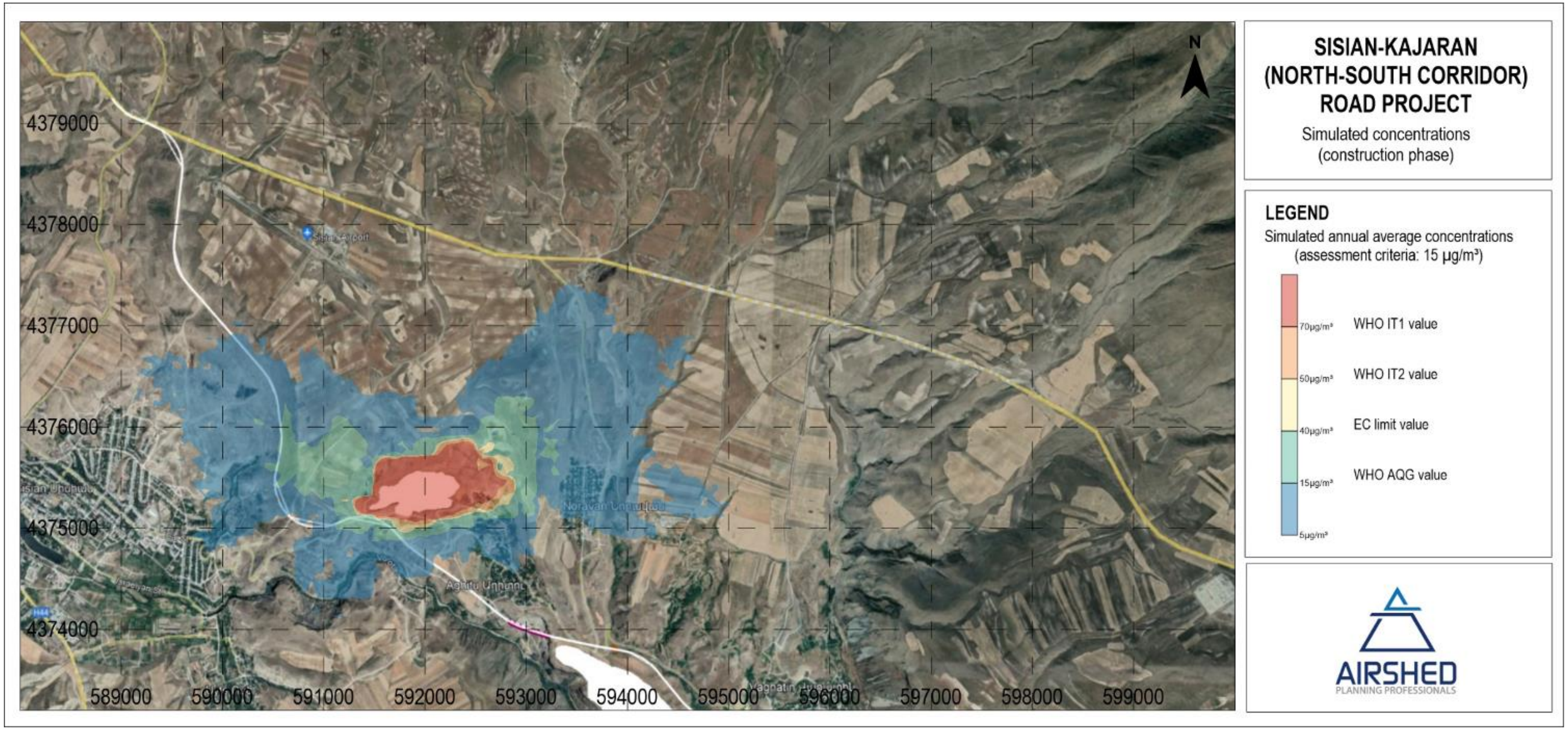


Figure 58. Simulated annual average ambient PM_{10} concentrations at Site 6 due to proposed project construction activities

<table>
<tr><th colspan="6">Impact of Dust (Particulate Matter) Emissions due to Construction Activities</th></tr>
<tr><td rowspan="2">Impact Nature</td><td colspan="2">Positive</td><td colspan="3">Negative</td></tr>
<tr><td colspan="5">Mechanically generated dust emitted by construction activities may cause impacts on nearby receptors, such as natural habitats, residential properties, agriculture and people through:
• Dusting / soiling of surfaces, crops, natural vegetation, water bodies, and others; and,
• Human health effects through exposure to airborne fine particulate matter.
In general terms dusting is not considered to be a material impact other than potentially in highly localised areas where mitigation could be applied if required and short-term in nature. Potential adverse human health effects are potentially more significant and so this risk is the subject of this assessment.</td></tr>
<tr><td rowspan="2">Impact Type</td><td>Direct</td><td colspan="2">Indirect</td><td>Reversible</td><td>Irreversible</td></tr>
<tr><td colspan="5">Dust, and fine particulate matter in particular, may directly impact on human health and such impacts are irreversible.</td></tr>
<tr><td rowspan="2">Impact Duration</td><td>Temporary</td><td>Short-term</td><td>Medium-term</td><td>Long-term</td><td>Permanent</td></tr>
<tr><td colspan="5">Should dust result in adverse health impacts these would be at least long term and potentially permanent.</td></tr>
<tr><td rowspan="2">Impact Extent</td><td>Local</td><td>Municipal</td><td>Regional</td><td>National</td><td>International</td></tr>
<tr><td colspan="5">Impacts associated with fine particulate matter would be limited to those receptors in the vicinity of the site as can be seen from the isopleth maps in Figure 57 and Figure 58. The nature of construction dust is for it to settle out of the atmosphere close to the source because it is largely mechanically generated and as such to be larger particles. There may be progressively reducing concentrations further from the site, but these types of impacts are likely to extend through the entire road routing to greater and lesser extents with the risk of people in close proximity to the construction corridor to be exposed.</td></tr>
<tr><td rowspan="2">Impact Magnitude</td><td>Negligible</td><td colspan="2">Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="5">The predicted ambient PM_{10} concentrations are seen to exceed even the Armenian standards albeit in close proximity to the source of the emissions. The annual average concentrations are deemed to be an exaggeration as the dust emissions would likely not be sustained at the modelled intensity for an entire year. However, the exceedances evident of the Armenian daily standards and accordingly also the WHO AQG implies a potential risk of at least medium intensity, again albeit in a very limited area close to the source of the emissions (potentially as much as 400 m).</td></tr>
<tr><td rowspan="2">Receptor Value / Sensitivity</td><td>Negligible</td><td colspan="2">Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="5">Wherever human health is at risk the receptor sensitivity must be seen as high. Given that the predicted daily average concentrations are seen to exceed health-based standards in the form of the WHO Guidelines, a definitive human health risk exists.</td></tr>
<tr><td rowspan="2">Impact Significance</td><td>Negligible</td><td colspan="2">Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="5">The risk of adverse human health effects is predicted to be of moderate significance even though it is likely to be relatively limited in spatial extent</td></tr>
</table>

Mitigation Measures

Develop and implement an Air Quality Management Plan to prevent construction emissions from manifesting as significant impacts. The Plan should include *inter alia*:

- Evaluating $PM_{2.5}$ and other exhaust emissions from construction vehicles once the construction activities are identified and further mitigation must be developed and implemented if the assessment shows a need for the same
- Minimizing dust from material handling sources, such as conveyors and bins, by using covers and/or control equipment (water suppression);
- Minimizing dust from open area sources, including storage piles, by using control measures such as installing enclosures and covers, and increasing the moisture content;

- Dust suppression techniques should be implemented, such as applying water or chemical binders to minimize dust from vehicle movement on unpaved roads;
- Use of dust screens close to material stockpiles
- Siting of Facilities and Equipment as close to the road as possible; to prevent impacts arising from asphalt plants, construction camps, batching plants and rock crushing plants, will be prohibited within 500 m of any residential area or sensitive receptor (school, hospital, etc.) and at least two kilometres from protected areas where possible, to avoid impacts to protected areas.
- Siting of Facilities and Equipment must also consider prevailing wind directions.

Residual Impacts

Dust control mitigation can be used to reduce both the extent and magnitude of the dust generated by construction activities. The mitigation should be especially rigorously applied where construction work is less than 500 m from residential areas or where third parties may otherwise be exposed. If the extent and magnitude of dust impacts could be reduced through mitigation so that concentrations of PM_{10} remained well below the WHO AQG then the impact significance of dust from construction activities could be reduced to **minor.**

Monitoring

Two forms of monitoring are recommended namely:

- Dust fallout monitoring using dust buckets as a relatively cost-effective measure of overall dust loading; and,
- Episodic continuous measurement campaigns to determine the airborne PM_{10} concentrations in areas where there is possible human exposure to the same.

3.1.1.5 Impact Assessment: Operation

The potential air quality impacts during operations of the proposed roadway are a function of exhaust emissions of nitrogen dioxide (NO_2), VOCs, sulphur dioxide (SO_2) and particulate matter ($PM_{2.5}$ and PM_{10}). These emissions are a function of the combustion of fuel in the vehicles and the release of uncombusted fuel, especially from poorly serviced vehicles and vehicles that are travelling slowly or are stopped and idling.

For the modelling and assessment, the entire roadway was divided into six sites with emissions modelled along the roadway length for each of the six sites (**Figure 56**) and for the two traffic scenarios viz. 2029 and 2048. Only emissions of NO_2 were fully modelled as experience from other projects indicates that ambient NO_2 concentrations are typically the only material risk source. In addition, although each site was modelled, only the isopleth maps from Site 5 are shown here for illustrative purposes as the scale does not readily allow presenting the whole roadway. The remaining air isopleth presentations are available in https://drive.google.com/drive/folders/1TmF80j3VeuDL1IwPnsoVHWpnAPoKqYJU?usp=drive_link.

Maximum predicted NO_2 concentrations for hourly, daily and annual average periods for the 2048 traffic fleet are shown in **Figure 59** to **Figure 61**.

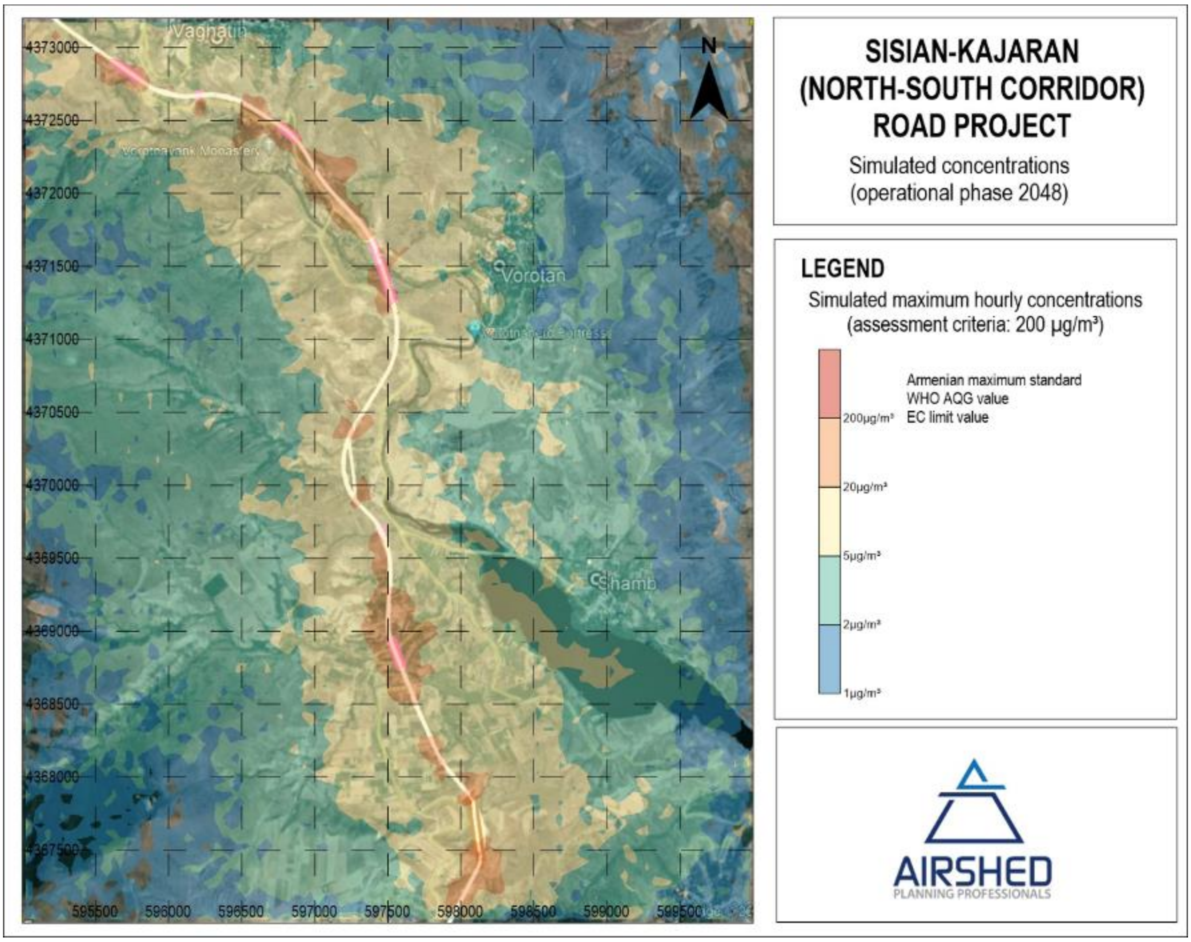


Figure 59. Site 5 Isopleth map of predicted hourly average NO_2 concentrations for the 2048 traffic fleet

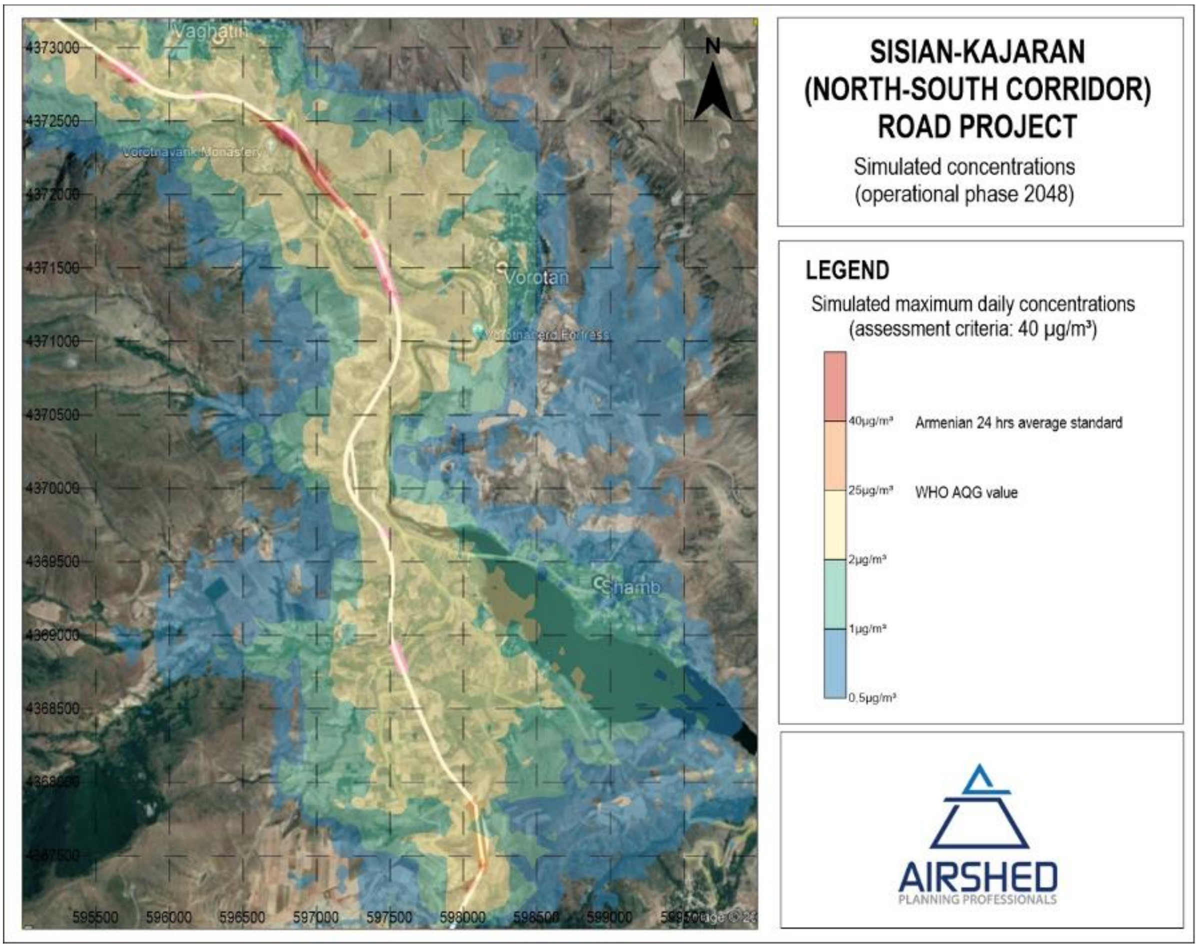


Figure 60. Site 5 Isopleth map of predicted daily average NO_2 concentrations for the 2048 traffic fleet

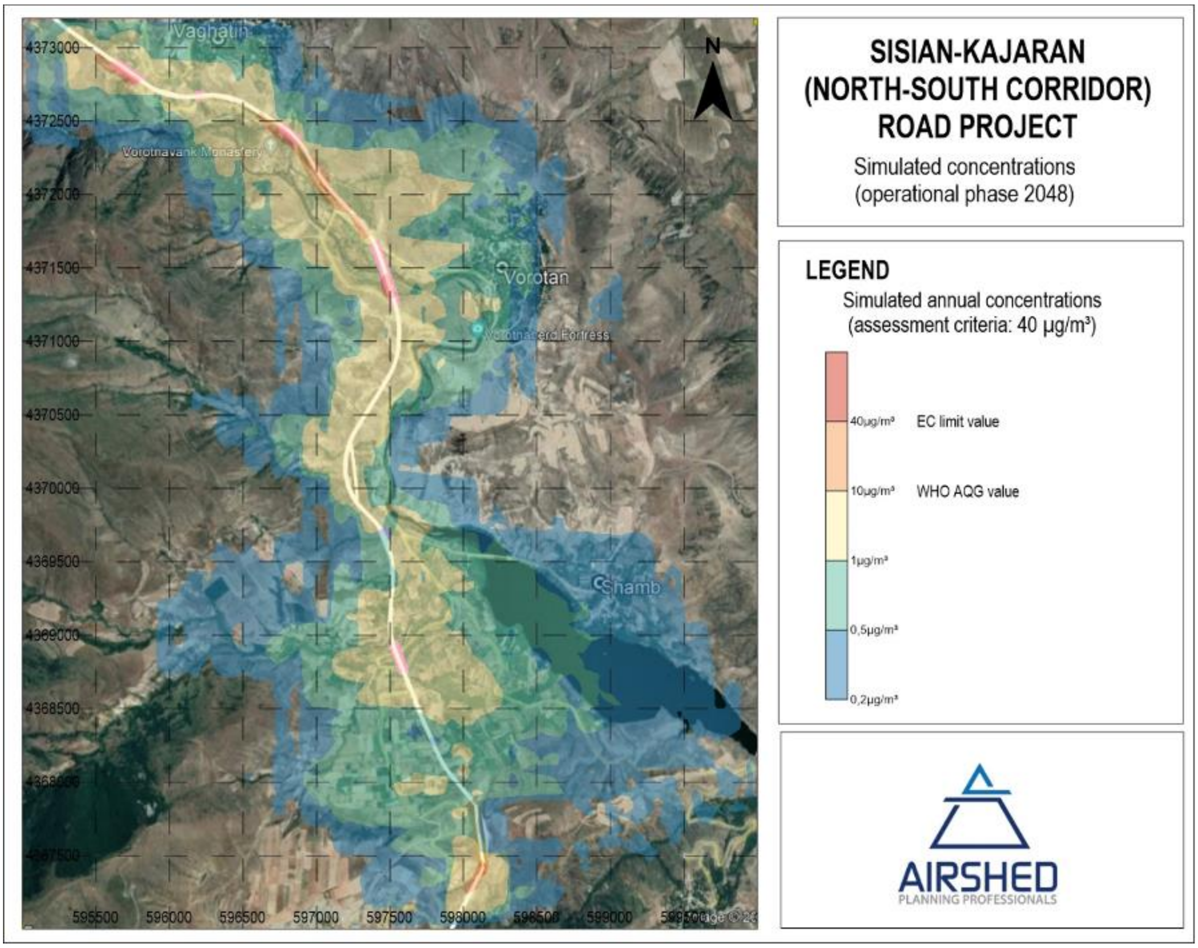


Figure 61. Site 5 Isopleth map of predicted annual average NO_2 concentrations for the 2048 traffic fleet

Operations in 2029

Predicted maximum hourly average NO_2 concentrations due to roadway operations (Year 2029) do not exceed the Armenian standard nor the WHO AQG and EC limit values of 200 µg/m³ at any sensitive receptors (**Figure 62**). Concentrations of approximately 20 µg/m³ are predicted along the entire road length. Predicted highest daily average NO_2 concentrations due to road operations (Year 2029) do not exceed the Armenian standard of 40 µg/m³ at any sensitive receptors (**Figure 63**). Concentrations of approximately 10 µg/m³ are predicted along the road. Predicted annual average NO_2 concentrations due to project operations (Year 2029) do not exceed the WHO AQG value of 10 µg/m³ or the EC limit value of 40 µg/m³ at any sensitive receptors (**Figure 64**). Concentrations of approximately 5 µg/m³ are predicted along the road. The patterns described here apply to each of the 6 sites selected for the modelling that collectively make up the entire roadway.

Operations in 2048

Predicted maximum hourly average NO_2 concentrations due to project operations (Year 2048) do not exceed the Armenian standard nor the WHO AQG or EC limit values of 200 µg/m³ at any sensitive receptors (**Figure 62**). Concentrations of approximately 50 µg/m³ are predicted along the road. Predicted maximum daily average NO_2 concentrations due to project operations (Year 2048) do not exceed the Armenian standard of 40 µg/m³ at any sensitive receptors (**Figure 63**). Concentrations of approximately 25 µg/m³ are simulated along the road. Predicted annual average NO_2 concentrations due to project operations (Year 2048) do not exceed the WHO AQG value of 10 µg/m³ nor the EC limit value of 40 µg/m³ at any sensitive receptors (**Figure 64**). Concentrations of approximately 10 µg/m³ are predicted along the road.

The patterns described here apply to each of the 6 sites selected for the modelling that collectively make up the entire roadway.

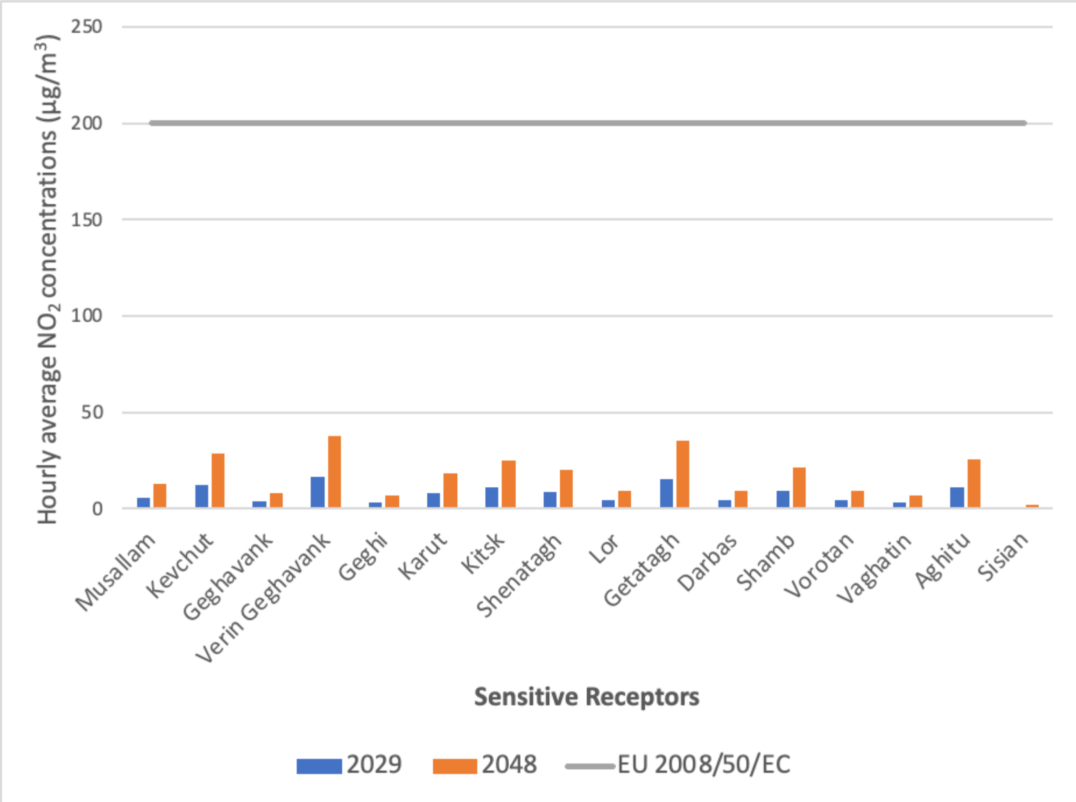


Figure 62. Predicted hourly average NO_2 concentrations at the various sensitive receptors along the proposed roadway for the 2029 and 2048 traffic fleet

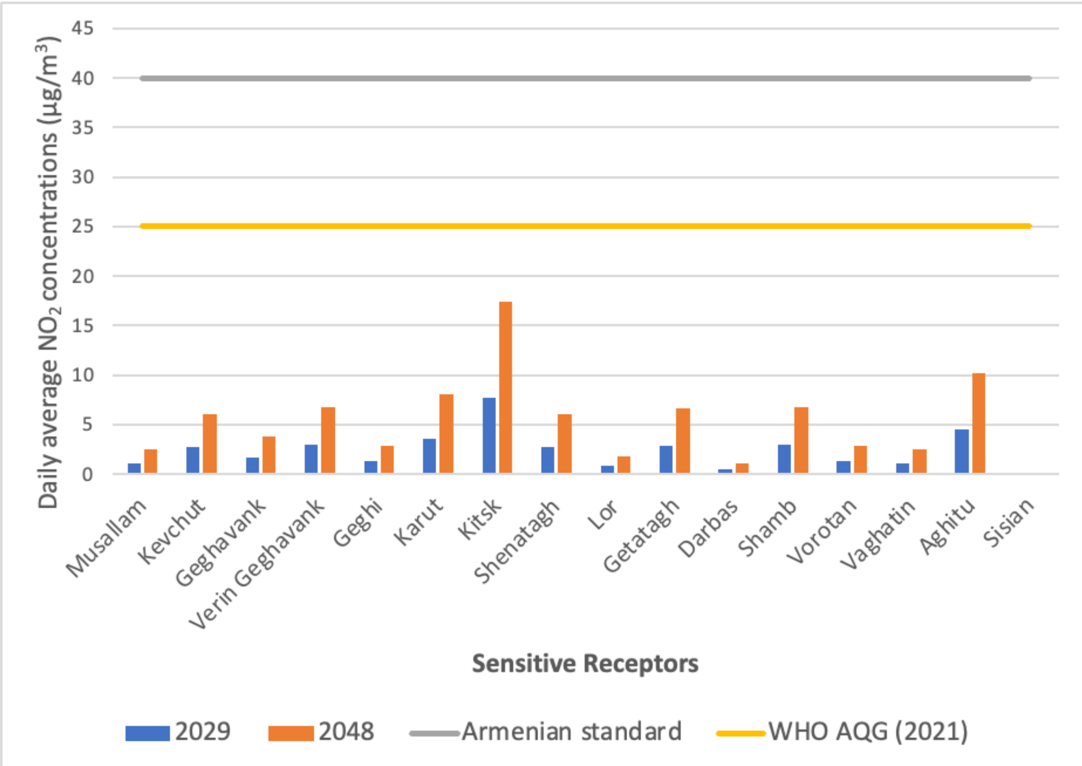


Figure 63. Predicted maximum daily average NO_2 concentrations at the various sensitive receptors along the proposed roadway for the 2029 and 2048 traffic fleet

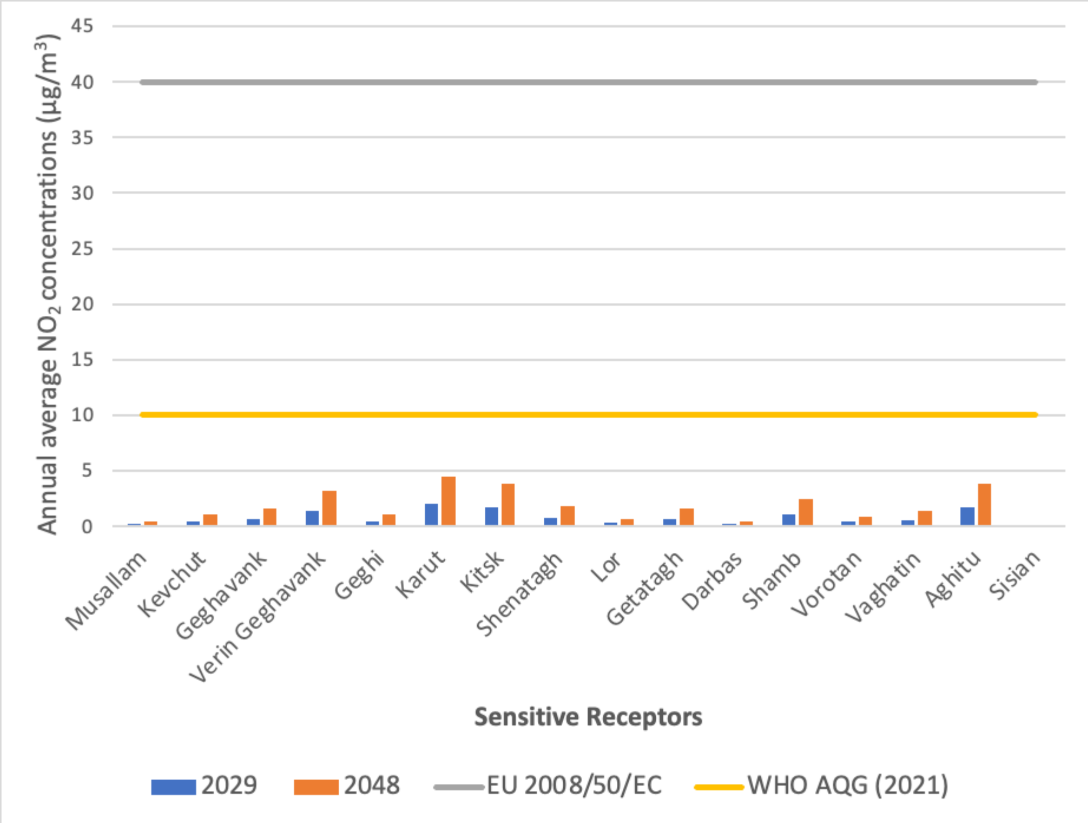


Figure 64. Predicted annual average NO_2 concentrations at the various sensitive receptors along the proposed roadway for the 2029 and 2048 traffic fleet

<table>
<tr><th colspan="7">Impact of NO_2 Emissions due to Road Operations</th></tr>
<tr><td rowspan="2">Impact Nature</td><td colspan="3">Positive</td><td colspan="3">Negative</td></tr>
<tr><td colspan="6">The potential air quality impacts during operations of the proposed roadway are a function of exhaust emissions of nitrogen dioxide (NO_2), VOCs, sulphur dioxide (SO_2) and particulate matter ($PM_{2.5}$ and PM_{10}). These emissions are a function of the combustion of fuel in the vehicles and the release of uncombusted fuel especially from poorly serviced vehicles and vehicles that are travelling slowly or are stopped and idling.
For a contemporary vehicle fleet, NO_2 emissions are deemed most likely to risk non-compliance with the Armenian standards and WHO AQG and so that is the focus of the assessment.</td></tr>
<tr><td rowspan="2">Impact Type</td><td colspan="2">Direct</td><td colspan="2">Indirect</td><td>Reversible</td><td>Irreversible</td></tr>
<tr><td colspan="6">Elevated concentrations of NO_2 may pose a risk of adverse human health effects along the new roadway at sensitive receptors in close proximity to the road.</td></tr>
<tr><td rowspan="2">Impact Duration</td><td>Temporary</td><td>Short-term</td><td>Medium-term</td><td colspan="2">Long-term</td><td>Permanent</td></tr>
<tr><td colspan="6">Should NO_2 concentrations result in adverse health impacts these would be at least long term and potentially permanent.</td></tr>
<tr><td rowspan="2">Impact Extent</td><td>Local</td><td>Municipal</td><td>Regional</td><td colspan="2">National</td><td>International</td></tr>
<tr><td colspan="6">Impacts associated with NO_2 pollution would be limited to a relatively short distance on either side of the operational roadway as can be seen from those receptors in the vicinity of the site as can be seen from the isopleth maps in Figure 59 to 61 but this continues for the length of the proposed roadway making the impact extent regional.</td></tr>
<tr><td rowspan="2">Impact Magnitude</td><td colspan="2">Negligible</td><td colspan="2">Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="6">The predicted ambient NO_2 concentrations are seen to comply with the Armenian Standards and indeed the WHO AQG for all the averaging periods and for both the 2029 and 2048 traffic fleets at all the sensitive receptors implying a low impact magnitude.</td></tr>
<tr><td></td><td colspan="2">Negligible</td><td colspan="2">Low</td><td>Medium</td><td>High</td></tr>
</table>

Receptor Value / Sensitivity	Wherever human health is at risk the receptor sensitivity must be seen as high.			
Impact Significance	Negligible	Minor	Moderate	Major
	The risk of adverse human health effects is predicted to be no more than moderate significance and probably closer to minor.			

Mitigation Measures

Develop and implement an Air Quality Management Plan to prevent operational roadway emissions from manifesting as significant impacts. The AQMP should include *inter alia*:

Campaigns to encourage driver behaviour to implement the following:

- Regardless of the size or type of vehicle, fleet owners /operators should implement the manufacturer recommended engine maintenance programs;
- Drivers should be instructed on the benefits of driving practices that reduce both the risk of accidents and fuel consumption, including measured acceleration and driving within safe speed limits;
- Operators with fleets of 120 or more units of heavy-duty vehicles (buses and trucks), or 540 or more light duty vehicles (cars and light trucks) within an airshed should consider additional ways to reduce potential impacts including:
    - Replacing older vehicles with newer, more fuel-efficient alternatives,
    - Converting high-use vehicles to cleaner fuels, where feasible,
    - Installing and maintaining emissions control devices, such as catalytic converters; and,
    - Implementing a regular vehicle maintenance and repair program.

- Engage with government to encourage adoption of legislation geared towards motor vehicle emissions reductions.
- Police vehicles that are in poor condition and conduct emissions testing on the vehicles (provided that legislation exists to allow for such policing.

Residual Impacts

The implementation of the above mitigation would reduce the potential impacts of atmospheric emissions from the operational roadway. Although the focus of this assessment has been on NO_2, the mitigation would reduce all atmospheric emissions from motor vehicles. This reduction together with the likely advances in vehicle anti-pollution technologies, cleaner fuels and the replacement of combustion engine vehicles with electric vehicles would likely see the impact significance of motor vehicle emissions from the operational roadway reduced to **minor.**

Monitoring

As the pollutant of concern is NO_2, it is recommended that passive NO_2 monitoring be implemented at all the sensitive receptor areas along the road project (viz. villages occurring along the proposed road alignment). Given that some elevated SO_2 concentrations are evident, campaign monitoring of SO_2 should also be included to confirm that the road project is not contributing significantly to the current baseline.

3.1.2 GHG Emissions

3.1.2.1 Construction

To estimate the GHG emissions from road construction, the average value developed by the ETSAP[35] has been used, namely, 1.07 ktCO2/km for a 13m wide road[36]. As the Project Road is 60 km and wider, the estimated GHG would be 64,200 tonnes of CO_2 for the duration of the construction period. In 2017, the national GHG emissions in Armenia were 10,624 Gg CO_2 eq. (Armenia's Third Biennial Update Report, 2021[37]). The share of Project-related GHG would be very small compared to the national level. As such GHG emitted during the construction phase are not expected to significantly impact regional or global GHG concentrations.

Residual impacts

Minor residual impacts are therefore anticipated during the construction phase.

3.1.2.2 Operations

Limitations:

The GHG calculations are based on the traffic study performed in 2016[38]. They will need to be updated after the new traffic study, that is ongoing as of summer of 2023, is completed.

The EV assumptions have not been included in the present calculations; however, they will be considered when revising the GHG calculations based on the forthcoming traffic study results.

Estimation

Greenhouse gases (GHG) calculations have been performed for CO_2, CH_4 and N_2O according to the European Monitoring and Evaluation Programme (EMEP)/European Environmental Agency (EEA) air pollutant emission inventory guidebook 2019 - Update Oct. 2020[39] (the "Guidebook"). The GHG estimate has been completed for 2029, the first year of road operations.

As per the traffic study report, the average number of all types of vehicles that will use the planned Sisian-Kajaran road will be 154 units/hour or 3 692 units/day in 2029. Annual emissions of CO_2, CH_4 and N_2O equate to CO_2eq annual emissions of 31,640.7 **tonnes for 2029.**

The same traffic count was used to calculate baseline GHG emissions for the "no Project" scenario. This scenario assumes that all the traffic will use the existing H45 road (117 km of

[35] Energy Technology Systems Analysis Program (ETSAP) is one of the longest running Technology Collaboration Programme of the International Energy Agency.

[36] IEA ETSAP - Technology Brief T14 – August 2011. https://iea-etsap.org/E-TechDS/PDF/T14_Road%20Transport%20Infrastructure_v4_Final.pdf

[37] https://unfccc.int/documents/274257

[38] North-South Road Corridor Investment Program, Tranche 4 - Section Artashat South - Kajaran, Traffic study report within the Feasibility study, 2016

[39] https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i . In line with the guidebook, the Tier 1 method of the Guidebook is used for the calculation of Carbone dioxide (CO2) emissions and the Tier 2 method is applied for calculating Methane and Nitrous oxide emissions. Then the CO2 equivalents (CO2eq) of Methane and Nitrous oxide have been determined based on their Global Warming Potential (as listed in the IPCC sixth assessment report at https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07_Supplementary_Material.pdf)

which 80 km are rural roads and 37 km are a highway). Annual emissions of CO_2, CH_4 and N_2O for 2029 equates to 61,787.1 tonnes of CO_2eq baseline emissions for that year.

The Project's net GHG emissions for the year of 2029 are the difference between the estimated 'with-Project' and 'no-Project' scenarios. The estimated net emissions are **minus 30,146.4 tonnes of CO_2eq emissions for 2029.** GHGs will be generated throughout the Project's lifecycle and this is unavoidable. However, it can be expected that more fuel-efficient cars would be used in future which would lead to a decrease in emissions generated on the Project road.

Residual impact

Based on the above, the residual impact is tentatively seen as **moderate**.

3.2 Noise and Vibration

3.2.1 Introduction and AoI

In this section of the ESIA potential noise and vibration impacts associated with the Project are described and assessed. The assessment was undertaken with reference to relevant national and international standards and reference criteria (see below). Major vibration impacts are not anticipated for the operational roadway.

Noise

Noise will be generated during both construction and operations of the proposed roadway and given the proximity of residential areas to the road alignment will add to the noise baseline in these areas. Most construction activities are sources of noise but rock and concrete-breaking, steel cutting with grinders and driven-in piling are the greater sources of noise. Heavy machinery including bulldozers, earth tamping and front-end loaders are lesser but still important sources. The key source of potentially damaging vibration is blasting especially in tunnel construction. During road operations the traffic itself is the source of the noise, typically perceived as a droning punctuated by intermittent bursts of noise from speeding or poorly maintained vehicles.

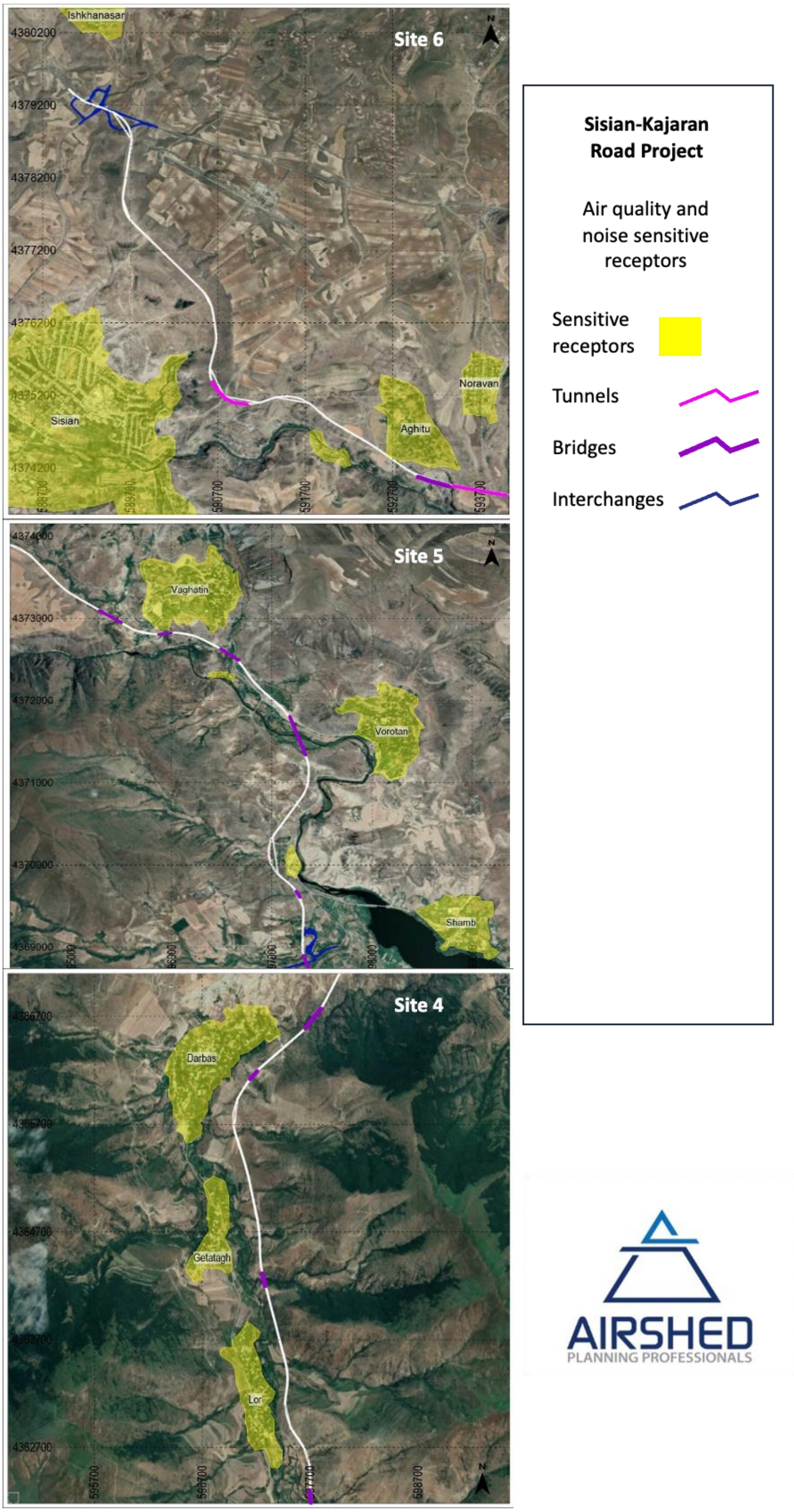


Figure 65. Air quality and noise sensitive receptors along the route of the roadway for sites 4-6

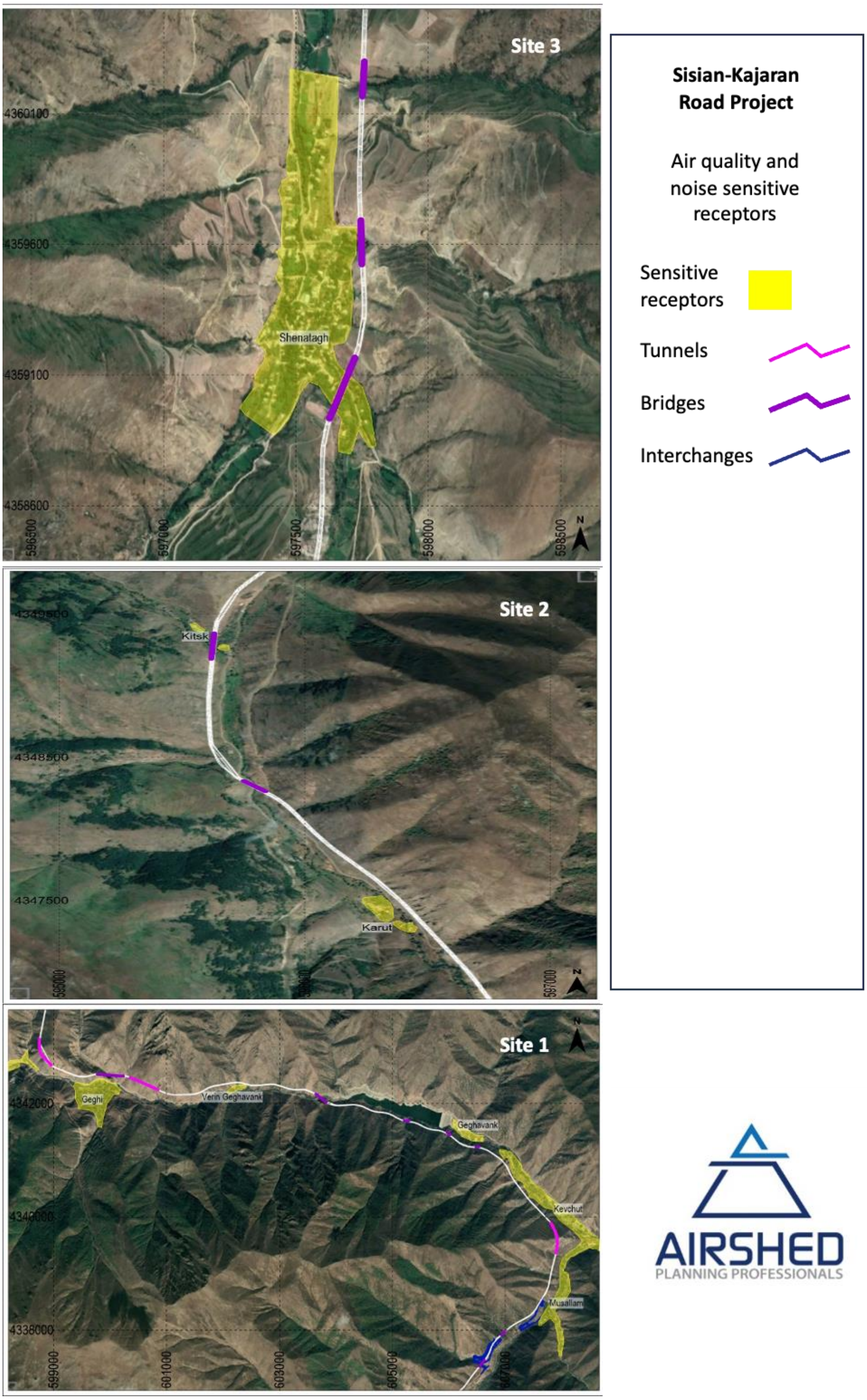


Figure 66. Air quality and noise sensitive receptors along the route of the roadway for sites 1-3

A site-specific baseline survey was carried out in June 2022 to determine baseline noise quality and presented in **Section 2.8**. The data from that assessment indicated that there are important noise sources in all the villages along the route but attributed largely to old and poorly maintained farm equipment. The area is principally rural and there are no major noise sources other than vehicles moving through the settlements. There are no large industrial sources of noise along the roadway but there is a military air base to the southeast of the northern termination of the roadway where it joins the existing road. The military aircraft that operate from the airfield and may be an additional noise source albeit episodically.

The AoI for the noise assessment includes all the villages and other residential areas along the proposed roadway routing within 1 000 m on either side of the roadway. For this assessment the entire roadway was divided into study sites to maintain an effective assessment scale and detailed. The study sites are shown in **Figure 67** and are listed in **Table 39**.

Vibration

There are multiple sources of vibration from road construction including heavy rollers, compaction, movement of heavy vehicles and others. In general terms receptors such as houses, cultural heritage items, public infrastructure, domestic and wild animals and people may experience the vibration, but damage is unlikely unless the receptors are in the immediate vicinity of the source which is seldom the case. Perhaps the most significant source of vibration during road construction is blasting.

Blasting may be required where the proposed road travels through an area of hard rock that needs to be excavated but the most important function is the drill and blast method for tunnel excavation. For drill and blast the tunnel face is drilled and then charges placed in the drill holes. When detonated the blast shears a section of the rock which is excavated, before drilling new holes and blasting again. Other than for the tunnels, it is not known at this stage where blasting would be required during road construction and for the tunnels it is assumed that all will require drilling and blasting for the excavation. Blasting is a source of vibration that can cause physical damage to infrastructure and which can be very negatively perceived by both animals and people although adverse health effects or injury from the vibration is highly unlikely. The approach to vibration risk from the project is to assess the risk of damage to structures (especially heritage structures) because of blasting.

The area of influence for the vibration from blasting is 100 m on either side of the centreline of the roadway as a high impact zone and 100-500 m as a moderate impact zone. Structures were identified in these two zones along the length of the road as sensitive receptors.

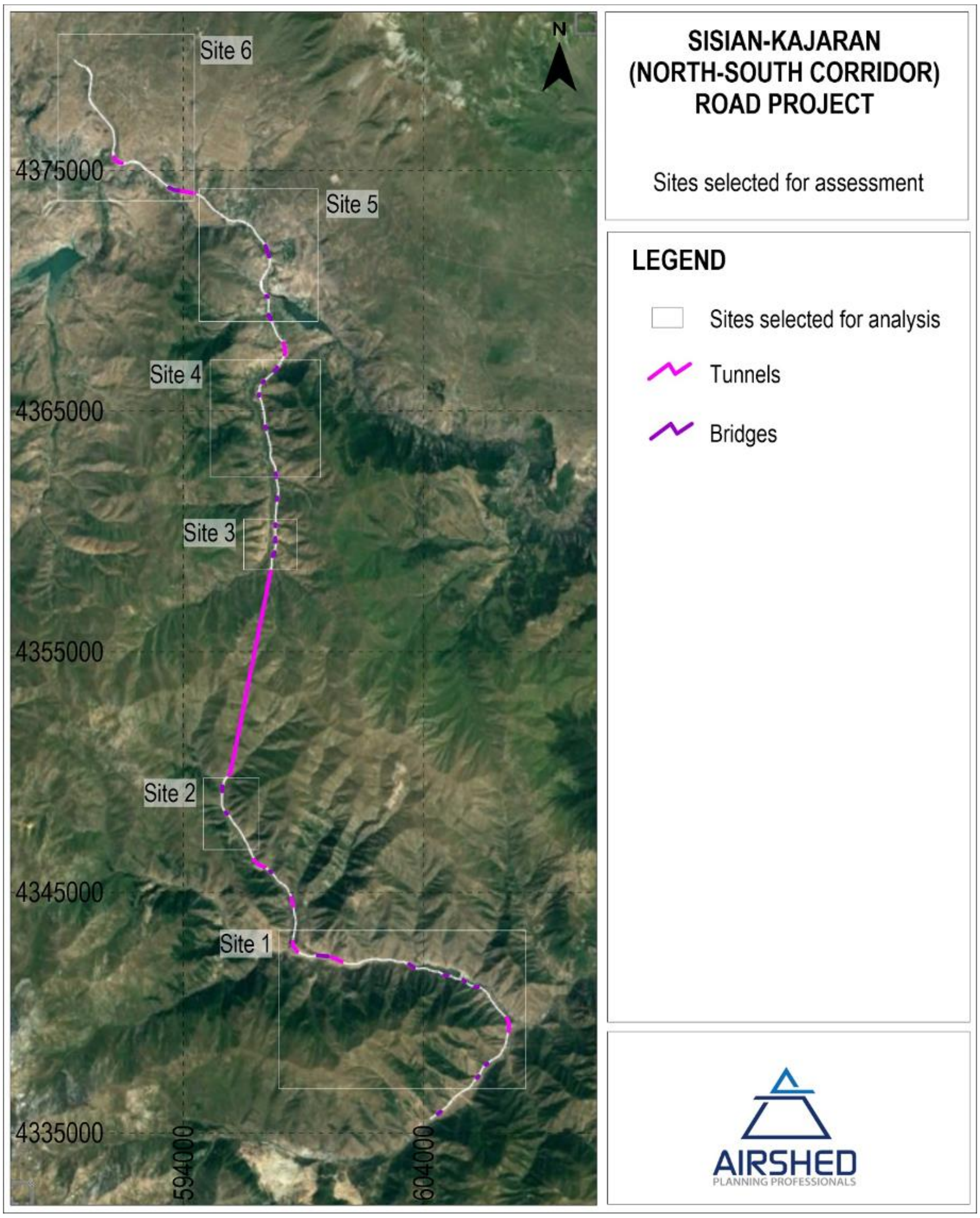


Figure 67. Area of Influence (AoI) along the proposed road and demarcation of study sites. Sensitive receptors are listed in Table 39 (and shown in a series of maps in Figure 65 and Figure 66)

Table 39. Sensitive receptors within the study sites shown in Figure 67 that were used in the noise assessment.

Study area	No	Sensitive receptor
1	1	Musallam
	2	Kavchut
	3	Geghavank
	4	Verin Geghavank
	5	Geghi
	6	Dwellings ~700 m to the west-northwest of Geghi
2	7	Karut
	8	Kitsk
3	9	Shenatagh
4	10	Lor
	11	Getatagh
	12	Darbas
5	13	Shamb

Study area	No	Sensitive receptor
	14	Dwellings ~1.2 km to the west-northwest of Shamb
	15	Vorotan
	16	Dwellings ~780 m to the south of Vaghatin
	17	Vaghatin
6	18	Noravan
	19	Aghitu
	20	Dwellings ~450 m to the west of Aghitu
	21	Sisian
	22	Ishkhanasar

3.2.2 Reference Criteria

3.2.2.1 Applicable noise standards

Threshold Limit Values (TLVs) for equivalent (average) and maximum noise/sound levels set by the RA Sanitary Norms №2-III-11.3 "Noise in the workplaces, in residential and public buildings and housing in construction areas"[40] are comparable with the IFC Environmental, Health, and Safety General Guidelines (2007)[41] and WHO Guidelines for Community Noise (1999). The national TLVs and IFC/WHO guidelines for noise are presented in **Table 40**.

Table 40. Threshold limit values (TLV) for noise

No	Premises and territories		TLV, dBA		
			National		IFC/WHO
			Equivalent to sound level	Maximum sound level	One hour equivalent sound level
1	Workplace		80		85
2	Shops, trading halls, airport and railway stations waiting rooms, drop-off points of public service providers		60	75	
	Industrial, commercial				70
3	Territories adjacent to residential buildings, clinics, ambulatories, rest houses, care homes, disabled persons homes, libraries, kinder gardens, schools and other educational facilities	day-time[42]	55	70	55
		night-time[43]	45	60	45

3.2.2.2 World Health Organisation Guidelines for Road Traffic Noise for the European Region

Noise is an important public health issue with negative impacts on human health and well-being and is a growing concern. The World Health Organisation (WHO) Regional Office for Europe has developed guidelines, for protecting human health from exposure to environmental noise originating from various sources: transportation (road traffic, railway and aircraft) noise, wind turbine noise and leisure noise. They provide robust public health advice

[40] https://www.arlis.am/documentview.aspx?docid=169599
[41] https://www.ifc.org/wps/wcm/connect/29f5137d-6e17-4660-b1f9-02bf561935e5/Final%2B-%2BGeneral%2BEHS%2BGuidelines.pdf?MOD=AJPERES&CVID=nPtguVM
[42] Between 07:00 and 23:00
[43] Between 23:00 and 07:00

underpinned by evidence, which is essential to drive policy action that will protect communities from the adverse effects of noise.

- The Guideline Development Group (GDG) at the WHO, set a guideline exposure level of 53.3 dB Lden for average exposure, based on the relevant increase of the absolute percentage of the population “highly annoyed”. It was confident that there was an increased risk for annoyance below this noise exposure level, but probably no increased risk for other priority health outcomes. The value was rounded to **53 dB $_{Lden}$.**[44]
- Based on the evidence of the adverse effects of road traffic noise on sleep disturbance, the GDG defined a guideline exposure level of 45.4 dB Lnight. The exact exposure value was rounded to **45 dB $_{Lnight}$.**

3.2.2.3 Applicable vibration standards

RA Hygienic Norms №2.2.4-009-06 "Vibration in the workplaces, in residential and public buildings"[45], define TLVs for the corrected (equivalent corrected) values for different categories of the vibration acceleration and are given in **Table 41**.

Table 41. Categories of vibration and TLVs for the vibration acceleration

No	Whole-body vibration	TLV for corrected and equivalent corrected values	
		m/s^2	dB
1	Transport-technological (2nd category) Technological vibration affecting a person at the workplace / equipment moving along surfaces of industrial facilities, industrial and mining sites. *Examples: excavators, industrial and construction cranes, machines for loading (filling) open-hearth furnaces in metallurgical production; mining combines, mine loading machines, self-propelled drilling carriages; track machines, concrete pavers, etc.*	0.28	109
2	Technological (3rd category) Technological vibration affecting a person at workplaces of stationary machines or transmitted to workplaces that do not have vibration sources. *Examples: metal and wood processing machines, forging and pressing equipment, foundry and electrical machines, stationary electrical installations, pumping units and fans, equipment for drilling wells, drilling rigs, machines for animal husbandry, grain cleaning and sorting (including dryers), equipment building materials industry (except for concrete pavers), installations of the chemical and petrochemical industries, etc.*		
2.1	Type a) Vibration at permanent workplaces in production facilities.	0.1	100
2.2	Type b) Vibration at workplaces in auxiliary and/or production facilities where there is no vibration source.	0.04	92
2.3	Type g) Vibration at workplaces of organizational, administrative, office and other non-production rooms.	0.014	83
3	Residential buildings, clinics, rest houses	0.004	72

[44] WHO, 2018. Environmental Noise Guidelines for the European Region, s.l.: s.n.
[45] https://www.arlis.am/documentview.aspx?docid=163276

Directive 2002/44/EC on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration)[46], define the following vibration limits for whole-body vibration:

- the daily exposure limit value standardized to an eight-hour reference period shall be 1.15 m/s^2,
- the daily exposure action value standardised to an eight-hour reference period shall be 0.5 m/s^2.

Note that the above standards are specifically for Occupational Health and Safety exposure whereas the requirement is to ascertain the risk of possible damage to buildings and structures. Damage criteria is not easy to find but the following serves as indicative damage thresholds that have been sourced from general literature[47].

- Tar roads: 150 mm/s
- Steel pipelines: 50 mm/s
- Electrical transmission lines: 75 mm/s
- Boreholes: 50 mm/s
- Structures: 25 mm/s
- Heritage structures: 6 mm/s (set conservatively to ensure no risk of damage).

People generally perceive ground vibration at 0.8 mm/s, find it unpleasant at 100 mm/s and intolerable at 250 mm/s (see **Box 3** for an explanation of some important concepts in vibration).

Box 3: Understanding vibration

Vibration is the back-and-forth motion of particles brought about by being displaced from an equilibrium or natural condition. Once the force that caused the displacement (such as a blast) is terminated the particles will progressively return to their original equilibrium position. For this application the particles are the various materials (rocks, sand, soil and so forth) that make up the surface of the earth which is referred to as ground. When a blast occurs the energy from the blast is transmitted though the ground as an energy wave until it eventually runs out of energy some distance from the source.

The unit of vibration that is used here is Peak Particle Velocity (PPV). PPV refers to the movement within the ground of very small particles as described above and is expressed in (mm/s). The greater the PPV the greater the potential for damage to physical structures. Vibration also has a frequency (the rate at which the back-and-forth motion occurs per unit of time) The lower the frequency the greater the potential for damage (this is because physical structures have a low frequency too).

[46] https://eur-lex.europa.eu/resource.html?uri=cellar:546a09c0-3ad1-4c07-bcd5-9c3dae6b1668.0004.02/DOC_1&format=PDF

[47] Chiapetta F., Van Vreden A., 2000. Vibration/Air blast Controls, Damage Criteria, Record Keeping and Dealing with Complaints. 9th Annual BME Conference on Explosives, Drilling and Blasting Technology, CSIR Conference Centre, Pretoria, 2000.

The model JKSimblast[48] was used to model the vibration from the blasting that would be required for construction of the road. JKSimBlast is a general-purpose software system for simulation and information management for blasting in mines and related operations with the aim of optimising blast management.[49]

3.2.2.4 Noise Impact Significance

Noise-specific Impact Magnitude Significance criteria applicable to the above reference criteria and the resulting impact significance for all receptors considered in the assessment is detailed in **Table 42**.

Table 42. Noise-specific impact significance criteria

Impact magnitude	Level above criteria threshold	Resulting impact significance
No Impact	< 0 dB	No Impact
Very Low	> 0 dB to < 1 dB	Negligible
Low	> 1 dB to < 3 dB	Minor
Medium	> 3 dB to < 5 dB	Moderate
High	> 5 dB	Major

3.2.3 Method, Assumptions and Limitations

For the assessment, noise sources were identified and sound power levels (LW's) (noise 'emissions') estimated. Thereafter, the ambient noise implications of the two phases were modelled to show both predicted sound pressure levels (LP's) (noise impacts) and their spatial extent. The model output was overlaid on the proposed roadway so that the noise levels relative to potentially sensitive receptors could be ascertained. Finally, predicted noise levels were compared to defined standards to be able to assess the significance of the impacts.

3.2.3.1 *Noise propagation modelling*[50]

Overview

The propagation of noise from proposed activities was simulated using the DataKustic CadnaA software. Use was made of:

- The International Organisation for Standardization's (ISO) 9613 module for outdoor noise propagation from industrial noise sources; and
- The traffic noise module.

Noise assessment principles are described in this section. Noise is notoriously difficult to understand and so the principles are outlined in **Box 4.**

Box 4: Understanding noise

What our ears register (hear) is sound and noise is defined as unwanted sound. Sound is produced by vibrating objects and travels through the air in waves and pulses of different air pressure. Human response to noise is complex and highly variable and is entirely subjective (i.e., different people experience noise differently). The speed of sound is 330 m/s or 1 188 km/hr. Sound or noise has

[48] JKSimBlast was developed by JKTech based on more than 20 years of mining research at JKMRC. It has over 900 users throughout the world in surface, underground and tunnel blasting applications, working in mines, explosives supply, consulting, contracting and education.
[49] https://jktech.com.au/products/software - University of Queensland
[50] The noise calculations and noise modelling that underpins this assessment was conducted by Airshed Planning Professionals and authored by Ms. Reneé von Grunewald.

several physical characteristics including frequency (the number of vibrations per second), sound power (the strength of the sound at its origin) and sound pressure (the strength of sound experienced by a receptor).

Noise is measured in decibels (dB) which is an expression of sound pressure. People hear high frequency noise better than low frequency noise and so noise measuring equipment has a built-in filter (called an A-weighting filter) that dampens the low frequency noise and thus 'emulates' human hearing. Noise is therefore expressed as dB(A) – viz. A-weighted decibels.

dB(A) is based in turn on a logarithmic scale and so computations must be logarithmic. If 75 dB(A) is added to 75 dB(A), for example, the result is 78 dB(A) and not 150 dB(A) as might be expected. The human ear would not perceive such a change in noise (even though the sound pressure level has doubled). An increase of between 8 and 10 dB is required for there to be a registerable increase in noise.

For the purposes of this assessment the following concepts need to be understood:

- L_{Aeq} (T) - the average noise over a defined period of time (T).
- L_{AF}max – the highest level of noise that occurred during a sampling period.

Note both units are A-weighted meaning that they emulate the hearing of the human ear.

ISO 9613 specifies an engineering method for calculating the attenuation of sound during propagation predicting the levels of environmental noise at a distance from a variety of sources. The method predicts the equivalent continuous A-weighted sound pressure level under meteorological conditions favourable to propagation from sources of known sound emission. These conditions are for downwind propagation or, equivalently, propagation under a well-developed moderate ground-based temperature inversion, such as commonly occurs at night.

The method also predicts an average A-weighted sound pressure level. The average A-weighted sound pressure level encompasses levels for a wide variety of meteorological conditions. The method specified in ISO 9613 consists specifically of octave-band algorithms (with nominal midband frequencies from 63 Hz to 8 kHz) for calculating the attenuation of sound which originates from a point sound source, or an assembly of point sources. The source (or sources) may be moving or stationary. Specific terms are provided in the algorithms for the following physical effects; geometrical divergence, atmospheric absorption, ground surface effects, reflection and obstacles.

This method is applicable in practice to a great variety of noise sources and environments and is applicable, directly or indirectly, to most situations concerning road or rail traffic, industrial noise sources, construction activities, and many other ground-based noise sources. To apply ISO 9613, several parameters need to be known with respect to the geometry of the source and of the environment, the ground surface characteristics, and the source strength in terms of octave-band sound power levels for directions relevant to the propagation.

Model domain and outputs

Noise modelling was conducted over an area of 24.4 km east-west by 49.6 km north-south to encompass the project area. The area was divided into a grid matrix with a 50 m resolution (viz. more than 3 million points). The model was set to calculate sound pressure levels at each grid and discrete receptor point, at a height of 1.5 m above ground level. Modelling was conducted for construction activities and for the 2029 and 2048 traffic forecasts. Noise impacts were calculated for:

- Day-time noise level (LAeq) (07:00-22:00); and
- Night-time noise level (LAeq) (22:00-07:00).

The modelling was also presented as isopleth maps, like the air quality assessment (**Section 3.1.1.3**). Isopleths present lines connecting the same predicted noise levels.

Atmospheric absorption and meteorology

Atmospheric absorption and meteorological conditions influence the propagation of noise from source to receiver. These meteorological parameters are principally wind velocity and temperature but also include relative humidity, air pressure, solar radiation and cloud cover which affect the stability of the atmosphere and the ability of the atmosphere to absorb sound energy. Wind data was not included in the modelling but CadnaA requires both temperature and humidity to be defined. An average temperature of 13°C and a humidity of 64% were assumed for the modelling.

Source inventory

Noise emissions from diesel powered mobile equipment were estimated using LW predictions for industrial machinery (Bruce & Moritz, 1998), where LW estimates are a function of the power rating of the equipment engine. The LW's for the asphalt and crusher plant were obtained from a database for similar operations. Values from the database are based on source measurements. Estimates of road traffic were made given traffic flow, average vehicle speeds and heavy vehicle percentages as supplied by the project team.

Construction Phase Assumptions

- Noise sources assumed for the project are listed in **Table 43**.
- Construction activities for roads and bridges were assumed to take place from 07:00 to 19:00.
- Construction activities for tunnels were assumed to take place for 24 hrs per day.
- All equipment per area (i.e., road, bridge, tunnel) were assumed to be operating simultaneously for construction activities.
- The location of construction camps was not available for the assessment and thus not taken into consideration. These construction camps will be located away from residential areas.
- Construction equipment using other roads to get to site was not taken into consideration for the current assessment.
- The road diversion to be used during construction was not provided and could thus not be assessed.
- Material transport and road diversion specifications were not available so were not included in the modelling.
- It was assumed the list of equipment provided (1 team) would operate simultaneously on the different sections.
- Stable plant locations were similarly not available but it was understood that the plants would not be located near residential areas and were accordingly excluded from the modelling.

Table 43. Equipment and vehicles listing assumed for construction activities

Area	Equipment Type and Characteristics	Minimum Number	Operating Hours
Tunnels (4 teams)	Jumbo drill 90-150 m/hr for blasting and bolts	4	00:00 - 23:00
	Excavator with hydraulic hammer and pince for installation of metal arches	4	00:00 - 23:00
	Road header	4	00:00 - 23:00
	Bulldozer 21 t	4	00:00 - 23:00

Area	Equipment Type and Characteristics	Minimum Number	Operating Hours
	Dumper trucks not less than 20 t	12	00:00 - 23:00
	Machinery for sprayed concrete	4	00:00 - 23:00
	Auxiliary loaders	4	00:00 - 23:00
	Drilling machine for forepoles umbrella	3	00:00 - 23:00
	Mobile formworks for tunnel lining	4	00:00 - 23:00
	Trucks with cement mixer and pump for concrete pouring	4	07:00 - 19:00
Bridges (5 teams)	Mobile cranes 40-50 t	10	07:00 - 19:00
	Mobile cranes 100 t	2	07:00 - 19:00
	Auxiliary loaders	5	07:00 - 19:00
	Excavator capacity of 1.0 m^3	5	07:00 - 19:00
	Excavator with hydraulic hammer	5	07:00 - 19:00
	Bulldozer 21 t	5	07:00 - 19:00
	Dumper trucks not less than 20 t	10	07:00 - 19:00
	Bored pile driving equipment capable of min Ø1.2 m of cast-in-place pile.	2	07:00 - 19:00
	Drilling machine for micropiles 220 mm and injection	4	07:00 - 19:00
	Trucks with cement mixer and pump for concrete pouring	5	07:00 - 19:00
	Equipment for frontal launch of steel deck	1	07:00 - 19:00
Cuts and Embankments and Minor Structures (6 teams)	Jumbo Drill 90-150 m/hr for blasting and bolts	6	07:00 - 19:00
	Excavator capacity of 1.0 m^3	6	07:00 - 19:00
	Excavator with hydraulic hammer	6	07:00 - 19:00
	Bulldozer 21 t	6	07:00 - 19:00
	Dumper trucks not less than 20 t	12	07:00 - 19:00
	Mobile cranes 40-50 t	6	07:00 - 19:00
	Auxiliary loaders	6	07:00 - 19:00
	Trucks with cement mixer and pump for concrete pouring	6	07:00 - 19:00
	Bored pile driving equipment capable of min Ø1.2 m of cast-in-place pile.	1	07:00 - 19:00
	Drilling machine for micropiles 220 mm and injection	2	07:00 - 19:00
	Grader 3.7m wide	4	07:00 - 19:00
	Vibrating Rollers 8 t	3	07:00 - 19:00
	Tire pneumatic rollers 12 t	2	07:00 - 19:00
	Asphalt pavers 7.0 m wide	2	07:00 - 19:00
Stable plants	Crushing plant	2	07:00 - 19:00
	Asphalt concrete plant capacity 120 tph	2	07:00 - 19:00
	Cement concrete plant min. capacity of 200 tph	2	07:00 - 19:00

Operational Phase Assumptions

- Vehicles numbers per day were assumed to be 3 692 (for the year 2029) and 8 194 (for the year 2048) as provided.
- The vehicle split was assumed to be 52% cars and minibuses, 5.5% buses and 42.5% trucks.
- The traffic on the road was assumed to be continuous with an even distribution of vehicle numbers per hour (for day- and night-time).
- All vehicles are assumed to be moving on all interchanges along the routes.
- Vehicle speeds are assumed to be 100 km/hr for cars, minibuses and busses and 80 km/hr for trucks.
- Road pavement[51] was assumed to comprise 10 cm of gravel-sand, 30 cm of crushed stone sand course C-5, 8 cm of crushed stone a/c high porosity, 7 cm of course-

[51] The road has been designed in accordance with (i) Bridge Design Building Code SNIP 2.05.03.84, Construction Norm of the RA IV11.05.02-99, AASHTO and Eurocodes.

grained dense a/c I cat B type and 5 cm of fine-grained dense a/c I cat A type. Shoulders will be covered with surface dressing.

Vibration assumptions

No blast designs are yet available and so four possible blast designs were developed for road surface preparation, cuttings, tunnel access areas and tunnel excavation. The charges for cuttings used in the modelling were 64.3 and 321.5 kg for minimum and maximum charges respectively and for road blasting 2.41 and 19.3 kg for minimum and maximum charges. Four blasts were then modelled at 2.41, 19.3, and for 321.5 kg to determine the expected ground vibration for each at various distances from the blast.

3.2.4 Impact Assessment: Construction

The potential impacts of construction noise and vibration may arise from:

- Activities carried out for the project infrastructure (earth moving and excavation, building, and so forth),
- Construction traffic such as large trucks, scrapers and graders, heavy rollers and heavy goods vehicles servicing, delivering and removing materials (including spoil and fill), and
- Tunnel blasting.

Construction noise is predicted to exceed the Armenian standards along virtually the entire length of the roadway with virtually every sensitive receptor along the proposed roadway experiencing the same. As the sensitive receptors are defined at village level it must be recognised that where a possible exceedance is noted that it does not imply that the entire village/town would be so affected. For example, only a small part of the north-eastern side of Sisian and similarly small portions on the southern side of Aghitu would experience exceedances of the noise standards (**Figure 70**). A similar pattern is seen for night-time activities (which are exclusively tunnel construction) where the night-time standard of 45 dB(A) is exceeded by the predicted sound pressure levels.

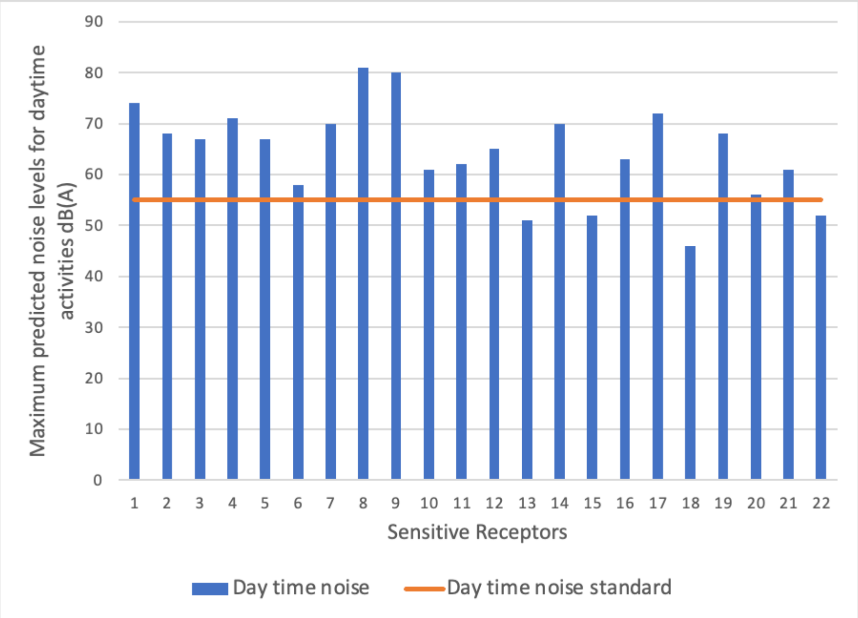


Figure 68. Summary of predicted day time noise levels in the sensitive receptors compared to the Armenian Standard. The names of the sensitive receptors are given relative to the numbers in Table 39

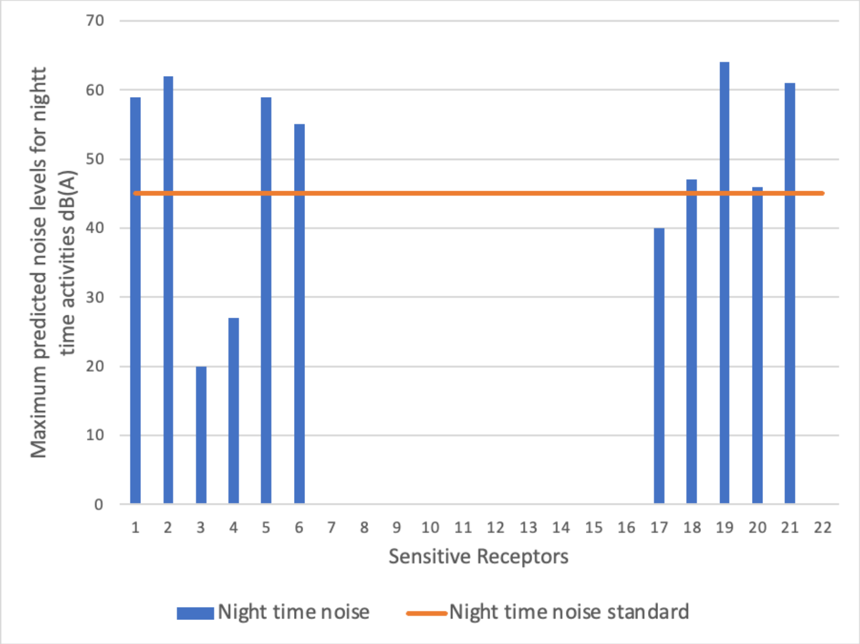


Figure 69. Summary of predicted night time noise levels in the sensitive receptors compared to the Armenian Standard. The names of the sensitive receptors are given relative to the numbers in Table 39

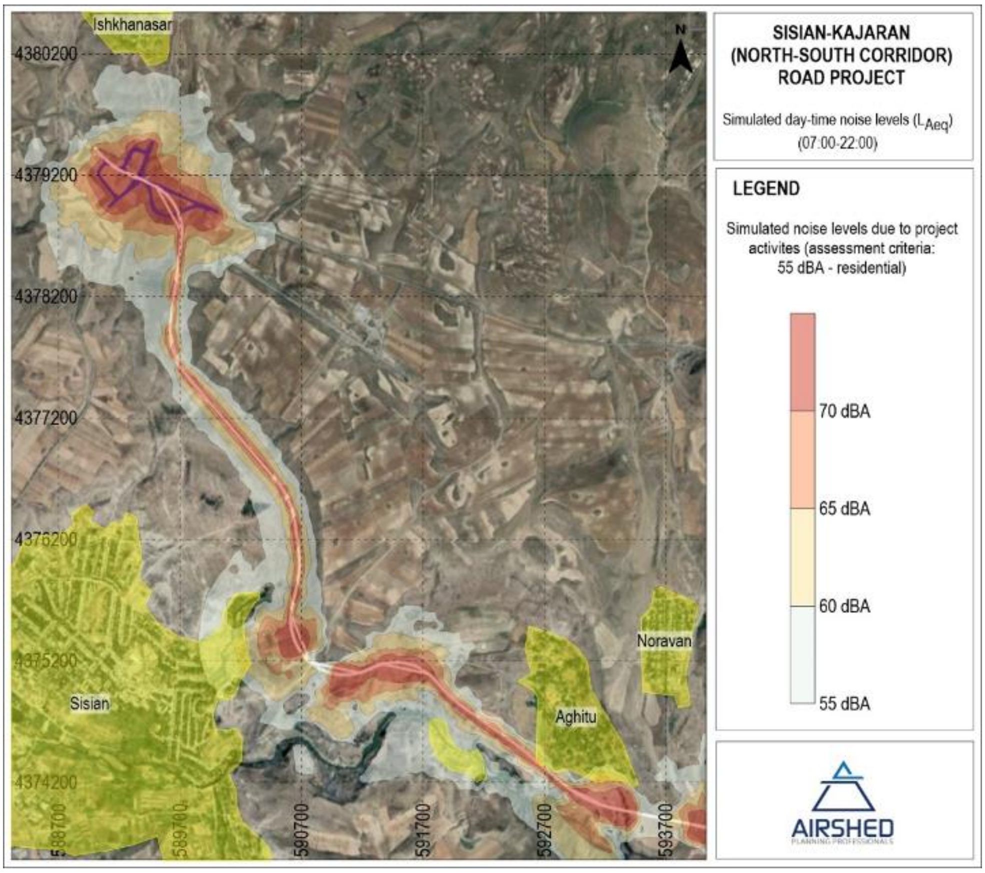


Figure 70. Isopleth map of noise generated by daytime construction activities for Study Area 6

3.2.4.1 Incremental Noise (Construction)

The International Finance Corporation (IFC) General Environmental Health and Safety Guidelines on noise consider impacts beyond the property boundary of the facility under consideration and provide noise guidelines. In addition to the day and night time guidelines, the IFC prescribes that noise impacts should not exceed a maximum increase above background levels of 3 dBA at the nearest receptor location off-site (IFC, 2007). For a person with average hearing acuity an increase of less than 3 dBA in the general ambient noise level is not detectable. A delta of 3 dBA is, therefore, a useful significance indicator for noise impact.

The potential increase (increment) in noise levels due to project construction have been calculated and are presented in **Figure 92**. The increase above background levels of 3 dBA (IFC noise guideline) is exceeded at all identified sensitive receptors for day-time construction activities with the exception of Shamb at site 5 and Noravan and Ishkhanasar at site 6 (**Figure 92**). Night-time noise levels due to construction activities exceed the IFC incremental increase in noise criteria (3 dBA) at sensitive receptors within study site 1 (Kavchut and Geghi) and site 6 (Aghitu and Sisian) where tunnel construction will be taking place (**Figure 71**).

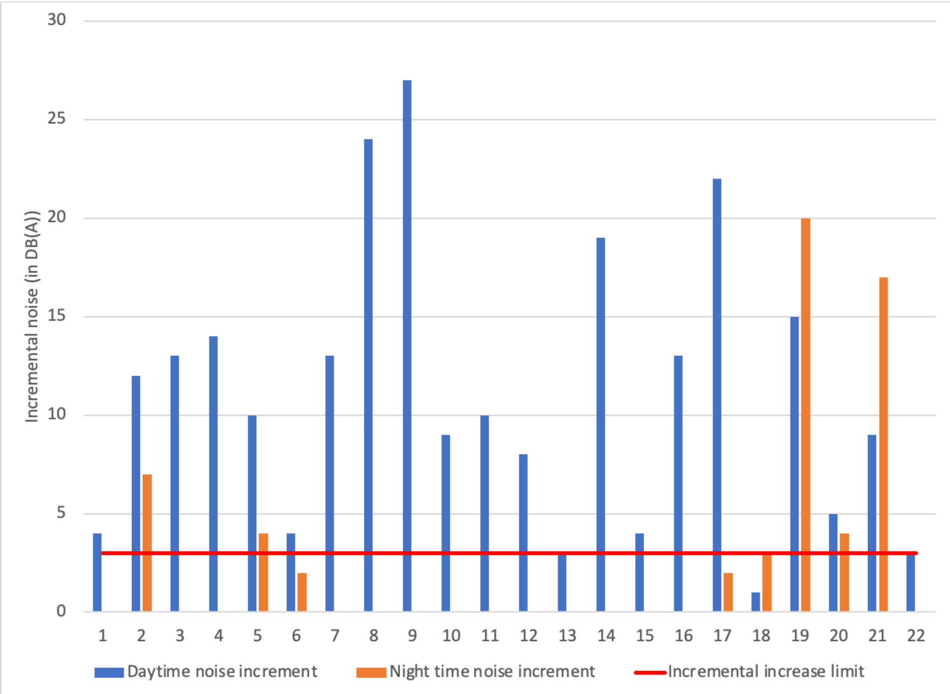


Figure 71. Incremental noise as a result of the combination of the baseline noise and the modelled noise levels during construction

Note that the other noise isopleth maps for the remainder of the route are shown in **https://drive.google.com/drive/folders/1lTKkmA2rFe22B2Xp7ImYkTckN7MXKBJ8?usp=drive_link** .

Impact of Noise due to Construction Activities				
Impact Nature	Positive		Negative	
	Various activities required for the construction of the roadway generate noise. Mechanical rock and concrete-breaking, steel cutting with grinders and driven-in piling are the greater sources of noise while heavy machinery including bulldozers, earth tamping and front-end loaders are lesser but still important sources. These noise generating activities can result in a potentially significant nuisance impact in towns and villages along the proposed road route. The key determinant of that impacts is whether the Armenian noise standards would be exceeded by the noise so generated.			
Impact Type	Direct	Indirect	Reversible	Irreversible

<table>
<tr><td></td><td colspan="4">Noise generated by construction activities has the potential to result in noise induced hearing loss for construction workers, but the off-site effects are deemed to be largely nuisance only and so the impacts would be reversible when the noise generating activities cease.</td></tr>
<tr><td rowspan="2">Impact Duration</td><td>Temporary</td><td>Short-term</td><td>Medium-term</td><td>Long-term</td></tr>
<tr><td colspan="4">In similar vein, given that the noise would cease once construction activities ceased, the impact is considered short-term. Although the road construction is expected to take approximately 6 years, that time period is largely dictated by the construction of the Bargushat Tunnel. The other parts of the roadway would have construction activities for a while, before they would move on to other sections of the road (earth works for 1km of the road are expected to take around 3-4 months).</td></tr>
<tr><td rowspan="2">Impact Extent</td><td>Local</td><td>Municipal</td><td>Regional</td><td>National</td></tr>
<tr><td colspan="4">Although the noise impact extends for most of the length of the road, the impacts must be seen as lateral to the road alignment on either side where villages and residences could be affected by the construction noise. As such the scale of the impact is no more than municipal in extent.</td></tr>
<tr><td rowspan="2">Impact Magnitude</td><td>Negligible</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="4">The predicted noise levels exceed the Armenian noise standards for both day and night-time work. However, night-time work is limited to the tunnels specifically and so would not affect a large part of the road alignment. At the same time the IFC incremental nosie guideline value of 3dB(A) is exceeded for a number of the receptors including a possible 27 dB(A) increment in Shenatagh.</td></tr>
<tr><td rowspan="2">Receptor Value / Sensitivity</td><td>Negligible</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="4">Wherever human health is at risk the receptor sensitivity must be seen as high. In this case, however, human health is unlikely to be affected and the impacts would manifest as more of a disturbance/nuisance.</td></tr>
<tr><td rowspan="2">Impact Significance</td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
<tr><td colspan="4">The predicted exceedances of the noise standards during the construction phase, imply noise impacts are moderate , although there may be some localised areas where the impacts are more major and where construction noise is of major significance.</td></tr>
</table>

Mitigation measures

Develop and implement a Noise and Vibration Management Plan to prevent construction noise from manifesting as significant impacts. The Noise and Vibration Management Plan should include *inter alia*:

For general activities, the following good engineering practice should be applied to the construction phases:

- All diesel-powered vehicles and equipment (such as generators and air compressors) should be kept at a high level of maintenance. This should particularly include the regular inspection and, if necessary, replacement of intake and exhaust silencers. Any change in the noise emission characteristics of equipment should serve as trigger for withdrawing it for maintenance.
- Equipment with lower sound power levels must be selected when making new purchases, where feasible. Vendors should be required to guarantee optimised equipment design noise levels.
- In managing noise specifically related to truck and vehicle traffic, efforts should be directed at:
  - Minimising individual vehicle engine, transmission, and body noise/vibration. This is achieved through the implementation of an equipment maintenance program.
  - Avoid unnecessary idling times.
  - Minimising the need for equipment to reverse. This will reduce the frequency at which disturbing but necessary reverse warnings will occur.
  - Equipment and vehicles should avoid unnecessary horn hooting.
  - Construction activities should be limited to day-time hours (for road and bridge construction).
- Noise barriers/ temporary enclosures should be used at tunnel entrances/ exits near NSRs to reduce night-time noise from these areas.
- A complaints register should be kept during construction operations. Solutions should be sought to solve complaints and feedback should be provided for all complaints.

Specific noise mitigation measures for sources other than diversion routes may include:

- Specification of the use of noise reduction construction methods, for example: specifying the use of rotary rather than driven piling.
- Provision of measures to reduce the noise reaching noise sensitive receptors, for example:
    - Installation of temporary barriers.
    - Restriction of some activities to less sensitive times, for example: restricting piling activity to the mid-day (10:00 – 14:00) only.
    - Providing noise insulation to houses, or temporarily rehousing local residents.

Residual Impacts

The residual impacts become minor even with the mitigation.

Monitoring

Noise monitoring is to comply with the following:

- Any surveys should be designed and conducted by a trained specialist.
- Sampling should be carried out using a Type 1 sound level meter (SLM) that meets all appropriate IEC standards and is subject to annual calibration by an accredited laboratory.
- The acoustic sensitivity of the SLM should be tested with a portable acoustic calibrator before and after each sampling session.
- Samples sufficient for statistical analysis should be taken with the use of portable SLM's capable of logging data continuously over the time period. Samples representative of the day- and night-time acoustic environment should be taken.
- The following acoustic indices should be recoded and reported: LAeq (T), LAIeq (T), statistical noise level LA90, LAFmin and LAFmax, octave band or 3rd octave band frequency spectra.
- The SLM should be located approximately 1.5 m above the ground and no closer than 3 m to any reflecting surface.
- Efforts should be made to ensure that measurements are not affected by the residual noise and extraneous influences, e.g., wind, electrical interference and any other non-acoustic interference, and that the instrument is operated under the conditions specified by the manufacturer. It is good practice to avoid conducting measurements when the wind speed is more than 5 m/s, while it is raining or when the ground is wet.
- A detailed log and record should be kept. Records should include site details, weather conditions during sampling and observations made regarding the acoustic environment of each site.
- Noise monitoring is to be conducted monthly in the areas where construction is taking place at the points highlighted as noise sensitive receptors in this assessment.

3.2.4.2 Vibration

The vibration that would be received by the heritage structures that have been identified along the roadway (see **ESIA Volume 4, Figure 27**) is shown in **Figure 72** as a function of the blast charges that have been assumed to be required for construction. Estimates were made of where the blasts would be needed, the distance to the nearest heritage item measured and the vibrations modelled. Any blast (even at the lowest charge) would need to be at least 12 m away from the heritage structure and 200 m away for the larger blast charges. All the points (heritage structures) that plot above the damage threshold line imply that the required blast would pose vibration damage risk to the structures.

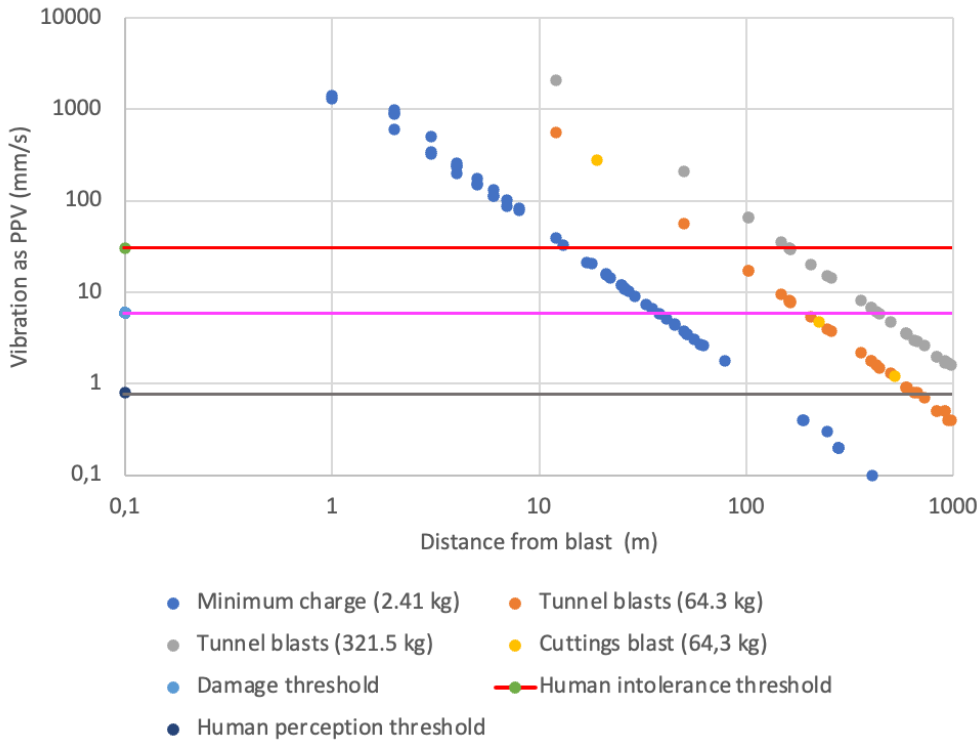


Figure 72. Scatterplot of the vibration that would be received by the heritage structures identified along the roadway for different blast charges. Note that both axes are plotted logarithmically

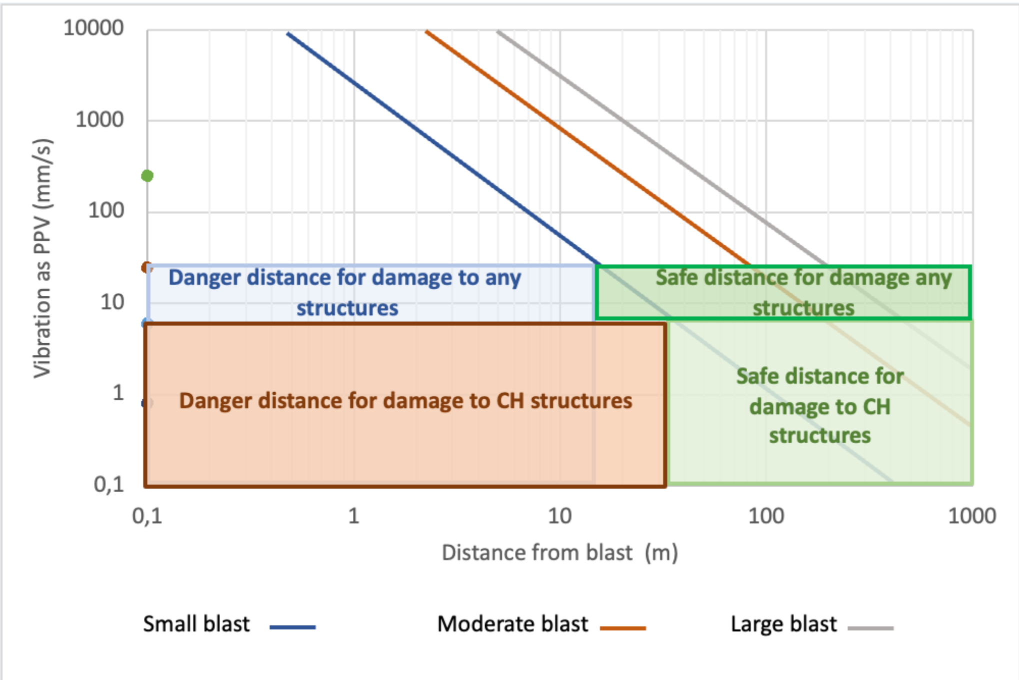


Figure 73. Conceptual interpretation of Figure 72 to assist in understanding the implication of the scatter plot for heritage and other structures

Table 44. Heritage structures at risk from possible blasting requirements together with the estimated distance to the blast and the predicted PPV. Note that these calculations are based on the minimum charge

Reference	Heritage structure	Distance to blast (m)	Predicted PPV
Heritage 19	Wall structure remnants near Natural monument 2	35	6,6
Heritage 16	Natural monument 3	33	7,4
Heritage 17	Natural monument 1	29	9,1
Heritage 52	Structure remains (Medieval village remains)	27	10,3
Heritage 26	Wall structures preserved in the area of old gardens	26	10,8
Heritage 15	Structure remnants in shape of walls and tombs 2	26	11,2
Heritage 29	Flint raw-material source for making stone tools	25	11,9
Heritage 31	Shrine (church) ruins, cemetery and khachkas (Parvants)	25	11,9
Heritage 03	Settlement and tomb field	22	14,2
Heritage 49	Natural monument 1	21	15,6
Heritage 11	Tomb field or cemetery	21	16,0
Heritage 30	Structure remnants in shape of tombs	18	20,7
Heritage 34	Cave complex carved in a section of diatomite origin lacustrine sediments	17	21,4
Heritage 44	Medieval village remains 1	13	32,8
Heritage 02	Shrine-sanctuary "Stepan ukht"	12	39,0
Heritage 27	Section of diatomite origin lacustrine sediments	8	79,7
Heritage 10	Structure remnants or settlement 1	8	83,2
Heritage 18	Natural monument 2	7	86,3
Heritage 25	Medieval village remains and Spring monument	7	102,2
Heritage 39	Surface finds at the base of a hill with an Iron Age fortress	6	111,9
Heritage 45	Church	6	131,1
Heritage 01	Natural monument	5	149,2
Heritage 21	Remnants of a truncated settlement	5	152,5
Heritage 12	Structure remnants or settlement 2	5	174,8
Heritage 13	Structure remnants in shape of walls and tombs 1	4	197,6
Heritage 53	Cave-complex Lernadzor-1	4	235,8
Heritage 05	Section of diatomite origin lacustrine sediments 2	4	236,2
Heritage 43	Natural monument complex 2	4	260,8
Heritage 50	Natural monument 2	3	328,6
Heritage 24	Wall structure remnants	3	338,5
Heritage 28	Vorotan (Vorotn) Medieval village remains and cemetery, Bronze-Iron Age tomb field	3	508,1
Heritage 41	"Sagu ghala" fortress	2	599,4
Heritage 07	Unclassified structure remains 1	2	900,1
Heritage 23	Surface finds around wall structure remnants	2	913,8
Heritage 14	Natural monument 2	2	991,2
Heritage 09	Unclassified structure remains 2	1	1 311,2
Heritage 04	Section of diatomite origin lacustrine sediments 1	1	1 400,3

Box 5: Why only heritage sites for the vibration assessment?

For the modelling of vibration, some 295 possible receptors were identified including rural buildings and structures of poor construction, houses, ruins, animal related installations and animal sensitive areas, graves, water boreholes, surface water resources, pipelines, powerlines, telephone lines, road infrastructure and heritage sites and structures. Of these receptors, the heritage sites are the most sensitive because they have the lowest damage threshold and are also potentially irreparable if they are damaged by vibration. This is not to say that the other receptors are unimportant they are just less sensitive. As such the heritage structures provided a plausible worst-case scenario for damage risk. At the same time, it was necessary to reduce the number of receptors to make the presentation of the results clear and so it was decided to only use the heritage structures.

There was no blasting plan available for the vibration assessment and so a plausible but generalised blasting plan was developed for the assessment. That blasting plan was then assessed for structural damage risk due to vibration using the cultural heritage structures as the most sensitive indicators. The assessment indicated significant potential risk to heritage structures close to the source of the blasting. The mitigation is to conduct a test blast and then to develop a blasting plan for ALL receptors that could be negatively affected by the blasting to ensure that the charge and blasting technique does not result in structural damage. A key requirement of the blasting plan will be pre-blasting surveys on structures that could be affected by the blasting.

Vibration would attenuate quickly through solid ground (viz. not at the surface). Modelling indicates that for a maximum charge blast the PPV at 10m from the blast would be 409.2 mm/s. By 50 m the PPV would have reduced to 28.7 mm/s. Given that the overburden through the Zangezhur area is about 1000m, it seems highly unlikely that there would be material vibration above the blast. The effect is therefore considered negligible. It is nevertheless recommended that when conducting the test blast that vibration monitoring be conducted directly above the overburden above the blast to confirm this assessment.

<table>
<tr><th colspan="5">Impacts due to construction vibration</th></tr>
<tr><td rowspan="2">Impact Nature</td><td colspan="2">Positive</td><td colspan="2">Negative</td></tr>
<tr><td colspan="4">The large energy of the various tools, vehicles and equipment used in road construction imparts energy into the ground which is known as vibration. For the most part these vibrations are limited to the immediate vicinity of where the activities are occurring place and not significant enough to result in off-site damage. When a much large energy source such as a blast occurs the vibration travels though the ground over a significant distance until the energy is dissipated. If physical structures are in the vibration path they can be damaged by the vibration if there is still enough energy in the wave.</td></tr>
<tr><td rowspan="2">Impact Type</td><td>Direct</td><td>Indirect</td><td>Reversible</td><td>Irreversible</td></tr>
<tr><td colspan="4">The concern with vibration is that it may result in damage to physical structures. Physical structures can obviously be repaired suggesting that the impact is reversible. Given, however, that the physical structures of concern are heritage structures, damage to such structures may well be irreparable meaning that the impact damage is irreversible.</td></tr>
<tr><td rowspan="2">Impact Duration</td><td>Temporary</td><td>Short-term</td><td>Medium-term</td><td>Long-term</td></tr>
<tr><td colspan="4">Vibration itself has a very limited duration although the multiple and in many instances repeat activities ensure that there is a sustained source of vibration during construction activities. As soon as the activity stops the energy needed for the vibration stops too. Again, however, the concern is damage to physical structures and especially heritage structures. Damage to such structures may be irreparable but even if not is likely to be medium to long term.</td></tr>
<tr><td rowspan="2">Impact Extent</td><td>Local</td><td>Municipal</td><td>Regional</td><td>National</td></tr>
<tr><td colspan="4">Although the vibration impact extends for most of the length of the road, the impacts must be seen as lateral to the road alignment on either side where heritage structures could be affected. As such the scale of the impact is no more than municipal in extent.</td></tr>
<tr><td rowspan="2">Impact Magnitude</td><td>Negligible</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="4">The assessment reveals that the relative proximity of many of the heritage structures to areas where blasting may be required, and even at very low charges, means that there is a significant risk of potential damage in the absence of mitigation. The larger charges exacerbate the risk still further. The impact magnitude is therefore potentially high.</td></tr>
<tr><td rowspan="2">Receptor Value / Sensitivity</td><td>Negligible</td><td>Low</td><td>Medium</td><td>High</td></tr>
<tr><td colspan="4">The heritage value of the heritage structures varies from structure to structure. The collective value of the heritage along the road is of high value and so the receptor sensitivity is deemed high.</td></tr>
<tr><td></td><td>Negligible</td><td>Minor</td><td>Moderate</td><td>Major</td></tr>
</table>

Impact Significance	The combination of high impact magnitude and high receptor sensitivity means that the impact significance is potentially major.

Mitigation measures

Develop and implement a Noise and Vibration Management Plan to prevent vibration from blasting manifesting as significant impacts. The Noise and Vibration Management Plan should include *inter alia*:

- Blast designs can be reviewed prior to first blast to ensure that the charge is appropriate not just to achieve the blast effect but to minimise the potential off-site impacts.
- Blast designs to be reviewed by the supervising contractor/engineer.
- Conduct a test blast to confirm levels and ground vibration and adjust the blast design as necessary.
- Engage with all parties who may be affected by noise and vibration related to blasting and agree optimised approaches to minimising disturbance.
- Electronically programmed detonators provide not only the ability to tightly control blast timing, but also the ability to extract blast data for a continuous improvement process. The ability to alter predictably, using feedback from the downstream processes, blasting variables including vibration, is a huge advantage.
- Changes to drill and blast design to mitigate ground vibration.
- Develop blast design based on a test blast, and the ground vibration levels to be adhered too.
- Only apply electronic initiation systems to facilitate single hole firing.

  Design for smaller diameter blast holes that will use fewer explosives per blast hole.
- Confirm areas on road surface that will require drilling and blasting. There may be areas where mechanical operations can be applied without the need for blasting. This will help reduce the possible impacts.

Residual impacts

With the implementation of the mitigation measures and especially paying careful attention where heritage structures are close to where the blast is required, damage to heritage structures can be prevented and impact significance reduced to **minor.**

Monitoring

The following elements should be part of such a monitoring program:

- Pre-blast surveys on structures that could be affected by blasting
- Ground vibration and air blast results.
- Blast Information summary.
- Meteorological information at time of the blast.
- Video Recording of the blast.
- Fly rock observations.

3.2.5 Impact Assessment: Operation

During road operations, traffic will generate noise from the roadway and vibration could occur from the road sections. The Federal Highway Administration of the USA has determined that “All studies the highway agencies have done to assess the impact of operational traffic induced vibrations have shown that both measured and predicted vibration levels are less than any known criteria for structural damage to buildings. In fact, normal living activities (e.g., closing doors, walking across floors, operating appliances) within a building have been shown to create greater levels of vibration than highway traffic."[52] As such, vibration risk during road operations is not considered further here.

Predicted sound pressure levels for the operational roadway exceed the Armenian day-time noise standard for many of the sensitive receptors for the 2029 estimated traffic count and for those sensitive receptors and several others for the 2048 estimated traffic count (Figure 74). Musallam, Karut, Kitsk, Shenatagh and Aghitu are the areas of greatest concern for both traffic counts. **Note that in addition to exceeding the Armenian standards, the predicted sound pressure levels also exceed the WHO guideline of 53 dB(A) above which road traffic noise may cause adverse health effects.**

The night-time circumstance is considerably worse as the predicted traffic noise does not reduce materially and in fact increases in some areas. During the night Musallam, Kavchut, Geghavank, Verin Geghavank, Karut, Kitsk, Shenatagh, Lor, dwellings ~1.2 km to the west-northwest of Shamb, dwellings ~780 m to the south of Vaghatin, Vaghatin and Aghitu are **all predicted to experience unacceptable noise levels that exceed both the Armenian Standard and the WHO guideline above which sleep disturbance is likely**. These predictions are for the 2029 and 2048 traffic counts with the latter again being worse than the former.

Isopleth maps are shown in **Figure 76** to **Figure 81** for study sites 2 and 3 to illustrate how noise from the operational roadway will impact Karut, Kitsk and Shenatagh. The most illustrative of these is where predicted noise levels exceed the 53 dB(A) isopleth as a recognised source of human health risk. For the 2029 traffic count Karut and Kitsk are entirely enveloped in the isopleth while portions of Shenatagh on the eastern side of the village are enveloped. For the 2048 traffic count almost all of Shenatagh would be enveloped by traffic noise exceeding 53 dB(A) (**Figure 81**). The remaining isopleth maps for the noise modelling are available at: **https://drive.google.com/drive/folders/1lTKkmA2rFe22B2Xp7ImYkTckN7MXKBJ8?usp=drive_link** .

[52] http://www.fhwa.dot.gov/environMent/noise/regulations_and_guidance/analysis_and_abatement_guidance/polguide09.cfm

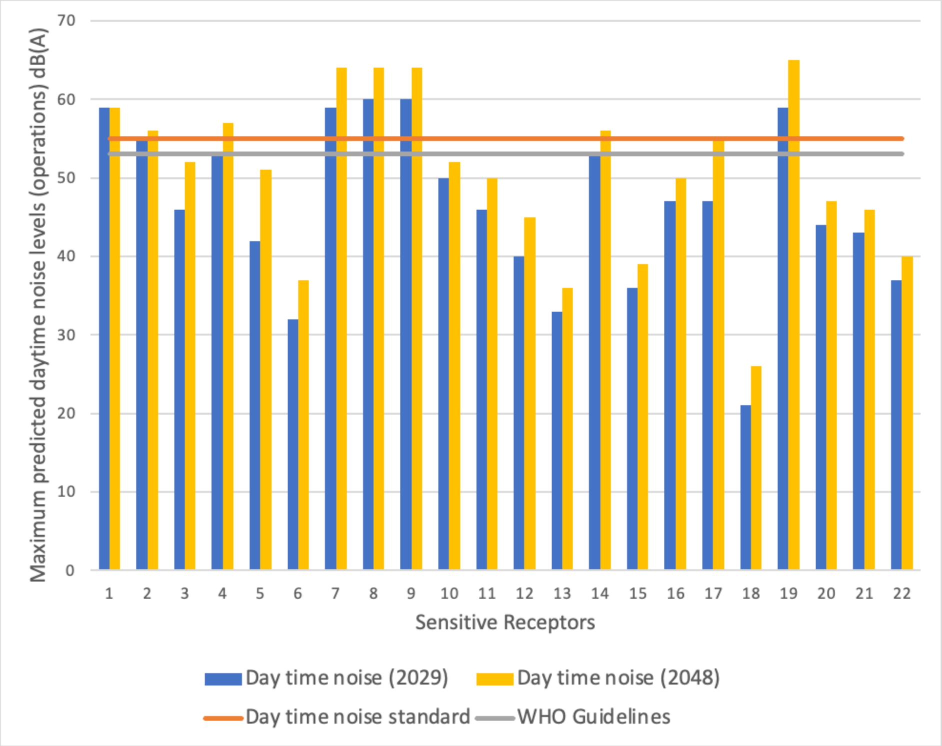


Figure 74. Predicted day-time noise levels during operations of the roadway (2029 and 2048) at sensitive receptors along the road alignment

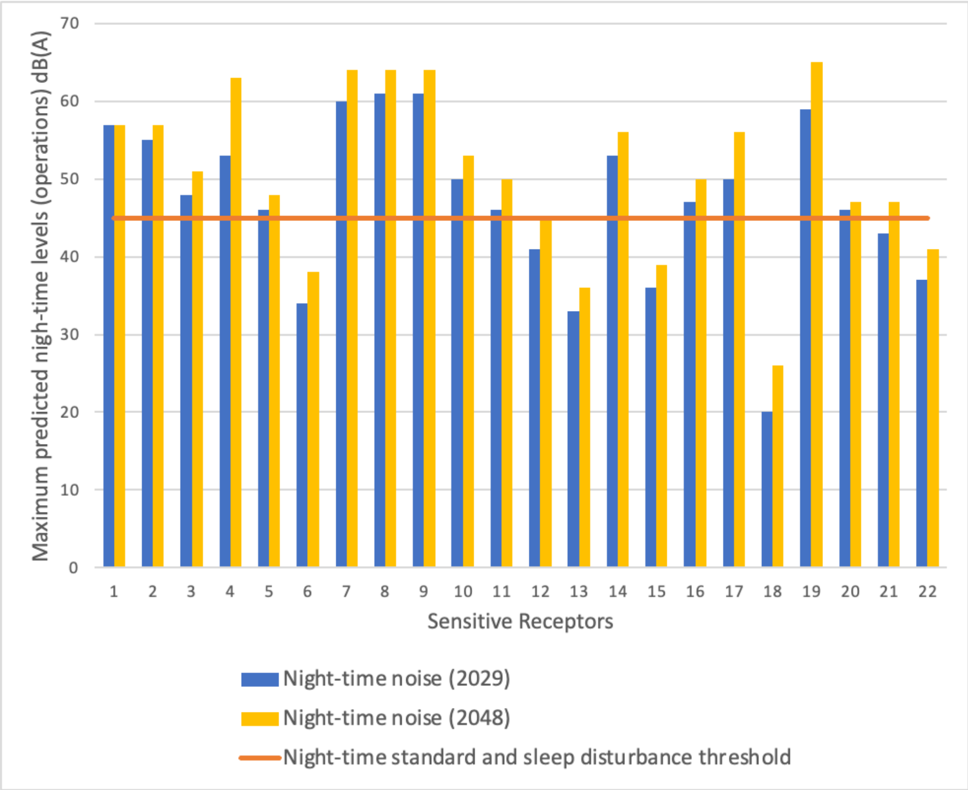


Figure 75. Predicted night-time noise levels during operations of the roadway (2029 and 2048) at sensitive receptors along the road alignment

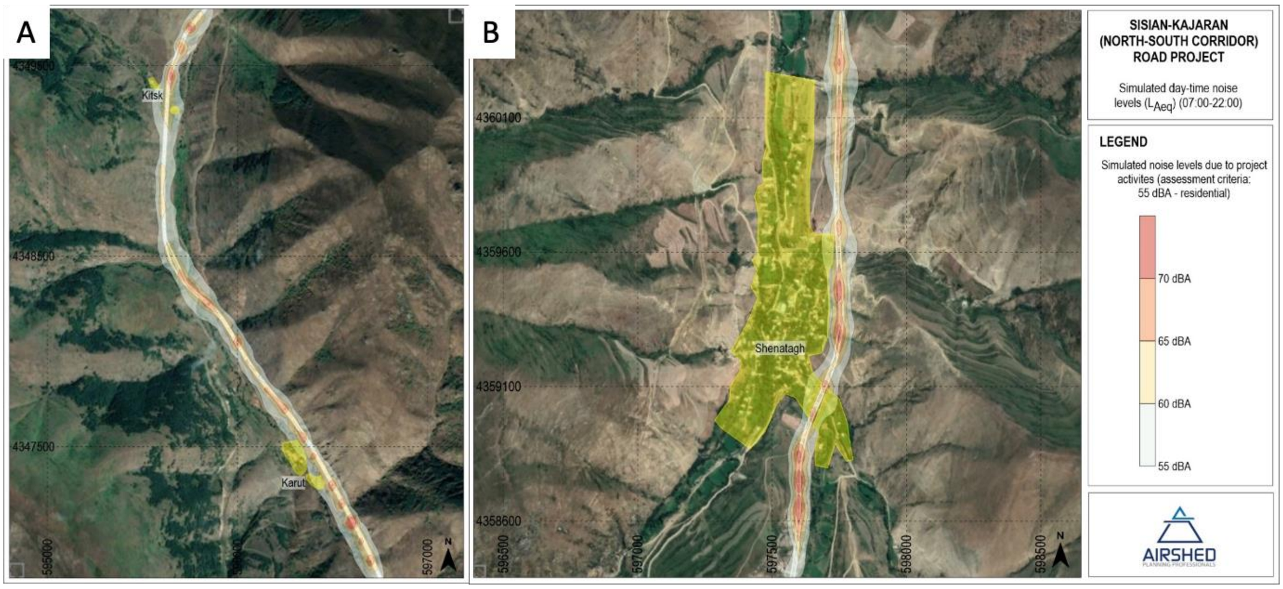


Figure 76. Predicted day-time noise levels during operations of the roadway (2029) in study area 1. A=Site 2 and B=Site 3

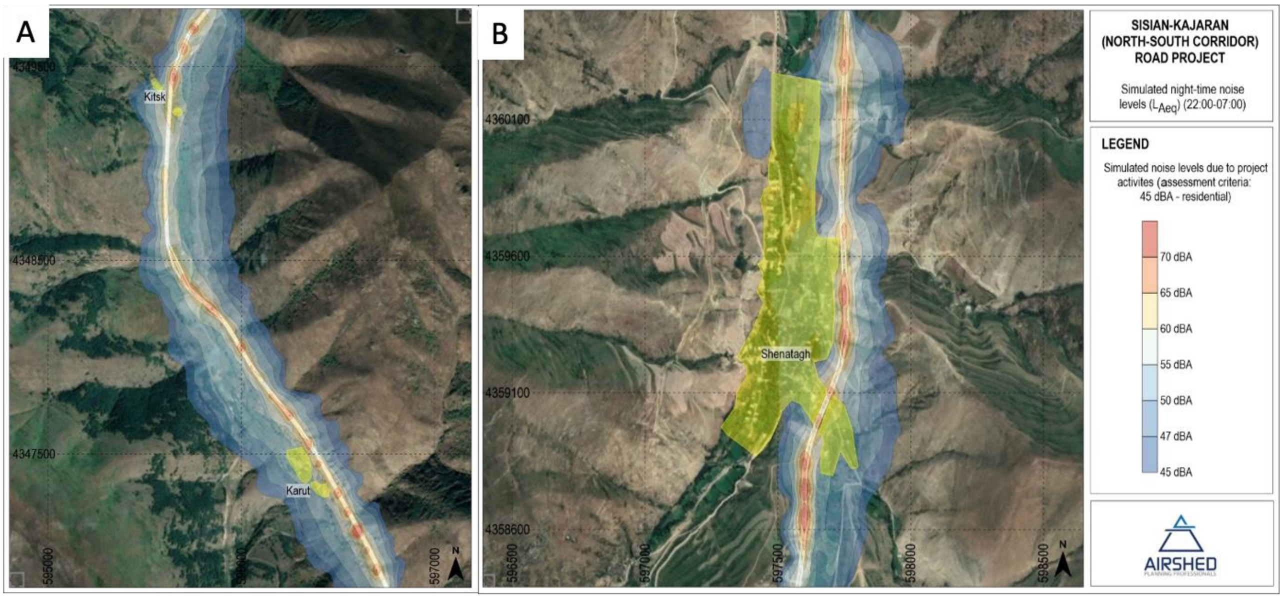


Figure 77. Predicted night-time noise levels during operations of the roadway (2029) in study area 1. A=Site 2 and B=Site 3

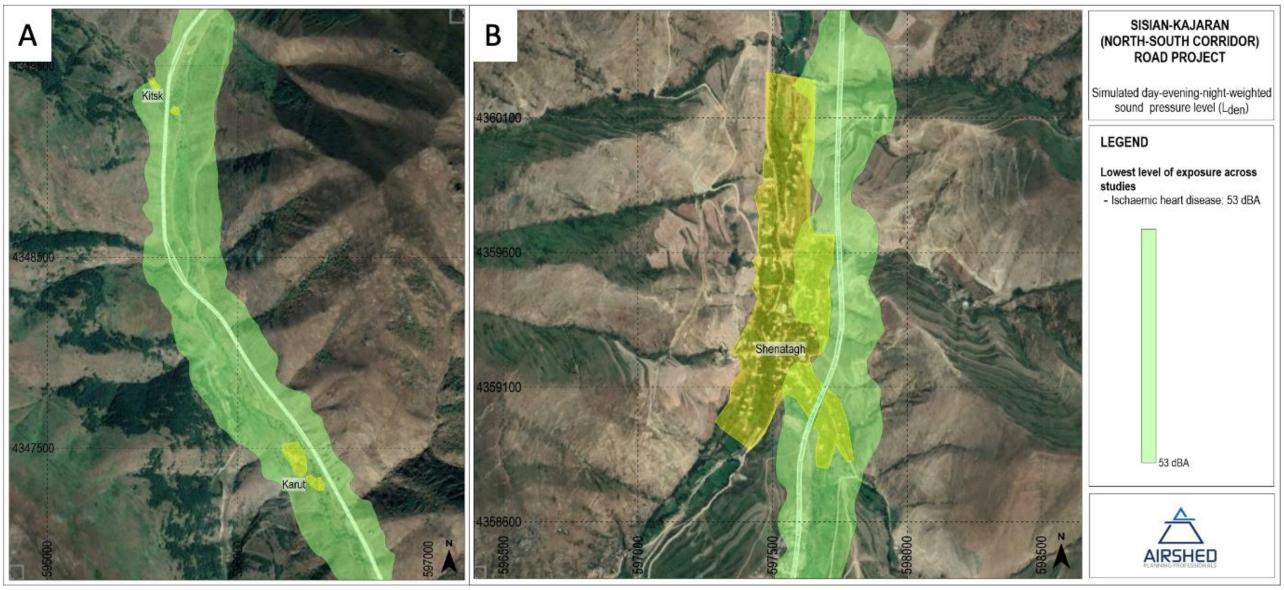


Figure 78. Spatial area where predicted noise levels during operations of the roadway (2029) in study area 1, exceed the WHO guideline of 53 dB(A). A=Site 2 and B=Site 3

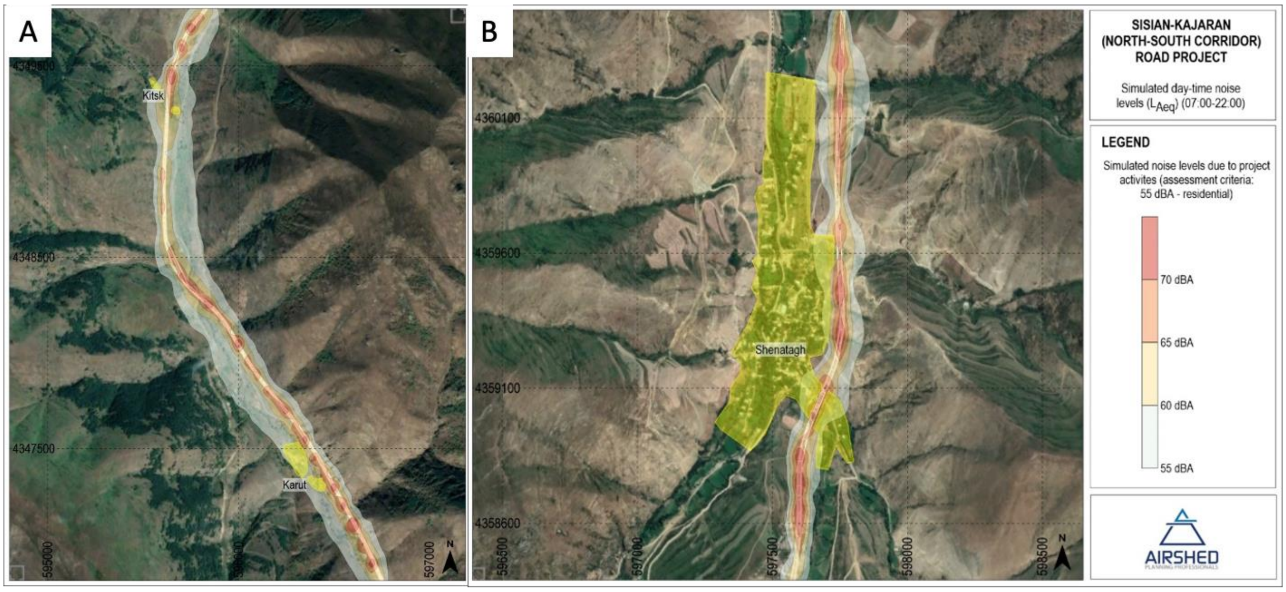


Figure 79. Predicted day-time noise levels during operations of the roadway (2048) in study area 1. A=Site 2 and B=Site 3

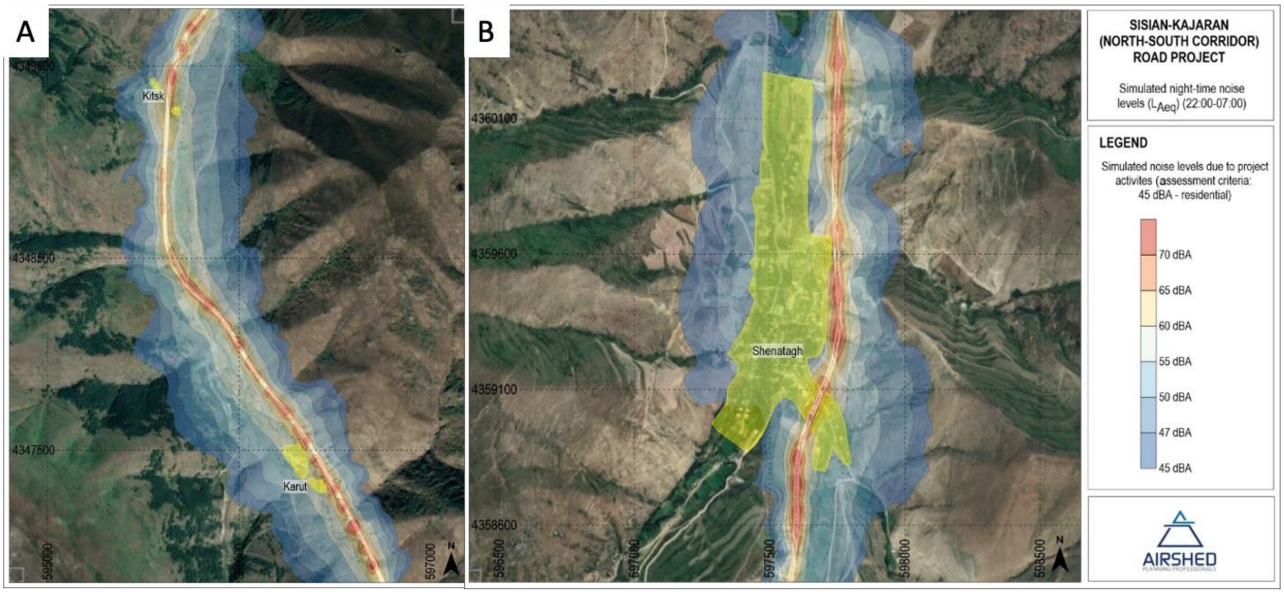


Figure 80. Predicted night-time noise levels during operations of the roadway (2048) in study area 1. A=Site 2 and B=Site 3

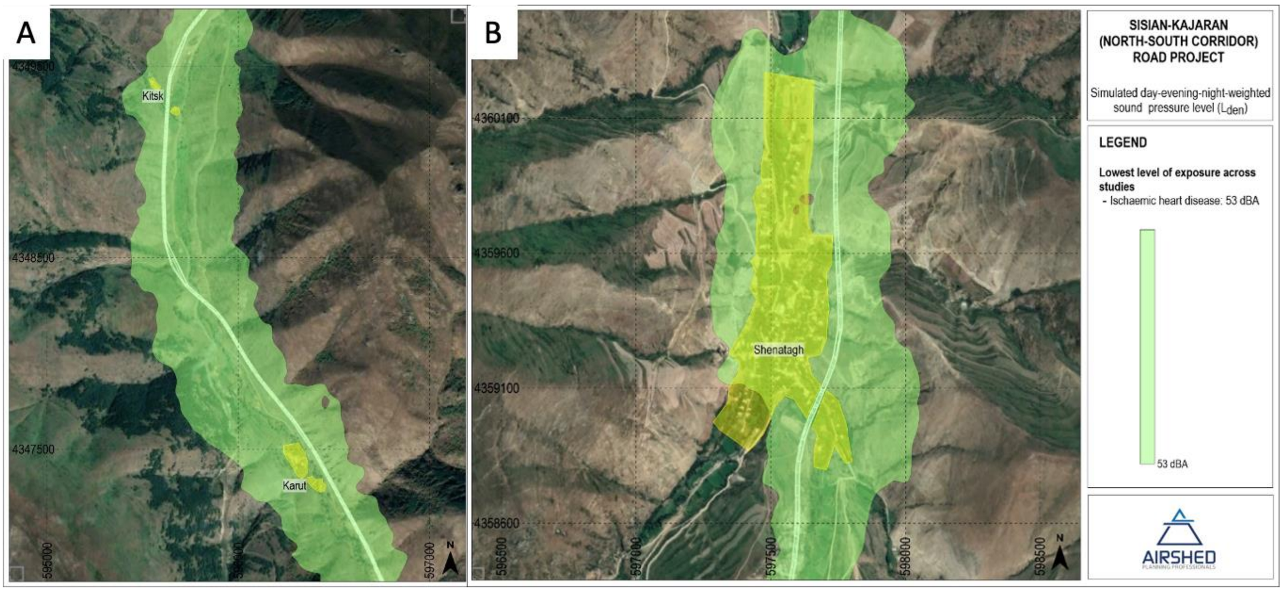


Figure 81. Spatial area where predicted noise levels during operations of the roadway (2048) in study area 1, exceed the WHO guideline of 53 dB(A). A=Site 2 and B=Site 3

<u>Incremental noise (operations)</u>

The potential increment in noise levels due to project operations for the 2029 and 2048 traffic counts, have been calculated and are presented in **Figure 82** and **Figure 83**. The increase in noise levels above background, due to project operations for the year 2029, exceed the IFC criteria of 3 dBA at NSR at site 2 (Karut and Kitsk), site 3 (Shenatagh), site 5 (dwellings ~1.2 km to the west-northwest of Shamb) and site 6 (Aghitu) (**Figure 82**). Night-time noise levels due to operations for the year 2029 exceed the IFC incremental increase in noise criteria (3 dBA) at sensitive receptors within study site 2 (Karut and Kitsk), site 3 (Shenatagh), site 4 (Getatagh), site 5 (dwellings ~1.2 km to the west-northwest of Shamb and dwellings ~780 m to the south of Vaghatin) and site 6 (Aghitu and dwellings ~450 m to the west of Aghitu) (**Figure 82**).

The increase in noise levels above background, due to project operations for the year 2048, exceed the IFC criteria of 3 dBA at NSR at site 2 (Karut and Kitsk), site 3 (Shenatagh), site 5 (dwellings ~1.2 km to the west-northwest of Shamb and Vaghatin) and site 6 (Aghitu) (**Figure 83**). Night-time noise levels due to operations for the year 2048 exceed the IFC incremental increase in noise criteria (3 dBA) at sensitive receptors within study site 1 (Kavchut and Verin Geghavank), site 2 (Karut and Kitsk), site 3 (Shenatagh), site 4 (Lor and Getatagh), site 5 (dwellings ~1.2 km to the west-northwest of Shamb, dwellings ~780 m to the south of Vaghatin and Vaghatin) and site 6 (Aghitu, dwellings ~450 m to the west of Aghitu and Sisian) (**Figure 83**).

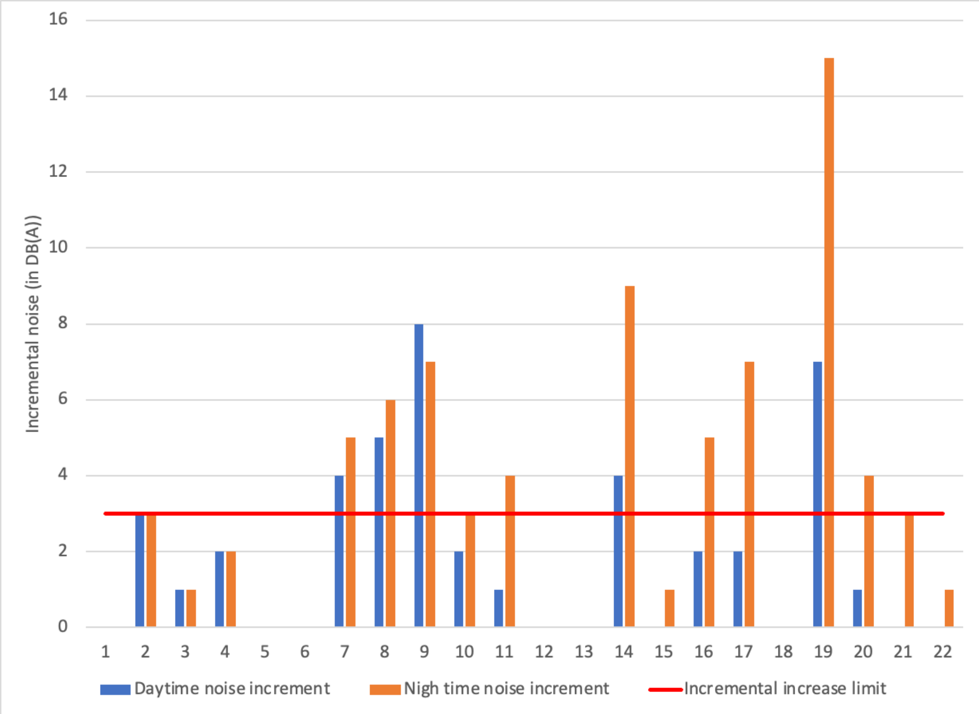


Figure 82. Incremental noise as a result of the combination of the baseline noise and the modelled noise levels for the 2029 traffic fleet.

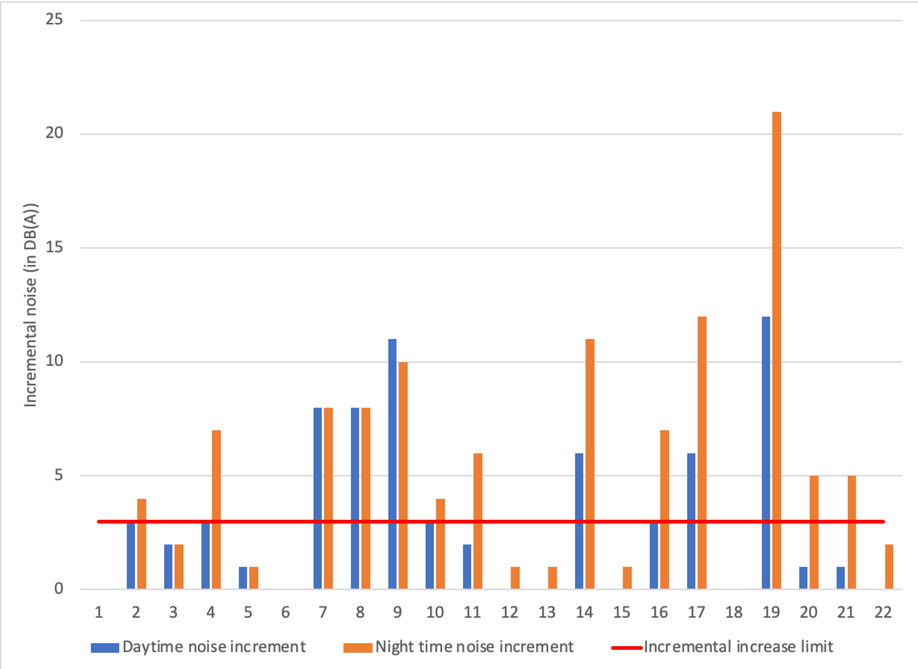


Figure 83. Incremental noise as a result of the combination of the baseline noise and the modelled noise levels for the 2048 traffic fleet

Impact of Noise due to Roadway Operations				
Impact Nature	Positive		Negative	
	The traffic using the road is an obvious source of noise once the road has been completed. As opposed to construction noise, noise from the operational road will be continuous (a drone) punctuated by an especially noisy vehicle either through speeding, very heavy loads, poor maintenance, age and combinations of these factors.			
Impact Type	Direct	Indirect	Reversible	Irreversible
	Noise is generally viewed as a nuisance or some kind of disturbance but it is now recognised that noise can and does have adverse health effects for those exposed to elevated noise levels and especially road traffic noise. The primary impact of operational road noise is therefore the risk of adverse health effects and should such health effects occur, they would be permanent.			
Impact Duration	Temporary	Short-term	Medium-term	Long-term
	Road operations noise would be quite different to construction noise in that it would continue unabated for at least 20 years and possibly more. While the noise itself is reversible – it stops once the traffic stops – adverse health effects brought about by noise exposure are unlikely to be reversible.			
Impact Extent	Local	Municipal	Regional	National
	Although the noise impact extends for much of the length of the road, the impacts must be seen as lateral to the road alignment on either side where villages and residences could be affected by the traffic noise. The scale of the impact is considered regional due to it extending along the length of the road.			
Impact Magnitude	Negligible	Low	Medium	High
	The predicted operational noise levels exceed the Armenian noise standards for both day and night. Many sensitive receptors along the road length are predicted to experience noise levels that exceed the Armenian noise standards. In addition there are a number of sensitive receptors where the incremental noise levels exceed the IFC guidelines of 3 dB(A). The impact magnitude is accordingly deemed high.			
Receptor Value / Sensitivity	Negligible	Low	Medium	High
	Wherever human health is at risk the receptor sensitivity must be seen as high.			
Impact Significance	Negligible	Minor	Moderate	Major
	The predicted exceedances of both the Armenian noise standards and the WHO guidelines on adverse human health and sleep disruption risks, make this an impact of **major significance**. The project cannot be allowed to proceed unless this impact is mitigated.			

Mitigation Measures

Develop and implement a Noise and Vibration Management Plan toto prevent operations phase noise from manifesting as significant impacts. The Noise and Vibration Management Plan should include *inter alia*:

Methods to control noise at source can be subdivided into the following basic categories:

(a) Limiting vehicle noise emissions.

(b) Road traffic control measures.

(c) Roadway design.

Noise control in the area between source and receiver may be affected by:

(a) Land-use planning.

(b) Noise attenuation barriers.

Each of these are outlined below.

<u>Motor Vehicle Noise Control</u>

This aspect of noise reduction relates more to manufacturer design, effective maintenance of vehicles by owners and driving techniques. Motor vehicle noise control falls more into the realm of enforcement.

<u>Road Traffic Control Measures</u>

The main factors affecting the noise generated by road traffic are the total number of vehicles, the percentage of heavy commercial vehicles in the traffic flow, the traffic speed and the operational characteristics (the latter relating to whether the traffic is free flowing or subject to interrupted operation as at traffic lights and junctions where vehicle interactions occur).

Under high-speed free flow conditions, however, other factors come into play, that is at high speeds the main component of the noise emanates from the tyre/road surface interaction whereas at low speeds and where steep gradients are involved mechanical noise from the vehicles tends to predominate. Therefore, the advantage obtained from the reduction of speed could well be offset by the increase in mechanical noise.

Roadway Design

The noise radiated by traffic can be influenced by both the vertical and horizontal alignment of the road and also by the type of road surface used.

Designing the road surface to control noise. The level of noise generated by a vehicle's tyres rolling over the road surface depends primarily on the speed of the vehicle and the design of the tyre and the road surface. There are road surfaces, however, which offer the combined advantage of both low noise and good skidding resistance performance. These surfaces generally have an open texture which is pervious to surface water, but which also offers good acoustic absorption.

Land-Use Planning and Noise Control

Planting vegetation that is high and dense enough to obscure the traffic visually will provide more attenuation than provided by the mere distance which the buffer strip represents. An attenuation of approximately 1 dBA to 3 dBA per 10 metre depth of extremely dense planting can be expected. Shrubs or other ground cover are necessary in this respect to provide the required density near the ground.

The psychological effect of planting is significant, as it has been found that by removing the noise source from view, plantings reduce human annoyance to noise. The fact that people cannot see the road generally reduces their awareness of it even though the noise remains.

Noise Attenuation Barriers

Intervening vertical walls or earth mounds can be used for noise attenuation barriers, but they must be specifically designed for that purpose. Barriers may be classified into one of the following types:

- wall
- earth berm
- wall/berm combination.

Barriers have been constructed from the following materials and where required various surface treatments have been used to increase the acoustic absorbency of the structure:

- concrete wall
- wooden wall
- brick wall
- metal wall
- glass and perspex
- natural material such as earth-berm and living plants woven into screens
- combinations of earth fill and retaining structures.

Noise barriers must be carefully integrated into the design of the road. The design objectives for a successful noise barrier are that it must possess sufficient mass to attenuate the sound, it must be relatively maintenance free once installed, and must not result in an increased risk of accident or injury.

The sound energy generated by a transportation source can be reflected by a barrier wall, thus affecting receivers located on the source side of the barrier. Where there are barriers on both sides of the road and these do not have acoustically absorbent surfaces a further problem may occur, namely that of multiple reflections between the barrier walls which may be diffracted over the barriers.

A trade-off must be found between the height of the noise barrier and the visual impact of the barrier. The shape of the barrier is also important. A simple wall has generally been found to be less effective than an earth berm of similar height.

The barrier must not deteriorate rapidly under the action of sunlight and other weathering effects.

Efficacy of mitigation

On average, noise barriers reduce A-weighted noise levels by 3–7 dB, depending on their design and height. If the barrier surface density exceeds 20 kg/m², a reduction of 5 dB can be achieved by having a barrier tall enough to break the line of sight from the road to the receiver and an additional 1.5 dB reduction can be achieved for each additional meter of height. In practice, however, environmental barriers normally have an upper attenuation limit of about 20 dB for a single barrier and 25 dB for a double barrier (Arenas, 2008). The length of the barrier is designed to be at least eight times as long as the distance from the receiver to the barrier (USDT, 2001). The physical mechanisms whereby noise barriers attenuate (reduce) noise are shown in **Figure 84**, with examples of noise barriers on roadways shown in **Figure 85**.

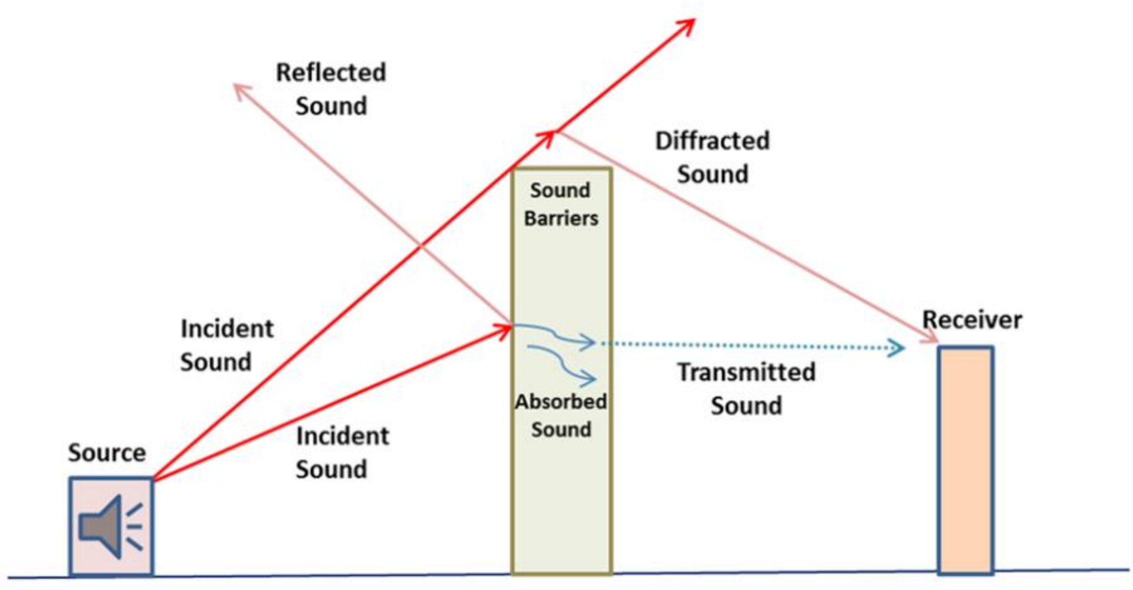


Figure 84. The different physical mechanisms for noise barrier performance

Figure 85. Examples of the shapes that noise barriers can take in attenuating noise from roads

To ascertain the efficacy of noise barriers in mitigating the noise impacts, 27 sensitive receptors were identified in Shenatagh (**Figure 86**). Then noise was modelled for generic noise barriers of different heights viz. 4, 6 and 8 m walls and the modelled outputs compared to the Armenian noise standards. The predicted, unmitigated, daytime noise levels are shown in **Figure 87** for the 2048 traffic count where it can be seen that the 55 dB(A) standard is exceeded at several sensitive receptors. The predicted daytime noise levels with the application of 8m walls as noise barriers are shown in **Figure 88**. The reduction in the spatial extent of the noise generated from road operations is evident between the two figures.

The predicted, unmitigated, night time noise levels are shown in **Figure 89** relative to the Armenian noise standard of 45 dB(A) for the 2048 traffic counts. Not unexpectedly, the spatial extent of the exceedance is materially larger than for the daytime standard. The predicted night time noise levels with the application of 8m walls as noise barriers are shown in **Figure 90**. Again, it is evident between the two figures that the noise barriers effect a large reduction in the spatial extent of the exceedances of the standard to the extent that there is compliance with the Armenian night time standard at all the sensitive receptors.

A summary of the potential noise impacts with no attenuation and with attenuation for 2029 and 2048 traffic operations at the sensitive receptors within 100 m of the road is summarised in **Figure 91**. The continuous day-time noise levels decrease to within the Armenian noise standards at all selected receptors with the implementation of a 4 m wall (noise barrier) bordering on both sides of the road. The continuous night-time noise levels decrease to within the Armenian noise standards at all selected receptors with the implementation of an 8 m wall.

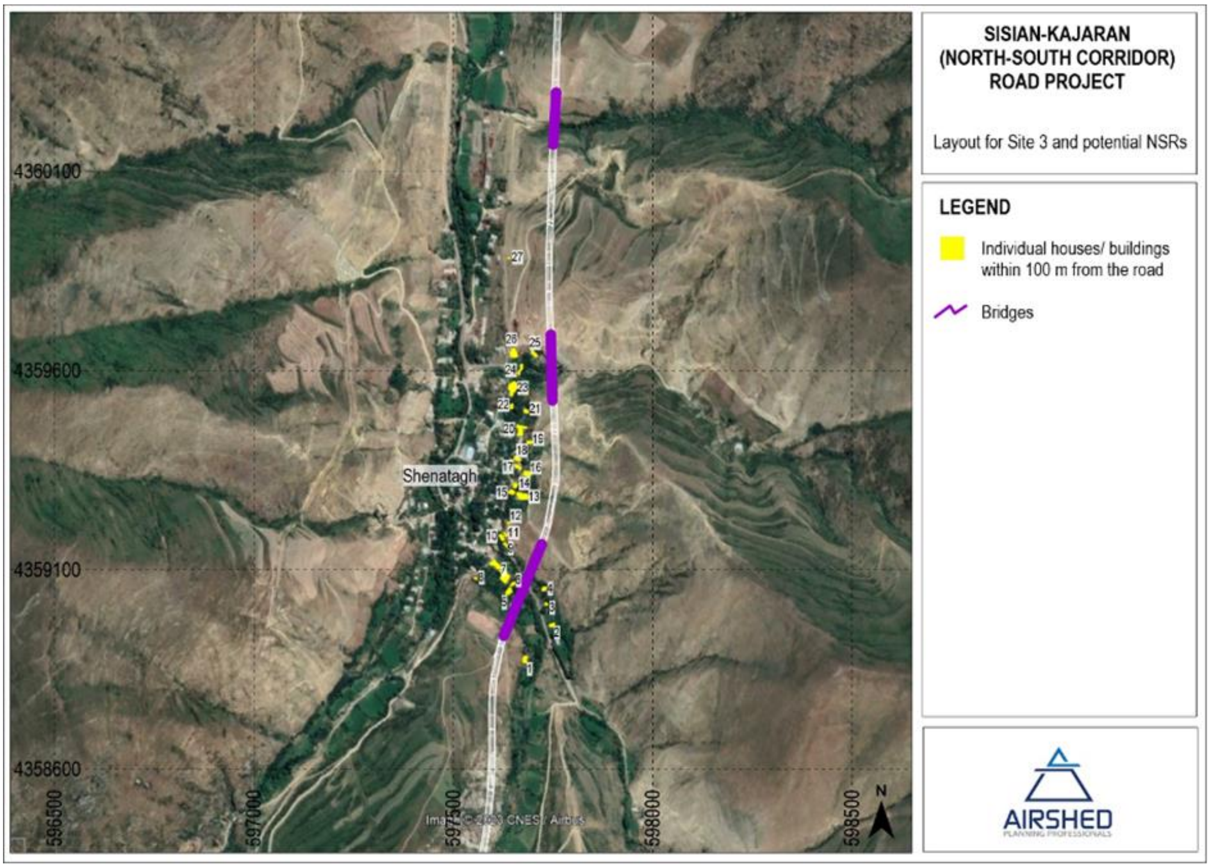


Figure 86. The 27 sensitive receptors identified in Shenatagh, for assessing the efficacy of noise attenuation/mitigation

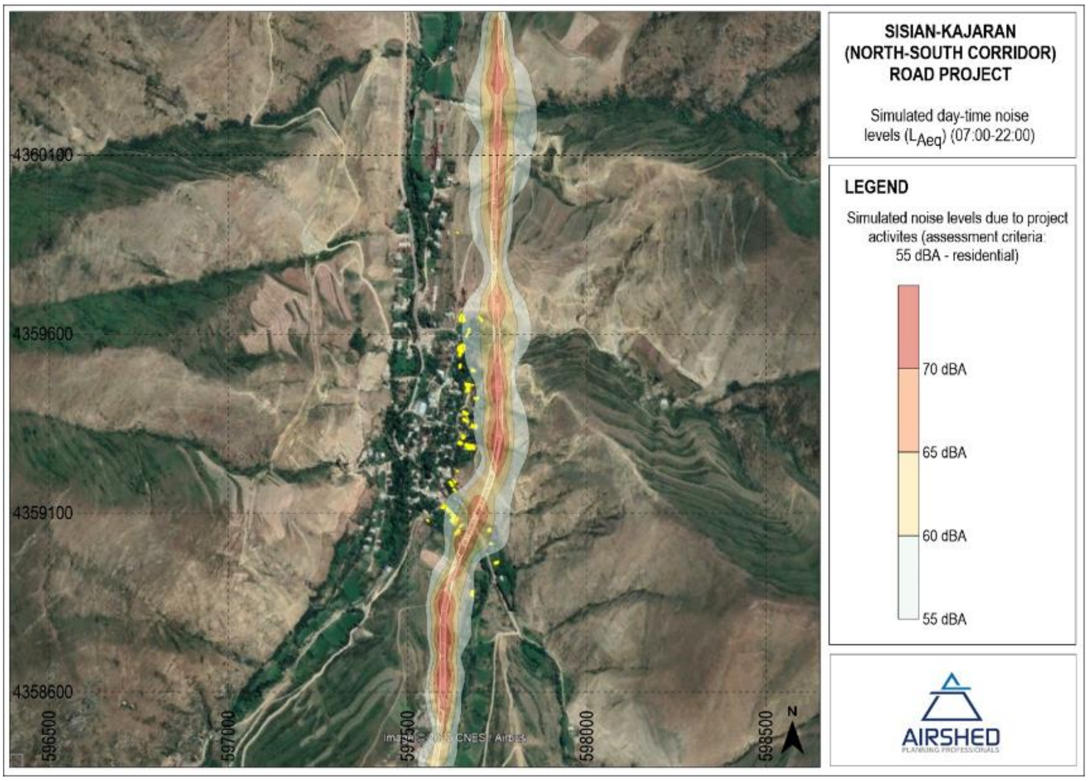


Figure 87. Predicted unmitigated noise levels for the section of road passing Shenatagh in 2048 relative to the Armenian daytime standard of 55 dB(A)

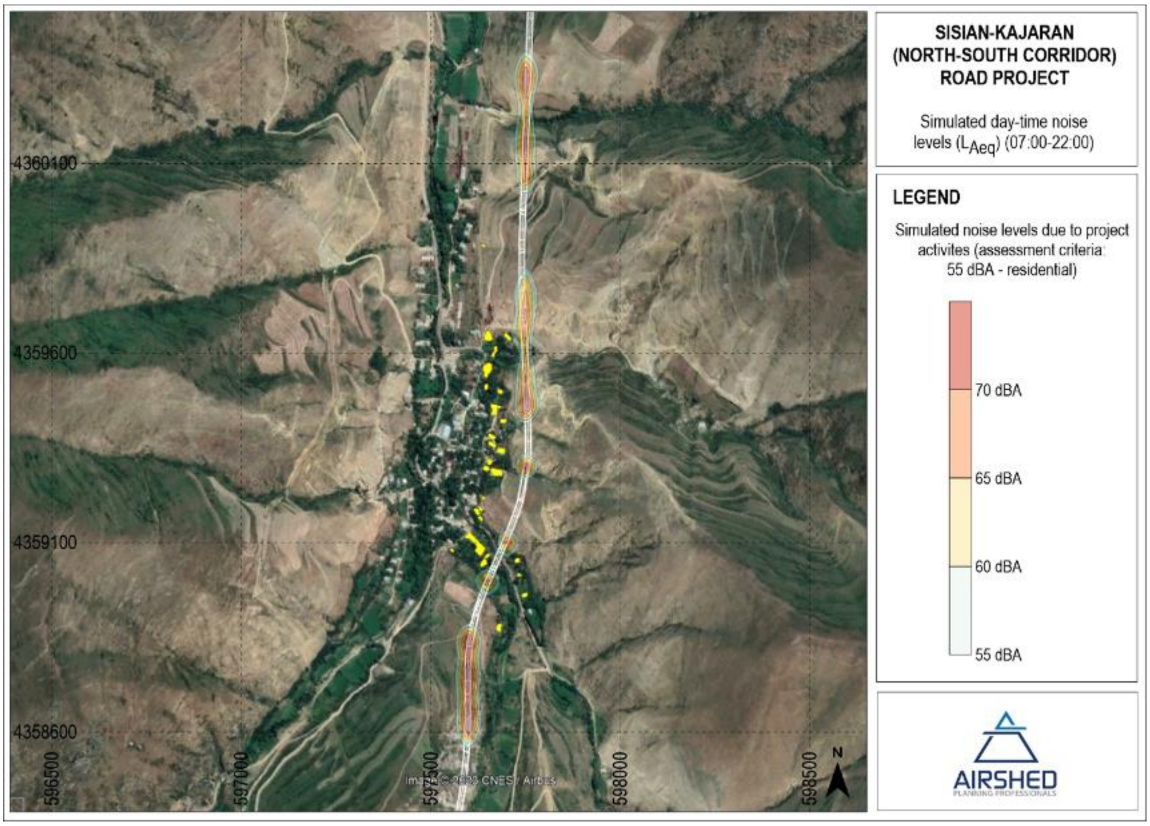


Figure 88. Predicted noise levels for the section of road passing Shenatagh in 2048 with a generic 8m wall as a noise barrier, relative to the Armenian daytime standard of 55 dB(A)

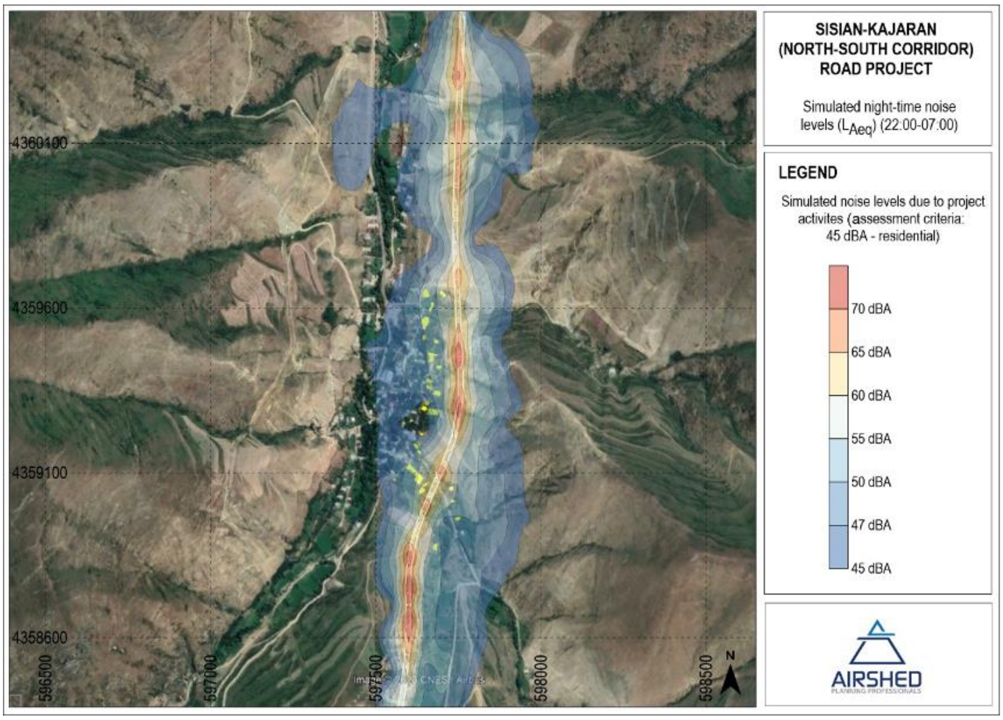


Figure 89. Predicted unmitigated noise levels for the section of road passing Shenatagh relative to the Armenian night time standard of 45 dB(A)

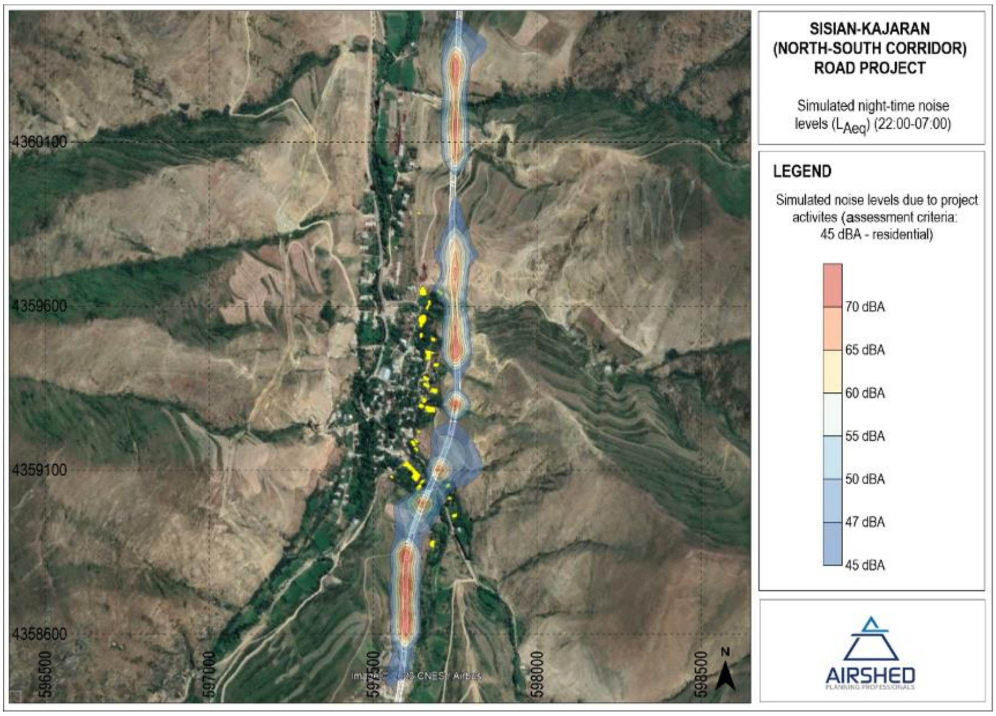
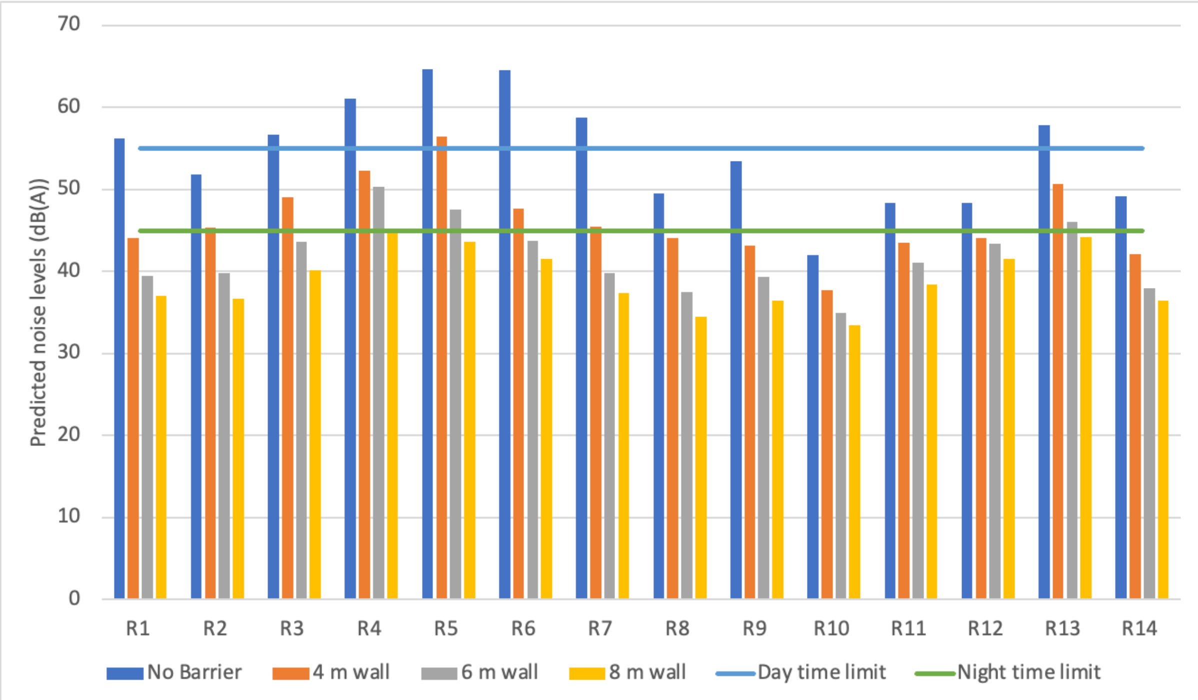


Figure 90. Predicted noise levels for the section of road passing Shenatagh with a generic 8m wall as a noise barrier, relative to the Armenian nighttime standard of 45 dB(A)



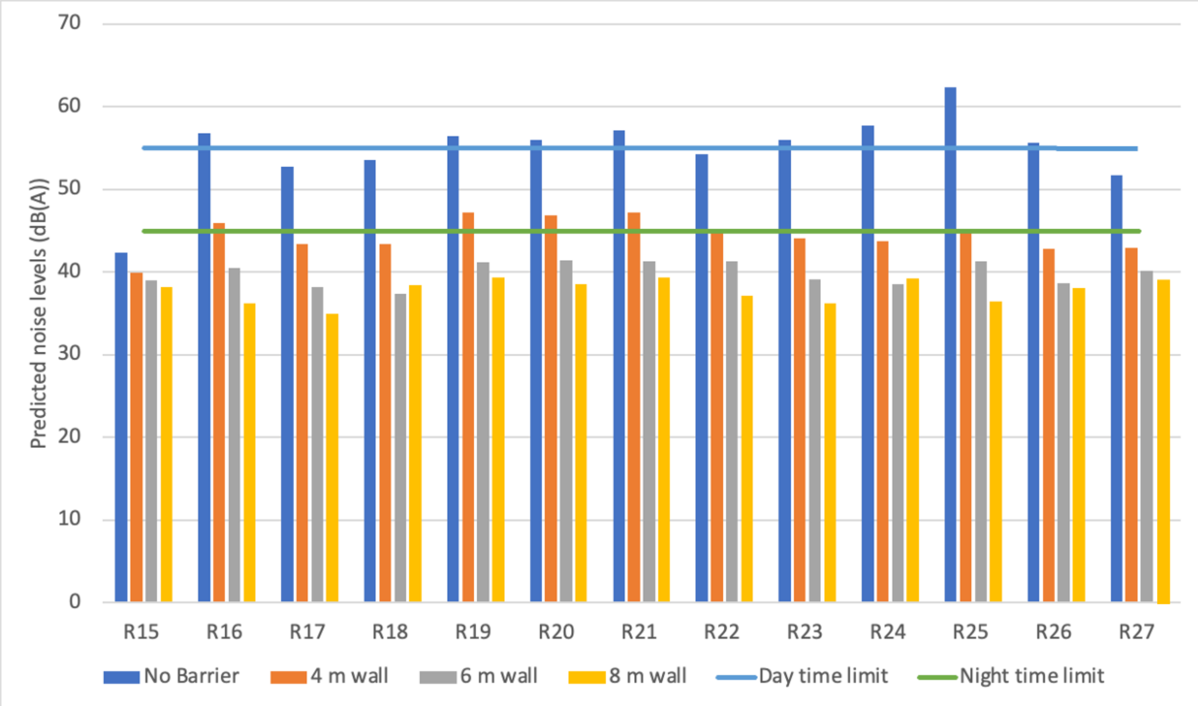


Figure 91. The effect of noise barriers of differing heights in attenuating noise from the 2048 operational roadway for 27 sensitive receptors identified in Shenatagh, relative to the Armenian noise limits

Residual Impacts

The modelling of the efficacy of noise barriers shows that noise attenuation andnoise barriers specifically are both feasible and effective. Tactical siting of the barriers to prevent noise propagation in the direction of a village or town, indicates that impact magnitude could be reduced to medium and impact significance **to moderate and even potentially minor.**

Monitoring

Noise monitoring must be implemented along the length of the road. Monitoring will provide information on:

- Ensuring mitigation measures included with the project design are incorporated.
- Ensuring specifications of additional noise mitigation measures (if implemented), including barriers, are sufficient to ensure that noise standards are met at NSRs along the corridor route.

It is recommended that campaign noise monitoring be conducted every quarter for the first two years of operation to verify the noise predicted and the efficacy of the mitigation. Thereafter such campaigns could be reduced to semi-annually for two years and thereafter annually.

3.3 Geology and Geo-hazards

3.3.1 Introduction and AoI

In this section of the ESIA the risks posed by geo-hazards are described and assessed. This impact area differs from the others in that it is an impact posed by the environment to the road and not *vice versa*. Nonetheless the construction activities may themselves trigger a geohazard through destabilisation of the ground from excavations, blasting and so forth. A generalised map of geohazard areas is shown in **Section 0** where these are predominantly in the southern section of the road alignment and include mud slides, avalanches, flooding and seismicity risks.

The AoI is also somewhat different from those of the other potential impacts as the sources may be hundreds of kms from the road alignment (e.g., seismic risk). The AoI remains thus about 500 m on either side of the road recognising that the source of the geohazard may be considerably further away from the road and it is the degree to which the geohazard encroaches into the road corridor that is important. An entire slope on which the road is constructed may also collapse although that would probably remain within the proposed 500 m AoI.

3.3.2 Reference Criteria

There is no direct environmental and/or social criteria that can be used to define thresholds for these types of risks, as the reference criteria is principally engineering criteria that must be applied in the construction of the road (including offsite infrastructure such as avalanche barriers). The following is provided qualitatively, however, as a series of objectives that must be met for both construction and operations of the road:

- No injury to construction workers as a result of geohazards including risks such as slumps in excavated areas, rockfalls and so forth that may be triggered by construction activities;
- No injury to operational road users because of geohazards specifically earthquakes, mudslides, rockfalls and avalanches or any combination of these risks;
- No siltation or blocking of rivers as a result of rock falls or mudslides;
- Maintaining the integrity of the roadway.

3.3.3 Assumptions and Limitations

3.3.4 Impact Assessment: Construction

During construction, road sections may require excavations resulting in impacts on the underlying geology and soil cover. Borrow pits may also be established to source aggregate needed for the road construction. The construction of the tunnels presents multiple risks of structural failure and collapse as does working on steep slopes. Seismic risk is an important consideration in the southern section of the alignment. For the most part these risks would be limited to construction areas and personnel rather than third party injury, however, third party risk can also not be discounted entirely. With proper planning and engineering construction methods can be developed and implemented in a manner that would reduce these risks to a tolerable level. Although the construction contractor has not been appointed, key criteria in the selection of that contractor would be experience of working in an environment such as this and their health and safety track record. For these reasons the focus in the geohazards assessment is the operational roadway rather than construction.

3.3.5 Impact Assessment: Operation

The impacts of geohazards are potentially severe if not effectively mitigated and posing the risk of human injury and/or loss of life. The risks include rock falls, avalanches, mud slides, earthquakes and possibly others that would pose such a risk.

<table>
<tr><th colspan="5">Geohazards</th></tr>
<tr><td rowspan="2">Impact Nature</td><td colspan="2">Positive</td><td colspan="2">Negative</td></tr>
<tr><td colspan="4">Given the mountainous terrain and the harsh climate through which the road passes, various geohazards exist that need to be investigated and characterised to ascertain the risk that they pose to the road and road users. In contrast to the other potential impacts, geohazards pose a risk to the project rather than the other way around but if they manifest that can cause significant injures and death to road users as well as creating environmental catastrophes such as blocking rivers and or creating significant soil/habitat loss. It must be recognised though that such environmental impacts may still occur even if they are prevented from causing injury to road users.</td></tr>
<tr><td rowspan="2">Impact Type</td><td>Direct</td><td>Indirect</td><td>Reversible</td><td>Irreversible</td></tr>
<tr><td colspan="4">In principle, the effects of geohazards could be repaired rehabilitated depending on the scale of the event. If, however, the impacts result in injury or death to road users such impacts would be permanent.</td></tr>
</table>

Impact Duration	Temporary	Short-term	Medium-term	Long-term
	Again, depending on the scale of the impact, the duration could be relatively short term but human injury or death would obviously be permanent.			
Impact Extent	Local	Municipal	Regional	National
	Despite the large damage potential of these impacts, they are likely to result in only localised areas.			
Impact Magnitude	Negligible	Low	Medium	High
	It is not possible to choose a single impact magnitude because of the array of possible events that could occur. That circumstance does not change the fact that were an event to occur that resulted in human injury or death, that event would be deemed to have high impact intensity.			
Receptor Value / Sensitivity	Negligible	Low	Medium	High
	Human receptors must by definition be considered high sensitivity			
Impact Significance	Negligible	Minor	Moderate	Major
	The combination of high impact magnitude and high receptor sensitivity means that the impact significance is potentially major. There is no doubt that an incident triggered by geohazards that resulted in human injury or death would be viewed as an incidence of **major** significance.			

Mitigation Measures

Objectives:

- Provide detailed and precise geodetic and geological data for detailed design of rehabilitation/ stabilization of the unstable slopes on the road link from Sisian to Kajaran, in accordance with the laws of Armenia and technical regulations and standards covering the field of designing.
- Complete a risk analysis of potential slope failures along the route, classifying each feature into high, medium or low risk to the integrity of the road.
- Provide a preliminary design of the proposed measures and an estimated cost
- To prepare, based on surveying and geological data gathered, detailed designs for the optimal technical-economic solution for each slope location (standard protective structures).

Specific actions

Risk assessment (general)

The investigation and modelling of geohazards must include: Rockfall, rockslides and unstable slopes/ landslides seismic risk and avalanches.

The risk assessment shall be carried out in two steps. The first step is a desktop study using available surface data (especially high resolution DTM) and available geologic and morphologic data (geological and geomorphic maps and surveys etc.) in order to define areas with potentially unstable slopes due to rock fall or landslides (see detailed description below)

Areas with no risk (Category 0) require no further investigations. Areas with potential georisk shall be investigated in detail in the next project phase including field survey and detailed simulations as the basis for detailed design of standard protective and slope stabilization measures.

Area of interest (AOI)

The area of interest is defined by the proposed highway corridor and the whole slope side on which the alignment is located from valley bottom to mountain ridge. It must also be recognised that the alignment might change and can be shifted within the slope.

The investigation and modelling of geohazards shall focus on geohazards upslope of the new road alignment and threaten the road an appurtenant infrastructure.

Downslope stabilisation is already part of the road design.

Phase I Basic risk assessment (desktop study)

The basic risk assessment shall be based on state of the art 3-D rockfall modelling software using a DTM (digital terrain model) provided by the client. The study must comprise the following items:

- Identification of morphological anomalies that could be an indicator for mass movements or slope failure
- GIS based slope inclination analysis to define possible source areas for rockfall and avalanches
- Analysis of geological geotechnical and other geohazard maps (seismic maps, etc.)
- Analysis of other available geomorphological, geological and geotechnical information, which may include satellite imagery, aerial photographs or publicly available data such as google maps
- Seismic and seismotectonic desktop study for the area of interest based on earthquake data including instrumental, historical and pre-historic earthquakes and on active faults and geodetic data. This also includes a review of existing hazard models covering the area of interest with respect to seismic ground motion (PGA).

The results of phase I shall be presented in a geological hazard map detailing distinguishing no risk areas, low risk areas and high-risk areas (slopes).

Phase II Detailed risk assessment (including field investigations)

Field investigations

Field surveys must be used to ground true information from the desk study and to observe geomorphology of the area and other site-specific conditions that could influence the selection of mitigation (including but not limited to surface topography and local runoff and rock conditions such as degree of weathering, fracture and joint density and patterns, bedding patterns and presence of faults)

The consultant must conduct field investigations in all areas defined as potential high or low risk areas to create the basis for the detailed rockfall simulations. The field work shall be based on ISRM and EN ISO 14688-1 and EN ISO 14689-1 standards and include *inter alia*, the following:

Morphological information.

- Slope inclination
- Slope anomalies
- Signs of recent or historical instabilities (open cracks, debris cones, etc.)

Geological information:

- Lithology/ geological unit and formation
- Genetic group (sedimentary, metamorphic or igneous rock)
- Weathering
- Rock strength (UCS, estimated)
- Stability in water
- Fracturing
- Discontinuity sets, presence of faults

Moreover, the required input data for a state-of-the-art rockfall and avalanche modelling such as source areas, terrain materials, forest, rock size and shape must be collected:

- Source areas

Generally, the source areas from the overview modelling (areas steeper 45° in the DEM) must be adopted and verified in the field considering geological information (lithology, discontinuities, failure modes, etc.)

- Terrain materials

Material Parameters like damping, depending on the slope surface conditions must be defined during field work (bedrock (clean, hard/ weathered), soft soil/ earth, debris, etc.)

- Forest

Detailed mapping must be carried out to generate a proper dataset of the forest cover for simulation for all slopes where a rockfall risk was detected.

- Rock size and shape

The data obtained in the field and used as input data for simulations must be presented and documented in map at an appropriate scale.

- 3-D Avalanche modelling

For the 3-D avalanche modelling, the data mentioned above can be used (morphology, forest, etc.) but information on snow depths sourced from state institutions or open data sources.

The results of avalanche modelling must define the range of avalanches in risk maps at an appropriate scale, as well as static equivalent loads.

- Seismic risk

The results from geological mapping must be integrated with seismic risk factors. A qualitative assessment of the susceptibility of slopes for mass movement and an assessment of failure modes (rock fall, surface slide, deep slide) as well as an identification of potentials for soil liquefaction must be done.

- Slope risk rating

Based on the geological description and the rock fall analysis, a slope risk rating and risk ranking of all possible geological hazard along the route for their potential to impact the integrity of the road shall be conducted by defining what can happen (e.g., rock fall with small blocks or big blocks on the road or slide of loose material on road, etc.) and how often this event is likely to occur. The likelihood of a possible event must be combined with possible costs of an event by defining consequence classes in a risk matrix resulting in a risk score.

This must also include the identification of road sections subjected to different levels of seismotectonic hazards (expert statement), identification of constructions requiring seismic engineering (e.g., bridges, tunnel portals).

Design

The design for the slope protection and stabilization works will follow European standards and technical requirements and – if available – Armenian legislation and regulations. Recommendations of the design shall be in in terms of the current condition, the proposed solution and the remedial construction in relation to the ground. Documentation shall include the assessment of the current state of slopes (unstable, conditionally stable and stable) and shall list priority of slopes for rehabilitation as defined in the risk assessment and matrix outlined above.

The most important factors are:

- Stability and durability of the structures
- Economic efficiency of structures
- Ease of maintenance of structures
- Safe work conditions
- Road safety.

The area to be included in the design is based on the latest road alignment and covers all slopes where rockfall or landslide events potentially impact the road alignment. These areas shall be extended if there is a risk of landslides from high slopes above (or below with a potential for headward erosion) the Project section, to ensure the final detailed design provides complete protection of the road from landslides, rockfall etc. In addition to the slopes above the Project section, slopes above the entrance and exit portals of tunnel sections and the protection of the road at the cuttings approaching tunnels need to be considered and protected if necessary.

The design shall be conducted in two steps:

- A preliminary design of the proposed measures with an initial order of magnitude cost estimate. This preliminary design should consider and state the estimated probability of success of the measures and should also include discussion of any annual maintenance works and associated costs.
- Developing the detailed design of the proposed works,

The detailed design must comprise all potentially unstable slopes, in which standard measures such as rock fall protection kits (fences), wire mesh nets, etc. are suitable to protect the road from rockfall or slides. If the designer concludes that additional detailed investigation measures and a customized special design of support measures (individual design of pre-stressed anchors, anchor beams, retaining walls, galleries, or comparable) are necessary, such must be specified in the report. The consultant shall also propose necessary investigation measures and set out possible solutions.

It shall be understood that at various junctures, approval of documentation by either or both the Beneficiary or state authorities shall be required. The engineer responsible for the design must supervise the construction to ensure that conditions encountered are as anticipated and the design is adequately constructed.

Residual Impacts

Should the above mitigation be implemented the risk would reduce dramatically. There are many mountainous roads throughout the world that are built on steep slopes and in areas of harsh climate to allow an effective characterisation of the risks posed to the Sisian Kajaran Road and to engineer the controls needed to prevent such risks from resulting in human injury or death. Impact significance would be reduced to **minor**.

Monitoring

As part of the process of characterising the risk of geohazards, the appointed service provider would also be required to define the necessary monitoring that could be implemented to provide early warning of the risks of a geohazard event.

3.4 Soil

3.4.1 Introduction and AoI

This section considers the potential soil quality impacts associated with the Project. The assessment was undertaken with reference to relevant national and international standards and reference criteria (see below).

3.4.2 Reference Criteria

The applicable soil quality criteria used for the current ESIA study are set in the RA Sanitary rules and norms No. 2.1.7.003-10 "Hygienic requirements for soil quality"[53] (see the table below).

Table 45. ACLs for chemical elements in soil per Sanitary Rules and Norms No. 2.1.7.003-10

No	Chemical elements	Unit	ACL of chemicals in soil
1	Lithium	gr/kg	-
2	Beryllium	gr/kg	-
3	Bor	gr/kg	-
4	Sodium	gr/kg	-
5	Magnesium	gr/kg	-
6	Aluminum	gr/kg	-
7	Total phosphorus	gr/kg	-
8	Potassium	gr/kg	-
9	Calcium	gr/kg	-
10	Titanium	gr/kg	-
11	Vanadium	gr/kg	0.15
12	Chrome	gr/kg	0.006
13	Iron	gr/kg	-
14	Manganese	gr/kg	1.5
15	Cobalt	gr/kg	0.005
16	Nickel	gr/kg	0.004
17	Copper	gr/kg	0.003
18	Zinc	gr/kg	0.023
19	Arsen	gr/kg	0.002
20	Selenium	gr/kg	-
21	Strontium	gr/kg	-
22	Molybdenum	gr/kg	-
23	Cadmium	gr/kg	-
24	Tin	gr/kg	-
25	Antimony	gr/kg	0.0045
26	Barium	gr/kg	-
27	Lead	gr/kg	0.032

As noted in the baseline section, no specific soil quality standards have been adopted by the EBRD or other international lenders, and there are no European Directives dealing specifically with the issue of soil quality and land contamination. The overall approach is one of risk management, which means that there are no generically defined quality standards. Owing to this critical difference between the Armenian and international approaches to soil pollution management, the Project will apply a risk-based approach while making sure that the above Armenian minimum soil quality standards are respected.

3.4.3 Assumptions and Limitations

None.

[53] https://www.arlis.am/DocumentView.aspx?docid=146741

3.4.4 Impact Assessment: Construction

During construction, road sections may require excavations resulting in impacts on soil cover. Potential impacts on soils during the construction phase include:

- Damage and/or loss of topsoil: the impact may occur if the topsoil is not removed; mixed with subsoil and/or other material during and after removal. Impact on topsoil outside the boundaries of the RoW may also happen with topsoil outside the road reserve being compacted by heavy vehicles, scattered during transportation to temporary stockpiling site as well as lost by wind and water erosion when in stockpiles. The quality of topsoil may deteriorate if the stockpiles are not managed properly during the period of temporary storage.
- Erosion: without adequate protection measures soil erosion could occur on road embankments and bridge embankments. It is also possible, that stockpiles of soil located close to surface waters could be washed into these water courses during heavy rainfall and cause siltation of the rivers.
- Contamination due to spills or hazardous materials: soil may be contaminated due to poorly managed fuels, oils and other hazardous materials required for road construction and poorly managed waste (solid and liquid waste streams) in the camps.
- Borrow Pits: may be required by the Contractor depending on the quality of the excavated material. This material could also be purchased from an existing borrow pit/quarry operator. In such a case the Contractor shall provide oversight on these facilities as described in more detail below. These impacts are unlikely to occur at a scale and intensity that would result in the project being prevented from being implemented. However, the contractor would be obliged to develop and implement the following management plans:
    - Topsoil Management Plan;
    - Waste Management Plan (including a Spoil Disposal sub-plan);
    - Wastewater and Stormwater Management Plan;
    - Spill Management Plan;
    - Erosion Control Plan;
    - Hazardous Materials Management Plan.

The overall significance of impact on soils is considered to be moderate.

Residual impact

Provided the above listed management plans are thoroughly developed and implemented the residual impact on soils is likely to be minor.

Monitoring

Monitoring according to the above listed management plans.

3.4.5 Impact Assessment: Operation

Motor vehicle accidents could result in large scale spills of hazardous materials, which if *not* effectively controlled may result in soil contamination. Soils may also be affected by:

- Roadside deposition of atmospheric pollutants.
- Filling stations along the Project Road may also be a source of contamination.
- Erosion and flooding caused by blockage of the drainage system (discussed above under Climate Change).
- Pollution with ice breaking salt. Use of ice breaking salt may lead to increase of sodium and chlorine ions in surface runoff and, respectively, in the soils. This will affect ion

exchange process, reduce water permeability and aeration ability and leads to increase of alkalinity.

These impacts are considered to be minor and manageable and are not assessed further in detail but the RD woud be required to develop and implement the following management plans.

- Waste Management Plan;
- Emergency Preparedness and Response Plan;
- Spill Response Plan.

Residual impact

Provided the above listed management plans are thoroughly developed and implemented the residual impact on soils is likely to be minor.

Monitoring

Monitoring according to the above listed management plans.

3.5 Surface Water Resources

3.5.1 Introduction and AoI

The potential impacts of the Project on surface water bodies during construction and operations are described in this section. The following potential impacts were identified during scoping:

- Temporary changes to hydrological regime of watercourses caused by the runoff from construction sites,
- Contamination of surface water quality by deposition of dust and exhaust gas emissions (from construction machinery), spills of hazardous materials,
- Deterioration of surface water quality due to soil erosion,
- Deterioration of surface water by runoff from construction camps, storage and parking areas for construction machinery, and so forth[54],
- Contamination of rivers by runoff from the planned road surface due to rainfall and snowmelt.

The water bodies/water channels that flow along with and/or cross the proposed road or are located in its vicinity and which may be affected by construction or operational activities are considered as located within the Project's AoI.

In total, 10 water samples (six points from water courses in Sisian-Shenatagh section and four points (K2, K7, K10 and K12) - Qirs-Kajaran section) (see **Annex 1**) were taken during surveys for laboratory analysis (key physical, chemical and microbiological water properties) in June 2022. The sampling points were confined to the following watercourses: Vorotan, Loradzor (Shenatagh), Karut, Geghi and Voghji Rivers and their tributaries that are deemed to be affected by the Project implementation. The results of the laboratory analysis represent the baseline water quality in the above noted water courses and have been compared with the criteria set by the RA Government decision No. 75 (see below).

[54] At the time of the report, the locations of construction camps, parking and maintenance areas for the construction machinery, etc. were not finally defined.

3.5.2 Reference Criteria

The RA Government decision No. 75 adopted in January 2011 specifies the requirements for river water quality. Based on the specific criteria (environmental norms) the noted decision defines five water quality categories/classes for the river basins of Armenia:

- Class 1: water quality – excellent;
- Class 2: water quality – good;
- Class 3: water quality – average;
- Class 4: water quality – poor; and
- Class 5: water quality – bad.

The rivers and/or their tributaries that could be affected due to Project implementation are part of the Vorotan, Voghji and Geghi River basins. The water quality criteria for those river basins are presented in **Table 46, Table 47,** and **Table 48** (as per annexes 20, 23 and 24 of the RA Government decisions No. 75).

Table 46. Water quality criteria for the Vorotan River basin

Quality criteria	Quality classes					Unit
	I	II	III	IV	V	
Dissolved oxygen	>7	>6	>5	>4	<4	mgO_2/l
BOD_5	3	5	9	18	>18	mgO_2/l
COD (bichromate)	10	25	40	80	>80	mgO_2/l
COD (permanganate)	1.0	10	15	20	>20	mgO_2/l
Nitrate ion	0.328	2.5	5.6	11.3	>11,3	mgN/l
Nitrite ion	0.007	0.06	0.12	0.3	>0.3	mgN/l
Ammonium ion	0.39	0.4	1.2	2.4	>2.4	mgN/l
Total inorganic nitrogen	0.27	4	8	16	>16	mgN/l
Phosphate ion	0.15	0.3	0.6	1.2	>1.2	mg/l
Total phosphorus	0.078	0.2	0.4	1.0	>1.0	mg/l
Zinc, total	2.0	100	200	500	>500	µg/l
Copper, total	2.0	22.0	50	100	>100	µg/l
Chrome, total	0.5	10.5	100	250	>250	µg/l
Arsenic, total	0.56	10	50	100	>100	µg/l
Cadmium, total	0.01	1.01	2.01	4.01	>4.01	µg/l
Lead, total	0.14	10.14	25	50	>50	µg/l
Nickel, total	0.45	10.45	50	100	>100	µg/l
Molybdenum, total	1	2	4	8	>8	µg/l
Manganese, total	4	8	16	32	>32	µg/l
Vanadium, total	8	16	32	64	>64	µg/l
Cobalt, total	0.14	0.28	0.56	1.12	>1.12	µg/l
Iron, total	0.08	0.16	0.5	1.0	>1.0	mg/l
Barium	0.006	0.012	0.024	1.0	>1.0	mg/l
Beryllium	0.027	0.054	0.108	1.0	>1.0	µg/l
Lithium	2.0	4.0	8.0	16.0	>16.0	µg/l
Boron	0.004	0.45	0.7	1.0	>1.0	mg/l
Aluminium	0.14	0.28	0.56	5.0	>5.0	mg/l
Selenium, total	0.34	20	40	80	>80	µg/l
Antimony, total	0.25	0.5	1.0	2.0	>2.0	µg/l
Tin, total	0.08	0.16	0.32	0.64	>0,64	µg/l
Sodium	4.2	60	120	240	240	mg/l
Potassium	2.2	20	40	80	>80	mg/l
Calcium	6.4	75	150	300	>300	mg/l
Magnesium	2.0	50	100	200	>200	mg/l
Chloride ion	4	75	150	300	>300	mg/l
Sulphate ion	8.5	75	150	300	>300	mg/l
Silicate ion	12	24	48	96	>96	mgSi/l
Total dissolved salts	55	500	1000	1500	>1500	mg/l
Electrical conductivity	81	770	1500	2300	>2300	µS/cm
Hardness	0.5	10	20	40	>40	mg eq./l
Suspended solids	4.6	30	60	120	>120	mg/l
Smell (20°C and 60°C)	<2 (natural)	2 (natural)	2	4	>4	rate

Quality criteria	Quality classes					Unit
	I	II	III	IV	V	
Colour	(natural)	<5 (natural)	20	30	>200	degree

Table 47. Water quality criteria for the Voghji River basin

Quality criteria	Quality classes					Unit
	I	II	III	IV	V	
Dissolved oxygen	>7	>6	>5	>4	<4	mgO_2/l
BOD_5	3	5	9	18	>18	mgO_2/l
COD (bichromate)	10	25	40	80	>80	mgO_2/l
COD (permanganate)	5	10	15	20	>20	mgO_2/l
Nitrate ion	0.194	2.5	5.6	11.3	>11.3	mgN/l
Nitrite ion	0.003	0.06	0.12	0.3	>0.3	mgN/l
Ammonium ion	0.017	0.4	1.2	2.4	>2.4	mgN/l
Total inorganic nitrogen	0.122	4	8	16	>16	mgN/l
Phosphate ion	0.1	0.3	0.6	1.2	>1.2	mg/l
Total phosphorus	0.016	0.2	0.4	1.0	>1.0	mg/l
Zinc, total	3	100	200	500	>500	µg/l
Copper, total	4	24	50	100	>100	µg/l
Chrome, total	0.46	10.46	100	250	>250	µg/l
Arsenic, total	0.27	10	50	100	>100	µg/l
Cadmium, total	0.1	1.1	2.1	4.1	>4.1	µg/l
Lead, total	0.1	10.1	25	50	>50	µg/l
Nickel, total	0.64	10.64	50	100	>100	µg/l
Molybdenum, total	15	30	60	120	>120	µg/l
Manganese, total	4	8	16	32	>32	µg/l
Vanadium, total	0.38	0.76	1.52	3.04	>3.04	µg/l
Cobalt, total	0.09	0.18	0.36	0.72	>0.72	µg/l
Iron, total	0.031	0.062	0.5	1.0	>1.0	mg/l
Barium	18.3	75	150	300	>300	mg/l
Beryllium	4.8	50	100	200	>200	µg/l
Lithium	0.02	0.04	0.08	1.0	>1.0	µg/l
Boron	0.028	0.056	0.112	100	>100	mg/l
Aluminium	1.45	20	40	80	>80	mg/l
Selenium, total	5.300	60	120	240	>240	µg/l
Antimony, total	5.0	10.0	20.0	40.0	>40.0	µg/l
Tin, total	0.032	0.45	0.7	1.0	>1.0	µg/l
Sodium	0.03	0.06	0.12	5.0	>5.0	mg/l
Potassium	1.1	20	40	80	>80	mg/l
Calcium	0.5	1	2	4	>4	mg/l
Magnesium	0.077	0.15	0.3	0.6	>0.6	mg/l
Chloride ion	6	75	150	300	>300	mg/l
Sulphate ion	27	75	150	300	>300	mg/l
Silicate ion	7.1	14	28	56	>56	mgSi/l
Total dissolved salts	105.800	500	1000	1500	>1500	mg/l
Electrical conductivity	168.500	770	1500	2300	>2300	µS/cm
Hardness	1.5	10	20	40	>40	mg eq./l
Suspended solids	8.4	30	60	120	>120	mg/l
Smell (20°C and 60°C)	<2 (natural)	2 (natural)	2	4	>4	rate
Colour	(natural)	<5 (natural)	20	30	>200	degree

Table 48. Water quality criteria for the Geghi River basin

Quality criteria	Quality classes					Unit
	I	II	III	IV	V	
Dissolved oxygen	>7	>6	>5	>4	<4	mgO_2/l
BOD_5	3	5	9	18	>18	mgO_2/l
COD (bichromate)	10	25	40	80	>80	mgO_2/l
COD (permanganate)	0.5	10	15	20	>20	mgO_2/l
Nitrate ion	0.214	2.5	5.6	11.3	>11.3	mgN/l
Nitrite ion	0.006	0.060	0.12	0.3	>0.3	mgN/l
Ammonium ion	0.02	0.4	1.2	2.4	>2.4	mgN/l
Total inorganic nitrogen	0.25	4	8	16	>16	mgN/l
Phosphate ion	0.09	0.3	0.6	1.2	>1.2	mg/l

Quality criteria	Quality classes					Unit
	I	II	III	IV	V	
Total phosphorus	0.015	0.200	0.400	1.0	>1.0	mg/l
Zinc, total	1.0	100	200	500	>500	µg/l
Copper, total	2.0	24	50	100	>100	µg/l
Chrome, total	0.46	10.46	100	250	>250	µg/l
Arsenic, total	0.28	10	50	100	>100	µg/l
Cadmium, total	0.03	1.03	2.03	4.03	>4.03	µg/l
Lead, total	0.11	10.11	25	50	>50	µg/l
Nickel, total	0.53	10.64	50	100	>100	µg/l
Molybdenum, total	7	14	28	56	>56	µg/l
Manganese, total	5	10	20	40	>40	µg/l
Vanadium, total	1	2	4	8	>8	µg/l
Cobalt, total	0.11	0.22	0.44	0.88	>0.88	µg/l
Iron, total	0.06	0.12	0.5	1.0	>1.0	mg/l
Barium	22.8	75	150	300	>300	mg/l
Beryllium	4.4	50	100	200	>200	µg/l
Lithium	0.02	0.04	0.08	1.0	>1.0	µg/l
Boron	0.009	0.018	0.036	100	>100	mg/l
Aluminium	1.12	20	40	80	>80	mg/l
Selenium, total	5.0	60	120	240	>240	µg/l
Antimony, total	7.0	14	28	56	>56	µg/l
Tin, total	0.016	0.45	0.7	1.0	>1.0	µg/l
Sodium	0.05	0.1	0.2	5.0	>5.0	mg/l
Potassium	0.25	20	40	80	>80	mg/l
Calcium	0.42	0.84	1.68	3.36	>3.36	mg/l
Magnesium	0.06	0.12	0.24	0.48	>0.48	mg/l
Chloride ion	3.5	75	150	300	>300	mg/l
Sulphate ion	16	75	150	300	>300	mg/l
Silicate ion	5.5	11.0	22.0	44.0	>44.0	mgSi/l
Total dissolved salts	127	500	1000	1500	>1500	mg/l
Electrical conductivity	183	770	1500	2300	>2300	µS/cm
Hardness	1.6	10	20	40	>40	mg eq./l
Suspended solids	10	30	60	120	>120	mg/l
Smell (20ºC and 60ºC)	<2 (natural)	2 (natural)	2	4	>4	rate
Colour	(natural)	<5 (natural)	20	30	>200	degree

Armenian water quality standards are defined for each river basin accounting for local specifics.

Some of the water quality criteria/parameters listed in **Tables 46-48** are also set by the Directive 2008/105/EC on environmental quality standards for water policy and Directive 2006/44/EC on fresh water quality needing protection or improvement in order to support fish life. The applicable water quality parameters from both Directives are summarized in **Table 49**.

Table 49. Summary of water quality parameters set by the relevant EU Directives

Parameters	Directive 2008/105/EC		Directive 2006/44/EC	
	AA-EQS	MAC-EQS	EQS-Salmonid waters	EQS-Cyprinid waters
Dissolved oxygen (mg/l O_2)			50% ≥ 9 100% ≥ 7	50% ≥ 8 100% ≥ 5
PH			6-9	
Suspended solids (mg/l)			≤25	≤25
Temperature, ºC			Temperature measured downstream of a point of thermal discharge (at the edge of the mixing zone) must not exceed the unaffected temperature by more than	
			1,5	3,0
			Thermal discharges must not cause the temperature downstream of the point of	

Parameters	Directive 2008/105/EC		Directive 2006/44/EC	
	AA-EQS	MAC-EQS	EQS-Salmonid waters	EQS-Cyprinid waters
			thermal discharge (at the edge of the mixing zone) to exceed the following:	
			21,5	28,0
			The 10°C temperature limit applies only to breeding periods of species which need cold water for reproduction and only to waters which may contain such species	
BOD_5 (mg/l O_2)			≤3	≤6
Nitrites (mg/l NO_2)			≤0,01	≤0,03
Non-ionised ammonia (mg/l NH_3)			≤0,025	≤0,025
Total ammonium (mg/l NH_4)			≤1	≤1
Total residual chlorine (mg/l HOCl)			≤0,005	≤0,005
Total zinc (mg/l Zn)*			≤0,3	≤1,0
Dissolved copper (mg/l Cu)*			≤ 0.04	≤ 0.04
Cadmium and its compounds (depending on water hardness classes) (µg/l)	≤0,08 (Class 1) 0,08 (Class 2) 0,09 (Class 3) 0,15 (Class 4) 0,25 (Class 5)	≤0,45 (Class 1) 0,45 (Class 2) 0,6 (Class 3) 0,9 (Class 4) 1,5 (Class 5)		
Lead and its compounds (µg/l)	7,2	n/a		
Nickel and its compounds, (µg/l)	20	n/a		

**Total zinc (mg/l Zn) and dissolved copper (mg/l Cu) concentrations are different depending on the water hardness values[55]*
AA - Annual average
MAC - Maximum Allowable Concentration
EQS - Environmental Quality Standard

3.5.3 Assumptions and Limitations

Some temporary water streams and irrigation ditches are filled only seasonally and are not considered in this assessment.

3.5.4 Impact Assessment: Construction

3.5.4.1 Temporary changes to hydrological regime

During construction and especially excavation and other earthworks, the redirection of surface runoff may have impact on watercourses. Interception and movement of runoff from construction sites, as well as changes in the runoff direction and rate as a result of the soil consolidation may influence the hydrological regime of Vorotan, Loradzor, Qirs, Geghi and Voghji river basins. This may lead to:

- Increase of flow velocity of rivers,
- Increase of downstream sedimentation,
- Changes of the aquatic environment as a result of the sedimentation of soil particles in water streams and consequent impact on the availability of fish species in rivers.

Impact on the hydrological regime of surface water resources during the construction stage		
Impact Nature	Positive	Negative
	Changes in runoff volumes and directions may increase the flow velocity and sedimentation in rivers as well as may amend their aquatic environment.	

[55]https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:264:0020:0031:EN:PDF#:~:text=Article%201-,1.,used%20for%20intensive%20fish%2Dfarming.

Impact on the hydrological regime of surface water resources during the construction stage					
Impact Type	Direct	Indirect	Reversible	Irreversible	
	The increased volume of runoff may have direct impact on aquatic environment of surface water bodies; however, it cannot drastically change the water quality and is considered as reversible impact.				
Impact Duration	Temporary	Short-term	Medium-term	Long-term	Permanent
	The impact on the hydrological regime of surface water bodies within the area of Project influence will be active only during the excavation/earthworks.				
Impact Extent	Local	Municipal	Regional	National	International
	Impact on the hydrological regime of surface water resources will be confined to the Project region.				
Impact Magnitude	Negligible	Low	Medium	High	
	The magnitude of the increase of runoff volume and its impact on the surface water resources is considered low.				
Receptor Value / Sensitivity	Negligible	Low	Medium	High	
	Most of the rivers located within the area of Project influence are partly used for hydropower and irrigation purposes, however also are habitats for fish species. They are therefore considered to have a medium value and sensitivity.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Taking into account the extend, magnitude and sensitivity of receptors, the impact significance is minor.				

Mitigation Measures

- Excavation and other earthworks as well as foundation works for bridges, retaining walls and other structures or close to the surface water bodies must be limited during the rainfall seasons,
- Construct intermediate collection pools between the runoff generation surfaces and downstream water courses to regulate the runoff flow to the water bodies (the soil particles will be settled at the bottom of the pools and the turbidity of the runoff will be decreased),
- Do not alter natural riverbed depth and courses, bottom sediments and flood plains,
- Small drains within the construction area should be covered with metal plates which can be passed over by construction machines, to protect them against disturbance, or conveyed to have free flow through the pipes placed for this purpose.

Residual Impacts

The residual impact significance will be negligible provided that the mitigation measures are implemented properly.

Monitoring

Surface water quality monitoring to determine the impact of the earthwork on the surface water (as a minimum the content of the TSS, BOD_5, hydrocarbons, heavy metals shall be determined) shall be included into the E&S monitoring plan and implemented during the construction works.

The regular monitoring (observation) of the condition of vegetation cover on slopes of the road embankment, erosion of areas prone to exogenous erosion processes, spoil disposal areas and water diversion network will be conducted.

3.5.4.2 Deterioration of Surface Water Quality

<u>Deterioration of surface water quality due to soil erosion</u>

Removal of topsoil, excavation and other earthworks will destabilize soil and vegetation cover within the Project area which may trigger or intensify soil erosion in river valleys and elsewhere. Such erosion may cause migration of soil into waterways with surface runoff, increase water turbidity and result in silting of water bodies. Increased turbidity of water will lead to a deterioration in surface water quality and aquatic organism habitat.

The maximum increase of turbidity of watercourses is expected in spring and autumn seasons (snowmelt and rainfall periods) when earthworks have already been completed, but the construction of road components (pillars of bridges, culverts, crossings, retaining walls, etc.) has not been started yet.

<u>Contamination of surface water quality by the onset of dust and exhaust gas emissions, spills of hazardous materials</u>

Dust particles emitted as a result of earthworks, blasting operations, mining of construction materials, concrete and asphalt works, loading/unloading, transportation and storage/disposal of spoil (including SDAs), top-soil (temporary storage areas) and friable construction materials, as well as the exhaust gas emissions from the construction equipment and heavy trucks can be partly settled into the surrounding surface watercourses and also possibly infiltrated into groundwater, degrading water quality. The potential spills/leakages of oil and lubricants from construction machinery will be washed out during the runoff and then discharged into downstream surface water.

<u>Deterioration of surface water due to construction camps, storage and parking areas for the construction machinery</u>

Routine operation of the construction camps (including concrete and asphalt plants), storage and parking areas may lead to the spills and leakages (and subsequent pollution) as a result of:

- Handling, storing and using construction materials, including activities such as importing materials to the camp and exporting from camp to the construction site,
- Collection, storing and transportation of wastes (industrial and domestic) from the camp and construction sites,
- Handling, storing and using fuels, oils and lubricants, including activities such as fuelling and maintaining construction plant, equipment and machinery,
- Handling, storing and using chemicals and their transportation to the camp and to the construction sites.

Spills and leaks can be swept by runoff to surface water resources contaminating them unless runoff catchment network and subsequent treatment (prior to the discharge to the water sources) is planned. Given the scope of construction materials and equipment that will be used during construction, it is possible that unplanned accidental spills and leaks may occur at the construction sites and cause contamination of the surface water if polluting substances directly or indirectly enter the drainage channels and rivers.

Impact on surface water resources due to the intensification of erosion processes, onset of dust and exhaust gas emissions, and spills of hazardous materials during the construction stage					
Impact Nature	Positive		Negative		
	Erosion processes, accidental spills/leakages of hazardous materials as well as dust and exhaust gas emissions may have negative impact on the quality of surface water resources.				
Impact Type	Direct	Indirect	Reversible	Irreversible	
	The runoff contaminated with soil particles, accidental spills/leakages of hazardous materiald and emissions of dust and gaseous pollutants are most likely to directly impact (i.e. contaminate) surface water quality. The noted impacts are potentially reversible if contaminant concentrations reduce to acceptable levels due to dilution or degradation.				
Impact Duration	Temporary	Short-term	Medium-term	Long-term	Permanent
	The impact duration is short-term and is limited to the construction works.				

Impact on surface water resources due to the intensification of erosion processes, onset of dust and exhaust gas emissions, and spills of hazardous materials during the construction stage					
Impact Extent	Local	Municipal	Regional	National	International
	The water resources contamination impacts will be confined to the Project region.				
Impact Magnitude	Negligible	Low	Medium	High	
	The impact magnitude will be low taking into account the localised nature of spills or leakages, and because a spill or leak will be quickly dealt with to minimise the volume and movement of the spilled or leaked substance.				
Receptor Value / Sensitivity	Negligible	Low	Medium	High	
	Most of the rivers located within the area of Project influence are partly used for industrial, hydropower and irrigation purposes, however also are habitats for fish species. They are therefore considered to have a medium value and sensitivity.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Taking into account the extend, magnitude and sensitivity of receptors, the impact significance is minor. However, spills and leaks are risks rather than planned activities, are likely to be small in scale and would be dealt with on site following standard pollution prevention and mitigation procedures.				

Mitigation Measures

- Minimize time between extraction and backfilling of soils at erosion-prone areas,
- Implement erosion prevention measures, manage topsoil and spoil removal and diversion of storm water,
- Where practical, local perimeter drains should be constructed around working areas (for construction camps, storage and parking areas, etc.) to collect suspended run-off, install wastewater treatment plant to avoid discharging of waste water into the primary surface water resources, if relevant or use septic tanks,
- Mud generated from the concrete plant operation and washing of cement trucks will be tested for hazardous characteristics and will be disposed of in line with national regulations,
- Adhere to construction procedure and schedule, adhere to time limits for storage of topsoil and spoil,
- An Emergency Response Plan (ERP) should be developed in line with the EBRD/IFC Environmental, Health, and Safety guidelines for handling spills of hazardous materials including oil products,
- Locate waste collection/storage areas so as to avoid substantial amount of runoff from upland zones,
- Transportation of waste and friable construction materials shall be carried out only by trucks covered by water-proof sheet.
- Formalized waste storage areas in the construction sites that have separation between the wastes and stormwater/surface water runoff. Such waste storage areas can be seen as no more than waste transition stations where waste gets removed from the sites at regular intervals (at least weekly).
- All hazardous materials including but not limited to hydrocarbons must be stored in waterproof and bunded areas so that the rupture of a storage tank or drum is contained;
- Procedures must also be developed for the safe transport, offloading, storage, dispensing, use and disposal of waste product for all hazardous materials. These procedures must include a detailed counter-measures plan in the event that there is

a spill so that the spill can be quickly and effectively remediated and not contaminate surface water runoff.

- All sewage/sanitary waste is to be removed from the construction area for off-site treatment and disposal;
- All construction vehicles and plant/machinery are to be regularly inspected to ensure that they are serviceable and do not leak oil, fuel or other lubricants.

Residual Impacts

The residual impact significance will be negligible provided that the mitigation measures are implemented properly.

Monitoring

As in the above sub-section for temporary changes to hydrological regime.

3.5.5 Impact Assessment: Operation

During the operation of the Sisian-Kajaran road, surface water bodies may become contaminated with oils and lubricants, tire particles, de-icing salt (mainly ammonium sulphate in winter and spring seasons), soot, compounds of lead and other heavy metals, dust, paint and other substances, which may migrate with surface runoffs (storm water, snowmelt water, wash water). Litter discarded from vehicles may also be washed into surface water. Exhaust gases from vehicles will partly settle in the surface watercourses.

The maintenance of the road will be accompanied by the generation of waste, which if not properly handled, can end up in the rivers.

Impact on surface water resources due to the runoff contaminated by oil products, heavy metals, solid particles, chemicals and litter washed downstream from the road pavement					
Impact Nature	Positive	Negative			
	The contaminated runoff from the road pavement as well as dust and exhaust gas emissions may negatively impact on the quality of surface water resources.				
Impact Type	Indirect	Indirect	Indirect	Indirect	
	The impact will be direct and reversible taking into account the low concentration of oil products, heavy metals, solid particles and chemicals in runoff.				
Impact Duration	Short-term	Short-term	Short-term	Short-term	Permanent
	The impact will be permanent during the road operation stage.				
Impact Extent	Municipal	Municipal	Municipal	Municipal	International
	The water resources contamination impacts will be confined to the Project region.				
Impact Magnitude	Negligible	Low	Medium	High	
	The concentration of oil products, heavy metals, solid particles and chemicals in runoff will be low and will have negligible impact on the quality of surface water bodies.				
Receptor Value / Sensitivity	Negligible	Low	Medium	High	
	Most of the rivers located within the area of Project influence are partly used for industrial, hydropower and irrigation purposes, however also are habitats for fish species. They are therefore considered to have a medium value and sensitivity.				
Impact Significance	Negligible	Minor	Moderate	Major	
	Taking into account the extend and magnitude of impact and sensitivity of receptors, the impact significance is minor.				

Mitigation Measures

- Where possible, limit the use of de-icing chemicals, give preference to mechanical means like scrubbers and snow ploughs,
- Remove litter from the roadside in a timely manner,
- Management procedures in the case of spills, fire, etc. involving hazardous/polluting materials along the Sisian-Kajaran road to prevent and clean up any significant impacts from drainage of contaminated liquids and fire-fighting water shall be developed and maintained.

- Dedicated hazardous material crews to be available for free.
- Regularly check operability of culverts, crossings, retaining walls and runoff diversion channels,
- The road maintenance works will be done in line with the site-specific environmental, health and safety management plans approved by the RD (or supervisor engineer).

Residual Impacts

The residual impact significance will be negligible provided the mitigation measures are implemented properly.

Monitoring

The condition of culverts, crossings, etc. along the road and SDAs as well as quality of surface water for petroleum products, benz(a)pyrene, heavy metals, BOD5, turbidity, suspended solids, pH, chlorides, ammonium ions shall be regularly monitored.

3.6 Groundwater Resources

3.6.1 Introduction and AoI

The baseline assessment for groundwater revealed limited information on the geohydrological circumstance that prevails in the area other than the positions of springs in various villages and the recognition that these springs are not the principal source of potable water in the villages. In addition, the springs appear to be more important for ceremonial purposes than drinking water. In the absence of better information, it is assumed that the groundwater in the area is both valuable and vulnerable.

3.6.2 Reference Criteria

3.6.3 Method, Assumptions and Limitations

It is assumed, in the absence of better information, that all groundwater potentially affected by road construction is of good quality, valuable and vulnerable.

3.6.4 Impact Assessment: Construction

During construction, water resources may be negatively affected by spillage of hazardous materials, especially hydrocarbons, that are transported into surface water resources, and potentially also infiltrate groundwater. Excavations may also require dewatering even if only on a temporary basis resulting in a localised cone of depression at the point of pumping.

The more significant impacts are potentially related to the tunnelling operations. During the tunnelling it will be necessary to drain the tunnel of groundwater that drains into the tunnel as the excavation progresses. This groundwater may be affected in two important ways, namely high pH brought about by contact with cement if the tunnel is to be shotblasted (likely if the tunnel is built using drill and blast techniques). At the same time contact with the cement and the drilling and blasting dust means that the groundwater accumulates sediment resulting in elevated concentrations of total suspended solids (TSS). Finally, but importantly the blasting material is likely to be ammonium nitrate (NH_4NO_3), a salt of ammonia and nitric acid, used widely in explosives. The net effect of that use would be an accumulation of both ammonia and nitrate in the groundwater being drained from the tunnel.

In addition, it will be important to understand the potential impact of the tunnelling on ground water levels during construction. It is understood that the tunnels would be lined to prevent groundwater ingress so that there will be a return to equilibrium after completion of the construction. If the tunnels are not going to be lined, especially the Bargushat tunnel then the tunnel would become a large drain of ground water from the ground above and beside it.

Impact on groundwater during the construction stage				
Impact Nature	Positive	Negative		
	Construction of the proposed road can result in several potential impacts on groundwater yield and quality. In the first instance spillage of hazardous materials, especially hydrocarbons, if unremedied, may percolate through to the underlying groundwater. More significantly perhaps is possible penetration of the groundwater due to excavations and tunnelling in particular. The spillage of hazardous materials would obviously impact on groundwater quality but penetration of the groundwater would result in the need to pump such groundwater (dewatering) and as such potential change the groundwater hydraulics. Where groundwater needs to be pumped or drained it is likely to be contaminated with materials on the surface or in the tunnels including sediment, cement (highly alkaline) and ammonia nitrate (or other blasting media).			
Impact Type	Direct	Indirect	Reversible	Irreversible
	Hydrocarbon spills that end up in groundwater are typically broken down by microbial action over time although this does not always apply to additives in the hydrocarbons. Groundwater contaminated in an excavation and in the tunnels especially could be treated on discharge to at least discharge water standards. In general terms then impacts on groundwater are potentially reversible.			
Impact Duration	Temporary	Short-term	Medium-term	Long-term
	The impact duration is short to medium term to recognise the possible impacts during the construction period and then for an unknown period following the constriction period. It should be noted that an unlined tunnel would continue to drain groundwater in perpetuity.			
Impact Extent	Local	Municipal	Regional	National
	Given that there are groundwater resources throughout the road alignment the impact extent is considered potentially municipal.			
Impact Magnitude	Negligible	Low	Medium	High
	Impact magnitude is considered to be no more than medium as it seems unlikely that hazardous materials would be spilled in such large volumes and countermeasures could be implemented to limit the extent and intensity of the spill. Groundwater contaminated in the tunnels would have a larger impact on surface water rather than groundwater, other than the loss of the groundwater resource.			
Receptor Value / Sensitivity	Negligible	Low	Medium	High
	In the absence of better information, the groundwater receptor value is considered to be high as a precautionary measure.			
Impact Significance	Negligible	Minor	Moderate	Major
	Project impacts on groundwater are potentially moderate given the likely magnitude of the impact and the assumed value of the groundwater resource			

Mitigation Measures

Develop and implement:

- Spill Management Plan;
- Tunnel Water Management Plan (including groundwater management);
- Wastewater and Stormwater Management Plan;
- As part of the process of the more detailed geological assessment required for building the tunnels, but especially the Bargushat Tunnel, a geohydrological assessment must be conducted to determine the likelihood of water draining through the tunnel;
- If water is going to be encountered during construction, then wastewater facilities must be established as part of the construction process for the tunnel(s)
- Such wastewater treatment to include as a minimum settlement and clarification facilities as well as a neutralisation function to reduce the high pH in the water.
- The point of discharge into surface water must also be assessed to ascertain the likely impact of the contaminated groundwater and additional treatment prescribed if needed.

- The tunnel must also be lined to prevent permanent seepage through the tunnel after construction has been completed, if so required.

Residual Impacts

If the above mitigation is implemented, then the residual impact significance could be reduced to moderate to minor.

Monitoring

- The quality of the tunnel discharge water must be monitored both before and after treatment.
- Water quality upstream and downstream of the discharge point must be monitored so as to understand the water quality effects on the receiving water quality.
- If the water quality monitoring highlights inadequacies in the treatment, then these must be addressed by upgrading the waste water treatment facilities.

3.6.5 Impact Assessment: Operation

During operations of the road network, contaminants on the road surface such as spilled fuel or lubricants may be washed into adjacent surface water during rainfall events. Motor vehicle accidents, especially involving freight carrying vehicles may see the release of a range of potentially hazardous materials that could end up being discharged and potentially impact on surface water and subsequently groundwater through recharge. At the same time a large spill of hazardous materials onto open ground may pose a similar risk of percolation and groundwater impact.

Impact on groundwater during the operations				
Impact Nature	Positive		Negative	
	The key risk to groundwater during road operations is possible spills of hazardous materials deriving either from poorly maintained vehicles or from a motor vehicle accident especially with bulk freight tankers where a large quantity of hazardous material could potentially be discharged.			
Impact Type	Direct	Indirect	Reversible	Irreversible
	The impact would be changes in groundwater quality as a result of the percolation of such hazardous materials either through the ground or in rainwater that recharges the groundwater. Contaminated groundwater is essentially irreversible without a major intervention and even then, would not guarantee complete recovery.			
Impact Duration	Temporary	Short-term	Medium-term	Long-term
	Contamination of groundwater would be at least long term if not permanent.			
Impact Extent	Local	Municipal	Regional	National
	An impact of the type proposed above would be localised in nature and limited to the area where the loss of containment occurred. Contaminated runoff would occur all along the alignment but the impact intensity would be significantly less than for a large-scale spill.			
Impact Magnitude	Negligible	Low	Medium	High
	Impact magnitude would be medium given that such an incident would be very localised. It is entirely possible, however, that a particularly hazardous material such as cyanide could be spilled in which case the impact magnitude would be potentially larger.			
Receptor Value / Sensitivity	Negligible	Low	Medium	High
	In the absence of better information, the groundwater receptor value is considered to be high as a precautionary measure.			
Impact Significance	Negligible	Minor	Moderate	Major
	Project impacts on groundwater are potentially moderate given the likely magnitude of the impact and the assumed value of the groundwater resource			

Mitigation Measures

- Stormwater drains and oil water separators must be regularly serviced and maintained to ensure that they remain effective and do not become saturated and or blocked over time; and,
- Emergency response provision must be made for effective countermeasures in the event of a spill on the roadway and the containment and removal of the same. Such provision should include not only spillage from a crashed motor vehicle as well as the recovery of a large-scale spill if a vehicle transporting hazardous materials is somehow damaged and loses containment.

Residual Impacts

With the implementation of the above mitigation the impact significance would be reduced to minor. That significance rating change is on the assumption that the deployment of spill countermeasures is quick and effective at containing and ultimately recovering a spill to minimise the potential contamination of groundwater.

Monitoring

No groundwater quality monitoring is advocated because it is extremely difficult to conduct routine groundwater monitoring across the entire road length that could be used meaningfully for management.

The reaction time and recovery effectiveness of accident crews should be monitored against set targets and improvement sought continually.

3.7 Waste and Spoil

3.7.1 Introduction and AoI

Waste is an inevitable consequence of construction and operations of a road. The obligations for a road project are to understand the nature and hazard properties of the waste likely to be generated together with the probable volumes. Provision must then be made to manage and ultimately dispose of the waste generated to so that the potential hazards are prevented from contaminating soil and ground and surface water. The AoI extends along the entire project footprint and includes areas used for temporary storage of waste and permanent disposal.

3.7.2 Method, Assumptions and Limitations

Given that there is no information on waste types and quantities indicative estimates have been derived for purposes of the assessment based wherever possible on experience from other projects.

3.7.3 Impact Assessment: Construction

The following waste types will be generated during the construction phase:

- Excavated material (spoil) from drilling, excavation and other earthworks;
- Residues of concrete and asphalt mixture (‘construction waste');
- Construction machinery maintenance waste (lubricants, diesel fuel residues, oily rags, spent batteries, used tires, etc.);
- Hazardous waste generated at the construction camps, concrete and asphalt plants (such as spent oil and lubricants, used tires, batteries, ferrous and non-ferrous scrap, used welding electrodes, oily rags, contaminated soil, empty fuel, lubricants and chemicals containers, etc.)
- Roadway demolition waste including concrete rubble, gravel, soils and asphalt (applicable to sections to be upgraded);
- Ferrous and non-ferrous metal scraps;

- Packaging from construction materials and dye and paint containers; and
- Household waste generated by construction workers (packaging materials, food waste).

The most significant waste by volume will be spoil material from the excavations that cannot be used again as fill material. In the project description, reference was made to a range of sites that had been identified preliminarily for possible use for spoil disposal. During the assessment it has become clear that many of these sites are unusable or the anticipated volume of disposal is considerably less than envisaged due to possible biodiversity impacts. As part of the assessment additional sites were considered including a *possible* disposal site adjacent to the northern tunnel portal. This so-called Shenatagh site provides considerable space for spoil disposal. In addition, the location of the site would allow for spoil to be moved to the disposal site by conveyor foregoing the need for truck transport with associated E&S impacts.

Remaining spoil disposal sites will need to be identified and vetted against acceptability criteria that is defined as part of this assessment. Currently available information is simply inadequate for further assessing the proposed SDA's. The appointed contractor must be obliged to define accurately the cut to fill ratios and to identify disposal sites for the excess spoil. The contractor would also be obliged to obtain all the necessary permits and permissions for the legal establishment of the disposal site. The chosen disposal sites must all be properly designed to ensure the stability of the disposal sites and the optimum configuration for the different waste types.

It is also recommended that waste transition and sorting areas be established at different points along the road alignment. The principle of these transition areas is to provide a formalized and well-managed temporary storage area for construction waste before it is taken for recycling, treatment or final disposal. These waste transition areas should be demarcated and managed in accordance with the risks posed by the different waste types to ensure:

- No risk of human exposure to wastes that are hazardous;
- No mixing of different waste types;
- Containment of hazardous materials in the event of a container being punctured;
- Minimal contact with rainwater;
- No risk of percolation of hazardous materials into the underlying soil and/or groundwater;
- No odours;
- Prevention of vermin risk;
- No risk of fire and/or explosion; and,
- That the area remains neat and tidy throughout the construction period.

As has been shown in **ESIA Volume 1**, the project is expected to generate about 37.5 tonnes of household waste per year which would translate into 225 tonnes per six years of construction works. That estimate shows that there is more than adequate capacity to receive the Project’s waste in addition to waste flow normally received by two landfills in Sisian and Kapan Communities (see also assessment on public infrastructure in **ESIA Volume 4, Section 3.4**). Modern large-scale construction projects have no excuse for not managing their waste in an effective and low risk manner that would serve to ensure that the magnitude of the impact is low. That significance rating is dependent however on the implementation of the following mitigation.

Construction waste		
Impact Nature	Positive	Negative
	During construction of the proposed roadway waste will be generated that requires safe disposal to prevent the waste from causing environmental and social impacts. The biggest potential impact stems from excess spoil and finding suitable areas for safe disposal of the same. At this stage no	

	definitive statements can be made as to the acceptability of the SDA's that have been proposed thus far other than outlining limitations as a result of the biodiversity in the area.			
Impact Type	Direct	Indirect	Reversible	Irreversible
	The waste will be generated during construction will be a permanent feature of the landscape and as such is irreversible.			
Impact Duration	Temporary	Short-term	Medium-term	Long-term
	The impact of construction waste will be permanent.			
Impact Extent	Local	Municipal	Regional	National
	Waste will be generated along the entire length of the roadway during construction but will be consolidated into no more than a municipal scale impact extent where disposed of.			
Impact Magnitude	Negligible	Low	Medium	High
	The domestic waste that will be generated during construction can be disposed at existing facilities and is well within the capacity of those facilities. The impact magnitude of such domestic waste is low. Disposal of the excess spoil is likely to have a medium impact magnitude.			
Receptor Value / Sensitivity	Negligible	Low	Medium	High
	The value of the biodiversity and especially the southern part of the alignment makes the receptor sensitivity high.			
Impact Significance	Negligible	Minor	Moderate	Major
	Impact significance for domestic waste will be minor but the disposal of excess spoil will be moderate (based on the potentially identified SDAs).			

Mitigation Measures

Mitigation of construction related waste impacts would require the development and implementation of a detailed **Waste Management Plan** (including **a Spoil Disposal Sub-Plan**) that sets out the following:

- Identifies all forms of waste that will be generated during the construction phase and quantifies the expected volumes.
- Each waste type must be assessed against the waste management hierarchy to explore options for minimizing the amount of waste that ultimately requires disposal;
- Volume targets for each waste type must be set for the contractor with an incentive/punitive mechanism for achieving the targets;
- The waste management programme must also detail the safe interim storage of the waste on the site prior to removal to ensure that there no risk of contamination of ground or surface water or windblown waste leaving the construction site;
- Detailed records must be kept of all waste and the final safe fate of the same; and,
- The programme must include frequent inspections across the site to ensure compliance with the requirements of the programme.

Residual Impacts

If the above mitigation is implemented, the residual impact significance could be reduced to minor.

Monitoring

Monitoring according to the construction Waste Management Plan and the Spoil Disposal Sub-Plan.

3.7.4 Impact Assessment: Operation

Waste expected during operations of the roadway includes:

- General litter;
- Scrap from signs, Armco railings and fencing that needs to be replaced;
- Car parts and vehicle wrecks;
- Waste rock and soil from landslides;

- Waste asphalt, concrete and building rubble from road repairs;
- Contaminated soils and road cleaning residue; and,
- Oily water from oil water separators.

To prevent these wastes from posing a risk to the natural environment it will be incumbent on the roads operator to develop and implement a waste management programme detailing the safe and timely removal and disposal of waste. A similar process would need to be run as for construction of categorizing the waste types, projected quantities, means of reducing, re-using or recycling and then safe final disposal of the waste that cannot be otherwise used. The programme must also detail what would be done to collect the waste along the roadway and scheduling of that process. The ability to rapidly respond to a spill of hazardous materials would be a key part of this waste management program.

Road operations waste				
Impact Nature	Positive		Negative	
	During road operations various forms of waste will be generated such as litter, spilled hazardous materials construction waste (from road maintenance) and others. Provided an effective program is implemented for the recovery transport and safe disposal of this waste risk to the natural environment should be low.			
Impact Type	Direct	Indirect	Reversible	Irreversible
	For the most part the impact is reversible as even if the waste is discarded it can be recovered and moved to a facility for safe disposal. The key requirement is to ensure that the waste is recovered collected and transported away before it can result in either soil, surface or groundwater contamination. It should be noted that the waste itself is not reversible although options exist for the reuse and recycling of that waste.			
Impact Duration	Temporary	Short-term	Medium-term	Long-term
	The impact duration it is viewed as long term because of the waste being irreversible but the direct impact is preventable and reversible through programs to collect and safely dispose of waste that occurs along the road.			
Impact Extent	Local	Municipal	Regional	National
	Impacts from waste generated during road operations would be Localized and not extend beyond the local scale			
Impact Magnitude	Negligible	Low	Medium	High
	Impact magnitude is low mostly related to the expected relatively small quantities of waste that will be generated. It should be recognized however that a large-scale spill of particularly hazardous materials would have a significantly higher impact magnitude.			
Receptor Value / Sensitivity	Negligible	Low	Medium	High
	The receptor value is high due to the valuable biodiversity and the natural heritage that prevails in the area.			
Impact Significance	Negligible	Minor	Moderate	Major
	Impact significance is minor provided that there is effective cleanup and waste removal and disposal during road operations.			

Mitigation measures

Mitigation of operations related waste impacts would require the development and implementation of an operations **Waste Management Plan** that ensures that there is no risk of contamination of surface or groundwater because of waste generated during operations of the proposed road. The operations waste management programme must detail and contain the following:

- Identifies all forms of waste that will be generated during the operations phase and quantifies the expected volumes;
- Each waste type must be assessed against the waste management hierarchy to explore options for minimizing the amount of waste that ultimately requires disposal;
- Volume targets for each waste type must be set together with management plans to achieve the targets;
- Detailed records must be kept of all waste and the final safe fate of the same; and,

- The programme must include frequent inspections of the express road to ensure compliance with the requirements of the programme.

Residual Impacts

If the above mitigation is implemented, the residual impact significance could be reduced to negligible.

Monitoring

Monitoring according to the operations Waste Management Plan.

3.8 Landscape and Visual Amenity

3.8.1 Introduction and AoI

In this section the visual impact of the road is assessed in relation to its impacts on cultural landscapes, their cultural heritage structures and other manmade patterns nested within. Visual amenity would be affected by the changes in landscape form bought about by the cuts and embankments and bridges needed for the road base and the road itself. At the same time and much more specifically, aesthetic changes to these landscapes could also affect the significances of certain cultural heritage structures by altering their spatial contexts and scenic outlooks. This assessment therefore addresses visual impacts from the road, leading to a loss of CH amenity within these areas.

For this assessment, certain viewpoints were determined along the road routing that would potentially be used by people and thereby the 'user experience' including sense of place and appreciation of the cultural landscape. An important part of that appreciation is visiting heritage structures where their significance is defined not only by the buildings themselves but also their outlooks which enhance the user experience. This is especially true of cultural landscapes where heritage structures dating back many years are experienced in context with, for example, agricultural landscapes which have retained their overall appearance for hundreds of years (ploughed fields, crops, cattle and sheep in fields and so forth). There is no doubt that the valley through which the road will pass comprises heritage landscapes of significant value containing culturally important structures and other development patterns.

3.8.2 Reference Criteria

There is limited quantitative reference criteria if any at all, as the visual impact assessment, including impacts on sense of place (*genius loci*) is principally qualitative.

3.8.3 Method, Assumptions and Limitations

The vantage points used to characterise the existing landscapes are listed in **Table 50**. Most of these vantage points are at well-known heritage structures but there are also points where the landscape is simply spectacular and can be so viewed from the existing road or other easily accessible places. At each of these points photographs were taken through a panorama from the vantage site each at 50 mm (minimum distortion).

Table 50. Vantage points and landscapes assessed for the visual amenity assessment

Vantage	Landscape
Church south of Lor	East through southeast. Caves on opposite side of valley
Gexi (Geghi)	Northwest through northeast.
Vorotnavank Monastery	South-easterly view down the valley
Existing road east of the proposed tunnel portal position	South-west though northwest
Zorats qarer	Northeast through southeast
	Same landscape at dusk and at night
Elevated position on existing road south of Shamb Reservoir	Northwest through northeast.

3.8.4 Impact Assessment: Construction

Construction activities will have an important effect on landscape character due to large scale ground clearing, excavations, borrow pits, temporary stockpiling of material, large construction vehicles and machinery, scaffolding and shuttering and so forth. Those effects notwithstanding, they will only be temporary and at worst for the full duration of the construction period (seven years). Many elements of the proposed road would be completed well within the overall construction period, the duration of which is directly dictated by the duration of the Bargushat tunnel construction. The ultimate impact on visual amenity will be the finalised road ready for operations. For this reason, the landscapes and visual amenity assessment is based on the operational phase only.

3.8.5 Impact Assessment: Operation

On completion of construction there will be a permanent change in the landscape character as a function of the finished project. The change will be tempered to some degree by the reestablishment of vegetation in disturbed areas and the removal of all construction equipment.

3.8.5.1 *Lor Caves*

A view of the landscape to the south of Lor is shown in **Figure 92** with the existing landscape showing a combination of agricultural landscapes in the valley and mountainous backdrops beyond. The vantage point is the church and although they are difficult to see in the picture, there are caves on the other side of the valley that were inhabited in the first half of the 20th century (see cultural heritage unit 56 in **Annex 5, ESIA Volume 4**). Neither the church, nor the caves have significant cultural heritage value, but this sector as a whole comprises one of many good cultural landscapes characterizing the area. In B the proposed roadway is shown in the landscape. The visual impact of the road is typical of much of its alignment, namely a cut into the side of the hill on the upslope side and a large embankment on the downslope side. The visual impact is dramatic and constitutes a significant change to the landscape. Despite the dramatic impact there is scope for mitigation on both upslope and downslope embankments. These have potential to be landscaped in a manner that would lessen the visual impact, although the upslope in particular, may need to be stepped to make planting easier.

3.8.5.2 *Geghi*

A view of the landscape looking north (and importantly in the road section south of the Bargushat tunnel which has a quite different aesthetic to the northern section of the road) is shown in **Figure 93** showing the current view in A. The view is from Gexi. The proposed roadway is shown in B and shows all the engineering elements of the proposed road namely cut and fill, a bridge and a tunnel entrance on the very right of the picture. Again, the visual impact on the landscape is dramatic but it is the cut and fill that creates the largest visual change. Further, at least the embankments could be landscaped to soften their visual impacts. The bridge is less obtrusive and most because it is a strongly formalised structure with pleasing lines (as opposed to the embankments which look disorderly). The visual impact of bridges is very much in the eye of the beholder as some people would experience the visual impacts of the bridge positively while others would see it as an intrusion. The visual impact of the tunnel portal is limited but could still be further reduced through effective landscaping.

Similarly, to that described above, the embankments both above and below the road could be landscaped to soften their visual impacts. The bridge, while contrasting in form with its surroundings, is not considered obtrusive. This is because of the high visual absorption capacity of the massively scaled and extensive mountain backdrops immediately beyond; all read against the strong formalised, yet slender, clean lines of the bridge which do not visually overpower within this context. The visual impact of bridges, like wind turbines, can be highly subjective and therefore much depends on the silhouette that such new structures create within extended landscapes. In this instance, the slender silhouette of the bridge does not overpower and avoids breaking the skyline. Impacts could nonetheless be further mitigated by an appropriate colour finish to the bridge. The visual impact of the tunnel portal is limited but could still be further reduced through effective landscaping.

3.8.5.3 *Vorotnavank Monastery*

The view from the Vorotnavank Monastery is shown in **Figure 94**.

The view is southeast essentially following the valley. The current view is strikingly picturesque (A) and, importantly, strongly emphasises the aura of the monastery as the dominant element in the landscape commanding access to the valley. The introduction of the road (B) has a strong negative visual impact because it is now the bridge form that is the dominant landscape element, seriously detracting from the historic landmark qualities of the monastery and its curtilage. In addition, whereas the existing road descends sharply (with the Vorotnavank turnoff about halfway down) and then follows the valley floor, the new road is kept at the same altitude as the monastery and brought much closer to it (by about 100 m). That, in turn, raises the issue of traffic noise on the sense of place of this ancient site. Much of the bridge that brings the road closer to Vorotnavank is hidden from view by vegetation that occurs east and northeast of the monastery, but the bridge still projects well into the monastery viewshed. The cut and fill required for this roadway section also has a profound negative visual impact especially with the large rock wall that will be exposed by the cut. Some mitigation would be possible, but this would relate primarily to the road embankments rather than any of the other features.

3.8.5.4 *Northern tunnel portal*

The northern tunnel portal is shown in **Figure 95**.

The view is from the opposite side of the valley and looking west and northwest. The dominant visual feature is a large craggy tufa (a variety of limestone formed when carbonate minerals precipitate out of water) in the centre of the vista (A). Against this backdrop the visual impact of the proposed road is far less severe than the other landscapes, softened by the similar textures and colours to the background (B). Another important feature is the retaining wall on the downslope side rather than an embankment. This imparts a structured and tidy aesthetic that, although to a limited degree, legible as a contrasting element, is capable of mitigation by, for example, natural stone cladding or a context sensitive colour finish in combination with appropriate landscaping.

3.8.5.5 *Zorats Qarer*

The view from Zorats Qarer (the Armenian Stonehenge) is shown in **Figure 96** looking northeast through southeast. Currently the view is over shallow undulating terrain with a prominent mountain backdrop. This is again a spectacular landscape, albeit spoilt marginally by the truck/car stop on the existing M2 at the Sisian turnoff (A). A major interchange will be established here as part of the proposed road project and is evident in the Figure (B). While the interchange is clearly visible it is not obtrusive given the expansive spatial context within which it is located and its curvilinear profile responding to the undulating forms of the broader landscape. The rest of the new road will be barely visible. For the assessment two additional scenes were created for dusk and nighttime conditions. Unfortunately, the scenes do not project well in print but it is clear from both, that lighting would not result in significant impacts. The interchange would be clearly visible due to the lighting required there but the rest of the landscape remains largely unaffected visually.

3.8.5.6 *Shamb Reservoir*

The view from the existing road above the Shamb Reservoir is probably the largest vista on the route and is shown in **Figure 97** (A). The view is vast and of high scenic quality with the Shamb reservoir a key landscape feature as a large expanse of water. The viewpoint is accessible on the existing road. The proposed road (B) will be an obvious change to the landscape but because the new road largely lies on the western side of the viewshed (as does the existing road) the negative effect is not particularly severe. In addition, the road goes into a tunnel underneath the current viewpoint. Notwithstanding the generally lesser landscape impact on this part of the alignment, the visual impact of the new road could be mitigated still further by landscaping, not only the fill components of the alignment but possibly also the arrestor beds for vehicles experiencing brake failure.

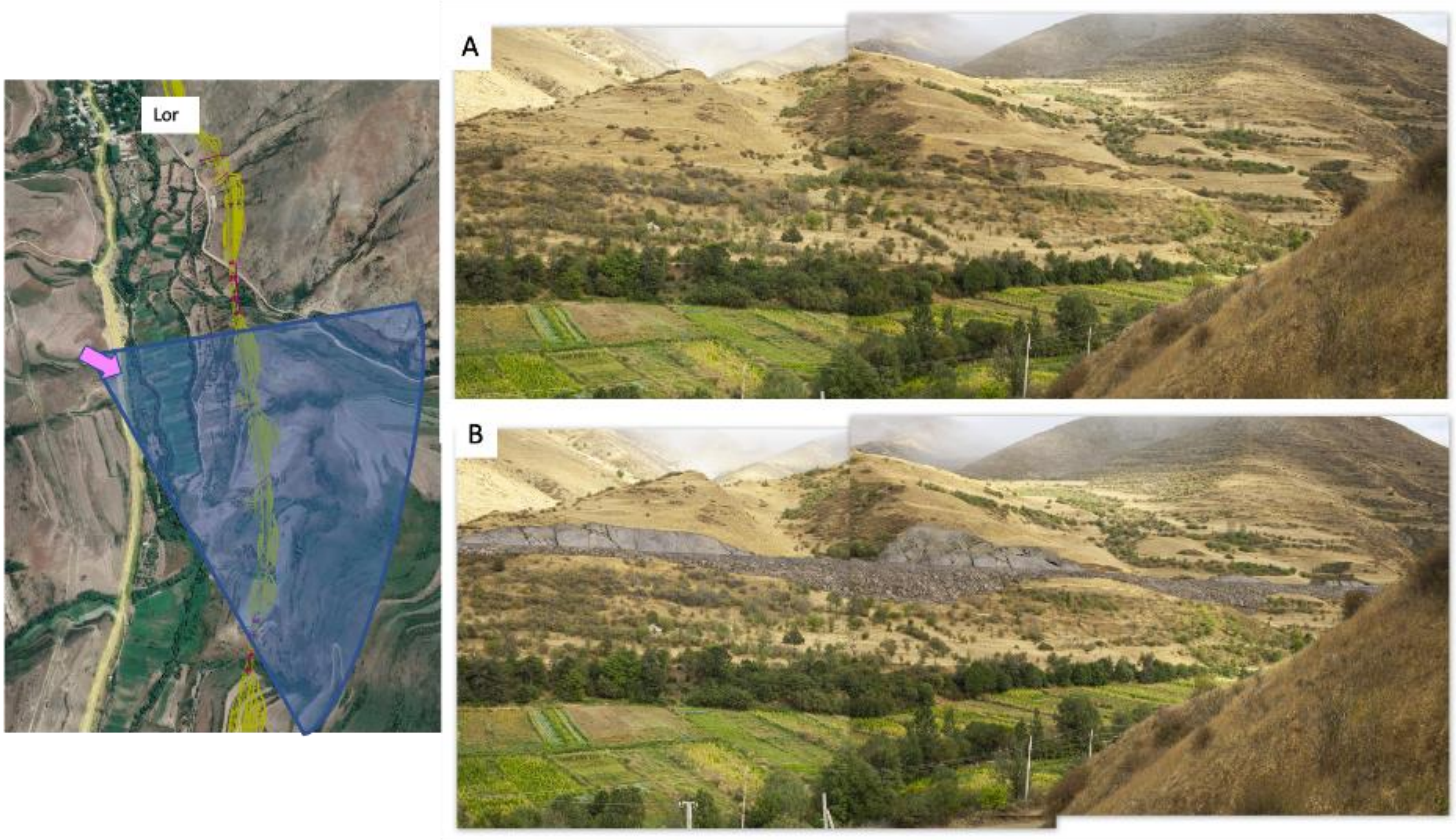


Figure 92. View as shown in inset on left, of the landscape south of Lor. A is the current landscape and B the presentation of the proposed road on that landscape

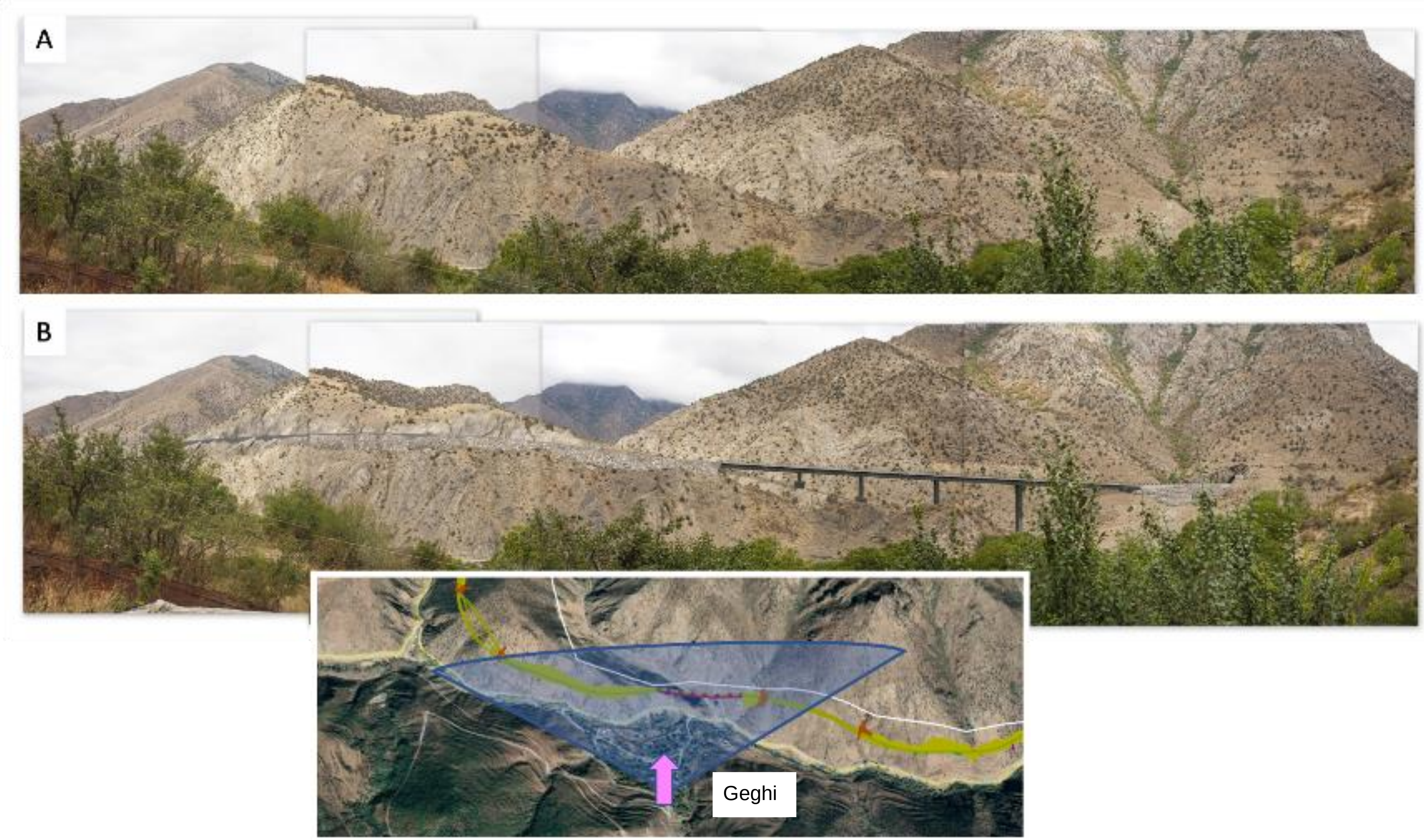


Figure 93. View as shown in inset at bottom, of the landscape north of Geghi. A is the current landscape and B the presentation of the proposed road on that landscape

Figure 94. View as shown in inset on left, from the parking area of the Vorotnavank Monastery. A is the current landscape and B the presentation of the proposed road on that landscape (note bridge crossing river on far right of image)

Figure 95. View as shown in inset on left, of the northern tunnel portal. A is the current landscape (note large tufa in middle frame) and B the presentation of the proposed road on that landscape (note large tufa in middle frame)

Figure 96. View as shown in inset on right, of the view from Zorats Qarer (the Armenian Stonehenge). A is the current landscape and B the presentation of the proposed road on that landscape (note large interchange on left of picture).

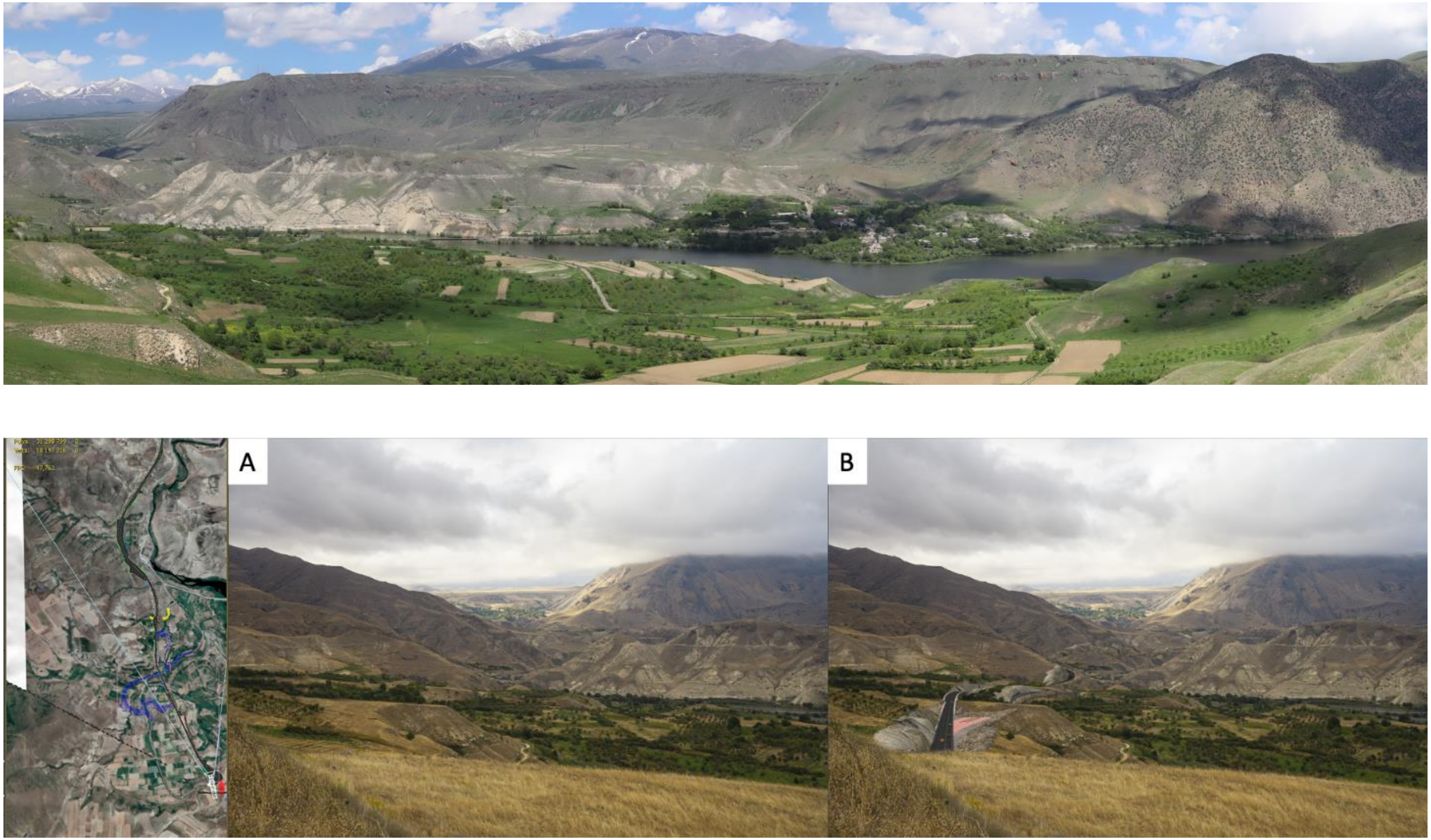


Figure 97. View of the Shamb Reservoir from the existing road looking north (top) and comparative views from the position shown in inset on bottom left. A is the current landscape and B the presentation of the proposed road on that landscape.

Landscape and visual amenity impacts during operations				
Impact Nature	Positive		Negative	
	The completed roadway will have resulted in major changes to the landscape through which it passes. The landscapes in the valley through which the road will pass are deemed to be cultural landscapes in that they contain features that reflect the progression through time of both natural features as well as features that reflect socio-economic transitions till today and elements of the culture of the communities living there. There are also multiple cultural heritage structures which, with their scenic outlooks, help to define their historic contexts and significances. The assessment must then be based on assessing how the landscape changes would potentially impact on the user experience at the cultural heritage structure and cultural landscapes in general.			
Impact Type	Direct	Indirect	Reversible	Irreversible
	Changes to landscape and visual amenity will be largely irreversible. While it is true in principle that the roadway could be decommissioned and landscapes rehabilitated to their original form, such decommissioning would be at least 30 years into the future and despite best efforts would never fully return the landscapes to their current form.			
Impact Duration	Temporary	Short-term	Medium-term	Long-term
	Impact duration would be long term given the project life span of at least 30 years.			
Impact Extent	Local	Municipal	Regional	National
	Changes in landscape and visual amenity would extend several kilometres on either side of the proposed roadway and for the full length of the roadway omitting of course the sections in tunnel. (Visual impacts are, in most cases substantially mitigated by distance at 3,5 to 5km or further). The scale of the impact is accordingly deemed regional.			
Impact Magnitude	Negligible	Low	Medium	High
	While the changes in landscape and visual amenity would be material there is only one viewshed where the impact of the change in landscape is considered to be intolerable and that is the view from the Vorotnavank Monastery. The proximity of the proposed road alignment to the monastery will result in a material change to the user experience of Vorotnavank significantly lessening the cultural heritage value of the structure and its curtilage. Whereas the monastery is currently the dominant visual feature within the context of the natural landscape and 'commands' the view, the new road would usurp that role but with no benefits for either cultural heritage or landscape character. The anticipated sterilisation of the view from Vorotnavank by the proposed road renders the impact magnitude as High – Very High with Low-Very Low prospects of successful mitigation.			
Receptor Value / Sensitivity	Negligible	Low	Medium	High
	The receptor sensitivity of the cultural landscape and the heritage structures included in the visual impact assessment are at least Medium, if not High. The cultural heritage value of the Vortonavank Monastery compels a rating of High.			
Impact Significance	Negligible	Minor	Moderate	Major
	The combination of High impact magnitude and high receptor sensitivity means that the impact significance is potentially major. This rating applies specifically to the Vorotnavank viewshed. The remaining landscape and visual amenity changes are considered to be no more than Moderate.			

Mitigation Measures

The critical mitigation requirement is a change in the proposed road alignment adjacent to the Vorotnavank Monastery to reduce the negative visual impact on this highly significant heritage resource and its curtilage and, thereby reducing visual impacts to acceptable levels. If the alignment could be directed to the valley bottom, there would be a material reduction in the scale of the cut and fill and reduce the size of the bridge and change its position.

In all circumstances where embankments are to be constructed the embankments are to be landscaped to reduce the juxtaposition with the existing landscape and at least create the illusion of a much smaller impact on the landscape. Landscaping may require stepping of the upslopes of road cuts which would then best be executed as part of the construction phase.

Residual Impacts

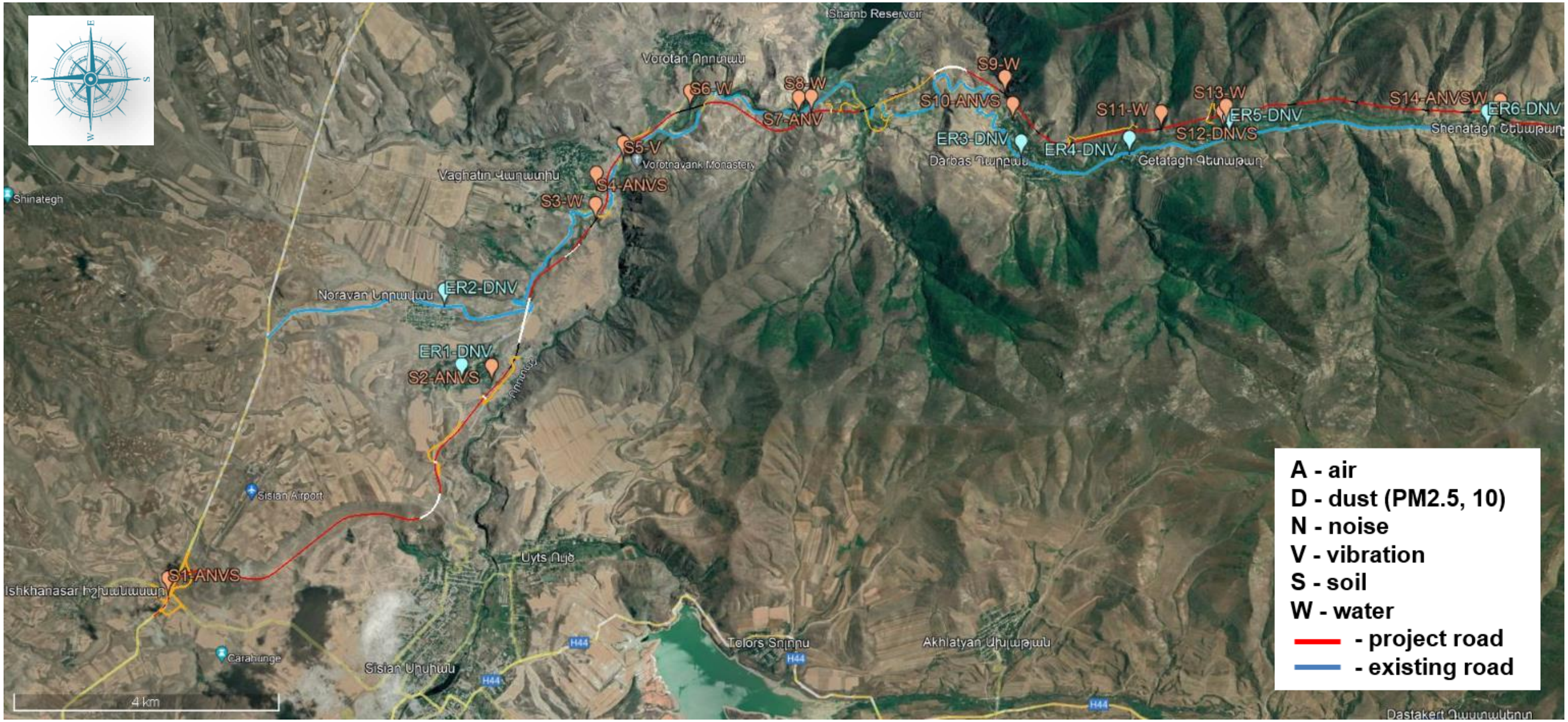
With effective implementation of the above mitigation the impact significance could be reduced to moderate for the Vorotnavank Monastery viewshed but only if the roadway passing this cultural heritage site is realigned; for the remaining landscape the residual impact significance is viewed as minor.

Monitoring

The condition of the landscaping is to be monitored to ensure that it continues to fulfil its function of screening the extent of the cut and fill operations.

Annex 1. AIR, NOISE, VIBRATION, WATER AND SOIL SAMPLING AND MEASUREMENT LOCATIONS

Sisian-Shenatagh section



Sampling and measurement points at sensitive receptors along the proposed Sisian-Shenatagh section of the road

Point S1-ANVS	Piquet: ~ km 0+420	**GPS coordinates**	
		39°33'27.30"N	46° 2'20.59"E
Point description and sensitivity	Intersection of M2 road with the starting point of project road Sisian-Shenatagh section, near the Ojax restaurant. The area is commercial.		

Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

Point S2-ANVS	Piquet: ~ km 7+250	**GPS coordinates**	
		39°30'51.67"N	46° 4'46.29"E
Point description and sensitivity	Aghitu settlement. In front of the nearest residential house (on the left side).		

Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

Point S3-W	Piquet: ~ km 10+400	**GPS coordinates**	
		39°30'3.03"N	46° 6'35.11"E
Point description and sensitivity	The Noravan river, under the planned bridge BR002.		

Parameters to be measured

☐ **CO, SO_2, NO_2, and PM2.5, PM10**	☐ **Noise**	☐ **Vibration**	☐ **Soil**	☒ **Water**

Point S4-ANVS	Piquet: ~ km 10+950	**GPS coordinates**	
		39°29'27.56"N	46° 7'33.26"E
Point description and sensitivity	Vaghatin settlement. In front of the nearest residential house (on the left side).		


Parameters to be measured

☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

Point S5-V	Piquet: ~ km 11+500	**GPS coordinates**	
		39°29'50.25"N	46° 7'15.97"E
Point description and sensitivity	In front of the Vorotanavank Monastery (on the right side).		


Parameters to be measured

☐ **CO, SO_2, NO_2, and PM2.5, PM10**	☐ **Noise**	☒ **Vibration**	☐ **Soil**	☐ **Water**

Point S6-W	Piquet: ~ km 12+850	**GPS coordinates**	
		39°29'17.69"N	46° 7'52.19"E
Point description and sensitivity	The Vorotan river, under the planned bridge BR005.		


Parameters to be measured

☐ CO, SO_2, NO_2, and PM2.5, PM10	☐ Noise	☐ Vibration	☐ Soil	☒ Water

		GPS coordinates	
Point S7-ANV	Piquet: ~ km 14+800	39°28'22.33"N	46° 7'51.01"E
Point description and sensitivity	In front of the Shamb HPP (on the right side). The area is industrial.		

Parameters to be measured

☒ CO, SO_2, NO_2, and PM2.5, PM10	☒ Noise	☒ Vibration	☐ Soil	☐ Water

		GPS coordinates	
Point S8-W	Piquet: ~ km 15+000	39°28'15.97"N	46° 7'51.99"E
Point description and sensitivity	The river (without name), under the planned bridge BR006.		

Parameters to be measured

☐ CO, SO_2, NO_2, and PM2.5, PM10	☐ Noise	☐ Vibration	☐ Soil	☒ Water

		GPS coordinates	
Point S9-W	Piquet: ~ km 18+300	39°26'38.56"N	46° 8'8.46"E
Point description and sensitivity	The Shenatagh river, under the planned bridge BR008.		

Parameters to be measured				
☐ CO, SO_2, NO_2, and PM2.5, PM10	☐ Noise	☐ Vibration	☐ Soil	☒ Water

Point S10-ANVS	Piquet: ~ km 18+550	**GPS coordinates**	
		39°26'34.00"N	46° 7'51.33"E
Point description and sensitivity	Darbas settlement. In front of the nearest residential house (on the right side).		

Parameters to be measured				
☒ CO, SO_2, NO_2, and PM2.5, PM10	☒ Noise	☒ Vibration	☒ Soil	☐ Water

Point S11-W	Piquet: ~ km 21+050	**GPS coordinates**	
		39°25'19.92"N	46° 7'48.37"E
Point description and sensitivity	The river (without name), under the planned bridge BR011.		

Parameters to be measured				
☐ CO, SO_2, NO_2, and PM2.5, PM10	☐ Noise	☐ Vibration	☐ Soil	☒ Water

Point S12-ANVS	Piquet: ~ km 22+150	**GPS coordinates**	
		39°24'49.07"N	46° 7'50.40"E
Point description and sensitivity	Lor settlement. In front of the nearest residential house (on the right side).		

Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

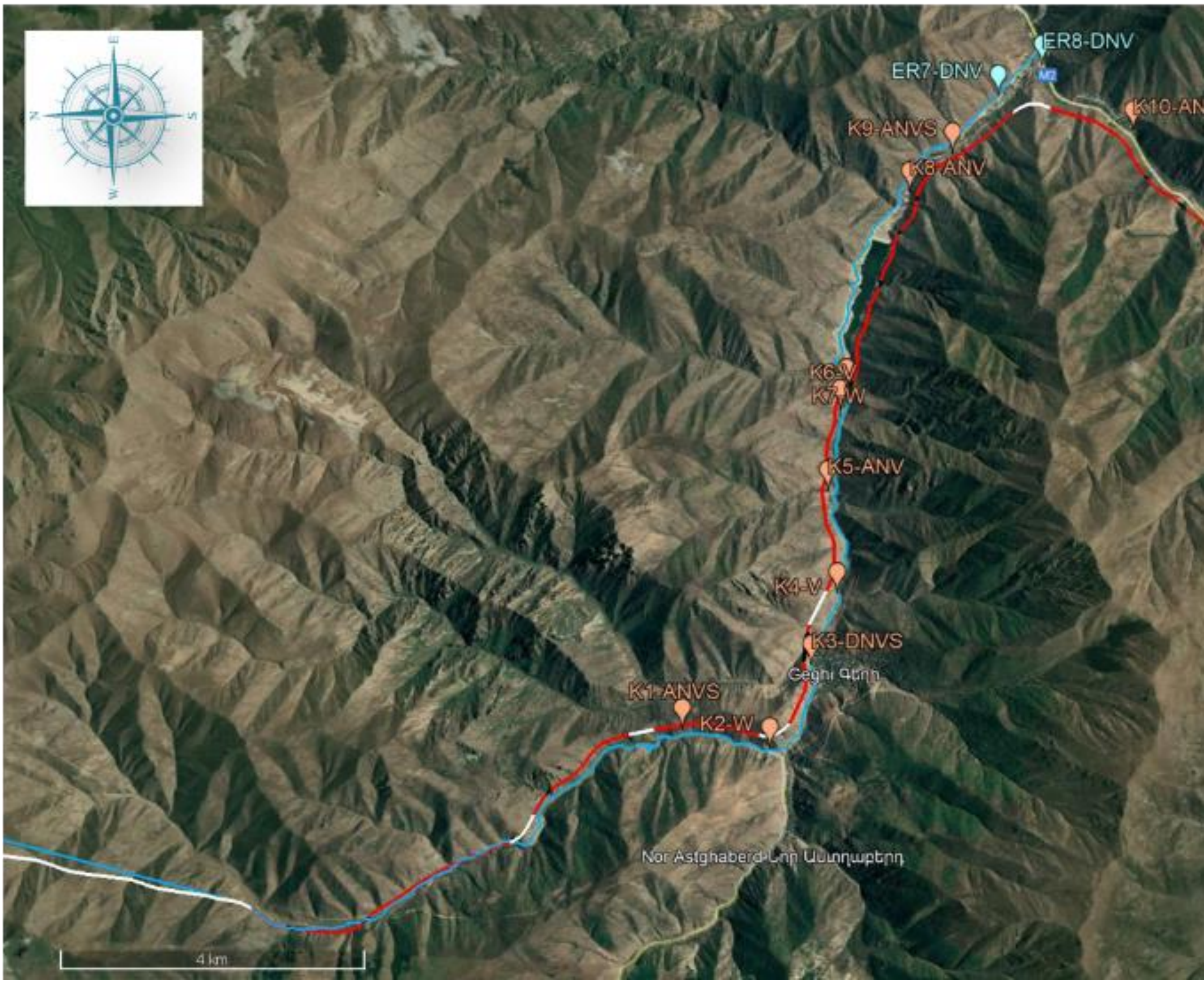
Point S13-W	Piquet: ~ km 22+200	**GPS coordinates**	
		39°24'47.70"N	46° 7'54.03"E
Point description and sensitivity	The Shenatagh river, near the piquet km 22+200.		

Parameters to be measured				
☐ **CO, SO_2, NO_2, and PM2.5, PM10**	☐ **Noise**	☐ **Vibration**	☐ **Soil**	☒ **Water**

Point S14-ANVSW	Piquet: ~ km 26+350	**GPS coordinates**	
		39°22'32.77"N	46° 8'2.67"E
Point description and sensitivity	Shenatagh settlement. Under the planned bridge BR0016.		

Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☒ **Water**

Qirs-Kajaran section



Sampling and measurement points at sensitive receptors along the proposed Qirs-Kajaran section of the road

Point K1-ANVS	Piquet: ~ km 42+800	**GPS coordinates**	
		39°14'25.85"N	46° 8'37.24"E
Point description and sensitivity	Unpopulated area located at the distance of approx. 1.5km to the north from the crossing point of the existing road with the road to Nor Astghaberd		


Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

Point K2-W	Piquet: ~ km 44+100	**GPS coordinates**	
		39°13'45.48"N	46° 8'28.00"E
Point description and sensitivity	The Karut River, near the discharging point with the Geghi river		


Parameters to be measured				
☐ **CO, SO_2, NO_2, and PM2.5, PM10**	☐ **Noise**	☐ **Vibration**	☐ **Soil**	☒ **Water**

Point K3-ANVS	Piquet: ~ km 45+300	**GPS coordinates**	
		39°13'28.38"N	46° 9'18.30"E
Point description and sensitivity	Geghi settlement. In front of the nearest residential house (on the right side).		


Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

Point K4-V	Piquet: ~ km 46+400	**GPS coordinates**	
		39°13'18.10"N	46°10'2.09"E
Point description and sensitivity	Industrial facility (Ler-Ex HPP) within the administrative boundaries of Geghi settlement (on the right side).		


Parameters to be measured				
☐ **CO, SO_2, NO_2, and PM2.5, PM10**	☐ **Noise**	☒ **Vibration**	☐ **Soil**	☐ **Water**

Point K5-ANV	Piquet: ~ km 48+100	**GPS coordinates**	
		39°13'24.71"N	46°11'3.02"E
Point description and sensitivity	Geghi (Verin Geghavank) settlement. In front of the nearest residential house (on the right side).		


Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

Point K6-V	Piquet: ~ km 49+200	**GPS coordinates**	
		39°13'20.71"N	46°11'52.18"E
Point description and sensitivity	HPP within the administrative boundaries of Geghi settlement (on the right side).		

				
Parameters to be measured				
☐ **CO, SO_2, NO_2, and PM2.5, PM10**	☐ **Noise**	☒ **Vibration**	☐ **Soil**	☐ **Water**

Point K7-W	Piquet: ~ km 49+400	**GPS coordinates**	
		39°13'18.29"N	46°12'4.75"E
Point description and sensitivity	The Geghi river, before discharging point to Geghi reservoir		

				
Parameters to be measured				
☐ **CO, SO_2, NO_2, and PM2.5, PM10**	☐ **Noise**	☐ **Vibration**	☐ **Soil**	☒ **Water**

Point K8-ANV	Piquet: ~ km 52+500	**GPS coordinates**	
		39°12'53.48"N	46°14'5.71"E
Point description and sensitivity	Geghi (Geghavank) settlement. After dam of Geghi reservoir (on the left side).		

				
Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☐ **Soil**	☐ **Water**

Point K9-ANVS	Piquet: ~ km 53+250	**GPS coordinates**	
		39°12'34.57"N	46°14'30.67"E

Point description and sensitivity	Kavchut settlement. In front of the nearest residential house (on the left side).			
				
Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☐ **Water**

Point K10-ANVSW	Piquet: ~ km 56+050	**GPS coordinates**	
		39°11'11.75"N	46°14'49.08"E
Point description and sensitivity	Dzagikavan settlement. In front of the nearest residential house (on the left side). Water sampling from Voghji river.		

Parameters to be measured				
☒ **CO, SO_2, NO_2, and PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☒ **Soil**	☒ **Water**

Point K11-ANV	Piquet: ~ km 59+650	**GPS coordinates**	
		39°10'1.82"N	46°12'51.51"E
Point description and sensitivity	Lernadzor settlement. Near Electrical substation (pillar) / Pump station of ZCMC[56].		

[56] Zangezur Copper Molybdenum Combine

Parameters to be measured				
☒ CO, SO_2, NO_2, and PM2.5, PM10	☒ Noise	☒ Vibration	☐ Soil	☐ Water

Point K12-W	Piquet: ~ km 59+900	GPS coordinates	
		39° 9'52.83"N	46°12'49.39"E
Point description and sensitivity	Water sampling from Voghji river.		

Parameters to be measured				
☐ CO, SO_2, NO_2, and PM2.5, PM10	☐ Noise	☐ Vibration	☐ Soil	☒ Water

Sampling and measurement points at sensitive receptors along the existing roads Sisian-Shenatagh and Qirs-Kajaran

Point ER1-DNV	Piquet: -	GPS coordinates	
		39°31'6.69"N	46° 4'46.35"E
Point description and sensitivity	Near the hospital within the administrative boundaries of Aghitu village.		

Parameters to be measured				
☒ PM2.5, PM10	☒ Noise	☒ Vibration	☐ Soil	☐ Water

Point ER2-DNV	Piquet: -	GPS coordinates	
		39°31'15.96"N	46° 5'34.07"E
Point description and sensitivity	Near the school within the administrative boundaries of Noravan village.		


Parameters to be measured				
☒ PM2.5, PM10	☒ Noise	☒ Vibration	☐ Soil	☐ Water

Point ER3-DNV	Piquet: -	GPS coordinates	
		39°26'29.21"N	46° 7'26.63"E
Point description and sensitivity	Near St. Stephan church and museum within the administrative boundaries of Darbas village.		

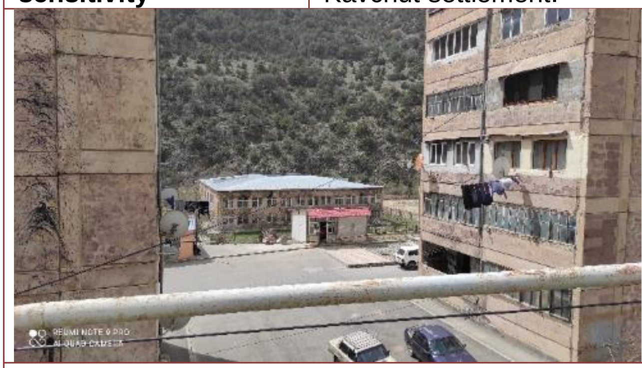

Parameters to be measured				
☒ PM2.5, PM10	☒ Noise	☒ Vibration	☐ Soil	☐ Water

Point ER4-DNV	Piquet: -	GPS coordinates	
		39°25'35.08"N	46° 7'31.24"E
Point description and sensitivity	Near Holy Mother church within the administrative boundaries of Getatagh village.		


Parameters to be measured				
☒ PM2.5, PM10	☒ Noise	☒ Vibration	☐ Soil	☐ Water

Point ER5-DNV	Piquet: -	**GPS coordinates**		
		39°24'45.79"N	46° 7'46.31"E	
Point description and sensitivity	Near St. Gevorg church and residential houses. Within the administrative boundaries of Lor village.			
				
Parameters to be measured				
☒ **PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☐ **Soil**	☐ **Water**

Point ER6-DNV	Piquet: -	**GPS coordinates**		
		39°22'38.50"N	46° 7'55.70"E	
Point description and sensitivity	Near the Memorial to R. Vasiryan within the administrative boundaries of Shenatagh village.			
				
Parameters to be measured				
☒ **PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☐ **Soil**	☐ **Water**

Point ER7-DNV	Piquet: -	**GPS coordinates**		
		39°12'14.62"N	46°15'7.17"E	
Point description and sensitivity	Near the 3 multi-residential buildings within the administrative boundaries of Kavchut settlement.			
				
Parameters to be measured				
☒ **PM2.5, PM10**	☒ **Noise**	☒ **Vibration**	☐ **Soil**	☐ **Water**

<table>
<tr><td rowspan="2">Point ER8-DNV</td><td rowspan="2" colspan="2">Piquet: -</td><td colspan="2">GPS coordinates</td></tr>
<tr><td>39°11'54.91"N</td><td>46°15'26.87"E</td></tr>
<tr><td>Point description and sensitivity</td><td colspan="4">Near the commercial facility located at the crossing point of M-2 road and the existing road to Qirs settlement.</td></tr>
<tr><td colspan="2"></td><td colspan="3"></td></tr>
<tr><td colspan="5">Parameters to be measured</td></tr>
<tr><td>☒ PM2.5, PM10</td><td>☒ Noise</td><td>☒ Vibration</td><td>☐ Soil</td><td>☐ Water</td></tr>
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