Contents

I. INTRODUCTION 6
I.1 Basis for conducting the study 6
I.3 Research Methodology 7
II. OVERVIEW OF THE RESEARCH AREA 13
II.1. Location 13
II.2. *Climate* 14
II.3. Geomorphological Features 24
II.4. Geological Formation 25
II.5. Tectonics 26
II.6. Earthquakes 28
II.7. Hydrogeological Conditions 30
II.8. Hydrological Conditions 38
Bayankhoshuu section 1 42
Bayankhoshuu section 2 43
Denjiin 1000 section 44
Khailaast section 45
Selbe River 46
Gants khudag section 47
Monel section 48
II.9. Permafrost 49
III. THE FIELD SURVEY WORKS 50
III.1. The Field Drilling Works 50
III.2. Soil Sampling 50
III.3. Standard Penetration Test 51
III.4. Pressiometric experiment 52
III.5. Dynamic Cone Penetrometer experiment 53

IV. ENGINEERING GEOLOGICAL AND GEOTECHNICAL CHARACTERISTICS, AND PHYSICAL-MECHANICAL ATTRIBUTES OF SOILS AND ROCKS IN THE INVESTIGATION AREA 54

BUILDING NORMS AND REGULATIONS /50-01-16/ 55

Soil of technogenic origin – tQ 55

EGE-1. Gravel with sand 55

EGE-2. Gravel with sandy loam 57

EGE-3. Loam 59

EGE-4. Clay (contains less than gravel) 61

EGE-5. Sandy loam 63

EGE-6. Gravel with loam 65

EGE-7. Gravel with clay 67

EGE-8. Gravel with sandy loam 70

EGE-9. Gravel with loam 72

EGE-10. Sandstone 74

HIGHWAY CLIMATE AND GEOTECHNICAL CONDITIONS /AZUAGN 2.01.01-2004/ 75

V. CONCLUSION 77

Longitude 79

VI. REFERENCES 86

VII. BOREHOLE CATALOG 87

VIII. BORING LOG 88

IX. PHOTO APPENDIX OF BOREHOLES` 95

APPENDIX MATERIAL – I

Borehole Location

Borehole Log

Laboratory Analysis of Soil Physical and Mechanical Properties

Standard Penetration Test (SPT)

Pressuremeter Test

Water Chemical Analysis

APPENDIX MATERIAL – II

Aerial Image Map, Scale 1:50,000

Geological Map, Scale 1:50,000

Tectonic Map, Scale 1:50,000

Hydrogeological Map, Scale 1:50,000

Hydrological Map, Scale 1:50,000

Seismic (Earthquake) Map, Scale 1:50,000

I. INTRODUCTION

I.1 Basis for conducting the study

In alignment with the Long-Term Development Policy of the Government of Mongolia, "Vision-2050", the Ulaanbaatar City Development Plan through 2040, and pursuant to Government Resolution No. 476 (2022) concerning the construction of the "SHINE TOIROG" (New Ring Road) in the capital city, as well as Order No. A/720 issued by the Capital City Government on June 19, 2024, the consulting firm CSCEC AECOM Consultants Co., Ltd. was formally appointed to undertake comprehensive reforms in road and bridge infrastructure.

Pursuant to Contract No. 25/05, dated May 15, 2025, entered into with Audi LLC for the provision of management and sub-consulting services under the "SHINE TOIROG 1" (New Ring Road 1) project-an initiative implemented within the framework of Ulaanbaatar's urban congestion mitigation program-comprehensive engineering geological and geotechnical investigations were undertaken.

The scope of the survey encompassed the designated tunnel structures along the project alignment, which include:

- Six (6) tunnel segments with a combined length of 2.02 kilometers
- Distributed along an 8.8-kilometer project corridor

These investigations were conducted over the period from May 15 to June 15, 2025, and were carried out to inform the development phase of the Technical and Economic Feasibility Study (TEFS).

Concurrently, in accordance with the contract and technical assignment executed between Land Test LLC and Avangard Design and Engineering LLC, an engineering geological survey was undertaken to support the preparation of the Technical and Economic Feasibility Study (TEFS) for the "SHINE TOIROG" (New Ring Road) project in Ulaanbaatar.

This survey was conducted over the period from March 10 to March 30, 2025, and focused on the proposed road alignment and associated infrastructure components within the project scope.

I.2 Field Study Location Overview

As part of the proposed "SHINE TOIROG 1" (New Ring Road 1) development project in Ulaanbaatar, a total of six (6) bridge structures and one (1) tunnel structure have been planned along the designated route. The locations and respective lengths of these structures are illustrated in the diagram below.

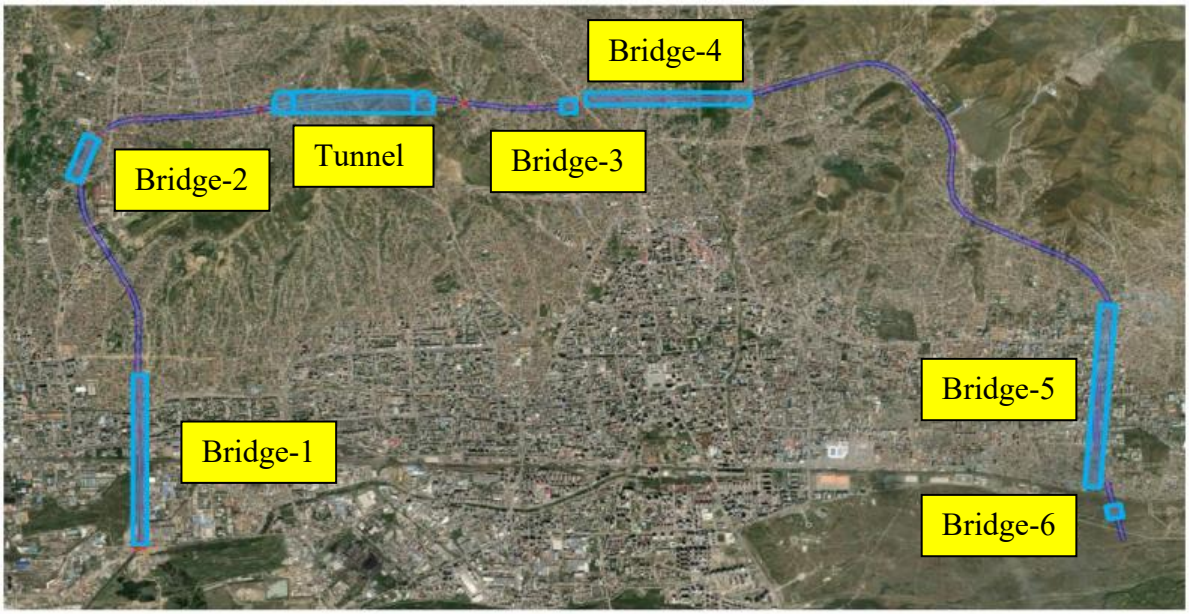

Figure I-1. *Location Map of Bridges, and Tunnel Structures – Shine Toirog 1 Project*

I.3 Research Methodology

- In accordance with the regulatory framework outlined in BNbD 11-03-21, Land Test LLC conducted geotechnical field investigations along the proposed alignment of the SHINE TOIROG 1 (New Ring Road 1) highway. A total of twenty-four (24) boreholes were drilled to depths ranging from 2.0 to 4.0 meters. The drilling activities were executed by Mr. Y. Zolbayar, under the technical supervision of Engineer-Geologist Mr. A. Orgilbold. Thirty-six (36) intact soil samples were collected from various locations along the highway corridor.
- Three (3) rock samples were extracted for detailed geomechanical analysis.
- All laboratory testing procedures were conducted by Ms. O. Ariunzaya and Ms. B. Enkhtuul, in full compliance with the applicable MNS (Mongolian National Standard) specifications.

In accordance with the technical assignment issued by AUDI LLC for design consultancy services, Terra Benefit LLC conducted comprehensive field surveys within the designated Bridge and Tunnel section of the SHINE TOIROG 1 (New Ring Road 1) project.

The fieldwork was executed by six (6) brigades under the leadership of Project Manager Mr. B. Enkhbat, and included the following personnel:

- Terra Benefit LLC:
    - Engineers: Ms. A. Ariunzaya, Mr. B. Belgudey
    - Supervisor: Mr. Ts. Od
    - Drill Masters: Mr. J. Batdelger, Mr. H. Batmanlay
    - Drilling Assistants: Mr. L. Otgon, Mr. H. Munkh-Aldar
- BIGS LLC:
    - Engineer: Mr. S. Battogtokh
    - Drill Masters: Mr. J. Naranhu
    - Drilling Assistants: Mr. Ch. Sumyaa
- Progress Engineering LLC:
    - Engineer: Mr. T.
    - Drill Masters: Mr. B. Gantulga
    - Drilling Assistants: Mr. N. Gantulga

Drilling activities were conducted in accordance with BNbD 11-03-21, utilizing specialized equipment including:

- UGB-1VS
- PBU-1
- UGB-50M
- POWER-6000
- SCHRAMM

A total of nineteen (19) boreholes were drilled to depths ranging from 10 to 42 meters, employing dry pipe drilling in sandy soils and stone column drilling techniques. The total drilled area amounted to 439 square meters.

These investigations provided essential subsurface data for the structural design and feasibility assessment of the bridge and tunnel components within the SHINE TOIROG 1 corridor.

The geological and geotechnical documentation pertaining to the tunnel field, including the evaluation of rock samples and mountain sediment formations, was prepared by Mr.G.Lhavgajargal, Geotechnical Engineer at Sardonyx LLC.

This work was undertaken in strict accordance with the JTG 3370.1-2018 standard, and was based on the technical assignment issued by the project subscriber. The documentation encompasses detailed stratigraphic profiling, lithological classification, and stability analysis of subsurface materials, serving as a critical input to the structural feasibility and safety evaluation of the tunnel section within the SHINE TOIROG 1 highway corridor.

In parallel with geological investigations, a comprehensive hydrogeological and hydrological survey was conducted to assess subsurface water conditions and surface water dynamics along the proposed alignment of the SHINE TOIROG 1 (New Ring Road 1) highway. Under the direction of Mr. L. Barhas, Hydrogeologist at Water Recovery LLC, a targeted private drainage experiment was performed to determine key groundwater parameters. The study focused on identifying locations with elevated or complex groundwater conditions that may affect construction feasibility.

Hydrogeological drilling operations were carried out by:

- Mr. L. Dashbyamba, Hydrogeologist
- Mr. R. Adyaajantsan, Drill Masters
- Mr. S. Enkhsaikhan, Drilling Assistant
- Mr. Sh. Batnasan, Driver

Drilling was executed using Canterra CT550 gas percussion equipment, enabling effective penetration in sandy soils and variable geological formations.

A hydrological analysis was conducted to estimate floodwater behavior along the highway corridor. This assessment utilized atmospheric satellite imagery and 30-meter precision elevation data to model flood scenarios under 1%, 5%, and 10% exceedance probability conditions within the urban context of Ulaanbaatar.

These findings are essential for evaluating drainage design, flood resilience, and environmental impact mitigation strategies within the scope of the Technical and Economic Feasibility Study (TEFS).

As part of the geotechnical investigation for the SHINE TOIROG 1 (New Ring Road 1) project, a series of in-situ tests and elevation measurements were conducted to determine the physical and mechanical properties of soils. A total of 129 elevation measurements were performed during drilling operations to establish the vertical profile and stratigraphic variation of the soil layers along the project corridor. To assess soil strength and deformation characteristics under field conditions, the following standardized tests were conducted:

- Standard Penetration Tests (SPT)
    - Conducted 16 times in accordance with the ASTM D1586 standard
    - Purpose: To evaluate soil resistance and relative density
- Dynamic Probe Tests
    - Performed 16 times
    - Purpose: To assess soil compaction and penetration resistance
- Pressiometric Tests
    - Executed 16 times
    - Purpose: To determine the modulus of soil deformation and assess compressibility under in-situ stress conditions

These tests provided essential data for the geotechnical characterization of the site and informed the design parameters used in the Technical and Economic Feasibility Study (TEFS).

The laboratory analysis was conducted by a team comprising Ts. Gerelee and Ts. Sarangerel, with the assistance of laboratory staff from Terra Benefit LLC, under the supervision of Senior Specialist A. Ariunzaya. The responsibility for the development of the settlement was assigned to the designated project subscribers.

The following laboratory tests were performed as part of the geotechnical investigation:

1. Analysis of the composition of soil practicle sizes (Sand) – 5 samples
2. Analysis of the composition of soil practicle sizes (Clay) – 124 samples
3. Determination of natural moisture content – 129 samples
4. Determination of specific gravity – 129 samples
5. Determination of wet density – 129 samples

6. Determination of liquid limit – 124 samples

7. Determination of plastic limit – 124 samples

8. Degree of soil weathering – 12 samples

9. Rock Direct shear– 2 samples

10. Strength Testing of Rock – 2 samples

A total of five groundwater samples were collected along the highway corridor. Detailed hydrochemical analyses were conducted at the laboratory of *Institute of Geography and Geoecology*. Additionally, samples obtained from the Hydrogeological Monitoring Unit were submitted to the *SGS IMME* laboratory for advanced testing and verification.

Table I-1 Amount of Total Work Completed

Description		Unit	Quantity	Total Amount
Drill	19 boreholes with depths ranging from 10 to 42 m deep	Steadfast meters	19	439
Field Experiments	SPT experiment	1 point	16	16
	Dynamic Probe Experiments	1 point	16	16
	Pressiometer experiments	1 point	16	16
Elevation	About 30% of the total number of square footage	Sample	129	129
	Groundwater	Sample	5	5
	Stone Samples	Sample	4	4
Laboratory Experiments and Tests	Physical and Mechanical Properties of Soils	Natural moisture	129	129
		Elements of the Fur		
		Aerometer		
		Tight		
		Tightness of the Solid Part		
		A Quiet Nalarhai		
	Mechanical properties of rocks	Degree of soil weathering, Rock Direct shear, Strength Testing of Rock	4	4
Report	Engineering, Geology, and Geotechnical Report	volume	1	1

All relevant field and processing materials—including drilling site photographs, borehole lithological profiles, borehole logs, soil laboratory test results, Standard Penetration

Test (SPT) data, pressiometry test results, and dynamic probing test records—are compiled and presented in Appendix 1.

As part of the research initiative, thematic imagery pertaining to the M1 section of the "SHINE TORIOG" Highway has been compiled at a scale of 1:50,000. The materials include atmospheric imagery, documentary records, geological imagery, tectonic imagery, hydrogeological imagery, hydrological imagery, and seismic micro-imagery. These datasets are systematically presented in Appendix 2.

As part of the TPP phase of the project, a comprehensive research report was prepared by a multidisciplinary team consisting of:

- Ch. Batsukh – Doctor of Geography (PhD), Consultant Engineer of Mongolia
- A. Ariunzaya – Doctoral Student
- B. Enkhbat – Doctoral Student
- B. Belgudei – Master Engineer
- A. Battushig – Master Geologist
- L. Barkhas – Hydrogeologist
- G. Lhagvarjargal – Geotechnical Engineer

In addition, *Land Test* compiled a summary report focusing on the highway component of the Technical and Economic Feasibility Study (TEFS) phase.

All source materials associated with the research have been systematically archived and securely maintained within the official records of *Terra Benefit LLC*.

II. OVERVIEW OF THE RESEARCH AREA

II.1. Location

The proposed SHINE TOIROG Highway 1 is a major infrastructure initiative currently under planning. The route is designed to traverse several administrative districts within Ulaanbaatar, including Bayangol District, Songinokhairkhan District, Sukhbaatar District, and Bayanzurkh District (refer to Table II-1). The project scope includes the construction of roadways, bridges, and tunnels along the designated corridor (see Image II-1).

Table II-1. Total Route Length by District and Associated Bridge and Tunnel Construction

Table II-1

No	Type of construction	District	Total length, km
1	Bridge-1	Bayangol	2.6
2	Bridge-2	Songino khairkhan	0.9
3	Tunnel	Songino khairkhan-Chingeltei	2.02
4	Bridge-3	Sukhbaatar	0.14
5	Bridge-4	Chingeltei-Sukhbaatar-Bayanzurkh	2.4
6	Bridge-5	Bayanzurkh	2.6
7	Bridge-6	Bayanzurkh	0.2

Figure II-1. *Layout of the "Shine Toirog Highway 1" Route Including Roadway, Bridge, and Tunnel Construction*

II.2. *Climate*

The research area is located within the Khan Khentii mountain range, characterized by a high-altitude atmospheric environment. For the purposes of Mongolian construction planning, the climatic classification of this region is determined in accordance with the standards set forth in *BNbD 23-01-09: Climate and Geophysical Indicators for Construction Applications*.

a.Climatic indicators used in this assessment are based on long-term observational data obtained from the National University of Mongolian (NUM), Amgalan, Dambadarjaa, and Takhilt meteorological stations. These data provide a reliable foundation for defining the construction-relevant climate zone of the study area (refer to Table II-2).

Given the complexity of the terrain and variability in climatic conditions, further detailed analysis and preparatory work are essential to ensure the suitability and resilience of construction activities in this high-altitude zone.

Table II-2. Average Annual Outdoor Temperature (°C)

Meteorological Stations	Months												year
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Octo	Nov	Dec	
NUM	-21	-15	-7.9	2	10	15	18	15	9	0.3	-11	-19	-0.5
Amgalan	-22	-18	-8.8	1	9.2	14	16	15	8	0.9	-12	-18	-1.2
Dambadarjaa	-23	-19	-10	1	8.8	13	16	14	7	-0	-12	-20	-2.1
Takhilt	-22	-16	-7.9	2	10	15	18	16	9	0.4	-11	-19	-0.6

Table II-3. Maximum Recorded Outdoor Temperature (°C)

Meteorological Stations	The highest absolute	Date	The absolute average in July
NUM	33.8	Aug.31.01989	31.6
Amgalan	33.5	June.20.1969	30.2
Dambadarjaa	33.8	Aug.31.1989	31.6
Takhilt	38.2	July.28.1999	30.4

Table II.4 Minimum Outdoor Air Temperature (°C)

Meteorological Stations	The lowest absolute	Date	The absolute average in January
NUM	-36	Jan.23.1988	-31.9
Amgalan	-39	Jan.14.1967	-32.0
Dambadarjaa	-36	Jan.23.1988	-31.9
Takhilt	-39.6	Jan.30.1979	-33.7

Table II.5 Estimated Indoor Temperatures for Buildings, Facilities, and Technical Installations

Meteorological Stations	Outdoor air temperature ^{0}C				
	The Coldest Period				A day temperature during the hottest period
	1 day	3 days	5 days	Air Exchanges	
NUM	-31.4	-30.3	-28.9	-25	26.4
Amgalan	-36.9	-35.6	-34.8	-25.8	23.8
Dambadarjaa	-35.7	-34.6	-33.6	-25.8	24.1
Takhilt	-31.8	-30.5	-29.4	-24	25.8

Table II.6 Calculation of Heating Time

Meteorological Stations	Heating Time				
	Start date	End Date	duration (Days)	Average temperature for the heating season, ^{0}C	Heating season energy, ^{0}C
NUM	17.09	8.05	233	-8.8	-2049.4
Amgalan	15.09	13.05	240	-8.9	-2136.7
Dambadarjaa	11.09	13.05	244	-9.5	-2325
Takhilt	17.09	8.05	233	-8.8	-2049.4

Table II.7 Air Humidity and Precipitation Levels

Meteorological Stations	Hur Sediments							
	Hot Month	Cold Month	year	Warm-period	Daily Maximum	year	month	Day
NUM	52	71	271.2	255.8	53.8	2003	07	18
Amgalan	67	72	245.2	232.5	68.6	1966	07	11
Dambadarjaa	52	71	271.2	255.8	53.8	2003	07	18
Takhilt	48	70	269.2	252.4	79.7	1984	08	27

Table II.8 Thunder Sound and Thunderstorm Classification

Classification	Thunder Sound and Thunderstorm			1 Thunder	Number of thunderbolts per 1 km2 area
	Day	Average duration, time	Longest Hour, in hours	minutes	
II	22-36 /29/	43-50 /46/	56-100	83-121 /94/	5-6

Table II.9 Recurrence and Stress Regions of Precipitation (Wet Snow, Sleet, Freezing Conditions)

Classification	Wet Snow		**Sleet**		Freeze		
	Number of days	Duration in hours	Number of days	Duration in hours	Number of days	Duration in hours	Thickness, mm

							Years	
							10	5
II	5-10	3-5	5-10	15	1-2	1-3	15	10

The standard freezing depth for seasonal soil freezing in Mongolia is specified in Table 1-01-09 of the national construction standard BNbD 23-01-09, titled "Climatic and Geophysical Parameters for Construction".

This table includes freezing depths for various locations such as:

- NUM
- Khureltogoot
- Dambardarjaa
- Takhilt

Table II.10 Standard Depth of Seasonal Soil Freezing (in meters)

No	EGE* Number	Soil Name	Seasonal freeze depth, m			
			NUM	Khureltogoot	Dambadarjaa	Takhilt
1	EGE-1	Gravel with sand	3.51	3.49	3.67	3.59
2	EGE-2	Gravel with sandy loam	3.51	3.49	3.67	3.59
3	EGE-3	Loam	2.46	2.44	2.57	2.51
4	EGE-4	Clay	2.46	2.44	2.57	2.51
5	EGE-5	Sandy loam	2.99	2.97	3.12	3.05
6	EGE-6	Gravel with loam	3.51	3.49	3.67	3.59
7	EGE-7	Gravel with clay	3.51	3.49	3.67	3.59
8	EGE-8	Gravel with sandy loam	3.51	3.49	3.67	3.59
9	EGE-9	Gravel with loam	3.51	3.49	3.67	3.59
10	EGE-10	Sandstone	At the upper boundary of the rocky soil			

* EGE- engineering geological elements

The study area is classified under Region II according to the Mongolian national standard for snow load on the surface of the land. In accordance with this classification, the normalized snow cover load is defined as 50 kg/m².

b. The climatic and geotechnical parameters relevant to the highway areas within the study region are systematically presented in tabular format, in accordance with the provisions of the standard “Climate and Geophysical Indicators for Use in Construction” (AZUAGN 2.01.01-2004).

Table II-11 Zone definition

Number and name of zone	Sub-Zone Index	Summary with the zone	Climatic and Soil Conditions
II. Climatic Steppe Zone of the Highway Corridor	II B. Intermontane Steppe Subzone	- Dry–Cold, Moderately Cool, Harsh, Semi-Arid, Cold Intermontane Steppe Subzone for Highway Climate Classification	-The Steppe Subzone is prone to seasonal soil freezing, which causes frost heave and settlement. Snow cover is thin, and winters are harsh and dry. -Earthquake 6-7 points.

Table II-12 Highway Climate Zones

Zone	Sub-zone	Winter			Spring		Summer		Autumn
		Start	End	Duration in days	End	Duration in days	End	Duration in days	Duration in days
II	II B	Sep.1-9 Sep.5	Mar.15-24 Mar.19	126-143 134	May.6-12 May.9	45-52 48	Sep.6-19 13.09	112-156 129	44-54 49

Table II-13 Soil air temperature (C) indicator

Zone	Sub-zone	Soil surface temperature, ^{0}C				Average air quality temperature, ^{0}C		
		Multi-annual mean	The Hottest	The Coldest	0° penetrating depth, cm	Multi-annual mean	The coldest month of the year	Warmest Month
II	II B	+0…+3	60-65	-41…-45	250-350	-2…+2	-20…-25	15… 20

Table II-14 Soil Freezing-Melting Climate time period

Zone	Sub-Zone	Freeze			Melt		
		Start	End	Days	Start	End	Days

II	II B	Oct.20-30 Oct.25	Mar.15.III- Apr.30 Apr.5	120-195 160	Mar.15 - Apr.10 Mar.25	Apr.15 - May.31 Apr.23	20-50 35

Table II-15 Depth of seasonal freezing standards in Mongolia's highway zones

Zone	Sub-Zone	EGE Number	Soil Name	Seasonal freeze depth, m
II	IIB	EGE-1	Gravel with sand	3.5
		EGE-2	Gravel with sandy loam	3.5
		EGE-3	Loam	2.5
		EGE-4	Clay	2.5
		EGE-5	Sandy loam	3.0
		EGE-6	Gravel with loam	3.5
		EGE-7	Gravel with clay	3.5
		EGE-8	Gravel with sandy loam	3.5
		EGE-9	Gravel with loam	3.5
		EGE-10	Sandstone	At the upper boundary of the rocky soil

Table II-16 Suitable Periods for Road Construction Work

Zone	Sub-Zone	Warmer Season			Cold Season
		start	End	Days	Days
II	II B	Apr.10	19.X	192	173

Table II-17 Wind speed, air pressure, and relative humidity for the four seasons of the year on the road

Zone	Sub-Zone	Wind speed, m/s				Pressure, mm Hg column height	Relative humidity, %
		Winter	Spring	Summer	Autumn		
II	II B	1.6-4	3-7	2-4	2.5-5.5	600-650	50-60

Table II-18 Precipitation levels in highway climatic zones, mm

Zone	Sub-Zone	Precipitation total, mm							
		Winter	Spring	Summer	Autumn	Years	Rainfall per 1 day, mm		Maximum rainfall energy mm/min
							2%	1%	
II	II B	3-10	15-30	150-200	20-35	220-250	80	104	1-1.50

Table II-19 Solar radiation and solar irradiance in the highway climate zone

Zone	Sub-Zone	Solar radiation, Md/m2			Sunshine and Clock				
		Sum	Direct	penetraded	Year	Dec	June	On the Dec day	On the Juny day
II	II B	4500-5300	2700-3200	3500-3700	2700-3300	150-200	270-300	6-7	9-10

Table II-20 Climatic phenomena that can negatively affect the level of road technical use, their effects, and cycle size

Zone	Sub-Zone	The harshness of the technical climate,in points.		Climate change in poinst	Total lightning activity		1 Thunderbolt's	
		Cold	Heat		Number of days	Duration in hours	Duration, minutes	Number of areas per 1 km2
II	II B	50-60	20-25	3-3.5	25-35	40-45	80-110	5-6

Continuation of Table II-21

Zone	Sub-Zone	Wet Snow		Sleet		Glacier		
		Number of days	Duration in hours	Number of days	Duration in hours	Number of days	Thickness, mm in 10 years	Thickness, mm 5 years
II	II B	3-5	3-4	3-5	10-13	1-2	10	5

Continuation of Table II-22

Zone	Sub-Zone	Load, kg/m2		Time of Metal Rust in hours	Inappropriate number of days					
		Wind	Snow		Heat	Snowstorms	Dust storms	Strong winds	Rainy	Snowy
II	II B	40-55	40-60	1500-2000	25-40	3-4	10-30	8-15	40-60	20-35

Continuation of Table II-23

Zone	Sub-Zone	Sum of Heat Reserves,° C		Sum of Cold Storage Supply,° C			Cold Snap Time in hours		
		+20	+25	-20	-25	-30	-20° C	-30° C	-40° C
II	II B	800-2000	1000-1300	-300-2000	-900-1000	-1000-1500	1300-1600	200-400	1-5

Continuation of Table II-24

Zone	Sub-Zone	Stable Snow Cover					
		Snow cover	Melting	Days	Thickest average, cm	Density, g/cm3	Storage water
II	II B	Nov.20 - Dec.1	Mar.10-20	60-120	10-15	0.20-0.25	10-20

Continuation of Table II-25

Zone	Sub-Zone	Time period of slippery condition on the road during a steady cold		Cold season temperatures (>8 m/s) and harsh periods		Soil moisture reserves 0-50 cm deep, mm	
		Start	End	Number of days	Time	Spring	Autumn
II	II B	Dec.1	Mar.15	100-125	500-650	10-30	30-50

Table II-26 Some indicators of the surface water regime of rivers

Zone	Sub-Zone	Surface water in a river							
		compactness	Average annual flow, l/sec	Average flow layer, mm	flash flood Peaks, mm	Module, l/sec, am.km	Average ice thickness, cm	Ice retention period	Ice Breakdown Time
II	II B	0.04-0.2	1-2	25-100	10-100	0.4-0.8	100-125	10-Sep.20	earlier than May.21

Table II-27 Bioclimatic Conditions of Outdoor Highway Workers

Zone	Sub-Zone	Oxygen density, g/cm3	Warmth of clothing, CLO (considered for harsh working conditions).			Atmosphere in the human body, days		
			Winter	Spring and autumn	Summer	comfortable	incomfortable	hard
II	II B	250-260	4.6-5.5	2.8-3.0	1.5-1.7	175-190	110-120	80-90

Table II-28 Factors for assessing the impact of climate change on road construction and road workers' labor

Zone	Sub-Zone	Impact and Service				
		Cold	Hard	Heat	Precipitation	Humidity
II	II B	1.00	1.00	1.00	1.00	1.00

Continuation of Table II-29

Zone	Sub-Zone	Impact and Service			
		Strong Winds and Storms	Thunder and Lightning	1 Heavy Rainfall	Snow
II	II B	1.00	1.00	1.00	1.00

Continuation of Table II-30

Zone	Sub-Zone	Impact and Service						Basic Climate
		The Impact of Labor Protective Clothing			The Effects of Climate on the Human Body			
		Winter	Spring and autumn	Summer	comfor table	incomfortable	hard	
II	II B	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table II-31 Suitable time for the preparation and laying of hot asphalt concrete mixture in highway climatic zones

Zone	Sub-Zone	Asphalt and road pavement		
		Start	End	Days
II	II B	Apr.18 -May.16 (May.2)	Mar.15 – Sep.19 (Sep.1)	91-154 (122)

Table II-30 Suitable time for cold and warm asphalt concrete paving in highway climate zones

Zone	Sub-Zone	Asphalt and road pavement		
		Start	End	Days

II	II B	Mar.3- Mar.30 (Mar.16)	Oct.30 -Dec.4 (Nov.15)	220-278 (250)

Table II-31 Soil moisture-thermal regime cycles of highway embankment

Zone	Sub-Zone	Autumn moisture accumulation in road dams			Winter moisture accumulation in dams		Moisture in the roadway		Road Dams Dry
		Start	End	Days	End	Days	End	Days	Days
II	II B	Oct.10	Sep.15	36	Apr.1	137	May.20	49	143

Table II-32 Minimum thickness for elevation of the surface of a road to be built without a ditch or dam above the level of the groundwater level and for the replacement of the soil.

Soil during Work	Minimum elevation of the pavement surface, m (For highway zones)
	II B
Fine grain sand, large grain light sandy loam	0.75
Silt sand, siltty sands	1.1
Heavy silt sandy loam, Light silt loam, Heavy silt loam	$\frac{1.5}{0.3}$
Light and Heavy loam and Clay	$\frac{1.8}{0.4}$

Table II-33 Choosing the height of the road embankment to avoid being swept away by snowdrifts

Zone	Sub-Zone	Calculate the minimum possible height of the embankment, (m) For each technical grade of the road				
		I	II	III	IV	V
II	II B	$\frac{0.1-0.15}{0.84}$	$\frac{0.1-0.1}{0.35}$	$\frac{0.1-0.15}{0.28}$	$\frac{0.1-0.15}{0.24}$	$\frac{0.1-0.15}{0.18}$

II.3. Geomorphological Types

The research zone is positioned in a circular arc stretching from the western to the eastern edges of Ulaanbaatar, following the northern boundary of the city. This area intersects a variety of depressions and sediment layers, each shaped by distinct geomorphological processes.

Located in central Mongolia, the site lies within the mountainous terrain and valleys of the southeastern section of the Khangai mountain range. The region features a moderate elevation, combining upland ridges and basin landscapes, which play a significant role in influencing the area's climate, hydrology, and geological structure.

-Bridge-1 hillock I Sedimentation and Accumulation Surface of the Tuul River;

-Bridge-2 Mountain slopes and accumulation surfaces;

-The Tunnel Field is a type of erosion and mountainside surface;

-Bridge-3 Mountain slopes and accumulation surfaces;

-Bridge-4 Slope and Accumulation Type;

-Bridge-5 Slopes and Accumulation Types Surface – Flood II Sedimentation and Accumulation Type;

-**Bridge-6** The hillock River I River Sedimentation-Accumulation Type-Sedimentary Surfaces, respectively.

The highway has its highest surface (1,519.02 m) and lowest point (1,271.99 m).

In the northern section of the study corridor—particularly around the Chingeltei, Sharkhad, and Dari-Ekh branches—there are conditions favorable for linear erosion caused by small intermontane gullies and meandering channels. These features indicate active surface runoff and localized washing of soil and sediments along the slopes.

In contrast, the valley of the Tuul River, especially at the southeastern and right-hand ends of the strip, is characterized by a flat terrain. This area experiences low-intensity surface runoff and is occasionally affected by shallow flooding due to the accumulation of water on the ground surface.

II.4. Geological Formation

Ulaanbaatar is located within the Ulaanbaatar Terrane, part of the Khangai-Khentii orogenic system in central Mongolia. This region is classified under the Orogenic Province in Mongolia's tectonic framework, as described by O. Tumurtogoo (2012).

The terrane is geologically diverse, consisting of:

- Turbidite formations from the Ordovician to Carboniferous periods, including sequences from the Ordovician–Lower Silurian, Late Silurian–Devonian, and Devonian–Carboniferous.
- A complex structure of tectonic Borehole and slices, which resemble oceanic plate stratigraphy first identified by Japanese geologists in the Pacific region [Wakita & Metcalfe, 2005].
- These older rock units are overlain by:
    - Permian volcanic and sedimentary (terrigenous) molasse deposits, and
    - Late to Early Triassic granitoid intrusions.

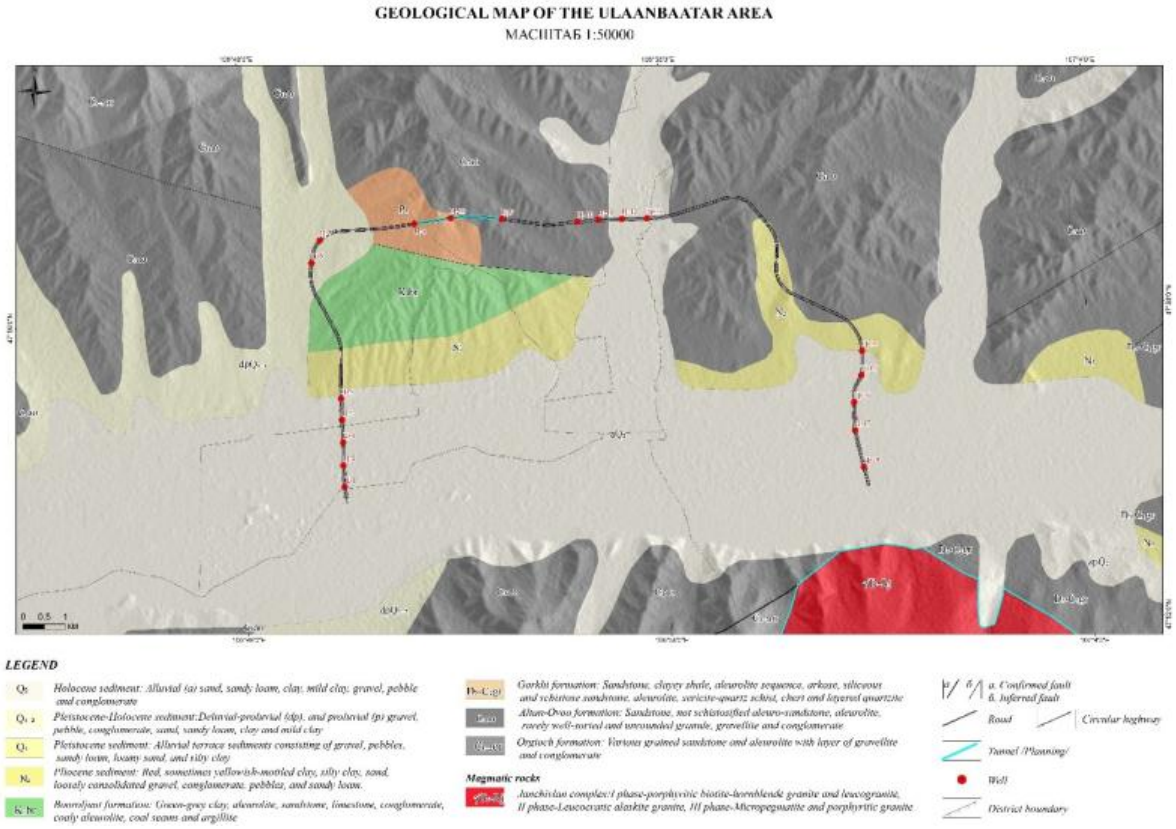

Figure II-2. *Geological Map Overview of Ulaanbaatar*

The route of SHINE TOIROG Highway 1 crosses several distinct geological formations, including:

- Stream Formation (S4–D3gr)
- Golden-Ovoo Formation (C_1ao)
- Orgioch Formation (C1–2or)
- Buuruljuut Formation (K1br)

These formations consist of various sedimentary and possibly volcanic rocks, reflecting a complex geological history.

Drilling surveys along the route have identified:

- Brownish-yellow and greenish-gray sandstones originating from eluvial-deluvial processes (edQ).
- Brownish-yellow, Brown red clay, clay with gravel, sandy loam with gravel, sand with gravel, sandy loam, loam indicating deposits from the Holocene and Pleistocene epochs (Q1–2).

II.5. Tectonic

The city of Ulaanbaatar is tectonically composed of the following 3 types of structural formations /**Error! Reference source not found.**/. These include:

- Paleozoic structures
- Mesozoic structure
- Cenozoic structure

Tectonically the area along the proposed highway is as follows:

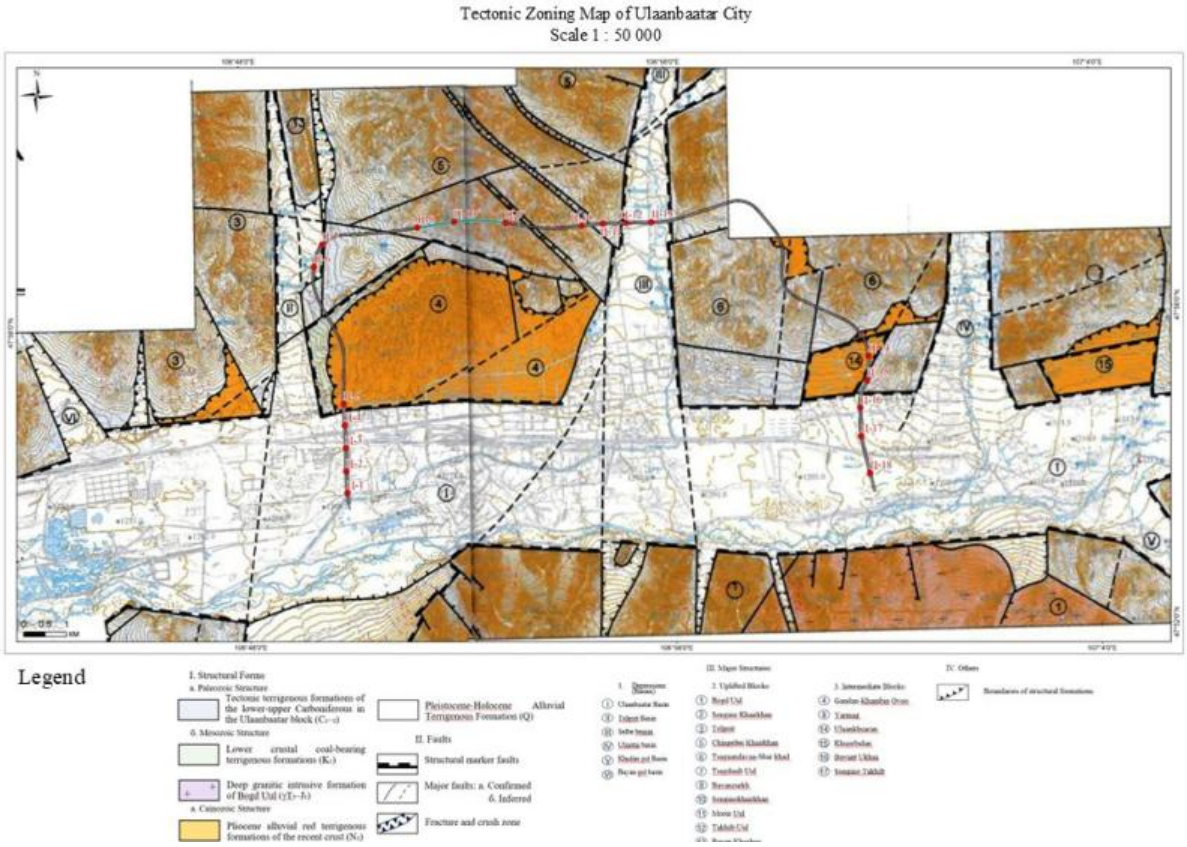

Figure II-3. *Tectonic map of Ulaanbaatar*

-Bridge-1

The Pleistocene–Holocene continental terrigenous deposits (Q) are associated with the Ulaanbaatar area, particularly in its northern section, at an elevation of approximately 220 meters.

To the south, the Pliocene continental terrigenous formation (N2) is linked to the Uliastai area. These two geological units are positioned along a structural boundary within the regional cross-section, marking a transition between different sedimentary environments and geological time periods.

The Pleistocene-Holocene continental terrigenous formation (Q) belongs to the Ulaanbaatar settlement, about 220 m in the northern part, and belongs to the Pliocene continental terrigenous formation (N_2) and the Uliastai settlement, and is located on the structural boundary of the cross-section.

-Bridge-2

The Pleistocene–Holocene continental terrigenous deposits (Q) in this area are part of the Tolgoit Formation. The bridge alignment crosses a structural boundary within the

geological cross-section, indicating a transition between different subsurface formations or tectonic zones.

-Tunnel

The Lower to Upper Carboniferous terrigenous sedimentary formation (C1–2) found in the Ulaanbaatar region is associated with an uplifted structural block known as the Chingeltei Khairkhan. This elevated zone contains sedimentary layers formed during the Carboniferous period, primarily composed of continental-derived materials.

-Bridge-3

The terrigenous sedimentary formation from the Lower to Upper Carboniferous period (C1-2) in the Ulaanbaatar region is part of the Chingeltei Khairkhan Uplifted Block. This formation remains undivided by any geological structures or subdivisions.

-Bridge-4

The route traverses several geological units in the Ulaanbaatar region, including the Lower to Upper Carboniferous terrigenous sedimentary formation (C1-2) within the Chingeltei Khairkhan Uplifted Block, the Pleistocene-Holocene continental terrigenous sedimentary formation (Q), the Selbi Settlement area—also situated on the Carboniferous terrigenous formation (C1-2), and the Tsagaandavaa-Sharhad uplifted block.

-Bridge-5

The Ulaanbaatar metropolitan area includes several geological units: red-colored terrigenous deposits from the Pliocene continental formation (N2), the Ulaankhuaran intercession block characterized by Lower to Upper Carboniferous terrigenous sedimentary rocks (C1-2), and the Pleistocene-Holocene continental terrigenous formation (Q). Along the bridge route, structural boundaries intersect at various crossing points.

-Bridge-6

The Pleistocene-Holocene continental terrigenous formation (Q) is a geological component of the Ulaanbaatar metropolitan region.

II.6. Earthquakes

The proposed highway route falls within the seismic microregion of Ulaanbaatar city, with seismic intensity levels of VIII (SPL 191-205 cm/s2), VIII (SPL 143-190 cm/s2), and VII (SPL 110-142 cm/s2).

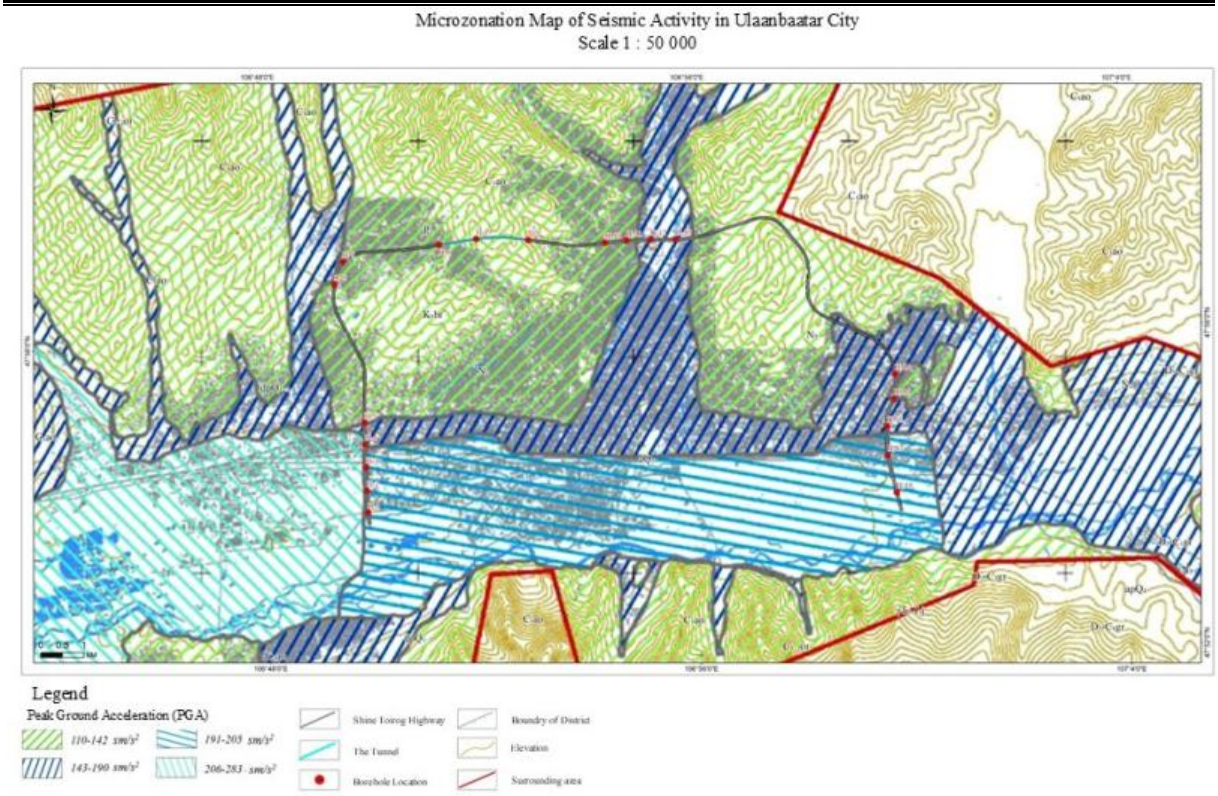

Figure II-4 *Ulaanbaatar earthquake microdistrict*

No	Type of Facilities	Peak Ground Acceleration /PGA/	Point	Peak Ground Acceleration /PGA/	Point
1	Bridge-1	191-205	VIII	143-190	VIII
2	Bridge-2	110-142	VII		
3	Tunnel	110-142	VII		
4	Bridge-3	110-142	VII		
5	Bridge-4	143-190	VIII		
6	Bridge-5	143-190	VIII		
7	Bridge-6	143-190	VIII	191-205	VIII

II.7. Hydrogeological Conditions

Along the project highway, 18 boreholes were drilled for engineering-geological and geotechnical investigations, and one borehole was drilled for hydrogeological conditions. Deep groundwater was encountered in the surveyed areas, as presented in Table II-2.

Table II-2 Groundwater level Detection and Fixed Depth /as of 2025/05/16-2025/05/27/

*BH-borehole

Borehole Number	Location of the Lock	Groundwater level, m	
		target	static
*BH-1	Bridge-1	6.8m,27.2m	6.0 m
BH -2	Bridge-1	6.2m	4.5m
BH-3	Bridge-1	4.2m	4.0m
BH -4	Bridge-1	2.2m	2.2m
BH -6	Bridge-2	8.4m	6.0m
BH -7	Bridge-2	6.0m	6.0m
BH -10	Bridge-3	3.0m	2.0m
BH -12	Bridge-4	4.4m	2.0m
BH -13	Bridge-4	2.0m	0.6m
BH -14	Bridge-5	2.8m	2.8m
BH -16	Bridge-5	9.0m	6.0m
BH -17	Bridge-5	9.0m	6.0m
BH -18	Bridge-6	9.0m	9.0m

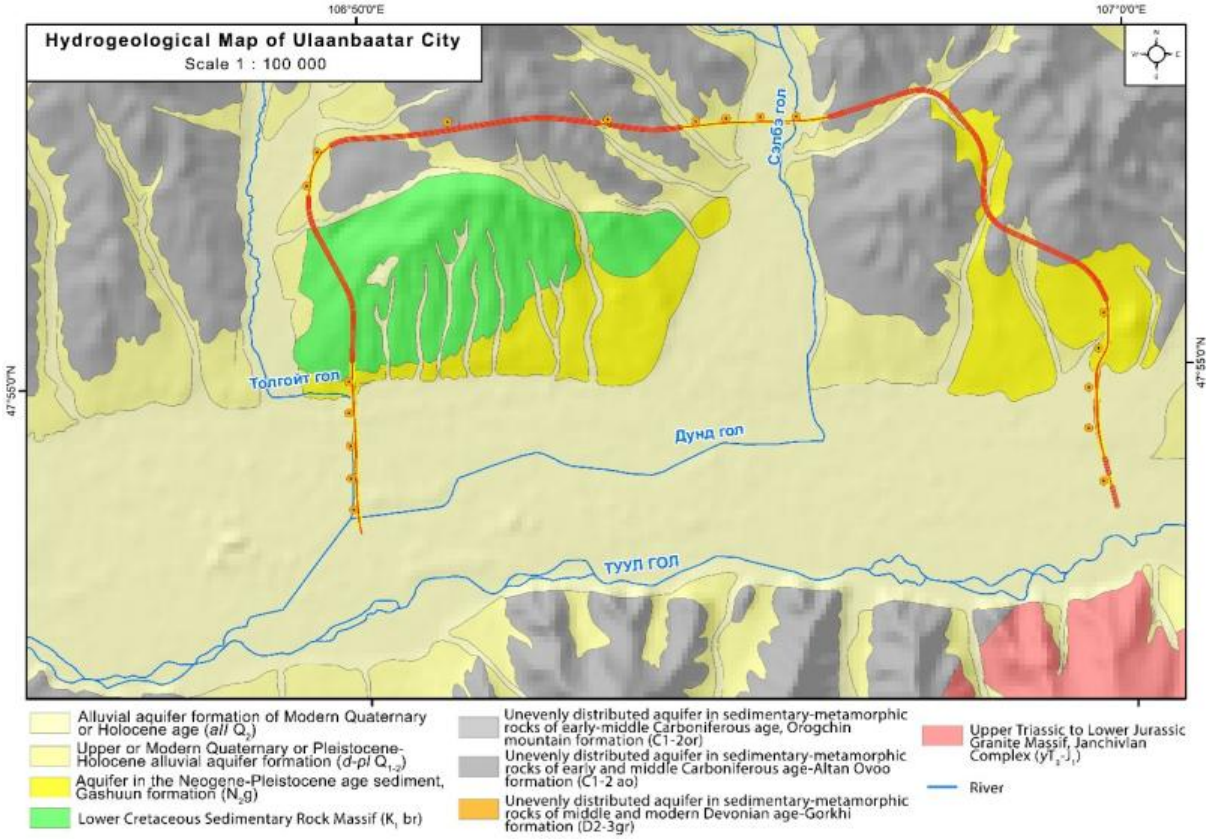

Figure II-5 *Hydrogeological Map of Ulaanbaatar*

For the "SHINE TOIROG Highway 1" project, hydrogeological assessments show that boreholes in the western, eastern, and northern areas of Ulaanbaatar encounter relatively low groundwater levels, indicating minimal interference from groundwater during construction. Borehole BH-1 was specifically drilled to bedrock for hydrogeological testing (refer to Image II-5). This location is near major water sources for the city, such as the Makh kambinat (Meat Processing Plant) Source to the west and the Industrial Source to the southeast. The site was chosen based on hydrogeological reports highlighting challenges like thick groundwater layers and significant sediment accumulation along the route.

Figure II-6 *Location of the Hydrogeological Research Unit*

Engineering hydrogeological drilling was performed using a step-by-step approach, addressing several key aspects. These included an in-depth analysis of the geological profile at the drilling site, identification of its lithological and rock characteristics, and evaluation of the geological structure and stratigraphy of the surrounding area. The study also examined the fundamental hydrogeological conditions. Additionally, the age, velocity, and density of the rocks encountered during drilling were categorized based on the distinct properties of their lithological and rock composition.

The borehole was drilled using a Canterra CT550 rig, manufactured in the United States. The survey was designed to utilize a 219 mm casing and was implemented with a single drainage chamber configuration.

Figure II-7. *Monitoring Borehole Drilling Process*

Shale samples were collected at one-meter intervals during drilling to determine rock depth and the thickness of the aquifer layer. The high-resolution data obtained enabled precise evaluation of the water layer's characteristics. A 219 mm steel pipe was used, with 20 cm long and 3 mm wide slots cut into the drainage sections. The length of the screens was selected based on the borehole type and the thickness of the water-bearing layers, and they were installed fully in accordance with standard methodology.

Figure II-8. *A broom with a basement*

To support the installation of pipes and drilling equipment at the required depths in hydrogeological boreholes, provisions were made for effective drainage, hydrochemical treatment, and hydrogeological monitoring and measurements. Additionally, all necessary tools, instruments, and equipment related to the hydrogeological experiments and drainage operations were properly placed and assembled within the borehole.

A single-level drainage test was conducted over a 24-hour period to gather preliminary hydrogeological data of the basin, such as flow rate, water level drawdown, groundwater movement, and depth. These measurements were obtained using a specialized field testing and drainage setup. Flow was monitored with a level gauge, and the collected data were analyzed accordingly (see *Figure* II-9).

Figure II-9 *yield determination meter B. Drainage test Process*

During the test-drain procedure, the extracted water was discharged into a small river located approximately 200 meters west of the site, where a flood control dam was present. Throughout the process, no water flowed back into the experimental drainage borehole.

Figure II-10 *Experiment-Drain Water Reservoir*

After the test, water samples were collected and transported following the standards MNS 3934:1986, "Water for Domestic and Industrial Supply – Methods for Chemical Analysis Sampling," and MNS ISO 5667-11:2000, "Guidelines for Deep Water Sampling." Samples were placed in 1.5-liter clean containers. Each container was rinsed twice with the test water

before being completely filled to eliminate air gaps, preventing oxygen interaction and agitation during transport. The samples were then stored in a cool, dark environment to maintain their quality.

The groundwater found throughout the study area contains the following chemical elements and compounds:

- BH-1: Sulphate-class, calcium group, type 3, qualitatively salty, very hard, and contaminated water.

  Water Composition: $M_{2.2}$ $\underline{SO_4^{-2}33HCO_3^{-}32Cl^{-}26}$

  $Ca^{2+}59+Mg^{2+}25Na^{+}+K^{+}14$

- BH-7: Sulphate-class, mixed-group, type 2, qualitatively salty, very hard, and contaminated.

  Water Composition: $M_{2.2}$ $\underline{SO_4^{-2}50HCO_3^{-}26Cl^{-}18}$

  $Na^{+}4+K35CA^{2+}33Mg^{+}32$

- BH-12: Hydrocarbonate class, calcium group, type 3, pure, very hard, polluting, and contaminated water.

  Composition of water: $M_{0.8}$ $\underline{HCO_3^{-}39SO_4^{2-}28Cl^{-}25}$

  $Ca^{2+}59Mg^{2+}25Na^{+}+K^{+}14$

  BH-13: Waters of the hydrocarbonate class, calcium group, type 2, qualitatively pure, hard, polluting, and contaminated.

  Water Composition: $M_{0.6}$ $\underline{HCO_3^{-}64SO_4^{2-}17Cl^{-}15}$

  $Ca^{2+}49Mg^{2+}27Na^{+}+K^{+}23$

Figure II-11 *Water samples from the test and drainage chamber*

To accurately evaluate the hydrogeological characteristics of sedimentary zones—especially in elevated watershed areas—it is essential to determine key parameters. These include the structural reliability of the sediment, its ability to conduct water, and its responsiveness to changes in water levels. By thoroughly analyzing these factors, we can better estimate how groundwater levels will decline over time as the hydrogeological zone is utilized. This estimation is crucial for assessing the load-bearing capacity and sustainability of hydrogeological exploration activities in the region.

Sweep trust calculations were performed using Aquifer Test Pro, incorporating Dupuit analytical methods. These calculations were based on data from drawdown levels in test wells, as well as information on aquifer barriers and leakage rates.

$$K = \frac{0.73Q \cdot LgR_0/r_0}{(2H - S_0)S_0}$$

K - Hydraulic conductivity, m/day

Q - Pumping rate during the pumping test, m^3/day

ro - borehole radius, m /0.1 m/

So - Drawdown in borehole, m /1.72 m/

H - Aquifer thickness, m /22.85 m/

Ro - The induced radius of influence in a well under steady-state groundwater seepage flow conditions. Based on average numerical data, values are typically taken within the range of

150–200 meters for unconfined aquifers with a free water surface and no tidal influence. Under these conditions, a value of 150 meters was directly selected.

$$K = \frac{0.73*2760}{(2x22.85-1.72)\times 1.72} lg \frac{150}{0.1} = 84.59 \text{ m/day.}$$

II.8. Hydrological Conditions

The project area runs through the Tolgoit River Valley and the Selbe River Valley /**Error! Reference source not found.**/.

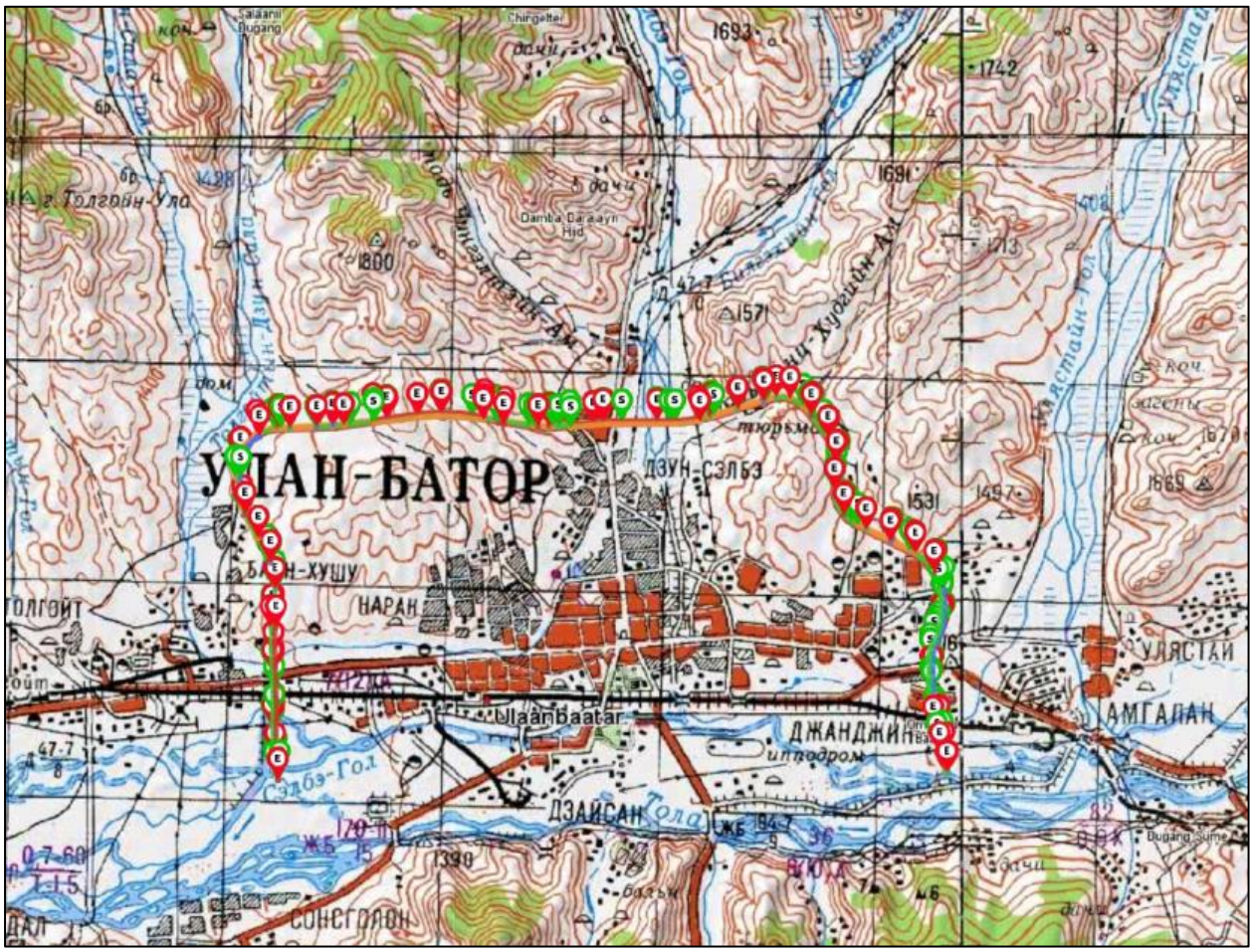

Figure II-12 *Location of the Hydrology, or surface water network, along the highway*

The rivers and streams of Mongolia typically experience a brief dry spell in May or June, following the spring flood season. This is then succeeded by the summer rainy period, which replenishes water levels. Notably, the Tuul River, along with its tributaries and nearby valleys, tends to flood only during summer rainfall events, rather than from spring snowmelt.

Small rivers, drainage channels, and seasonal water collection areas (*sairs*) that originate from the mountains surrounding Ulaanbaatar often flow through gravel, pebbly soils, and mudslide-prone terrain. These features are located in a part of Mongolia that is particularly susceptible to intense flooding. Among the most frequent natural disasters in this region are annual floods, especially affecting the Tuul River and its tributaries.

Flood prediction is a complex task that requires in-depth and detailed research. One of the most critical aspects is the precise calculation of peak flood runoff caused by heavy rainfall,

which plays a vital role in the planning and design of economic projects, water infrastructure, and transportation systems. To ensure safety and reliability, these high-flow estimations must be based on scientifically validated and realistic approaches.

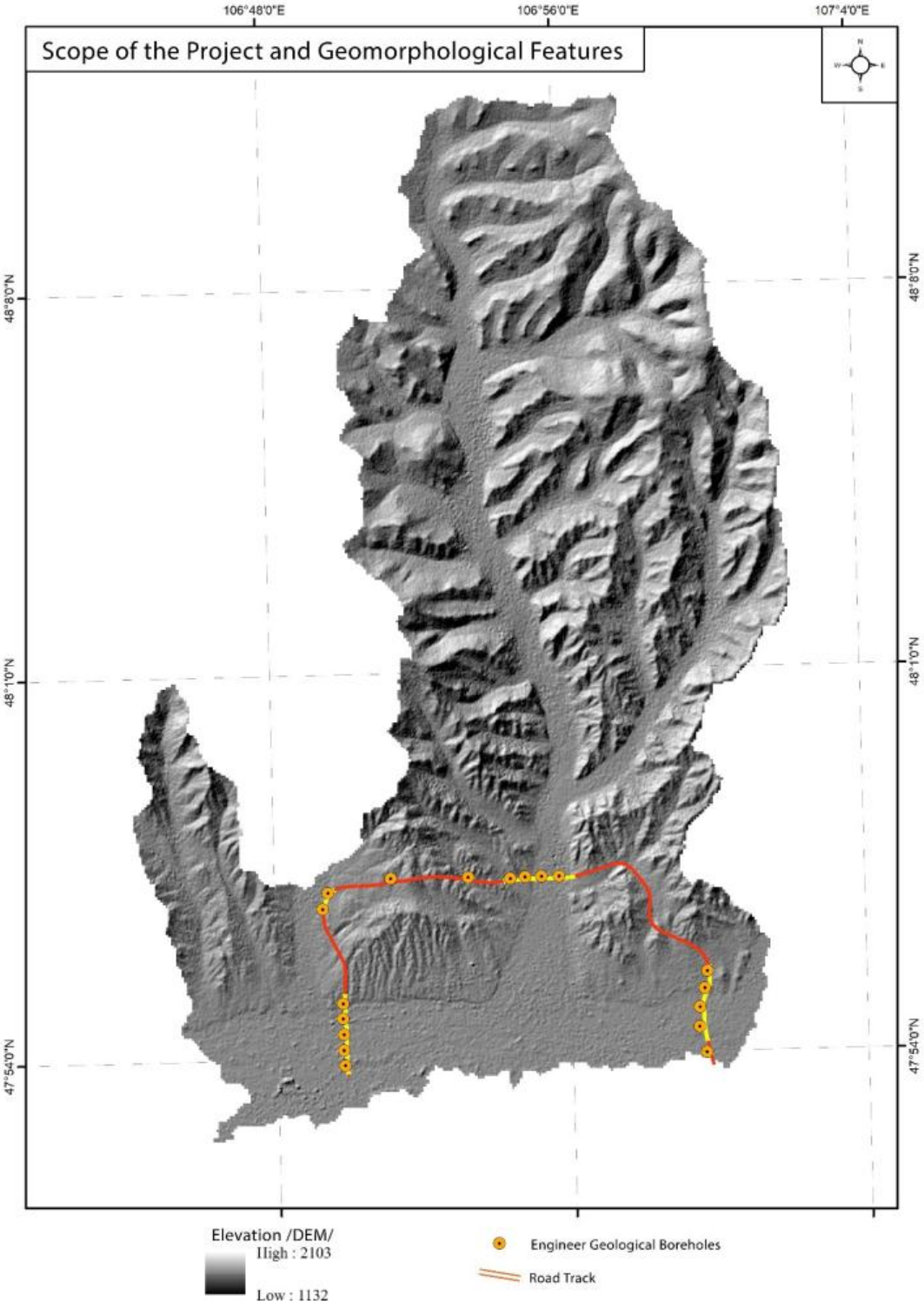

Figure II-13 *Project Scope and Geomorphological Characteristics*

Locations that will be affected by the project's development

Using satellite imagery and hydrological modeling through ArcSWAT software, surface water flow was detected at eight specific points along the highway, helping to identify areas at risk of flooding.

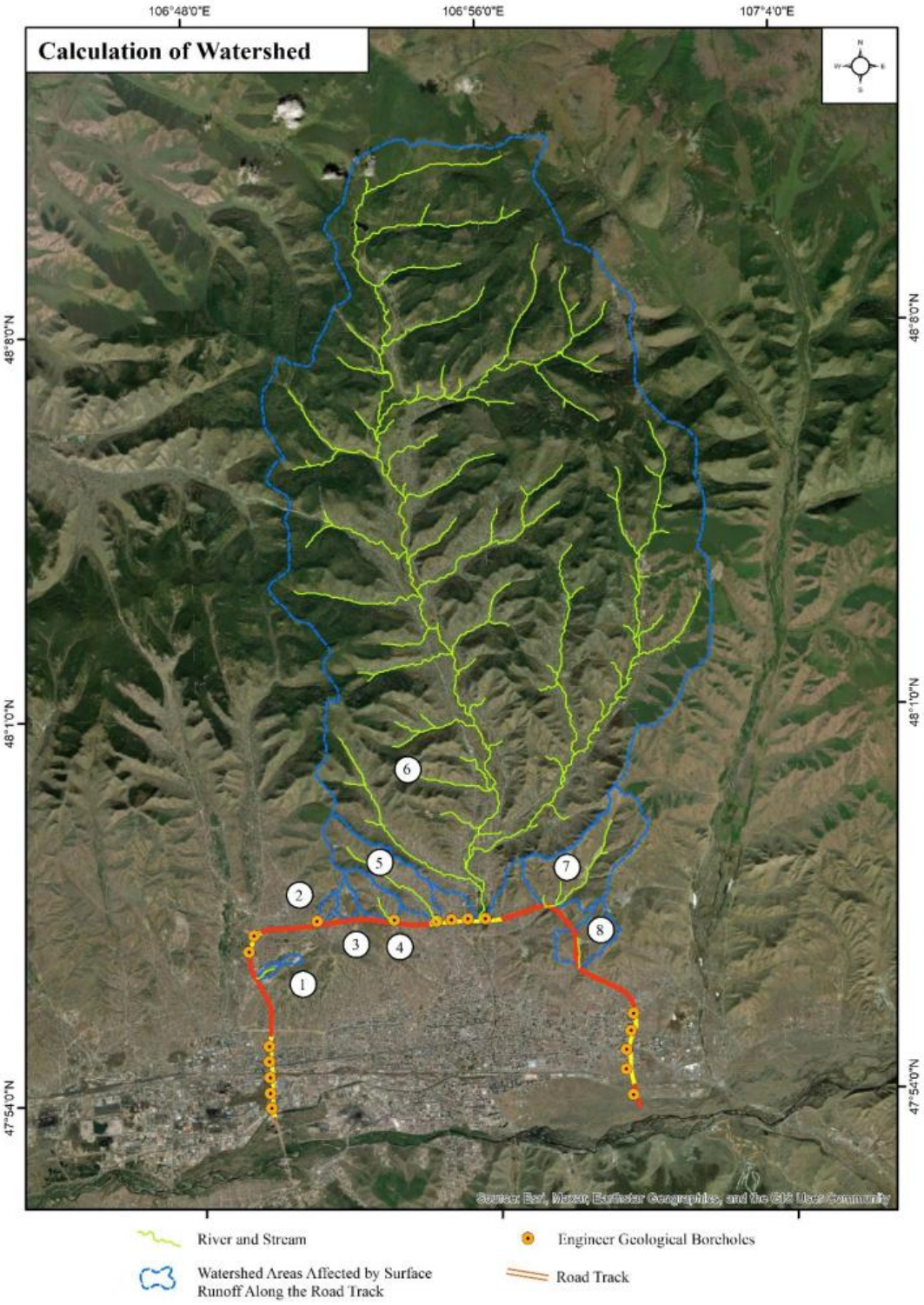

Figure II-14 *Calculation of the Drainage Area*

The eight locations mentioned above have been assigned individual numbers and are included in the flood analysis section according to this numbering system.

Flood calculations

The following table presents the names of the eight flood-prone outlets, along with their intersection locations and the corresponding watershed areas.

Table II-3 Flood Risk Locations

No	Nomenclature	Location		water catchment area, hectares
		Longitude	Latitude	
1	Kaniin material gap	5311003	636282	38.17
2	Bayankhoshuu gap 1	5312845	638524	39.04
3	Bayankhoshuu gap 2	5312978	639385	65.37
4	Denjiin 1000 gap	5312909	640871	179.39
5	Khailaast gap	5312891	642422	496.99
6	Selbe river	5312959	643809	27158.73
7	Gants khudag gap	5313466	646031	812.86
8	Monel gap	5311397	647181	255.97

Kaniin material gap

This gap collects water from 38.17 hectares above the highway and has a flood risk of 6.17 m 3/sec at 1% supply, 4.1 m 3/sec at 5% supply, and 3.3 m 3/sec at 10% supply.

Figure II-15 *Location 1 End Gap of Khaniin Material*

According to the location map, the drainage area is mostly composed of exposed ground surfaces, which significantly increases the risk of surface runoff and flooding. To reduce this risk, it is advisable to install large flow-control barriers at the upper section of the highway pipeline bridge. These structures will help regulate water flow through the area, thereby protecting the road from potential damage.

Bayankhoshuu section 1

This gap collects water from 39.04 hectares above the highway and has a flood risk of 6.30 m 3/sec at 1% supply, 4.2 m 3/sec at 5% supply, and 3.3 m 3/sec at 10% supply.

Figure II-16 *Location 2 Bayankhoshuu-1*

The planned tunnel location at the western end of the highway indicates the need for a flood control structure at the site. Based on the results of flood modeling and runoff calculations, an appropriate solution—such as a flood dam or a bridge—should be selected to effectively manage water flow and reduce flood risk.

Bayankhoshuu section 2

This gap collects water from a 65.37-hectare area above the highway and has a flood risk of 13.9 m^3/sec at 1% supply, 5.4 m 3/sec at 5% supply, and 4.3 m 3/sec at 10% supply.

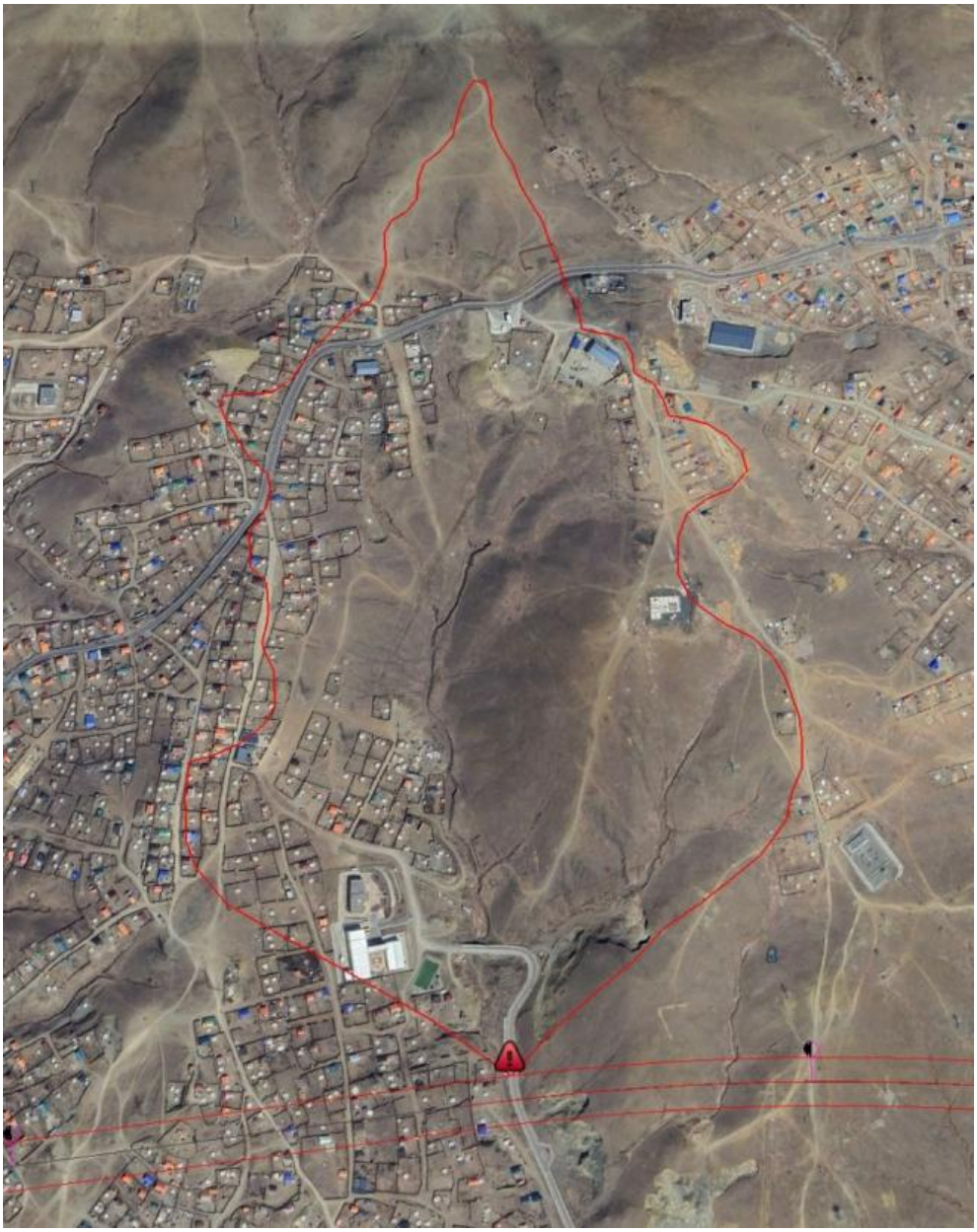

Figure II-17 *Location 3 Bayankhoshu-1*

At this location, the highway intersects with another route, making it necessary to construct a pipeline bridge at the junction to facilitate proper infrastructure integration and water flow management.

Denjiin 1000 section

This gap collects water from 179.39 hectares of land on the highway and has a flood risk of 13.4 m^3/sec at 1% supply, 9.3 m 3/sec at 5% supply, and 1.4 m 3/sec at 10% supply.

Figure II-18 *Location 4 Bayankhoshuu-1*

At this location, the highway intersects with another roadway, and a pipeline bridge is necessary at the intersection point to support infrastructure and manage water flow effectively.

Khailaast section

The gap of the Highway will collect water from 496.99 hectares on the highway and has a flood risk of 25.7 m 3/sec at 1% supply, 17.7 m 3/sec at 5% supply, and 9.2 m 3/sec at 10% supply.

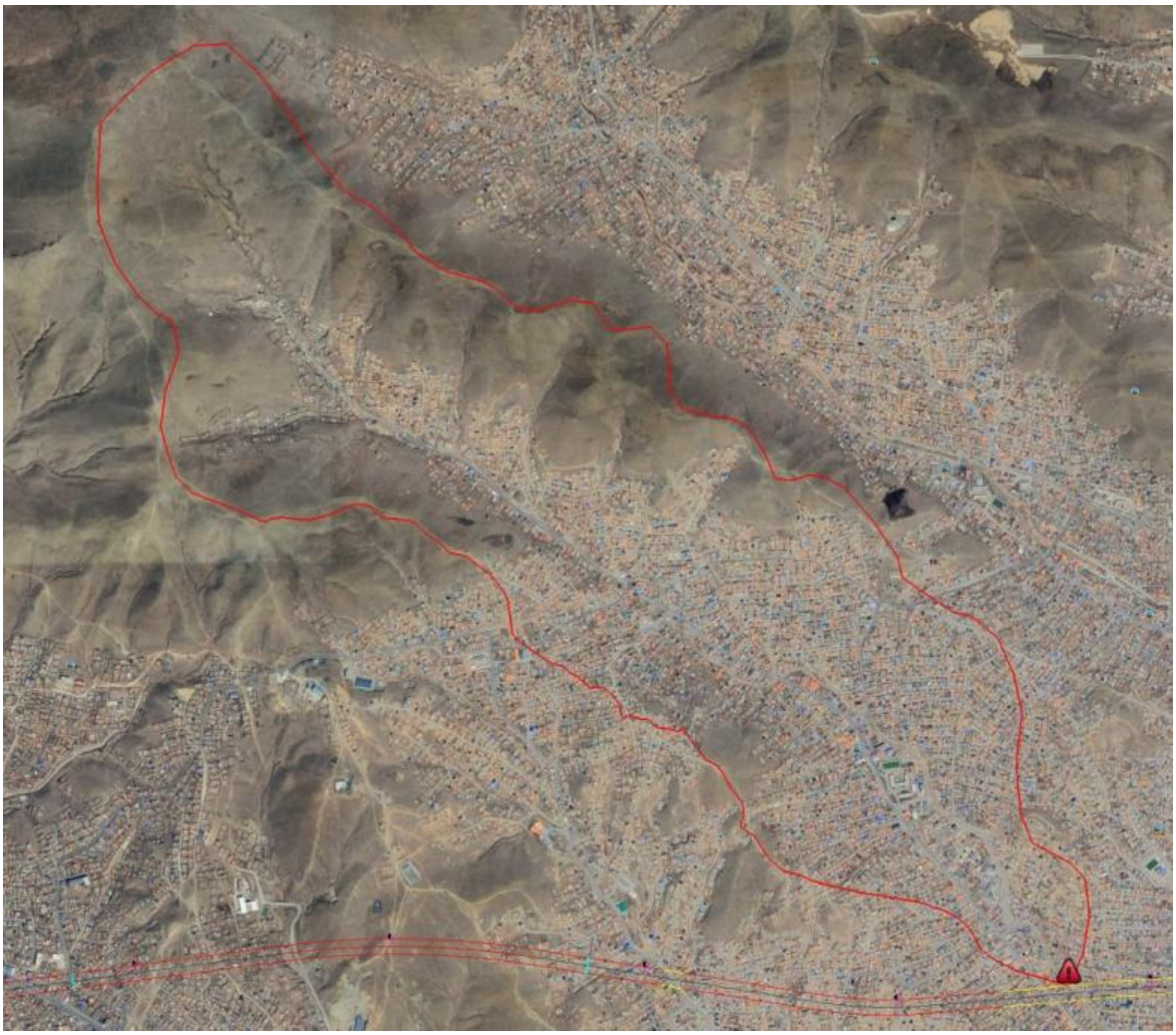

Figure II-19 *Location-5 The gap of the Hygienist*

The Khailaast gap is identified as a high-risk flood zone due to its large drainage area. However, the planned bridge construction in this region offers a solution to reduce flood hazards by improving water flow and enhancing flood control measures.

Selbe River

Extensive flood assessments have been conducted along the Selbe River, with the most recent being the "Urban Engineering Preparedness Master Plan". According to this report, the nearest point to the highway is projected to have the following flood discharge rates based on different probability levels:

- 0.1% exceedance probability: 626.8 m^3/s
- 1% exceedance probability: 401.8 m^3/s
- 5% exceedance probability: 277.2 m^3/s
- 10% exceedance probability: 221.0 m^3/s

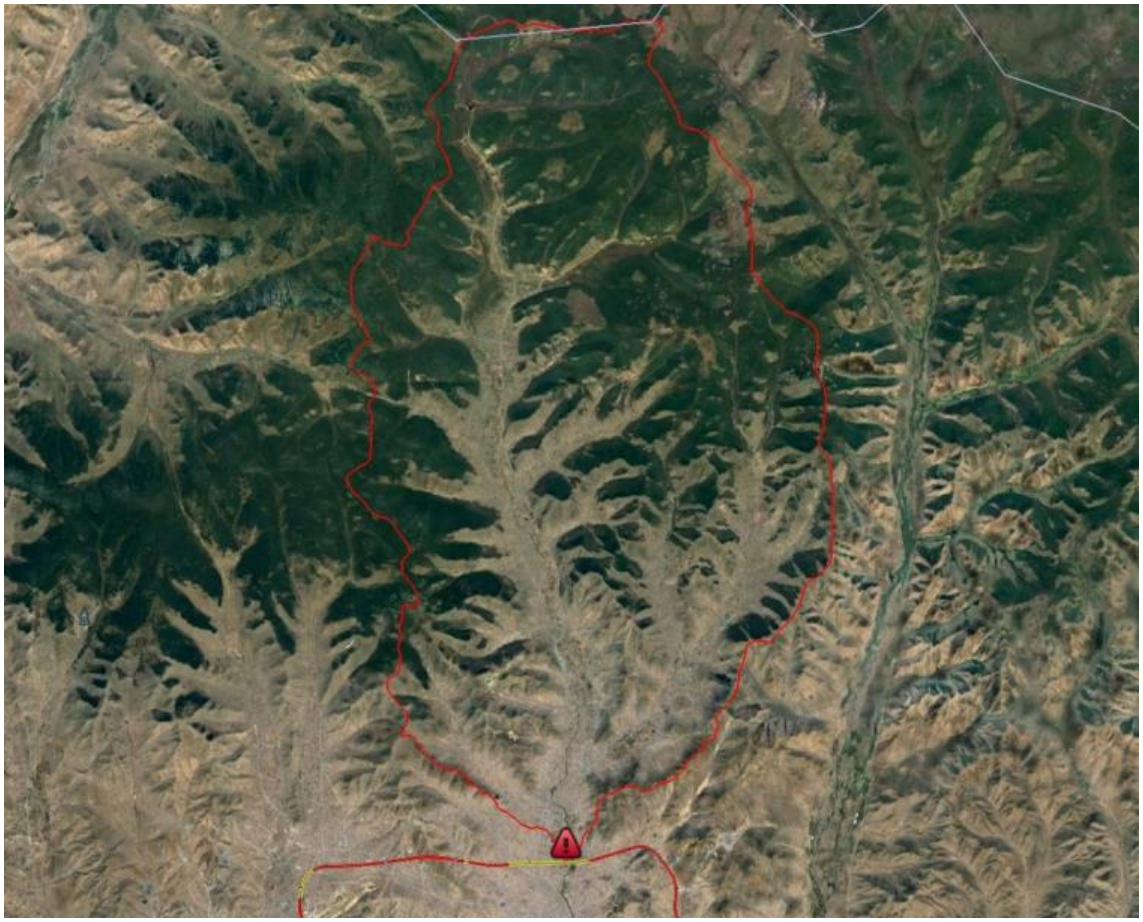

Figure II-20 *Location 6 Selbe River*

The Selbe River poses a significant flood risk due to its large drainage area. However, the planned bridge construction in this region is expected to help mitigate flooding by improving water flow and enhancing flood control measures

Gants khudag section

This section of the highway drainage system receives runoff from an area of 812.86 hectares. It faces potential flooding, with estimated peak flow rates of 23.22 m³/s for events with a 1% chance of occurring annually, 15.6 m³/s for a 5% chance, and 12.4 m³/s for a 10% chance.

Figure II-21 *Location 7 Gants hudag gap*

Given the area's geomorphological features—characterized by steep mountain slopes and continuous material movement from higher elevations—the risk of flooding is significantly elevated. To effectively mitigate this hazard, it is advisable to allocate at least 5% of the total project budget to bridge construction. This strategic investment can help prevent future flood-related damages.

Monel section

This gap collects water from 255.97 hectares of land above the highway and has a flood risk of 10.8 m^3/sec at 1% supply, 7.4 m 3/sec at 5% supply, and 3.8 m 3/sec at 10% supply.

Figure II-22 *Location 8 Monel gap*

While the water flow at this outlet may appear modest overall, certain areas exhibit steep gradients that can intensify the current. Additionally, sediment buildup—particularly at highway intersections—can contribute to conditions that significantly elevate the risk of major flooding.

II.9. Permafrost

No permafrost affecting the highway were observed during the survey conducted in the study area

III. THE FIELD SURVEY WORKS

III.1. The Field Drilling Works

In accordance with the ISO 22475-1:2021 standard, drilling operations were conducted using dry rotary methods with drill diameters ranging from 219 mm to 110 mm. Equipment used included the UGB-1BC, PBU-1, UGB-50M, POWER-6000, and SCHRAMM rigs, all selected to preserve the natural characteristics of the soil. For deeper boreholes, the POWER-6000 rig was employed with water-assisted rotary drilling using PQ and HQ diameter tools. Subsequent drilling was performed using the diamond rotary technique.

At each designated drilling location, the site was clearly marked, and soil samples were collected and displayed on-site. All relevant data and documentation were recorded in accordance with procedural requirements. Upon encountering bedrock, drilling was extended to a minimum depth of 5 meters to ensure adequate sampling.

Figure III-1 *Drilling Process /Power-6000/, UGV-1VC*

A total of 439 cubic meters of drilling was completed within the exploration area. This included 323.5 meters drilled through soil layers and 115.5 meters drilled into semi-rock and bedrock formations.

III.2. Soil Sampling

Soil and rock excavation across the exploration area was carried out concurrently with the field drilling activities. In compliance with BNbD 11-03-01 and based on the client's request, 129 disturbed samples were collected from each engineering-geological element (EGE). These samples were selected for physical and mechanical testing, considering factors such as layer thickness, composition, condition, and soil properties. As a result of these coordinated efforts, the overall efficiency of field drilling operations reached 30%.

Figure III-2 *Soil Samples for Laboratory Testing*

III.3. Standard Penetration Test

To evaluate the soil's strength properties within the study area, Standard Penetration Tests (SPT) were carried out 16 times. These tests were conducted at specific depths within the soil layers identified during drilling. Each test involved dropping a 63.5 kg hammer from a height of 760 mm to drive a standard split-barrel sampler into the ground. The sampler used had an outer diameter of 50.8 mm and an inner diameter of 35 mm, consistent with standard testing specifications.

The sampler is driven into the soil to a depth of 450 mm, divided into three stages of 150 mm each. The initial 150 mm is used to properly seat the sampler and ensure stable placement; this portion is excluded from the blow count. The SPT N-value is calculated by summing the number of blows required to penetrate the second and third 150 mm intervals (totaling 300 mm), and this value is documented in the test report.

Table III-1 Initial results of the Standard Penetration Test

Borehole Number	Depth, m	Soil Name	N^15	N^30	N^45	Nvalue
BH-4	2.5	Gravel with sand	51/8			51
BH-2	12	Gravel with sandy loam	51/10			51
BH-4	16	Gravel with sandy loam	51/10			51
BH-16	21	Gravel with sandy loam	51/11			51
BH-17	9	Gravel with sandy loam	51/15			51
BH-12	1.2	Loam	23/15	28/15	23/8	51
BH-13	1.5	Clay	25/15	18/15	28/15	46
BH-16	11.5	Clay	22/15	22/15	29/15	51
BH-18	18	Clay	24/15	26/15	21/15	47
BH-3	18	Gravel with loam	18/15	24/15	27/15	51
BH-12	24	Gravel with loam	19/15	25/15	26/15	51
BH-12	7	Gravel with loam	21/15	23/15	22/15	45

BH-5	1.5	Gravel with loam (contain less than 50%)	15/15	18/15	28/15	46
BH-6	15	Gravel with clay	18/15	31/15	20/8	51
BH-13	7.5	Gravel with clay	21/15	25/15	26/11	51
BH-11	4	weathering sandstone	20/15	29/15	22/7	51

The processing of the initial experimental results is summarized in .

Table III-1 Results of the Standard Penetration Test

Borehole Id	Depth, m	Soil name	N	Dr (%)	ϕ°	Unit weight (Cohesionless), kN/m^3	Unconfined Comp. Test, kPa	Unit weight (Saturated), kN/m3	Su, kPa	Status	Engineer geology element
BH-4	2.5	Gravel with sand	51	85-100	>41	>20,4				Very dense	ИГЭ-16
BH-2	12	Gravel with sandy loam	51	85-100	>41	>20,4				Very dense	ИГЭ-2а
BH-4	16	Gravel with sandy loam	51	85-100	>41	>20,4				Very dense	ИГЭ-2а
BH-16	21	Gravel with sandy loam	51	85-100	>41	>20,4				Very dense	ИГЭ-2а
BH-17	9	Gravel with sandy loam	51	85-100	>41	>20,4				Very dense	ИГЭ-2а
BH-12	1.2	Loam	51				>400	>20,4	>200	Hard	ИГЭ-3
BH-13	1.5	Gravel with clay	46	65-85	36-41	17,3-22,0				Dense	ИГЭ-7а
BH-16	11.5	Clay (contains less than gravel)	51				>400	>20,4	>200	Hard	ИГЭ-46
BH-18	18	Gravel with loam	47	65-85	36-41	17,3-22,0				Dense	ИГЭ-6а
BH-3	18	Gravel with loam	51	85-100	>41	>20,4				Very dense	ИГЭ-6а
BH-12	24	Gravel with loam	51	85-100	>41	>20,4				Very dense	ИГЭ-6в
BH-12	7	Gravel with loam	45	65-85	36-41	17,3-22,0				Dense	ИГЭ-6в
BH-5	1.5	Gravel with loam	46	65-85	36-41	17,3-22,0				Dense	ИГЭ-6а
BH-6	15	Gravel with clay	51	85-100	>41	>20,4				Very dense	ИГЭ-7а
BH-13	7.5	Gravel with clay	51	85-100	>41	>20,4				Very dense	ИГЭ-7а
BH-11	4	Gravel with sandy loam	51	85-100	>41	>20,4				Very dense	ИГЭ-8

III.4. Pressiometric experiment

The soil deformation modulus for each engineering-geological element (EGE) identified in the field was measured using a fast and accelerated pressiometric method. This test was conducted under horizontal static loading at depths reaching up to 30 meters. The procedure involved using a 30-meter-long gas and water supply pipe to apply nitrogen gas pressure within a 0.6-meter test section, centered at 50 mm diameter, to evaluate soil response. A total of 16 pressiometric tests were performed during the fieldwork. The preliminary results are compiled in Table III-3.

Table III-2 Results of the pressiometric experiment

№	Borehole Id	Depth, m	Soil name	Construction	Pressuremeter Test											
					P0, kPa	Pf, kPa	Kh, MPa/м	Vo, sm3	Vf, sm3	σ0, kPa	E0, MPa	E, MPa	Em, MPa	Gm, MPa	ES, MPa	Engineer geology element
1	BH-4	2.5	Gravel with sand	Bridge-1	-211	534	679	159.8	172	565	49.14	43.46	43.95	17.91	43.28	ИГЭ-16
2	BH-2	12	Gravel with sandy loam	Bridge-1	261	655	693.5	142.3	157	597	49.64	42.97	43.47	17.12	42.79	ИГЭ-2а
3	BH-4	16	Gravel with sandy loam	Bridge-1	246	590	711.4	140.9	153.4	503	50.82	44.07	44.51	17.52	43.81	ИГЭ-2а
4	BH-16	21	Gravel with sandy loam	Bridge-5	220	562	679.5	141	154	533	48.55	42.09	42.52	16.74	41.85	ИГЭ-2а
5	BH-17	9	Gravel with sandy loam	Bridge-5	230	572	692.2	149.1	162	514	49.77	43.16	43.59	17.16	42.9	ИГЭ-2а
6	BH-12	1.2	Loam	Bridge-4	208	548	182.4	88.1	135	330.5	12.66	11.92	12.4	4.37	10.92	ИГЭ-3
7	BH-13	1.5	Gravel with clay	Bridge-4	182	524	151.1	88.3	145.5	379	10.53	9.83	10.32	3.63	9.08	ИГЭ-7а
8	BH-16	11.5	Clay (contains less than gravel)	Bridge-5	205	645	225.1	113.7	164	521.8	15.97	15.02	15.64	5.51	13.77	ИГЭ-46
9	BH-18	18	Gravel with loam	Bridge-6	289	577	461	138.8	155	428.8	32.92	28.47	28.83	11.35	28.38	ИГЭ-6а
10	BH-3	18	Gravel with loam	Bridge-1	308	747	486.8	139.6	163	565.8	34.89	30	30.56	12.03	30.07	ИГЭ-6а
11	BH-12	24	Gravel with loam	Bridge-4	213	695	550.6	122	144.4	484.8	38.9	33.46	34.07	13.41	33.53	ИГЭ-6в
12	BH-12	7	Gravel with loam	Bridge-4	199	593	466	122.9	144.6	524.9	32.94	28.35	28.85	11.36	28.39	ИГЭ-6в
13	BH-5	1.5	Gravel with loam	Bridge-1	136	574	217.7	106.5	158	505.9	15.37	13.51	14.1	5.3	13.25	ИГЭ-6а
14	BH-6	15	Gravel with clay	Bridge-2	193	436	389.8	138.9	155	367.9	27.84	24.64	24.96	9.6	24	ИГЭ-7а
15	BH-13	7.5	Gravel with clay	Bridge-4	170	659	360.9	88.1	122	468.6	24.92	22.21	22.86	8.59	21.48	ИГЭ-7а
16	BH-11	4	Gravel with sandy loam	Bridge-4	269	618	556.3	139.7	156	549.9	39.76	34.38	34.82	13.71	34.27	ИГЭ-8

Explanation of the Experimental Meanings:

E0 – Deformation modulus (MPa)

E – Quasi elastic modulus (MPa)

Em – Pressuremeter modulus (MPa)

Po – Initial Pressure

Vo – Volume deformation of initial pressure

Pf – Temporary plastic pressure

Vf – The temporary plastic pressure pf corresponding to the volume deformation (cm3)

σ0 – Basic bearing capacity of foundation

μ – Poisson's ratio

a – pore pressure coefficient of all kinds of soil (experiment meaning)

Sand 0

silt 0.1-0.2

silty clay 0.15-0.25

clay 0.25-0.5

III.5. Dynamic Cone Penetrometer experiment

The Dynamic Cone Penetrometer (DCP) test is a field-based method used to quickly assess soil strength and density. In this test, an 8 kg hammer is dropped freely from a height of 575 mm, driving a 20 mm diameter steel cone into the ground. The depth of penetration per blow is measured in millimeters. This procedure allows for rapid evaluation of soil compaction on-site. In total, the test was performed 16 times at the research location./appendix 1/

IV. ENGINEERING GEOLOGICAL AND GEOTECHNICAL CHARACTERISTICS, AND PHYSICAL-MECHANICAL ATTRIBUTES OF SOILS AND ROCKS IN THE INVESTIGATION AREA

From the drilled holes in the study area, under the tehnogenic-originated embankment were discovered Pleistocene-Holocene age (Q1-2) brownish-yellow color, gravel with sand with moisture-saturated ; brownish yellow color, gravel with sandy loam solid-liquid consistency; brownish yellow color, loam solid consistency; brownish yellow- reddish brown color, clay solid-medium consistency; brownish yellow color, sandy loam liquid consistency; brownish yellow-brownish brown color, gravel with loam solid—medium-soft consistency; brownish yellow-brownish brown color, gravel with clay solid—medium consistency; then Eluvial Deluvial (*edQ*) brownish-yellow, green-gray color, weathered gravel with sandy loam solid consistency; brownish-yellow, green-gray color, weathered gravel with loam solid consistency; and lastly, Carboniferous Carboniferous Altan-Ovoo Formation Sandstone, which totally made up 10 Engineering Geological Element Classifications. These are shown in Table IV-1.

Table IV-1 Engineering and Geological Elements

No	Soil Name	Natural moisture/Atterberg limits	EGE Number	
Pleistocene-Holocene soils-Q_{1-2}				
1	Gravel with sand	Little moisture/-	EGE-1	1a
		saturated/-		1b
2	Gravel with sandy loam	-/solid consistency	EGE-2	2a
		-/liquid consistency		2b
3	Loam	-/ solid consistency	EGE-3	
4	Clay	-/ solid consistency	EGE-4	4a
		-/medium consistency		4b
5	Sandy loam	-/ liquid consistency	EGE-5	
6	Gravel with loam	-/ solid consistency	EGE-6	6a
		-/ medium consistency		6b
		-/soft consistency		6c
7	Gravel with clay	-/ solid consistency	EGE-7	7a
		-/ medium consistency		7b
Soils of Eluvial Deluvial Origin – edQ				
8	Gravel with sandy loam	-/solid consistency	EGE-8	
9	Gravel with loam	-/ solid consistency	EGE-9	
Carboniferous, Altan Ovoo Formation – C_{1ao}				
10	Sandstone		EGE-10	

BUILDING NORMS AND REGULATIONS /50-01-16/

The engineering-geological elements (EGEs) distributed throughout the study site were categorized based on the BNbD 50-01-16 standard. Their mechanical properties, typical seasonal soil freezing depth, allowable bearing pressure, and frost heaving characteristics were systematically evaluated.

Soil of technogenic origin – tQ

Technogenic origin soil consisting of Gravel with loam and construction waste R0=150 kPa

EGE-1. Gravel with sand

Table IV.2 shows the laboratory practices size of gravel with sand brownish-yellow color, with little moisture-saturated.

Table IV-2

Soil Name		Practicle size, %		
		Gravel	Sand	Silt / Clay
Gravel with sand	1a	63.5	29.8	6.7
	1b	60.7	32.3	7.0

The soil moisture parameters of gravel with sand brownish-yellow color, with little moisture-saturated are presented in the Table IV-3.

Table IV-3

Soil Name		Natural Moisture, W	Degree saturation, Sr
Gravel with sand	1a	0.041	0.44
	1b	0.127	0.94

Density parameters of gravel with sand brownish-yellow color, with little moisture-saturated are presented in the Table IV-4

Table IV-4

Soil Name		Specific gravity, ρs	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
		g/cm3			*Percent*	*Unit Percent*
Gravel with sand	1a	2.67	2.23	2.14	23.79	0.248
	1b	2.68	2.22	1.97	32.04	0.361

The Normative and calculated values of the parameters of mechanical characteristics of gravel with sand brownish-yellow color, with little moisture-saturated are presented in BNbD 50-01-16 (Table IV-5).

Table IV-5

Soil Name		Cohesion, *kPa*		Angle of internal friction, *degrees*		Deformation, *MPa*		Allowable bearing pressure, *kPa*
		C^{I}	$C^{н}=C^{II}$	φ^{I}	$\varphi^{н}=\varphi^{II}$	$E_{БНбД}$	$E_{пр}$	Ro
Gravel with sand	1a	1.3	2	36	40	45	-	600
	1b	1.3	2	36	40	45	49.1	600

Table IV-6 presents the Standard Penetration Test (SPT) results for the gravel with sand.

Table IV-6

N value (SPT stroke / 300 mm) [1 test]					
Soil Name		Minimum	Maximum	Medium	Number of Experiments Stopped[(a)]
Gravel with sand	1b	51	51	51	1

a. *The Standard Penetration Test (SPT) was discontinued after achieving an N-value of 51 within a penetration depth of less than 0.3 meters. This result indicates that the soil is exceptionally dense and hard, and is classified as a highly compacted engineering-geological formation.*

The Standard Penetration Test (SPT) results for the gravel with sand were analyzed using the empirical formulas developed by Peck (1974) and Bowles (1988). These computational values are presented in Table IV-7

Table IV-7

Soil Name		Adjusted Meaning of Number of blows, N1(60)	Density index, %	Angle of internal friction, *degrees*	Cohesion, *kPa*	volume weight (moisture), kN/m3	Density
Gravel with sand	1b	37	85-100	>41	-	>20.4	Very dense

The results of the pressuremeter test conducted on gravel with sand are presented in Table IV-8.

Table IV-8

Soil Name	Modulus E_0, mPa

		Number of tests	Maximum	Minimum	Medium
Gravel with sand	1b	1	49.1	49.1	49.1

The standard average electrical resistance for Gravel with sand is ***710 ohms***, *and* 60 ohms ***when saturated*** .

- Gravel with sand in its natural state is generally without frost heaving
- Gravel with sand, when used in earthworks carried out during thawing conditions, is classified under Category IV.

EGE-2. Gravel with sandy loam

Table IV.9 shows the practices size of gravel with sandy loam brownish-yellow color, with solid consistency.

Table IV-9

Soil Name		Particle size , %		
		Gravel	Sand	Silt / Clay
Gravel with sandy loam	2a	61.6	25.7	12.7
	2b	61.4	25.9	12.7

The average physical characteristics of gravel with sandy loam soils were determined through laboratory analyses, with the findings documented in Table IV-10 and Table IV-11.

The soil moisture parameters of gravel with sandy loam, brownish-yellow color, solid consistency are presented in table Table IV-10

Table IV-10

Soil Name		Natural moisture , W	Degree of saturation, Sr
Gravel with sandy loam	2a	0.072	0.63
	2b	0.174	0.97

Density parameters of gravel with sandy loam, brownish-yellow color, solid consistency are summarized in Table IV-11.

Table IV-11

Soil Name		Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
		g/cm3			*Percent*	*Unit percent*
	2a	2.70	2.21	2.07	23.41	0.306

Gravel with sandy loam	2b	2.69	2.13	1.81	32.44	0.480

Status characteristics of gravel with sandy loam, brownish-yellow color, solid consistency with atterberg limits characteristics are presented in Table IV-12.

Table IV-12

Soil Name		Liquid limit, WL	Plastic limit, Wp	Plasticity index, Jp	Consistency, IL
		Percent			*Unit percent*
Gravel with sandy loam	2a	0.182	0.133	0.049	-1.34
	2b	0.185	0.138	0.047	0.77

The normative and calculated values of the parameters of mechanical characteristics of gravel with sandy loam, brownish-yellow color, solid consistency are presented in BNbD 50-01-16 (

Table IV-13).

Table IV-13

Soil Name		Cohesion, *kPa*		Angle of internal friction, *degree*		Deformation, *MPa*		Allowable bearing pressure R0 (кPa)
		C^{I}	$C^{н}=C^{II}$	φ^{I}	$\varphi^{н}=\varphi^{II}$	$E_{БНбД}$	Pr	Ro
Gravel with sandy loam	2a	11	16	38	44	46	49.6	450
	2b	4	6	38	44	45	-	400

Table IV-14 presents the Standard Penetration Test (SPT) results for the gravel with sandy loam.

Table IV-14

N value (SPT stroke / 300 mm) [4 tests]					
Soil Name		Minimum	Maximum	Medium	Number of tests Stopped[(a)]
Gravel with sandy loam	2a	51	51	51	4

a.*The Standard Penetration Test (SPT) was discontinued after achieving an N-value of 51 within a penetration depth of less than 0.3 meters. This result indicates that the soil is exceptionally dense and hard, and is classified as a highly compacted engineering-geological formation.*

The Standard Penetration Test (SPT) results for the gravel with sandy loam were analyzed using the empirical formulas developed by Peck (1974) and Bowles (1988). These computational values are presented in Table IV-15

Table IV-15

Soil Name		Adjusted Meaning of Number of blows, N1(60)	Density index, %	Angle of internal friction, *degrees*	Cohesion, *kPa*	volume weight (moisture), kN/m3	Density
Gravel with sandy loam	2a	49	85-100	>41	-	>20.4	Very dense

The results of the pressuremeter test conducted on gravel with sandy loam are presented in Table IV-16.

Table IV-16

Soil Name		Modulus E0, mPa			
		Number of tests	Maximum	Minimum	Medium
Gravel with sandy loam	2a	4	50.8	48.5	49.6

- The standard average electrical resistance for gravel with sandy loam is *710 ohms* .
- Gravel with sandy loam in its natural state exposed to slight frost heaving. (EGE-2a – D=5.36, Sr=0.63)
- Gravel with sandy loam in its natural state exposed to strong frost heaving. (EGE-2b – D=3.45, Sr=0.97)
- Gravel with sandy loam, when used in earthworks carried out during thawing conditions, is classified under Category IV

EGE-3. Loam

Table IV-17 shows the particles size of loam, brownish color, solid consistency.

Table IV-17

Soil Name	Particle size , %		
	Gravel	Sand	Silt / Clay
Loam	46.8	31.8	21.4

The average physical characteristics of loam soils were determined through laboratory analyses, with the findings documented in Table IV-18, Table IV-19.

The soil moisture parameters of loam, brownish color, solid consistency are presented in Table IV-18

Table IV-18

Soil Name	Natural moisture , Wб	Degree of saturation, Sr
Loam	0.148	0.85

Density parameters of loam, brownish color, solid consistency are summarized in Table IV-19

Table IV-19

Soil Name	Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
	g/cm3			*Percent*	*Unit percent*
Loam	2.72	2.13	1.86	31.55	0.472

Status characteristics of loam, brownish color, solid consistency with atterberg limits characteristics are presented in Table IV-20.

Table IV-20

Soil Name	Liquid limit, WL	Plastic limit, Wp	Plasticity index, Jp	Consistency, IL
	Percent			*Unit percent*
Loam	0.278	0.179	0.099	-0.34

The Normative and calculated values of the parameters of mechanical characteristics of loam, brownish color, solid consistency are presented in BNbD 50-01-16 (Table IV-521).

Table IV-21

Soil Name	Cohesion, *kPa*		Angle of internal friction, *degree*		Deformation, *MPa*		Allowable bearing Pressure R_0 (кPa)
	C^I	$C^н=C_{II}$	φ^I	$\varphi^н=\varphi^{II}$	$E_{БНбД}$	E_{PR}	R_o

Loam	30	45	22	25	31	12.7	300

Table IV-22 presents the Standard Penetration Test (SPT) results for the loam.

Table IV-22

N value (SPT stroke / 300 mm) [1 test]				
Soil Name	Minimum	Maximum	Medium	Number of tests Stopped[(a)]
Loam	51	51	51	1

a. *The Standard Penetration Test (SPT) was discontinued after achieving an N-value of 51 within a penetration depth of less than 0.3 meters. This result indicates that the soil is exceptionally dense and hard, and is classified as a highly compacted engineering-geological formation.*

The Standard Penetration Test (SPT) results for the loam were analyzed using the empirical formulas developed by Peck (1974) and Bowles (1988). These computational values are presented in Table IV-23

Table IV-23

Soil Name	Adjusted Meaning of Number of blows, N1(60)	Density index, %	Angle of internal friction, *degrees*	Cohesion, *kPa*	volume weight (moisture), kN/m3	Density
Loam	31	>20.4	-	>400 km	>200 km	Very dense

The results of the pressuremeter test conducted on loam are presented in Table IV-24.

Table IV-24

Soil Name	Modulus E_0, mPa			
	Number of tets	Maximum	Minimum	Medium
Loam	3	15	11	14

- The standard average electrical resistance for loam is ***80ohms***.
- Loam in its natural state exposed to slight frost heaving. (***Rf=0.11***)
- Loam, when used in earthworks carried out during thawing conditions, is classified under Category II.

EGE-4. Clay (contains less than gravel **)**

Table IV-25 shows the particles size of clay, brownish-brown color, solid consistency

Table IV-25

Soil Name	Particle size , %

		Gravel	Sand	Silt / Clay
Clay	4a	13.7	49.8	36.5
	4b	19.0	46.5	34.5

The average physical characteristics of clay soils were determined through laboratory analyses, with the findings documented in Table IV-26, Table IV-27.

The soil moisture parameters of clay, brownish-brown color, solid consistency are presented in Table IV-26 .

Table IV-26

Soil Name		Natural moisture , Wб	Degree of saturation, Sr
Clay	4a	0.132	0.63
	4b	0.229	0.83

Density parameters of clay, brownish-brown color, solid consistency are summarized in Table IV-27.

Table IV-27

Soil Name		Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
		g/cm3			*Percent*	*Unit percent*
Clay	4a	2.72	1.96	1.74	36.30	0.570
	4b	2.72	1.91	1.56	42.78	0.748

Status characteristics of clay, brownish-brown color, solid consistency with atterberg limits characteristics are presented in Table IV-28.

Table IV-28

Soil Name		Liquid limit, WL	Plastic limit, Wp	Liquid limit, WL	Plastic limit, Wp
		Percent			
Clay	4a	0.361	0.179	0.182	-0.26
	4b	0.357	0.183	0.173	0.27

The Normative and calculated values of the parameters of mechanical characteristics of clay, brownish-brown color, solid consistency are presented in BNbD 50-01-16 (Table IV-529).

Table IV-29

Soil	Cohesion, *kPa*	Angle of	Deformation, *MPa*	All owa ble bea

Name				internal friction, *degree*			
		C^{I}	$C^{н}=C^{II}$	φ^{I}	$\varphi^{н}=\varphi^{II}$	$E_{БНбД}$	Ro
Clay	4a	52	78	18	21	27	600
	4b	33	50	15	17	18	300

Table IV-30 presents the Standard Penetration Test (SPT) results for the clay.

Table IV-30

N value (SPT stroke / 300 mm) [1 test]					
Soil Name		Minimum	Maximum	Medium	Number of tests Stopped[(a)]
Clay	4b	51	51	51	1

a. *The Standard Penetration Test (SPT) was discontinued after achieving an N-value of 51 within a penetration depth of less than 0.3 meters. This result indicates that the soil is exceptionally dense and hard, and is classified as a highly compacted engineering-geological formation.*

The Standard Penetration Test (SPT) results for the clay were analyzed using the empirical formulas developed by Peck (1974) and Bowles (1988). These computational values are presented in Table IV-31.

Table IV-31

Soil Name		Adjusted Meaning of Number of blows, N1(60)	Density index, %	Angle of internal friction, *degrees*	Cohesion, *kPa*	volume weight (moisture), kN/m3	Density
Clay	4b	41	-	-	>400 km	>200 km	Very dense

- The standard average electrical resistance for clay is ***50 ohms***.
- Clay in its natural state esposed to slight frost heaving. (EGE-4a)
- Clay in its natural state exposed to strong frost heaving. (EGE-4b)
- Clay, when used in earthworks carried out during thawing conditions, is classified under Category II

EGE-5. Sandy loam

Table IV-32 shows the particles size of sandy loam, brownish color, liquid consistency.

Table IV-32

Soil name	Particle size , %

	Gravel	Sand	Silt / Clay
Sandy loam	17.7	65.4	16.9

The average physical characteristics of sandy loam soils were determined through laboratory analyses, with the findings documented in Table IV-33, Table IV-34.

The soil moisture parameters of sandy loam, brownish color, liquid consistency are presented in Table IV-33.

Table IV-33

Soil Name	Natural moisture , Wб	Degree of saturation, Sr
Sandy loam	0.160	0.71

Density parameters of sandy loam, brownish color, liquid consistency are summarized in Table IV-34

Table IV-34

Soil Name	Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
	g/cm3			*Percent*	*Unit percent*
Sandy loam	2.69	1.94	1.67	37.79	0.608

Status characteristics of sandy loam, brownish color, liquid consistency with atterberg limits characteristics are presented in Table IV-35.

Table IV-35

Soil Name	Liquid limit, WL	Plastic limit, Wp	Plasticity index, Jp	Consistency, IL
	Percent			*Unit percent*
Sandy loam	0.189	0.145	0.044	0.32

The Normative and calculated values of the parameters of mechanical characteristics of sandy loam, brownish color, liquid consistency are presented in BNbD 50-01-16 (Table IV-5).

Table IV-36

Soil Name	Cohesion, *kPa*		Angle of internal friction, *degree*		Deformation, *MPa*		Allowable bearing
	C^{I}	$C^{H}=C_{II}$	φ^{I}	$\varphi^{H}=\varphi^{II}$	$E_{БНбД}$	E_{Pr}	R_o

Sandy loam	9	14	21	24	20	-	300

- The standard average electrical resistance for sandy loam is ***70 ohms***.
- Sandy loam in its natural state esposed to slight frost heaving. (Rf = 0.10)
- Sandy loam, when used in earthworks carried out during thawing conditions, is classified under Category II.

EGE-6. Gravel with loam

Table IV-37 shows the particles size of gravel with loam, brownish brow color, solid consistency, medium consistency, liquid consistency

Table IV-37

Soil Name		Particle size , %		
		Gravel	Sand	Silt / Clay
Gravel with loam	6a	56.3	26.0	17.7
	6b	59.7	20.8	19.5
	6c	54.0	25.3	20.8

The average physical characteristics of gravel with loam soils were determined through laboratory analyses, with the findings documented in Table IV-38 and Table IV-39.

The soil moisture parameters of gravel with loam are presented in Table IV-38

Table IV-38

Soil Name		Natural moisture , Wб	Degree of saturation, Sr
Gravel with loam	6a	0.117	0.85
	6b	0.207	0.95
	6c	0.239	0.98

Density parameters of gravel with loam are summarized in Table IV-39.

Table IV-39

Soil Name		Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
		g/cm3			*Percent*	*Unit percent*
Gravel with loam	6a	2.72	2.21	1.98	27.21	0.374
	6b	2.72	2.06	1.70	37.35	0.597
	6c	2.73	2.03	1.64	39.96	0.666

Status characteristics of gravel with loam with atterberg limits characteristics are presented in Table IV-40.

Table IV-40

Soil Name		Liquid limit, WL	Plastic limit, Wp	Plasticity index, Jp	Consistency, IL
		Percent			*Unit percent*
Gravel with loam	6a	0.278	0.178	0.100	-0.61
	6b	0.285	0.180	0.105	0.26
	6c	0.283	0.178	0.105	0.58

The Normative and calculated values of the parameters of mechanical characteristics of gravel with loam are presented in BNbD 50-01-16 (Table IV-5).

Table IV-41

Soil Name		Cohesion, *kPa*		Angle of internal friction, *degree*		Deformation, *MPa*	Allowable bearing pressure R0 (кPa)
		C^{I}	$C^{н}=C_{II}$	φ^{I}	$\varphi^{н}=\varphi^{II}$	$E_{БНбД}$	Ro
Gravel with loam	6a	17	25	36	41	39	450
	6b	8	12	39	45	30	450
	6c	5	8	32	37	18	400

Table IV-42 presents the Standard Penetration Test (SPT) results for the gravel with loam

Table IV-42

N value (SPT stroke / 300 mm) [5 tests]					
Soil Name		Minimum	Maximum	Medium	Number of tests Stopped[(a)]
Gravel with loam	6a	46	51	48	2
	6c	45	51	48	1

a.*The Standard Penetration Test (SPT) was discontinued after achieving an N-value of 51 within a penetration depth of less than 0.3 meters. This result indicates that the soil is exceptionally dense and hard, and is classified as a highly compacted engineering-geological formation.*

The Standard Penetration Test (SPT) results for the gravel with loam were analyzed using the empirical formulas developed by Peck (1974) and Bowles (1988). These computational values are presented in Table IV-43.

Table IV-43

Soil Name		Adjusted Meaning of Number of blows, N1(60)	Density index, %	Angle of internal friction, *degrees*	Cohesion, *kPa*	volume weight (moisture), kN/m3	Density
Gravel with loam	6a	43	65-85	36-41	-	17.3-22.0	dense
	6c	45	65-85	36-41	-	17.3-22.0	dense

The results of the pressuremeter test conducted on gravel with loam are presented in Table IV-44.

Table IV-44

Soil Name		Modulus E_0, mPa			
		Number of tests	Maximum	Minimum	Medium
Gravel with loam	6a	3	34.9	15.4	35.9
	6c	2	38.9	32.9	27.7

- The standard average electrical resistance for Gravel with loam is ***450ohms***.
- Gravel with loam in its natural state esposed to medium frost heaving. (EGE-6a - D = 4.89 and Sr = 0.85)
- Gravel with loam in its natural state esposed to medium frost heaving. (EGE-6b - D = 3.50 and Sr = 0.95)
- Gravel with loam in its natural state exposed to strong frost heaving. (EGE-6c - D=2.85 and Sr = 0.98)
- Gravel with loam, when used in earthworks carried out during thawing conditions, is classified under Category IV.

EGE-7. Gravel with clay

Error! Reference source not found. shows the particles size of gravel with clay, brownish-brown color, solid consistency and medium consistency

Table IV-45

Soil Name		Particle size , %		
		Gravel	Sand	Silt / Clay
Gravel with clay	7a	53.1	24.6	22.3
	7b	50.5	24.3	25.2

The average physical characteristics of gravel with clay soils were determined through laboratory analyses, with the findings documented in Table IV-46 and Table IV-47.

The soil moisture parameters of gravel with clay soils are presented in Table IV-46.

Table IV-46

Soil Name		Natural moisture , Wб	Degree of saturation, Sr
Gravel with clay	7a	0.132	0.91
	7b	0.263	1.00

Density parameters of gravel with clay soils are summarized in Table IV-47

Table IV-47

Soil Name		Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
		g/cm3			*Percent*	*Unit percent*
Gravel with clay	7a	2.73	2.22	1.96	28.36	0.396
	7b	2.73	2.01	1.59	41.83	0.719

Status characteristics of gravel with clay soils with atterberg limits characteristics are presented in Table IV-48

Table IV-48

Soil Name		Liquid limit, WL	Plastic limit, Wp	Plasticity index, Jp	Consistency, IL
		Percent			*Unit percent*
Gravel with clay	7a	0.383	0.206	0.176	-0.42
	7b	0.385	0.208	0.177	0.31

The Normative and calculated values of the parameters of mechanical characteristics of gravel with clay are presented in BNbD 50-01-16 (Table IV-5).

Table IV-49

Soil Name	Cohesion, *kPa*		Angle of internal friction, *degree*		Deformation, *MPa*	Allowable bearing pressure R0 (кPa)
	C^{I}	$C^{H}=C_{II}$	φ^{I}	$\varphi^{H}=\varphi^{II}$	$E_{БНбД}$	Ro

Gravel with clay	7a	21	32	30	35	32	450
	7b	11	17	38	44	20	450

Table IV-50 presents the Standard Penetration Test (SPT) results for the gravel with clay.

Table IV-50

N value (SPT stroke / 300 mm) [2 tests]					
Soil Name		Minimum	Maximum	Medium	Number of tests Stopped[(a)]
Gravel with clay	7a	51	51	51	2

a.*The Standard Penetration Test (SPT) was discontinued after achieving an N-value of 51 within a penetration depth of less than 0.3 meters. This result indicates that the soil is exceptionally dense and hard, and is classified as a highly compacted engineering-geological formation.*

The Standard Penetration Test (SPT) results for the gravel with clay were analyzed using the empirical formulas developed by Peck (1974) and Bowles (1988). These computational values are presented in Table IV-51.

Table IV-51

Soil Name		Adjusted Meaning of Number of blows, N1(60)	Density index, %	Angle of internal friction, *degrees*	Cohesion, *kPa*	volume weight (moisture), kN/m3	Density
Gravel with clay	7a	48	85-100	>41	-	>20.4	Very dense

The results of the pressuremeter test conducted on gravel with clay are presented in Table IV-52.

Table IV-52

Soil Name		Modulus E_0, mPa			
		Number of tests	Maximum	Minimum	Medium
Gravel with clay	7a	2	27.8	24.9	26.3

- The standard average electrical resistance for Gravel with clay is ***450 ohms***.
- Gravel with clay in its natural state esposed to medium frost heaving. (EGE-7a - D = 5.96 and Sr = 0.91)
- Gravel with clay in its natural state esposed to strong frost heaving. (EGE-7b - D=3.35, Sr=1.00)

- Gravel with clay, when used in earthworks carried out during thawing conditions, is classified under Category IV

Eluvial Deluvial Origin - edQ

EGE-8. Gravel with sandy loam

A weathered sandstone with a green-gray color and solid consistency was examined. Laboratory tests were conducted to determine the average composition of gravel with sandy loam soils, with the results presented in Table IV-53.

Table IV-53

Soil Name	Soil name		
	Gravel	Sand	Silt / Clay
Gravel with sandy loam	66.4	21.5	12.1

The average physical characteristics of gravel with sandy loam soils were determined through laboratory analyses, with the findings documented in Table IV-54 and Table IV-55.

The soil moisture parameters of gravel with sandy loam are presented in Table IV-54.

Table IV-54

Soil Name	Natural moisture , Wб	Degree of saturation, Sr
Gravel with sandy loam	0.082	0.78

Density parameters of gravel with sandy loam are summarized in Table IV-55

Table IV-55

Soil Name	Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
	g/cm3			*Percent*	*Unit percent*
Gravel with sandy loam	2.68	2.27	2.09	22.01	0.282

Status characteristics of gravel with sandy loam soils with atterberg limits characteristics are presented in Table IV-56.

Table IV-56

Soil Name	Liquid limit, WL	Plastic limit, Wp	Plasticity index, Jp	Consistency, IL
	Percent			*Unit percent*

Gravel with sandy loam	0.184	0.140	0.044	-1.51

The Normative and calculated values of the parameters of mechanical characteristics of gravel with sandy loam are presented in BNbD 50-01-16 (Table IV-57).

Table IV-57

Soil Name	Cohesion, *kPa*		Angle of internal friction, *degree*		Deformation, *MPa*	Allowable bearing pressure R0 (кPa)
	C^I	$C^H=C^{II}$	φ^I	$\varphi^H=\varphi^I_I$	C^I	$C^H=C^{II}$
Gravel with sandy loam	17	15	25	29	58	400

Table IV-58 provides a summary of the weathering coefficient and the present weathering status of gravel with sandy loam soils derived from eluvial processes.

Table IV-58

Soil Name	Experimented Soil (weathering)	Experimental Conditions	Yield Ratio, Kvk	Gravel content, %		Degrees of weathering
Gravel with sandy loam	Total Sample Average Indicators	before	0.83	K0	0.51	Strong weathering
		after		K1	3.01	

Table IV-59 presents the Standard Penetration Test (SPT) results for the gravel with sandy loam.

Table IV-59

N value (SPT stroke / 300 mm) [1 test]				
Soil Name	Minimum	Maximum	Medium	Number of tests Stopped[(a)]
Gravel with sandy loam	51	51	51	1

a.*The Standard Penetration Test (SPT) was discontinued after achieving an N-value of 51 within a penetration depth of less than 0.3 meters. This result indicates that the soil is exceptionally dense and hard, and is classified as a highly compacted engineering-geological formation.*

The Standard Penetration Test (SPT) results for the gravel with sandy loam were analyzed using the empirical formulas developed by Peck (1974) and Bowles (1988). These computational values are presented in Table IV-60

Table IV-60

Soil Name	Adjusted Meaning of Number of blows, N1(60)	Density index, %	Angle of internal friction, *degrees*	Cohesion, *kPa*	volume weight (moisture), kN/m3	Density
Gravel with sandy loam	37	85-100	>41	-	>20.4	Very dense

- The standard average electrical resistance for gravel with sandy loam is ***710 ohms***.
- Gravel with sandy loam in its natural state esposed to slight frost heaving. (D = 5.95 and Sr = 0.78)
- Gravel mixed with sandy loam, when used in earthworks carried out during thawing conditions, is classified under Category V.

EGE-9. Gravel with loam

Table IV-61 shows the particles size of gravel with loam, green gray color, solid consistency.

A weathered sandstone with a green-gray color and solid consistency was examined. Laboratory tests were conducted to determine the average composition of gravel with loam soils, with the results presented.

Table IV-61

EGE number	Soil name		
	Gravel	Sand	Silt / Clay
Gravel with loam	54.1	24.8	21.1

The average physical characteristics of gravel with loam green-gray color, solid conisitency soils were determined through laboratory analyses, with the findings documented in Table IV-62 and Table IV-63.

The soil moisture parameters of gravel with loam green-gray color, solid conisitency are presented in **Error! Reference source not found.**

Table IV-62

Soil Name	Natural moisture , Wб	Degree of saturation, Sr
Gravel with loam	0.128	0.92

Density parameters of gravel with loam green-gray color, solid conisitency are summarized in indicators Table IV-63.

Table IV-63

Soil Name	Specific gravity, ps	Density of soil, ρ	Dry density, ρd	Porosity, n	Void ratio, e
	g/cm3			*Percent*	*Unit percent*
Gravel with loam	2.72	2.23	1.97	27.33	0.376

Status characteristics of gravel with loam green-gray color, solid conisitency with atterberg limits characteristics are presented in Table IV-64.

Table IV-64

Soil name	Liquid limit, WL	Plastic limit, Wp	Plasticity index, Jp	Consistency, IL
	Percent			*Unit percent*
Gravel with loam	0.273	0.178	0.095	-0.53

The Normative and calculated values of the parameters of mechanical characteristics of gravel with loam are presented in BNbD 50-01-16 (Table IV-5).

Table IV-65

Soil Name	Cohesion, *kPa*		Angle of internal friction, *degree*		Deformation, *MPa*	Allowable bearing pressure R0 (кPa)
	C^{I}	$C^{н}=C^{II}$	φ^{I}	$\varphi^{н}=\varphi^{II}$	$E_{БНбД}$	Ro
Gravel with loam	17	25	25	29	58	500

Table IV-66 provides a summary of the weathering coefficient and the present weathering status of gravel with loam soils derived from eluvial processes.

Table IV-66

Soil Name	Experimented Soil (weathering)	Experimental Conditions	Yield Ratio, K_{BK}	Gravel content, %		Degrees of weathering
Gravel with loam	Total Sample Average Indicators	before	0.56	K0	0.85	Sligth weathering
		After		K1	1.94	

- The standard average electrical resistance for Gravel with loam is ***450 ohms***.
- Gravel with loam in its natural state esposed to medium frost heaving. (D = 5.63 and Sr = 0.92)
- Gravel with loam, when used in earthworks carried out during thawing conditions, is classified under Category V

EGE-10. Sandstone

A greenish-gray sandstone of Carboniferous sedimentary origin.

Volume weight	2.50 g/cm3
Average density of unweathered sandstone	2.70 g/cm3
Degrees of weathering	Kwr=0.93 /given/
In Natural moisture	Rc=50.0-30.0 MPa
Saturated	Rc=27.0-15.0 MPa
Flexibility Modulus /E, GPa/	0.4-29
Direct shear module /G, GPa/	0.19-0.45
Poisson's ratio /V/	0.13-0.24

HIGHWAY CLIMATE AND GEOTECHNICAL CONDITIONS /AZUAGN 2.01.01-2004/

The engineering-geological elements (EGEs) found throughout the study area were classified based on the AZUAGN 2.01.01-2004 standard. This classification incorporated mechanical characteristics, the typical depth of seasonal soil freezing, and the degree of soil frost heaving.

EGE Number		Soil Name	Soil classification applied during highway construction corresponds to /Category 27/	Highway soil calculation Indicators /Table 3.19/			Normative depth of soil freezing /Table 4b/	Frost heaving Ratio during the freezing time /Table 3.33/		
				$E_{хөрс}$, МПа	$\varphi_{хөрс}$, град	$C_{хөрс}$, МПа	IIB	Soil group	A Degree of frost heaving	Relative frost heaving %
EGE-1	1a	Gravel with sand	Coarse sand	130	42	0.005	3.5	I	without frost heaving	1
	1b			130	42	0.005				
EGE-2	2a	Gravel with sandy loam	Coarse silt sandy loam	108	32	0.045	3.5	IV	A strong frost heaving	7-10
	2b			108	32	0.045				
EGE-3		Loam	Lightweight Silt loam	108	32	0.045	2.5	V	Excessive frost heaving	10
EGE-4	4a	Clay	Sandy Clay	83	26	0.034	2.5	III	frost heaving	4-7
	4b			34	15	0.015				
EGE-5		Sandy loam	Lightweight Sandy loam	56	36	0.014	3.0	III	frost heaving	4-7
EGE-6	6a	Gravel with loam	Lightweight silt loam	108	32	0.045	3.5	V	Excessive frost heaving	10
	6b			72	24	0.030				
	6c			51	20	0.021				
EGE-7	7a	Gravel with clay	Coarse silt clay	108	32	0.045	3.5	III	frost heaving	4-7
	7b			38	17	0.018				
Eluvial Deluvial Origin - edQ										

EGE-8	Gravel with sandy loam	heavy gravel silt sandy loam	108	32	0.045	3.5	IV	A strong frost heaving	10
EGE-9	Gravel with loam	Lightweight gravel silt sandy loam	108	32	0.045	3.5	IV	A strong frost heaving	10
Carboniferous, Altan-Ovoo Formation – C_{1ao}									
EGE-10	Sandstone	In Natural moisture Rc=50.0-30.0 MPa Saturated Rc=27.0-15.0 MPa Flexibility Modulus /E, GPa/ 0.4-29 Direct shear module /G, GPa / 0.19-0.45 Poisson's ratio /V / 0.13-0.24				Boundary of rocky soil	without frost heaving		

V. CONCLUSION

1. ***Location:*** The proposed bridge and tunnel structures along the SHINE TOIROG Highway 1' will pass through Bayangol, Songinokhairkhan, Sukhbaatar, and Bayanzurkh districts in Ulaanbaatar. The project includes the construction of roads, bridges, and tunnels, as documented in the official plans(look at documentary)

2**. *Geomorphological Characteristics:*** Ulaanbaatar is located in a semi-circular arc from west to east along its northern edge. The city is surrounded by various depressions and sedimentary formations of different geomorphological origins. It lies in central Mongolia, within the mountainous valleys of the southeastern Khangai Range, characterized by mid-altitude terrain. The planned highway includes several bridges and a tunnel, each situated in distinct geological zones:

-Bridge-1 hillock I Sedimentation and Accumulation Surface of the Tuul River;

-Bridge-2 Mountain slopes and accumulation surfaces;

-The Tunnel Field is a type of erosion and mountainside surface;

-Bridge-3 Mountain slopes and accumulation surfaces;

-Bridge-4 Slope and Accumulation Type;

-Bridge-5 Slopes and Accumulation Types Surface – Flood II Sedimentation and Accumulation Type;

-**Bridge-6** The hillock River I River Sedimentation-Accumulation Type-Sedimentary Surfaces, respectively.

The highway has its highest surface (1,519.02 m) and lowest point (1,271.99 m).

3. ***Geological Formation****:* The route of SHINE TOIROG Highway 1 crosses several distinct geological formations, including:

- Stream Formation (S4–D3gr)
- Golden-Ovoo Formation (C_1ao)
- Orgioch Formation (C1–2or)
- Buuruljuut Formation (K1br)

These formations consist of various sedimentary and possibly volcanic rocks, reflecting a complex geological history.

Drilling surveys along the route have identified:

- Brownish-yellow and greenish-gray sandstones originating from eluvial-deluvial processes (edQ).
- Deposits from the Holocene and Pleistocene epochs (Q_{1-2})Brownish-yellow, Brown red clay, gravel with clay, gravel with loam, gravel with sandy loam, sandy loam, loam, gravel with sand covered with technogenic originated embankments.

4. ***Hydrogeological Conditions:*** Groundwater levels observed in boreholes along the route ranged from 2.0 to 9.0 meters in depth. To assess the area's potential for high irrigation demand or groundwater resistance, experimental drainage tests were conducted. The analysis was carried out using the following hydrogeological methods:

- Dupuit Method
- Theis Method
- Cooper & Jacob II Method

The findings are compiled in Table V-1.

Table V-1 Averge of Hydraulic conductivity

BH-1 Calculation Methods	Thickness of the aquifer, m	Statictic levels	Groundwater Level	Hydraulic conductivity, m/day
Dupue's method /analytical/	22.85	6.95	8.67	84.59
Theis	22.85	6.95	8.67	51.6
Cooper & Jacob II	22.85	6.95	8.67	54.8
Average				63.66

The groundwater found throughout the study area contains the following chemical elements and compounds:

- BH-1: Sulphate-class, calcium group, type 3, qualitatively salty, very hard, and contaminated water.

  Water Composition: $M_{2.2}$ $\underline{SO_4^{-2}33HCO_3^{-}32Cl^{-}26}$

  $Ca^{2+}59+Mg^{2+}25Na^{+}+K^{+}14$
- BH-7: Sulphate-class, mixed-group, type 2, qualitatively salty, very hard, and contaminated.

  Water Composition: $M_{2.2}$ $\underline{SO_4^{-2}50HCO_3^{-}26Cl^{-}18}$

  $Na^{+}4+K35CA^{2+}33Mg^{+}32$
- BH-12: Hydrocarbonate class, calcium group, type 3, pure, very hard, polluting, and contaminated water.

  Composition of water: $M_{0.8}$ $\underline{HCO_3^{-}39SO_4^{2-}28Cl^{-}25}$

$Ca^{2+}59Mg^{2+}25Na^{+}+K^{+}14$

BH-13: Waters of the hydrocarbonate class, calcium group, type 2, qualitatively pure, hard, polluting, and contaminated.

Water Composition: $M_{0.6}$ $\underline{HCO_3^{-}64SO_4^{2-}17Cl^{-}15}$

$Ca^{2+}49Mg^{2+}27Na^{+}+K^{+}23$

5. ***Hydrological Conditions:*** Watershed areas along and intersecting the highway route were identified, and surface runoff was calculated for each zone. Using runoff estimates at 1%, 5%, and 10% probability levels, the analysis revealed that the Selbe River crossing is the most critical point, showing the highest runoff volume and potential flood risk along the alignment.

Table V-2 Calculation of at points where the watershed and the highway intersect along the route

No	Nomenclature	Location		Watershed runoff		
		Latitude	Longitude	1%, m3/sec	5%, m3/sec	10%, m3/sec
1	Khaniin material gap	5311003	636282	6.17	4.1	3.3
2	Bayankhoshuu gap 1	5312845	638524	6.3	4.2	3.3
3	Bayankhoshuu gap 2	5312978	639385	13.9	5.4	4.3
4	Denjiin 1000 gap	5312909	640871	13.4	9.3	1.4
5	Khailaast gap	5312891	642422	25.7	17.7	9.2
6	Selbe river	5312959	643809	401.8	277.2	221
7	Gants khudag gap	5313466	646031	23.22	15.6	12.4
8	Monel gap	5311397	647181	10.8	7.4	3.8

6. The depth of freeze of the soil in the survey area, the level of soil compaction and the level of frost heaving in the study area according to BNbD 50-01-16 Table 21–d shown in the chart.

Table V-3

EGE Number		Soil Name	Seasonal freeze depth, m (Sacrifice)	A Degree of frost heaving	Soil Work Degree
EGE-1	1a	Gravel with sand	3.59	without frost heaving	IV
	1b			without frost heaving	
EGE-2	2a	Gravel with sandy loam	3.59	slight frost heaving	IV
	2b			strong frost heaving	
EGE-3		Loam	2.51	slight frost heaving	II
EGE-4	4a	Clay	3.05	slight frost heaving	II
	4b			strong frost heaving	
EGE-5		Sandy loam	3.59	slight frost heaving	II
EGE-6	6a	Gravel with loam	3.59	medium frost heaving	IV
	6b			medium frost heaving	

	6c			strong frost heaving	
EGE-7	7a	Gravel with clay	3.59	medium frost heaving	IV
	7b			strong frost heaving	
Soil of Eluvie-Deluvy Origin - edQ					
EGE-8		Gravel with sandy loam	3.59	slight frost heaving	V
EGE-9		Gravel with loam	3.59	medium frost heaving	V
Carboniferous, Altan-Ovoo Formation – C_{1ao}					
EGE-10		Sandstone	Boundary of the Rocky Soil	without frost heaving	VII

7. The Normative and calculated values of the parameters of mechanical characteristics of soils are presented in BNbD 50-01-16 (Table V-4).

Table V-4

EGE Number		Soil Name	Cohesion, *kPa*		Angle of internal friction, *degree*			Deformation, *MPa*	
			C^I	$C^н=C^{II}$	φ^I	$\varphi^н=\varphi^{II}$	$\varphi^{СПТ}$	$E_{БНбД}$	$E_{пр}$
EGE-1	1a	Gravel with sand	1.3	2	36	40	-	45	-
	1b		1.3	2	36	40	>41	45	49.1
EGE-2	2a	Gravel with sandy loam	11	16	38	44	>41	46	49.6
	2b		4	6	38	44	-	45	-
EGE-3		Loam	30	45	22	25	-	31	12.7
EGE-4	4a	Clay	52	78	18	21	-	27	-
	4b		33	50	15	17	-	18	-
EGE-5		Sandy loam	9	14	21	24	-	20	-
EGE-6	6a	Gravel with loam	17	25	36	41	36-41	39	35.9
	6b		8	12	39	45	-	30	-
	6c		5	8	32	37	36-41	18	27.7
EGE-7	7a	Gravel with clay	21	32	30	35	>41	32	26.3
	7b		11	17	38	44	-	20	-
Soil of Eluvial Deluvial Origin – edQ									
EGE-8		Gravel with sandy loam	11	17	18	21	>41	39	-
EGE-9		Gravel with loam	14	21	21	24	-	49	-
Carboniferous, Altan Ovoo Formation – C_{1ao}									
EGE-10		Sandstone	In Natural moisture Rc=50.0-30.0 Mpa Saturated Rc=27.0-15.0 Mpa Flexibility Modulus /E, Gpa/ 0.4-29 Direct shear module /G, Gpa / 0.19-0.45 Poisson's ratio /V / 0.13-0.24						

Notes: Strength Indicators:

C^I; φ^I – calculated values

Defermation Modulus values:

$E_{БНбД}$ – Norm and normative values

$E_{пр}$ – pressuremeter test results

8. This classification incorporated mechanical characteristics, the typical depth of seasonal soil freezing, and the degree of soil frost heaving are shown in the table as shown in AZUAGN 2.01.01-2004.

Table V-5

EGE Number		Soil Name	Soil classification applied during highway construction corresponds to /Category 27/	Normative depth of soil freezing	Frost heaving Ratio during the freezing time /Table 3.33/		
				IIB	Soil group	A Degree of frost heaving	Relative frost heaving %
EGE-1	1a	Gravel with sand	Coarse sand	3.5	I	without frost heaving	1
	1b						
EGE-2	2a	Gravel with sandy loam	Coarse silt sandy loam	3.5	IV	A strong frost heaving	7-10
	2 b						
EGE-3		Loam	Lightweight silt loam	2.5	V	Excessive frost heaving	10
EGE-4	4a	Clay	Sandy Clay	2.5	III	frost heaving	4-7
	4 b						
EGE-5		Sandy loam	Lightweight Sandy loam	3.0	III	frost heaving	4-7
EGE-6	6a	Gravel with loam	Lightweight silt loam	3.5	V	Excessive frost heaving	10
	6 b						
	6c						
EGE-7	7a	Gravel with clay	Coarse silt clay	3.5	III	frost heaving	4-7
	7 b						
Soil of Eluvial Deluvial Origin - edQ							
EGE-8		Gravel with sandy loam	heavy gravel silt sandy loam	3.5	IV	A strong frost heaving	10
EGE-9		Gravel with loam	Lightweight gravel silt sandy loam	3.5	IV	A strong frost heaving	10
Carboniferous Age, Golden-Ovoo Formation – C1ao							
EGE-10		Sandstone		Boundary of rocky soil	without frost heaving		

9. The Normative and calculated values of the parameters of mechanical characteristics of soils are presented in AZUAGN 2.01.01-2004.(Table V-6).

Table V-6

EGE Number		Soil Name	Soil classification applied during highway construction corresponds to /Category 27/	Highway soil calculation Indicators /Table 3.19/		
				$E_{хөрс}$, МПа	$E_{хөрс}$, МПа	$E_{хөрс}$, МПа
EGE-1	1a	Gravel with sand	Coarse sand	130	42	0.005
	1b			130	42	0.005
EGE-2	2a	Gravel with sandy loam	Coarse silt sandy loam	108	32	0.045
	2b			108	32	0.045
EGE-3		Loam	Lightweight Silt loam	108	32	0.045
EGE-4	4a	Clay	Sandy Clay	83	26	0.034
	4b			34	15	0.015
EGE-5		Sandy loam	Lightweight Sandy loam	56	36	0.014
EGE-6	6a	Gravel with loam	Lightweight silt loam	108	32	0.045
	6b			72	24	0.030
	6c			51	20	0.021
EGE-7	7a	Gravel with clay	Coarse silt clay	108	32	0.045
	7b			38	17	0.018
Soil of Eluvial Deluvial Origin - edQ						
EGE-8		Gravel with sandy loam	heavy gravel silt sandy loam	108	32	0.045
EGE-9		Gravel with loam	Lightweight gravel silt sandy loam	108	32	0.045
EGE-10		Sandstone	In Natural moisture Rc=50.0-30.0 MPa Saturated Rc=27.0-15.0 MPa Flexibility Modulus /E, GPa/ 0.4-29 Direct shear module /G, GPa / 0.19-0.45 Poisson's ratio /V / 0.13-0.24			

10. Weathering coefficient and degrees of weathering for Gravel with sand and Gravel with loam eluvial deluvial origin soil (Table V-7).

Table V-7

EGE Number	Soil Name	Yield Ratio, K_{BK}	Degrees of weathering
EGE-8	Gravel with sandy loam	0.83	Strong weathering
EGE-9	Gravel with loam	0.56	Slight weathering

11. Comparison of the results of the standard penetration test with the value of the resistance calculation in accordance with BNbD 50-01-16. (Table V-8)

Table V-8

EGE number		Soil Name	Adjusted Meaning of Number of blows, N1(60)	Density index, %	SPT ()kPa	Allowable bearing pressure R0 (кPa)	Density
EGE-1	1a	Gravel with sand	-	-	-	600	-
	1b		37	85-100	-	600	Very dense
EGE-2	2a	Gravel with sandy loam	49	85-100	-	450	Very dense
	2b		-	-	-	400	-
EGE-3		Loam	31	-	>400 km	300	Very dense
EGE-4	4a	Clay	-	-	-	600	-
	4b		41	-	>400 km	300	Very dense
EGE-5		Sandy loam	-	-	-	300	-
EGE-6	6a	Gravel with loam	43	65-85	-	450	dense
	6b		-	-	-	450	
	6c		45	65-85	-	400	dense
EGE-7	7a	Gravel with clay	48	85-100	-	450	-
	7b		-	-	-	450	-
Soil of eluvial deluvial Origin - edQ							
EGE-8		Gravel with sandy loam	37	85-100		400	-
EGE-9		Gravel with loam	-	-	-	500	-
Carboniferous, Altan Ovoo Formation – C_{1ao}							
EGE-10		Sandstone	-	-	-	-	-

12. Results of pressuremeter tests Table V-9.

Table V-9

Soil Name		Modulus E_0, mPa			
		Number of Experiments	Maximum	Minimum	Medium
Gravel with sand	EGE-1b	1	49.14	49.14	49.1
Gravel with sandy loam	EGE-2a	4	48.55	50.82	49.7
Loam	EGE-3	1	12.66	12.66	12.7
Clay	EGE-4b	1	15.97	15.97	15.9
Gravel with loam	EGE-6a	3	15.37	34.89	27.7
	EGE-6V	2	32.94	38.9	35.9
Gravel with clay	EGE-7a	3	10.53	27.84	21.1

Gravel with sandy loam	EGE-8	1	39.76	39.76	39.8

13. The results of electrical resistance of the soil scattered in the study area are shown in the table below.

Table V-10

EGE Number	Soil Name	Electrical Resistance, Om*m /from reference/	
		Fluctuations	In nature.
EGE-1	Gravel with sand	500-1100	710
EGE-2	Gravel with sandy loam	500-1100	710
EGE-3	Loam	40-150	80
EGE-4	Clay	20-80	50
EGE-5	Sandy loam	40-150	70
EGE-6	Gravel with loam	300-800	450
EGE-7	Gravel with clay	300-800	450
EGE-8	Gravel with sandy loam	500-1100	710
EGE-9	Gravel with loam	300-800	450
EGE-10	Sandstone		

14. No permafrost affecting the highway were observed during the survey conducted in the study area

15. Determining the seismic microregions for each of the bridges and tunnels of the research area.

Table V-11 Seismic Points and Peak Ground Acceleration of the Bridges and the Tunnel Structure of the Research Area

No	Type of Facilities	Peak Groind Acceleration PGA, cm/s^2	MSK-64 points
1	Bridge-1	191-205	VIII
		143-190	VIII
2	Bridge-2	110-142	VII
3	Tunnel	110-142	VII
4	Bridge-3	110-142	VII
5	Bridge-4	143-190	VIII
6	Bridge-5	143-190	VIII
7	Bridge-6	143-190	VIII
		191-205	VIII

Table V-12 Along the highway, the seismic score and the peak of the ground per borehole.

No	Borehole No.	MSK-64 points	Peak Ground Acceleration PGA, cm/s2
1	Borehole No. 1-3	8	191-205

2	Borehole No. 3-4	8	143-190
3	Borehole No. 4-5	7	110-142
4	Borehole No. 5-6	8	143-190
5	Borehole No. 6-9	7	110-142
6	Borehole No. 9-11	8	143-190
7	Borehole No. 11-22	7	110-142
8	Borehole No. 22-24	8	206-283

Reviewed by: *B. Belgudei*

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G. Lhagvajargal

A. Battushig

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VII. BOREHOLE CATALOG

Object: Engineering geological and geotechnical survey report for technical and economic feasibility study (tefs) stage of bridges and tunnels along the "SHINE TOIROG"

Borehole Id	Borehole location	Elevation	Coordinate /UTM 48/		Borehole depth, м	Ground water level, m		Date
			X	Y		water table	static	
BH-1	Bridge-1	1273.2	636865	5306598	42	6.8m,27.2m	6.0 m	2025-05-19
BH-2	Bridge-1	1272.23	636837	5307103	20	6.2m	4.5m	2025-05-16
BH-3	Bridge-1	1271.99	636826	5307645	20	4.2m	4.0m	2025-05-17
BH-4	Bridge-1	1273.67	636801	5308177	20	2.2m	2.2m	2025-05-16
BH-5	Bridge-1	1288.17	636778	5308679	20			2025-05-17
BH-6	Bridge-2	1332.27	636079	5311881	20	8.4m	6.0m	2025-05-18
BH-7	Bridge-2	1344.45	636274	5312408	10	6.0m	6.0m	2025-05-18
BH-8	Tunnel	1457.03	638506	5312808	30			2025-05-31
BH-9	Tunnel	1424.92	640571	5312918	25			2025-06-04
BH-10	Bridge-3	1359.68	642354	5312853	20	3.0m	2.0m	2025-05-18
BH-11	Bridge-4	1346.58	642849	5312902	12			2025-05-19
BH-12	Bridge-4	1325.52	643406	5312920	25	4.4m	2.0m	2025-05-23
BH-13	Bridge-4	1326.3	643991	5312934	20	2.0m	0.6m	2025-05-20
BH-14	Bridge-5	1345.74	649074	5309808	20	2.8m	2.8m	2025-05-23
BH-15	Bridge-5	1328.62	649050	5309234	20			2025-05-27
BH-16	Bridge-5	1311.62	648888	5308593	25	9.0m	6.0m	2025-05-26
BH-17	Bridge-5	1310.74	648906	5307929	25	9.0m	6.0m	2025-05-28
BH-18	Bridge-6	1304.35	649115	5307069	25	9.0m	9.0m	2025-05-25
BH-19	Tunnel	1471.09	639366	5312943	40			2025-06-05

VIII. BORING LOG

Object: Engineering geological and geotechnical survey report for technical and economic feasibility study (tefs) stage of bridges and tunnels along the "shine toirog"

Borehole 1

Depth 42.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.23

1. Embankment (0.00-2.00)/2.00
2. Brownish yellow color, saturated with Gravel with sand (2.00-13.0)/11.0
3. Brownish yellow color, medium consistency with Gravel with loam (13.0-15.0)/2.00
4. Brownish yellow color, saturated with Gravel with sand (15.0-18.5)/3.50
5. Ligth yellow color, medium consistency with Gravel with loam (18.5-27.2)/8.70
6. Brownish yellow color, little moisture with Gravel with sand (27.2-30.5)/3.30
7. Brownish yellow color, solid consistency with weathering Gravel with loam (30.5-36.0)/5.50
8. Green-gray color sandstone (36.0-42.0)/6.00

Groundwater was detected at depths of 2.0 meters and 15.0 meters, with the water level stabilizing at approximately 2.0 meters below ground surface

Borehole 2

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.16

1. Embankment (0.00-0.50)/0.50
2. Brownish gray color, moisture, saturated in depth of 6.2 m with Gravel with sand (0.50-6.80)/6.30
3. Brownish yellow color, solid consistency with Gravel with sandy loam (6.80-20.0)/13.2

Groundwater was detected at depths of 6.2 meters, with the water level stabilizing at approximately 4.5 meters below ground surface

Borehole 3

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.16

1. Embankment (0.00-1.50)/1.50

2. Brownish gray color, solid consistency with Gravel with sandy loam (1.50-4.20)/2.70

3. Brownish gray color, liquid consistency with Gravel with sandy loam (4.20-12.5)/8.30

4. Brownish gray color, solid consistency with Gravel with loam (12.5-15.5)/3.00

5. Brownish gray color, solid consistency with Gravel with sandy loam (15.5-17.5)/2.00

6. Brownish yellow color, solid consistency with Gravel with loam (17.5-20.0)/2.50

Groundwater was detected at depths of 4.2 meters, with the water level stabilizing at approximately 4.0 meters below ground surface

Borehole 4

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.16

1. Embankment (0.00-2.20)/2.20

2. Brownish yellow color, saturated with Gravel with sand (2.20-5.80)/3.60

3. Brownish yellow color, solid consistency with Gravel with sandy loam (5.80-20.0)/14.2

Groundwater was detected at depths of 2.2 meters, with the water level stabilizing at approximately 2.2 meters below ground surface

Borehole 5

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.17

1. Brownish yellow color, solid consistency with Gravel with loam (0.00-20.0)/20.0

Borehole 6

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.17

1. Embankment (0.00-0.70)/0.70

2. Brownish gray color, solid consistency with Gravel with clay (0.70-8.40)/7.70

3. Brownish gray color, medium consistency with Gravel with clay (8.40-8.70)/0.30

4. Brownish gray color, solid consistency with Gravel with clay (8.70-20.0)/11.3

Groundwater was detected at depths of 8.4 meters, with the water level stabilizing at approximately 6.0 meters below ground surface

Borehole 7

Depth 10.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.17

1. Embankment (0.00-2.00)/2.00

2. Brownish yellow color, solid consistency with Gravel with clay (2.00-4.50)/2.50

3. Blue-gray color, solid consistency with weathering Gravel with loam (4.50-7.50)/3.00

4. Blue-gray sandstone (7.50-10.0)/2.50

Borehole 8

Depth 30.0 m Elevation: 1457.30 m

Diameter 96-63.5mm Drilled 2025.05.31

1. Brown color, sandy loam and clay (weak consistency, gravel with big granules) (0.00-1.00)/1.00

2. Brownish brown color, filled with sandy loam and clay (weak consistency, sandy loam, clay and gravel layer) (1.00-4.50)/3.50

3. Brown and Brownish-Grey color Sandstone (meduim density, gravel with rocks) (4.50-5.70)/1.20

4. Crimson-gray color Mudstone (denser, in concrete condition, with rocks) (5.70-9.00)/3.30

5. Dark gray, grey color siltstone, and thin layer of mudstone (Well concreted, less fractures rock) (9.00-18.0)/9.00

6. Dark Grey color siltstone, (Dense, Horizontally Layers the same type) (18.00-22.9)/4.90

7. Dark gray color sandstone and gravelite sediments (fragile structure, gravelite sediment, transformation zone) (22.9-23.9)/1.00

8. Dark Grey color gravelite (whole-shaped, stable rock) (23.90-30.0)/6.10

Borehole 9

Depth 25.0 m Elevation 1424.92 m

Diameter 96-63.5mm Drilled 2025.06.04

1. Grey, brown-grey color sand and gravels (0.00-3.60)/3.60

2. Gray-brown color, damaged by run-off and split in medium granules (3.60-8.50)/4.90

3. Gray-brown color, siltstone and thin layer of sandstone (8.50-20.0)/11.50

4. Gray color, small-grained sandstone (20.50-25.0)/5.00

Borehole 10

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.18

1. Embankment (0.00-3.00)/3.00

2. Brownish yellow color, medium consistency with Gravel with clay (3.00-5.20)/2.20

3. Reddish-brown color, solid consistency with Gravel with clay (5.20-12.8)/7.60

4. Blue-gray color, solid consistency with weathering Gravel with loam (12.8-15.0)/2.20

5. Blue-gray color, sandstone (15.0-20.0)/5.00

Groundwater was detected at depths of 3.0 meters, with the water level stabilizing at approximately 2.0 meters below ground surface

Borehole 11

Depth 12.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.19

1. Brownish yellow color, solid consistency with Gravel with clay (0.00-7.50)/7.50

2. Blue-gray color, solid consistency with strong weathering Gravel with loam (7.50-10.0)/2.50

3. Blue-gray color sandstone (10.0-12.0)/2.00

Borehole 12

Depth 25.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.20

1. Embankment (0.00-0.40)/0.40

2. Dark gray and gray brown-color, solid consistency with Loam (0.40-1.40)/1.00

3. Brownish yellow color, solid consistency with Gravel with sandy loam (1.40-3.00)/1.60

4. Brownish yellow color, solid consistency with Gravel with loam (3.00-4.40)/1.40

5. Brownish yellow color, soft consistency with Gravel with loam (4.40-25.0)/20.6

Groundwater was detected at depths of 4.4 meters, with the water level stabilizing at approximately 2.0 meters below ground surface

Borehole 13

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.21

1. Embankment (0.00-1.40)/1.40

2. Brownish yellow color, medium consistency with clay (1.40-2.00)/0.60

3. Brownish yellow color, solid consistency with Gravel with clay (2.00-20.0)/18.0

Groundwater was detected at depths of 2.0 meters, with the water level stabilizing at approximately 0.6 meters below ground surface

Borehole 14

Depth 20.0 m Elevation: 1504.84 m

Diameter 168-110mm Drilled 2025.05.21

1. Top Soil (0.00-0.30)/0.30

2. Brownish yellow color, medium consistency with gravel with loam (0.30-2.00)/1.70

3. Reddish-brown color, medium consistency with loam (2.00-2.80)/0.80

4. Brownish yellow color, liquid consistency with gravel with loam (2.80-3.20)/0.40

5. Brownish yellow color, medium consistency with gravel with loam (3.20-5.60)/2.40

6. Azure green color, solid consistency with clay (5.60-6.60)/1.00

7. Reddish-brown color; solid consistency with clay (6.60-7.50)/0.90

8. Brownish yellow color, solid consistency with gravel with loam (7.50-13.0)/5.50

9. Brownish yellow color, solid consistency with strong weathering Gravel with loam (13.0-20.0)/7.00

Groundwater was detected at depths of 2.8 meters, with the water level stabilizing at approximately 2.8 meters below ground surface

Borehole 15

Depth 20.0 m Elevation 1328.62m

Diameter 168-110mm Drilled 2025.05.27

1. Top Soil (0.00-0.40)/0.40

2. Brownish yellow color, solid consistency with gravel with sandy loam (0.40-2.40)/2.00

3. Brownish yellow color, solid consistency with gravel with loam (2.40-8.50)/6.00

4. Brownish yellow color, medium consistency with gravel with loam (8.50-8.80)/0.30

5. Brownish yellow color, solid consistency with gravel with loam (8.80-20.0)/11.2

Borehole 16

Depth 25.0 m Elevation: 1311.62 m

Diameter 168-110mm Drilled 2025.05.26

1. Embankment (0.00-1.50)/1.50

2. Brownish yellow color, solid consistency with gravel with sandy loam (1.50-9.00)/7.50

3. Brownish yellow color, medium consistency with clay (9.00-12.00)/3.00

4. Brownish yellow color, medium consistency with loam (12.0-18.0)/6.00

5. Brown and reddish color, solid consistency with gravel with sandy loam (18.0-25.0)/7.00

Groundwater was detected at depths of 9.0 meters, with the water level stabilizing at approximately 6.0 meters below ground surface

Borehole 17

Depth 25.0 m Elevation: 1310.74 m

Diameter 168-110mm Drilled 2025.05.28

1. Embankment (0.00-0.50)/0.50

2. Brownish yellow color, solid consistency with gravel with sandy loam (0.50-9.00)/8.50

3. Brownish yellow color, liquid consistency with gravel with sandy loam (9.00-18.0)/9.00

4. Brown and a reddish-brown color, solid consistency clay (18.0-25.0)/7.00

Groundwater was detected at depths of 9.0 meters, with the water level stabilizing at approximately 6.0 meters below ground surface

Borehole 18

Depth 25.0 m Elevation: 1304.35 m

Diameter 168-110mm Drilled 2025.05.25

1. Embankment (0.00-1.00)/1.00

2. Brownish yellow color, solid consistency with gravel with loam (1.00-9.00)/8.00

3. Brownish yellow color, liquid consistency with gravel with loam (9.00-12.5)/3.50

4. Brownish yellow color, solid consistency with clay (12.5-25.0)/12.5

Groundwater was detected at depths of 9.0 meters, with the water level stabilizing at approximately 9.0 meters below ground surface

Borehole 19

Depth 40.0 m Elevation: 1471.09 m

Diameter 96-63.5mm Drilled 2025.06.05

1. Brown-gray and gray-color, medium-grained sandstone (0.00-4.20)/4.20

2. Brownish yellow color, solid consistency with gravel with loam (4.20-18.20)/14.0

3. Grey and blue-gray color small grains with siltstones and thin layer of sandstone (18.20-40.0)/21.8

Field notes were taken by

Engineer /A.Ariunzaya/

IX. PHOTO APPENDIX OF BOREHOLES`

Photo.1 Drilling process

Photo.2 Hydrogeological borehole

Photo.3 Hydrogeological borehole

Photo.4 Drilling process

Photo.5 Soil sampling

Photo.6 Drilling process

Photo.7 Soil sampling

Photo.8 Deep Borehole Drilling Process

Photo.9 Rock sampling

Photo.10 Laboratory test Process

Photo.11 Laboratory test Process

Photo.12 Laboratory test Process

APPENDIX-I

APPENDIX-II