The Afghanistan Engineering Support Program assembled this deliverable. It is an approved, official USAID document. Budget information contained herein is for illustrative purposes. All policy, personal, financial, and procurement sensitive information has been removed. Additional information on the report can be obtained from Firouz Rooyani, Tetra Tech Sr. VP International Operations, (703) 387-2151.

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ENGINEERING SUPPORT PROGRAM

W0-A-0049
BADAKSHAN BRIDGE #12
FINAL INVESTIGATION REPORT
KESHIM-FAIZABAD ROAD, BADAKSHAN PROVINCE

September 20, 2010

This publication was produced for review by the United States Agency for International Development. It was prepared by Tetra Tech, Inc.

This report was prepared for the United States Agency for International Development, Contract No. EDH-I-00-08-00027-00, Task Order 01, Afghanistan Engineering Support Program.

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TETRA TECH

September 20, 2010

[redacted] COTR
[redacted] ACOTR
USAID – Office of Infrastructure, Engineering and Energy (OIEE)
Café Compound
U.S. Embassy
Great Masood Road Kabul, Afghanistan

Re: WO-A-0049
Bridge #12 Final Investigation Report
Keshim-Faizabad Road, Badakshan Province

[redacted]

In response to USAID's request, Tetra Tech has reviewed the information provided by your office to assess the cause of failure of Bridge #12 on the Keshim-Faizabad Road. This information included reports and calculations regarding the design of the bridge. The attached report discusses the design information provided, along with Tetra Tech's assessment of that information and subsequent conclusions.

Per your request, we have included recommendations for additional data and field investigations that would be helpful in drawing more conclusive determinations.

We hope you find this assessment helpful. If you have questions or need additional information please do not hesitate to contact us.

Sincerely,

[redacted]

[redacted], P.E.
Chief of Party (OIEE-AESP)
Tetra Tech Inc.

Cc: [redacted] USAID-OIEE)
[redacted] D-OIEE)

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AFGHANISTAN ENGINEERING SUPPORT PROGRAM

WO-A-0049
Bridge #12 Final Investigation Report
Keshim-Faizabad Road, Badakshan Province

September 20, 2010

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1.0 Introduction

In response to USAID's request, Tetra Tech has reviewed the information provided for the failure of Bridge #12 located on the Keshim-Faizabad Road in the Badakshan Province in northern Afghanistan. Tetra Tech reviewed reports and calculations, regarding the design of the bridge, that were made available (See Appendix B) to determine the cause of the failure.

The nature of the failure appears to be related to a greater depth of flow than originally estimated during the bridge design process. Based on photographic evidence, the water appears to have crested in excess of five meters above the design elevation, causing a loss of the steel superstructure.

Using the data available, a limited hydrologic, hydraulic, and structural assessment was conducted. The conclusions, design discrepancies, and recommendations of this study are stated herein.

2.0 Background

USAID is currently constructing several bridges along the Keshim-Faizabad Road in the Badakshan Providence of Afghanistan. During the construction of Bridge #12, (located approximately 49 km west of Faizabad), information provided by USAID indicated that runoff from two storm events in 2010, occurring within days of each other, damaged the newly placed superstructure of the bridge. Specifically, the flood water rose and swept the beams from the top of the northern abutment. The water level on the south abutment reached approximately half-way up the abutment. No scour was observed at either abutment.

Figure 1: North Abutment

Figure 2: South Abutment

USAID has asked Tetra Tech to investigate this failure.

Specifically, the scope of work requested "a Senior Hydraulic/Hydrology Engineer to perform a forensic study to determine cause. Work to include; review of design reports, construction bridge plans and other documents to determine if the bridge was designed to acceptable engineering methods and standards. This work may require a field visit to the site to view conditions and estimate storm event upstream flow rates to determine the impact to the bridge structure as designed. This could require survey of a stream channel cross section to establish the storm high water mark. The finished report will discuss findings of calculations, the hydraulic report, and adequacy of the design and cause of failure. The ultimate outcome is to determine if there is an error in design."

3.0 Hydrology

There is little published data on historical rainfall in this area of Afghanistan. The designer (Louis Berger Group) conducted a statistical analysis, using the short record period available from a nearby gauge. This analysis appears to have been done correctly. In their notes, the designer correctly acknowledges that the period of record is too short to generate reliable statistical data. Tetra Tech agrees that the available period of records (eight years) is not long enough to provide reliable recurrence data. The designer does not appear to have added any factors to the rainfall data to provide the margin of safety needed by such a short sample period.

The designer appears to have used a 50-year storm projection for the bridge design (and has stated such to their client as part of the process). In comparison, most US bridge designs use either a 100-year or 500-year storm event in the design considerations.

Tetra Tech requested rainfall data for the storm events that caused the bridge failure, so that the data could be compared to the design storm data. Unfortunately, such information was not available.

A reference was made concerning an assumption by the bridge designer that an earthen dam upriver in the watershed may have been breached during this flood to cause a higher than anticipated flow rate through the bridge. (See attached correspondence from [redacted] P.E., OIEE, dated August 04, 2010). Tetra Tech has not been provided information to confirm if this occurred, and found no reference to an upstream dam in the Hydrological or Hydraulic Reports provided.

The designer used the United States Army Corps of Engineer's (USACE) HEC-1 software for generating peak flood flow data and appears to have properly delineated the drainage area as represented on a topographic map provided to Tetra Tech.

A key component of using HEC-1 for calculating flow rate is calculating a lag time for each watershed. A lag time formula was presented but the origin of the formula is uncertain. There is little published information on calculating lag times in mountain regions, but the flow rate is very sensitive to the calculation of lag time. A lower lag time would produce a peak flow possibly twice what was used to design this bridge.

Tetra Tech also believes the curve number (89) used in the method may be lower than representative for the mountain slopes and soils; however, Tetra Tech was unable to find published values for similar applications.

4.0 Hydraulics

The designer used the USACE HEC-RAS program for calculating water surface elevations through and under the bridge. This is appropriate software for this application. The actual input file was not provided to Tetra Tech; however, a topographic map with cross section locations was provided.

Tetra Tech's review of a printed output table, provided by the designer, indicates the software was run in "subcritical" mode. This caused the software to set the water surface elevation to a level that produces critical depth at many cross sections. Tables from the HEC-RAS output for Bridge #12 showed Froude number calculations approximately equal to 1. This should have alerted the designer to rerun the model in supercritical or mixed flow mode. The Froude number is a dimensionless indicator that defines the subcritical and supercritical flow regimes. Subcritical flow is defined by low velocities and is the most common flow condition experienced in nature. Supercritical flow is characterized by high, erosive velocities and is relatively uncommon. However, steep mountainous terrain is one place where supercritical flow may be expected.

One property of supercritical flow is that disturbances in the flow (such as caused by channel transitions like the bend upstream of the bridge, or the abutment and the training dikes) will be carried downstream, rather than quickly dissipating. This can create localized areas of higher depths and velocities. This may be the reason why the water depth at the north abutment was reported to be higher than at the south abutment.

Supercritical flow in the upstream channel bend is also problematic as significant superelevation of the water surface (i.e. a higher elevation at the outside of the bend) can occur. This may also be a cause for the report of the higher water surface elevation at the northern abutment

The transition from supercritical to subcritical flow occurs through a hydraulic jump. A hydraulic jump is an extremely turbulent condition with the potential to be highly erosive to the channel.

Tetra Tech set up a numeric model, using HEC-RAS, from the cross sections provided. The model indicates this channel is steeply sloping and the flow in most of the locations is supercritical. Therefore, the model was run in “mixed flow” regime where both subcritical and supercritical flow regimes can be analyzed. At the supercritical locations, much higher velocities were produced than were predicted by the designer.

Table 1 shows the output from the HEC-RAS model that Tetra Tech developed. It shows limited flow rates and downstream river elevations and that a hydraulic jump may occur in the vicinity of Bridge 12. The predicted hydraulic jump would cause localized areas of erosive velocities and are generally to be avoided adjacent to an unprotected bridge foundation.

Table 1: Tetra Tech HEC-RAS Output

HEC-RAS Plan: Mixed			River: Unknown		Reach: Study		Profile: PF 1				
Reach	River Sta	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl°	Flow Area†	Top Width†	Froude # Chl‡
		(m3/s)	(m)	(m)	(m)	(m)	(m/m)	(m/s)	(m2)	(m)	
Study*	140	166.38	1008.21	1009.51	1009.51	1009.92	0.009757	2.81	59.12	74.45	1.01
Study*	120	166.38	1007.14	1007.94	1008.34	1009.40	0.063847	5.36	31.02	60.80	2.40
Study*	100	166.38	1006.02	1006.88	1007.26	1008.21	0.052372	5.11	32.54	59.22	2.20
Study*	80	166.38	1004.83	1005.59	1006.00	1007.06	0.061180	5.38	30.94	58.56	2.36
Study*	60	166.38	1003.28	1005.71	1005.00	1005.93	0.001790	2.11	79.04	70.99	0.49
Study	43	Bridge									
Study	20	166.38	1000.81	1002.27	1002.73	1003.86	0.036883	5.58	29.84	98.94	1.95
Study	0	166.38	999.51	1000.53	1001.06	1002.60	0.090612	6.38	26.10	51.17	2.85

Note: *Indicates a River Station that is upstream of the bridge.
°The velocities approaching and leaving the bridge are very high.
†Cross-sections provided by Louis Berger
‡Froude numbers greater than 1 indicate supercritical flow

5.0 Structural

Tetra Tech provided a limited review of the bridge structure since the failure was clearly related to a hydraulic event as opposed to a structural failure. Damage to the cheekwall and wingwalls on the north abutment was obvious from the photos, but these were designed to be above the water level and not to resist the lateral forces generated by this type of event. No survey was performed to determine if additional damage was done to the abutments as this was outside the scope of our investigation.

Beyond these general observations, Tetra Tech did review the information provided and notes the following:

- Information was not provided that indicates specific attachment or restraint of the bridge bearings to the abutment bearing seat, nor do the reinforcing details indicate the presence of reinforcement in the abutment 250mm return walls.

- The Bridge 12 plans provided to Tetra Tech do not appear to be the plans that were used for the construction based on the photos. The abutments were built with counterfort abutment walls for support which are a significant deviation from the plans provided.

- The design calculations provided for review were for different bridges (#1 & #17) which include loads and load combinations per American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Highway Bridges. It is not clear if the abutment back walls and return walls were designed to provide adequate lateral resistance.

- The provided photographs were taken from a significant distance and indicate structural failure of the return walls and bearings that have either failed or are damaged in place. It is conceivable that the impact forces generated by the flood would significantly exceed the bridge lateral design forces required by structural code, thereby causing the observed failure.

6.0 Summary

Based on the information provided, Tetra Tech does not have adequate information to determine what caused the 2010 failure of Bridge 12. More information on actual rainfall, confirmation of an upstream dam failure or breach, and more observations of water surface elevations upstream and downstream of the bridge would be required. However, Tetra Tech's review of this bridge indicates there are several design issues that likely contributed to this failure and may contribute to future problems. A brief summary of some of these concerns follows:

- There are not enough historical rainfall records for this area to accurately determine if the design rainfall (and therefore peak stream flow) is accurate.

- A 50-year design storm provides substantially less energy than the storm event typically designed for in United States applications

- Tetra Tech believes the peak flow for a given storm may be higher than predicted by the designers. This is due to both the lack of historical rainfall data to accurately select design storms and perhaps due to assumptions made for the HEC-1 input.

- The bridge is located at the foot of a mountain range. The channel slope is steep and presents numerous design challenges. We believe the supercritical nature of this flow was a strong contributor to the bridge failure. The channel bend and the training dikes likely contributed to the elevated water surface at the northern bank relative to the southern bank. Tetra Tech feels that high velocity and water levels may occur again if the transition into and out of the bridge is not improved.

- Tetra Tech recommends that a thorough hydraulic analysis be conducted (from approximately 1 km above the bridge, to the receiving river downstream) to better assess the potential for this bridge to be choking the river flow. This analysis would reevaluate the 35-meter span used for this bridge. For a United States interstate highway evaluation, a design analysis in such extreme conditions would likely consist of a two dimensional computer model and/or a physical model of the bridge structure.

To obtain a more accurate conclusion as to the actual causes of the bridge failure, Tetra Tech recommends that the following parameters and steps be executed by the bridge designer and provided to USAID for further evaluation:

1. The consultant shall review the previous hydrologic calculations and complete a flow prediction calculation that is consistent with mountainous watersheds. The consultant may wish to consider calculating a new peak flow rate using regression equations for this geographic area from other projects. Additional research on design rainfall events in Afghanistan is warranted.

2. The consultant shall obtain and compile new input field data from the bridge location. New river cross sections should be obtained every 150 meters upstream for a minimum of 1 kilometer and extend to the receiving river downstream of the bridge. At river bends, bridges, etc. measurements will be obtained every 30 meters. Elevation data shall also be obtained in a grid resolution of 10 meters or less, including channel overbank areas.

3. The consultant shall perform a new modeling run using the HEC-RAS software program. The cross-sectional information obtained during the field investigation shall be used.

4. The consultant shall also select a two-dimensional modeling software program that is capable of being applied for use at this bridge location. As stated in the summary above, certain locations within the flow regime at this bridge location must be considered supercritical. Additionally, significant superelevation values may exist at this site. The selected software model must take these parameters into account.

5. The consultant shall set-up and run the two-dimensional model using the grid information obtained during the field investigation above. The model shall be calibrated utilizing the new field data and observational rainfall date from 2010.

6. The consultant shall summarize the model results and provide recommendations to USAID regarding the existing bridge design, span and location. The consultant shall propose and provide design alterations as needed to adhere to the model results. Recommendations shall also include whether the two-dimensional model results are sufficient to describe the channel hydraulics, or a more sophisticated technique (three-dimensional modeling or a physical model) is warranted.

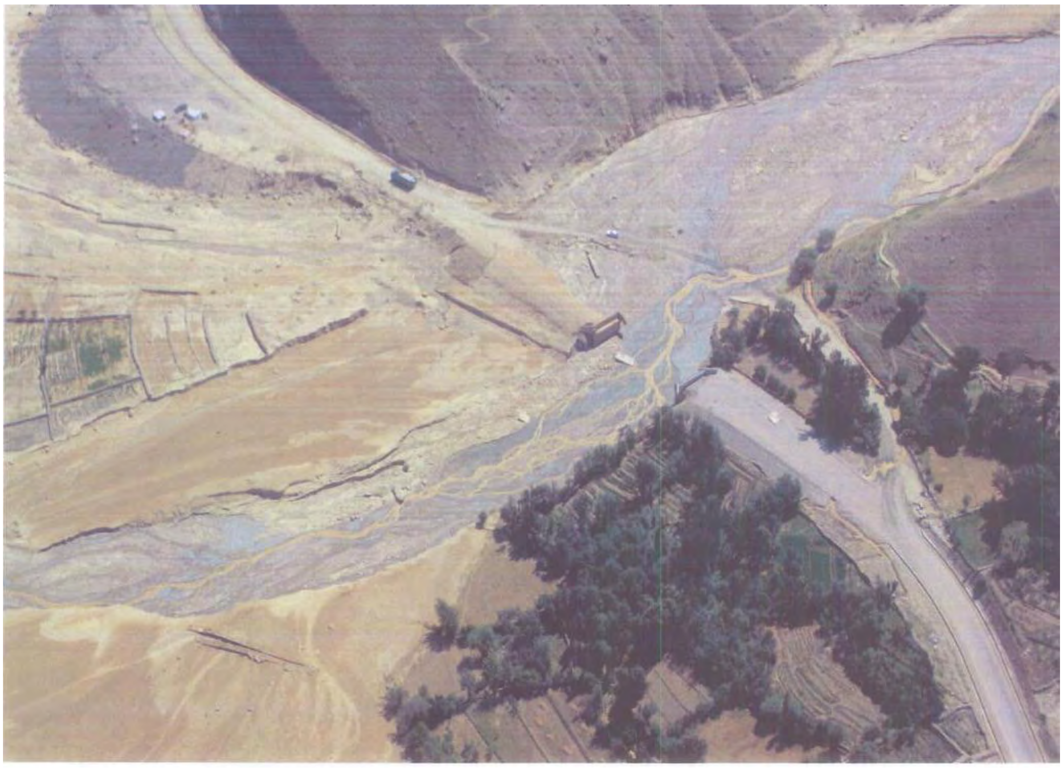
Appendix A: Photos

Bridge opening looking downstream

North abutment looking over south abutment

North abutment

Bridge superstructure approximately 300 meters downstream



Aerial photo of bridge remains

Appendix B: Reference Documents

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Appendix B – Reference Documents

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2. Hydraulic Design of Bridge 12 Using HEC-RAS
3. Bridge 12 Design Information
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5. Geotechnical Report
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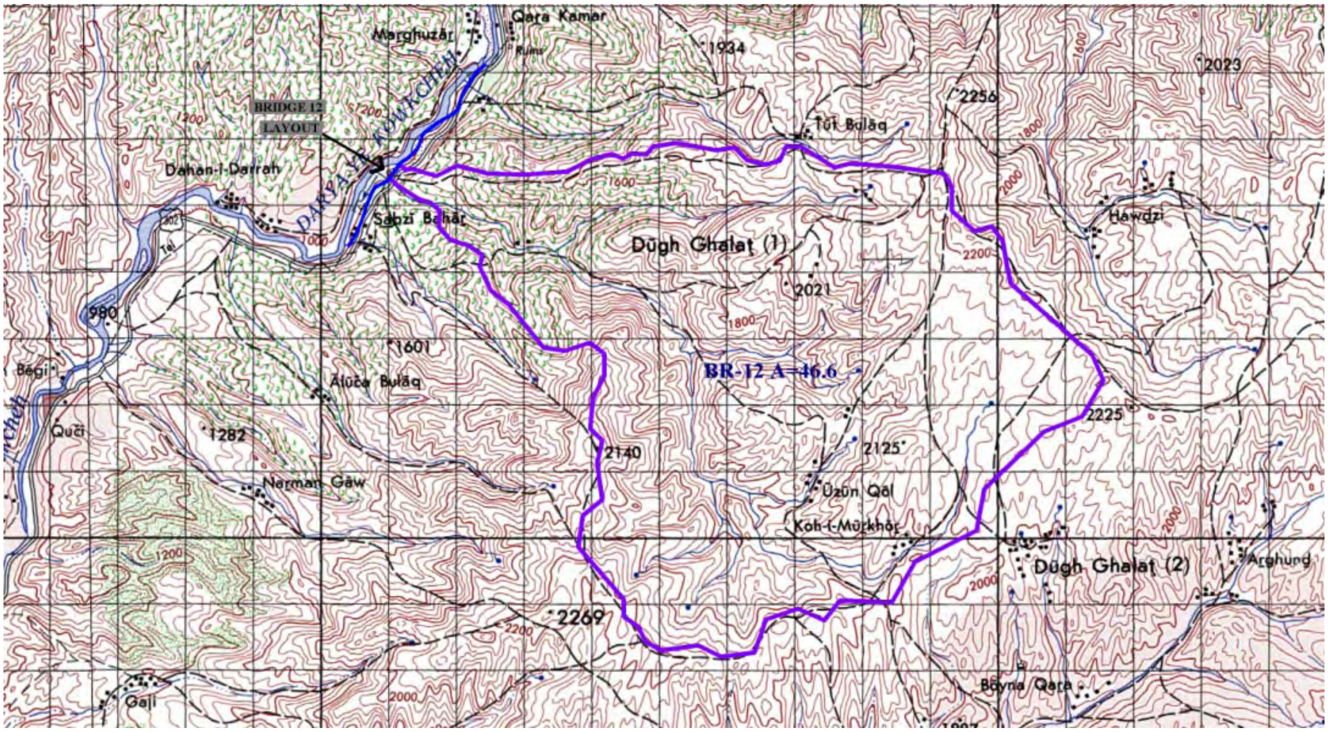
    c. RCN
    d. TC
    e. PH 50
    f. Atlas 14
    g. Tables
    h. RAW
    i. Comparisons
    j. Rec.
    k. Pipes
    l. Structures
10. Email Correspondence Re: WO_A_0049 Bridge Assessment - Badakshan



Catchment area of Bridge no 12.

TABLE 4: WATERWAY OPENING AND DHWL FOR BRIDGES USING HEC-RAS

RIVER 1 STATION 12+460

River Sta Reach 1	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
200.10	778.90	849.50	852.00	852.00	852.70	0.008036	3.71	209.90	150.86	1.00
180.10	778.90	848.19	850.93	850.93	851.66	0.007517	3.79	207.33	151.98	0.99
160.10	778.90	847.54	850.41	850.41	851.14	0.007846	3.77	207.28	150.36	1.00
140.10	778.90	847.61	850.39		850.73	0.002427	2.19	316.57	178.29	0.56
120.10	778.90	846.88	850.44		850.66	0.001104	2.15	395.75	180.27	0.42
103.10	778.90	846.13	850.48		850.62	0.000632	1.81	485.27	195.10	0.32
100.10	778.90	846.07	850.49		850.61	0.000472	1.68	528.78	195.34	0.28
95.00	778.90	845.63	850.53		850.59	0.000242	1.20	740.13	266.97	0.20
80.10	778.90	845.50	850.51		850.59	0.000275	1.40	638.00	200.00	0.22
60.10	778.90	845.57	850.54		850.57	0.000078	0.76	1054.34	275.00	0.12
40.10	778.90	845.40	850.48	847.90	850.56	0.000227	1.31	664.22	200.00	0.20

RIVER 3 STATION 22+788

River Sta Reach 1	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
200.00	2115.17	803.15	821.06		821.45	0.000306	2.79	762.12	64.49	0.25
190.00	2115.17	803.20	821.04		821.45	0.000300	2.84	756.17	62.73	0.25
180.00	2115.17	802.53	820.96		821.44	0.000441	3.07	689.88	62.43	0.29
170.00	2115.17	803.72	820.55		821.39	0.000989	4.08	518.93	54.72	0.42
160.00	2115.17	803.67	817.79	817.79	821.12	0.006440	8.12	264.16	40.84	0.98
140.00	2115.17	801.77	813.10	813.10	816.78	0.008002	8.49	249.00	34.03	1.00
120.00	2115.17	801.99	810.78	810.78	814.10	0.005928	8.07	262.19	39.65	1.00
103.00	2115.17	801.86	810.84		813.44	0.004203	7.15	295.98	41.73	0.86
100.00	2115.17	801.82	810.75	810.06	813.37	0.004306	7.16	295.22	42.95	0.87
95.00	2115.17	801.76	810.00	810.00	813.29	0.005861	8.03	263.35	40.42	1.00
90.00	2115.17	801.73	809.82	809.82	813.12	0.006098	8.05	262.90	40.22	1.00
80.00	2115.17	801.71	808.95	808.95	811.45	0.005617	7.00	302.24	61.39	1.01

RIVER 12 STATION 55+786

River Sta Reach 1	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
140.00	166.38	1009.77	1011.13	1011.13	1011.56	0.009258	2.94	56.81	65.11	1.00
120.00	166.38	1008.90	1009.93	1009.93	1010.30	0.009697	2.72	61.25	81.50	1.00
100.00	166.38	1007.63	1008.76	1008.76	1009.16	0.009600	2.81	59.66	76.62	1.00
80.00	166.38	1006.31	1007.69	1007.69	1008.10	0.009719	2.85	58.46	72.64	1.01
60.00	166.38	1005.08	1006.54	1006.54	1007.02	0.009156	3.07	54.30	58.22	1.01
43.00	166.38	1004.00	1005.63	1005.63	1006.06	0.009410	2.91	57.22	67.14	1.00
40.00	166.38	1003.55	1005.25	1005.16	1005.65	0.006964	2.79	59.57	58.24	0.88
35.00	166.38	1003.28	1005.42		1005.55	0.002232	1.59	104.39	100.82	0.50
20.00	166.38	1002.43	1005.49		1005.51	0.000147	0.71	235.24	99.68	0.15
0.00	166.38	1000.74	1005.50	1002.32	1005.51	0.000038	0.48	349.36	94.59	0.08

RIVER 13 STATION 59+203

River Sta Reach 1	Q Total (m3/s)	Min Ch El (m)	W.S. Elev (m)	Crit W.S. (m)	E.G. Elev (m)	E.G. Slope (m/m)	Vel Chnl (m/s)	Flow Area (m2)	Top Width (m)	Froude # Chl
100.00	41.69	1019.74	1020.88	1020.88	1021.19	0.010642	2.46	16.94	27.74	1.01
80.00	41.69	1017.67	1018.57	1018.57	1018.84	0.010972	2.32	17.96	32.77	1.00
60.00	41.69	1015.37	1016.37	1016.37	1016.62	0.011298	2.18	19.14	39.66	1.00
53.00	41.69	1014.48	1015.98		1016.01	0.000697	0.86	48.62	50.38	0.28
50.00	41.69	1013.99	1015.99		1016.01	0.000161	0.52	79.84	57.71	0.14
45.00	41.69	1012.24	1016.00		1016.00	0.000033	0.31	133.29	62.85	0.07
40.00	41.69	1011.23	1016.00		1016.00	0.000009	0.20	215.55	78.40	0.04
30.00	41.69	1011.99	1016.00	1005.91	1016.00	0.000000	0.03	809.99	126.50	0.01

Hydraulic Inspection of Bridge

Bridge No. ***12*** Station: *55+786*

Drainage Basin No. *xxx*

Drainage Area: ~~*49.53 sqkm ~ 19.12 sqmi ~ 12,239 acres*~~ *46.07sqkm ~ 17.8 sqmi*

Flow rate (Q50) ~~*166.38 cms ~ 5,875 cfs*~~ *153.0cms ~ 5,403 cfs*

Runoff/unit: ~~*3.36cms/sqkm ~ 0.48 cfs/ acre*~~ *0.474 cfs/acre*

Watershed Land Use: *Undeveloped ~rocky outcrops w/ steep slopes*

Watershed soil type: *Hydrologic Soil Type D - poor vegetative cover*

Channel Conditions

Upstream channel material: *gravel/ cobble* Channel width: *75 meters*

Upstream channel stability left: *stable* right: *stable*

Upstream channel soils left: *gravel/cobble* right: *sand/gravel*

Upstream channel sides slopes left: *3:1* right: *3:1*

Upstream channel slope: *5%*

Upstream channel migration potential: *no indication of future migration*

Bed Lowering upstream: *minor* downstream: *none*

Downstream channel material: *stone/cobble* Channel width: *100 meters*

Downstream channel stability left: *stable* right: *stable*

Downstream channel soils left: *sand/gravel* right: *sand/gravel*

Downstream channel slope: *5%*

Downstream channel migration potential: *no indication of future migration*

Kokcha Bank material upstream: *n/a* downstream: *n/a*

Kokcha River migration potential: *none*

Existing Structure Condition

Type: *Masonry wall structures* Size/Span: *30 meter low flow*

Height: *n/a* Condition: *Fair condition*

Wingwall condition: *good* Evidence of ponding: *none*

Scour upstream: *n/a* downstream: *n/a*

Evidence of Debris: *none* Sediment: *none*

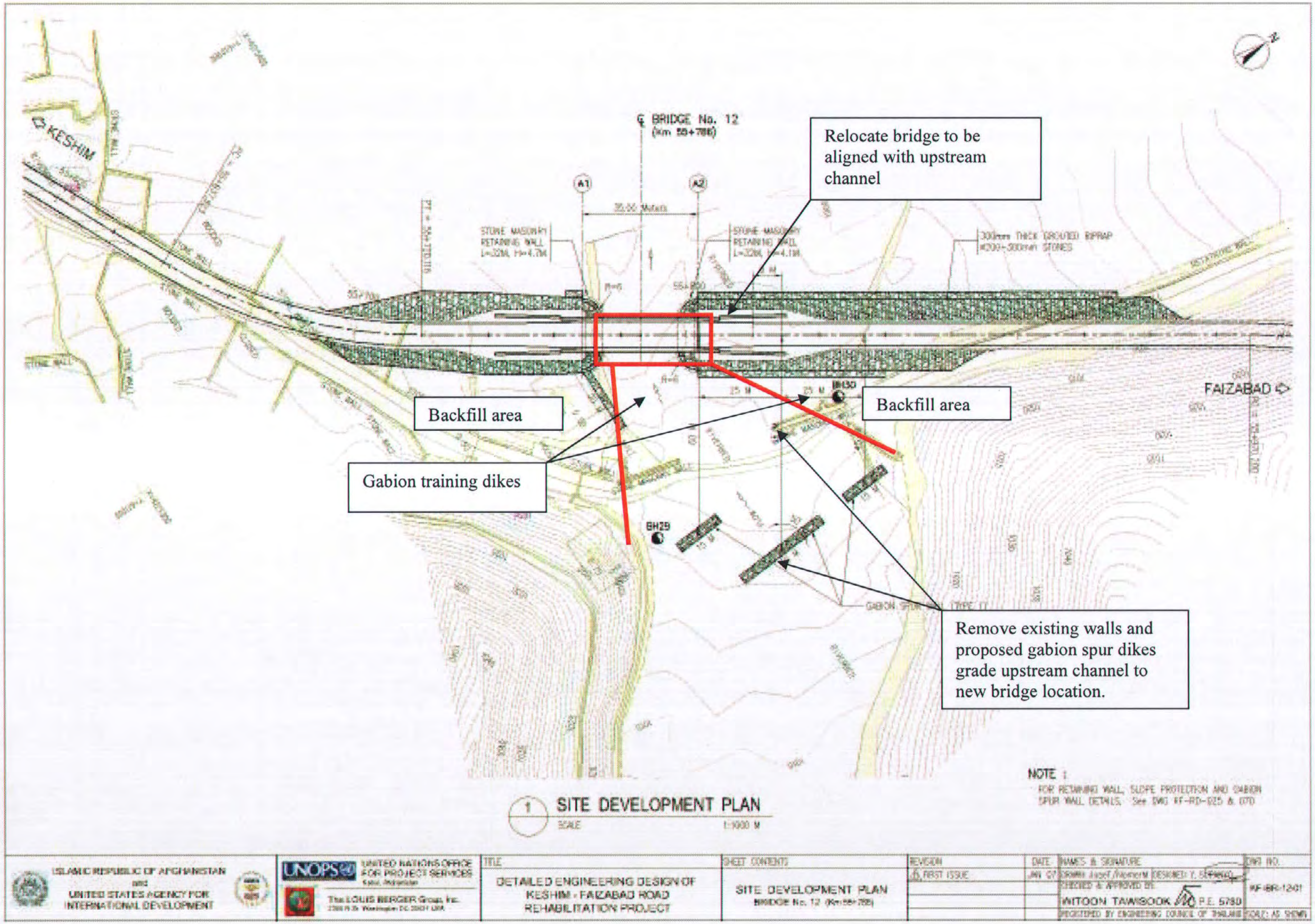
Erosion Control Measures: *none*

Scour potential at proposed abutment: *potential for scour at proposed abutments*

Scour potential at proposed pier: *n/a "clear span*

Remarks : *Proposed structure: 1 span 35 meter bridge. Proposed bridge does not appear to be aligned with direction of flow.*

Recommendations: *Remove gabion spur walls upstream of bridge as located they will train flow to north abutment. Training dikes or embankment should be extended to existing stone masonry walls. Abutments should be designed to resist designed scour depths. Move bridge north 5 meters and regrade existing channel to train flow into bridge.*



BRIDGE No. 12
(km 55+786)
KESHIM
FAIZABAD
Relocate bridge to be aligned with upstream channel
Backfill area
Backfill area
Gabion training dikes
Remove existing walls and proposed gabion spur dikes grade upstream channel to new bridge location.
STONE MASONRY RETAINING WALL
300mm THICK GROUTED RIPRAP
GABION SPUR
BH29
BH30
A1
A2
1 SITE DEVELOPMENT PLAN
SCALE 1:1000 M
NOTE :
FOR RETAINING WALL, SLOPE PROTECTION AND GABION SPUR WALL DETAILS, See DWG KF-RD-025 & 070
ISLAMIC REPUBLIC OF AFGHANISTAN
and
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT
UNOPS
UNITED NATIONS OFFICE FOR PROJECT SERVICES
The LOUIS BERGER Group, Inc.
DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT
SITE DEVELOPMENT PLAN
BRIDGE No. 12
FIRST ISSUE
WITOON TAWSOOK P.E. 5780
SCALE: AS SHOWN

BRIDGE NO. 12

Looking south on existing alignment

Looking south to proposed abutment location

Looking upstream from existing structure

Looking north along existing alignment

WATER SHED AREA FOR KESHIM - FAIZABAD ROAD(Second List)

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	AREA SQ.KM	2.905	3.667	8.707	17.276	34.957
1	2759298.155	2.759	1.559	1.967	4.672	9.269	18.755
2	758394.478	0.758	0.428	0.541	1.284	2.548	5.155
3	8579050.179	8.579	4.846	6.117	14.525	28.819	58.313
4	7364493.284	7.364	4.160	5.251	12.468	24.739	50.058
5	868191.182	0.868	0.490	0.619	1.470	2.916	5.901
6	229836.670	0.230	0.130	0.164	0.389	0.772	1.562
7	485331.779	0.485	0.274	0.346	0.822	1.630	3.299
8	674346.374	0.674	0.381	0.481	1.142	2.265	4.584
9	127874.233	0.128	0.072	0.091	0.216	0.430	0.869
10	468121.960	0.468	0.264	0.334	0.793	1.573	3.182
11	1987340.564	1.987	1.123	1.417	3.365	6.676	13.508
12	913207.594	0.913	0.516	0.651	1.546	3.068	6.207
13	101567.767	0.102	0.057	0.072	0.172	0.341	0.690
14	402041.298	0.402	0.227	0.287	0.681	1.351	2.733
15	237226.687	0.237	0.134	0.169	0.402	0.797	1.612
16	582853.871	0.583	0.329	0.416	0.987	1.958	3.962
17	4034398.904	4.034	2.279	2.877	6.830	13.552	27.423
18	161189.514	0.161	0.091	0.115	0.273	0.541	1.096
19	679044.422	0.679	0.384	0.484	1.150	2.281	4.616
20	179918.750	0.180	0.102	0.128	0.305	0.604	1.223
21	28679.747	0.029	0.016	0.020	0.049	0.096	0.195
22	162056.983	0.162	0.092	0.116	0.274	0.544	1.102
23	1680070.454	1.680	0.949	1.198	2.844	5.644	11.420
24	310663.752	0.311	0.175	0.222	0.526	1.044	2.112
25	1731187.211	1.731	0.978	1.234	2.931	5.815	11.767
26	342997.198	0.343	0.194	0.245	0.581	1.152	2.331
27	5066461.896	5.066	2.862	3.613	8.578	17.019	34.438
28	152584.031	0.153	0.086	0.109	0.258	0.513	1.037
29	156448.473	0.156	0.088	0.112	0.265	0.526	1.063
30	946250.006	0.946	0.534	0.675	1.602	3.179	6.432
31	1108610.480	1.109	0.626	0.790	1.877	3.724	7.535
32	265787.834	0.266	0.150	0.190	0.450	0.893	1.807
33	168987.229	0.169	0.095	0.120	0.286	0.568	1.149
34	4305111.073	4.305	2.432	3.070	7.289	14.462	29.263
35	108221.100	0.108	0.061	0.077	0.183	0.364	0.736
36	260233.214	0.260	0.147	0.186	0.441	0.874	1.769
37	127472.468	0.127	0.072	0.091	0.216	0.428	0.866
38	493768.176	0.494	0.279	0.352	0.836	1.659	3.356
39	116268.174	0.116	0.066	0.083	0.197	0.391	0.790
40	200235.555	0.200	0.113	0.143	0.339	0.673	1.361
41	376348.015	0.376	0.213	0.268	0.637	1.264	2.558
42	108220.367	0.108	0.061	0.077	0.183	0.364	0.736
43	174473.440	0.174	0.099	0.124	0.295	0.586	1.186
44	60382.755	0.060	0.034	0.043	0.102	0.203	0.410
45	43494.000	0.043	0.025	0.031	0.074	0.146	0.296
46	52594.912	0.053	0.030	0.038	0.089	0.177	0.357
47	37730.554	0.038	0.021	0.027	0.064	0.127	0.256

48	1235845.636	1.236	0.698	0.881	2.092	4.151	8.400

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	**AREA SQ.KM**	2.905	3.667	8.707	17.276	34.957
49	60777.349	0.061	0.034	0.043	0.103	0.204	0.413
50	29021.995	0.029	0.016	0.021	0.049	0.097	0.197
51	19798.327	0.020	0.011	0.014	0.034	0.067	0.135
52	19003.733	0.019	0.011	0.014	0.032	0.064	0.129
53	658641.383	0.659	0.372	0.470	1.115	2.213	4.477
54	2751926.951	2.752	1.554	1.962	4.659	9.244	18.705
55	3779957.070	3.780	2.135	2.695	6.400	12.698	25.693
56	14329.089	0.014	0.008	0.010	0.024	0.048	0.097
57	7391727.132	7.392	4.175	5.271	12.514	24.830	50.243
58	25735.693	0.026	0.015	0.018	0.044	0.086	0.175
59	46393.570	0.046	0.026	0.033	0.079	0.156	0.315
60	69029.252	0.069	0.039	0.049	0.117	0.232	0.469
61	175182.678	0.175	0.099	0.125	0.297	0.588	1.191
62	86933.018	0.087	0.049	0.062	0.147	0.292	0.591
63	498522.650	0.499	0.282	0.355	0.844	1.675	3.389
64	86933.018	0.087	0.049	0.062	0.147	0.292	0.591
65	93541.323	0.094	0.053	0.067	0.158	0.314	0.636
66	87249.342	0.087	0.049	0.062	0.148	0.293	0.593
67	130124.528	0.130	0.074	0.093	0.220	0.437	0.884
68	461381.781	0.461	0.261	0.329	0.781	1.550	3.136
69	103284.094	0.103	0.058	0.074	0.175	0.347	0.702
70	273143.599	0.273	0.154	0.195	0.462	0.918	1.857
71	73526.217	0.074	0.042	0.052	0.124	0.247	0.500
72	67676.580	0.068	0.038	0.048	0.115	0.227	0.460
73	79443.611	0.079	0.045	0.057	0.135	0.267	0.540
74	116872.386	0.117	0.066	0.083	0.198	0.393	0.794
75	66188.849	0.066	0.037	0.047	0.112	0.222	0.450
76	109564.126	0.110	0.062	0.078	0.185	0.368	0.745
77	189410.715	0.189	0.107	0.135	0.321	0.636	1.287
78	197727.396	0.198	0.112	0.141	0.335	0.664	1.344
79	50459.018	0.050	0.029	0.036	0.085	0.170	0.343
80	86501.244	0.087	0.049	0.062	0.146	0.291	0.588
81	63186.219	0.063	0.036	0.045	0.107	0.212	0.429
82	143983.930	0.144	0.081	0.103	0.244	0.484	0.979
83	207128.371	0.207	0.117	0.148	0.351	0.696	1.408
84	418902.957	0.419	0.237	0.299	0.709	1.407	2.847
85	143983.930	0.144	0.081	0.103	0.244	0.484	0.979
86	207128.371	0.207	0.117	0.148	0.351	0.696	1.408
87	305377.392	0.305	0.172	0.218	0.517	1.026	2.076
88	93304.947	0.093	0.053	0.067	0.158	0.313	0.634
89	228364.712	0.228	0.129	0.163	0.387	0.767	1.552
90	76628.031	0.077	0.043	0.055	0.130	0.257	0.521
91	43758.211	0.044	0.025	0.031	0.074	0.147	0.297
92	311238.721	0.311	0.176	0.222	0.527	1.046	2.116
93	53126.064	0.053	0.030	0.038	0.090	0.178	0.361
94	275466.183	0.275	0.156	0.196	0.466	0.925	1.872
95	317985.492	0.318	0.180	0.227	0.538	1.068	2.161
96	1238954.275	1.239	0.700	0.883	2.098	4.162	8.421

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	**AREA SQ.KM**	2.905	3.667	8.707	17.276	34.957
97	96518.956	0.097	0.055	0.069	0.163	0.324	0.656
98	699153.128	0.699	0.395	0.499	1.184	2.349	4.752
99	224445.119	0.224	0.127	0.160	0.380	0.754	1.526
100	1238954.275	1.239	0.700	0.883	2.098	4.162	8.421
101	57281.460	0.057	0.032	0.041	0.097	0.192	0.389
102	1542570.306	1.543	0.871	1.100	2.612	5.182	10.485
103	224445.119	0.224	0.127	0.160	0.380	0.754	1.526
104	23838.817	0.024	0.013	0.017	0.040	0.080	0.162
105	32822.587	0.033	0.019	0.023	0.056	0.110	0.223
106	39061.336	0.039	0.022	0.028	0.066	0.131	0.266
107	128266.600	0.128	0.072	0.091	0.217	0.431	0.872
108	37776.569	0.038	0.021	0.027	0.064	0.127	0.257
109	37156.883	0.037	0.021	0.026	0.063	0.125	0.253
110	28891.409	0.029	0.016	0.021	0.049	0.097	0.196
111	296837.434	0.297	0.168	0.212	0.503	0.997	2.018
112	134409.570	0.134	0.076	0.096	0.228	0.452	0.914
113	28314.165	0.028	0.016	0.020	0.048	0.095	0.192
114	51102.299	0.051	0.029	0.036	0.087	0.172	0.347
115	106285.279	0.106	0.060	0.076	0.180	0.357	0.722
116	4595040.963	4.595	2.596	3.276	7.780	15.436	31.233
117	71420.993	0.071	0.040	0.051	0.121	0.240	0.485
118	71421.917	0.071	0.040	0.051	0.121	0.240	0.485
119	227847.236	0.228	0.129	0.162	0.386	0.765	1.549
120	45526.568	0.046	0.026	0.032	0.077	0.153	0.309
121	24383.205	0.024	0.014	0.017	0.041	0.082	0.166
122	61214.342	0.061	0.035	0.044	0.104	0.206	0.416
123	106600.870	0.107	0.060	0.076	0.180	0.358	0.725
124	84821.450	0.085	0.048	0.060	0.144	0.285	0.577
125	524816.226	0.525	0.296	0.374	0.889	1.763	3.567
126	35436.645	0.035	0.020	0.025	0.060	0.119	0.241
127	22810.579	0.023	0.013	0.016	0.039	0.077	0.155
128	54634.092	0.055	0.031	0.039	0.092	0.184	0.371
129	38187.963	0.038	0.022	0.027	0.065	0.128	0.260
130	56608.315	0.057	0.032	0.040	0.096	0.190	0.385
131	84821.450	0.085	0.048	0.060	0.144	0.285	0.577
132	1029452.763	1.029	0.581	0.734	1.743	3.458	6.997
133	5342564.837	5.343	3.018	3.809	9.045	17.947	36.314
134	24808.792	0.025	0.014	0.018	0.042	0.083	0.169
135	35226.308	0.035	0.020	0.025	0.060	0.118	0.239
136	43262.334	0.043	0.024	0.031	0.073	0.145	0.294
137	35288.555	0.035	0.020	0.025	0.060	0.119	0.240
138	839665.089	0.840	0.474	0.599	1.422	2.821	5.707
139	478544.729	0.479	0.270	0.341	0.810	1.608	3.253
140	104455.496	0.104	0.059	0.074	0.177	0.351	0.710
141	5549673.068	5.550	3.135	3.957	9.396	18.643	37.722
142	62543.730	0.063	0.035	0.045	0.106	0.210	0.425
143	1221179.208	1.221	0.690	0.871	2.067	4.102	8.301
144	41980.158	0.042	0.024	0.030	0.071	0.141	0.285
145	37129.207	0.037	0.021	0.026	0.063	0.125	0.252

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	**AREA SQ.KM**	2.905	3.667	8.707	17.276	34.957
146	3791725.329	3.792	2.142	2.704	6.419	12.737	25.773
147	433502.046	0.434	0.245	0.309	0.734	1.456	2.947
148	48810.722	0.049	0.028	0.035	0.083	0.164	0.332
149	29006.900	0.029	0.016	0.021	0.049	0.097	0.197
150	298816.968	0.299	0.169	0.213	0.506	1.004	2.031
151	32545.247	0.033	0.018	0.023	0.055	0.109	0.221
152	141148.170	0.141	0.080	0.101	0.239	0.474	0.959
153	58396.409	0.058	0.033	0.042	0.099	0.196	0.397
154	57780.653	0.058	0.033	0.041	0.098	0.194	0.393
155	32088.582	0.032	0.018	0.023	0.054	0.108	0.218
156	114578.056	0.115	0.065	0.082	0.194	0.385	0.779
157	48591.832	0.049	0.027	0.035	0.082	0.163	0.330
158	178005.585	0.178	0.101	0.127	0.301	0.598	1.210
159	86555.860	0.087	0.049	0.062	0.147	0.291	0.588
160	50762.558	0.051	0.029	0.036	0.086	0.171	0.345
161	48591.832	0.049	0.027	0.035	0.082	0.163	0.330
162	796075.377	0.796	0.450	0.568	1.348	2.674	5.411
163	19714.603	0.020	0.011	0.014	0.033	0.066	0.134
164	260522.789	0.261	0.147	0.186	0.441	0.875	1.771
165	21741.388	0.022	0.012	0.016	0.037	0.073	0.148
166	743202.215	0.743	0.420	0.530	1.258	2.497	5.052
167	75255.254	0.075	0.043	0.054	0.127	0.253	0.512
168	32960.682	0.033	0.019	0.024	0.056	0.111	0.224
169	32009.046	0.032	0.018	0.023	0.054	0.108	0.218
170	75255.254	0.075	0.043	0.054	0.127	0.253	0.512
171	108522.704	0.109	0.061	0.077	0.184	0.365	0.738
172	181723.829	0.182	0.103	0.130	0.308	0.610	1.235
173	74150.294	0.074	0.042	0.053	0.126	0.249	0.504
174	477238.813	0.477	0.270	0.340	0.808	1.603	3.244
175	105692.967	0.106	0.060	0.075	0.179	0.355	0.718
176	3948508.758	3.949	2.230	2.815	6.685	13.264	26.839
177	20306.362	0.020	0.011	0.014	0.034	0.068	0.138
178	79698.308	0.080	0.045	0.057	0.135	0.268	0.542
179	78101.784	0.078	0.044	0.056	0.132	0.262	0.531
180	116969.660	0.117	0.066	0.083	0.198	0.393	0.795
181	6000755.882	6.001	3.390	4.279	10.159	20.158	40.788
182	194486.741	0.194	0.110	0.139	0.329	0.653	1.322
183	304527.562	0.305	0.172	0.217	0.516	1.023	2.070
184	259398.906	0.259	0.147	0.185	0.439	0.871	1.763
185	490357.609	0.490	0.277	0.350	0.830	1.647	3.333
186	952167.055	0.952	0.538	0.679	1.612	3.199	6.472
187	83321.928	0.083	0.047	0.059	0.141	0.280	0.566
188	41183.265	0.041	0.023	0.029	0.070	0.138	0.280
189	8839996.413	8.840	4.993	6.303	14.966	29.696	60.087
190	2559388.943	2.559	1.446	1.825	4.333	8.598	17.397
191	2811973.921	2.812	1.588	2.005	4.761	9.446	19.114
192	54163.309	0.054	0.031	0.039	0.092	0.182	0.368
193	42285.533	0.042	0.024	0.030	0.072	0.142	0.287
194	72836.410	0.073	0.041	0.052	0.123	0.245	0.495

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	**AREA SQ.KM**	2.905	3.667	8.707	17.276	34.957
195	126058.540	0.126	0.071	0.090	0.213	0.423	0.857
196	46551.741	0.047	0.026	0.033	0.079	0.156	0.316
197	676444.308	0.676	0.382	0.482	1.145	2.272	4.598
198	24615.061	0.025	0.014	0.018	0.042	0.083	0.167
199	17061.007	0.017	0.010	0.012	0.029	0.057	0.116
200	37762.934	0.038	0.021	0.027	0.064	0.127	0.257
201	53357.825	0.053	0.030	0.038	0.090	0.179	0.363
202	40322.744	0.040	0.023	0.029	0.068	0.135	0.274
203	42296.938	0.042	0.024	0.030	0.072	0.142	0.288
204	74618.828	0.075	0.042	0.053	0.126	0.251	0.507
205	7306667.830	7.307	4.127	5.210	12.370	24.545	49.665
206	577620.967	0.578	0.326	0.412	0.978	1.940	3.926
207	2470150.826	2.470	1.395	1.761	4.182	8.298	16.790
208	20859.807	0.021	0.012	0.015	0.035	0.070	0.142
209	47870.888	0.048	0.027	0.034	0.081	0.161	0.325
210	105532.217	0.106	0.060	0.075	0.179	0.355	0.717
211	254105.310	0.254	0.144	0.181	0.430	0.854	1.727
212	143839.414	0.144	0.081	0.103	0.244	0.483	0.978
213	82732.470	0.083	0.047	0.059	0.140	0.278	0.562
214	5105870.300	5.106	2.884	3.641	8.644	17.152	34.706
215	67535.624	0.068	0.038	0.048	0.114	0.227	0.459
216	157142.312	0.157	0.089	0.112	0.266	0.528	1.068
217	74132.881	0.074	0.042	0.053	0.126	0.249	0.504
218	46836081.781	46.836	26.456	33.395	79.295	157.333	318.354
219	71491.419	0.071	0.040	0.051	0.121	0.240	0.486
220	50988.486	0.051	0.029	0.036	0.086	0.171	0.347
221	863981.793	0.864	0.488	0.616	1.463	2.902	5.873
222	40864.430	0.041	0.023	0.029	0.069	0.137	0.278
223	82916.901	0.083	0.047	0.059	0.140	0.279	0.564
224	27180.639	0.027	0.015	0.019	0.046	0.091	0.185
225	36978.453	0.037	0.021	0.026	0.063	0.124	0.251
226	50988.486	0.051	0.029	0.036	0.086	0.171	0.347
227	9953118.255	9.953	5.622	7.097	16.851	33.435	67.653
228	338887.211	0.339	0.191	0.242	0.574	1.138	2.303
229	533531.007	0.534	0.301	0.380	0.903	1.792	3.627
230	155436.288	0.155	0.088	0.111	0.263	0.522	1.057
231	280342.257	0.280	0.158	0.200	0.475	0.942	1.906
232	1750922.690	1.751	0.989	1.248	2.964	5.882	11.901
233	166288.441	0.166	0.094	0.119	0.282	0.559	1.130
234	160266.778	0.160	0.091	0.114	0.271	0.538	1.089
235	95856.271	0.096	0.054	0.068	0.162	0.322	0.652
236	1276974.334	1.277	0.721	0.911	2.162	4.290	8.680
237	61127.995	0.061	0.035	0.044	0.103	0.205	0.415
238	83877.426	0.084	0.047	0.060	0.142	0.282	0.570
239	159093.155	0.159	0.090	0.113	0.269	0.534	1.081
240	79396.780	0.079	0.045	0.057	0.134	0.267	0.540
241	124551.685	0.125	0.070	0.089	0.211	0.418	0.847
242	105536.966	0.106	0.060	0.075	0.179	0.355	0.717
243	88366.144	0.088	0.050	0.063	0.150	0.297	0.601

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	**AREA SQ.KM**	2.905	3.667	8.707	17.276	34.957
244	640724.002	0.641	0.362	0.457	1.085	2.152	4.355
245	43740.918	0.044	0.025	0.031	0.074	0.147	0.297
246	348138.858	0.348	0.197	0.248	0.589	1.169	2.366
247	114898.098	0.115	0.065	0.082	0.195	0.386	0.781
248	56571.674	0.057	0.032	0.040	0.096	0.190	0.385
249	63932.199	0.064	0.036	0.046	0.108	0.215	0.435
250	50429.053	0.050	0.028	0.036	0.085	0.169	0.343
251	61588.387	0.062	0.035	0.044	0.104	0.207	0.419
252	59462.295	0.059	0.034	0.042	0.101	0.200	0.404
253	103533.176	0.104	0.058	0.074	0.175	0.348	0.704
254	115286.770	0.115	0.065	0.082	0.195	0.387	0.784
255	151085.558	0.151	0.085	0.108	0.256	0.508	1.027
256	124567.525	0.125	0.070	0.089	0.211	0.418	0.847
257	126435.113	0.126	0.071	0.090	0.214	0.425	0.859
258	591411.296	0.591	0.334	0.422	1.001	1.987	4.020
259	1278788.517	1.279	0.722	0.912	2.165	4.296	8.692
260	925143.987	0.925	0.523	0.660	1.566	3.108	6.288
261	306716.410	0.307	0.173	0.219	0.519	1.030	2.085
262	138125.926	0.138	0.078	0.098	0.234	0.464	0.939
263	658697.595	0.659	0.372	0.470	1.115	2.213	4.477
264	7655594.996	7.656	4.324	5.459	12.961	25.717	52.037
265	98578.608	0.099	0.056	0.070	0.167	0.331	0.670
266	197360.770	0.197	0.111	0.141	0.334	0.663	1.341
267	37468.916	0.037	0.021	0.027	0.063	0.126	0.255
268	57365.314	0.057	0.032	0.041	0.097	0.193	0.390
269	445771.840	0.446	0.252	0.318	0.755	1.497	3.030
270	51267.596	0.051	0.029	0.037	0.087	0.172	0.348
271	175676.995	0.176	0.099	0.125	0.297	0.590	1.194
272	45021.042	0.045	0.025	0.032	0.076	0.151	0.306
273	51625.728	0.052	0.029	0.037	0.087	0.173	0.351
274	156157.894	0.156	0.088	0.111	0.264	0.525	1.061
275	775455.344	0.775	0.438	0.553	1.313	2.605	5.271
276	28965.163	0.029	0.016	0.021	0.049	0.097	0.197
277	136250.453	0.136	0.077	0.097	0.231	0.458	0.926
278	124712.004	0.125	0.070	0.089	0.211	0.419	0.848
279	357561.070	0.358	0.202	0.255	0.605	1.201	2.430
280	98518.997	0.099	0.056	0.070	0.167	0.331	0.670
281	53699.323	0.054	0.030	0.038	0.091	0.180	0.365
282	550169.703	0.550	0.311	0.392	0.931	1.848	3.740
283	76351.906	0.076	0.043	0.054	0.129	0.256	0.519
284	214805.730	0.215	0.121	0.153	0.364	0.722	1.460
285	248490.817	0.248	0.140	0.177	0.421	0.835	1.689
286	170959.802	0.171	0.097	0.122	0.289	0.574	1.162
287	134001.703	0.134	0.076	0.096	0.227	0.450	0.911
288	775455.344	0.775	0.438	0.553	1.313	2.605	5.271
289	27772866.401	27.773	15.688	19.803	47.020	93.295	188.778
290	129686.714	0.130	0.073	0.092	0.220	0.436	0.882
291	87295.626	0.087	0.049	0.062	0.148	0.293	0.593
292	381684.605	0.382	0.216	0.272	0.646	1.282	2.594

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	**AREA SQ.KM**	2.905	3.667	8.707	17.276	34.957
293	434665.237	0.435	0.246	0.310	0.736	1.460	2.955
294	531018.460	0.531	0.300	0.379	0.899	1.784	3.609
295	598350.771	0.598	0.338	0.427	1.013	2.010	4.067
296	153078.880	0.153	0.086	0.109	0.259	0.514	1.041
297	109920.267	0.110	0.062	0.078	0.186	0.369	0.747
298	74776.511	0.075	0.042	0.053	0.127	0.251	0.508
299	96913.261	0.097	0.055	0.069	0.164	0.326	0.659
300	7182697.518	7.183	4.057	5.121	12.161	24.128	48.822
301	46460.418	0.046	0.026	0.033	0.079	0.156	0.316
302	129996.272	0.130	0.073	0.093	0.220	0.437	0.884
303	271064.035	0.271	0.153	0.193	0.459	0.911	1.842
304	77913.050	0.078	0.044	0.056	0.132	0.262	0.530
305	2971486.589	2.971	1.678	2.119	5.031	9.982	20.198
306	271064.035	0.271	0.153	0.193	0.459	0.911	1.842
307	124335.788	0.124	0.070	0.089	0.211	0.418	0.845
308	194307.468	0.194	0.110	0.139	0.329	0.653	1.321
309	141006.352	0.141	0.080	0.101	0.239	0.474	0.958
310	79392.316	0.079	0.045	0.057	0.134	0.267	0.540
311	5278442.509	5.278	2.982	3.764	8.937	17.731	35.879
312	49354.705	0.049	0.028	0.035	0.084	0.166	0.335
313	88342.707	0.088	0.050	0.063	0.150	0.297	0.600
314	88342.707	0.088	0.050	0.063	0.150	0.297	0.600
315	167771.109	0.168	0.095	0.120	0.284	0.564	1.140
316	150773.495	0.151	0.085	0.108	0.255	0.506	1.025
317	93675.192	0.094	0.053	0.067	0.159	0.315	0.637
318	334209.371	0.334	0.189	0.238	0.566	1.123	2.272
319	259925.581	0.260	0.147	0.185	0.440	0.873	1.767
320	1072888.970	1.073	0.606	0.765	1.816	3.604	7.293
321	239031.588	0.239	0.135	0.170	0.405	0.803	1.625
322	93379.573	0.093	0.053	0.067	0.158	0.314	0.635
323	96507.395	0.097	0.055	0.069	0.163	0.324	0.656
324	14727025.513	14.727	8.319	10.501	24.933	49.471	100.102
325	578462.311	0.578	0.327	0.412	0.979	1.943	3.932
326	83456.281	0.083	0.047	0.060	0.141	0.280	0.567
327	443112.679	0.443	0.250	0.316	0.750	1.489	3.012
328	174498.971	0.174	0.099	0.124	0.295	0.586	1.186
329	90955.623	0.091	0.051	0.065	0.154	0.306	0.618
330	331651.318	0.332	0.187	0.236	0.561	1.114	2.254
331	1955419.462	1.955	1.105	1.394	3.311	6.569	13.291
332	37818.156	0.038	0.021	0.027	0.064	0.127	0.257
333	930465.655	0.930	0.526	0.663	1.575	3.126	6.325
334	6237700.327	6.238	3.523	4.448	10.561	20.954	42.399
335	43095.343	0.043	0.024	0.031	0.073	0.145	0.293
336	140016.758	0.140	0.079	0.100	0.237	0.470	0.952
337	31477.150	0.031	0.018	0.022	0.053	0.106	0.214
338	42276.801	0.042	0.024	0.030	0.072	0.142	0.287
339	94434.713	0.094	0.053	0.067	0.160	0.317	0.642
340	320578.684	0.321	0.181	0.229	0.543	1.077	2.179
341	593501.118	0.594	0.335	0.423	1.005	1.994	4.034

NO.	DRAINAGE AREA		I - 5 yr	I - 10 yr	I - 25 yr	I - 50 yr	I -100 yr
	AREA SQ.M.	**AREA SQ.KM**	2.905	3.667	8.707	17.276	34.957
342	114902.275	0.115	0.065	0.082	0.195	0.386	0.781
343	496386.889	0.496	0.280	0.354	0.840	1.667	3.374
344	139875.148	0.140	0.079	0.100	0.237	0.470	0.951
345	33133830.323	33.134	18.716	23.625	56.096	111.304	225.217
346	106639.065	0.107	0.060	0.076	0.181	0.358	0.725
347	53441.676	0.053	0.030	0.038	0.090	0.180	0.363
348	200819.943	0.201	0.113	0.143	0.340	0.675	1.365
349	1070712.958	1.071	0.605	0.763	1.813	3.597	7.278
350	445443.663	0.445	0.252	0.318	0.754	1.496	3.028
351	215850.697	0.216	0.122	0.154	0.365	0.725	1.467
352	557629.672	0.558	0.315	0.398	0.944	1.873	3.790
353	460640.973	0.461	0.260	0.328	0.780	1.547	3.131
354	972884.130	0.973	0.550	0.694	1.647	3.268	6.613
355	1950896.568	1.951	1.102	1.391	3.303	6.553	13.261
356	364235.918	0.364	0.206	0.260	0.617	1.224	2.476
357	296584.871	0.297	0.168	0.211	0.502	0.996	2.016
358	3707332.083	3.707	2.094	2.643	6.277	12.454	25.199
359	4443840.288	4.444	2.510	3.169	7.524	14.928	30.206
360	520548.497	0.521	0.294	0.371	0.881	1.749	3.538
361	561307.064	0.561	0.317	0.400	0.950	1.886	3.815
362	510525.374	0.511	0.288	0.364	0.864	1.715	3.470
363	386648.018	0.387	0.218	0.276	0.655	1.299	2.628
364	2924562.893	2.925	1.652	2.085	4.951	9.824	19.879
365	748321.397	0.748	0.423	0.534	1.267	2.514	5.086
366	21831841.896	21.832	12.332	15.567	36.962	73.338	148.395
367	17749026.738	17.749	10.026	12.656	30.050	59.623	120.644
368	1672792.847	1.673	0.945	1.193	2.832	5.619	11.370
369	492807.922	0.493	0.278	0.351	0.834	1.655	3.350
370	33239759.698	33.240	18.776	23.701	56.276	111.660	225.937
371	3497565.893	3.498	1.976	2.494	5.921	11.749	23.774
372	6343363.344	6.343	3.583	4.523	10.739	21.309	43.117
373	533913.839	0.534	0.302	0.381	0.904	1.794	3.629
374	498463.811	0.498	0.282	0.355	0.844	1.674	3.388
375	564784.233	0.565	0.319	0.403	0.956	1.897	3.839
376	1956998.869	1.957	1.105	1.395	3.313	6.574	13.302
377	962340.955	0.962	0.544	0.686	1.629	3.233	6.541
378	418394.791	0.418	0.236	0.298	0.708	1.405	2.844
379	6343363.344	6.343	3.583	4.523	10.739	21.309	43.117
380	78841.031	0.079	0.045	0.056	0.133	0.265	0.536
381	109371.928	0.109	0.062	0.078	0.185	0.367	0.743
382	59444.864	0.059	0.034	0.042	0.101	0.200	0.404
383	108140.744	0.108	0.061	0.077	0.183	0.363	0.735
384	170311.247	0.170	0.096	0.121	0.288	0.572	1.158
385	244027.860	0.244	0.138	0.174	0.413	0.820	1.659

GEOTECHNICAL REPORT

KESHIM – FAIZABAD ROAD PROJECT

BADAKHSHAN PROVINCE, AFGHANISTAN

ISLAMIC REPUBLIC OF AFGHANISTAN

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

SUBMITTED TO :

UNITED NATIONS OFFICE FOR PROJECT SERVICES

PREPARED BY :

THE LOUIS BERGER GROUP, INC.
2300 N Street NW, Washington, DC 20037

JANUARY 2007

SEALS PAGE

Name:	Geotechnical Investigation Report for Keshim Faizabad Road, Rehabilitation/Reconstruction Project Badakshan Province, Afghanistan
Location:	Badakshan Province, Afghanistan
Dated:	January 2007
Prepared for:	UNOPS-United Nations Office of Project Services
Prepared by:	The Louis Berger Group, Inc.

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EXECUTIVE SUMMARY

On behalf of the UNOPS-United Nations Office for Project Services, The Louis Berger Group, Inc. (Berger) performed a geotechnical investigation for the proposed Keshim-Faizabad Road Reconstruction/Rehabilitation Project in Badakshan Province, Afghanistan for the detail engineering design of the 103.5 km "all weather" asphalt concrete roadway. The proposed roadway will follow the route of the existing unpaved roadway from Keshim to Faizabad along the Keshim and Kokcha rivers. For most of its length, the roadway will consist of two lanes with a carriageway width of seven (7) meters and shoulders between 2.5 meters in flat areas and one (1) meter in mountainous areas.

Berger performed geologic and geotechnical reconnaissance surveys along the route and assigned a subcontractor, [redacted], to conduct route engineering geologic mapping of 1:2000 scale, 48 boreholes in soil and rock and 92 test pits along the route and borrow areas between July and September 2006. Selected soil samples were tested for the identification, index and chemical properties at the Louis Berger Adraskan Laboratory. Some samples were transported to a U.S. laboratory, mainly to assess potential sulfate and chloride attacks on the concrete and steel elements of the structures.

The general geology of the area consists of recent and old river alluviums which cut through conglomerate, sandstone and mudstone (siltstone) in the first 60 km. At this section, rock slopes will be cut in conglomerate, sandstone and siltstone; both produce stable rock slopes and can be cut by conventional excavators. In addition, rock blasting can also be a feasible alternative for mass excavations. The roadway in between km 60 and km 80 will be constructed generally within the Paleozoic metamorphic rock series. Significant volumes of rock blasting will be required along this section. The remaining section will mostly be constructed in old river terraces and alluvial plains where rock/soil cut by conventional excavators would be feasible. The subgrade for the roadway and for the structure foundations consists of satisfactory granular material. This report evaluates the possible excavation methods and makes recommendations for rock blasting and rock cutting as well as safe rock slope angles.

This report presents factual accounts of the field investigation and laboratory testing, and presents our geotechnical evaluations, conclusions and recommendations for the proposed structures with respect to the subsurface conditions. A shallow foundation system with spread footing is recommended for the design of the bridge foundations. Recommended pavement design parameters and the preparation of subgrade for the pavement were evaluated. In order to maintain long-term roadway safety and rock slope stability and to mitigate rock falls, rock slope stabilization measures were evaluated, selected and recommended. Measures mitigating for the protection of the structures and the embankment crossing over the seasonally dry/wet alluvial valleys and steep gorges, were outlined. Based on the field work and laboratory test results, potential borrow areas for the roadway fill, subbase and base, as well as concrete aggregates, were reviewed and recommended. Site seismicity was evaluated and design parameters were recommended. Potential sulfate attack and corrosion for concrete and steel elements were reviewed.

GEOTECHNICAL INVESTIGATION REPORT FOR KESHIM-FAIZABAD ROAD REHABILITATION/ RECONSTRUCTION PROJECT, BADAKSHAN PROVINCE, AFGHANISTAN

1.0 PURPOSE

The purpose of this report is to evaluate the subsurface physical conditions based on the site reconnaissance survey, route engineering geologic mapping, borings, test pits and laboratory tests at the proposed Keshim-Faizabad Road alignment and to provide recommendations for the design and construction of the foundation elements for proposed structures, roadway and construction material availability as influenced by the subsurface physical conditions.

As part of the subsurface investigations, a geotechnical subconsultant ([redacted] was retained to conduct the following services:

- Route engineering geologic mapping of 1:2000 scale
- A total of 48 boreholes in soil and rock
- A total of 92 test pits along the route and borrow areas

Laboratory tests were conducted at the Louis Berger Adraskan Laboratory. Selected soil samples were also transported to a U.S. laboratory, mainly to assess potential sulfate and chloride attacks on the concrete and steel elements of the structures.

The information provided by the subconsultant, Yuksel Proje, includes the borehole logs and rock core photographs which are presented in Appendices A and B, respectively. Test pit logs prepared by Yuksel Proje are presented in Appendix C. Laboratory test results are given in Appendix D.

A copy of the Route Engineering Geologic Mapping conducted by the subconsultant, Yuksel Proje, is given in a separate volume for informational purposes only.

2.0 PROJECT DESCRIPTION

This project is part of the construction of an “all weather” asphalt concrete road between Keshim and Faizabad in Badakshan Province in Afghanistan. Berger’s scope includes detailed engineering design of this 103.5-kilometer long roadway in accordance with AASHTO and the Afghanistan Ministry of Public Works (MPW) standards. The proposed roadway will generally follow the existing unpaved roadway from Keshim to Faizabad along the Keshim and Kokcha rivers. For most of its length, the roadway will be two-lanes with a carriageway width of seven (7) meters and shoulders between 2.5 meters in flat areas and one (1) meter in mountainous areas. For a length of about 0.6 kilometers in Keshim and three (3) kilometers in Faizabad, the roadway will be four (4) lanes (i.e. dual carriageway) with two (2) seven (7)-meter roadways, a center concrete curb median (0.4 to 4.0 meters in width) and concert drainage channels and sidewalks.

The roadway is planned to have a pavement structure with an asphalt concrete (AC) wearing course with polymer modified bitumen (PMB), an AC binder course and a crushed aggregate base. The pavement shoulders will be single bituminous surface treatment (SBST).

The project will also include 22 new bridges including 2 multi-span (three span and four span) and 19 single span structures. The bridge superstructure will be steel with steel I-girders and reinforced concrete deck slabs. The bridge substructure will be reinforced concrete footings and piers. The four-span bridge would be supported on reinforced concrete circular column bents; the three-span bridge is to be supported on steel column pier bents. Anticipated stress under the proposed bridge foundations was estimated to range between 350 kN/m^2 and 510 kN/m^2. The design will also include the construction of approximately 80 new reinforced concrete box culverts of various sizes and about 240 new concrete pipe culverts.

The roadway design also includes the construction of slope protection and stabilization structures in order to mitigate rock fall and rock slope instability.

Approximate quantities of some of the estimated work are as follows:

Roadway excavation: 1.6 million cubic meters,
Rock excavation: 2 million cubic meters
Embankment construction: 1 million cubic meters.

Stations referred to in the report are based on the project survey information for which the project beginning station is Km 0+000 at a bridge in Keshim.

3.0 REGIONAL GEOLOGY

The site is located in the Western Badakshan region of northern Afghanistan. This area lies on the border of the Afghan-Tajik Basin and Southeast Afghanistan Geologic Provinces (USGS, 1998). It is situated on the North Afghan platform and bordered by the Central Badakshan fault on the east. This region was formed by igneous and metamorphic rocks, primarily during the Carboniferous-Permian Hercynian Orogeny, with Late Hercynian folding continued from the Northern Pamir's zone of the Tajikistan (Ministry of Mines and others, 1973). Igneous intrusive rocks belong to a Western Hindu-Kush-Western Badakshan plutonic belt/structural area. Within the Hercynian-Alpine folded structure, there are folds and blocks of basement complexes separated by faults. Since the Hercynian Orogeny, the igneous/metamorphic basement complex of the platform area has remained comparatively stable.

The region is seismically active, with the Darvaz, Central Badakshan and Henjvan faults, all located within the North Afghan platform, being known major or active faults at or in the vicinity of the site. A plate boundary zone and the North Afghan platform (with or without the area east of the Darvaz and Henjvan faults) were defined as seismic source zones (Weeler and others, 2005) and are considered to have the most significant effect at the site from a design standpoint.

As can be seen on a regional geologic map, the subsurface geology of the project area is diverse, with different rock types with different engineering properties present along the roadway alignment. At the northeast segment of the alignment (in the vicinity of Faizabad between approximately Sta 105+00 and Sta 80+00), the local mountains are formed by pre-Cambrian metamorphic rock complexes composed predominantly of gneissic rocks, and to lesser extent schist, migmatite, quartzite, marble and amphibolite (Doebrich and Wahl, 2006). Progressing westward along the alignment (Sta 80+00 to Sta 56+00), older metamorphic rocks are intruded by early Carboniferous-age plutons. Intrusive rock types include diorite and granodiorite, as well as smaller gabbroic bodies. Igneous and metamorphic basement rocks are folded and faulted in the area. West of the mountain front, the basement rocks are overlain by a clastic sedimentary cover that thickens to the west. Specifically, the remainder of the project area (Sta 56+00 to Sta 0+00) is underlain by Pliocene sedimentary rocks, mostly conglomerates and sandstones, with a sedimentary sequence fining laterally (i.e. mostly conglomerates to mostly sandstones) away from the mountain front. Minor siltstone, clay, limestone, gypsum and salt may be encountered in clastic deposits. In addition, Quaternary alluvial sediments are present along the river valleys. They include fluvial (channel) sediments and alluvial fans. Their stratigraphy and thickness are very poorly studied. By and large, they are composed of Holocene and late Pleistocene gravel, sand, and to a lesser extent silt and clay.

4.0 ENGINEERING EVALUATION

4.1 Bridges

The subsurface conditions at each proposed bridge are summarized below, followed by the engineering analysis, conclusions and recommendations, presented separately for each proposed bridge. In engineering analysis, where applicable guidelines given in the USDOT FHWA Load and Resistance Factor Design (LRFD) for Highway Bridge Substructures (1968) was used. The borehole and test pit logs prepared by the subconsultant, Yuksel Proje, in which the soils are described according to the Unified Soil Classification System, are presented in Appendix A and Appendix C, respectively.

4.1.1 Bridge No. 1 (Km12+460):

This is a 120-meter long, four-span bridge crossing one of the major alluvial valleys. Boreholes 12400-1 and 12402 and test pits TP12400-1 through TP12400-6 were used to characterize subsurface conditions at this site.

Subsurface Conditions

Based on the boring and test pit information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (Cobbles and boulders):** The uppermost soil stratum is about 4.4 meters thick, variously colored, generally rounded, with cobbles and boulders a maximum 0.6 meters in size mixed with gravel and sand. The Standard Penetration Resistance (N) values of this layer were always greater than 50, indicating its coarse size, as well as its dense and compact nature.

Stratum 2 **Gravel:** Variously colored, well-graded gravel was observed at elevation below approximately +850m. It consists of gray and brown-reddish, well-graded gravel with sand, fine to coarse grained, hard, rounded to subrounded; containing 20 to 30 percent sand of probable quartz origin, about five percent fines, and occasional cobbles up to 100 mm in size. The Standard Penetration Resistance values (N) ranged between 42 and refusal, indicating the very dense and compact nature of this stratum. The borings were terminated within this stratum at a depth of 15 meters below the existing grade.

Based on observations during boring, the groundwater level was estimated to be at a depth of about 7.5 meters below the existing grade, corresponding to an approximate elevation of +840m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system using spread footings is recommended for this structure. Both Stratum 1 and Stratum 2 are satisfactory bearing strata. The foundation depth, therefore, is governed by the frost penetration depth, which should be at least 1.5 meters below the final grade for frost protection (for example Elevation +845m or lower). In addition, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. At this depth (or below), an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm. Post-construction settlements would be less than 10 mm.

During construction of the footing, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No.1):

Soil Type/Parameter	**Stratum 1 Boulders and Cobbles**	**Stratum 2 Gravel**
Approximate depth below present grade (m)	0-4.4	4.4-15+
Angle of Internal Friction (°)	32	36
Unit Weight, above ground water (t/m^3)	1.8	2.0
Unit Weight, submerged (t/m^3)	-	1.0
Coefficient of Active Pressure (Ka)	0.30	0.26
Coefficient of Passive Resistance (Kp)	3.25	3.84
Friction factor between foundation concrete and soil (δ)	0.55	0.55

4.1.2 Bridge No. 2 (Km15+597):

This is a 25 meter long single-span bridge crossing the minor stream. Subsurface conditions at this site were evaluated using boreholes 14800-1 and 14800-2.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (Gravel):** The uppermost soil stratum is between 0.95 meters and 1.6 meters thick, light brown, fine to coarse, 0.15 meter in maximum dimension, generally rounded gravel mixed with sand and silt, interpreted as slopewash.

Stratum 2 **Bedrock (conglomerate~siltstone):** Bedrock was observed at existing grade and below surface deposits at elevation below approximately +801m. It consisted of gray to light brown, fine- to coarse-grained, slightly weathered, hard sandstone with scattered conglomerate layers and up to 1.8-meter thick, moderately weathered siltstone/claystone lenses and layers. The Total Core Recovery (TCR) of rock samples ranged between 72 and 100 percent, and the Rock Quality Designation (RQD) varied from 72 to 100 percent, averaging about 93 percent, indicating generally "good" to "excellent" rock quality consistent with slightly weathered rock containing widely-spaced fractures. The borings were terminated within this stratum at a maximum depth of 13.5 meters below the existing grade.

Based on observations during boring, the groundwater level was estimated to be at a depth between 5.55 meters and 7.40 meters below the existing grade, corresponding to an approximate average elevation of +793.5m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, both Stratum 1 and Stratum 2 are satisfactory bearing strata, thus a shallow foundation system with spread footings is recommended for this structure. However, in order to provide uniform response in an earthquake event, the foundations should be placed on the bedrock, which is expected to be about 1.6 meters below the existing grade. We therefore anticipate the approximate foundation bottom elevation would be about +798m or below. At this depth, an allowable bearing pressure of 1,000 kN/m^2 can be assigned for the design of the foundations on bedrock. The load distribution zone for the footings should be selected as 2.5V:1H or flatter and should extend to a depth at least four times the width of the footing. The design should verify that the load distribution zone remains within the rock mass. Total settlement and post-construction settlement under this magnitude of stress are expected to be negligible.

In design calculations, the following soil parameters can be used (Bridge No. 2):

Soil Type/Parameter	**Stratum 1 Gravel**	**Stratum 2 Bedrock**
Approximate depth below present grade (m)	0-1.6	1.6-13.5+
Angle of Internal Friction (°)	32	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.30	0.24
Coefficient of Passive Resistance (Kp)	3.25	4.20
Friction factor between foundation concrete and soil (δ)	Not recommended	0.45

Due to siltstone/mudstone nature of the founding rock, a reduced friction factor of 0.45 was selected for this bridge. The design should verify the need of a “key” to provide added resistance for sliding.

4.1.3 Bridge No.3 (Km 22+787):

This is a 55 meter long single-span bridge crossing an alluvial valley which usually carries seasonal water. Subsurface conditions at this site were evaluated using boreholes 22180-1 through 22180-4.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (gravel):** The uppermost soil stratum alluvium has a thickness of between 0.9 and 7.4 meters. However, at the proposed bridge location, the average thickness is about 1.6 meters Alluvium consists of variously colored, fine to coarse, 0.15 meter in maximum dimension, well graded, generally rounded gravel mixed with sand and silt, and local cobbles and boulders up to 0.5 meter in size, interpreted as slopewash. The SPT "N" values and collection of cores indicated the dense to very dense nature of this stratum. In addition, about 1.6 meters of fill composed of fine to coarse silty sand with gravel were observed locally at the south abutment (boring 22180-4).

Stratum 2 **Bedrock (siltstone/claystone):** Bedrock was observed below Stratum 1 deposits below an approximate average elevation of +820m. Erosional bedrock surface was sloping to the south from elevation +820m to +815m at around station 22+830. Bedrock consisted of gray, fine- to coarse-grained, slightly weathered, hard sandstone with an about three-to-five-meter thick, moderately to slightly weathered siltstone/claystone layer. The Total Core Recovery (TCR) of rock samples ranged between 49 and 100 percent, and the Rock Quality Designation (RQD) varied from 43 to 100 percent, averaging about 93 percent, indicating generally "good" to "excellent" rock quality consistent with slightly weathered rock containing widely-spaced fractures. The borings were terminated within this stratum at a maximum depth of 12 meters below the existing grade.

Based on observations during boring, the groundwater level was estimated to be at a depth between 1.5 and 4.5 meters below the existing grade, corresponding to approximate elevations between +811m +818.5m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, except for the made ground in boring 22180-4, both Stratum 1 and Stratum 2 are satisfactory bearing strata, thus a shallow foundation system with spread footings is recommended for this structure. However, in order to provide uniform response in an earthquake event, the foundations should be placed on the bedrock which is expected to be about 1.8 meters below the existing grade in the west abutment, and a minimum of 3.0 meters below the existing grade in the east abutment. We anticipate a foundation elevation of approximately +819m. If the bedrock is encountered at a shallower depth, a higher foundation elevation may be selected. At this depth, an allowable bearing pressure of 800 kN/m^2 can be assigned for the design of the foundations on bedrock. The load distribution zone for the footings should be selected as 2.5V:1H or flatter and should extend to a depth at least four times the width of the footing. The design should verify that the load distribution zone remains within the rock mass. Total settlement and post-construction settlement under this magnitude of stress are expected to be negligible.

During construction of the footing, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 3):

Soil Type/Parameter	**Stratum 1 Gravel**	**Stratum 2 Bedrock**
Approximate depth below present grade (m)	0-1.6	1.6-12+
Angle of Internal Friction (°)	32	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.30	0.24
Coefficient of Passive Resistance (Kp)	3.25	4.20
Friction factor between foundation concrete and soil (δ)	Not recommended	0.45

Due to siltstone/mudstone nature of the founding rock, a reduced friction factor of 0.45 was selected for this bridge. The design should verify the need of a "key" to provide added resistance for sliding.

4.1.4 Bridge No. 4 (Km27+495):

This is a 25 meter long single-span bridge crossing the small alluvial valley. There were no borings completed at this site. We anticipate that generalized subsurface conditions consist of unconsolidated slopewash deposits (i.e., gravel with possible cobbles and boulders) underlain by sedimentary bedrock (i.e., sandstone with conglomerate and siltstone/claystone lenses/layers).

Foundation Support:

Based on these generalized subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. The foundation should be placed on rock which is expected to be about 1.5 meters below the existing grade, corresponding to an elevation of about +833m. In addition, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. We anticipate approximate foundation elevations of between +833 and +835m. At such depths, an allowable bearing pressure of 600 kN/m^2 can be assumed for the design of the foundations. The load distribution zone for the footings should be selected as 2.5V:1H or flatter and should extend to a depth at least four times the width of the footing. The design should verify that the load distribution zone remains within the rock mass. Settlements under this magnitude of stress are expected to be negligible.

In design calculations, the following soil parameters can be used (Bridge No. 4):

Soil Type/Parameter	Stratum 1 Gravel	Stratum 2 Bedrock
Approximate depth below present grade (m)	0-1.5	1.5-15+
Angle of Internal Friction (°)	32	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.30	0.24
Coefficient of Passive Resistance (Kp)	3.25	4.20
Friction factor between foundation concrete and soil (δ)	Not recommended	0.45

Due to siltstone/mudstone nature of the founding rock, a reduced friction factor of 0.45 was selected for this bridge. The design should verify the need of a "key" to provide added resistance for sliding.

4.1.5 Bridge No. 5 (Km 27+909):

This is a 25 meter long single-span bridge crossing the intermediate stream. Subsurface conditions at this site were evaluated using boreholes 27500-1 and 27500-2.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Fill:** The uppermost soil stratum is a thin (between 0.45 meter and 0.80 meter thick) layer of fill composed of sandy silt with gravel and filled materials. It is underlain by bedrock.

Stratum 2 **Bedrock (Sandstone):** Bedrock was observed below fill deposits at an approximate average elevation of +850m. It consisted of gray to greenish gray, fine- to coarse-grained, slightly weathered, hard sandstone. The Total Core Recovery (TCR) of rock samples ranged between 52 and 100 percent, and the Rock Quality Designation (RQD) varied from 46 to 100 percent, averaging about 93 percent, indicating generally "excellent" rock quality consistent with slightly weathered rock containing widely-spaced fractures. The borings were terminated within this stratum at a maximum depth of 12 meters below the existing grade.

Based on observations during boring, the groundwater level was estimated to be at a depth between 4.6 and 5.8 meters below the existing grade, corresponding to an approximate average elevation of
+845.5m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. The foundation should extend into bedrock to an approximate elevation of +846m or below. At this depth, an allowable bearing pressure of 800 kN/m^2 can be assigned for the design of the foundations resting on rock. The load distribution zone for the footings should be selected as 2.5V:1H or flatter and should extend to a depth at least four times the width of the footing. The design should verify that the load distribution zone remains within the rock mass. Total settlement and post-construction settlement under this magnitude of stress are expected to be negligible.

In design calculations, the following soil parameters can be used (Bridge No. 5):

Soil Type/Parameter	Stratum 1 Fill	Stratum 2 Bedrock
Approximate depth below present grade (m)	0-1.5	1.5-12+
Angle of Internal Friction (°)	32	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.30	0.24
Coefficient of Passive Resistance (Kp)	3.25	4.20
Friction factor between foundation concrete and soil (δ)	Not recommended	0.50

4.1.6 Bridge No.6 (Km28+836):

This is a 35 meter long single-span bridge crossing a seasonably dry/wet alluvial valley. Subsurface conditions at this site were evaluated using boreholes 28300-1 and 28300-2.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (Gravel):** The uppermost soil stratum is between 4.3 and 5.5 meters thick, variously colored, fine to coarse, well graded gravel with sand, cobbles, and boulders up to 0.3 meter in maximum dimension, generally rounded, containing 20 to 30 percent sand and up to five (5) percent fines, interpreted as slope wash. The SPR "N" values ranged from over 50 to refusal, indicating the very dense nature of these deposits.

Stratum 2 **Bedrock (Sandstone-Siltstone):** Bedrock was observed below Stratum 1 deposits at elevations approximately between +835m and +838m. It consisted of gray, fine- to coarse-grained, highly to moderately weathered, medium hard to hard sandstone with thin (0.7 meter thick), moderately weathered siltstone lenses. The Total Core Recovery (TCR) of rock samples ranged between 20 and 100 percent, and the Rock Quality Designation (RQD) varied from 0 to 100 percent, averaging about 71 percent, indicating from "very poor" to "excellent" rock quality consistent with highly to slightly weathered rock containing closely- to widely-spaced fractures. The borings were terminated within this stratum at a maximum depth of 10.8 meters below the existing grade.

Based on observations during boring, the groundwater level was estimated to be at a depth between 1.9 and 3.6 meters below the existing grade, corresponding to an approximate average elevation of +839.5m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. The foundation depth should be at least 1.5 meters below the existing or final grade for frost protection (i.e. +840m, or below). In addition, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. At this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm. Post-construction settlements would be less than 10 mm.

During construction of the footing, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 6):

Soil Type/Parameter	**Stratum 1 Gravel**	**Stratum 2 Bedrock**
Approximate depth below present grade (m)	0-5	5-11+
Angle of Internal Friction (°)	32	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.30	0.24
Coefficient of Passive Resistance (Kp)	3.25	4.20
Friction factor between foundation concrete and soil (δ)	0.55	0.50

4.1.7 Bridge No. 7 (Km30+868):

This is a 55 meter long single-span bridge crossing a seasonably dry gorge. Boreholes 30800-1, 30800-2, 30800-3 and 30800-4 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring and test pit information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Colluvium (gravels, cobbles and silt):** The uppermost soil stratum consisted of well graded gravel in the west abutment and silt in the east abutment. The gravel (west abutment) is gray to light brown, well graded, with sand (20-30 percent) and silt (5-10 percent). It also contains infrequent boulders. The thickness of the gravel is expected to be on the order of six meters. In the east abutment, this layer consists of greenish, dark gray non-plastic silts with fine to medium sand. Except for the upper one meter, the Standard Penetration Resistance (N) values of this layer were greater than 40, indicating its very dense and compact nature. Borings in the west abutment were terminated within this formation about six meters below the existing grade due to damage to a drill tool.

Stratum 2 **Bedrock (Congolomera~Siltstone):** Bedrock was observed to range between the elevations of +859m and +867m and consist of light brown to gray, medium hard, moderately strong, slightly weathered sandstone and siltsone. Total core recovery in the upper zones ranged between 20 and 39, while the RQD values were between 20 and 26, indicating fractured and poor rock characteristics. At depth, both RQD and TCR values increase to designate “good” rock quality. Borings in the east abutment were terminated within bedrock.

Based on observations during boring, the groundwater level was estimated to be at a depth of between 1.5 and 6.0 meters below the existing grade, corresponding to an approximate elevation of between +857m and +863m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footing is recommended for this structure. Due to the steep nature of the gorge, in order to avoid potential foundation instability, the bottom of the foundation should be placed on the bedrock which varies between 1.10 meters and 3.05 meters in the East Abutment and about six (6) meters in the west abutment. Accordingly, the foundation’s bottom elevation should be selected at or below +855m in the west abutment and +858m in the east abutment. Due to poor and fractured state of the upper part of the bedrock, at this depth, an allowable bearing pressure of 400 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be negligible. A shear key would be beneficial to increase the stability of the foundations. For this bridge the load distribution zone for the footings should be selected as 2.5V:1H or flatter and should extend to a depth at least four times the width of the footing. The design should verify that the load distribution zone remains within the rock mass.

During construction of the footing, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 7):

Soil Type/Parameter	**Stratum 1 Colluvium**	**Stratum 2 bedrock**
Approximate depth below present grade (m)	0	1.1 to 6.0
Angle of Internal Friction (°)	32	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.30	0.24
Coefficient of Passive Resistance (Kp)	3.25	4.20
Friction factor between foundation concrete and soil (δ)	0.55	0.50

4.1.8 Bridge No. 8 (Km 37+110):

This is a 30 meter long single-span bridge crossing a dry gorge. Due to access issues, the contractor did not perform any borings at this location. Subsurface conditions were characterized based on the detailed engineering geologic maps of the route.

Subsurface Conditions

Based on the engineering geologic maps of the area, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (sand gravels, cobbles and silt):** The uppermost soil stratum consisted of well graded sand and gravel mixed with variable amounts of silt and cobbles. The thickness of this unit is expected to be on the order of two meters.

Stratum 2 **Bedrock (Congolomera~Sandstone, infrequent siltstone):** Bedrock is expected to be at elevation +895m and consist of light to dark to gray, medium hard, moderately strong, moderately to slightly weathered sandstone and siltstone.

At the time of the field investigations, groundwater was not observed. However, the groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. Due to the steep nature of the gorge, in order to avoid potential foundation instability, the bottom of the foundation should be placed on the bedrock which is expected to be within two meters of the existing grade, corresponding to an elevation of +897m or below. For the foundations resting on bedrock, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be negligible. A shear key would be beneficial to increase the stability of the foundations.

In design calculations, the following soil parameters can be used (Bridge No.8):

Soil Type/Parameter	**Stratum 1 Alluvium**	**Stratum 2 bedrock**
Approximate depth below present grade (m)	0~2m	2.0m+
Angle of Internal Friction (°)	30	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.33	0.24
Coefficient of Passive Resistance (Kp)	3.0	4.20
Friction factor between foundation concrete and soil (δ)	0.55	0.50

4.1.9 Bridge No. 9 (Km 38+541):

This is a 40 meter long single-span bridge crossing a dry flood plain. Boreholes 38200-1 and 38200-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring and test pit information, the generalized subsurface conditions at the bridge site below a thin layer (i.e., 1.3 meters) of fill are as follows:

Stratum 1 **Alluvium (Gravel):** The uppermost soil stratum consists of well graded gravel in and greenish gray, well graded gravel with sand in both abutments. Infrequently, boulders with an approximate size of about 0.4 meter were also observed. Sand content varies between about 20 to 30 percent. The thickness of the gravel under the proposed footing locations is expected to be on the order of three meters. The Standard Penetration Resistance (N) values of this layer were greater than 50 indicating its very dense and compact nature. Boring 38+200-2 was 13.5 meters (?) below the existing grade.

Stratum 2 **Bedrock (Sandstone~Siltstone):** Bedrock was observed to be about 1.3 meters below the existing grade in the south abutment and is expected to be about three meters at the north footing location. The top of the bedrock is expected to be at about +904m. It consists of beige, hard, strong to moderately strong sandstone with layers of gray, hard, fine grained siltstone. Except for the upper

0.5 meter, the total core recovery and the RQD values were greater than 80 percent, indicating sound and good rock characteristics. Boring 38+200-1 was terminated within this layer at 6.0 meters below the existing grade.

Based on observations during boring, the groundwater level was estimated to be at a depth of between 1.35 meters and 3.80 meters below the existing grade, corresponding to approximate elevations of about +899m and +900m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. The borings are not at the proposed pier locations. However, both the Stratum 1 gravel and the underlying bedrock (Stratum 2) are competent bearing strata to withstand the structural loads. Accordingly, we recommend that unless the bedrock is observed at a shallow depth, the minimum foundation depth should be selected at least 1.5 meters below the existing or final grade, whichever is deeper (i.e., elevation +898m or below). In addition, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. At this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 10 mm on gravel, negligible on rock.

During construction of the footing, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 9):

Soil Type/Parameter	Stratum 1 Alluvium	Stratum 2 Bedrock
Approximate depth below present grade (m)	0 to 6.0	1.30+
Angle of Internal Friction (°)	36	38
Unit Weight, above ground water (t/m^3)	2.0	2.1
Unit Weight, submerged (t/m^3)	1.0	-
Coefficient of Active Pressure (Ka)	0.26	0.24
Coefficient of Passive Resistance (Kp)	3.84	4.20
Friction factor between foundation concrete and soil (δ)	0.55	0.50

4.1.10 Bridge No. 10 (Km 40+748):

This is a 25 meter long single-span bridge crossing a seasonably dry flood plain. Boreholes 40200-1, 40200-2 and test pits TP40200-1 through TP40203-3 and TP41000-1 through TP41000-5 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring and test pit information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (Gravel):** All borings at test pits at this location were drilled and terminated within alluvium confirming that the thickness of the alluvium would be in excess of 16.5 meters. The alluvium consists of variously colored, well graded gravel with sand, rounded and containing 25 to 30 percent fine to coarse sand. Except for infrequent low penetration resistance values, the Standard Penetration Resistance (N) values of this layer were greater than 25, generally indicating its dense nature. Borings 40+200-1 and 40+200-2 were terminated within this stratum.

Groundwater was not observed during boring. However, as the borings are away from the actual bridge locations, groundwater may be present within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. The borings are not at the proposed pier locations. However, Stratum 1 gravel is a satisfactory bearing stratum for the proposed bridge abutments. The foundation bottom elevation is governed by the frost penetration depth. Therefore, for foundations within alluvium gravel, the foundation depth should be selected a minimum of 1.5 meters below the final grade. In addition, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. At this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm.

During construction of the footing, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 10):

Soil Type/Parameter	**Stratum 1 Alluvium**
Approximate depth below present grade (m)	0 to 6.0
Angle of Internal Friction (°)	36
Unit Weight, above ground water (t/m^3)	2.0
Unit Weight, submerged (t/m^3)	1.0
Coefficient of Active Pressure (Ka)	0.26
Coefficient of Passive Resistance (Kp)	3.84
Friction factor between foundation concrete and soil (δ)	0.55

4.1.11 Bridge No. 11 (Km 42+398):

This is a 35 meter long, single-span bridge crossing a dry flood plain. Boreholes 41800-1 and 41800-2 were used to characterize the subsurface conditions at this site.
Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site below a thin layer (i.e., 1.3 meters) of fill are as follows:

Stratum 1 **Colluvium (Boulders and Cobbles):** The uppermost soil stratum consisted of greenish gray, subangular to rounded boulders and cobbles up to 0.4 meter in size, containing about 25-30 percent fine to coarse gravel, about 15 percent sand and some silt. The thickness of the colluvium ranges between 5.3 meters in the south abutment and about 1.9 meters in the north abutment. The thickness of this layer is estimated to be about 3.0 meters under the proposed footing locations. Due to coarse grain size, almost all of the Standard Penetration Resistance (N) values of this layer yielded a refusal.

Stratum 2 **Bedrock (Sandstone~Siltstone):** Bedrock was observed between 1.95 and 5.30 meters below the existing grade and consists of siltstone and sandstone. Sandstone is gray, hard, moderately strong, slightly weathered and contains layers of siltstone. Siltstone was observed about 7.5 meters below the existing grade and is gray, slightly weathered, and moderately weak to moderately strong. Both the total core recovery and the RQD values were greater than 80 percent, indicating sound and good rock characteristics. Both boreholes were terminated within this layer at 6.0 meters below the existing grade.

Based on observations during boring, the groundwater level was estimated to be at a depth of between 4.5 and 5.7 meters below the existing grade, corresponding to approximate elevations of between +913m and +917m. The groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. However, due to variable thickness of the Stratum 1, colluvium, foundations for the abutments should be located on the bedrock (Stratum 2) at Elevation + 918m (or below) in the west abutment and Elevation +916m (or below) in the east abutment. The thickness of the colluvium to be removed is expected to be on the order of three meters. For the shallow foundations, we recommend an allowable bearing pressure of 800 kN/m^2 for the design of the foundations. Total settlement under this magnitude of stress is expected to be negligible.

During construction of the footing, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 11):

Soil Type/Parameter	Stratum 1 Colluvium	Stratum 2 Bedrock
Approximate depth below present grade (m)	1.95 to 5.30	~3.0-10.15
Angle of Internal Friction (°)	32	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.30	0.24
Coefficient of Passive Resistance (Kp)	3.25	4.20
Friction factor between foundation concrete and soil (δ)	Not recommended	0.50

4.1.12 Bridge No. 12 (Km 55+786):

This is a 35 meter long single-span bridge crossing a seasonably dry flood plain. Boreholes 56000-1 and 56000-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (Gravel):** All borings at test pits at this location were drilled and terminated within alluvium confirming that the thickness of the alluvium would be in excess of 15.0 meters. The alluvium mostly consists of gravel with some cobbles and boulders below 6.25 meters. This stratum is typically greenish grey, well graded gravel with sand and silt with hard rounded sand in about 15 to 20 percent and about 15 percent fines. Except for the upper 3.0 meters, the Standard Penetration Resistance (N) values of this layer were greater than 25, indicating the dense to very dense nature of the alluvium. Both borings were terminated within this stratum.

Groundwater was not observed during boring. However, as the borings are away from the actual bridge locations, groundwater may be present within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. Stratum 1 gravel is a satisfactory bearing stratum for the proposed bridge abutments. For foundations within alluvium gravel, the foundation depth should be selected at a minimum of 2.5 meters below the existing grade to account for the less compact layers, corresponding to an elevation approximately +1004m or below. Also, in order to reduce the potential for the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint, plus 1.5 meters from all sides, water(W)-

cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 12):

Soil Type/Parameter	**Stratum 1 Alluvium**
Approximate depth below present grade (m)	0
Angle of Internal Friction (°)	36
Unit Weight, above ground water (t/m^3)	2.0
Unit Weight, submerged (t/m^3)	1.0
Coefficient of Active Pressure (Ka)	0.26
Coefficient of Passive Resistance (Kp)	3.84
Friction factor between foundation concrete and soil (δ)	0.55

4.1.13 Bridge No. 13 (Km 59+203):

This is a 35 meter long single-span bridge crossing a seasonably dry flood plain. Boreholes 59000-1 and 59000-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (Gravel):** The uppermost soil stratum is about 6.0 meters thick and consisted of variously colored, well graded gravel with sand (about 25 percent) and silt (about 10 percent), generally fine to coarse grained. This layer also includes occasional boulders and cobbles. Except for the upper 2.0 meters, the Standard Penetration Resistance (N) values of this layer were greater than 35, indicating the very dense and compact nature of the alluvium. In boring 59+000-2 below 5.50 meters, sand content increases and the stratum is defined as greenish dark gray, well graded sand with gravel and silt.

Stratum 2 **Alluvium (Cobbles and Boulders):** With depth, the nature of the alluvium changes from gravel to cobbles and boulders. This stratum consists of variously colored, generally round boulders and cobbles up to 0.6 meters in size with gravel about 30 percent and sand about 25 percent. The Standard Penetration Resistance (N) values of this layer were always greater than 50, probably due to the coarse size of the material. Both borings were terminated within this stratum about 15.0 meters below grade of which the thickness of cobbles and boulders was in excess of 8.0 meters.

Groundwater was not observed during boring. However, groundwater may be present seasonably within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. Stratum 1 gravel is a satisfactory bearing stratum for the proposed bridge abutments. For foundations within alluvium gravel, the foundation depth should be selected at a minimum of 2.0 meters below the existing grade to account for the near surface medium to loose gravel (i.e., elevation +1012m or below). Also, in order to reduce the potential for the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint, plus 1.5 meters from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained

In design calculations, the following soil parameter can be used (Bridge No. 13):

Soil Type/Parameter	**Stratum 1 Alluvium (Gravel)**	**Stratum 2 Cobbles and Boulders**
Approximate depth below present grade (m)	0-6.0	6.0-15+
Angle of Internal Friction (°)	36	34
Unit Weight, above ground water (t/m^3)	2.0	2.0
Unit Weight, submerged (t/m^3)	1.0	1.0
Coefficient of Active Pressure (Ka)	0.26	0.28
Coefficient of Passive Resistance (Kp)	3.84	3.53
Friction factor between foundation concrete and soil (δ)	0.55	0.55

4.1.14 Bridge No. 14 (Km 59+896):

This is a 25 meter long single-span bridge crossing a dry flood plain. Boreholes 60400-1 and 60400-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Fill:** The uppermost soil stratum consists of a layer of fill material about 1.10 meters in thickness. The fill is composed of variously colored, well graded gravel mixed with variable amounts of sand, some boulders and little silt. The Standard Penetration Resistance in fill ranged between 54 and refusal, generally indicating its very dense nature as well as the presence of coarse material.

Stratum 2 **Colluvium (Gravel and Cobbles and Boulders):** Approximately 1.1 meters below grade, variously colored, well graded gravel underlies the fill. The gravel includes about 25 to 30 percent sand and about 5 to 10 percent silt with occasional boulders and cobbles about 0.3 meter in size. Between approximately 5.0 and 7.0 meters below grade, the nature of this stratum changes from gravel to cobbles and boulders. Cobbles and boulders are described as greenish gray, hard, subrounded to rounded material containing about 30 percent gravel, 15 percent fines and about 25 percent sand. The Standard Penetration Resistance (N) values in gravel ranged from 15 to refusal, while in cobbles and boulders they were greater than 50, generally indicating the dense to very dense and compact nature of this stratum. Both borings were terminated within this stratum about 12.0 meters below the existing grade.

Groundwater was not observed during boring. However, groundwater may be present seasonably within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. Stratum 1 fill is heterogeneous and cannot be considered as a bearing stratum. Stratum 2 gravel, on the other hand, is a satisfactory bearing stratum for the proposed bridge abutments. For foundations within Stratum 2 gravel, the foundation depth should be selected at a minimum of 1.5 meters below the existing or final grade (whichever is deeper) to account for the removal of the Stratum 1 fill and also for providing adequate frost penetration. In addition, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. Accordingly, the recommended foundation bottom elevation is +1016m or below. For the abutments, the load distribution zone for the footings should be selected as 1.0V:1.0H and should extend to a depth at least five times the width of the footing. The design should, therefore, consider locating the footings outside of the load distribution stability zone and/or provide added stability measures (i.e., retaining walls) to provide resistance against sliding/overturning. Also, in order to reduce the potential for the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint, plus 1.5 meters from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 14):

Soil Type/Parameter	**Stratum 1 Fill**	**Stratum 2 Colluvium (Gravel)**
Approximate depth below present grade (m)	0~1.1m	1.10-12.0+
Angle of Internal Friction (°)	30	36
Unit Weight, above ground water (t/m^3)	1.8	2.0
Unit Weight, submerged (t/m^3)	0.8	1.0
Coefficient of Active Pressure (Ka)	0.33	0.26
Coefficient of Passive Resistance (Kp)	3.0	3.84
Friction factor between foundation concrete and soil (δ)	Not recommended	0.55

4.1.15 Bridge No. 15 (Km 61+730):

This is a 30 meter long single-span bridge crossing a dry gorge. Due to access issues, the contractor did not perform any borings at this location. Subsurface conditions were characterized based on the detailed engineering geologic maps of the route.

Subsurface Conditions

Based on the engineering geologic maps of the area, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Colluvium (sand gravels, cobbles and silt):** The uppermost soil stratum consists of variously colored, angular to subangular cobbles and boulders about 0.3 meter in size mixed with gravel, sand and silt. This unit generally contains about 20 percent sand and about 25 percent gravel. It is formed as slopewash. The thickness of this unit is expected to be on the order of two meters.

Stratum 2 **Bedrock (Schist, meta sandstone):** Bedrock is expected within about 2.0 meters of the existing grade and consists of a moderately to highly weathered, moderately weak to moderately strong mix of metasandstone, mica schist and slate. Schistosity planes generally range between 10 and 200 mm.

At the time of the field investigations, groundwater was not observed. However, groundwater may be present during the snow melt period and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. Due to the steep nature of the gorge, in order to avoid potential foundation instability, the bottom of the foundation should be placed on the bedrock which is expected to be within two meters of the existing grade at elevation +1056m or below. If bedrock is not encountered at this elevation, the footing elevation should be lowered to rest on the bedrock. For the foundations resting on bedrock, an allowable bearing pressure of 600 kN/m^2 is assigned due to unavailability of rock cores. Total settlement under this magnitude of stress is expected to be negligible. A shear key would be beneficial to increase the stability of the foundations.

In design calculations, the following soil parameters can be used (Bridge No. 15):

Soil Type/Parameter	**Stratum 1 Colluvium**	**Stratum 2 bedrock**
Approximate depth below present grade (m)	0~2m	2.0m+
Angle of Internal Friction (°)	30	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.33	0.24
Coefficient of Passive Resistance (Kp)	3.0	4.20
Friction factor between foundation concrete and soil (δ)	Not recommended	0.50

4.1.16 Bridge No. 16 (Km 69+215):

This is a 30 meter long single-span bridge crossing a dry flood plain. Boreholes 69300-1 and 69300-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Fill:** The uppermost soil stratum fill was only observed in the west abutment to a depth of 3.20 meters below grade, corresponding to an elevation of +1078m. It consisted of beige silty sand with about 10 percent gravel and up to 30 percent fines. One Standard Penetration Resistance in fill was N=43, indicating a very dense or heterogeneous nature.

Stratum 2 **Clay (CL):** Brown sand lean clay was observed in the east abutment from the existing grade to a depth of about 1.80 meters, corresponding to an elevation of +1077m. Clay also contained layers of gravel and about 15 percent sand. The Standard Penetration Resistance in clay ranged from 16 to 27, indicating its stiff and very stiff nature. The observed thickness of the clay layer was 1.80 meters.

Stratum 3 **Colluvium (Gravel and Cobbles and Boulders):** At elevation about +1078 in the west abutment and elevation +1077 in the east abutment, colluvium mostly consisting of light brown, well graded gravel with sand (about 25 percent) and fines (less than 10 percent) was observed to a depth of about 11 meters below the existing grade. Below approximately elevation +1069, gravel graded into rounded cobbles and boulders about 0.6 meter in size, which also included significant proportions of gravel and sand. The Standard Penetration Resistance (N) values in gravel ranged from 25 to refusal, generally indicating dense to very dense and coarse grain size. Both borings were terminated within this stratum about 14.0 meters below the existing grade.

Groundwater was not observed during boring. However, groundwater may be present seasonably within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, neither Stratum 1 nor Stratum 2 are considered to be a bearing stratum. Therefore, a shallow foundation system with spread footings with a minimum foundation elevation of +1077m (or below) is recommended for this structure. Also, the foundation depth should be a minimum of 1.5 meters below the final grade for adequate frost protection. Unless bedrock is encountered at a shallower depth, in order to reduce potential of instability of the bridge foundations, the load distribution zone for the footings should be selected as 1.0V:1.0H and should extend to a depth at least five times the width of the footing. The design should, therefore, consider locating the footings outside of the load distribution stability zone and/or provide added stability measures (i.e., retaining walls) to provide resistance against sliding/overturning. Also, unless bedrock is encountered at the foundation elevation, in order to reduce the potential for the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint plus 1.5 meters from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained.

Subsurface investigations conducted by the drilling contractor, Yuksel Proje, have identified a probable fault at Station 69+235. According to their engineering geologic map, this normal fault has a footwall close to the east abutment. Based on this information, the edge of the footing at the east abutment pier is recommended to be located at least five meters away from the fault zone to approximately station +/- 69+240 to mitigate potential damage during an earthquake.

In design calculations, the following soil parameters can be used (Bridge No. 16):

Soil Type/Parameter	**Stratum 1 Fill**	**Stratum 2 Clay**	**Stratum 3 Colluvium (Gravel)**
Approximate depth below present grade (m)	0~3.20	0~1.80	0-6.0
Angle of Internal Friction (°)	30		36
Cohesion (kN/m2)	-	60	-
Unit Weight, above ground water (t/m^3)	1.8	1.9	2.0
Unit Weight, submerged (t/m^3)	0.8	0.9	1.0
Coefficient of Active Pressure (Ka)	0.33	0.50	0.26
Coefficient of Passive Resistance (Kp)	3.0	1.50	3.84
Friction factor between foundation concrete and soil (δ)	Not recommended	Not recommended	0.55

4.1.17 Bridge No. 17 (Km 69+723):

This is a 105 meter long three-span bridge crossing a seasonably dry flood plain. Due to access issues, the contractor did not perform any borings at this location. Subsurface conditions were characterized based on the detailed engineering geologic maps of the route.

Subsurface Conditions

Based on the engineering geologic maps of the area, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Colluvium (sand, gravels, cobbles and silt):** The uppermost soil stratum in the central pier locations consists of angular to subangular gravel mixed with cobbles and boulders of about 0.4 meter in size. This unit is expected to be present between the stations 69+680 and 69+760, with an estimated thickness of about two meters under the pier locations.

Stratum 2 **Bedrock (Schist, meta sandstone):** Under a limited thickness of colluvium deposits, bedrock is expected within about 2.0 meters of the existing grade and consists of a moderately weathered, moderately weak to moderately strong mix of metasandstone, mica schist and slate. Schistosity planes generally range between 10 and 200 mm.

At the time of the field investigations, groundwater was not observed. However, groundwater may be present during the snow melt period and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. Foundation elevations should be selected at about +1090m (or below) for the east and west abutments and +1073m (or below) for the central piers. In any case, the bottom of the foundations should be at least 1.5 meters below the final grade for frost protection. In addition, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. For the foundations resting on bedrock, an allowable bearing pressure of 600 kN/m^2 is conservatively assigned due to lack of borehole core samples for the design of the foundations. Total settlement under this magnitude of stress is expected to be negligible. A shear key for the abutment foundations is recommended to increase the factor of safety of the foundations.

Subsurface investigations conducted by the drilling contractor, Yuksel Proje, have identified a probable fault at Station 69+730. According to their engineering geologic map, this normal fault has a footwall approximately 15 meters away from the east pier footing. During construction, the location of the footings should be checked and confirmed that the probable fault line is not within at least 10 meters of the footings. The location of the probable fault could be identified by the presence of highly fractured and fragmental pieces of rock in the form of fault breccia (i.e. crush zone), which is usually formed due to excessive shearing.

In design calculations, the following soil parameters can be used (Bridge No. 17):

Soil Type/Parameter	**Stratum 1 Colluvium**	**Stratum 2 bedrock**
Approximate depth below present grade (m)	0~2m	2.0m+
Angle of Internal Friction (°)	30	38
Unit Weight, above ground water (t/m^3)	1.8	2.1
Unit Weight, submerged (t/m^3)	0.8	-
Coefficient of Active Pressure (Ka)	0.33	0.24
Coefficient of Passive Resistance (Kp)	3.0	4.20
Friction factor between foundation concrete and soil (δ)	Not recommended	0.50

4.1.18 Bridge No. 18 (Km 72+563):

This is a 30 meter long single-span bridge crossing a seasonably dry flood plain. Test pits TP74100-1, TP74100-5 and TP74100-6 represent the general area and the TP74100-5 was used to characterize the subsurface conditions at this site.

Subsurface Conditions

Stratum 1 **Colluvium (Cobbles and Boulders):** All test pits were excavated within cobbles and boulders between the elevations +1096m and +1093m (top). Colluvium in this dry river bed consisted of light brown, hard, subangular cobbles and boulders with a maximum size of 1.0 meter which contained about 10 percent fines, about 15 percent sand and about 30 percent subrounded to subangular gravel. Test pits were excavated down to about 3.5 meters below the existing grade, corresponding to a bottom elevation of about +1081m.

Groundwater was observed to range between the elevations of +1089m and +1094m in TP74100-2 and TP74100-3, close to the river bed. However, groundwater may be present seasonably within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings resting on the Stratum 1 cobbles and boulders is selected for this structure. As the Stratum 1 is relatively uniform, foundation depth/elevation will be governed by the frost penetration depth and hydraulic (scour protection, etc.) requirements of the project. The foundation depth should be a minimum of 1.5 meter below the final grade for adequate frost protection. Also, unless suggested otherwise by the design hydrologist, a minimum of 0.5m cover over the spread footing would be required. In addition, in order to reduce the potential for the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint, plus 1.5 meters from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 450 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 18):

Soil Type/Parameter	**Stratum 1 Colluvium Cobbles and Boulders**
Approximate depth below present grade (m)	0-3.5+
Angle of Internal Friction (°)	36
Unit Weight, above ground water (t/m^3)	2.0
Unit Weight, submerged (t/m^3)	1.0
Coefficient of Active Pressure (Ka)	0.26
Coefficient of Passive Resistance (Kp)	3.84
Friction factor between foundation concrete and soil (δ)	0.55

4.1.19 Bridge No. 19 (Km 96+588):

This is a 30 meter long single-span bridge crossing a seasonably dry flood plain. Boreholes 98700-1 and 98700-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Silt (ML):** Light brown, soft silt was observed in both boreholes from the existing grade to a depth of about 0.80 meter, corresponding to an elevation of +1162m. Silt also contains plant roots and also mixed with topsoil. The Standard Penetration Resistance in silt ranged from 5 to 32, indicating the soft and heterogeneous characteristics of the material.

Stratum 2 **Alluvium (Gravel):** Below silt, from approximately elevation +1162, alluvium was observed. It consisted of variously colored, well graded gravel with sand and pieces of cobbles 150 mm or less in size. The Standard Penetration Resistance (N) values in gravel ranged from 33 to refusal, indicating the very dense nature of the material. Both borings were terminated within this stratum about 11.0 meters below the existing grade.

During boring, groundwater was observed at about 2.8 meters below the existing grade, corresponding to an elevation of approximately +1160m. However, groundwater may be present seasonably within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, Stratum 2 is a satisfactory bearing stratum for a shallow foundation system for this structure. Therefore, a shallow foundation system with a minimum foundation elevation of +1162 meters (or below) is recommended for this structure. In addition, the foundation depth should be a minimum of 1.5 meters below the final grade for adequate frost protection and a minimum of 0.5m cover over the spread footing would be required. Due to coarse grain size and the presence of cobbles, in order to reduce the potential for the movements of the fines (i.e. silt and clay) under water action in snow melt, under each abutment footprint plus 1.5 meters from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 19):

Soil Type/Parameter	Stratum 1 Silt	Stratum 2 Alluvium (Gravel)
Approximate depth below present grade (m)	0~0.80	0.80~11.0+
Angle of Internal Friction (°)	-	36
Cohesion (kN/m2)	30	-
Unit Weight, above ground water (t/m^3)	1.8	2.0
Unit Weight, submerged (t/m^3)	0.8	1.0
Coefficient of Active Pressure (Ka)	0.80	0.26
Coefficient of Passive Resistance (Kp)	1.30	3.84
Friction factor between foundation concrete and soil (δ)	Not recommended	0.55

4.1.20 Bridge No.20 (Km 97+577):

This is a 30 meter long single-span bridge crossing a seasonably dry flood plain. Boreholes 99800-1 and 99800-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Alluvium (Gravel):** The uppermost soil stratum is about 3.0 meters thick and consists of variously colored, well graded, fine to coarse gravel with sand (about 30 percent) and fines (about 5 percent). This layer also includes occasional pieces of rocks, rock flour, boulders and cobbles. The Standard Penetration Resistance (N) values of this layer range between 20 and refusal, indicating the dense to very dense and compact nature of this layer. Gravel transit into cobbles and boulders at elevation approximately +1177m.

Stratum 2 **Alluvium (Cobbles and Boulders):** With depth, the nature of the alluvium changes from gravel to cobbles and boulders. This stratum consists of variously colored, generally round boulders and cobbles up to 0.6 meter in size, with sand and gravel. The Standard Penetration Resistance (N) values of this layer were always greater than 50, probably due to the coarse grain size of the material, but also its very dense and compact nature. Both borings were terminated within this stratum at about 11.0 meters below grade where the thickness of cobbles and boulders was in excess of 7.0 meters.

Groundwater was observed in borehole 99800-1 approximately 8.15 meters below grade, corresponding to an elevation of +1171.5m. Groundwater level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Based on the subsurface conditions, a shallow foundation system with spread footings is recommended for this structure. Stratum 1 gravel is a satisfactory bearing stratum for the proposed bridge abutments. For foundations within alluvium gravel, the foundation depth could be selected at any elevation within Stratum 1, provided that the bottom of the foundation has a minimum cover of 1.5 meters below the final grade for frost protection. In order to reduce the potential for the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint plus 1.5 m from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 20):

Soil Type/Parameter	**Stratum 1 Alluvium (Gravel)**	**Stratum 2 Alluvium (Cobbles and boulders)**
Approximate depth below present grade (m)	0~3.0m	3.0-11.0+
Angle of Internal Friction (°)	36	36
Unit Weight, above ground water (t/m^3)	2.0	2.0
Unit Weight, submerged (t/m^3)	1.0	1.0
Coefficient of Active Pressure (Ka)	0.26	0.26
Coefficient of Passive Resistance (Kp)	3.84	3.84
Friction factor between foundation concrete and soil (δ)	0.55	0.55

4.1.21 Bridge No. 21 (Km 98+288):

This is a 25 meter long single-span bridge crossing a dry flood plain. Boreholes 100500-1 and 100500-2 were used to characterize the subsurface conditions at this site.

Subsurface Conditions

Based on the boring information, the generalized subsurface conditions at the bridge site are as follows:

Stratum 1 **Silt (ML):** Brown, medium to stiff, low to medium plasticity silt was observed in both boreholes from the existing grade to a depth of about 4.70 meters, corresponding to an elevation of +1174m. Silt also contained about 10 to 15 percent sand and about 10 percent clay. The Standard Penetration Resistance in silt ranged from 6 to 17, indicating medium to stiff consistency. The thickness of the silt layer was relatively uniform and ranged between 4.60 and 4.70 meters.

Stratum 2 **Alluvium (Cobbles and Boulders):** Silt was underlain by alluvial formations of cobbles and boulders. This layer consisted of variously colored, hard rounded cobbles and boulders up to 0.25 meter in size and contained about 15 percent fines, about 30 percent gravel and about 20 percent sand. The Standard Penetration Resistance (N) values of this layer were always greater than 50, probably due to coarse grain size of the material, but also its very dense and compact nature. Both borings were terminated within this stratum at about 15.0 meters below grade, where the thickness of cobbles and boulders was in excess of 10.0 meters.

Groundwater was not observed during boring. However, groundwater may be present seasonably within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Stratum 1 silt is compressible, and thus is not an acceptable bearing stratum for this structure. Based on the subsurface conditions, a shallow foundation system with spread footings resting on the Stratum 2, cobbles and boulders, is recommended. Accordingly, the foundation bottom should be selected after excavation and removal of the silt layer at a minimum depth of 4.60 meters, corresponding to an elevation +1174m. In order to reduce the potential for settlement and also the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint plus 1.5 meters from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 600 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

During construction of the footings, open temporary excavations using a side slope of 1V:2H can be maintained.

In design calculations, the following soil parameters can be used (Bridge No. 21):

Soil Type/Parameter	**Stratum 1 Silt**	**Stratum 2 Cobbles and Boulders**
Approximate depth below present grade (m)	0~4.70	4.60~15.0+
Angle of Internal Friction (°)	-	36
Cohesion (kN/m2)	30	-
Unit Weight, above ground water (t/m^3)	1.8	2.0
Unit Weight, submerged (t/m^3)	0.8	1.0
Coefficient of Active Pressure (Ka)	0.80	0.26
Coefficient of Passive Resistance (Kp)	1.30	3.84
Friction factor between foundation concrete and soil ($\tilde{\delta}$)	Not recommended	0.45

4.1.22 Bridge No. 22 (Km 98+639):

This is a 30 meter long single-span bridge crossing a seasonably dry flood plain. For unknown reasons, the contractor did not perform any borings at this location. Subsurface conditions were characterized based on the detailed engineering geologic maps of the route as well as from the borings conducted at the location of Bridge 21. The elevations, hydraulic conditions and engineering geologic setting of Bridge No. 21 are similar to those of Bridge No. 22. Therefore, similar subsurface conditions will be developed and recommendations similar to those of Bridge No. 21 will be derived.

Subsurface Conditions

It is assumed that the generalized subsurface conditions at the bridge site would be as follows:

Stratum 1 **Silt (ML):** This stratum is expected to have a maximum thickness of 5.0 meters and is expected to consist of brown, medium to stiff, low to medium plasticity silt. Silt would have significant portions of sand and some clay.

Stratum 2 **Alluvium (Cobbles and Boulders):** Below the silt, at a maximum of 5.0 meters below the existing grade, the alluvial formations of cobbles and boulders mixed with variable amounts of gravel, sand and silt are expected. Based on the borings at the adjacent bridge site, the soil is expected to be very dense and compact. Its thickness is estimated to be in excess of 10 meters.

Groundwater was not expected within the construction limits. However, groundwater may be present seasonably within the alluvium and its level is expected to fluctuate depending upon climatic factors, drainage conditions and other factors.

Foundation Support:

Stratum 1 silt is compressible, and thus is not an acceptable bearing stratum for this structure. Based on the subsurface conditions, a shallow foundation system with spread footings resting on the Stratum 2, cobbles and boulders, is recommended. Accordingly, the foundation bottom should be selected after excavation and removal of the silt layer which is expected at a depth of a maximum of 5.0 meters below the existing grade, corresponding to an elevation +1176m. If gravel or cobbles and boulders are encountered at a shallower depth, the foundation bottom could be selected at a higher elevation, provided that the subgrade is gravel, cobbles and boulders and provided that a minimum cover of 1.5 meters is maintained below the final grade for frost protection. Additionally, in order to reduce the potential for settlement and also the movements of the fines (i.e., silt and clay) under water action in snow melt, under each abutment footprint, plus 1.5 meters from all sides, water(W)-cement(C) slurry with a mix ratio of W/C=1 should be poured until saturation. After this foundation treatment, at this depth, an allowable bearing pressure of 450 kN/m^2 can be assigned for the design of the foundations. Total settlement under this magnitude of stress is expected to be less than 25 mm, of which less than 10 mm is expected to be post construction.

In design calculations, the following soil parameters can be used (Bridge No. 22):

Soil Type/Parameter	Stratum 1 Silt	Stratum 2 Cobbles and Boulders
Approximate depth below present grade (m)	0~5.0	5.0~15.0+
Angle of Internal Friction (°)	-	36
Cohesion (kN/m2)	30	-
Unit Weight, above ground water (t/m^3)	1.8	2.0
Unit Weight, submerged (t/m^3)	0.8	1.0
Coefficient of Active Pressure (Ka)	0.80	0.26
Coefficient of Passive Resistance (Kp)	1.30	3.84
Friction factor between foundation concrete and soil ($\tilde{\delta}$)	Not recommended	0.45

4.2 Roadway

The proposed roadway alignment runs approximately north-south in its first 60 km and about east- west in the remaining 40 km. The most challenging section of the roadway in terms of slope stability, rock excavation and rock slope stabilization is approximately between km 60 and km 80, which is generally characterized by steep topography, change in geology, the fractured yet very strong nature of the rock and an infrequent but unfavorable rock strike and dip orientation. The controlling factors for the proposed roadway are:

- Subgrade for the pavement
- Widening and excavation
- Slope stability and stabilization measures
- Scour protection and hydraulic controlling measures

4.2.1 Subgrade for the pavement

The subgrade between km 0+000 and km 16+000 is expected to be alluvial deposits (i.e., former river terrace) over conglomerate and siltstone. The fines content of this material is generally above 30-40 percent. Between the stations km 16+000 and km 35+500, the subgrade would consist of conglomerate, sandstone and siltstone alternations. Between km 35+500 and 37+600, the subgrade would consist of alluvial deposits (former river terrace). The conglomerate, sandstone, siltstone series is expected to constitute the subgrade between the stations km 37+600 and km 60+000. Between km 60+000 and km 78+800, the subgrade would include a thin layer of slopewash material over metamorphic rock series. The subgrade at the last segment of the roadway between the stations of km 78+800 and km 103+500 would consist of the former terrace deposits of the alluvial plain. Generally, the subgrade along the entire roadway would provide adequate support for the pavement. However, due to generally high contents of fines (i.e., silt and clay), the subgrade has poor drainage characteristics and is highly moisture-sensitive. In addition, due to heavy traffic along the existing track, the upper 100 to 200 mm of the existing alignment contains highly disturbed and segregated subgrade.

In considering the above conditions, a CBR of 10 percent for the existing subgrade is assigned for a flexible pavement design for the entire roadway. If the existing subgrade elevation is maintained, a minimum of 100 mm cut and disposal of the cut material would be needed prior to placement of the subbase and base of the pavement section. Due to the generally moisture-sensitive nature of the subgrade, effective pavement drainage would be required for satisfactory performance and the longevity of the roadway. Based on the laboratory tests, a CBR of 20 percent is assigned for the topping material to be placed over the existing subbase.

As a rule, prior to placement of the subbase/base of the pavement section in soil, the final subgrade should be compacted to 95 percent of the maximum modified proctor density in accordance with AASHTO T180-95.

Part of the roadway, in particular the alluvial fun crossings, would consist of a combination of an embankment and a bridge and/or culvert. Embankment material would readily be available after crushing and screening local alluvial material. The locations of potential borrow areas are provided in Section 5. In the design of the embankments, the use of side slopes 1V:1.5H (downstream) to 1V:2H (upstream) is recommended. The embankment side slopes, in particular the upstream slope, should be protected by designing a layer of riprap. The design should specify that the toe of the riprap should extend beneath the stream bed into a toe trench to protect against turbulent erosion. The riprap should be produced by crushing boulders to produce block-like stone as the available river alluvium is too round and thus unacceptable for riprap. The roadway embankment should be constructed in lifts at a maximum of 300 mm of loose thickness. Each lift should be compacted as specified or to 95 percent of the Maximum Modified Density as observed in AASHTO T180-95 at its optimum moisture content (+/-2 percent).

Unless otherwise stated in the specification, the top one (1)-meter section of the embankment material should meet the following grading requirements:

- Maximum particle size – 75mm.
- No more than 30% by weight retained on the 19mm sieve
- No more than 40% by weight passing the #100 sieve
- No more than 8% by weight passing the #200 sieve, non-plastic.

4.2.2 Widening and Excavation

Most of the existing dirt road will need to be graded, realigned and widened, which will require significant amounts of soil excavation and fill, soft rock cut and soft/hard rock cut and blasting.

The methods of excavation would be decided on by cost, project schedule, local regulations and other factors and are shown on the design drawings and specifications. However, at or near the following stations (approximate), either rock cutting or careful blasting (i.e. Cautious Blasting Technique, a.k.a. Swedish Blasting Technique) must be carried out to avoid potentially unstable rock slopes, which may result in costly and time-consuming remedial measures:

- Only cut slopes to 1.5V:1H in between approximately km 5+900 and km 9+400 and to 2.5V:1H between approximately km 9+400 and km 10+900. Blasting should not be allowed as it may shatter the stable rock masses.
- Cut slope to 2.5V:1H around km 11+500 (soft conglomerate siltstone alternations) and 3:0V:1H between km 13+900 and km 16+000 (siltstone). As an alternative to cutting, the final rock slope can also be achieved by careful blasting. If careful blasting is selected, the final rock face must be blasted by pre-splitting.
- Similarly, cut slopes to 2.5V:1H between km 21+000 and km 28+300. Alternatively, slopes can be cut by Cautious Blasting Technique. The final rock face must be blasted by presplitting.
- Between km 29+000 and km 33+000, cut slope to 3V:1H where required (mostly conglomerate), toward km 33+000 (conglomerate siltstone alternations). As an alternative to cutting, the final rock slope can also be achieved by Cautious Blasting Technique. The final rock face must be blasted by presplitting.
- Cut slope to 2.5V:1H between km 34+200 and km 40+800 (soft conglomerate siltstone alternations) and to 3:0V:1H up to km 42+900. Blasting is not required, unless the contractor exercises the option to do so at his own risk. A final smooth, stable rock slope is required without a need for stabilization.
- Between approximately km 68+600 and km 78+700, either soft rock or fractured rocks exist. Blasting is not required. If the contractor should decide to blast, he will be responsible for stabilization and presplitting to maintain the long-term stability of the rock mass
- Between the stations km 76+500 and km 78+700, blasting is not allowed. Cut rock to 3V:1H.

Rock blasting should be conducted as specified. A blast design must be prepared and approved prior to any test or production blasting activity.

4.2.3 Slope Stability and Stabilization Measures

Proposed soil/rock cut angles range between 1.5V:1H and 3V:1H and were marked on the roadway sections (see Design Drawings Plans and Profiles). It is important that the rock cutting by blasting must adhere to the approved blasting design to reduce the development of potential unstable rock masses, and thus costly rock stabilization measures. Nevertheless, some rock stabilization measures will still be required to maintain the long term safety of the roadway and rock slope stability, and to mitigate rock falls, scaling of the rock slope and block failures. The design and locations of the rock slope stabilization measures, which include a catch trench with or without a catch wall, rock draping and installation of rock bolts, were provided in the design drawings and project specifications. Catch walls coupled with a catch trench were designed to mitigate the bouncing of falling rocks onto the roadway. Due to the local construction capabilities and material availability, “catch wall” would serve in lieu of “catch fence” that is commonly used in the western hemisphere. The catch trench was also designed so as to provide a roadway longitudinal drainage channel.

The design and construction details of the rock slope stabilization measures were provided in the project design documents and the specifications.

4.2.4. Scour Protection and Hydraulic Controlling Measures

At several locations, the roadway crosses over seasonally dry/wet large alluvial valleys, as well as steep gorges. Generally, the size of transported material ranges between 0.1 and 1.0 cubic meter boulders. In addition, the fines content of the subgrade under the proposed embankment could be as much as 30 percent. Therefore, measures mitigating for the transportation of boulders, undermining of the foundation/embankment subgrade and protection of the mostly upstream embankment would be required. For example, rounded edges for the piers would somewhat mitigate formation of a local scour for footings not founded on bedrock. This measure however would not provide adequate protection against floating boulders.

As a minimum, the design should include proper sized riprap as a scour counter-protection for spread footings founded on readable alluvial soil.

Any channel improvement or scour protection measures should be designed by a specialist with local knowledge. It is also advisable to review FHWA HEC23 “Bridge Scour and Stream Instability Countermeasures”.

5.0 BORROW AREAS

Borrow for roadway fill, subbase and base, as well as concrete coarse and fine aggregate, were reviewed based on the field work as well as laboratory test results. Generally, the use of material should be guided by the project specifications. Specific aggregate tests should be conducted prior to the selection of a special type of aggregate which may require screening, crushing or both.

As a guideline, the approximate stations of the potential borrow areas, as well as the type of material, are summarized below:

5.1. Suitable Borrow Areas

The following areas may be used without significant processing for sand and gravel which generally can be defined as well graded sand and well graded gravel. The roundness of the material and its acceptability, however, must be checked and approved prior to its selection as a borrow location:

- 12+500 gravel
- 27+900 sand and gravel to a depth of 4.5 meters only along the stream crossing
- 39+100 gravel
- 39+400 sand
- 40+800 sand (only in the vicinity of TP40200-3)
- 42+900 gravel
- 51+200 sand
- 53+600 sand
- 56+000 sand and gravel
- 58+300 gravel and sand
- 59+900 gravel, between 1.0 and 5.0 meters
- 69+200 gravel, between 2.0 and 10.0 meters
- 74+200 gravel
- 76+100 gravel
- 89+900 gravel, between 3.0 and 5.0 meters
- 96+600 gravel, below 1.0 meter
- 97+600 gravel to 3.0 meters

5.2. Borrow Areas That May be Suitable After Processing

The following areas currently are not suitable as borrow source. They may, however, be suitable after screening to specification grading requirements:

- 12+000 (in the vicinity of test pits 1, 2 and 3)
- 45+500
- 52+700 to 3.0 meters only
- 57+500
- 70+900
- 96+100 to 3.0 meters only

5.3. Unsuitable Borrow Material for Pavement Subgrade, Subbase and Base

The following areas are unsuitable as borrow source, as they contain excessive moisture- and frost-sensitive material. Therefore, their use as fill should be avoided within a minimum of 1.0 meter, and ideally 1.5 meters, below the pavement box:

- 12+300 (in the vicinity of test pits 4 and 5)
- 19+300
- 30+800
- 39+800
- 40+700 (in the vicinity of test pit 1)
- 41+500
- 42+400
- 49+000
- 75+300
- 69+200 (top 2.0 meters)
- 89+200
- 88+300 (to a depth of 3.0 meters)
- 96+600 (top 1.0 meter)
- 98+300 (top 5.0 meter)

5.4. Unsuitable Excavated Material (i.e. cut for fill) for Pavement Subgrade, Subbase and Base

In addition to unsuitable borrow areas, the excavated material between the following stations would contain excessive moisture-sensitive and frost-sensitive material. Therefore, wherever possible the use of material excavated from these areas should be restricted to a minimum of 1.0 meters, and preferably 1.5 meters, below the pavement box to avoid poor pavement drainage as well as adverse frost effects in the cold season. If there is no excessive material, the subgrade, however, is suitable to receive the pavement box after a cut, provided that the recommendations provided in Section 4.1 of this report are followed.

- 5+000 to 5+8000
- 9+500 to 12+000
- 15+400 to 16+000
- 16+500 to 23+600
- 34+200 to 35+700
- 39+200 to 42+400
- 86+000 to 103+500

6.0 SEISMIC CONSIDERATIONS

Based on the review of Seismicity of Afghanistan, the project area lies in a high seismic zone, with a high probability of damage during an earthquake. In fact, the largest instrument-measured earthquake in Afghanistan, with a magnitude of 8.1, was recorded on November 21, 1921 in Badakshan Province.

Accordingly, the proposed structure(s) should be designed with seismic considerations according to the AASHTO Design Guidelines, Division IA, Section 3-Seismic Design, according to which a Site Coefficient (S) for Soil Profile Type I.2, described as “Stiff soil conditions where the soil depth is less than 60 meters and the soil types overlying rock are stable deposits of sands, gravels, or stiff clays” with a Site Coefficient of 1 can be assigned for the project site. As recommended by the project srtructural designer, the Amateur Seismic Center, the Acceleration Coefficient value between 0.35 and 0.48 is suggested.

The groundwater is generally well below the foundation depths of the structures. Also, the material is granular, dense to very dense. Therefore, the project site is not susceptible to liquefaction under seismic loading.

7.0 CORROSION POTENTIAL AND SULFATE ATTACK ON CONCRETE

Tests including soil resistivity, pH, soluble sulfate and chloride contents were performed on selected soil samples in order to evaluate corrosion potential for ferrous metals (i.e. uncoated steel) and sulfate attack on concrete. Tested soil samples were collected from the soils at or near the proposed foundation elevations. The test results are presented in Appendix D.

Analyses on samples show that the concentration of sulfate (as SO_4) ranges from non-detected to 1200 ppm, and that of chloride between none detected and 160 ppm. The measured soil resistivity ranged between 900 and 4,000 ohm-cm, and the pH between 7.2 and 8.2.

Except for the area designated by the borehole 69300 (i.e. at the vicinity of the proposed Bridge No. 16), the measured sulfate values indicate that no special measures against a sulfate attack will be required. Therefore, no special measure is proposed here. However, as a rule buried concrete should be dense, fully compacted using Ordinary Portland Cement (OPC) and the requirement of minimum cement content of concrete should be observed in accordance with the requirements of ACI. For the foundations and other structures at and near the Bridge No.16, “moderate” sulfate exposure is expected. At and near the Bridge No.16, If possible Portland Cement, Type II (ASTM C 150) should be used. If this is not possible, using OPC, the maximum free water/cement ratio should be 0.45 and the minimum content of cement should be 330kg/m^3, using 20mm size aggregate, or 380 kg/m^3 using 10mm aggregate. At and near this location, the minimum concrete strength should be specified as 27.5 Mpa.

Similarly, except for the area designated by the borehole 69300, chloride contents and the resistivity measurements also do not indicate a corrosive environment. Generally, adequate cover for reinforcement steel in accordance with ACI requirements should be provided. Pipes in contact with soil should also be protected in accordance with the manufacturer’s recommendations. For the foundations and other structures at and near the Bridge No.16, the resistivity measurements indicate a corrosive environment. Accordingly, for the foundations in contact with soil at and near this location, the minimum cover for the r-bars should be selected 75mm. Additionally, r-bars should not be stored in contact with local soils and should be cleaned prior to their installation.

8.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the foregoing engineering evaluation, the following conclusions and recommendations are provided:

1. Based on geotechnical analyses, the proposed structures can be supported on a shallow foundation system using spread type footings. For the design of the footings, allowable bearing pressures for each structure were provided in the preceding sections which range between 450 kN/m^2 and 1000 kN/m^2. For the design of the culverts, an allowable bearing pressure of 350 kN/m^2 can be assigned. Post construction settlement under that magnitude of stress would be less than 10mm.

2. A CBR of 10 percent for the existing subgrade and a CBR value of 20 percent for the topping material are assigned for a flexible pavement design for the entire roadway. It is recommended that if the existing subgrade elevation is maintained, a minimum of 100mm cut and disposal of the cut material would be needed prior to placement of subbase and base of the pavement section. Due to generally moisture sensitive nature of the subgrade effective pavement drainage would be required for a satisfactory performance and the longevity of the roadway.

3. Most of the existing dirt road will need to be graded, re-aligned and widened which will require significant amounts of soil excavation and fill, soft rock cut and soft/hard rock cut and blasting. The methods of excavation would be decided on cost, project schedule, local regulations and other factors and are shown on the design drawings and specifications. As discussed in Section 4.2.2 of this report, blasting will require the application of “Cautious Blasting Techniques, also known as Swedish Blasting Technique” with presplitting in order to avoid potential unstable rock masses.

4. Recommended soil/rock cut angles various between 1.5V:1H and 3V:1H. In order to maintain long term roadway safety, rock slope stability and to mitigate rock falls, rock slope stabilization measures will be required. The design and locations of the rock slope stabilization measures which include catch trench with or without catch wall, rock draping and installation of rock bolts were provided in the design drawings and project specifications.

5. For the protection of the structures and the embankment crossing over the seasonally dry/wet alluvial valleys and steep gorges, measures mitigating for the transportation of boulders, undermining of the foundation/embankment subgrade and protection of the mostly upstream embankment would be required. In order to provide vertical and lateral channel stability and minimize or eliminate aggredation, degradation, lateral erosion and local scour as a minimum should include the reduction of the flow velocity as well as rounding the shape of the piers. A specialist advice in design of the crossings of the snow melt/flood plain crossings should be sought.

6. Based on the field work and laboratory test results, potential borrow areas for the roadway fill, subbase and base as well as concrete coarse and fine aggregate were

reviewed and areas were defined in terms of suitable, or unsuitable for various construction activities.

7. The project area lies in a high seismic zone with high probability of damage during an earthquake. Based on the AASHTO Design Guidelines, Division IA, Section 3-Seismic Design, a Site Coefficient (S) for Soil Profile Type I.2 with a Site Coefficient of 1 can be assigned for the project site. As recommended by the project srtructural designer, the Amateur Seismic Center, the Acceleration Coefficient value between 0.35 and 0.48 is suggested.

   Due to dense to very dense nature of subgrade, the grain size and the depth to groundwater, it is concluded that the project site is not susceptible to liquefaction in an earthquake event.

8. Based on the sulfate, chloride resistivity and pH measurements, except for the area at and near the Bridge Number 16, sulfate and chloride contents do not pose a threat against corrosion and sulfate attack, therefore, no special measures will be required. Generally, it is recommended to use dense, ASTM C150 Type I or II cement for concrete and meet the requirement of the minimum cement content. For the foundations in contact with soil, the minimum cover for the r-bars should be selected 75mm. At and near the Bridge Number 16, we recommend the use of ASTM C150 Type II cement. If this is not possible, in Type I cement a minimum cement content of 380 kg /m3, if 10mm size aggregate is used, or 330 kg /m3 if 20mm size aggregate is used. The maximum free water/cement ratio should be less than 0.50. Also, provide the cover for reinforcement steel mitigating for “corrosive” threat to corrosion in accordance with ACI requirements. We recommend providing the use of epoxy coating of all reinforcing bars at the foundation level of the Bridge Number 16.

9. Generally, it is recommended that, steel coming in contact with soil or groundwater should be avoided at all times. Also it is recommended to provide measures to protect structural steel, pipes or other steel members of the structure in contact with the soil in accordance with the manufacturer’s recommendations.

9.0 LIMITATIONS

Our professional geotechnical engineering services have been performed using that degree of care and skill ordinarily exercised, under similar circumstances, by reputable geotechnical consultants practicing in this or similar localities. No other warranty, expressed or implied, is made as to the professional advice included in this report. This report has been prepared by Berger for the UNOPS-United Nations Office for Project Services to be used solely in the design of the Keshim –Faizabad Road Rehabilitation and Reconstruction Project. The report has not been prepared for use by other parties, and may not contain sufficient information for the purposes of other parties or other uses.

The recommendations provided in this report are based upon our understanding of the described project information and on our interpretation of the data collected during our geotechnical survey of the route as well as surface and subsurface explorations conducted by our subcontractor, Yuksel Proje. We have made our recommendations based upon experience with similar subsurface conditions. The recommendations apply to the specific project discussed in this report; therefore, any change in the structure configuration, loads, location, or site grades should be provided to us so that we can review our conclusions and recommendations and make any necessary modifications.

Regardless of the thoroughness of a geotechnical exploration, there is always a possibility that conditions between borings will be different from those at specific test locations and that conditions will not be as anticipated by the designers or contractors. Specifically, some areas of the site were not accessible for exploratory borings or test pits. In addition, the construction process may itself alter soil and rock conditions. Therefore, experienced geotechnical personnel should observe and document the construction procedures used and the conditions encountered. Unanticipated conditions and inadequate procedures should be reported to the design team along with timely recommendations to solve the problems created.

10.0 REFERENCES

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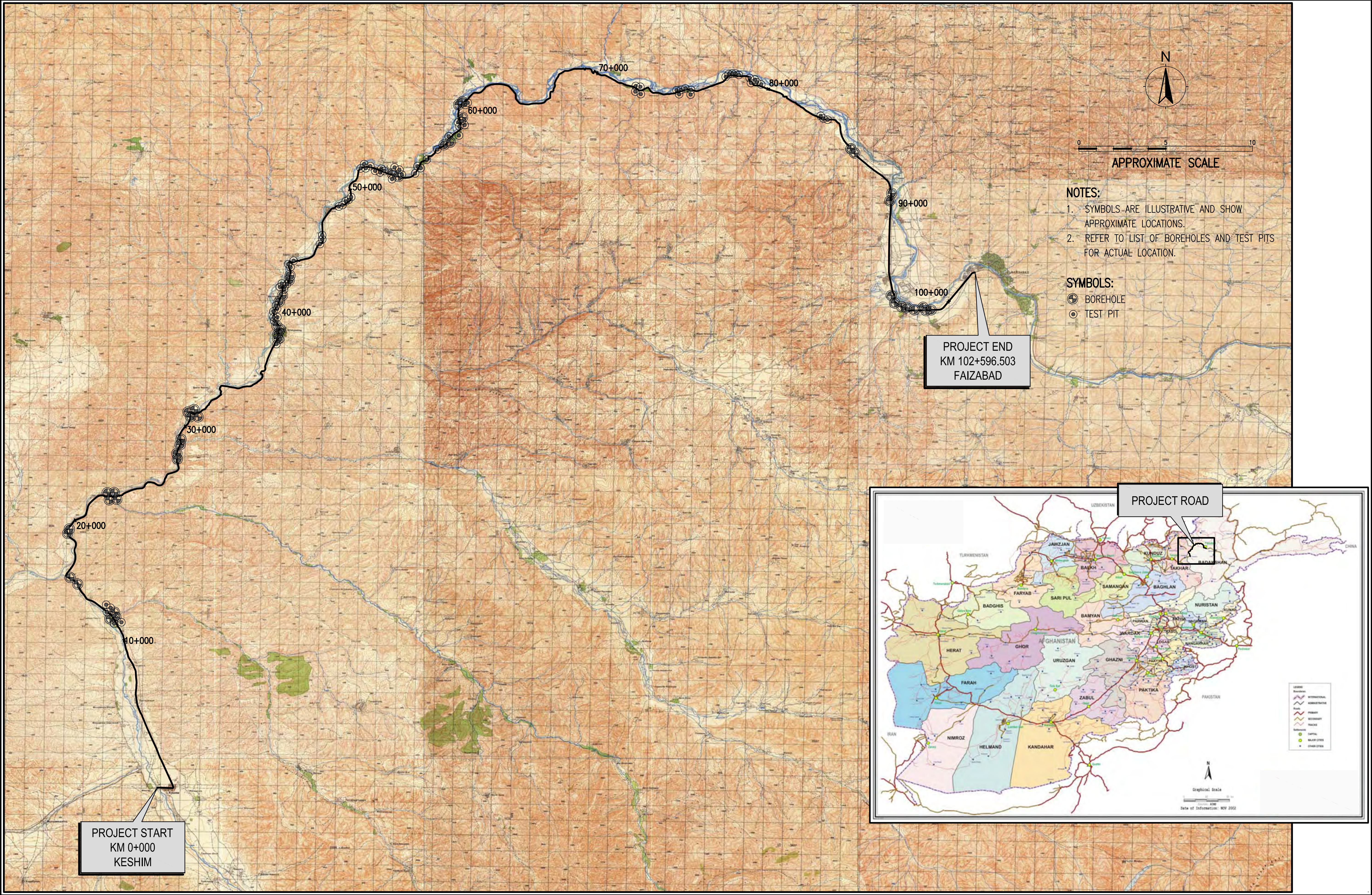


ISLAMIC REPUBLIC OF AFGHANISTAN and UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT	UNOPS — UNITED NATIONS OFFICE FOR PROJECT SERVICES Kabul, Afghanistan The LOUIS BERGER Group, Inc. 2300 N St. Washington DC 20037 USA	TITLE DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT	SHEET CONTENTS BOREHOLES AND TEST PITS LOCATION PLAN	REVISION FIRST ISSUE	DATE OCT 06	NAMES & SIGNATURE DRAWN: S. SOLETE DESIGNED: YUKSEL PROJE NOTED BY: BERNARDO P. UMLAS C.E. 0027008 REGISTERED, PROFESSIONAL REGULATIONS COMMISSION, PHILS.	DWG NO. KF-GT-001 SCALE: AS SHOWN

BOREHOLES

REFERENCE LOCATION	BOREHOLE NO.	STATION	OFFSET FROM ROAD ℄	GPS COORDINATES Y	X	Z
12+400	12400–1	12+517.184	7.601	595 339	4 086 040	848
	12400–2	12+565.341	2.612	595 301	4 086 070	847
14+800	14800–1	15+583.673	7.886	593 329	4 088 224	803
	14800–2	15+617.914	4.805	593 309	4 088 252	805
18+600	18600–1	19+293.671	4.536	593 179	4 091 501	812
	18600–2	19+334.050	10.468	593 193	4 091 542	816
22+180	22180–1	22+731.847	8.716	595 173	4 093 757	819
	22180–2	22+746.226	2.740	595 160	4 093 744	819
	22180–3	22+827.536	18.700	595 252	4 093 782	830
	22180–4	22+832.711	11.070	595 258	4 093 775	819
27+500	27500–1	27+880.363	3.931	598 520	4 096 270	848
	27500–2	27+921.132	3.006	598 513	4 096 311	846
28+300	28300–1	28+813.511	4.035	598 653	4 097 168	842
	28300–2	28+855.105	6.507	598 653	4 097 168	842
30+800	30800–1	30+814.895	16.190	599 256	4 098 945	864
	30800–2	30+818.695	6.400	599 253	4 098 955	863
	30800–3	30+926.190	6.370	599 318	4 099 026	862
	30800–4	30+913.054	13.006	599 340	4 099 018	867
38+200	38200–1	38+527.943	7.822	603 590	4 103 933	903
	38200–2	38+574.436	34.786	603 574	4 103 994	900
39+600	39600–1	39+126.692	3.705	603 639	4 104 523	895
	39600–2	39+124.018	33.585	603 609	4 104 523	895
40+200	40200–1	40+736.085	7.508	603 536	4 106 012	901
	40200–2	40+766.877	9.933	603 551	4 106 039	899
41+800	41800–1	42+379.485	7.034	604 028	4 107 479	932
	41800–2	42+414.539	5.180	604 047	4 107 511	915
53+500	53500–1	52+742.253	16.347	608773	4 114 622	982
	53500–2	52+788.132	3.381	608 820	4 114 614	991
56+000	56000–1	55+791.336	61.514	611 097	4 115 423	1013
	56000–2	55+845.832	18.768	611 091	4 115 492	1012
59+000	59000–1	59+114.263	14.122	612 657	4 118 099	1019
	59000–2	59+220.052	7.141	612 621	4 188 169	1016
60+400	60400–1	59+876.289	12.500	612 660	4 118 808	1012
	60400–2	59+910.451	4.408	612 657	4 118 846	1012
69+300	69300–1	69+265.809	9.724	632 787	4 116 323	1125
	69300–2	69+265.809	9.724	632 787	4 116 323	1125
89+400	89400–1	86+265.720	13.329	632 784	4 116 321	1124
	89400–2	86+270.983	2.361	632 796	4 116 323	1123
90+100	90100–1	88+249.623	39.173	634 154	4 114 883	1141
	90100–2	88+259.621	18.363	634 161	4 114 905	1143
98+300	98300–1	96+120.847	10.711	635 005	4 107 325	1169
	98200–2	96+158.051	19.108	635 046	4 107 301	1167
98+700	98700–1	96+574.603	11.901	635 087	4 106 897	1169
	98700–2	96+612.535	27.434	635 118	4 106 852	1168
99+800	99800–1	97+548.480	10.711	635 670	4 106 194	1180
	99800–2	97+590.859	30.206	635 694	4 106 154	1180
100+500	100500–1	98+269.246	11.025	636 423	4 106 144	1183
	100500–2	98+311.220	12.435	636 381	4 106 144	1183

NOTES:
69+300, ONLY ONE GPS OBSERVATION MADE. ONE BORING DONE ON EACH SIDE OF GORGE.

TEST PITS

REFERENCE LOCATION	TEST PIT NO.	STATION	OFFSET FROM ROAD ℄	GPS COORDINATES Y	X	Z
11+700	TP11700–1	12+023.190	9.982	595 702	4 085 708	863
	TP11700–2	12+245.740	0.409	595 528	4 085 845	859
	TP11700–3	12+292.906	15.096	595 485	4 085 870	857
	TP11700–4	12+293.995	12.469	595 505	4 085 889	853
	TP11700–5	12+304.405	52.736	595 523	4 085 924	855
11+800	TP11800–1	12+385.881	41.845	595 457	4 085 973	848
	TP11800–2	12+358.111	106.159	595 522	4 086 000	851
	TP11800–3	12+444.095	127.513	595 475	4 086 075	849
12+400	TP12400–1	12+464.382	9.397	595 365	4 085 991	846
	TP12400–2	12+523.174	16.360	595 318	4 086 027	846
	TP12400–3	12+569.878	18.541	595 283	4 086 058	846
	TP12400–4	12+616.523	16.479	595 251	4 086 092	845
	TP12400–5	12+661.852	21.507	595 215	4 086 120	841
	TP12400–6	12+713.575	15.451	595 182	4 086 160	846
38+200	TP38200–1	38+269.993	5.963	603 472	4 103 704	898
	TP38200–2	38+377.937	1.951	603 515	4 103 803	902
	TP38200–3	38+473.115	3.962	603 554	4 103 890	898
	TP38200–4	38+556.060	46.130	603 637	4 103 940	891
	TP38200–5	38+597.847	13.911	603 628	4 103 992	898
	TP38200–6	38+601.575	22.803	603 597	4 104 012	903
39+700	TP39700–1	39+318.285	43.126	603 592	4 104 692	907
	TP39700–2	39+421.228	31.916	603 545	4 104 763	918
	TP39700–3	39+492.757	27.812	603 492	4 104 821	899
40+000	TP40000–1	39+784.025	29.743	603 341	4 105 084	900
	TP40000–2	39+846.986	51.110	603 314	4 105 152	895
	TP40000–3	40+034.399	17.638	603 344	4 105 340	910
40+200	TP40200–1	40+736.085	13.768	603 348	4 105 333	911
	TP40200–2	40+766.877	13.768	603 348	4 105 333	911
	TP40200–3	42+379.485	13.768	603 348	4 105 333	911
41+000	TP41000–1	41+427.955	51.045	603 691	4 106 681	934
	TP41000–2	41+543.192	5.713	603 765	4 106 778	957
	TP41000–3	41+701.803	213.755	603 480	4 106 842	921
	TP41000–4	41+664.659	46.332	603 728	4 106 899	946
	TP41000–5	41+604.910	293.684	603 561	4 106 938	921
42+500	TP42500–1	42+922.720	112.672	604 075	4 108 034	930
	TP42500–2	43+090.005	94.440	604 083	4 108 151	914
	TP42500–3	43+280.033	27.375	604 117	4 108 323	909
45+500	TP45500–1	45+370.950	14.559	605 443	4 109 544	923
	TP45500–2	45+489.107	7.703	605 473	4 109 659	920
	TP45500–3	45+647.162	7.605	605 525	4 109 809	920
49+000	TP49000–1	48+746.719	41.160	606 558	4 112 510	929
	TP49000–2	48+941.758	4.654	606 732	5 112 602	943
	TP49000–3	49+214.581	52.356	606 879	6 112 835	938
	TP49000–4	49+383.022	23.314	607 017	7 112 940	941
	TP49000–5	49+586.514	62.089	607 135	8 113 109	942
51+000	TP51000–1	51+156.599	12.195	607 543	4 114 473	945
	TP51000–2	51+210.318	23.115	607 508	4 114 527	938
	TP51000–3	51+212.528	44.022	607 529	4 114 526	937
	TP51000–4	51+270.240	54.711	607 494	4 114 584	940

TEST PITS

REFERENCE LOCATION	TEST PIT NO.	STATION	OFFSET FROM ROAD ℄	GPS COORDINATES Y	X	Z
53+000	TP53000–1	52+021.345	25.019	608 117	4 114 921	967
	TP53000–2	52+707.420	36.239	608 282	4 115 064	966
	TP53000–3	52+150.125	41.863	608 245	4 114 899	960
	TP53000–4	52+219.869	181.752	608 353	4 115 012	964
53+900	TP53900–1	52+662.453	25.516	608 697	4 114 648	984
	TP53900–2	52+694.533	9.149	608 733	4 114 649	966
	TP53900–3	52+752.669	12.970	608 795	4 114 644	979
	TP53900–4	52+803.571	8.393	608 839	4 114 618	972
54+800	TP54800–1	53+633.492	3.114	609 610	4 114 331	974
	TP54800–2	53+648.775	29.741	609 642	4 114 348	975
	TP54800–3	53+727.550	36.623	609 709	4 114 306	973
	TP54800–4	53+754.154	0.910	611 107	4 114 262	964
56+000	TP56000–1	55+854.682	21.350	611 098	4 115 498	1003
	TP56000–2	55+966.325	64.303	611 195	4 115 568	1009
	TP56000–3	56+057.707	25.378	611 976	4 115 685	995
57+600	TP57600–1	57+562.3	26.407	612 157	4 116 753	1001
	TP57600–2	57+629.809	16.519	612 157	4116 833	1002
	TP57600–3	57+609.773	180.350	612 008	4 116 904	991
59+000	TP59000–1	58+645.003	39.216	612 146	4 116 858	1026
	TP59000–2	58+240.424	103.037	612 522	4 117 341	1058
	TP59000–3	58+525.065	81.709	612 634	4 117 489	999
72+400	TP72400–1	70+926.112	5.632	620 488	4 120 683	1098
	TP72400–2	70+958.144	4.082	620 521	4 120 677	1095
	TP72400–3	71+071.640	7.140	620 623	4 120 627	1090
	TP72400–4	71+093.056	7.691	620 642	4 120 618	1086
74+100	TP74100–1	72+103.245	57.069	621 588	4 120 310	1088
	TP74100–2	72+136.330	132.205	621 634	4 120 242	1098
	TP74100–3	72+186.504	163.694	621 689	4 120 220	1096
	TP74100–4	72+205.906	219.062	621 718	4 120 169	1103
	TP74100–5	72+610.236	70.620	622 011	4 120 191	1116
	TP74100–6	72+714.558	50.297	622 111	4 120 155	1089
76+500	TP76500–1	75+008.434	203.602	624 322	4 120 177	1087
	TP76500–2	75+204.755	200.082	624 383	4 120 184	1066
	TP76500–3	75+277.230	176.941	624 462	4 120 190	1071
	TP76500–4	75+302.879	115.933	624 519	4 120 144	1078
	TP76500–5	75+357.190	73.566	624 599	4 120 113	1089
77+200	TP77200–1	76+009.476	15.899	625 218	4 120 202	1086
	TP77200–2	76+082.367	11.798	625 285	4 120 231	1084
	TP77200–3	76+131.855	7.738	625 330	4 120 253	1098
	TP77200–4	76+201.501	5.273	625 393	4 120 283	1092
	TP77200–5	76+304.691	8.698	625 489	4 120 321	1083
82+200	TP82000–1	80+854.020	6.409	629 192	4 119 793	1117
	TP82000–2	80+894.931	20.945	629 213	4 119 755	1118
	TP82000–3	81+008.021	21.335	629 300	4 119 680	1114

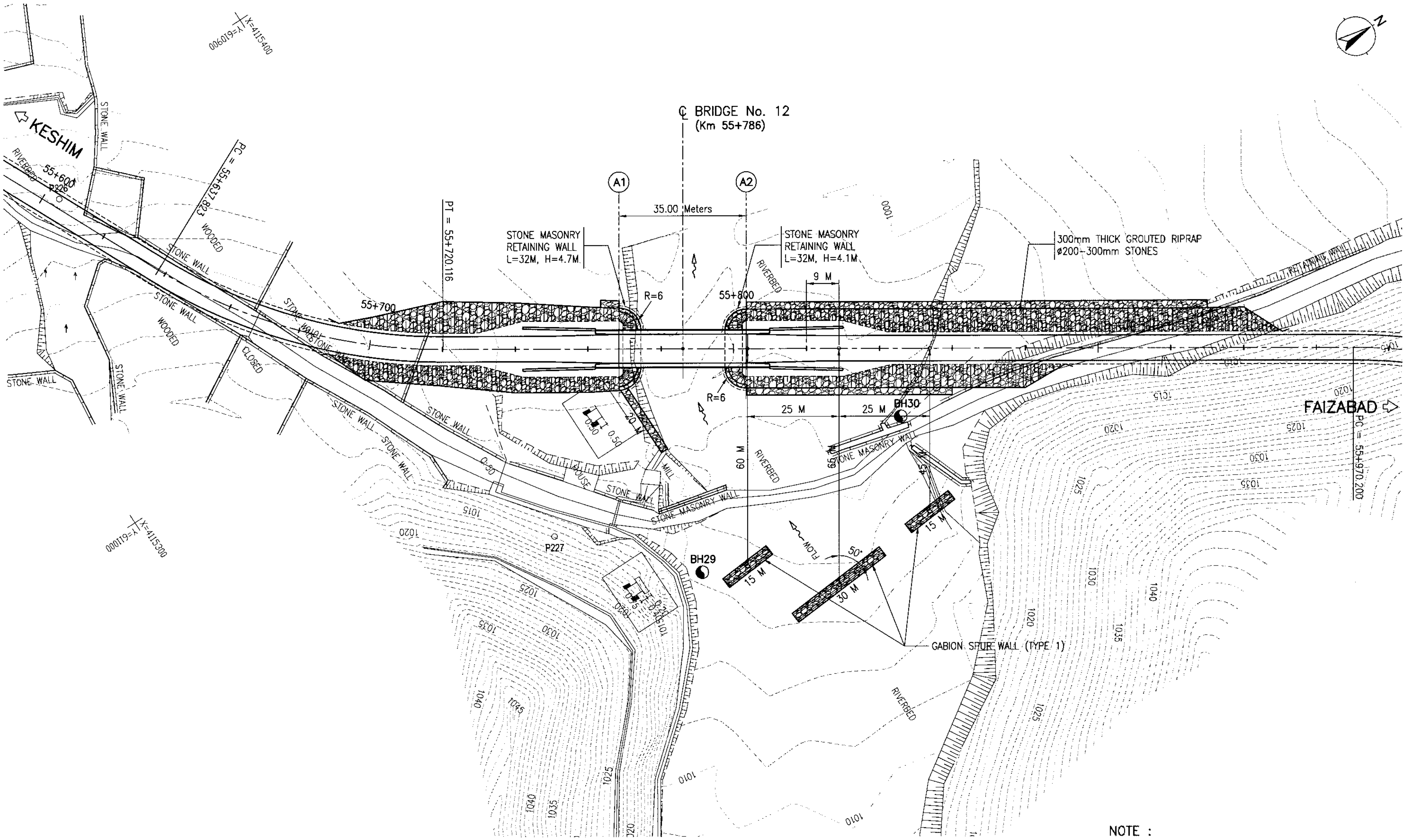
NOTES:
40+200, GPS OBSERVATION APPEAR TO BE INCORRECT. VISUAL INSPECTION WAS MADE TO RELOCATE TEST PIT.
45+500, NO GPS OBSERVATION MADE DUE TO TECHNICAL PROBLEM.
OFFSET AT 57+600–3 APPEARS TO BE INCORRECT BUT LOCATION ON GROUND IS VISIBLE.

ISLAMIC REPUBLIC OF AFGHANISTAN
and
UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

UNITED NATIONS OFFICE FOR PROJECT SERVICES
Kabul, Afghanistan

The LOUIS BERGER Group, Inc.
2300 N St. Washington DC 20037 USA

TITLE	SHEET CONTENTS	REVISION	DATE	NAMES & SIGNATURE		DWG NO.
DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT	BOREHOLES AND TEST PITS GPS LOCATION	FIRST ISSUE	OCT 06	DRAWN: S. SOLETE	PREPARED BY: YUKSEL PROJE	KF-GT-002
				NOTED BY: BERNARDO P. UMLAS C.E. 0027008		
				REGISTERED, PROFESSIONAL REGULATIONS COMMISSION, PHILS.		SCALE: AS SHOWN



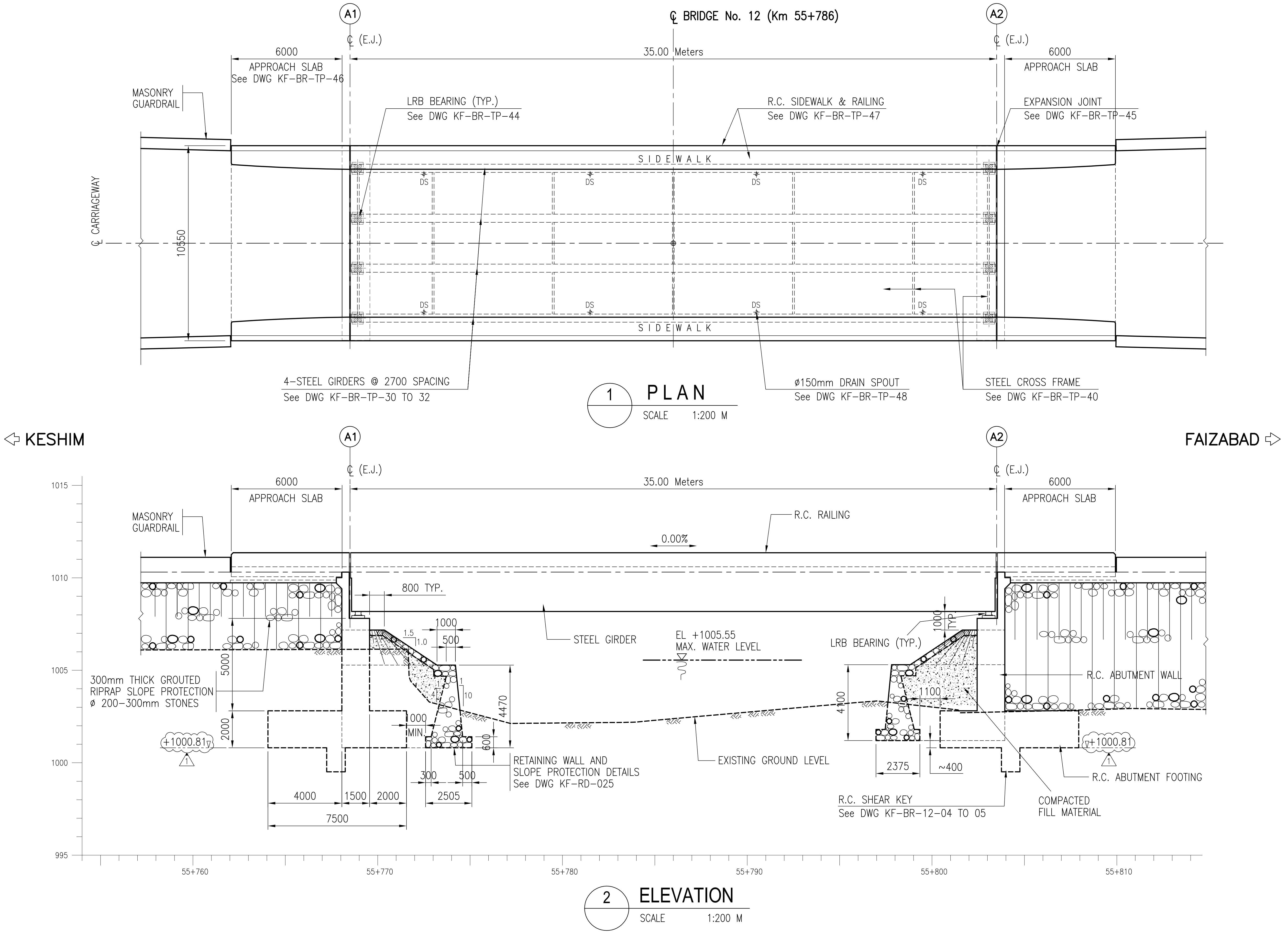
NOTE :

FOR RETAINING WALL, SLOPE PROTECTION AND GABION SPUR WALL DETAILS, See DWG KF-RD-025 & 070

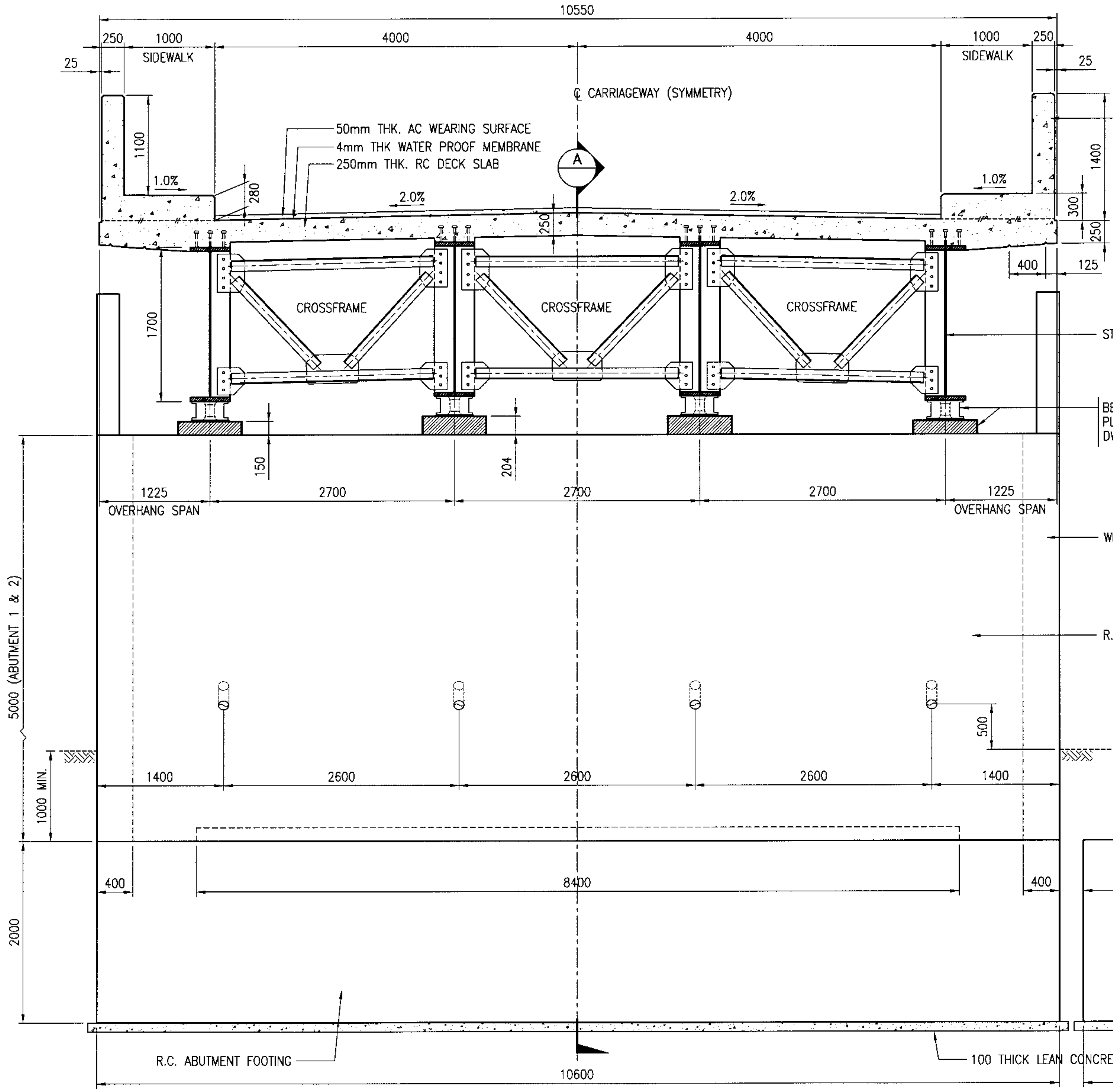
1 SITE DEVELOPMENT PLAN

SCALE 1:1000 M

ISLAMIC REPUBLIC OF AFGHANISTAN and UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT	UNOPS UNITED NATIONS OFFICE FOR PROJECT SERVICES Kabul, Afghanistan. The LOUIS BERGER Group, Inc. 2300 N St. Washington DC 20037 USA	TITLE: DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT	SHEET CONTENTS: SITE DEVELOPMENT PLAN BRIDGE No. 12 (Km 55+786)	REVISION: FIRST ISSUE	DATE: JAN 07	NAMES & SIGNATURE: DRAWN: JoseT/NomerM DESIGNED: Y. SUPANYO; CHECKED & APPROVED BY: WITOON TAWISOOK P.E. 5780; REGISTERED BY ENGINEERING COUNCIL OF THAILAND	DWG NO. KF-BR-12-01; SCALE: AS SHOWN

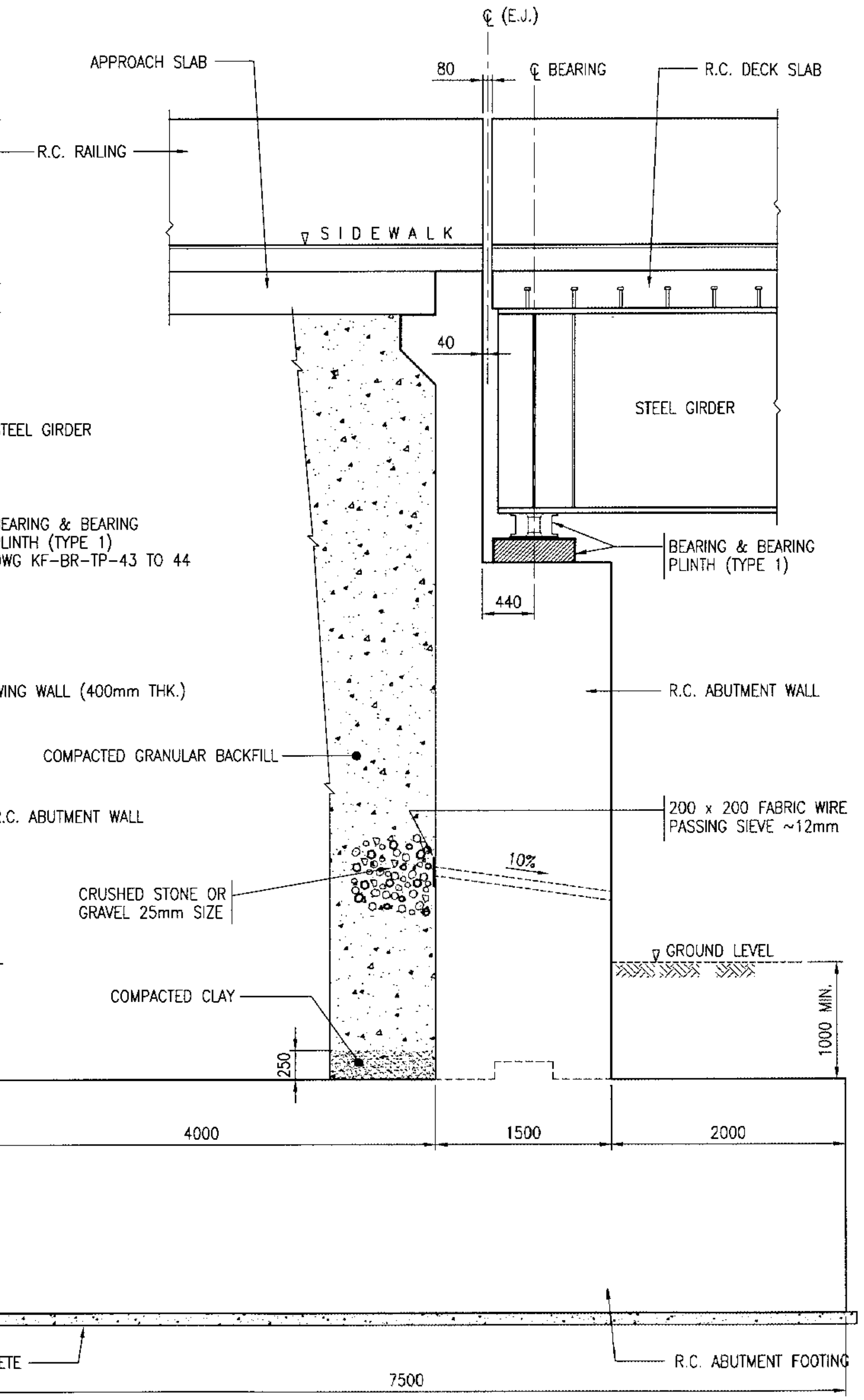


ISLAMIC REPUBLIC OF AFGHANISTAN and UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT	UNOPS UNITED NATIONS OFFICE FOR PROJECT SERVICES Kabul, Afghanistan The LOUIS BERGER Group, Inc. 2300 N St. Washington DC 20037 USA	TITLE DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT	SHEET CONTENTS GENERAL ARRANGEMENT BRIDGE No. 12 (Km 55+786)	REVISION 1 FIRST ISSUE 1 AS CLOUDED	DATE JAN 07 FEB 07	NAMES & SIGNATURE DRAWN: JoseT/NomerM DESIGNED: Y. SUPANYO CHECKED & APPROVED BY: WITOON TAWISOOK P.E. 5780 REGISTERED BY ENGINEERING COUNCIL OF THAILAND	DWG NO. KF-BR-12-02 SCALE: AS SHOWN



1 CROSS SECTION AT ABUTMENT LOCATION

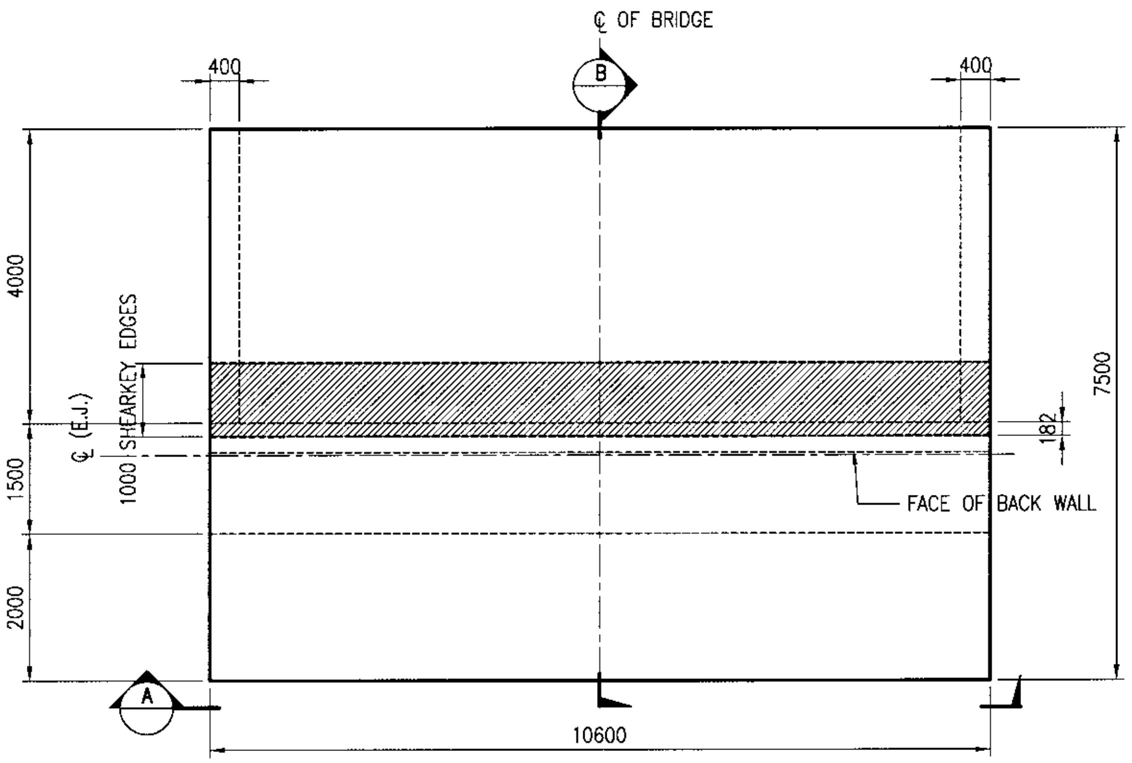
SCALE 1:50 M



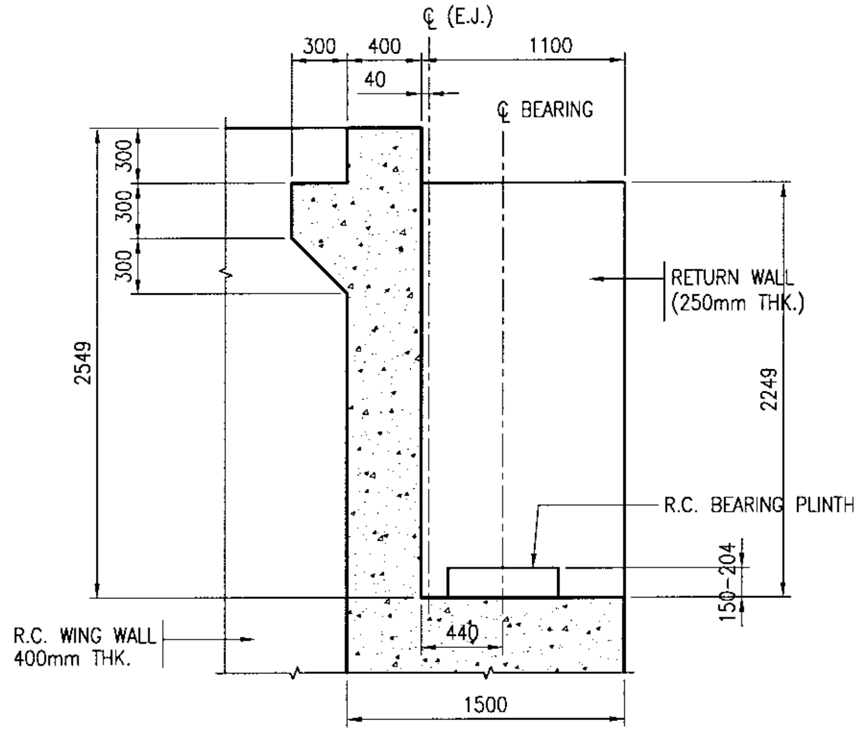
2 SECTION A

SCALE 1:50 M

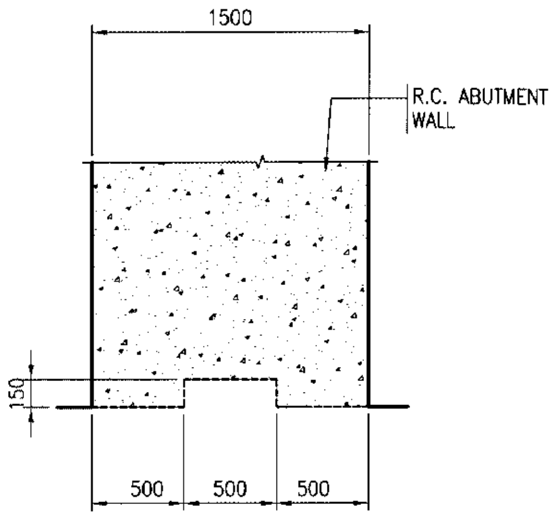
ISLAMIC REPUBLIC OF AFGHANISTAN and UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT	UNOPS UNITED NATIONS OFFICE FOR PROJECT SERVICES Kabul, Afghanistan The LOUIS BERGER Group, Inc. 2300 N St. Washington DC 20037 USA	TITLE DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT	SHEET CONTENTS CROSS SECTION AT ABUTMENT BRIDGE No. 12	REVISION FIRST ISSUE	DATE JAN 07	NAMES & SIGNATURE DRAWN: JoseT/NomerM DESIGNED: Y. SUPANYO CHECKED & APPROVED BY: WITOON TAWISOOK P.E. 5780 REGISTERED BY ENGINEERING COUNCIL OF THAILAND	DWG NO. KF-BR-12-03 SCALE: AS SHOWN



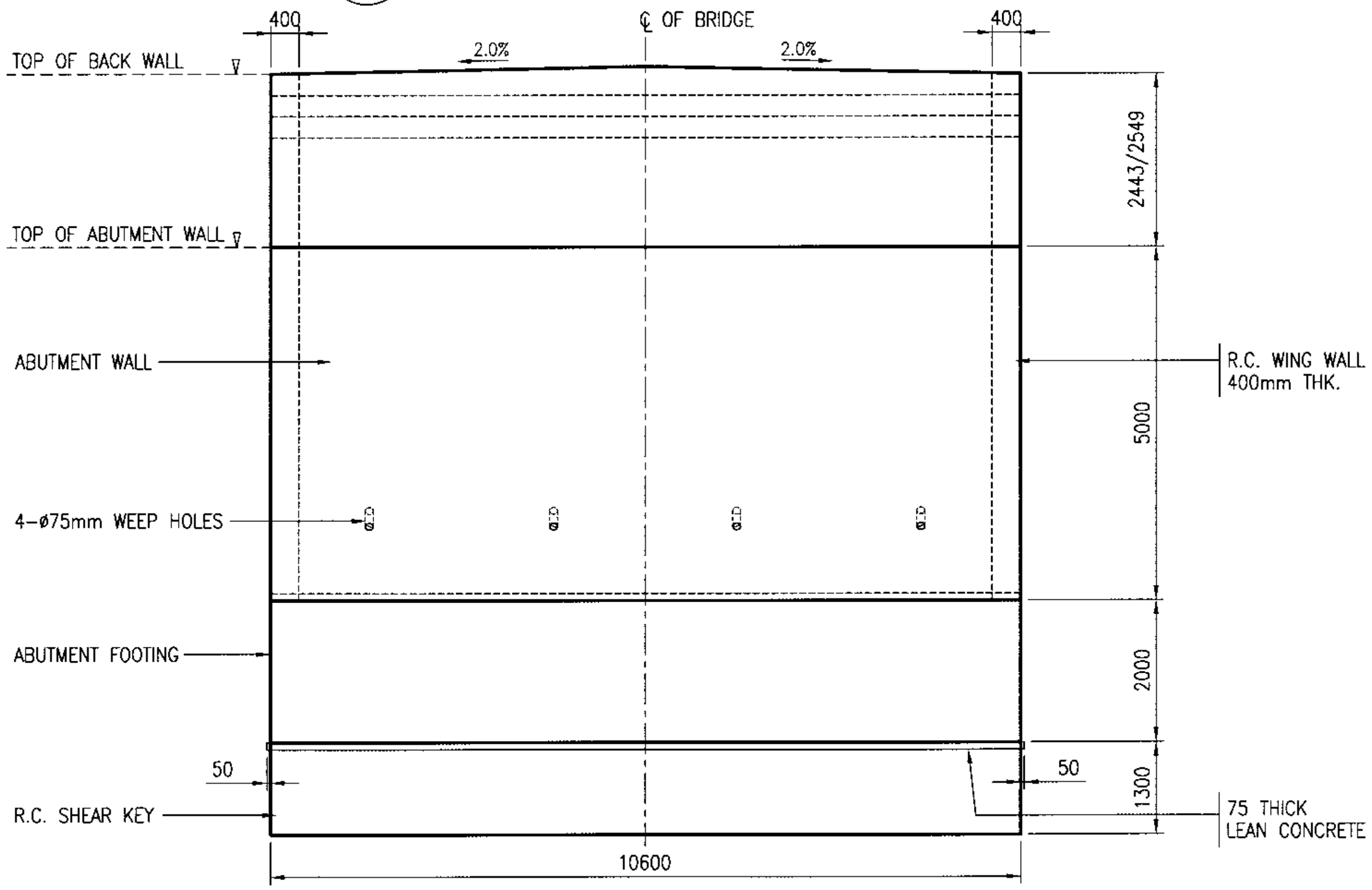
1 ABUTMENT FOUNDATION PLAN
SCALE 1:100 M



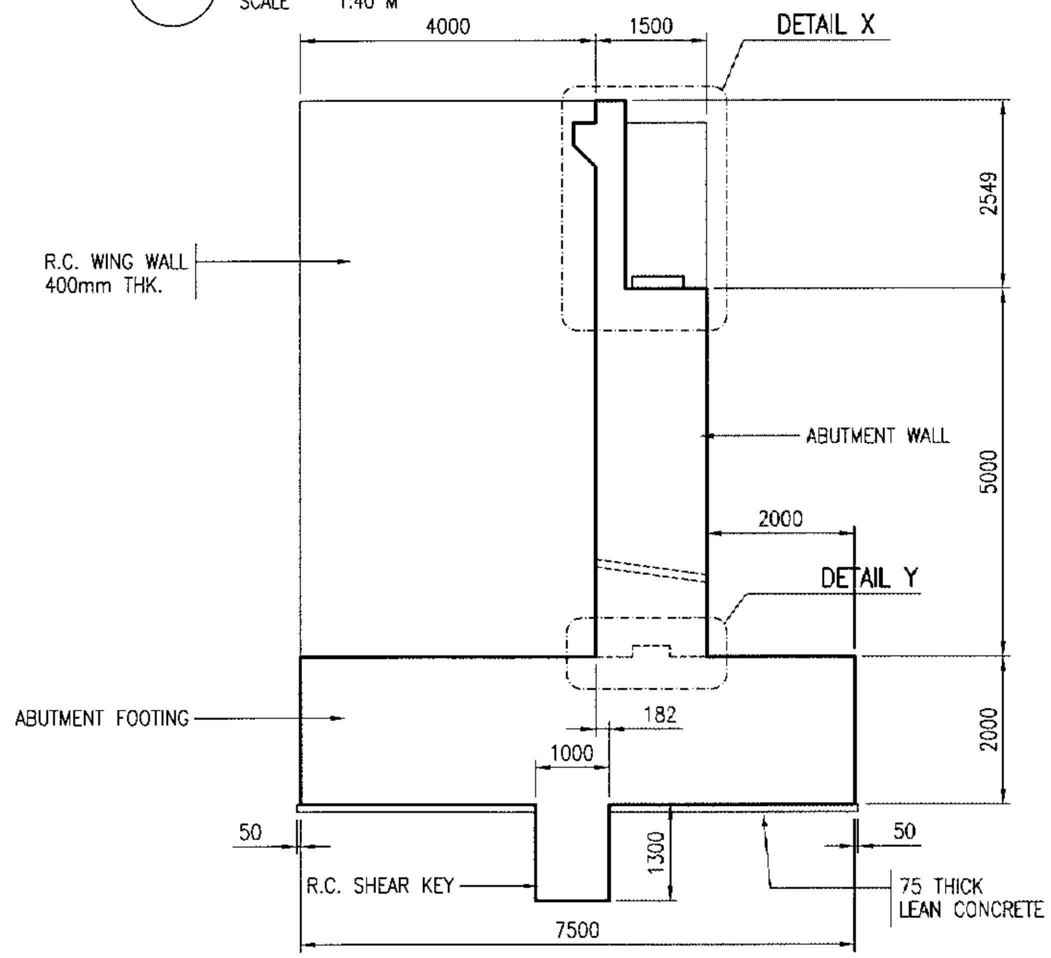
3 DETAIL X
SCALE 1:40 M



4 DETAIL Y
(CONST. JOINT SHEAR KEY)
SCALE 1:40 M



2 SECTION A
SCALE 1:100 M



5 SECTION B
SCALE 1:100 M

ISLAMIC REPUBLIC OF AFGHANISTAN
and
UNITED STATES AGENCY FOR
INTERNATIONAL DEVELOPMENT

UNOPS UNITED NATIONS OFFICE FOR PROJECT SERVICES
Kabul, Afghanistan

The LOUIS BERGER Group, Inc.
2300 N St. Washington DC 20037 USA

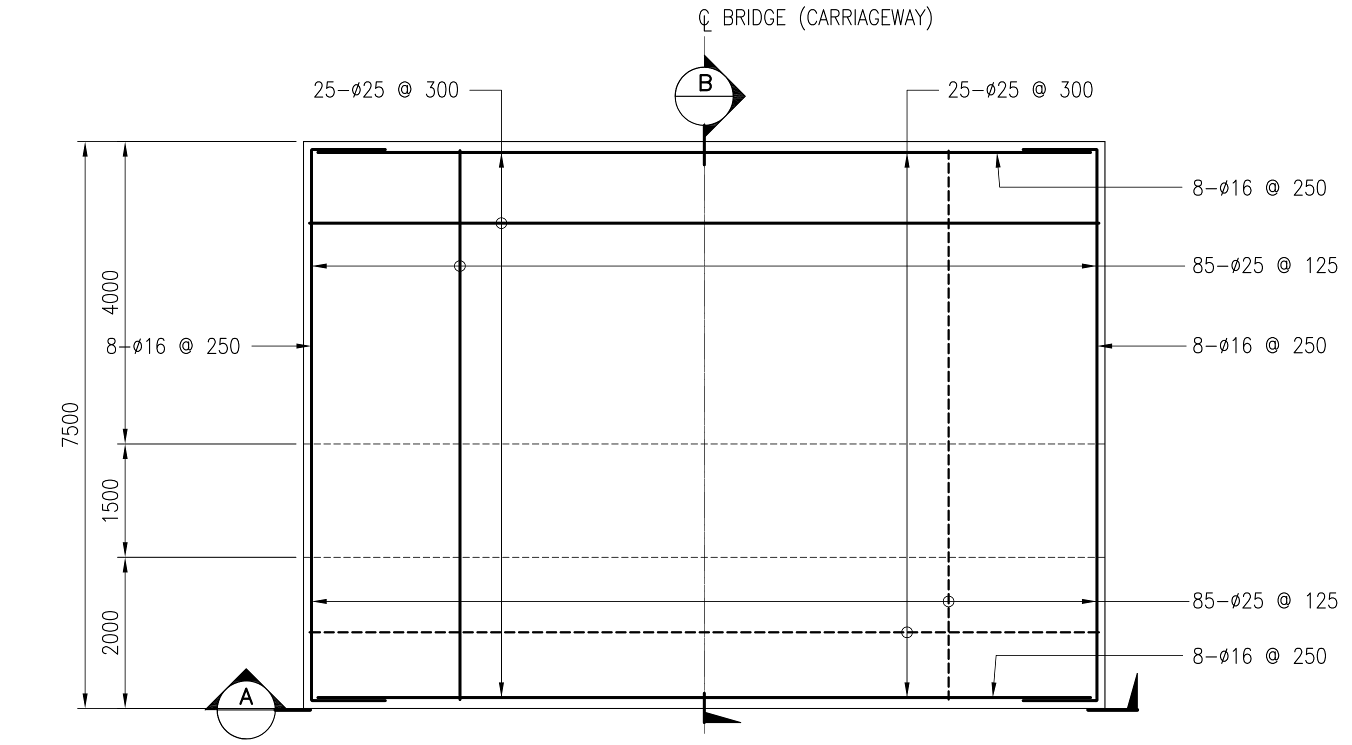
TITLE
DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT

SHEET CONTENTS
ABUTMENT DETAILS
BRIDGE No. 12

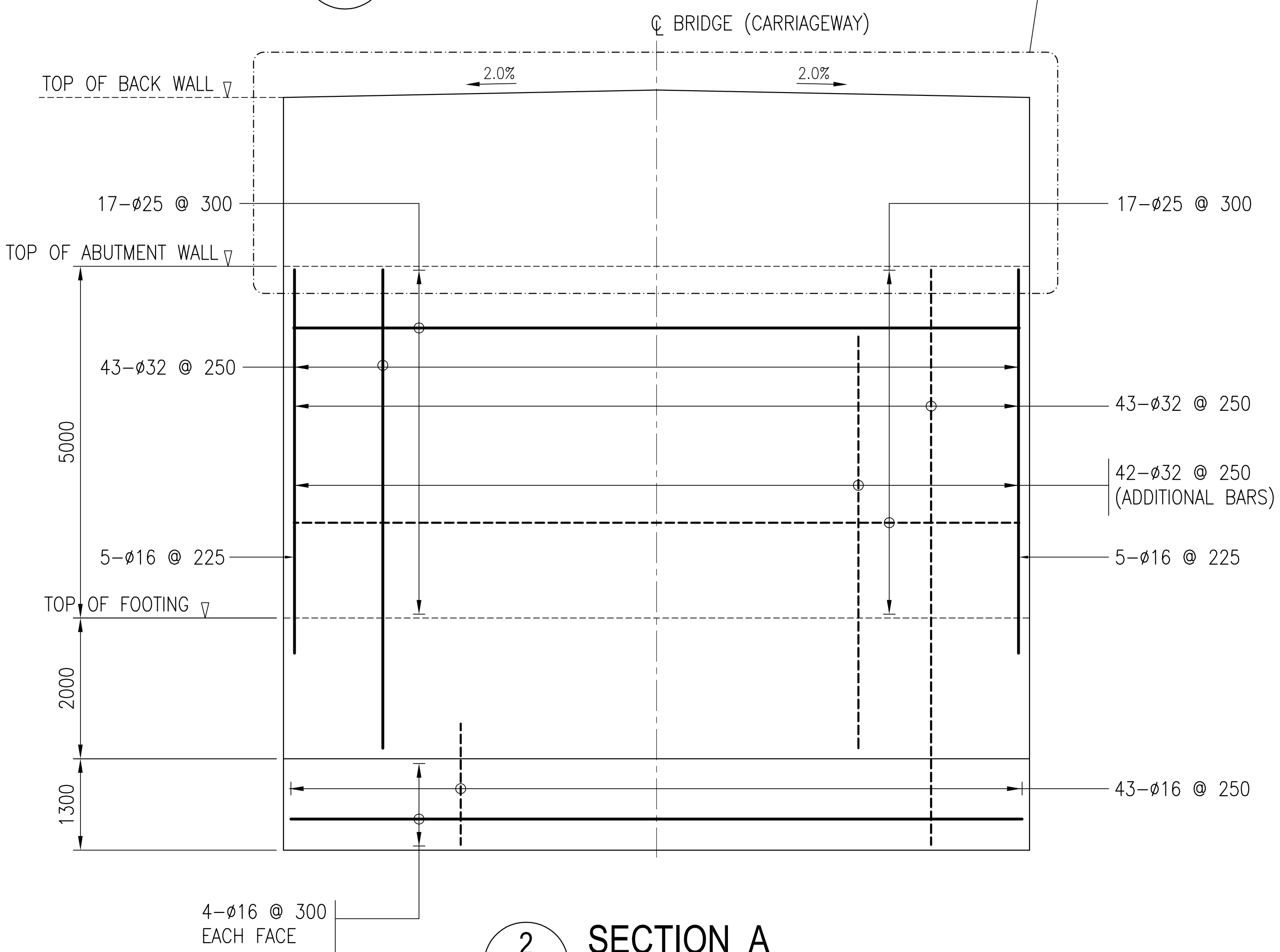
REVISION	DATE
FIRST ISSUE	JAN 07

NAMES & SIGNATURE
DRAWN: JoseT/NomerM | DESIGNED: Y. SUPANYO
CHECKED & APPROVED BY:
WITOON TAWISOOK P.E. 5780
REGISTERED BY ENGINEERING COUNCIL OF THAILAND

DWG NO. KF-BR-12-04
SCALE: AS SHOWN



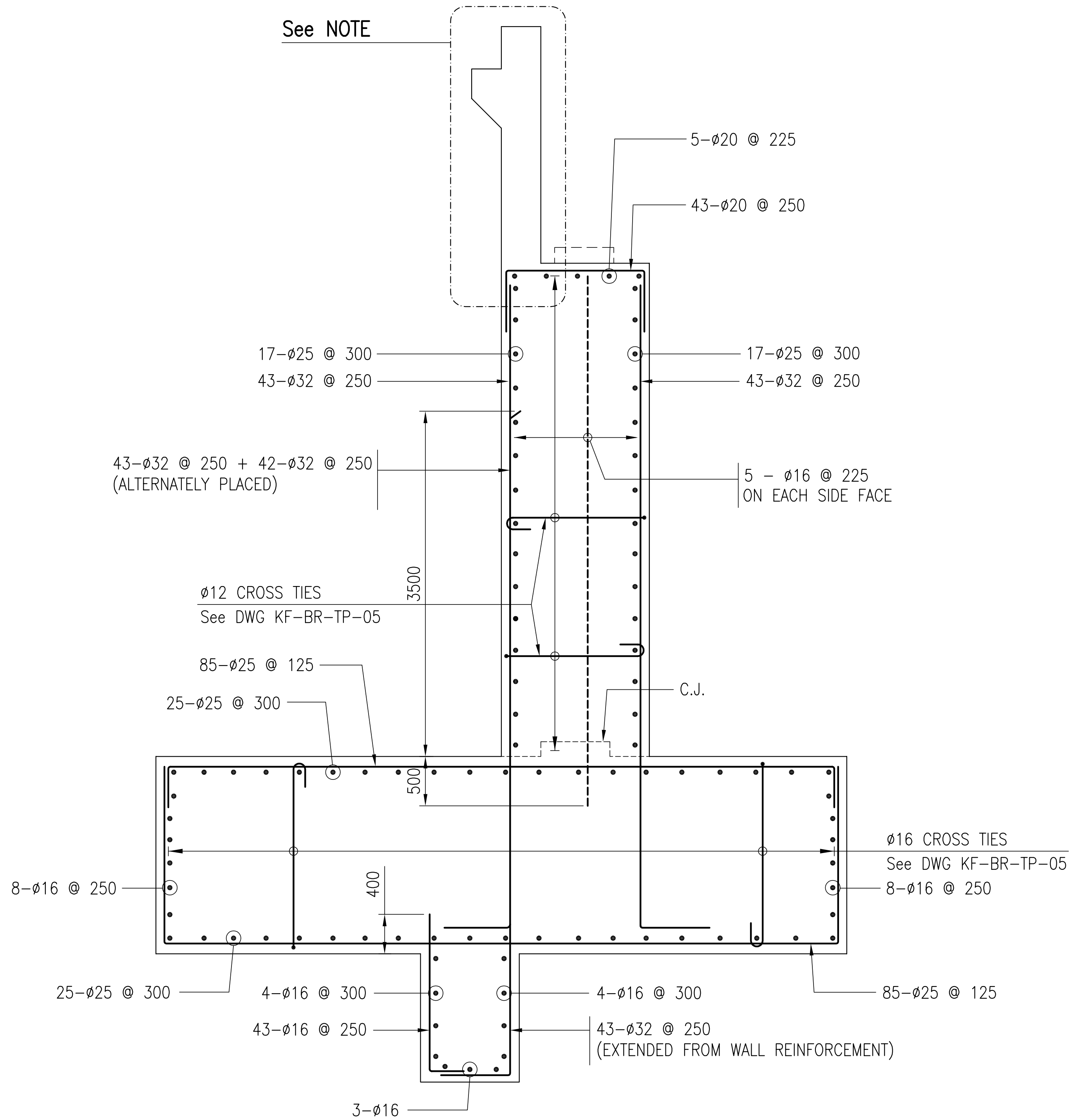
1 FOOTING REINFORCEMENT PLAN
SCALE 1:100 M



2 SECTION A
SCALE 1:100 M

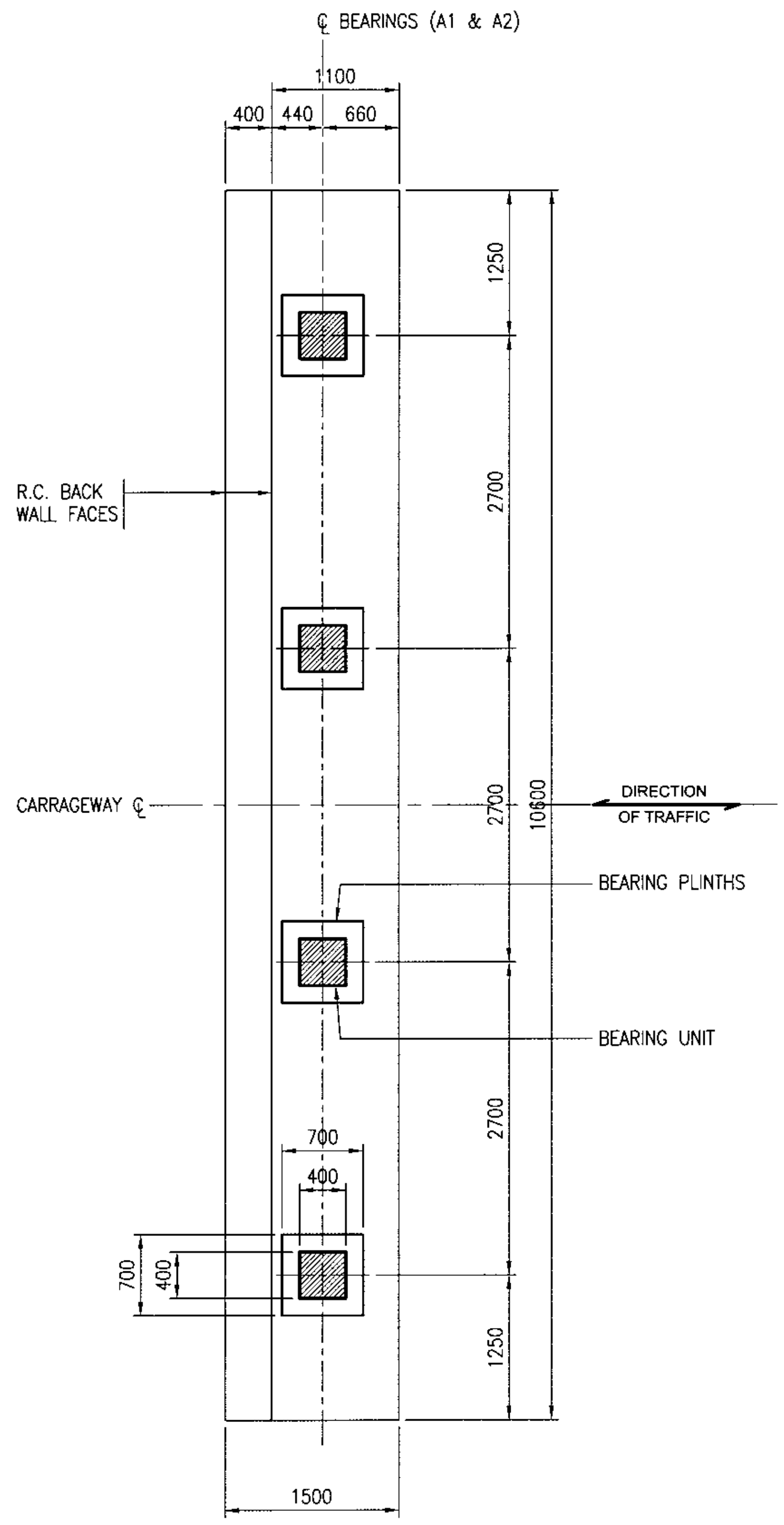
NOTES :

1. FOR WING WALLS, BACK WALL AND RETURN WALLS REINFORCEMENT See DWG KF-BR-TP-10 & 11
2. AFTER EXCAVATION AND COMPACTION, SOIL MASS UNDERNEATH BOTTOM AND AROUND SIDE FACES OF ABUTMENT FOOTING SHALL BE IMPROVED BY APPLYING CEMENT SLURRY ACCORDING TO METHODOLOGY SPECIFIED IN DWG KF-BR-TP-02 (1)



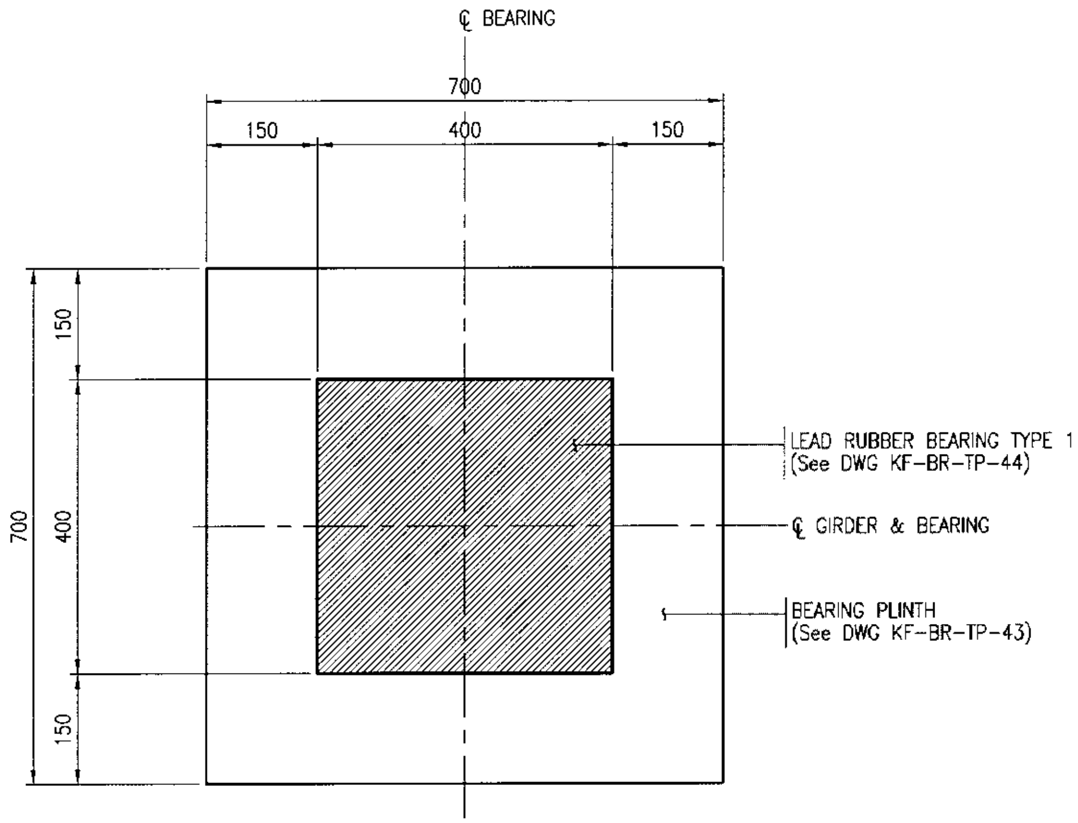
3 SECTION B
SCALE 1:60 M

ISLAMIC REPUBLIC OF AFGHANISTAN and UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT	UNOPS UNITED NATIONS OFFICE FOR PROJECT SERVICES Kabul, Afghanistan; The LOUIS BERGER Group, Inc. 2300 N St. Washington DC 20037 USA	TITLE: DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT	SHEET CONTENTS: ABUTMENT REINFORCEMENT BRIDGE No. 12	REVISION: FIRST ISSUE; (1) AS CLOUDED	DATE: JAN 07; FEB 07	NAMES & SIGNATURE: DRAWN: JoseT/NomerM; DESIGNED: Y. SUPANYO; CHECKED & APPROVED BY: WITOON TAWISOOK P.E. 5780; REGISTERED BY ENGINEERING COUNCIL OF THAILAND	DWG NO. KF-BR-12-05; SCALE: AS SHOWN



1 TYPICAL LAYOUT OF BEARINGS

SCALE 1:60 M



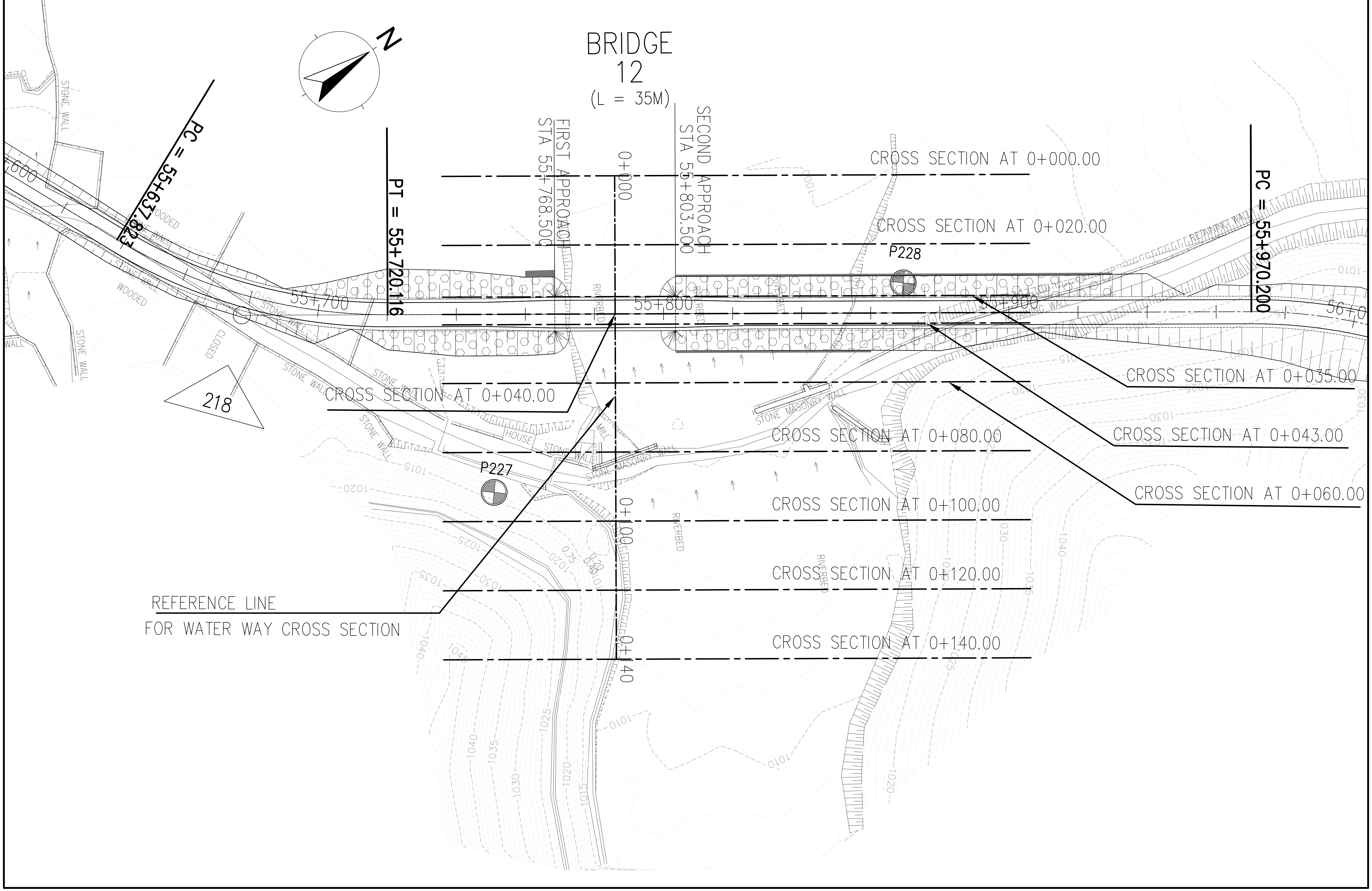
2 PLAN OF BEARING

SCALE 1:10 M

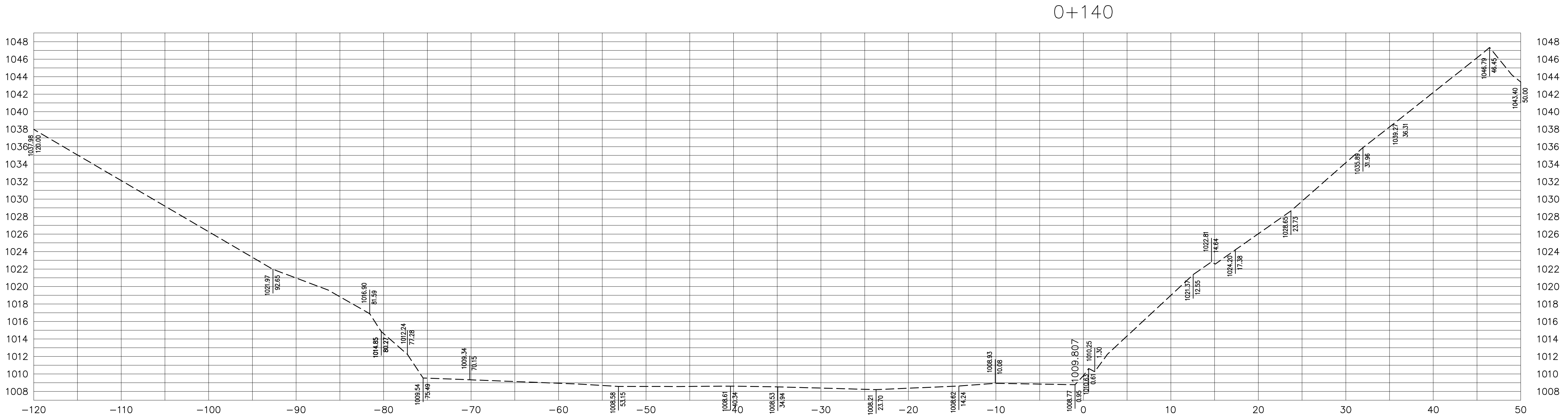
NOTES :

ISLAMIC REPUBLIC OF AFGHANISTAN and UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT	UNOPS UNITED NATIONS OFFICE FOR PROJECT SERVICES Kabul, Afghanistan The LOUIS BERGER Group, Inc. 2300 N St. Washington DC 20037 USA	TITLE DETAILED ENGINEERING DESIGN OF KESHIM - FAIZABAD ROAD REHABILITATION PROJECT	SHEET CONTENTS LAYOUTS FOR ELASTOMERIC BEARINGS & BEARING PLINTHS BRIDGE No. 12	REVISION ⚠ FIRST ISSUE	DATE JAN 07	NAMES & SIGNATURE DRAWN: JoseT/NomerM DESIGNED: Y. SUPANYO CHECKED & APPROVED BY: WITOON TAWISOOK P.E. 5780 REGISTERED BY ENGINEERING COUNCIL OF THAILAND	DWG NO. KF-BR-12-06 SCALE: AS SHOWN

PLAN AT BRIDGE NO 12

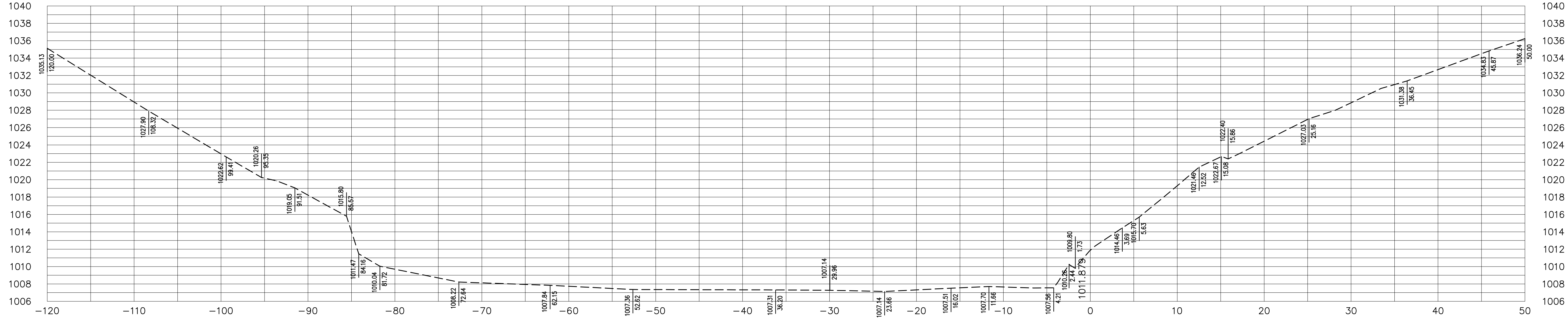


CROSS SECTION OF WATER WAY AT BRIDGE NO. 12



CROSS SECTION OF WATER WAY AT BRIDGE NO. 12

0+120



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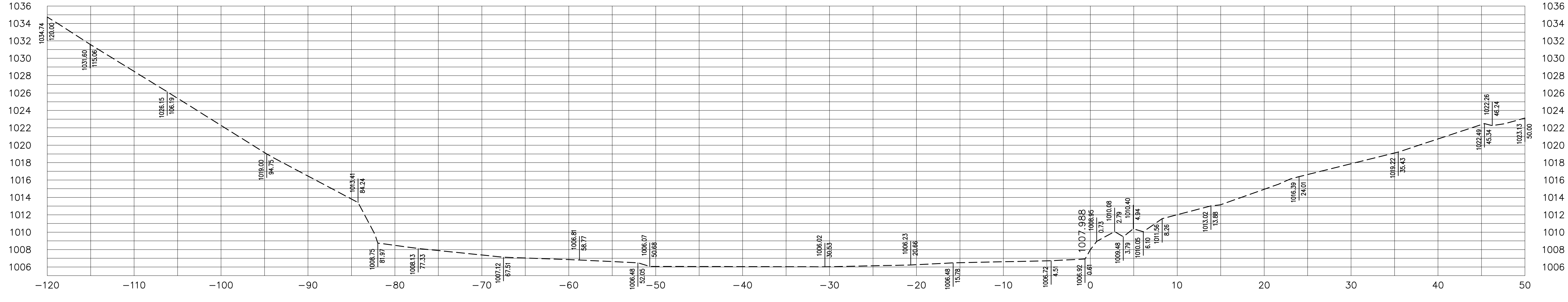

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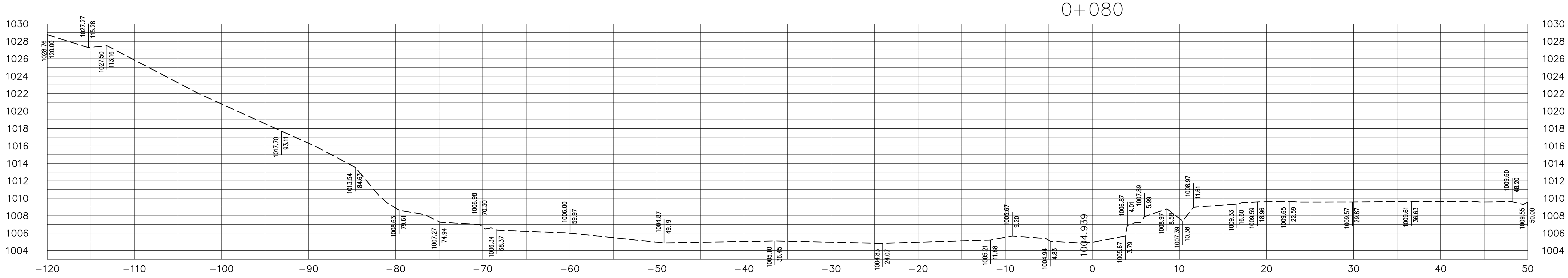

CROSS SECTION OF WATER WAY AT BRIDGE NO. 12

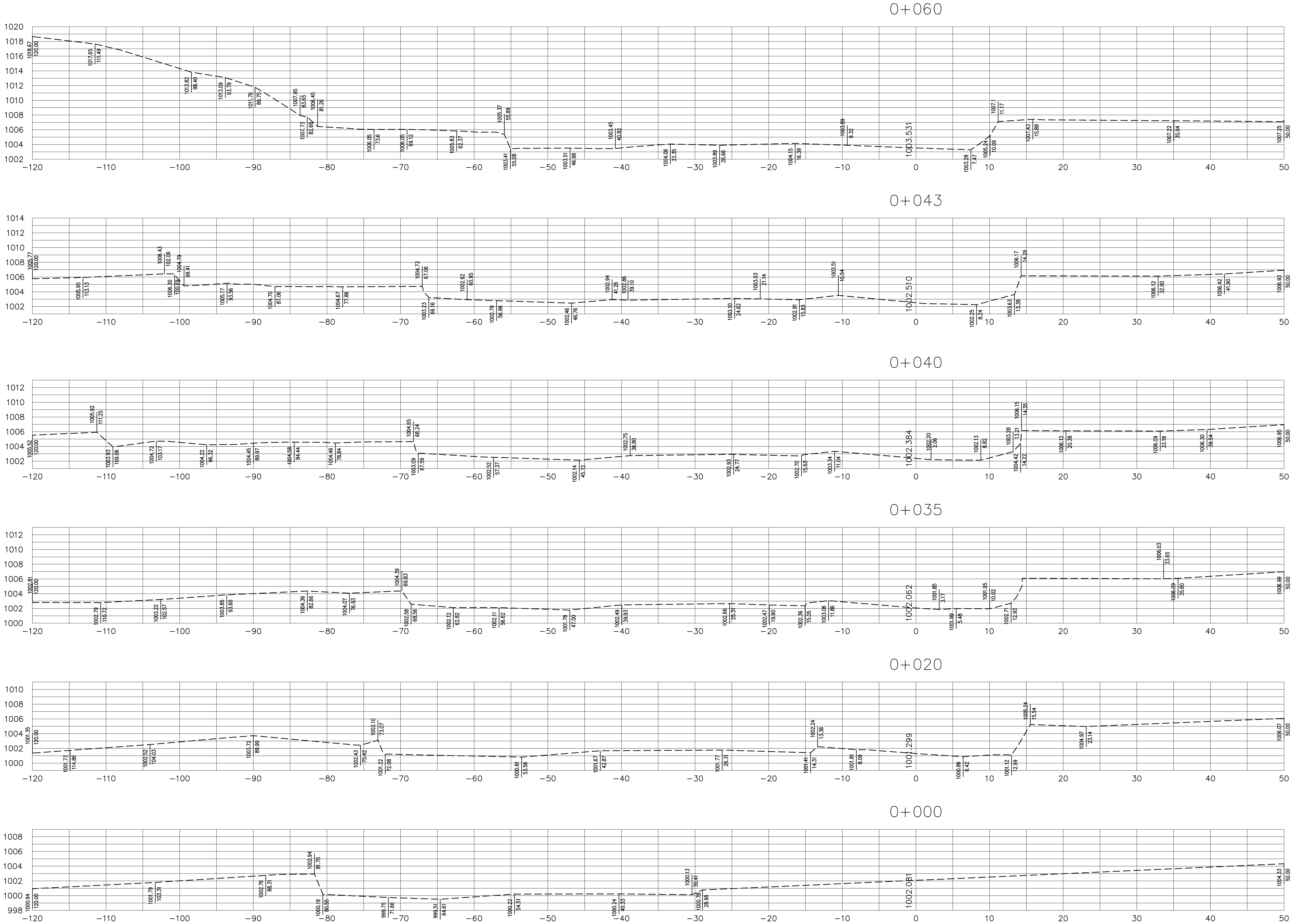

TABLE 2 PROBABLE RAINFALL FREQUENCY IN 24 HRS IN KESI

Project:Keshim - Faizabad Road

Year	*Depth* (mm/24hr)	m	*Descending* Order	*Return* Period	*LOG X*
1974	**31.6**	**1**	**33.8**	**11.000**	**1.528917**
1975	**29.8**	**2**	**32.2**	**5.500**	**1.507856**
1976	**32.2**	**3**	**31.6**	**3.667**	**1.499687**
1977	**29.5**	**4**	**29.8**	**2.750**	**1.474216**
1979	**22.2**	**5**	**29.5**	**2.200**	**1.469822**
1980	**33.8**	**6**	**26.6**	**1.833**	**1.424882**
1981	**25.4**	**7**	**25.4**	**1.571**	**1.404834**
1982	**23.9**	**8**	**25.2**	**1.375**	**1.401401**
1983	**26.6**	**9**	**23.9**	**1.222**	**1.378398**
1983	**25.2**	**10**	**22.2**	**1.100**	**1.346353**
Total=					**14.436365**
Mean					**1.443636**
Standard Deviation					**0.0610**
Skew Coefficient					**-0.1412**
	n	**10**			

Based on tl
developed.
$P = m D^{0.67}$

$m_T = P_{24,T}/2$
Intensity di:

LOG Xn =Mean LOG X+ k(0.0610)				m	$I_{24,T}$	$I_{12,T}$	$I_{6,T}$	$I_{3,T}$
Return Period	***Frequency Factor, k***	***LOG Xn***	***24 hr Precipitation***		mm/h	mm/h	mm/h	mm/h
year			**(mm/24hr)**					
2	**0.023592**	**1.445076**	27.866	3.3	1.2	1.5	1.8	2.3
5	**0.847648**	**1.495368**	31.287	3.7	1.3	1.6	2.1	2.6
10	**1.265056**	**1.520841**	33.177	3.9	1.4	1.7	2.2	2.7
25	**1.701168**	**1.547457**	35.274	4.2	1.5	1.8	2.3	2.9
50	**1.97734**	**1.564311**	36.670	4.4	1.5	1.9	2.4	3.0

HIM - FAIZABAD, AFGHANISTAN

:he analysis of Tistung Rainfall of July 1993, the following model is
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:4$^{0.67}$

stribution is calculted according to Nepal's Tistung Rainfall distribution curve

$I_{1,T}$	$I_{0.5,T}$	$I_{0.25,T}$	$I_{0.2,T}$	$I_{0.166,T}$
mm/h	mm/h	mm/h	mm/h	mm/h
3.3	4.2	5.2	5.6	6.0
3.7	4.7	5.9	6.3	6.7
3.9	5.0	6.2	6.7	7.1
4.2	5.3	6.6	7.1	7.6
4.4	5.5	6.9	7.4	7.9

Precipitation Data of Faizabad

Lat	**36.18**
Long	**36.56**
Elev	**1200**

Station: Faizabad	1975					1976					1977					1979		
	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C	Precipitation, mm		Snowfall
Months	Monthly Total	24 hr Max	Absolute Height	Days		Monthly Total	24 hr Max	Absolute Height	Days		Monthly Total	24 hr Max	Absolute Height	Days		Monthly Total	24 hr Max	Absolute Height
Jan	43.8	15	6	15	5	56.6	12.6	0	0	9	86.3	11.4	22	26	2	43.8	10.4	4
Feb	55	14.8	7	13	7	110.1	32.2	12	25	6.1	20.5	9.6	19	1	8.3	63.7	14.4	14
Mar	70	20.6	5	4	13	103.6	24	6	4	12.1	40.6	17.2	0	0	19.3	66.7	10.8	4
Apr	141.8	23.2	0	0	18.5	138.8	24.7	0	0	20.2	86.3	15.2	0	0	21.5	98.4	17.3	0
May	96.3	29.8	0	0	23.5	72.1	18.6	0	0	25.9	101.4	19	0	0	23.5	134.7	22.2	0
Jun	1.8	1.2	0	0	31.8	8.1	29	0	0	31.3	9.1	6.8	0	0	32.8	3.9	2.9	0
Jul	0	0	0	0	36	0	0	0	0	37	0	0	0	0	36.6	0	0	0
Aug	0	0	0	0	35.1	0	0	0	0	35.5	0	0	0	0	34.7	0	0	0
Sep	0.6	0.6	0	0	30.1	0	0	0	0	30.7	0	0	0	0	30.3	1.3	1.3	0
Oct	27	14	0	0	22.2	32.4	11	0	0	21.8	74.5	27.8	0	0	22.9	0	0	0
Nov	44.9	18.3	2	15	11.5	10.2	6.2	0	0	13.3	37.9	10.3	0	0	15.9	3	3	0
Dec	39.4	11	4	25	2	14.2	4	1	26	8.1	101.4	29.5	1	26	9	35.2	12.6	1
Yearly	**520.6**	**29.8**	**7**	**25**	**36**	**546.1**	**32.2**	**12**	**26**	**37**	**558**	**29.5**	**22**	**26**	**36.6**	**450.7**	**22.2**	**14**

Year	***Depth***
	(mm/24hr)
1974	
1975	29.8
1976	32.2
1977	29.5
1979	22.2
1980	33.8
1981	25.4
1982	23.9
1983	26.6
Max	**33.8**

Months	Faizabad		Faizabad from Ministry of Civil Aviation	
	Average monthly precipitation (mm)		24 hr max from Persian book	
	Altitude	1200	1969-78	
	Year	1963-81	>=30mm prec. Days	**24 hr max**
Jan		47.0	1.0	40.0
Feb		71.0	1.0	32.2
Mar		93.0	1.0	34.1
Apr		92.0	0.0	29.5
May		82.0	2.0	48.4
Jun		7.2	0.0	19.4
Jul		5.5	0.0	13.7
Aug		1.1	0.0	5.0
Sep		1.6	0.0	7.0
Oct		22.0	0.0	27.8
Nov		29.0	0.0	19.0
Dec		34.0	0.0	NA
24 hr max		**75.0**		**48.4**
Yealy average		486.0		

Months	1975-1983			
	Precipitation, mm		Snowfall (cm)	
	Mean Monthly	24 hr Max	Mean Absolute Height	Days
Jan	57.98	20.00	7.75	16.38
Feb	65.95	32.20	9.25	8.88
Mar	71.39	26.60	1.88	1.75
Apr	107.90	26.40	0.00	0.00
May	66.14	29.80	0.00	0.00
Jun	8.56	29.00	0.00	0.00
Jul	3.10	6.40	0.00	0.00
Aug	0.56	3.00	0.00	0.00
Sep	1.05	3.60	0.00	0.00
Oct	24.39	27.80	0.00	0.00
Nov	24.89	33.80	0.75	3.25
Dec	34.13	29.50	1.25	13.63
Yearly	466.03	33.80	10.88	20.88

		1980					1981					1982					1983					
(cm)	Mean Max Air Temp, C	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C	Precipi mı
Days		Monthly Total	24 hr Max	Absolute Height	Days		Monthly Total	24 hr Max	Absolute Height	Days		Monthly Total	24 hr Max	Absolute Height	Days		Monthly Total	24 hr Max	Absolute Height	Days		Monthly Total
27	8.1	62	17.5	18	26	4.7	68.9	15.9	missing	missir	8.6	43	14.6	5	22	8.4	59.4	20	7	15	6.6	9.5
20	11	87	22.9	8	4	6.5	103.5	25.2	missing	missir	9.1	65.6	15.4	6	7	6.4	22.2	13	8	1	13.2	16.5
6	12.6	89	13.2	0	0	13.6	74.6	18	missing	missir	16.4	58.7	6.1	0	0	14.1	67.9	26.6	0	0	12.3	25.2
0	21.9	103.3	24	0	0	23.6	50.4	19	missing	missir	22.1	87.5	23.3	0	0	22.3	156.7	26.4	0	0	19.7	16.3
0	21	49.8	27	0	0	27.8	6.2	25.4	missing	missir	27.6	42.2	20.4	0	0	26.3	26.4	6	0	0	26.5	12.8
0	31.3	8.6	7.1	0	0	33.4	15.6	7.8	missing	missir	30.5	0.3	0.3	0	0	31.7	21.1	15.6	0	0	31.3	0
0	36.8	4.1	4.1	0	0	6.7	4.4	1.5	missing	missir	34.7	9.6	5.6	0	0	35	6.7	6.4	0	0	35.9	0
0	33.7	0	0	0	0	34.7	4.5	3	missing	missir	33.6	0	0	0	0	33.9	0	0	0	0	36.2	0
0	29.6	0	0	0	0	30.6	2.7	2	missing	missir	20.6	0.2	0.2	0	0	27.6	3.6	3.6	0	0	30.1	0
0	26.4	1.2	1.2	0	0	25.1	34	18.6	missing	missir	20.7	24.4	13.4	0	0	23.1	1.6	1.6	0	0	22.5	18.7
0	16.5	58.8	33.8	0	0	17.8	14.2	6.2	missing	missir	17.5	23	23.9	4	11	11.7	7.1	5.4	0	0	19.1	missing
23	11	13.8	11	0	0	12.8	28.2	8	missing	missir	12.1	25.3	8	3	9	8.8	15.5	4.1	0	0	9.4	missing
27	**36.8**	**477.6**	**33.8**	**18**	**26**	**34.7**	**407.2**	**25.4**	**0**	**0**	**34.7**	**379.8**	**23.9**	**6**	**22**	**35**	**388.2**	**26.6**	**8**	**15**	**36.2**	**99**

Mean Max Air	
	Temp, C
	6.55
	8.45
	14.18
	21.23
	25.26
	31.76
	32.34
	34.68
	28.7
	23.09
	15.41
	9.15
	35.88

1984				1975-1983				
itation, m	Snowfall (cm)		Mean Max Air Temp, C	Precipitation, mm		Snowfall (cm)		Mean Max Air Temp, C
24 hr Max	Absolute Height	Days		Mean Monthly	24 hr Max	Mean Absolute Height	Days	
12th jan	0	0	6.1	57.98	20.00	7.75	16.38	6.55
15th	28	12	0.9	65.95	32.20	9.25	8.88	8.45
9th	4	1	14.4	71.39	26.60	1.88	1.75	14.18
1st	0	0	21.1	107.90	26.40	0.00	0.00	21.23
13th	0	0	26.7	66.14	29.80	0.00	0.00	25.26
0	0	0	33.4	8.56	29.00	0.00	0.00	31.76
0	0	0	36.1	3.10	6.40	0.00	0.00	32.34
0	0	0	36.7	0.56	3.00	0.00	0.00	34.68
0	0	0	28.4	1.05	3.60	0.00	0.00	28.70
8th		0	21.3	24.39	27.80	0.00	0.00	23.09
				24.89	33.80	0.75	3.25	15.41
				34.13	29.50	1.25	13.63	9.15
0	**28**	**12**	**36.7**	**466.03**	**33.80**	**10.88**	**20.88**	**35.88**

Table 4
50-year, 6 hr Precipitation Frequency Estimates f/ NOAA Atlas

No.	Elevation (ft)	5-min (in)	15-min (in)	60-min (in)	2-hr (in)	3-hr (in)	6-hr (in)
1	4,186.00	0.42	0.79	1.32	1.49	1.54	1.71
2	4,878.00	0.46	0.88	1.46	1.66	1.72	1.96
3	6,463.00	0.50	0.94	1.56	1.82	1.93	2.25
4	7,208.00	0.45	0.85	1.42	1.63	1.74	2.01
5	8,645.00	0.54	1.02	1.71	2.01	2.22	2.56
6	9,432.00	0.49	0.93	1.54	1.78	1.97	2.35
10	10,682.00	0.48	0.91	1.52	1.87	2.04	2.42
11	11,683.00	0.53	0.99	1.66	1.96	2.14	2.54

Table 1. Assigned Runoff Curve Nu

Land Cover	RCN
Permanent Marshland	80
Rainfed Crops (Flat)	75
Rainfed Crops (Sloping)	76
Rangeland	72
Rock Outcrop / Bare Soil	77
Permanent Snow	
Sand Dunes	
Settlements	86

Table 5
100-year, 6 hr Precipitation Frequency Estimates f/ NOAA Atlas

No.	Elevation (ft)	5-min (in)	15-min (in)	60-min (in)	2-hr (in)	3-hr (in)	6-hr (in)
1	4,186.00	0.51	0.78	1.61	1.80	1.83	1.96
2	4,878.00	0.57	1.07	1.78	2.00	2.06	2.23
3	6,463.00	0.60	1.14	1.89	2.19	2.30	2.57
4	7,208.00	0.55	1.03	1.72	1.97	2.07	2.30
5	8,645.00	0.66	1.24	2.06	2.41	2.62	2.91
6	9,432.00	0.60	1.13	1.88	2.14	2.32	2.68
10	10,682.00	0.58	1.10	1.83	2.25	2.42	2.77
11	11,683.00	0.63	1.19	1.98	2.35	2.54	2.91

Table 6. NOAA Atlas 2 Depth Area Reduction Factors

Drainage Area (sq.miles)	Drainage Area km^2	NOAA 2 DARF	Range km^2	Applied DARF
0	0	1.00	0 - 13	0.99
5	13	0.99	13 - 26	0.98
10	26	0.98	26 - 52	0.97
20	52	0.96	52 - 78	0.95
30	78	0.95	78 - 104	0.94
40	104	0.94	104 - 129	0.93
50	129	0.93	129 - 259	0.91
100	259	0.89	259 - 388	0.88
150	388	0.87	388 - 518	0.86
200	518	0.85		

Table 7. CCRFCD Depth Area Reduction Factors

Drainage Area (sq.miles)	Drainage Area km^2	CCRFCD DARF	Range km^2	Applied DARF
0	0	1.00	0 - 1	0.99
0.5	1	0.98	1 - 3	0.98
1	3	0.97	3 - 5	0.95
2	5	0.93	5 - 10	0.92
4	10	0.91	10 - 21	0.91
8	21	0.90	21 - 26	0.89
10	26	0.88	26 - 52	0.87
20	52	0.86	52 - 78	0.83
30	78	0.79	78 - 129	0.77
50	129	0.74	129 - 259	0.71
100	259	0.68	259 - 388	0.64
150	388	0.60	388 - 518	0.58
200	518	0.55		

umbers.

NRCS Definition
Herbaceous, Poor, B
Small Grain, Straight Row, Good, B
Small Grain, Straight Row, Poor, B
Desert Shrub, Fair, B
Desert Shrub, Poor, B
Developing Urban Areas, B

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*DIAGRAM
*FREE
ID  US AID Contract No. 306.C-00-02-0050-00
ID
ID  PHASE 1
ID  HYDROLOGIC ANALYSIS FOR THE KESHIM - FAIZABAD ROAD PROJECT
ID  AFGHANISTAN
ID  STORM = 50 YEAR
ID
IT  5                 0      0   1500
IM
IO  5                 0      0
IN  5                 0      0
JR  PREC              1
*
KK  BR1a
BA  39.740
PH 0 10.61 20.29 31.21 37.41 38.31 42.74
LS  0 89.0
UD  0.79
*
KK  BRBR1a
KM  ROUTE BASIN BR1a THROUGH BASIN BR1b
RD  8893     .07    .025       0    TRAP      75
*
KK  BR1b
BA  40.984
PH 0 10.41 19.88 31.21 36.39 36.89 40.71
LS  0 89.0
UD  1.03
*
KK  CP1
KM  COMBINE BR1a AND BR1b
HC  2
*
KK  RCP1
KM  ROUTE COMBINATION POINT CP1 THROUGH BASIN BR1c
RD  17728    .07    .025       0    TRAP      75
*
KK  BR1c
BA  87.115
PH 0 10.02 19.12 30.29 34.88 35.19 38.64
LS  0 89.0
UD  1.78
*
KK  CP2
KM  COMBINE FLOWS FROM CP1 WITH BR1c
HC  2
*
KK  RCP2
KM  ROUTE COMBINATION POINT CP2 THROUGH BASIN BR1d
RD  9241     .06    .025       0    TRAP      75
*
KK  BR1d
BA  41.526
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PH 0 10.22 19.50 31.21 35.45 35.57 38.82
LS  0 89.0
UD  0.97
*
KK  CP3
KM  COMBINE BASIN BR1d AND CP2
HC  2.00
*
KK  BR2
BA  1.826
PH 0 10.40 19.84 32.00 35.95 35.92 39.02
LS  0 89.0
UD  0.71
*
KK  BR3a
BA  234.924
PH 0 10.01 19.14 29.24 35.38 36.35 40.70
LS  0 89.0
UD  1.93
*
KK  RBR3a
KM  ROUTE BR9a THROUGH BASIN BR9b
RD  13204    .026   .025       0    TRAP     300
*
KK  BR3b
BA  181.929
PH 0 9.89 18.89 29.24 34.76 35.48 39.45
LS  0 89.0
UD  1.47
*
KK  CP4
KM  COMBINE FLOWS FROM BR3a AND BASIN BR3b
HC  2
*
KK  RCP4
KM  ROUTE CP4 THROUGH BASIN BR3c
RD  20625    .013   .025       0    TRAP     200
*
KK  BR3c
BA  145.007
PH 0 9.66 18.44 29.24 33.63 33.91 37.21
LS  0 89.0
UD  0.83
*
KK  CP5
KM  COMBINE FLOWS FROM CP4 AND BASIN BR3c
HC  2
*
KK  RCP5
KM  ROUTE CP5 THROUGH BASIN BR3d
RD  9240     .013   .036       0    TRAP     175
*
KK  BR3d
BA  76.170
PH 0 10.06 19.20 30.71 34.90 35.02 38.24
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```
LS  0 89.0
UD  2.00
*
KK  CP6
KM  COMBINE FLOWS FROM CP5 AND BASIN BR3d
HC  2
*
KK  BR4
BA  1.281
PH 0 10.40 19.84 32.00 35.95 35.91 39.01
LS  0 89.0
UD  0.42
*
KK  BR5
BA  1.600
PH 0 10.40 19.83 32.00 35.92 35.88 38.96
LS  0 89.0
UD  0.60
*
KK  IGNORE1
KM  FALSE COMBINATION POINT FOR MODELING
HC  5
*
KK  BR6a
BA  105.744
PH 0 10.18 19.46 29.95 35.87 36.72 40.96
LS  0 89.0
UD  1.73
*
KK  RBR6a
KM  ROUTE BR6a THROUGH BASIN BR6b
RD  5632     .177   .025       0    TRAP     350
*
KK  BR6b
BA  232.055
PH 0 9.97 19.06 29.24 35.19 36.09 40.33
LS  0 89.0
UD  2.82
*
KK  CP7
KM  COMBINE BR6a AND BR6b
HC  2
*
KK  RCP7
KM  ROUTE CP7 THROUGH BASIN BR6c
RD  1850     .032   .025       0    TRAP     280
*
KK  BR6c
BA  86.963
PH 0 10.23 19.55 30.29 35.96 36.69 40.78
LS  0 89.0
UD  1.54
*
KK  CP8
KM  COMBINE BR6c WITH CP7
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HC   2
*
KK   RCP8
KM   ROUTE CP8 THROUGH BASIN BR6d
RD   15880    .013   .025       0    TRAP     380
*
KK   BR6d
BA   128.512
PH 0 9.95 19.00 29.95 34.72 35.11 38.65
LS   0 89.0
UD   2.09
*
KK   CP9
KM   COMBINE BR6d WITH CP8
HC   2
*
KK   RCP9
KM   ROUTE CP9 THROUGH BASIN BR6e
RD   17129    .030   .025       0    TRAP     175
*
KK   BR6e
BA   52.765
PH 0 10.06 19.20 30.71 34.91 35.04 38.26
LS   0 89.0
UD   1.68
*
KK   CP10
KM   COMBINE BR6e WITH CP9
HC   3
*
KK   BR7
BA   4.847
PH 0 10.44 19.92 32.00 36.15 36.19 39.42
LS   0 89.0
UD   0.78
*
KK   BR8
BA   6.852
PH 0 10.50 20.04 32.00 36.45 36.61 40.01
LS   0 89.0
UD   0.67
*
KK   IGNORE2
KM   FALSE COMBINATION POINT FOR MODELING
HC   3
*
KK   BR9a
BA   58.435
PH 0 10.42 19.91 30.71 36.67 37.50 41.78
LS   0 89.0
UD   1.08
*
KK   RBR9a
KM   ROUTE BR9a THROUGH BASIN BR9b
RD   10927    .022   .025       0    TRAP     250
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*
KK  BR9b
BA  73.460
PH 0 10.27 19.62 30.71 35.95 36.50 40.34
LS  0 89.0
UD  1.29
*
KK  CP11
KM  COMBINE BR9a AND BR9b
HC  2
*
KK  RCP11
KM  ROUTE CP11 THROUGH BASIN BR9c
RD  19936    .020   .025       0    TRAP     150
*
KK  BR9c
BA  204.752
PH 0 9.70 18.52 29.24 33.82 34.17 37.58
LS  0 89.0
UD  2.23
*
KK  CP12
KM  COMBINE BR9c AND CP11
HC  2
*
KK  RCP12
KM  ROUTE CP12 THROUGH BASIN BR9d
RD  11215    .041   .025       0    TRAP     100
*
KK  BR9d
BA  54.861
PH 0 10.12 19.30 30.71 35.17 35.40 38.77
LS  0 89.0
UD  1.34
*
KK  CP13
KM  COMBINE CP12 AND BASIN BR9d
HC  2
*
KK  BR10
BA  11.751
PH 0 10.52 20.08 32.00 36.56 36.76 40.23
LS  0 89.0
UD  0.85
*
KK  BR11
BA  1.597
PH 0 10.41 19.85 32.00 35.98 35.96 39.08
LS  0 89.0
UD  0.18
*
KK  IGNORE 4
KM  FALSE COMBINATION POINT FOR MODELING
HC  4
*
```

```
KK  BR12a
BA  24.757
PH 0 10.49 20.03 31.64 36.58 36.96 40.64
LS  0 89.0
UD  0.87
*
KK  RBR12a
KM  ROUTHE BASIN BR12a THROUGH BASIN BR12b
RD  5969     .087   .025       0    TRAP      75
*
KK  BR12b
BA  21.314
PH 0 10.43 19.91 31.64 36.27 36.52 40.02
LS  0 89.0
UD  1.00
*
KK  CP14
KM  COMBINE BR12a AND BR12b
HC  2
*
KK  BR13
BA  1.763
PH 0 10.50 20.03 32.00 36.44 36.60 40.00
LS  0 89.0
UD  0.39
*
KK  IGNORE5
KM  FALSE COMBINATION POINT FOR MODELING
HC  3
*
KK  BR14
BA  1.684
PH 0 10.50 20.03 32.00 36.44 36.60 39.99
LS  0 89.0
UD  0.30
*
KK  BR15
BA  0.654
PH 0 10.48 19.99 32.00 36.34 36.46 39.80
LS  0 89.0
UD  0.23
*
KK  BR16
BA  1.059
PH 0 10.50 20.04 32.00 36.46 36.63 40.04
LS  0 89.0
UD  0.23
*
KK  BR17
BA  0.206
PH 0 10.46 19.96 32.00 36.25 36.33 39.61
LS  0 89.0
UD  0.07
*
KK  IGNORE6
```

```
KM  FALSE COMBINATION POINT FOR MODELING
HC  5
*
KK  BR18a
BA  14.488
PH 0 10.55 20.14 31.64 36.86 37.34 41.19
LS  0 89.0
UD  0.55
*
KK  RBR18a
KM  ROUTE BASIN BR18a THROUGH BASIN BR12b
RD  5935     .119   .025       0    TRAP      75
*
KK  BR18b
BA  12.973
PH 0 10.44 19.94 31.64 36.35 36.63 40.17
LS  0 89.0
UD  0.71
*
KK  CP15
KM  COMBINE BR18a AND BR18b
HC  2
*
KK  IGNORE7
KM  FALSE COMBINATION POINT FOR MODELING
HC  2
*
KK  BR19a
BA  5.565
PH 0 10.56 20.15 32.00 36.74 37.02 40.59
LS  0 89.0
UD  0.71
*
KK  RBR19a
KM  ROUTE BASIN BR19a THROUGH BASIN BR19b
RD  1879     .059   .025       0    TRAP     100
*
KK  BR19b
BA  12.813
PH 0 10.55 20.13 32.00 36.67 36.92 40.46
LS  0 89.0
UD  1.03
*
KK  CP16
KM  COMBINE BR19a AND BR19b
HC  2
*
KK  BR20a
BA  7.508
PH 0 10.57 20.17 32.00 36.78 37.08 40.68
LS  0 89.0
UD  0.79
*
KK  RBR20a
KM  ROUTE BASIN BR19a THROUGH BASIN BR19b
```

```
RD   859       .263   .025       0    TRAP      90
*
KK   BR20b
BA   26.109
PH 0 10.34 19.74 31.21 36.04 36.39 40.00
LS   0 89.0
UD   1.11
*
KK   CP17
KM   COMBINE BR20a AND BR20b
HC   2
*
KK   IGNORE8
KM   FALSE COMBINATION POINT FOR MODELING
HC   3
*
KK   BR21
BA   3.377
PH 0 10.50 20.04 32.00 36.45 36.61 40.01
LS   0 89.0
UD   0.52
*
KK   BR22
BA   5.512
PH 0 10.54 20.13 32.00 36.67 36.92 40.45
LS   0 89.0
UD   0.61
*
*
ZZ
```

Table B.1.2

Basin	Area (km^2)	Precipitation Data - PH	Area (Ha)	Area (mi^2)	Mixed Storms	
BR1a	39.74	PH 0 10.61 20.29 31.21 37.41 38.31 42.74	3974.035	15.34	100	
BR1b	40.98	PH 0 10.41 19.88 31.21 36.39 36.89 40.71	4098.430	15.82	100	
BR1c	87.12	PH 0 10.02 19.12 30.29 34.88 35.19 38.64	8711.507	33.64	100	
BR1d	41.53	PH 0 10.22 19.50 31.21 35.45 35.57 38.82	4152.584	16.03	100	
BR2	1.83	PH 0 10.40 19.84 32.00 35.95 35.92 39.02	182.579	0.70	100	
BR3a	234.92	PH 0 10.01 19.14 29.24 35.38 36.35 40.70	23492.398	90.70	100	
BR3b	181.93	PH 0 9.89 18.89 29.24 34.76 35.48 39.45	18192.859	70.24	100	
BR3c	145.01	PH 0 9.66 18.44 29.24 33.63 33.91 37.21	14500.703	55.99	100	
BR3d	76.17	PH 0 10.06 19.20 30.71 34.90 35.02 38.24	7616.982	29.41	100	
BR4	1.28	PH 0 10.40 19.84 32.00 35.95 35.91 39.01	128.078	0.49	100	
BR5	1.60	PH 0 10.40 19.83 32.00 35.92 35.88 38.96	159.955	0.62	100	
BR6a	105.74	PH 0 10.18 19.46 29.95 35.87 36.72 40.96	10574.393	40.83	100	
BR6b	232.06	PH 0 9.97 19.06 29.24 35.19 36.09 40.33	23205.521	89.60	100	
BR6c	86.96	PH 0 10.23 19.55 30.29 35.96 36.69 40.78	8696.314	33.58	100	
BR6d	128.51	PH 0 9.95 19.00 29.95 34.72 35.11 38.65	12851.154	49.62	100	
BR6e	52.77	PH 0 10.06 19.20 30.71 34.91 35.04 38.26	5276.530	20.37	100	
BR7	4.85	PH 0 10.44 19.92 32.00 36.15 36.19 39.42	484.704	1.87	100	
BR8	7	PH 0 10.50 20.04 32.00 36.45 36.61 40.01	685.207	2.65	100	
BR9a	58.435344	PH 0 10.42 19.91 30.71 36.67 37.50 41.78	5843.5344	22.56201246	100	
BR9b	73.460147	PH 0 10.27 19.62 30.71 35.95 36.50 40.34	7346.0147	28.36312133	100	
BR9c	205	PH 0 9.70 18.52 29.24 33.82 34.17 37.58	20475.205	79.06	100	
BR9d	55	PH 0 10.12 19.30 30.71 35.17 35.40 38.77	5486.093	21.18	100	
BR10	12	PH 0 10.52 20.08 32.00 36.56 36.76 40.23	1175.087	4.54	100	
BR11	1.5973	PH 0 10.41 19.85 32.00 35.98 35.96 39.08	159.730	0.61672175	100	
BR12a	24.75664	PH 0 10.49 20.03 31.64 36.58 36.96 40.64	2475.664	9.558592143	100	
BR12b	21.314038	PH 0 10.43 19.91 31.64 36.27 36.52 40.02	2131.4038	8.22939608	100	
BR13	1.762807	PH 0 10.50 20.03 32.00 36.44 36.60 40.00	176.2807	0.680623588	100	
BR14	1.684306	PH 0 10.50 20.03 32.00 36.44 36.60 39.99	168.4306	0.650314182	100	
BR15	0.654334	PH 0 10.48 19.99 32.00 36.34 36.46 39.80	65.4334	0.25263977	100	
BR16	1.059043	PH 0 10.50 20.04 32.00 36.46 36.63 40.04	105.9043	0.408898788	100	
BR17	0.206025	PH 0 10.46 19.96 32.00 36.25 36.33 39.61	20.6025	0.079546697	100	
BR18a	14.488136	PH 0 10.55 20.14 31.64 36.86 37.34 41.19	1448.8136	5.593900584	100	
BR18b	12.973268	PH 0 10.44 19.94 31.64 36.35 36.63 40.17	1297.3268	5.009006779	100	

BR19a	5.565358	PH 0 10.56 20.15 32.00 36.74 37.02 40.59	556.5358	2.148796737	100
BR19b	12.81289	PH 0 10.55 20.13 32.00 36.67 36.92 40.46	1281.289	4.947084487	100
BR20a	7.508384	PH 0 10.57 20.17 32.00 36.78 37.08 40.68	750.8384	2.89900327	100
BR20b	26.109326	PH 0 10.34 19.74 31.21 36.04 36.39 40.00	2610.9326	10.08086713	100
BR21	3.377277	PH 0 10.50 20.04 32.00 36.45 36.61 40.01	337.7277	1.30397394	100
BR22	5.512174	PH 0 10.54 20.13 32.00 36.67 36.92 40.45	551.2174	2.12826228	100

Choose the Storm
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Basin	COUNT	Area_ha	SUM_WGTRCN	AVGRCN
BR1a	1	3974.0348	353689.0972	89.0
BR1b	1	4098.4296	364760.2344	89.0
BR1c	1	8711.5069	775324.1141	89.0
BR1d	1	4152.5842	369579.9938	89.0
BR2	1	182.5794	16249.5666	89.0
BR3a	1	23492.3977	2090823.3953	89.0
BR3b	1	18192.8592	1619164.4688	89.0
BR3c	1	14500.7031	1290562.5759	89.0
BR3d	1	7616.9818	677911.3802	89.0
BR4	1	128.0776	11398.9064	89.0
BR5	1	159.9550	14235.9950	89.0
BR6a	1	10574.3934	941121.0126	89.0
BR6b	1	23205.5212	2065291.3868	89.0
BR6c	1	8696.3135	773971.9015	89.0
BR6d	1	12851.1541	1143752.7149	89.0
BR6e	1	5276.5302	469611.1878	89.0
BR7	1	484.7043	43138.6827	89.0
BR8	1	685.2066	60983.3874	89.0
BR9a	1	5843.5344	520074.5616	89.0
BR9b	1	7346.0147	653795.3083	89.0
BR9c	1	20475.2053	1822293.2717	89.0
BR9d	1	5486.0928	488262.2592	89.0
BR10	1	1175.0874	104582.7786	89.0
BR11	1	159.7302	14215.9878	89.0
BR12a	1	2475.664	220334.096	89.0
BR12b	1	2131.4038	189694.9382	89.0
BR13	1	176.2807	15688.9823	89.0
BR14	1	168.4306	14990.3234	89.0
BR15	1	65.4334	5823.5726	89.0
BR16	1	105.9043	9425.4827	89.0
BR17	1	20.6025	1833.6225	89.0
BR18a	1	1448.8136	128944.4104	89.0
BR18b	1	1297.3268	115462.0852	89.0
BR19a	1	556.5358	49531.6862	89.0
BR19b	1	1281.289	114034.721	89.0
BR20a	1	750.8384	66824.6176	89.0
BR20b	1	2610.9326	232373.0014	89.0
BR21	1	337.7277	30057.7653	89.0
BR22	1	551.2174	49058.3486	89.0

Table No. 2: Time of Concentration Calculations

STATION (m)	LENGTH (m)	ELEVUS (m)	ELEVDS (m)	DROP (m)	SLOPE (S) (m/m)	L (m)	L_c (m)	SLOPE (S) (ft/mi)	L (mi)	L_c (mi)	K_n	TLAG (min)	TLAG (hour)
BR1a	10752	3037	2200	837	0.08	7073	3679	411.0	4.39	2.29	0.05	47.59	0.79
BR1b	13688	2200	1600	600	0.04	8893	4795	231.4	5.53	2.98	0.05	61.59	1.03
BR1c	29625	2312	1170	1142	0.04	17728	11897	203.5	11.02	7.39	0.05	106.61	1.78
BR1d	13967	1770	880	890	0.06	9241	4726	336.5	5.74	2.94	0.05	58.36	0.97
BR2	8530	1200	795	405	0.05	6230	2300	250.7	3.87	1.43	0.05	42.41	0.71
BR3a	43780	4500	1740	2760	0.06	33401	10379	332.9	20.75	6.45	0.05	115.81	1.93
BR3b	31363	3300	1400	1900	0.06	25546	5817	319.9	15.87	3.61	0.05	88.15	1.47
BR3c	10297	1400	1140	260	0.03	2025	8272	133.3	1.26	5.14	0.05	49.55	0.83
BR3d	28869	1140	805	335	0.01	20968	7901	61.3	13.03	4.91	0.05	120.01	2.00
BR4	4149	1225	840	385	0.09	2481	1668	489.9	1.54	1.04	0.05	25.20	0.42
BR5	5837	1100	850	250	0.04	3171	2666	226.1	1.97	1.66	0.05	36.24	0.60
BR6a	32771	3700	1800	1900	0.06	21913	10858	306.1	13.62	6.75	0.05	103.71	1.73
BR6b	58286	3794	1700	2094	0.04	33711	24575	189.7	20.95	15.27	0.05	169.40	2.82
BR6c	25875	2884	1640	1244	0.05	16914	8961	253.8	10.51	5.57	0.05	92.17	1.54
BR6d	36733	2300	1430	870	0.02	26595	10138	125.1	16.53	6.30	0.05	125.28	2.09
BR6e	25220	1436	840	596	0.02	17129	8091	124.8	10.64	5.03	0.05	100.62	1.68
BR7	9899	1500	845	655	0.07	6198	3701	349.4	3.85	2.30	0.05	46.89	0.78
BR8	8547.000	1600	900	700	0.0819	5853.0000	2694.0000	432.4324	3.6369	1.6740	0.05	40.00	0.67
BR9a	17848.000	3500	2000	1500	0.0840	12202.0000	5646.0000	443.7472	7.5820	3.5083	0.05	64.80	1.08
BR9b	20205.000	2560	1760	800	0.0396	14752.0000	5453.0000	209.0572	9.1665	3.3883	0.05	77.22	1.29
BR9c	36774.000	2160	1360	800	0.0218	23228.0000	13546.0000	114.8638	14.4332	8.4171	0.05	133.69	2.23
BR9d	21218.000	2000	898	1102	0.0519	13462.0000	7756.0000	274.2275	8.3649	4.8194	0.05	80.48	1.34
BR10	13416.000	2127	905	1222	0.0911	9969.0000	3447.0000	480.9302	6.1944	2.1419	0.05	50.83	0.85
BR11	1900.000	1200	920	280	0.1474	1640.0000	260.0000	778.1053	1.0190	0.1616	0.05	11.03	0.18
BR12a	12018	2020	1520	500	0.04160426	9290	2728	219.6704943	5.77253838	1.695100612	0.05	52.32	0.87
BR12b	15207	2100	1003	1097	0.07213783	10381	4826	380.8877491	6.45045435	2.998737374	0.05	59.82	1.00
BR13	3831	1400	1013	387	0.10101801	2283	1548	533.3750979	1.41859043	0.961882606	0.05	23.59	0.39
BR14	3351	1820	1025	795	0.23724261	2351	1000	1252.641003	1.46084367	0.621371192	0.05	17.91	0.30
BR15	2242	1600	1050	550	0.24531668	1474	768	1295.272079	0.91590114	0.477213076	0.05	14.00	0.23
BR16	2080	1520	1080	440	0.21153846	1292	788	1116.923077	0.80281158	0.489640499	0.05	13.85	0.23
BR17	428	1280	1080	200	0.46728972	293	135	2467.28972	0.18206176	0.083885111	0.05	4.16	0.07
BR18a	6541	2220	1800	420	0.06421037	4985	1556	339.0307292	3.09753539	0.966853575	0.05	32.95	0.55
BR18b	9057	1800	1090	710	0.0783924	5935	3122	413.9118914	3.68783803	1.939920862	0.05	42.50	0.71
BR19a	7872	1600	1280	320	0.04065041	5349	2523	214.6341463	3.32371451	1.567719518	0.05	42.66	0.71
BR19b	14552	1911	1170	741	0.05092084	9723	4829	268.8620121	6.0415921	3.000601487	0.05	62.02	1.03
BR20a	10857	2100	1240	860	0.07921157	7297	3560	418.2370821	4.53414559	2.212081444	0.05	47.43	0.79
BR20b	17642	2400	1085	1315	0.07453803	11695	5947	393.5608208	7.26693609	3.69529448	0.05	66.30	1.11
BR21	5260	1500	1178	322	0.06121673	3376	1884	323.2243346	2.09774914	1.170663326	0.05	31.11	0.52
BR22	8007	2031	1180	851	0.106282	5422	2585	561.1689771	3.3690746	1.606244532	0.05	36.86	0.61

Precipitation Data - PH-50 (Salt Lake City, Utah)

Table B.8.1
50-year, 6 hr Precipitation Frequency Estimates f/ NOAA Atlas

No.	Elevation	5-min	15-min	60-min	2-hr	3-hr	6-hr
	(ft)	(in)	(in)	(in)	(in)	(in)	(in)
1	4,186.00	0.42	0.79	1.32	1.49	1.54	1.71
2	4,878.00	0.46	0.88	1.46	1.66	1.72	1.96
3	6,463.00	0.50	0.94	1.56	1.82	1.93	2.25
4	7,208.00	0.45	0.85	1.42	1.63	1.74	2.01
5	8,645.00	0.54	1.02	1.71	2.01	2.22	2.56
6	9,432.00	0.49	0.93	1.54	1.78	1.97	2.35
10	10,682.00	0.48	0.91	1.52	1.87	2.04	2.42
11	11,683.00	0.53	0.99	1.66	1.96	2.14	2.54

Table B.8.2: Adjusted Precipitation Data - PH-50 (in) (Afghanistan

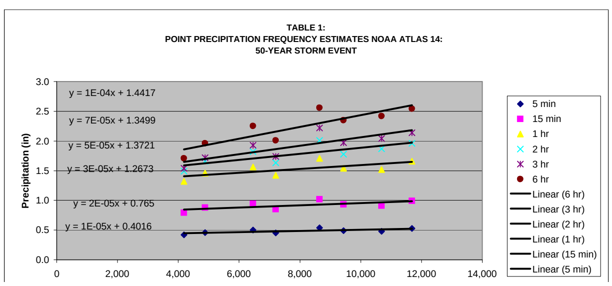
	Drainage Area	DARF	Avg. Elevation	5-min	15-min	60-min	2-hr	3-hr	6-hr
Basin	(sq. km)		(ft)	(in)	(in)	(in)	(in)	(in)	(in)
BR1a	40	0.97	2,940	0.42	0.80	1.23	1.47	1.51	1.68
BR1b	41	0.97	2,115	0.41	0.78	1.23	1.43	1.45	1.60
BR1c	87	0.94	1,748	0.39	0.75	1.19	1.37	1.39	1.52
BR1d	42	0.97	1,349	0.40	0.77	1.23	1.40	1.40	1.53
BR2	2	0.99	1,038	0.41	0.78	1.26	1.42	1.41	1.54
BR3a	235	0.91	3,219	0.39	0.75	1.15	1.39	1.43	1.60
BR3b	182	0.91	2,681	0.39	0.74	1.15	1.37	1.40	1.55
BR3c	145	0.91	1,706	0.38	0.73	1.15	1.32	1.33	1.46
BR3d	76	0.95	1,363	0.40	0.76	1.21	1.37	1.38	1.51
BR4	1	0.99	1,033	0.41	0.78	1.26	1.42	1.41	1.54
BR5	2	0.99	1,015	0.41	0.78	1.26	1.41	1.41	1.53
BR6a	106	0.93	2,912	0.40	0.77	1.18	1.41	1.45	1.61
BR6b	232	0.91	3,059	0.39	0.75	1.15	1.39	1.42	1.59
BR6c	87	0.94	2,647	0.40	0.77	1.19	1.42	1.44	1.61
BR6d	129	0.93	1,938	0.39	0.75	1.18	1.37	1.38	1.52
BR6e	53	0.95	1,371	0.40	0.76	1.21	1.37	1.38	1.51
BR7	5	0.99	1,196	0.41	0.78	1.26	1.42	1.42	1.55
BR8	7	0.99	1,430	0.41	0.79	1.26	1.43	1.44	1.58
BR9a	58	0.95	2,827	0.41	0.78	1.21	1.44	1.48	1.65
BR9b	73	0.95	2,232	0.40	0.77	1.21	1.42	1.44	1.59
BR9c	205	0.91	1,869	0.38	0.73	1.15	1.33	1.35	1.48
BR9d	55	0.95	1,584	0.40	0.76	1.21	1.38	1.39	1.53
BR10	12	0.99	1,516	0.41	0.79	1.26	1.44	1.45	1.58
BR11	2	0.99	1,060	0.41	0.78	1.26	1.42	1.42	1.54
BR12a	25	0.98	1,860	0.41	0.79	1.25	1.44	1.45	1.60
BR12b	21	0.98	1,612	0.41	0.78	1.25	1.43	1.44	1.58
BR13	2	0.99	1,427	0.41	0.79	1.26	1.43	1.44	1.57
BR14	2	0.99	1,423	0.41	0.79	1.26	1.43	1.44	1.57
BR15	1	0.99	1,346	0.41	0.79	1.26	1.43	1.44	1.57
BR16	1	0.99	1,440	0.41	0.79	1.26	1.44	1.44	1.58
BR17	0	0.99	1,270	0.41	0.79	1.26	1.43	1.43	1.56
BR18a	14	0.98	2,080	0.42	0.79	1.25	1.45	1.47	1.62
BR18b	13	0.98	1,673	0.41	0.78	1.25	1.43	1.44	1.58
BR19a	6	0.99	1,662	0.42	0.79	1.26	1.45	1.46	1.60
BR19b	13	0.99	1,607	0.42	0.79	1.26	1.44	1.45	1.59
BR20a	8	0.99	1,696	0.42	0.79	1.26	1.45	1.46	1.60
BR20b	26	0.97	1,828	0.41	0.78	1.23	1.42	1.43	1.57
BR21	3	0.99	1,429	0.41	0.79	1.26	1.43	1.44	1.58
BR22	6	0.99	1,606	0.42	0.79	1.26	1.44	1.45	1.59

Table B.8.3: Adjusted Precipitation Data - PH-50 (mm) (Afghanistan

	Drainage Area	DARF	Avg. Elevation	5-min	15-min	60-min	2-hr	3-hr	6-hr
Basin	(sq. km)		(m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
BR1a	40	0.97	896.11	10.61	20.29	31.21	37.41	38.31	42.74
BR1b	41	0.97	644.65	10.41	19.88	31.21	36.39	36.89	40.71
BR1c	87	0.94	532.64	10.02	19.12	30.29	34.88	35.19	38.64
BR1d	42	0.97	411.02	10.22	19.50	31.21	35.45	35.57	38.82
BR2	2	0.99	316.23	10.40	19.84	32.00	35.95	35.92	39.02
BR3a	235	0.91	981.15	10.01	19.14	29.24	35.38	36.35	40.70
BR3b	182	0.91	817.02	9.89	18.89	29.24	34.76	35.48	39.45
BR3c	145	0.91	519.99	9.66	18.44	29.24	33.63	33.91	37.21
BR3d	76	0.95	415.29	10.06	19.20	30.71	34.90	35.02	38.24
BR4	1	0.99	314.71	10.40	19.84	32.00	35.95	35.91	39.01
BR5	2	0.99	309.37	10.40	19.83	32.00	35.92	35.88	38.96
BR6a	106	0.93	887.58	10.18	19.46	29.95	35.87	36.72	40.96
BR6b	232	0.91	932.38	9.97	19.06	29.24	35.19	36.09	40.33
BR6c	87	0.94	806.65	10.23	19.55	30.29	35.96	36.69	40.78
BR6d	129	0.93	590.55	9.95	19.00	29.95	34.72	35.11	38.65
BR6e	53	0.95	417.88	10.06	19.20	30.71	34.91	35.04	38.26
BR7	5	0.99	364.39	10.44	19.92	32.00	36.15	36.19	39.42
BR8	7	0.99	435.86	10.50	20.04	32.00	36.45	36.61	40.01
BR9a	58	0.95	861.52	10.42	19.91	30.71	36.67	37.50	41.78
BR9b	73	0.95	680.16	10.27	19.62	30.71	35.95	36.50	40.34
BR9c	205	0.91	569.67	9.70	18.52	29.24	33.82	34.17	37.58
BR9d	55	0.95	482.65	10.12	19.30	30.71	35.17	35.40	38.77
BR10	12	0.99	462.08	10.52	20.08	32.00	36.56	36.76	40.23
BR11	2	0.99	323.09	10.41	19.85	32.00	35.98	35.96	39.08
BR12a	25	0.98	566.93	10.49	20.03	31.64	36.58	36.96	40.64
BR12b	21	0.98	491.19	10.43	19.91	31.64	36.27	36.52	40.02
BR13	2	0.99	434.80	10.50	20.03	32.00	36.44	36.60	40.00
BR14	2	0.99	433.58	10.50	20.03	32.00	36.44	36.60	39.99
BR15	1	0.99	410.11	10.48	19.99	32.00	36.34	36.46	39.80
BR16	1	0.99	438.91	10.50	20.04	32.00	36.46	36.63	40.04
BR17	0	0.99	387.10	10.46	19.96	32.00	36.25	36.33	39.61
BR18a	14	0.98	633.98	10.55	20.14	31.64	36.86	37.34	41.19
BR18b	13	0.98	509.93	10.44	19.94	31.64	36.35	36.63	40.17
BR19a	6	0.99	506.43	10.56	20.15	32.00	36.74	37.02	40.59
BR19b	13	0.99	489.66	10.55	20.13	32.00	36.67	36.92	40.46
BR20a	8	0.99	516.79	10.57	20.17	32.00	36.78	37.08	40.68
BR20b	26	0.97	557.02	10.34	19.74	31.21	36.04	36.39	40.00
BR21	3	0.99	435.56	10.50	20.04	32.00	36.45	36.61	40.01
BR22	6	0.99	489.36	10.54	20.13	32.00	36.67	36.92	40.45

Table B.8.4: PH Summary

Basin	PH 50 Yr
BR1a	PH 0 10.61 20.29 31.21 37.41 38.31 42.74
BR1b	PH 0 10.41 19.88 31.21 36.39 36.89 40.71
BR1c	PH 0 10.02 19.12 30.29 34.88 35.19 38.64
BR1d	PH 0 10.22 19.50 31.21 35.45 35.57 38.82
BR2	PH 0 10.40 19.84 32.00 35.95 35.92 39.02
BR3a	PH 0 10.01 19.14 29.24 35.38 36.35 40.70
BR3b	PH 0 9.89 18.89 29.24 34.76 35.48 39.45
BR3c	PH 0 9.66 18.44 29.24 33.63 33.91 37.21
BR3d	PH 0 10.06 19.20 30.71 34.90 35.02 38.24
BR4	PH 0 10.40 19.84 32.00 35.95 35.91 39.01
BR5	PH 0 10.40 19.83 32.00 35.92 35.88 38.96
BR6a	PH 0 10.18 19.46 29.95 35.87 36.72 40.96
BR6b	PH 0 9.97 19.06 29.24 35.19 36.09 40.33
BR6c	PH 0 10.23 19.55 30.29 35.96 36.69 40.78
BR6d	PH 0 9.95 19.00 29.95 34.72 35.11 38.65
BR6e	PH 0 10.06 19.20 30.71 34.91 35.04 38.26
BR7	PH 0 10.44 19.92 32.00 36.15 36.19 39.42
BR8	PH 0 10.50 20.04 32.00 36.45 36.61 40.01



Precipitation Frequency Estimates (inches)																		
ARI* (years)	**5 min**	**10 min**	**15 min**	**30 min**	**60 min**	**120 min**	**3 hr**	**6 hr**	**12 hr**	**24 hr**	**48 hr**	**4 day**	**7 day**	**10 day**	**20 day**	**30 day**	**45 day**	**60 day**
2	0.17	0.26	0.32	0.42	0.53	0.67	0.78	1.02	1.3	1.68	1.94	2.32	2.79	3.2	4.3	5.24	6.57	7.86
5	0.23	0.35	0.43	0.58	0.72	0.87	0.98	1.23	1.57	2	2.33	2.81	3.36	3.83	5.09	6.18	7.73	9.24
10	0.28	0.43	0.54	0.72	0.9	1.06	1.16	1.42	1.8	2.27	2.64	3.2	3.83	4.34	5.71	6.91	8.65	10.31
25	0.38	0.57	0.71	0.96	1.19	1.38	1.46	1.71	2.15	2.65	3.08	3.75	4.48	5	6.5	7.84	9.83	11.68
50	0.46	0.71	0.88	1.18	1.46	1.66	1.72	1.96	2.43	2.94	3.41	4.19	4.99	5.51	7.08	8.53	10.71	12.67
100	0.57	0.86	1.07	1.44	1.78	2	2.06	2.23	2.74	3.24	3.75	4.64	5.51	6.02	7.64	9.19	11.57	13.63
200	0.69	1.05	1.3	1.75	2.16	2.41	2.46	2.58	3.08	3.54	4.1	5.1	6.05	6.52	8.18	9.83	12.4	14.55
500	0.88	1.35	1.67	2.25	2.78	3.07	3.12	3.22	3.59	3.96	4.56	5.72	6.77	7.18	8.87	10.64	13.46	15.7
1000	1.07	1.62	2.01	2.71	3.35	3.68	3.72	3.8	4.01	4.27	4.92	6.22	7.33	7.68	9.36	11.22	14.24	16.54

* These precipitation frequency estimates are based on a partial duration maxima series. **ARI** is the Average Recurrence Interval.
Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.
http://hdsc.nws.noaa.gov/cgi-bin/hdsc/buildout.perl?type=pf&units=us&series=pd&statename=NEVADA&stateabv=nv&study=sa&season=All&intype=5&plat=39.459&plon=-119.957&liststation=0&slat=36&slon=-115&m

Table 3. NOAA Atlas 14 Precipitation Frequency Estimates (mm) for Las Vegas, NV.

ARI* (years)	5 min	15 min	1 hr	2 hr	3 hr	6 hr
2	4.3	8.1	13.5	17.0	19.8	25.9
5	5.8	10.9	18.3	22.1	24.9	31.2
10	7.1	13.7	22.9	26.9	29.5	36.1
25	9.7	18.0	30.2	35.1	37.1	43.4
50	11.7	22.4	37.1	42.2	43.7	49.8
100	14.5	27.2	45.2	50.8	52.3	56.6

* These precipitation frequency estimates are based on a partial duration maxima series. **ARI** is the Average Recurrence Interval.

nlat=39.459&mlon=-119.957&elev=7673

Raw Data

No.	Description	Area (m^2)	Area (Km^2)	Highest Elevation (m)	Lowest Elevation (m)	Length (m) L	Length (m) Lc	Upstream FL (m)
1	BR1a	39740348	39.7	3,680	2,200	7,073	3,679	3,037
2	BR1b	40984296	41	2,630	1,600	8,893	4,795	2,200
3	BR1c	87115069	87	2,325	1,170	17,728	11,897	2,312
4	BR1d	41525842	42	1,817	880	9,241	4,726	1,770
5	BR2	1825794	2	1,280	795	6,230	2,300	1,200
6	BR3a	234923977	235	4,698	1,740	33,401	10,379	4,500
7	BR3b	181928592	182	3,961	1,400	25,546	5,817	3,300
8	BR3c	145007031	145	2,272	1,140	2,025	8,272	1,400
9	BR3d	76169818	76	1,920	805	20,968	7,901	1,140
10	BR4	1280776	1	1,225	840	2,481	1,668	1,225
11	BR5	1599550	2	1,180	850	3,171	2,666	1,100
12	BR6a	105743934	106	4,024	1,800	21,913	10,858	3,700
13	BR6b	232055212	232	4,418	1,700	33,711	24,575	3,794
14	BR6c	86963135	87	3,653	1,640	16,914	8,961	2,884
15	BR6d	128511541	129	2,445	1,430	26,595	10,138	2,300
16	BR6e	52765302	53	1,902	840	17,129	8,091	1,436
17	BR7	4847043	5	1,546	845	6,198	3,701	1,500
18	BR8	6852066	6.9	1,960	900	5,853	2,694	1,600
19	BR9a	58435344	58.4	3,653	2,000	12,202	5,646	3,500
20	BR9b	73460147	73.5	2,703	1,760	14,752	5,453	2,560
21	BR9c	204752053	204.8	2,378	1,360	23,228	13,546	2,160
22	BR9d	54860928	54.9	2,269	898	13,462	7,756	2,000
23	BR10	11750874	11.8	2,127	905	9,969	3,447	2,127
24	BR11	1597302	1.6	1,200	920	1,640	260	1,200
25	BR12a	24756640	24.8	2,200	1,520	9,290	2,728	2,020
26	BR12b	21314038	21.3	2,220	1,003	10,381	4,826	2,100
27	BR13	1762807	1.8	1,840	1,013	2,283	1,548	1,400
28	BR14	1684306	1.7	1,820	1,025	2,351	1,000	1,820
29	BR15	654334	0.7	1,641	1,050	1,474	768	1,600
30	BR16	1059043	1.1	1,800	1,080	1,292	788	1,520
31	BR17	206025	0.2	1,460	1,080	293	135	1,280
32	BR18a	14488136	14.5	2,360	1,800	4,985	1,556	2,220
33	BR18b	12973268	13.0	2,256	1,090	5,935	3,122	1,800
34	BR19a	5565358	5.6	2,043	1,280	5,349	2,523	1,600
35	BR19b	12812890	12.8	2,043	1,170	9,723	4,829	1,911
36	BR20a	7508384	7.5	2,151	1,240	7,297	3,560	2,100
37	BR20b	26109326	26.1	2,570	1,085	11,695	5,947	2,400
38	BR21	3377277	3.4	1,680	1,178	3,376	1,884	1,500
39	BR22	5512174	5.5	2,031	1,180	5,422	2,585	2,031

Slope
(%)
0.12
0.07
0.06
0.10
0.07
0.08
0.07
0.13
0.02
0.16
0.08
0.09
0.06
0.07
0.03
0.03
0.11
0.12
0.12
0.05
0.03
0.08
0.12
0.17
0.05
0.11
0.17
0.34
0.37
0.34
0.68
0.08
0.12
0.06
0.08
0.12
0.11
0.10
0.16

Table X. Summary Comparison Table

No.	Structure No.	Station	Study Description	Area (km^2)	Acre (acres)	Acre (mi^2)	Flowrate (cms)	Flowrate (cfs)	Difference (%)	Difference (cfs)
1	Bridge 1	12+460	Dec-2006	231.87	57296	90	778.9	27507	-25.02%	-6883
			Jan-2008	209.36	51734	81	584	20624		
2	Bridge 2	15+597	Dec-2006	2.75	680	1	9.24	326	-24.24%	-79
			Jan-2008	1.83	452	1	7	247		
3	Bridge 3*	22+787	Dec-2006	629.66	155592	243	2115.17	74697	-62.89%	-46975
			Jan-2008	638.03	157661	246	785	27722		
4	Bridge 4	27+495	Dec-2006	1.24	306	0	4.16	147	92.31%	136
			Jan-2008	1.28	316	0	8	283		
5	Bridge 5	27+909	Dec-2006	2.35	581	1	7.89	279	1.39%	4
			Jan-2008	1.6	395	1	8	283		
6	Bridge 6	28+836	Dec-2006	569	140603	220	1911.4	67500	-49.25%	-33245
			Jan-2008	606.04	149756	234	970	34255		
7	Bridge 7	30+866	Dec-2006	6.64	1641	3	22.31	788	-19.32%	-152
			Jan-2008	4.85	1198	2	18	636		
9	Bridge 8	37+110	Dec-2006	8.24	2036	3	27.68	978	8.38%	82
			Jan-2008	6.85	1693	3	30	1059		
10	Bridge 9	38+541	Dec-2006	389	96124	150	1306.74	46147	-44.67%	-20615
			Jan-2008	391.51	96744	151	723	25533		
11	Bridge 10	40+748	Dec-2006	17.04	4211	7	57.24	2021	-26.62%	-538
			Jan-2008	11.75	2903	5	42	1483		
12	Bridge 11	42+398	Dec-2006	0.8	198	0	2.67	94	649.06%	612
			Jan-2008	1.6	395	1	20	706		
13	Bridge 12	55+786	Dec-2006	49.53	12239	19	166.38	5876	-8.04%	-473
			Jan-2008	46.07	11384	18	153	5403		
14	Bridge 13	59+203	Dec-2006	1.72	425	1	5.78	204	107.61%	220
			Jan-2008	1.76	435	1	12	424		
15	Bridge 14	59+896	Dec-2006	0.86	213	0	2.9	102	382.76%	392
			Jan-2008	1.68	415	1	14	494		
16	Bridge 15	61+730	Dec-2006	0.83	205	0	2.79	99	150.90%	149
			Jan-2008	0.65	161	0	7	247		
17	Bridge 16	69+215	Dec-2006	0.78	193	0	2.6	92	323.08%	297
			Jan-2008	1.06	262	0	11	388		
18	Bridge 17	69+723	Dec-2006	0.14	35	0	0.46	16	769.57%	125
			Jan-2008	0.21	52	0	4	141		
19	Bridge 18	72+563	Dec-2006	27.77	6862	11	93.31	3295	39.32%	1296
			Jan-2008	27.46	6786	11	130	4591		
20	Bridge 19	96+588	Dec-2006	22.57	5577	9	75.82	2678	-22.18%	-594
			Jan-2008	18.38	4542	7	59	2084		
21	Bridge 20	97+577	Dec-2006	32.23	7964	12	108.27	3824	-9.49%	-363
			Jan-2008	33.62	8308	13	98	3461		
22	Bridge 21	98+288	Dec-2006	3.57	882	1	11.99	423	58.47%	248
			Jan-2008	3.38	835	1	19	671		
23	Bridge 22	98+639	Dec-2006	6.28	1552	2	21.1	745	27.96%	208
			Jan-2008	5.51	1362	2	27	953		

**(Basin) represents Basin C-377B, referenced from plan and profile drawings for Keshim - Faizabad Road Project, which indicates a station of 75+200 versus the station of 75+270 from Hydrological report for Keshim - Faizabad Road Project, dated Dec 2006.*

Table 3: Summary of Structure Locations

No.	Station	Structure Designation	Structure Type	No. of Structures	Bridge Length (m)
1	12+460	Bridge 1	Bridge	1	140
2	15+597	Bridge 2	Bridge	1	25
3	22+787	Bridge 3*	Bridge	1	55
4	27+495	Bridge 4	Bridge	1	25
5	27+909	Bridge 5	Bridge	1	25
6	28+836	Bridge 6	Bridge	1	35
7	30+866	Bridge 7	Bridge	1	55
8	37+110	Bridge 8	Bridge	1	30
9	38+541	Bridge 9	Bridge	1	40
10	40+748	Bridge 10	Bridge	1	25
11	42+398	Bridge 11	Bridge	1	35
12	55+786	Bridge 12	Bridge	1	35
13	59+203	Bridge 13	Bridge	1	35
14	59+896	Bridge 14	Bridge	1	25
15	61+730	Bridge 15	Bridge	1	30
16	69+215	Bridge 16	Bridge	1	30
17	69+723	Bridge 17	Bridge	1	105
18	72+563	Bridge 18	Bridge	1	30
19	96+588	Bridge 19	Bridge	1	30
20	97+577	Bridge 20	Bridge	1	30
21	98+288	Bridge 21	Bridge	1	25
22	98+639	Bridge 22	Bridge	1	30

RCBC		Pipe (mm)	Recommendations
Width (m)	Length (m)		

Table 1: Summary of Pipes

No.	Station	Structure Designation	Structure Type	No. of Structures	Bridge Length (m)
1	12+460	Bridge 1	Bridge	1	140
2	15+597	Bridge 2	Bridge	1	25
3	22+787	Bridge 3*	Bridge	1	55
4	27+495	Bridge 4	Bridge	1	25
5	27+909	Bridge 5	Bridge	1	25
6	28+836	Bridge 6	Bridge	1	35
7	30+866	Bridge 7	Bridge	1	55
8	34+791.698	C-188	RCPC	1	
9	37+110	Bridge 8	Bridge	1	30
10	38+541	Bridge 9	Bridge	1	40
11	38+649.139	C-208	RCBC	1	
12	40+748	Bridge 10	Bridge	1	25
13	42+398	Bridge 11	Bridge	1	35
14	45+034.217	C-235	RCPC	1	
15	45+989.819	C-240	RCBC	2	
16	46+304.043	C-242	RCPC	1	
17	49+047.345	C-253	RCPC	2	
18	49+354.326	C-255	RCPC	2	
19	49+553.492	C-256			
20	52+725.833	C-271A	RCBC	1	
21	53+642.515	C-274	RCBC	2	
22	54+820	C-282A	RCBC	1	
23	55+786	Bridge 12	Bridge	1	35
24	57+420	C-299	RCBC	1	
25	59+203	Bridge 13	Bridge	1	35
26	59+896	Bridge 14	Bridge	1	25
27	61+730	Bridge 15	Bridge	1	30
28	66+550	C-342	RCBC	1	
29	69+215	Bridge 16	Bridge	1	30
30	69+723	Bridge 17	Bridge	1	105
31	72+563	Bridge 18	Bridge	1	30
32	75+200	C-377B	RCBC	2	
33	76+118	C-380A	RCBC	1	
34	77+560	C-386A	RCBC	2	
35	80+900	C-401A	RCBC	1	
36	83+440	C-409A	RCBC	2	
37	86+280	C-417A	RCBC	3	
38	96+120	C-446	RCPC	1	
39	96+588	Bridge 19	Bridge	1	30
40	97+577	Bridge 20	Bridge	1	30
41	98+288	Bridge 21	Bridge	1	25
42	98+639	Bridge 22	Bridge	1	30

Table X: Details of Reinforced Concrete Pipe Culverts (RCPC)

Station	Structure Designation	Diameter (mm)	Diameter (ft)	Flowrate (cms)

34+791.698	C-188	1520	5	
45+034.217	C-235	910	3	
46+304.043	C-242	1520	5	
49+047.345	C-253	910	3	
49+354.326	C-255	910	3	
96+120	C-446	910	3	

Table X: Details of Reinforced Concrete Box Culverts (RCBC)

Station	Structure Designation	Diameter (mm)	Diameter (ft)	Flowrate (cms)
34+791.698	C-188	1520	5	
45+034.217	C-235	910	3	
46+304.043	C-242	1520	5	
49+047.345	C-253	910	3	
49+354.326	C-255	910	3	
96+120	C-446	910	3	

RCBC		Pipe (mm)	RCBC		Pipe Diameter (ft)	Recommendations
Width (m)	Length (m)		Width (ft)	Length (ft)		
		1520			5	
2.5	2.5		8	8		
		910			3	
2.5	2.5		8	8		
		1520			5	
		910			3	
		910			3	
2.0	2.0		7	7		
2.0	2.0		7	7		
2.0	2.0		7	7		
3.0	3.0		10	10		
3.5	3.5		11	11		
3.5	3.5		11	11		
2.0	2.0		7	7		
3.0	3.0		10	10		
1.0	1.0		3	3		
2.5	2.5		8	8		
3.0	3.0		10	10		
		910			3	

Flowrate (cfs)

0
0
0
0
0
0

Flowrate (cfs)
0
0
0
0
0
0

Table 3: Summary of Structure Locations

No.	Structure	Station	Sub-basins designation	No. of sub-basins
1	Bridge 1	12+460	BR1a	1
			BR1b	2
			BR1c	3
			BR1d	4
2	Bridge 2	15+597	BR2	5
3	Bridge 3*	22+787	BR3a	6
			BR3b	7
			BR3c	8
			BR3d	9
4	Bridge 4	27+495	BR4	10
5	Bridge 5	27+909	BR5	11
6	Bridge 6	28+836	BR6a	12
			BR6b	13
			BR6c	14
			BR6d	15
			BR6e	16
7	Bridge 7	30+866	BR7	17
8	Bridge 8	37+110	BR8	18
9	Bridge 9	38+541	BR9a	19
			BR9b	20
			BR9c	21
			BR9d	22
10	Bridge 10	40+748	BR10	23
11	Bridge 11	42+398	BR11	24
12	Bridge 12	55+786	BR12a	25
			BR12b	26
13	Bridge 13	59+203	BR13	27
14	Bridge 14	59+896	BR14	28
15	Bridge 15	61+730	BR15	29
16	Bridge 16	69+215	BR16	30
17	Bridge 17	69+723	BR17	31
18	Bridge 18	72+563	BR18a	32
			BR18b	33
19	Bridge 19	96+588	BR19a	34
			BR19b	35
20	Bridge 20	97+577	BR20a	36
			BR20b	37
21	Bridge 21	98+288	BR21	38
22	Bridge 22	98+639	BR22	39

**data referenced from Keshim - Faizabad Road Project Plan and Profile drawings, Jan 07.*

Table B.1.2

Basin	Area (km^2)	Precipitation Data - PH	Area (Ha)	Area (mi^2)	Mixed Storms	
BR1a	39.74	PH 0 10.61 20.29 31.21 37.41 38.31 42.74	3974.035	15.34	100	
BR1b	40.98	PH 0 10.41 19.88 31.21 36.39 36.89 40.71	4098.430	15.82	100	
BR1c	87.12	PH 0 10.02 19.12 30.29 34.88 35.19 38.64	8711.507	33.64	100	
BR1d	41.53	PH 0 10.22 19.50 31.21 35.45 35.57 38.82	4152.584	16.03	100	
BR2	1.83	PH 0 10.40 19.84 32.00 35.95 35.92 39.02	182.579	0.70	100	
BR3a	234.92	PH 0 10.01 19.14 29.24 35.38 36.35 40.70	23492.398	90.70	100	
BR3b	181.93	PH 0 9.89 18.89 29.24 34.76 35.48 39.45	18192.859	70.24	100	
BR3c	145.01	PH 0 9.66 18.44 29.24 33.63 33.91 37.21	14500.703	55.99	100	
BR3d	76.17	PH 0 10.06 19.20 30.71 34.90 35.02 38.24	7616.982	29.41	100	
BR4	1.28	PH 0 10.40 19.84 32.00 35.95 35.91 39.01	128.078	0.49	100	
BR5	1.60	PH 0 10.40 19.83 32.00 35.92 35.88 38.96	159.955	0.62	100	
BR6a	105.74	PH 0 10.18 19.46 29.95 35.87 36.72 40.96	10574.393	40.83	100	
BR6b	232.06	PH 0 9.97 19.06 29.24 35.19 36.09 40.33	23205.521	89.60	100	
BR6c	86.96	PH 0 10.23 19.55 30.29 35.96 36.69 40.78	8696.314	33.58	100	
BR6d	128.51	PH 0 9.95 19.00 29.95 34.72 35.11 38.65	12851.154	49.62	100	
BR6e	52.77	PH 0 10.06 19.20 30.71 34.91 35.04 38.26	5276.530	20.37	100	
BR7	4.85	PH 0 10.44 19.92 32.00 36.15 36.19 39.42	484.704	1.87	100	
BR8	7	PH 0 10.50 20.04 32.00 36.45 36.61 40.01	685.207	2.65	100	
BR9a	58.435344	PH 0 10.42 19.91 30.71 36.67 37.50 41.78	5843.5344	22.56201246	100	
BR9b	73.460147	PH 0 10.27 19.62 30.71 35.95 36.50 40.34	7346.0147	28.36312133	100	
BR9c	205	PH 0 9.70 18.52 29.24 33.82 34.17 37.58	20475.205	79.06	100	
BR9d	55	PH 0 10.12 19.30 30.71 35.17 35.40 38.77	5486.093	21.18	100	
BR10	12	PH 0 10.52 20.08 32.00 36.56 36.76 40.23	1175.087	4.54	100	
BR11	1.5973	PH 0 10.41 19.85 32.00 35.98 35.96 39.08	159.730	0.61672175	100	
BR12a	24.75664	PH 0 10.49 20.03 31.64 36.58 36.96 40.64	2475.664	9.558592143	100	
BR12b	21.314038	PH 0 10.43 19.91 31.64 36.27 36.52 40.02	2131.4038	8.22939608	100	
BR13	1.762807	PH 0 10.50 20.03 32.00 36.44 36.60 40.00	176.2807	0.680623588	100	
BR14	1.684306	PH 0 10.50 20.03 32.00 36.44 36.60 39.99	168.4306	0.650314182	100	
BR15	0.654334	PH 0 10.48 19.99 32.00 36.34 36.46 39.80	65.4334	0.25263977	100	
BR16	1.059043	PH 0 10.50 20.04 32.00 36.46 36.63 40.04	105.9043	0.408898788	100	
BR17	0.206025	PH 0 10.46 19.96 32.00 36.25 36.33 39.61	20.6025	0.079546697	100	
BR18a	14.488136	PH 0 10.55 20.14 31.64 36.86 37.34 41.19	1448.8136	5.593900584	100	
BR18b	12.973268	PH 0 10.44 19.94 31.64 36.35 36.63 40.17	1297.3268	5.009006779	100	

BR19a	5.565358	PH 0 10.56 20.15 32.00 36.74 37.02 40.59	556.5358	2.148796737	100
BR19b	12.81289	PH 0 10.55 20.13 32.00 36.67 36.92 40.46	1281.289	4.947084487	100
BR20a	7.508384	PH 0 10.57 20.17 32.00 36.78 37.08 40.68	750.8384	2.89900327	100
BR20b	26.109326	PH 0 10.34 19.74 31.21 36.04 36.39 40.00	2610.9326	10.08086713	100
BR21	3.377277	PH 0 10.50 20.04 32.00 36.45 36.61 40.01	337.7277	1.30397394	100
BR22	5.512174	PH 0 10.54 20.13 32.00 36.67 36.92 40.45	551.2174	2.12826228	100

Choose the Storm
50

Basin	COUNT	Area_ha	SUM_WGTRCN	AVGRCN
BR1a	1	3974.0348	353689.0972	89.0
BR1b	1	4098.4296	364760.2344	89.0
BR1c	1	8711.5069	775324.1141	89.0
BR1d	1	4152.5842	369579.9938	89.0
BR2	1	182.5794	16249.5666	89.0
BR3a	1	23492.3977	2090823.3953	89.0
BR3b	1	18192.8592	1619164.4688	89.0
BR3c	1	14500.7031	1290562.5759	89.0
BR3d	1	7616.9818	677911.3802	89.0
BR4	1	128.0776	11398.9064	89.0
BR5	1	159.9550	14235.9950	89.0
BR6a	1	10574.3934	941121.0126	89.0
BR6b	1	23205.5212	2065291.3868	89.0
BR6c	1	8696.3135	773971.9015	89.0
BR6d	1	12851.1541	1143752.7149	89.0
BR6e	1	5276.5302	469611.1878	89.0
BR7	1	484.7043	43138.6827	89.0
BR8	1	685.2066	60983.3874	89.0
BR9a	1	5843.5344	520074.5616	89.0
BR9b	1	7346.0147	653795.3083	89.0
BR9c	1	20475.2053	1822293.2717	89.0
BR9d	1	5486.0928	488262.2592	89.0
BR10	1	1175.0874	104582.7786	89.0
BR11	1	159.7302	14215.9878	89.0
BR12a	1	2475.664	220334.096	89.0
BR12b	1	2131.4038	189694.9382	89.0
BR13	1	176.2807	15688.9823	89.0
BR14	1	168.4306	14990.3234	89.0
BR15	1	65.4334	5823.5726	89.0
BR16	1	105.9043	9425.4827	89.0
BR17	1	20.6025	1833.6225	89.0
BR18a	1	1448.8136	128944.4104	89.0
BR18b	1	1297.3268	115462.0852	89.0
BR19a	1	556.5358	49531.6862	89.0
BR19b	1	1281.289	114034.721	89.0
BR20a	1	750.8384	66824.6176	89.0
BR20b	1	2610.9326	232373.0014	89.0
BR21	1	337.7277	30057.7653	89.0
BR22	1	551.2174	49058.3486	89.0

Table No. 2: Time of Concentration Calculations

STATION (m)	LENGTH (m)	ELEVUS (m)	ELEVDS (m)	DROP (m)	SLOPE (S) (m/m)	L (m)	Lc (m)	SLOPE (S) (ft/mi)	L (mi)	Lc (mi)	K_n	T_{LAG} (min)	T_{LAG} (hour)
BR1a	10752	3037	2200	837	0.08	7073	3679	411.0	4.39	2.29	0.05	47.59	0.79
BR1b	13688	2200	1600	600	0.04	8893	4795	231.4	5.53	2.98	0.05	61.59	1.03
BR1c	29625	2312	1170	1142	0.04	17728	11897	203.5	11.02	7.39	0.05	106.61	1.78
BR1d	13967	1770	880	890	0.06	9241	4726	336.5	5.74	2.94	0.05	58.36	0.97
BR2	8530	1200	795	405	0.05	6230	2300	250.7	3.87	1.43	0.05	42.41	0.71
BR3a	43780	4500	1740	2760	0.06	33401	10379	332.9	20.75	6.45	0.05	115.81	1.93
BR3b	31363	3300	1400	1900	0.06	25546	5817	319.9	15.87	3.61	0.05	88.15	1.47
BR3c	10297	1400	1140	260	0.03	2025	8272	133.3	1.26	5.14	0.05	49.55	0.83
BR3d	28869	1140	805	335	0.01	20968	7901	61.3	13.03	4.91	0.05	120.01	2.00
BR4	4149	1225	840	385	0.09	2481	1668	489.9	1.54	1.04	0.05	25.20	0.42
BR5	5837	1100	850	250	0.04	3171	2666	226.1	1.97	1.66	0.05	36.24	0.60
BR6a	32771	3700	1800	1900	0.06	21913	10858	306.1	13.62	6.75	0.05	103.71	1.73
BR6b	58286	3794	1700	2094	0.04	33711	24575	189.7	20.95	15.27	0.05	169.40	2.82
BR6c	25875	2884	1640	1244	0.05	16914	8961	253.8	10.51	5.57	0.05	92.17	1.54
BR6d	36733	2300	1430	870	0.02	26595	10138	125.1	16.53	6.30	0.05	125.28	2.09
BR6e	25220	1436	840	596	0.02	17129	8091	124.8	10.64	5.03	0.05	100.62	1.68
BR7	9899	1500	845	655	0.07	6198	3701	349.4	3.85	2.30	0.05	46.89	0.78
BR8	8547.000	1600	900	700	0.0819	5853.0000	2694.0000	432.4324	3.6369	1.6740	0.05	40.00	0.67
BR9a	17848.000	3500	2000	1500	0.0840	12202.0000	5646.0000	443.7472	7.5820	3.5083	0.05	64.80	1.08
BR9b	20205.000	2560	1760	800	0.0396	14752.0000	5453.0000	209.0572	9.1665	3.3883	0.05	77.22	1.29
BR9c	36774.000	2160	1360	800	0.0218	23228.0000	13546.0000	114.8638	14.4332	8.4171	0.05	133.69	2.23
BR9d	21218.000	2000	898	1102	0.0519	13462.0000	7756.0000	274.2275	8.3649	4.8194	0.05	80.48	1.34
BR10	13416.000	2127	905	1222	0.0911	9969.0000	3447.0000	480.9302	6.1944	2.1419	0.05	50.83	0.85
BR11	1900.000	1200	920	280	0.1474	1640.0000	260.0000	778.1053	1.0190	0.1616	0.05	11.03	0.18
BR12a	12018	2020	1520	500	0.04160426	9290	2728	219.6704943	5.77253838	1.695100612	0.05	52.32	0.87
BR12b	15207	2100	1003	1097	0.07213783	10381	4826	380.8877491	6.45045435	2.998737374	0.05	59.82	1.00
BR13	3831	1400	1013	387	0.10101801	2283	1548	533.3750979	1.41859043	0.961882606	0.05	23.59	0.39
BR14	3351	1820	1025	795	0.23724261	2351	1000	1252.641003	1.46084367	0.621371192	0.05	17.91	0.30
BR15	2242	1600	1050	550	0.24531668	1474	768	1295.272079	0.91590114	0.477213076	0.05	14.00	0.23
BR16	2080	1520	1080	440	0.21153846	1292	788	1116.923077	0.80281158	0.489640499	0.05	13.85	0.23
BR17	428	1280	1080	200	0.46728972	293	135	2467.28972	0.18206176	0.083885111	0.05	4.16	0.07
BR18a	6541	2220	1800	420	0.06421037	4985	1556	339.0307292	3.09753539	0.966853575	0.05	32.95	0.55
BR18b	9057	1800	1090	710	0.0783924	5935	3122	413.9118914	3.68783803	1.939920862	0.05	42.50	0.71
BR19a	7872	1600	1280	320	0.04065041	5349	2523	214.6341463	3.32371451	1.567719518	0.05	42.66	0.71
BR19b	14552	1911	1170	741	0.05092084	9723	4829	268.8620121	6.0415921	3.000601487	0.05	62.02	1.03
BR20a	10857	2100	1240	860	0.07921157	7297	3560	418.2370821	4.53414559	2.212081444	0.05	47.43	0.79
BR20b	17642	2400	1085	1315	0.07453803	11695	5947	393.5608208	7.26693609	3.69529448	0.05	66.30	1.11
BR21	5260	1500	1178	322	0.06121673	3376	1884	323.2243346	2.09774914	1.170663326	0.05	31.11	0.52
BR22	8007	2031	1180	851	0.106282	5422	2585	561.1689771	3.3690746	1.606244532	0.05	36.86	0.61

Precipitation Data - PH-50 (Salt Lake City, Utah)

Table B.8.1
50-year, 6 hr Precipitation Frequency Estimates f/ NOAA Atlas

No.	Elevation	5-min	15-min	60-min	2-hr	3-hr	6-hr
	(ft)	(in)	(in)	(in)	(in)	(in)	(in)
1	4,186.00	0.42	0.79	1.32	1.49	1.54	1.71
2	4,878.00	0.46	0.88	1.46	1.66	1.72	1.96
3	6,463.00	0.50	0.94	1.56	1.82	1.93	2.25
4	7,208.00	0.45	0.85	1.42	1.63	1.74	2.01
5	8,645.00	0.54	1.02	1.71	2.01	2.22	2.56
6	9,432.00	0.49	0.93	1.54	1.78	1.97	2.35
10	10,682.00	0.48	0.91	1.52	1.87	2.04	2.42
11	11,683.00	0.53	0.99	1.66	1.96	2.14	2.54

Table B.8.2: Adjusted Precipitation Data - PH-50 (in) (Afghanistan

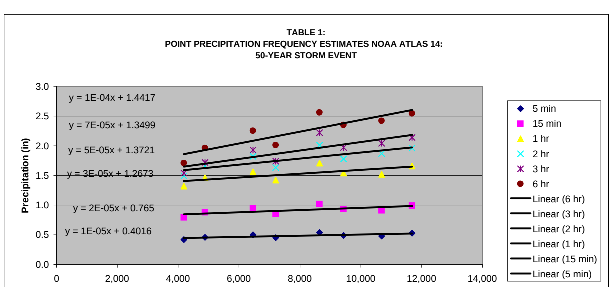
	Drainage Area	DARF	Avg. Elevation	5-min	15-min	60-min	2-hr	3-hr	6-hr
Basin	(sq. km)		(ft)	(in)	(in)	(in)	(in)	(in)	(in)
BR1a	40	0.97	2,940	0.42	0.80	1.23	1.47	1.51	1.68
BR1b	41	0.97	2,115	0.41	0.78	1.23	1.43	1.45	1.60
BR1c	87	0.94	1,748	0.39	0.75	1.19	1.37	1.39	1.52
BR1d	42	0.97	1,349	0.40	0.77	1.23	1.40	1.40	1.53
BR2	2	0.99	1,038	0.41	0.78	1.26	1.42	1.41	1.54
BR3a	235	0.91	3,219	0.39	0.75	1.15	1.39	1.43	1.60
BR3b	182	0.91	2,681	0.39	0.74	1.15	1.37	1.40	1.55
BR3c	145	0.91	1,706	0.38	0.73	1.15	1.32	1.33	1.46
BR3d	76	0.95	1,363	0.40	0.76	1.21	1.37	1.38	1.51
BR4	1	0.99	1,033	0.41	0.78	1.26	1.42	1.41	1.54
BR5	2	0.99	1,015	0.41	0.78	1.26	1.41	1.41	1.53
BR6a	106	0.93	2,912	0.40	0.77	1.18	1.41	1.45	1.61
BR6b	232	0.91	3,059	0.39	0.75	1.15	1.39	1.42	1.59
BR6c	87	0.94	2,647	0.40	0.77	1.19	1.42	1.44	1.61
BR6d	129	0.93	1,938	0.39	0.75	1.18	1.37	1.38	1.52
BR6e	53	0.95	1,371	0.40	0.76	1.21	1.37	1.38	1.51
BR7	5	0.99	1,196	0.41	0.78	1.26	1.42	1.42	1.55
BR8	7	0.99	1,430	0.41	0.79	1.26	1.43	1.44	1.58
BR9a	58	0.95	2,827	0.41	0.78	1.21	1.44	1.48	1.65
BR9b	73	0.95	2,232	0.40	0.77	1.21	1.42	1.44	1.59
BR9c	205	0.91	1,869	0.38	0.73	1.15	1.33	1.35	1.48
BR9d	55	0.95	1,584	0.40	0.76	1.21	1.38	1.39	1.53
BR10	12	0.99	1,516	0.41	0.79	1.26	1.44	1.45	1.58
BR11	2	0.99	1,060	0.41	0.78	1.26	1.42	1.42	1.54
BR12a	25	0.98	1,860	0.41	0.79	1.25	1.44	1.45	1.60
BR12b	21	0.98	1,612	0.41	0.78	1.25	1.43	1.44	1.58
BR13	2	0.99	1,427	0.41	0.79	1.26	1.43	1.44	1.57
BR14	2	0.99	1,423	0.41	0.79	1.26	1.43	1.44	1.57
BR15	1	0.99	1,346	0.41	0.79	1.26	1.43	1.44	1.57
BR16	1	0.99	1,440	0.41	0.79	1.26	1.44	1.44	1.58
BR17	0	0.99	1,270	0.41	0.79	1.26	1.43	1.43	1.56
BR18a	14	0.98	2,080	0.42	0.79	1.25	1.45	1.47	1.62
BR18b	13	0.98	1,673	0.41	0.78	1.25	1.43	1.44	1.58
BR19a	6	0.99	1,662	0.42	0.79	1.26	1.45	1.46	1.60
BR19b	13	0.99	1,607	0.42	0.79	1.26	1.44	1.45	1.59
BR20a	8	0.99	1,696	0.42	0.79	1.26	1.45	1.46	1.60
BR20b	26	0.97	1,828	0.41	0.78	1.23	1.42	1.43	1.57
BR21	3	0.99	1,429	0.41	0.79	1.26	1.43	1.44	1.58
BR22	6	0.99	1,606	0.42	0.79	1.26	1.44	1.45	1.59

Table B.8.3: Adjusted Precipitation Data - PH-50 (mm) (Afghanistan

	Drainage Area	DARF	Avg. Elevation	5-min	15-min	60-min	2-hr	3-hr	6-hr
Basin	(sq. km)		(m)	(mm)	(mm)	(mm)	(mm)	(mm)	(mm)
BR1a	40	0.97	896.11	10.61	20.29	31.21	37.41	38.31	42.74
BR1b	41	0.97	644.65	10.41	19.88	31.21	36.39	36.89	40.71
BR1c	87	0.94	532.64	10.02	19.12	30.29	34.88	35.19	38.64
BR1d	42	0.97	411.02	10.22	19.50	31.21	35.45	35.57	38.82
BR2	2	0.99	316.23	10.40	19.84	32.00	35.95	35.92	39.02
BR3a	235	0.91	981.15	10.01	19.14	29.24	35.38	36.35	40.70
BR3b	182	0.91	817.02	9.89	18.89	29.24	34.76	35.48	39.45
BR3c	145	0.91	519.99	9.66	18.44	29.24	33.63	33.91	37.21
BR3d	76	0.95	415.29	10.06	19.20	30.71	34.90	35.02	38.24
BR4	1	0.99	314.71	10.40	19.84	32.00	35.95	35.91	39.01
BR5	2	0.99	309.37	10.40	19.83	32.00	35.92	35.88	38.96
BR6a	106	0.93	887.58	10.18	19.46	29.95	35.87	36.72	40.96
BR6b	232	0.91	932.38	9.97	19.06	29.24	35.19	36.09	40.33
BR6c	87	0.94	806.65	10.23	19.55	30.29	35.96	36.69	40.78
BR6d	129	0.93	590.55	9.95	19.00	29.95	34.72	35.11	38.65
BR6e	53	0.95	417.88	10.06	19.20	30.71	34.91	35.04	38.26
BR7	5	0.99	364.39	10.44	19.92	32.00	36.15	36.19	39.42
BR8	7	0.99	435.86	10.50	20.04	32.00	36.45	36.61	40.01
BR9a	58	0.95	861.52	10.42	19.91	30.71	36.67	37.50	41.78
BR9b	73	0.95	680.16	10.27	19.62	30.71	35.95	36.50	40.34
BR9c	205	0.91	569.67	9.70	18.52	29.24	33.82	34.17	37.58
BR9d	55	0.95	482.65	10.12	19.30	30.71	35.17	35.40	38.77
BR10	12	0.99	462.08	10.52	20.08	32.00	36.56	36.76	40.23
BR11	2	0.99	323.09	10.41	19.85	32.00	35.98	35.96	39.08
BR12a	25	0.98	566.93	10.49	20.03	31.64	36.58	36.96	40.64
BR12b	21	0.98	491.19	10.43	19.91	31.64	36.27	36.52	40.02
BR13	2	0.99	434.80	10.50	20.03	32.00	36.44	36.60	40.00
BR14	2	0.99	433.58	10.50	20.03	32.00	36.44	36.60	39.99
BR15	1	0.99	410.11	10.48	19.99	32.00	36.34	36.46	39.80
BR16	1	0.99	438.91	10.50	20.04	32.00	36.46	36.63	40.04
BR17	0	0.99	387.10	10.46	19.96	32.00	36.25	36.33	39.61
BR18a	14	0.98	633.98	10.55	20.14	31.64	36.86	37.34	41.19
BR18b	13	0.98	509.93	10.44	19.94	31.64	36.35	36.63	40.17
BR19a	6	0.99	506.43	10.56	20.15	32.00	36.74	37.02	40.59
BR19b	13	0.99	489.66	10.55	20.13	32.00	36.67	36.92	40.46
BR20a	8	0.99	516.79	10.57	20.17	32.00	36.78	37.08	40.68
BR20b	26	0.97	557.02	10.34	19.74	31.21	36.04	36.39	40.00
BR21	3	0.99	435.56	10.50	20.04	32.00	36.45	36.61	40.01
BR22	6	0.99	489.36	10.54	20.13	32.00	36.67	36.92	40.45

Table B.8.4: PH Summary

Basin	PH 50 Yr
BR1a	PH 0 10.61 20.29 31.21 37.41 38.31 42.74
BR1b	PH 0 10.41 19.88 31.21 36.39 36.89 40.71
BR1c	PH 0 10.02 19.12 30.29 34.88 35.19 38.64
BR1d	PH 0 10.22 19.50 31.21 35.45 35.57 38.82
BR2	PH 0 10.40 19.84 32.00 35.95 35.92 39.02
BR3a	PH 0 10.01 19.14 29.24 35.38 36.35 40.70
BR3b	PH 0 9.89 18.89 29.24 34.76 35.48 39.45
BR3c	PH 0 9.66 18.44 29.24 33.63 33.91 37.21
BR3d	PH 0 10.06 19.20 30.71 34.90 35.02 38.24
BR4	PH 0 10.40 19.84 32.00 35.95 35.91 39.01
BR5	PH 0 10.40 19.83 32.00 35.92 35.88 38.96
BR6a	PH 0 10.18 19.46 29.95 35.87 36.72 40.96
BR6b	PH 0 9.97 19.06 29.24 35.19 36.09 40.33
BR6c	PH 0 10.23 19.55 30.29 35.96 36.69 40.78
BR6d	PH 0 9.95 19.00 29.95 34.72 35.11 38.65
BR6e	PH 0 10.06 19.20 30.71 34.91 35.04 38.26
BR7	PH 0 10.44 19.92 32.00 36.15 36.19 39.42
BR8	PH 0 10.50 20.04 32.00 36.45 36.61 40.01



Precipitation Frequency Estimates (inches)																		
ARI* (years)	**5 min**	**10 min**	**15 min**	**30 min**	**60 min**	**120 min**	**3 hr**	**6 hr**	**12 hr**	**24 hr**	**48 hr**	**4 day**	**7 day**	**10 day**	**20 day**	**30 day**	**45 day**	**60 day**
2	0.17	0.26	0.32	0.42	0.53	0.67	0.78	1.02	1.3	1.68	1.94	2.32	2.79	3.2	4.3	5.24	6.57	7.86
5	0.23	0.35	0.43	0.58	0.72	0.87	0.98	1.23	1.57	2	2.33	2.81	3.36	3.83	5.09	6.18	7.73	9.24
10	0.28	0.43	0.54	0.72	0.9	1.06	1.16	1.42	1.8	2.27	2.64	3.2	3.83	4.34	5.71	6.91	8.65	10.31
25	0.38	0.57	0.71	0.96	1.19	1.38	1.46	1.71	2.15	2.65	3.08	3.75	4.48	5	6.5	7.84	9.83	11.68
50	0.46	0.71	0.88	1.18	1.46	1.66	1.72	1.96	2.43	2.94	3.41	4.19	4.99	5.51	7.08	8.53	10.71	12.67
100	0.57	0.86	1.07	1.44	1.78	2	2.06	2.23	2.74	3.24	3.75	4.64	5.51	6.02	7.64	9.19	11.57	13.63
200	0.69	1.05	1.3	1.75	2.16	2.41	2.46	2.58	3.08	3.54	4.1	5.1	6.05	6.52	8.18	9.83	12.4	14.55
500	0.88	1.35	1.67	2.25	2.78	3.07	3.12	3.22	3.59	3.96	4.56	5.72	6.77	7.18	8.87	10.64	13.46	15.7
1000	1.07	1.62	2.01	2.71	3.35	3.68	3.72	3.8	4.01	4.27	4.92	6.22	7.33	7.68	9.36	11.22	14.24	16.54

* These precipitation frequency estimates are based on a partial duration maxima series. **ARI** is the Average Recurrence Interval.
Please refer to the documentation for more information. NOTE: Formatting forces estimates near zero to appear as zero.
http://hdsc.nws.noaa.gov/cgi-bin/hdsc/buildout.perl?type=pf&units=us&series=pd&statename=NEVADA&stateabv=nv&study=sa&season=All&intype=5&plat=39.459&plon=-119.957&liststation=0&slat=36&slon=-115&m

Table 3. NOAA Atlas 14 Precipitation Frequency Estimates (mm) for Las Vegas, NV.

ARI* (years)	**5 min**	**15 min**	**1 hr**	**2 hr**	**3 hr**	**6 hr**
2	4.3	8.1	13.5	17.0	19.8	25.9
5	5.8	10.9	18.3	22.1	24.9	31.2
10	7.1	13.7	22.9	26.9	29.5	36.1
25	9.7	18.0	30.2	35.1	37.1	43.4
50	11.7	22.4	37.1	42.2	43.7	49.8
100	14.5	27.2	45.2	50.8	52.3	56.6

* These precipitation frequency estimates are based on a partial duration maxima series. **ARI** is the Average Recurrence Interval.

Table 4
50-year, 6 hr Precipitation Frequency Estimates f/ NOAA Atlas

No.	Elevation (ft)	5-min (in)	15-min (in)	60-min (in)	2-hr (in)	3-hr (in)	6-hr (in)
1	4,186.00	0.42	0.79	1.32	1.49	1.54	1.71
2	4,878.00	0.46	0.88	1.46	1.66	1.72	1.96
3	6,463.00	0.50	0.94	1.56	1.82	1.93	2.25
4	7,208.00	0.45	0.85	1.42	1.63	1.74	2.01
5	8,645.00	0.54	1.02	1.71	2.01	2.22	2.56
6	9,432.00	0.49	0.93	1.54	1.78	1.97	2.35
10	10,682.00	0.48	0.91	1.52	1.87	2.04	2.42
11	11,683.00	0.53	0.99	1.66	1.96	2.14	2.54

Table 1. Assigned Runoff Curve Numbers.

Land Cover	RCN	NRCS Definition
Permanent Marshland	80	Herbaceous, Poor, B
Rainfed Crops (Flat)	75	Small Grain, Straight Row, Good, B
Rainfed Crops (Sloping)	76	Small Grain, Straight Row, Poor, B
Rangeland	72	Desert Shrub, Fair, B
Rock Outcrop / Bare Soil	77	Desert Shrub, Poor, B
Permanent Snow		
Sand Dunes		
Settlements	86	Developing Urban Areas, B

Table 5
100-year, 6 hr Precipitation Frequency Estimates f/ NOAA Atlas

No.	Elevation (ft)	5-min (in)	15-min (in)	60-min (in)	2-hr (in)	3-hr (in)	6-hr (in)
1	4,186.00	0.51	0.78	1.61	1.80	1.83	1.96
2	4,878.00	0.57	1.07	1.78	2.00	2.06	2.23
3	6,463.00	0.60	1.14	1.89	2.19	2.30	2.57
4	7,208.00	0.55	1.03	1.72	1.97	2.07	2.30
5	8,645.00	0.66	1.24	2.06	2.41	2.62	2.91
6	9,432.00	0.60	1.13	1.88	2.14	2.32	2.68
10	10,682.00	0.58	1.10	1.83	2.25	2.42	2.77
11	11,683.00	0.63	1.19	1.98	2.35	2.54	2.91

Table 6. NOAA Atlas 2 Depth Area Reduction Factors

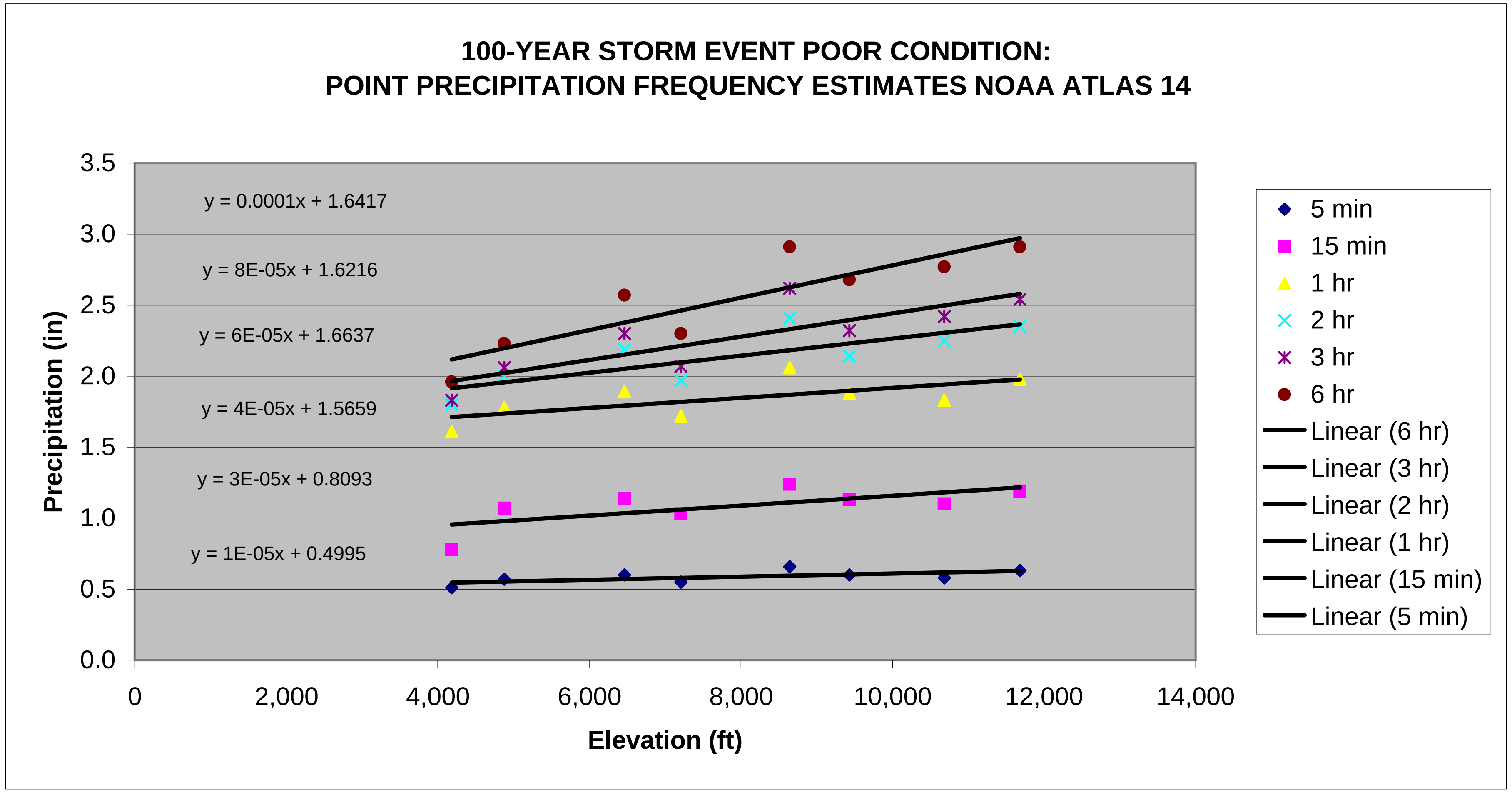
Drainage Area (sq.miles)	Drainage Area km^2	NOAA 2 DARF	Range km^2	Applied DARF
0	0	1.00	0 - 13	0.99
5	13	0.99	13 - 26	0.98
10	26	0.98	26 - 52	0.97
20	52	0.96	52 - 78	0.95
30	78	0.95	78 - 104	0.94
40	104	0.94	104 - 129	0.93
50	129	0.93	129 - 259	0.91
100	259	0.89	259 - 388	0.88
150	388	0.87	388 - 518	0.86
200	518	0.85		

Table 7. CCRFCD Depth Area Reduction Factors

Drainage Area (sq.miles)	Drainage Area km^2	CCRFCD DARF	Range km^2	Applied DARF
0	0	1.00	0 - 1	0.99
0.5	1	0.98	1 - 3	0.98
1	3	0.97	3 - 5	0.95
2	5	0.93	5 - 10	0.92
4	10	0.91	10 - 21	0.91
8	21	0.90	21 - 26	0.89
10	26	0.88	26 - 52	0.87
20	52	0.86	52 - 78	0.83
30	78	0.79	78 - 129	0.77
50	129	0.74	129 - 259	0.71
100	259	0.68	259 - 388	0.64
150	388	0.60	388 - 518	0.58
200	518	0.55		

Raw Data

No.	Description	Area (m^2)	Area (Km^2)	Area (mi^2)	Area (acres)	Area (Ha)	Highest Elevation (m	Highest Elevation (ft	Lowest Elevation (m	Lowest Elevation (ft	Average Elevation (m	Average Elevation (ft	Length (ft) L	Length (m) L	length (ft) Lc	Length (m) Lc	Upstream F (m)	Upstream F (ft)	Slope (%)
1	BR1a	39740348	39.7	15.3	9820	3974	3,680	12,073	2,200	7,218	2,940	9,646	23,205	7,073	12,070	3,679	3,037	9,964	0.12
2	BR1b	40984296	41	16	10127	4098	2,630	8,629	1,600	5,249	2,115	6,939	29,177	8,893	15,732	4,795	2,200	7,218	0.07
3	BR1c	87115069	87	34	21527	8712	2,325	7,628	1,170	3,839	1,748	5,733	58,163	17,728	39,032	11,897	2,312	7,585	0.06
4	BR1d	41525842	42	16	10261	4153	1,817	5,961	880	2,887	1,349	4,424	30,318	9,241	15,505	4,726	1,770	5,807	0.10
5	BR2	1825794	2	1	451	183	1,280	4,199	795	2,608	1,038	3,404	20,440	6,230	7,546	2,300	1,200	3,937	0.07
6	BR3a	234923977	235	91	58051	23492	4,698	15,413	1,740	5,709	3,219	10,561	109,583	33,401	34,052	10,379	4,500	14,764	0.08
7	BR3b	181928592	182	70	44956	18193	3,961	12,995	1,400	4,593	2,681	8,794	83,812	25,546	19,085	5,817	3,300	10,827	0.07
8	BR3c	145007031	145	56	35832	14501	2,272	7,454	1,140	3,740	1,706	5,597	6,644	2,025	27,139	8,272	1,400	4,593	0.13
9	BR3d	76169818	76	29	18822	7617	1,920	6,299	805	2,641	1,363	4,470	68,793	20,968	25,922	7,901	1,140	3,740	0.02
10	BR4	1280776	1	0	316	128	1,225	4,019	840	2,756	1,033	3,387	8,140	2,481	5,472	1,668	1,225	4,019	0.16
11	BR5	1599550	2	1	395	160	1,180	3,871	850	2,789	1,015	3,330	10,404	3,171	8,747	2,666	1,100	3,609	0.08
12	BR6a	105743934	106	41	26130	10574	4,024	13,202	1,800	5,906	2,912	9,554	71,893	21,913	35,623	10,858	3,700	12,139	0.09
13	BR6b	232055212	232	90	57342	23206	4,418	14,495	1,700	5,577	3,059	10,036	110,600	33,711	80,627	24,575	3,794	12,448	0.06
14	BR6c	86963135	87	34	21489	8696	3,653	11,985	1,640	5,381	2,647	8,683	55,492	16,914	29,400	8,961	2,884	9,462	0.07
15	BR6d	128511541	129	50	31756	12851	2,445	8,022	1,430	4,692	1,938	6,357	87,254	26,595	33,261	10,138	2,300	7,546	0.03
16	BR6e	52765302	53	20	13039	5277	1,902	6,240	840	2,756	1,371	4,498	56,198	17,129	26,545	8,091	1,436	4,711	0.03
17	BR7	4847043	5	2	1198	485	1,546	5,072	845	2,772	1,196	3,922	20,335	6,198	12,142	3,701	1,500	4,921	0.11
18	BR8	6852066	6.9	2.6	1693.2	685.2	1,960	6,430	900	2,953	1,430	4,692	19,203	5,853	8,839	2,694	1,600	5,249	0.12
19	BR9a	58435344	58.4	22.6	14439.7	5843.5	3,653	11,985	2,000	6,562	2,827	9,273	40,033	12,202	18,524	5,646	3,500	11,483	0.12
20	BR9b	73460147	73.5	28.4	18152.4	7346.0	2,703	8,868	1,760	5,774	2,232	7,321	48,399	14,752	17,890	5,453	2,560	8,399	0.05
21	BR9c	204752053	204.8	79.1	50595.3	20475.2	2,378	7,802	1,360	4,462	1,869	6,132	76,207	23,228	44,442	13,546	2,160	7,087	0.03
22	BR9d	54860928	54.9	21.2	13556.4	5486.1	2,269	7,444	898	2,946	1,584	5,195	44,167	13,462	25,446	7,756	2,000	6,562	0.08
23	BR10	11750874	11.8	4.5	2903.7	1175.1	2,127	6,978	905	2,969	1,516	4,974	32,707	9,969	11,309	3,447	2,127	6,978	0.12
24	BR11	1597302	1.6	0.6	394.7	159.7	1,200	3,937	920	3,018	1,060	3,478	5,381	1,640	853	260	1,200	3,937	0.17
25	BR12a	24756640	24.8	9.6	6117.5	2475.7	2,200	7,218	1,520	4,987	1,860	6,102	30,479	9,290	8,950	2,728	2,020	6,627	0.05
26	BR12b	21314038	21.3	8.2	5266.8	2131.4	2,220	7,283	1,003	3,291	1,612	5,287	34,058	10,381	15,833	4,826	2,100	6,890	0.11
27	BR13	1762807	1.8	0.7	435.6	176.3	1,840	6,037	1,013	3,323	1,427	4,680	7,490	2,283	5,079	1,548	1,400	4,593	0.17
28	BR14	1684306	1.7	0.7	416.2	168.4	1,820	5,971	1,025	3,363	1,423	4,667	7,713	2,351	3,281	1,000	1,820	5,971	0.34
29	BR15	654334	0.7	0.3	161.7	65.4	1,641	5,384	1,050	3,445	1,346	4,414	4,836	1,474	2,520	768	1,600	5,249	0.37
30	BR16	1059043	1.1	0.4	261.7	105.9	1,800	5,906	1,080	3,543	1,440	4,724	4,239	1,292	2,585	788	1,520	4,987	0.34
31	BR17	206025	0.2	0.1	50.9	20.6	1,460	4,790	1,080	3,543	1,270	4,167	961	293	443	135	1,280	4,199	0.68
32	BR18a	14488136	14.5	5.6	3580.1	1448.8	2,360	7,743	1,800	5,906	2,080	6,824	16,355	4,985	5,105	1,556	2,220	7,283	0.08
33	BR18b	12973268	13.0	5.0	3205.8	1297.3	2,256	7,402	1,090	3,576	1,673	5,489	19,472	5,935	10,243	3,122	1,800	5,906	0.12
34	BR19a	5565358	5.6	2.1	1375.2	556.5	2,043	6,703	1,280	4,199	1,662	5,451	17,549	5,349	8,278	2,523	1,600	5,249	0.06
35	BR19b	12812890	12.8	4.9	3166.1	1281.3	2,043	6,703	1,170	3,839	1,607	5,271	31,900	9,723	15,843	4,829	1,911	6,270	0.08
36	BR20a	7508384	7.5	2.9	1855.4	750.8	2,151	7,057	1,240	4,068	1,696	5,563	23,940	7,297	11,680	3,560	2,100	6,890	0.12
37	BR20b	26109326	26.1	10.1	6451.8	2610.9	2,570	8,432	1,085	3,560	1,828	5,996	38,369	11,695	19,511	5,947	2,400	7,874	0.11
38	BR21	3377277	3.4	1.3	834.5	337.7	1,680	5,512	1,178	3,865	1,429	4,688	11,076	3,376	6,181	1,884	1,500	4,921	0.10
39	BR22	5512174	5.5	2.1	1362.1	551.2	2,031	6,663	1,180	3,871	1,606	5,267	17,789	5,422	8,481	2,585	2,031	6,663	0.16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Precipitation (in)
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2.0
1.5
1.0
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0.0
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4,000
6,000
8,000
10,000
12,000
14,000
Elevation (ft)
5 min
15 min
1 hr
2 hr
3 hr
6 hr
Linear (6 hr)
Linear (3 hr)
Linear (2 hr)
Linear (1 hr)
Linear (15 min)
Linear (5 min)

Table X. Summary Comparison Table

No.	Structure No.	Station	Study Description	Area (km^2)	Acre (acres)	Acre (mi^2)	Flowrate (cms)	Flowrate (cfs)	Difference (%)	Difference (cfs)
1	Bridge 1	12+460	Dec-2006	231.87	57296	90	778.9	27507	-25.02%	-6883
			Jan-2008	209.36	51734	81	584	20624		
2	Bridge 2	15+597	Dec-2006	2.75	680	1	9.24	326	-24.24%	-79
			Jan-2008	1.83	452	1	7	247		
3	Bridge 3*	22+787	Dec-2006	629.66	155592	243	2115.17	74697	-62.89%	-46975
			Jan-2008	638.03	157661	246	785	27722		
4	Bridge 4	27+495	Dec-2006	1.24	306	0	4.16	147	92.31%	136
			Jan-2008	1.28	316	0	8	283		
5	Bridge 5	27+909	Dec-2006	2.35	581	1	7.89	279	1.39%	4
			Jan-2008	1.6	395	1	8	283		
6	Bridge 6	28+836	Dec-2006	569	140603	220	1911.4	67500	-49.25%	-33245
			Jan-2008	606.04	149756	234	970	34255		
7	Bridge 7	30+866	Dec-2006	6.64	1641	3	22.31	788	-19.32%	-152
			Jan-2008	4.85	1198	2	18	636		
9	Bridge 8	37+110	Dec-2006	8.24	2036	3	27.68	978	8.38%	82
			Jan-2008	6.85	1693	3	30	1059		
10	Bridge 9	38+541	Dec-2006	389	96124	150	1306.74	46147	-44.67%	-20615
			Jan-2008	391.51	96744	151	723	25533		
11	Bridge 10	40+748	Dec-2006	17.04	4211	7	57.24	2021	-26.62%	-538
			Jan-2008	11.75	2903	5	42	1483		
12	Bridge 11	42+398	Dec-2006	0.8	198	0	2.67	94	649.06%	612
			Jan-2008	1.6	395	1	20	706		
13	Bridge 12	55+786	Dec-2006	49.53	12239	19	166.38	5876	-8.04%	-473
			Jan-2008	46.07	11384	18	153	5403		
14	Bridge 13	59+203	Dec-2006	1.72	425	1	5.78	204	107.61%	220
			Jan-2008	1.76	435	1	12	424		
15	Bridge 14	59+896	Dec-2006	0.86	213	0	2.9	102	382.76%	392
			Jan-2008	1.68	415	1	14	494		
16	Bridge 15	61+730	Dec-2006	0.83	205	0	2.79	99	150.90%	149
			Jan-2008	0.65	161	0	7	247		
17	Bridge 16	69+215	Dec-2006	0.78	193	0	2.6	92	323.08%	297
			Jan-2008	1.06	262	0	11	388		
18	Bridge 17	69+723	Dec-2006	0.14	35	0	0.46	16	769.57%	125
			Jan-2008	0.21	52	0	4	141		
19	Bridge 18	72+563	Dec-2006	27.77	6862	11	93.31	3295	39.32%	1296
			Jan-2008	27.46	6786	11	130	4591		
20	Bridge 19	96+588	Dec-2006	22.57	5577	9	75.82	2678	-22.18%	-594
			Jan-2008	18.38	4542	7	59	2084		
21	Bridge 20	97+577	Dec-2006	32.23	7964	12	108.27	3824	-9.49%	-363
			Jan-2008	33.62	8308	13	98	3461		
22	Bridge 21	98+288	Dec-2006	3.57	882	1	11.99	423	58.47%	248
			Jan-2008	3.38	835	1	19	671		
23	Bridge 22	98+639	Dec-2006	6.28	1552	2	21.1	745	27.96%	208
			Jan-2008	5.51	1362	2	27	953		

**(Basin) represents Basin C-377B, referenced from plan and profile drawings for Keshim - Faizabad Road Project, which indicates a station of 75+200 versus the station of 75+270 from Hydrological report for Keshim - Faizabad Road Project, dated Dec 2006.*

Table 3: Summary of Structure Locations

No.	Station	Structure Designation	Structure Type	No. of Structures	Bridge Length (m)	RCBC		Pipe (mm)	Recommendations
						Width (m)	Length (m)		
1	12+460	Bridge 1	Bridge	1	140				
2	15+597	Bridge 2	Bridge	1	25				
3	22+787	Bridge 3*	Bridge	1	55				
4	27+495	Bridge 4	Bridge	1	25				
5	27+909	Bridge 5	Bridge	1	25				
6	28+836	Bridge 6	Bridge	1	35				
7	30+866	Bridge 7	Bridge	1	55				
8	37+110	Bridge 8	Bridge	1	30				
9	38+541	Bridge 9	Bridge	1	40				
10	40+748	Bridge 10	Bridge	1	25				
11	42+398	Bridge 11	Bridge	1	35				
12	55+786	Bridge 12	Bridge	1	35				
13	59+203	Bridge 13	Bridge	1	35				
14	59+896	Bridge 14	Bridge	1	25				
15	61+730	Bridge 15	Bridge	1	30				
16	69+215	Bridge 16	Bridge	1	30				
17	69+723	Bridge 17	Bridge	1	105				
18	72+563	Bridge 18	Bridge	1	30				
19	96+588	Bridge 19	Bridge	1	30				
20	97+577	Bridge 20	Bridge	1	30				
21	98+288	Bridge 21	Bridge	1	25				
22	98+639	Bridge 22	Bridge	1	30				

Table 1: Summary of Pipes

No.	Station	Structure Designation	Structure Type	No. of Structures	Bridge Length (m)	RCBC		Pipe (mm)	RCBC		Pipe Diameter (ft)	Recommendations
						Width (m)	Length (m)		Width (ft)	Length (ft)		
1	12+460	Bridge 1	Bridge	1	140							
2	15+597	Bridge 2	Bridge	1	25							
3	22+787	Bridge 3*	Bridge	1	55							
4	27+495	Bridge 4	Bridge	1	25							
5	27+909	Bridge 5	Bridge	1	25							
6	28+836	Bridge 6	Bridge	1	35							
7	30+866	Bridge 7	Bridge	1	55							
8	34+791.698	C-188	RCPC	1				1520			5	
9	37+110	Bridge 8	Bridge	1	30							
10	38+541	Bridge 9	Bridge	1	40							
11	38+649.139	C-208	RCBC	1		2.5	2.5		8	8		
12	40+748	Bridge 10	Bridge	1	25							
13	42+398	Bridge 11	Bridge	1	35							
14	45+034.217	C-235	RCPC	1				910			3	
15	45+989.819	C-240	RCBC	2		2.5	2.5		8	8		
16	46+304.043	C-242	RCPC	1				1520			5	
17	49+047.345	C-253	RCPC	2				910			3	
18	49+354.326	C-255	RCPC	2				910			3	
19	49+553.492	C-256										
20	52+725.833	C-271A	RCBC	1		2.0	2.0		7	7		
21	53+642.515	C-274	RCBC	2		2.0	2.0		7	7		
22	54+820	C-282A	RCBC	1		2.0	2.0		7	7		
23	55+786	Bridge 12	Bridge	1	35							
24	57+420	C-299	RCBC	1		3.0	3.0		10	10		
25	59+203	Bridge 13	Bridge	1	35							
26	59+896	Bridge 14	Bridge	1	25							
27	61+730	Bridge 15	Bridge	1	30							
28	66+550	C-342	RCBC	1		3.5	3.5		11	11		
29	69+215	Bridge 16	Bridge	1	30							
30	69+723	Bridge 17	Bridge	1	105							
31	72+563	Bridge 18	Bridge	1	30							
32	75+200	C-377B	RCBC	2		3.5	3.5		11	11		
33	76+118	C-380A	RCBC	1		2.0	2.0		7	7		
34	77+560	C-386A	RCBC	2		3.0	3.0		10	10		
35	80+900	C-401A	RCBC	1		1.0	1.0		3	3		
36	83+440	C-409A	RCBC	2		2.5	2.5		8	8		
37	86+280	C-417A	RCBC	3		3.0	3.0		10	10		
38	96+120	C-446	RCPC	1				910			3	
39	96+588	Bridge 19	Bridge	1	30							
40	97+577	Bridge 20	Bridge	1	30							
41	98+288	Bridge 21	Bridge	1	25							
42	98+639	Bridge 22	Bridge	1	30							

Table X: Details of Reinforced Concrete Pipe Culverts (RCPC)

Station	Structure Designation	Diameter (mm)	Diameter (ft)	Flowrate (cms)	Flowrate (cfs)

34+791.698	C-188	1520	5		0
45+034.217	C-235	910	3		0
46+304.043	C-242	1520	5		0
49+047.345	C-253	910	3		0
49+354.326	C-255	910	3		0
96+120	C-446	910	3		0

Table X: Details of Reinforced Concrete Box Culverts (RCBC)

Station	Structure Designation	Diameter (mm)	Diameter (ft)	Flowrate (cms)	Flowrate (cfs)
34+791.698	C-188	1520	5		0
45+034.217	C-235	910	3		0
46+304.043	C-242	1520	5		0
49+047.345	C-253	910	3		0
49+354.326	C-255	910	3		0
96+120	C-446	910	3		0

Table 3: Summary of Structure Locations

No.	Structure	Station	Sub-basins designation	No. of sub-basins
1	Bridge 1	12+460	BR1a	1
			BR1b	2
			BR1c	3
			BR1d	4
2	Bridge 2	15+597	BR2	5
3	Bridge 3*	22+787	BR3a	6
			BR3b	7
			BR3c	8
			BR3d	9
4	Bridge 4	27+495	BR4	10
5	Bridge 5	27+909	BR5	11
6	Bridge 6	28+836	BR6a	12
			BR6b	13
			BR6c	14
			BR6d	15
			BR6e	16
7	Bridge 7	30+866	BR7	17
8	Bridge 8	37+110	BR8	18
9	Bridge 9	38+541	BR9a	19
			BR9b	20
			BR9c	21
			BR9d	22
10	Bridge 10	40+748	BR10	23
11	Bridge 11	42+398	BR11	24
12	Bridge 12	55+786	BR12a	25
			BR12b	26
13	Bridge 13	59+203	BR13	27
14	Bridge 14	59+896	BR14	28
15	Bridge 15	61+730	BR15	29
16	Bridge 16	69+215	BR16	30
17	Bridge 17	69+723	BR17	31
18	Bridge 18	72+563	BR18a	32
			BR18b	33
19	Bridge 19	96+588	BR19a	34
			BR19b	35
20	Bridge 20	97+577	BR20a	36
			BR20b	37
21	Bridge 21	98+288	BR21	38
22	Bridge 22	98+639	BR22	39

**data referenced from Keshim - Faizabad Road Project Plan and Profile drawings, Jan 07.*

[redacted]

From: [redacted]
Sent: Monday, August 30, 2010 2:19 PM
To: [redacted]
Subject: FW: WO_A_0049 Bridge Assessment - Badakshan
Attachments: left abutment, look Up St.jpg; brige opening look down St.JPG; looking upstream.JPG; TO4 Bridge 12 arial.pdf; causeway.JPG; water level up stream.jpg

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From: [redacted]]
Sent: Wednesday, August 04, 2010 7:21 AM
To: [redacted]
Cc: [redacted]
Subject: RE: WO_A_0049 Bridge Assessment - Badakshan

[redacted]

From what was reported, a large wall of water (flash flood event) came down the channel. The river channel turns sharply to the left upstream of bridge causeway and bridge. The bridge was located to the far left bank (see photos). The water surged over the top of the earth embankment and hit the right abutment with sufficient force to remove the steel girders. The bridge was under construction with no concrete deck in place. The girders were washed downstream 300 meters (see one in photos). The left abutment water level was only half way up the face, by mudkmar (see photos). In brief the water speed and force did not allow it to flow around the channel curve to reach the bridge opening on the far left side, but surged over the top of the earth causeway.

Let me know if you received the reports and photos sent to your Kabul office.

The answer to the questions in red. I will ask LBG for the information.

Hydrology

Calculation and backup information of peak flow (Louis Berger). Also include methodology for determining the design rainfall in this region. I sent the hydraulic report for the bridge design. Should I send this information again?

Did peak flow calculation consider snowmelt (LB)?

Can anyone confirm if there was snow melt as part of this storm? If so, can the snow before and after the storm be quantified? This storm did not involve snow melt. I believe the drainage basin is not large enough to include the Hindu Kush mountain range to the east, which has snow cover at higher altitude.

Are there any measurements of rainfall for the storm that caused the failure? LBG has a weather station in the area, I will check if they record rainfall. LBG possible explanation for the failure was a earthen dam created by a landslide failed. The location or length of time the earthen dam was in place within the drainage area was not identified. It was raining during the time of the event.

Hydraulics

HEC-RAS input file from Louis Berger. I do not think LBG modeled the stream flow, I will ask. If not, more than likely they will not have stream cross sections. That is why I left the opportunity to get the survey done if you would like to model the bridge.

Sketch of cross section locations for the HEC-RAS file

Are there any observations of where the water surface was relative to the bridge deck during the failure? There were water marks on the upstream channel banks.

Scour

Scour calculations and HEC-RAS file used to generate the data for the calculations

Are there any observations of a scour hole forming next to the abutments? There was no scour, the flow transported sediment and deposits were up to 3-6 ft. Can get more accurate values.

Did the abutments move or fail? If I'm interpreting the photos correctly, the abutments are still in place and largely in their original position. Please confirm. The abutments did not fail, however large rocks are believed to have impacted the wingwall and caused the damage.

Photo's
Are there any photo's of the bridge taken shortly before the incident? I can find photos before the event. The bridge was under construction with only the 4 steel girder place on the abutments. There was no bridge deck.

Regards,
[redacted]
Project Manager - Highways
USAID Kabul
Office of Infrastructure, Engineering & Energy
[redacted]

This email is UNCLASSIFIED.

From: [redacted]
Sent: Wednesday, August 04, 2010 1:45 PM
To: [redacted]
Subject: FW: WO_A_0049 Bridge Assessment - Badakshan
Importance: High

[redacted],

We are in process with our investigation and report development.

Our assigned Hydraulic/Hydrology Engineer, [redacted], is requesting additional data and information as listed below.

Is there a way you can obtain this data from LB?

Regards,

[redacted]

US Contact: Tetra Tech Architects & Engineers
215 The Commons | Ithaca, NY 14850 | www.tetratechae.com

From: [redacted]
Sent: Tuesday, August 03, 2010 2:29 PM
To: [redacted]
Subject: RE: WO_A_0049 Bridge Assessment - Badakshan

Data Request

Hydrology

Calculation and backup information of peak flow (Louis Berger). Also include methodology for determining the design rainfall in this region.

Did peak flow calculation consider snowmelt (LB)?

Can anyone confirm if there was snow melt as part of this storm? If so, can the snow before and after the storm be quantified?

Are there any measurements of rainfall for the storm that caused the failure?

Hydraulics

HEC-RAS input file from Louis Berger

Sketch of cross section locations for the HEC-RAS file

Are there any observations of where the water surface was relative to the bridg deck during the failure?

Scour

Scour calculations and HEC-RAS file used to generate the data for the calculations

Are there any observations of a scour hole forming next to the abutments?

Did the abutments move or fail? If I'm interpreting the photos correctly, the abutments are still in place and largely in their original position. Please confirm.

Photo's

Are there any photo's of the bridge taken shortly before the incident?

[redacted]

From: [redacted]
Sent: Thursday, July 15, 2010 4:53 PM
To: [redacted]
Subject: Re: Tetra Tech bridge Hydraulic review

[redacted]

I would like for Tetra Tech to review the hydraulic reports and design of a bridge under construction in Badakshan Province that washed out due to flooding last month. Below is the Scope of work.

In June 2010 a bridge under construction on the USAID's Kishem to Fayzabad road project was severely damaged from a high water event. OIEE requests that a Senior Hydraulic/Hydrology Engineer perform a forensic study to determine cause. Work to include; review of design reports, construction bridge plans and other documents to determine if bridge was design to acceptable engineering methods and standards. This work may require a field visit to the site conditions and to investigate and estimate storm event upstream flow rates and cause to determine impact to bridge structure as designed. This could require survey of stream channel cross section and establish the storm high water mark. The finished report to discuss finding of review of calculations, hydraulic report, adequacy of design and determination cause of failure. The ultimate outcome is to determine if there is an error in design.

OIEE will provide all the documentation mentioned above.   Tetra Tech should request additional information as required to perform analysis and to propose method to perform work.

Regards,

[redacted]
Project Manager - Highways
USAID Kabul
Office of Infrastructure, Engineering & Energy
[redacted]

This email is UNCLASSIFIED.

USAID/Afghanistan.
U.S. Embassy Cafe Compound
Great Masood Road
Kabul, Afghanistan
Tel: 202.216.6288
http://afghanistan.usaid.gov