MINISTRY IN CHARGE OF EMERGENCY MANAGEMENT (MINEMA)

DRAFT FINAL REPORT FOR FEASIBILITY STUDY; VOLUME 4- (DRAINAGE DESIGN SECTION) FOR KARONGI DISTRICT

BEZA CONSULTING ENGINEERS PLC
In Joint Venture with
ASTRIK INTERNATIONAL LTD

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1. INTRODUCTION

This report covers the hydrological and hydraulic study prepared by the consultant for the rehabilitation and widening of Kibuye-Gisovu-Uwisumo with the spur to the refugee camp road (43 km). This report aims to:

- The diagnosis of the existing Hydraulic Structures: We distinguish between two types of Hydraulic Structures, that is Longitudinal Drainage Hydraulic Structures and Crossing Hydraulic Structures;
- The determination of flood flows for watersheds that discharge in the Road and for watersheds that are drained by natural flows crossing the Road of the Study area;
- Estimating the Hydraulic capacity of all Hydraulic Structures using the discharge obtained from the Catchment.

2. THE DIAGNOSIS OF THE EXISTING HYDRAULIC STRUCTURES

The existing transverse hydraulic structures are either single, circular reinforced concrete pipe culverts or masonry box culverts with timber decks.

Their conditions are generally NOT SATISFYING: some nozzles are partially or completely clogged, some others are partially or completely overgrown by vegetation, and some others have damaged Head Walls.

The types of deterioration of hydraulic structures have been diagnosed are:

(i) *Good Conditions*: The hydraulic structure has a good structure that won't require a specific intervention;

(ii) *Obscuration: Accumulation of deposits and materials in the nozzle: The hydraulic structure is either completely clogged (than 100 %) or partially clogged (than: 10%, 20%, 30%, 50%.);*

(iii) *Overgrown with vegetation: The hydraulic structure (mainly the downstream part) is surrounded by vegetation that will require cleaning and recalibration;*

(iv) *Deterioration of the Headwalls: The upstream catch basin or the simple headwalls are partially or completely damaged.*

The Longitudinal drainage structures that have been localized along the road are: The V-shaped ditches in concrete blocks and the uncoated ditches (earthen ditches) that are generally overgrown by vegetation or eroded;

Irrespective of the types and the levels of deterioration of drainage structures it is expected that they will be demolished (with possible usage) during the road widening.

Briefly, most existing structures (as listed in the diagnosis report) were silted. In addition, the structures which are of a width less than the new roadway width of 7 meters plus shoulders, with structures of the same width, allowing additional width for the placement of structure rails and/or headwalls were replaced. We give below a sample Diagnosis of the existing hydraulic structures of the road under study and **the detailed diagnosis report is presented in Annex C.**

2.1 Drainage situation and recommended intervention

Table 1 Sample Diagnosis of all the existing hydraulic structures of Kibuye-Gisovu-Uwisumo road

No.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Problem	Inlet Photo	Outlet Photo	Remark
9	2+980	PC	1	100	Right	• 70 % of the pipe clogged with sediment. • Channelization and protection work at the outlet required. • Silt removal.			• To be replaced
10	3+370	PC	1	80	Right	• Jointing problem. • Outlet protection required. • Silt removal.			• To be replaced

No.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Problem	Inlet Photo	Outlet Photo	Remark
11	3+680	PC	1	80	Right	• Vegetation removal. • Jointing problem. • Paved water way clearing. • Pipe bed silt cleaning. • Headwall failure.			• To be replaced
12	4+390	PC	1	80	Left	• The pipe is clogged with vegetation. • Paved water way clearing. • Pipe bed silt cleaning.			• To be replaced

No.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Problem	Inlet Photo	Outlet Photo	Remark
13	4+390	PC	1	100	Left	• Vegetation removal. • Paved water way clearing.			• To be replaced
14	4+710	PC	1	80	Left	• Vegetation removal. • Paved water way clearing. • Headwall failure.			• To be replaced

No.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Problem	Inlet Photo	Outlet Photo	Remark
16	5+550	PC	1	80	Left	• outlet wall failure. • Clogged up to 70% at the outlet. • Silt removal. • Outlet protection works required.			• To be replaced
17	5+110	PC	1	80	Left	• Jointing problem. • Paved water way clearing. • Pipe bed silt cleaning. • Headwall failure.			• To be replaced

No.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Problem	Inlet Photo	Outlet Photo	Remark
20	5+550	PC	1	80	Left	• Vegetation removal. • Jointing problem. • Paved water way clearing.			• To be replaced
21	5+950	PC	1	80	Left	• Jointing problem. • Paved water way clearing. • Headwall failure. • Outlet apron and cascade failure			• To be replaced

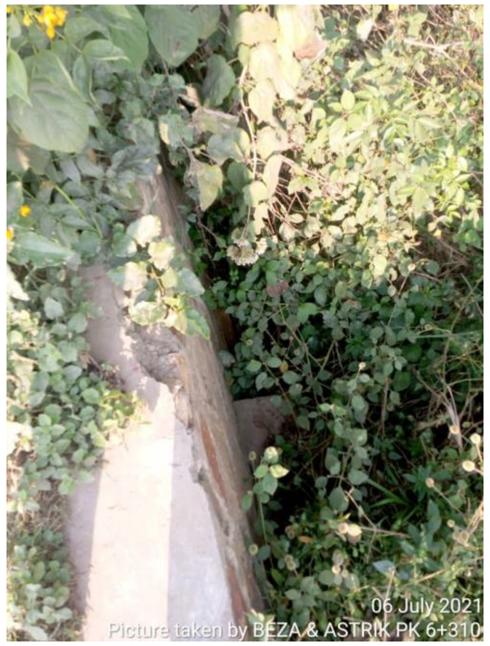
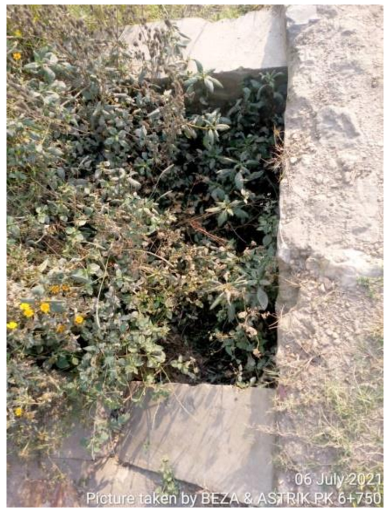
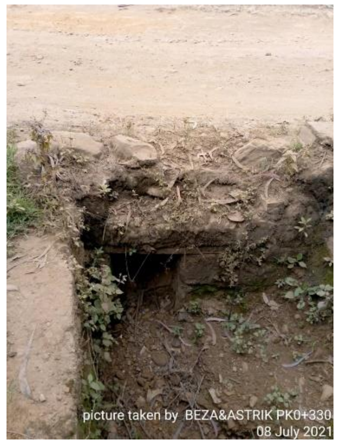
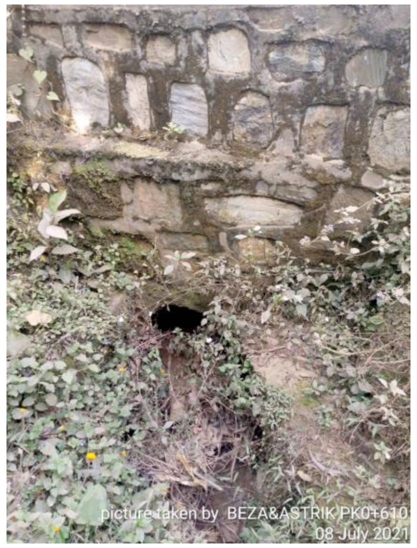
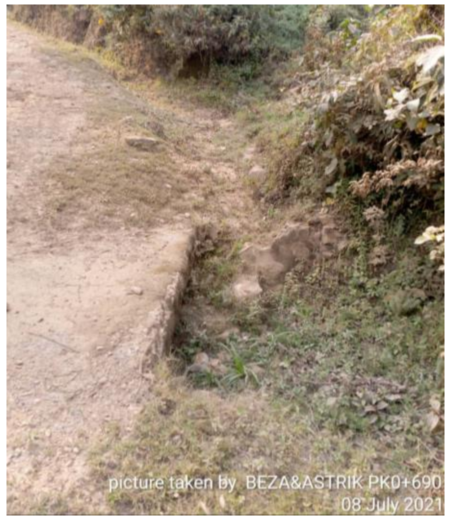
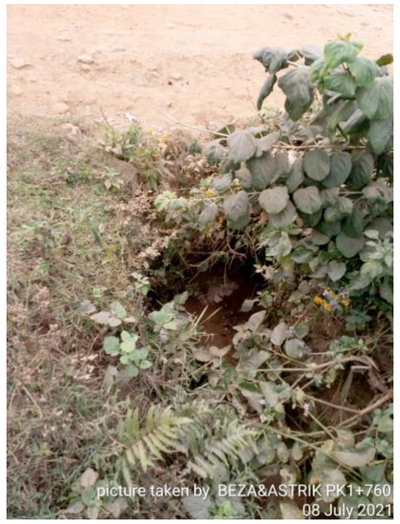
No.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Problem	Inlet Photo	Outlet Photo	Remark
22	6+310	PC	1	80	Left	• The pipe is fully clogged. • Outlet protection works required.			• To be replaced
23	6+750	PC	1	80	Left	• The pipe is fully clogged. • Outlet protection works required. • Vegetation removal. • Not functional • Pipe bed silt cleaning. • Headwall failure.			• To be replaced

Table 2 :Sample Diagnosis of all the existing hydraulic structures of access Road to KIZIBA refugee camp

o.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Remark	Inlet Photo	Outlet Photo	Remark

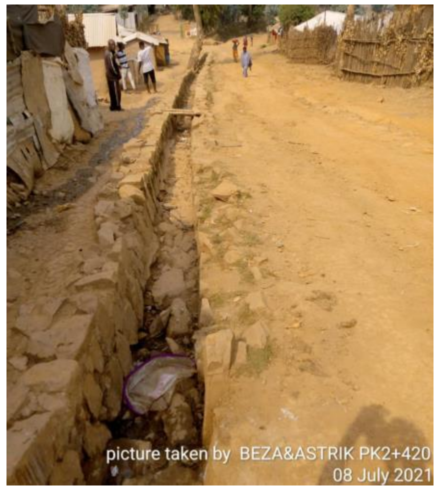
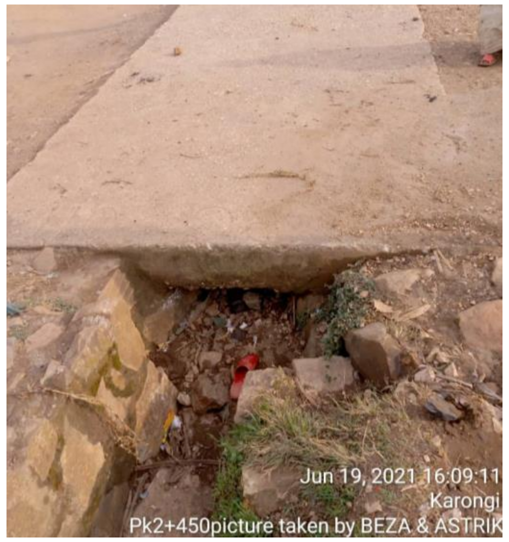
o.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Remark	Inlet Photo	Outlet Photo	Remark
1	0+330	TS	1	50*40	Right	• The drainage is fully clogged with sediments • It is small in size • Inlet construction required • Outlet protection works required			• To be replaced
2	0+375	PC	1	RCPC Dia 60	Right	• The pipe is clogged with debris at inlet. • Outlet protection works required			• To be replaced

o.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Remark	Inlet Photo	Outlet Photo	Remark
3	0+610	PC	1	RCPCDia 60	Right	• The pipe is clogged with sediments and vegetation both at inlet and outlet. • Vegetation removal at both ends. • Pipe bed silt cleaning.			• To be replaced
4	0+690	CS	1	100*40	Right	• The crossing ditch is clogged. • Outlet protection works required. • Vegetation removal at both ends. • Paved water way clearing.			• To be replaced

o.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Remark	Inlet Photo	Outlet Photo	Remark
6	1+760	PC	1	60	Right	• The pipe is clogged at outlet • Inlet and outlet protection works required			• To be replaced
7	1+880	PC	1	60	Right	• The pipe is clogged at outlet • Inlet and outlet protection works required • Wing walls & headwalls failure and improper construction. • Silt deposited at outlet bed			• To be replaced

o.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Remark	Inlet Photo	Outlet Photo	Remark
8	2+095	TS	1	50*40	Right	• Small in size • Timber slabs failure • The crossing ditch is clogged with debris and silt. • Outlet protection works required.			• To be replaced
9	2+140	PC	1	60	Right	• The pipe is clogged with silt and vegetation • Outlet protection works required • Water way clearing required			• To be replaced

o.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Remark	Inlet Photo	Outlet Photo	Remark
10	2+350	TS	1	50*40	Right	• Small in size • Timber slabs failure • The crossing ditch is clogged with debris and silt. • Outlet protection works required.			• To be replaced

No.	Station	Type	No. opening	Opening Size(cm)	Flow Direction	Problem	Inlet Photo	Outlet Photo	Remark
11	2+420	MD	1	40*30		• Pavement failure • Not covered • Small in size which leads to overflow towards carriageway			• To be replaced
12	2+450	CS	1	Not det.		• Small in size • The crossing ditch is fully clogged with sediments • Silt removal.			• To be replaced
13	2+520	PC	1	60	Right	• Clogged up to 60% at the outlet. • Silt removal. • Outlet protection works required.			• To be replaced

3. ESTIMATING MAXIMUM FLOW IN A WATERCOURSE

In determination of flood flows for watersheds that discharge in the Road and for watersheds that are drained by natural flows crossing the Road of the Study area, the Rational Method – for estimating peak discharges for small drainage areas up to about100 hectares was used in combination with the Direct observation of the size of watercourse, erosion and debris on the banks, history and local knowledge; and replicating successful practice.

3.1 THE RATIONAL METHOD

The flow of water in a channel, **Q(m³/s)**, is calculated using the following formula:

Q = 0.278 x C x I x A

Where:

C = the catchment run-off coefficient

I = the intensity of the rainfall (mm/hour) for the Tc (time of concentration of the catchment area)

A = the area of the catchment (km^2)

3.1.1 The Catchment Run-off Coefficient "C"

The Catchment Run-off Coefficient "C" is obtained from Table below:

Figure 1 : Runoff coefficient Values

C_T (slope-topography		C_S (soils)		C_V (vegetation	
Very flat (<1%)	0.03	Sand and gravel	0.04	Forest	0.04
Undulating (1-5%)	0.08	Sandy clays	0.08	Farmland	0.11
Hilly (5-10%)	0.16	Clay and loam	0.16	Grassland	0.21
Mountainous (>10%)	0.26	Sheet rock	0.26	No vegetation	0.28
Runoff coefficient $C = C_T + C_S + C_V$					

3.1.2 Hydrological analysis: the intensity of the rainfall (mm/hour)

3.1.2.1 Climate Regime of Rwanda

The climate study aims to analyse the climatic parameters that determine runoff and flood genesis of watersheds. Generally, weather conditions play an important role in the hydrological response of watersheds (or catchments). Indeed, rainfall acts directly in the hydrological behaviour of watersheds.

The climate is generally equatorial, which is extensively modified by the relief, hence a temperate climate with rains and moderate temperatures. Temperatures show little variation throughout the year. The rainfall year has two rainy seasons and two dry seasons:

- Great rainy season: from March to May, it concentrates 40% of the total annual rainfall over 3months;
- Great dry season: from June to September;
- Small rainy season: from mid-September to mid-December (27% of rainfall);
- Small dry season: from mid-December to February (scarce rainfall: rainfall decreases but does not disappear).

3.1.2.2 Insight into the factors that control the Rwandan Climate

The main factor that controls the rainy seasons of Rwanda is the ZICT (Inter tropical Convergence Zone). It is characterized by low pressure, the humidity and the maximum wind convergence. It crosses Rwanda twice a year and it determines two rainy seasons: from mid-September to mid - December and from March to May. The ZICT is in turn controlled by the position and intensity of the subtropical anticyclones such as Saint Helena, the Azores and back of Arabia.

- During the small rainy season from mid - September to mid -December, the prevailing winds are from the Northeast and the contribution of moisture from the masses moistened by the Indian Ocean and Lake Victoria;
- The following dry season (mid- December to late February) is characterized by the penetration of the East African air masses dry and cold from the Dorsal Arabia. However, the moderating effect of Lake Victoria and the diversity of terrain Rwanda maintains some rainfall in the country;
- During the Great rainy season from March to May, Rwanda is influenced by a front located between the dry winds of the South -east and South-west winds that carry moisture from the South Atlantic via by the Congolese watershed;
- Finally, during the dry season from June to mid-September, the air masses of Southeast winds arriving in Rwanda are drained by the continental crossing Tanzania and having a divergence in the lower layers. These conditions are unfavourable for rainfall.

3.1.2.3 Rainfall analysis

3.1.2.3.1 Monthly Rainfall Data

Rainfall data concerning the study area are derived from Rubengera Metrological station, with coordinate: Latitude: -2.07, Longitude: 29.41 and elevation of 1700 m. This station will be used for the Hydrological Model of the watersheds. It is the closest and it has got daily rainfall data from the year **1981 up to year 2020 i.e., 40 years.**

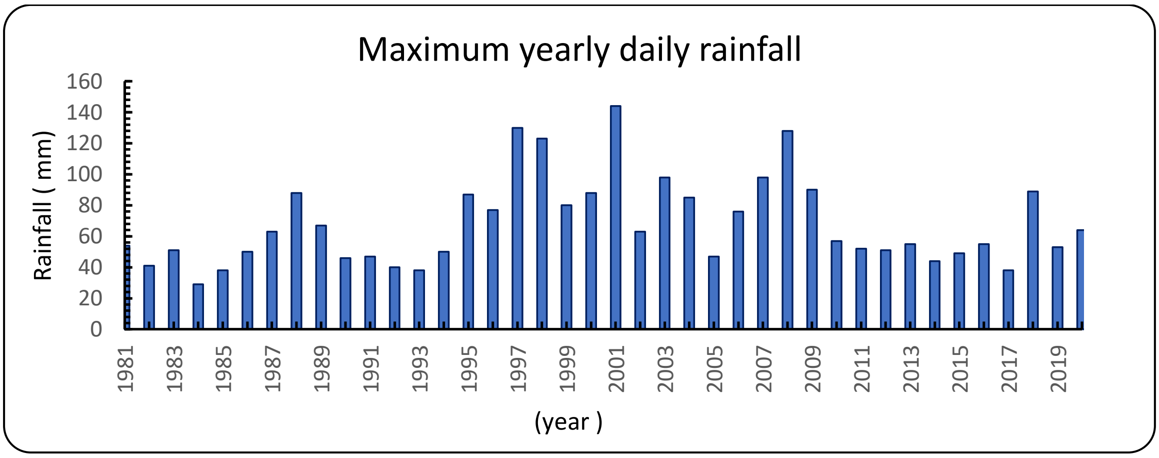
The first step in the analysis was to extract the maximum daily storm events for each year and the results are presented in the following table.

Table 3: Maximum daily rainfall at Rubengera Meteo station

Year	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Max daily rain fall (mm)	54	41	51	29	38	50	63	88	67	46	47	40	38	50
Year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	
Max daily rain fall (mm)	87	77	130	123	80	88	144	63	98	85	47	76	98	
Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	
Max daily rain fall (mm)	128	90	57	52	51	55	44	49	55	38	89	53	64	

Plotting the above data and according with the related figure below, the minimum rainfall event occurred in 1984 with 29mm/day, and the maximum rainfall event occurred in 2001with 144 mm/day.

Figure 2: Maximum daily rainfall

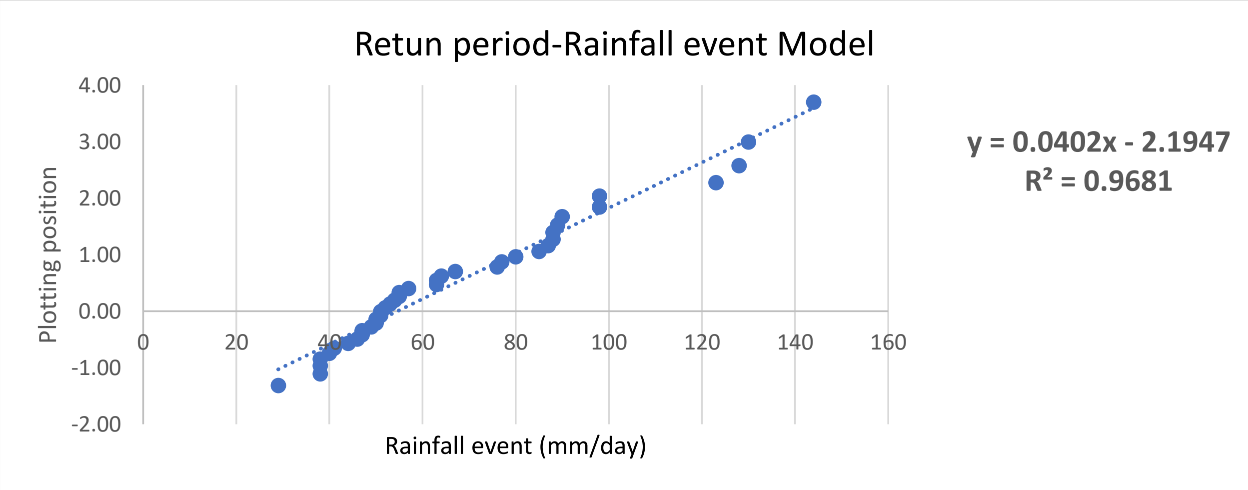


3.1.2.3.2 Frequency analysis and computation of design rainfall intensity

This analysis helps to relate the magnitude of extreme hydrological events with their number of occurrences such that their chance of occurrence with time can be predicted successfully. Frequent and magnitude of an event are inversely related. This means that, in rainfall context, low magnitude may lead to drought and higher magnitude may lead to flooding. Therefore, the rainfall data could be assessed to relate the magnitude and frequency of an event through the use of probability distribution.

In this design, we have used the method of **Gumble extreme model since extreme rainfall is likely to cause floods.** This extreme annual rainfall analysis will determine the return period of rainfall event and the output from return period calculation will help to understand the "exceedance probability" of a given floods. The resulting model is mathematically presented here below.

Figure 3 :Model for Exceedence Probability



The plotting position is plotted against the annual maximum daily rainfall and linear trend line is derived to get Y formula: **Y= 0.0402 X -2.1947.** Note: The model is reliable at 96.81% in estimating the rainfall event given a Return period.

Table 4 : Rainfall intensity at 100, 50, 25, and 10 years return period

Return Period T=1/(1-PL)	**Left side probability (PL)**	**Y (Plotting position) Y=-LN(-LN (PL))**	**Rainfall event (mm/day)**	**Intensity (mm/h)**
100	0.99	4.60	169.03	82.53
50	0.98	3.90	151.66	74.05
25	0.96	3.20	134.16	65.51
10	0.9	2.25	110.57	53.99

The recommended Design Frequency. The Desirable design storm frequencies are as follows:

Ditches and road surface	1 in 10 years
Pipe culverts	1 in 10 years
Box culverts	1 in 25 years
Bridges	1 in 50 years

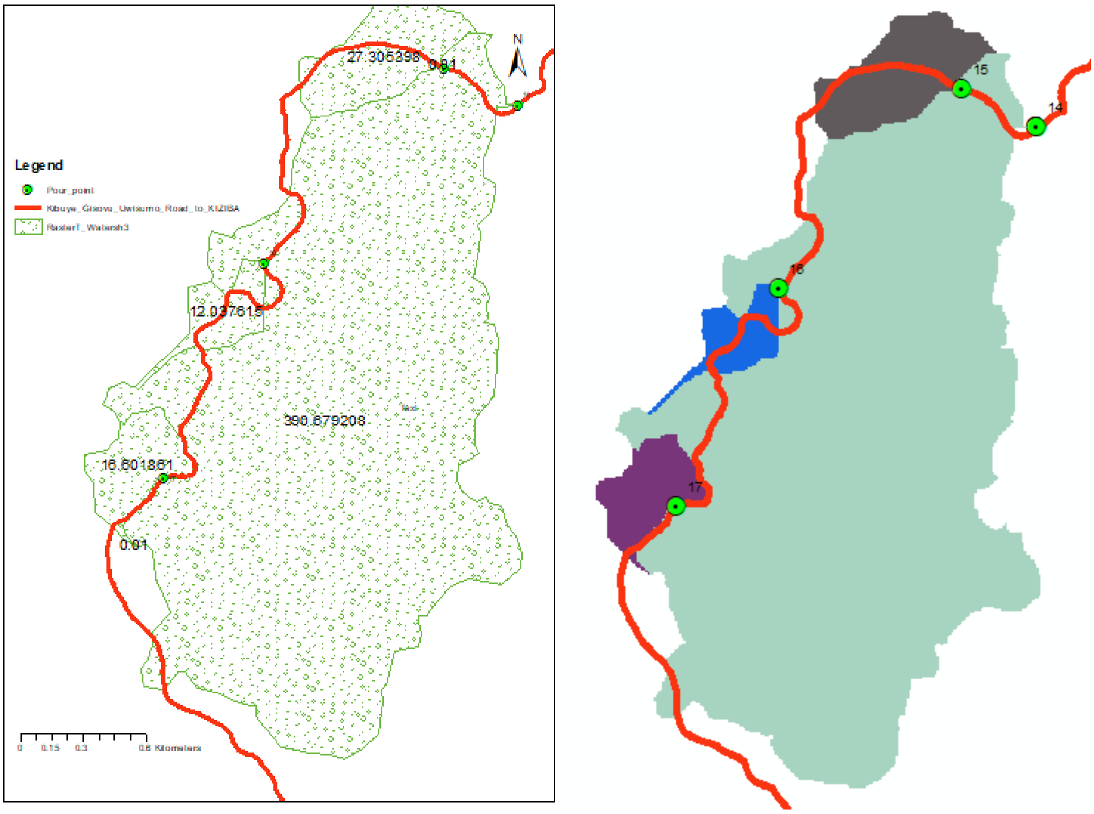
3.1.2.4 Delineation of catchment areas (A)

The catchment areas were delineated using a digital elevation model (DEM) and the Arc GIS Spatial Analyst Extension. Briefly, the delineation was carried into the following steps:

- Fill the DEM to remove all the sinks. When a sink is filled, the boundaries of the filled area create new sinks that need to be filled.
- Flow direction: to determine the slope direction at each pixel
- Flow accumulation: to determine the number of up gradient pixels that slope toward each point in the DEM grid.
- Add a point that represents the outlet of the watershed
- Under hydrology in the Spatial Analyst Tools, select Watershed. You will get new layer that is the shape of the watershed
- Finally convert this layer of watershed to a polygon and this will enable you to visualize the catchment areas

From our case study, the obtained typical catchment area is presented in the figure below:

Figure 4 :Typical delineated catchment



Almost all catchments areas are small (10 hectares or less), and the flow can be handled using pipe culverts. This is because the road follows a ridgeline alignment for most of its alignment. Table below gives the major catchment areas for Kibuye-Gisovu -Uwisumo road.

Table 5: Major catchment area for Kibuye-Gisovu -Uwisumo road

ID	Chainage	Area_Ha
1	0+280	18.312547
2	0+780	23.087176
3	2+940	33.182233
4	3+780	30.060383
5	6+240	13.252517
6	7+210	24.129873
7	0+150 (Spur to refugee camp)	29.276406
8	18+185	13.188817
9	13+570	17.467941
10	16+840	21.356465
11	17+310	12.667956
12	21+100	21.612863
13	22+560	27.305398
17	**24+820**	**390.67921**
18	25+300	12.007604
19	27+110	64.051006
20	28+790	21.861007
21	33+950	26.806867
23	**40+085**	**260.17853**
24	41+450	53.645277

3.1.2.5 Major Runoff flow of the Project Road

The peak runoff flow results obtained for measurable catchments are presented in Table below.

Table 6: Peak runoff flow results

ID	Chainage	Q (m^3/s)
1	0+280	2.44
2	0+780	3.07
3	2+940	4.42
4	3+780	4
5	6+240	1.76
6	7+210	3.21
7	**0+150 (Spur to refugee camp)**	**3.9**
8	18+185	1.76
9	13+570	2.32
10	16+840	2.84
11	17+310	1.69
12	21+100	2.88
13	22+560	3.63
17	**24+820**	**51.99**

18	25+300	1.6
19	27+110	8.52
20	28+790	2.91
21	33+950	3.57
23	**40+085**	**34.62**
24	41+450	7.14

According to the above table, there are two important catchments having a **highest discharge above 34 cum/s.**

3.2 Design of hydraulic structures according to the pick discharge

The consultant selected Reinforced Concrete Pipe and Box Culverts.

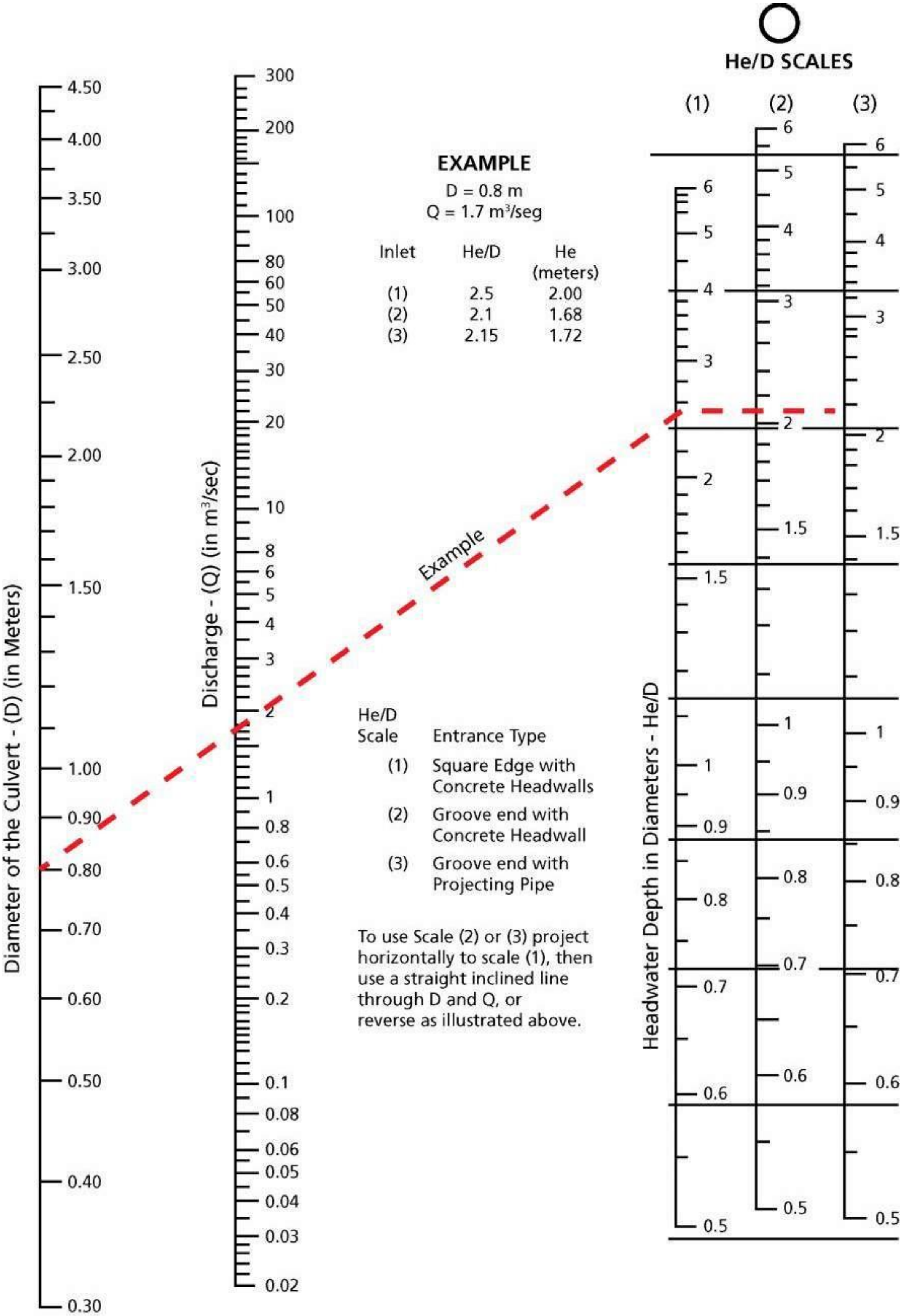
The required size of a culvert opening is estimated using the **monographs** in Figure 5 for concrete pipes and Figure 6 for concrete box culverts. These figures apply to culverts with inlet control where there is no restriction to the downstream flow of the water.

The monographs are used by identifying the value for the flow of water generated by the design storm on the middle scale and drawing a line from that point across to the left-hand scale of the three scales on the right labelled H/D. These scales are for the three types of inlets shown on the monographs. H/D is the ratio of the maximum head of water to the diameter of the culvert opening that is required to discharge the design flow through the culvert. In general, risks are reduced if the maximum flow does not cause the culvert to run at maximum capacity except for the design storm. Finally, the line is extended to the left to intersect the line labelled "Diameter of Culvert (D) in metres". The culvert size obtained from the monograph will probably not be one of the standard sizes that are available, in this case the next higher available size were chosen or the nearest available size if the difference is small (<10 % in diameter).

A pipe culvert should have a minimum cover from the top of the culvert to the finish grade line of 500mm, inclusive of embankment and wearing course.

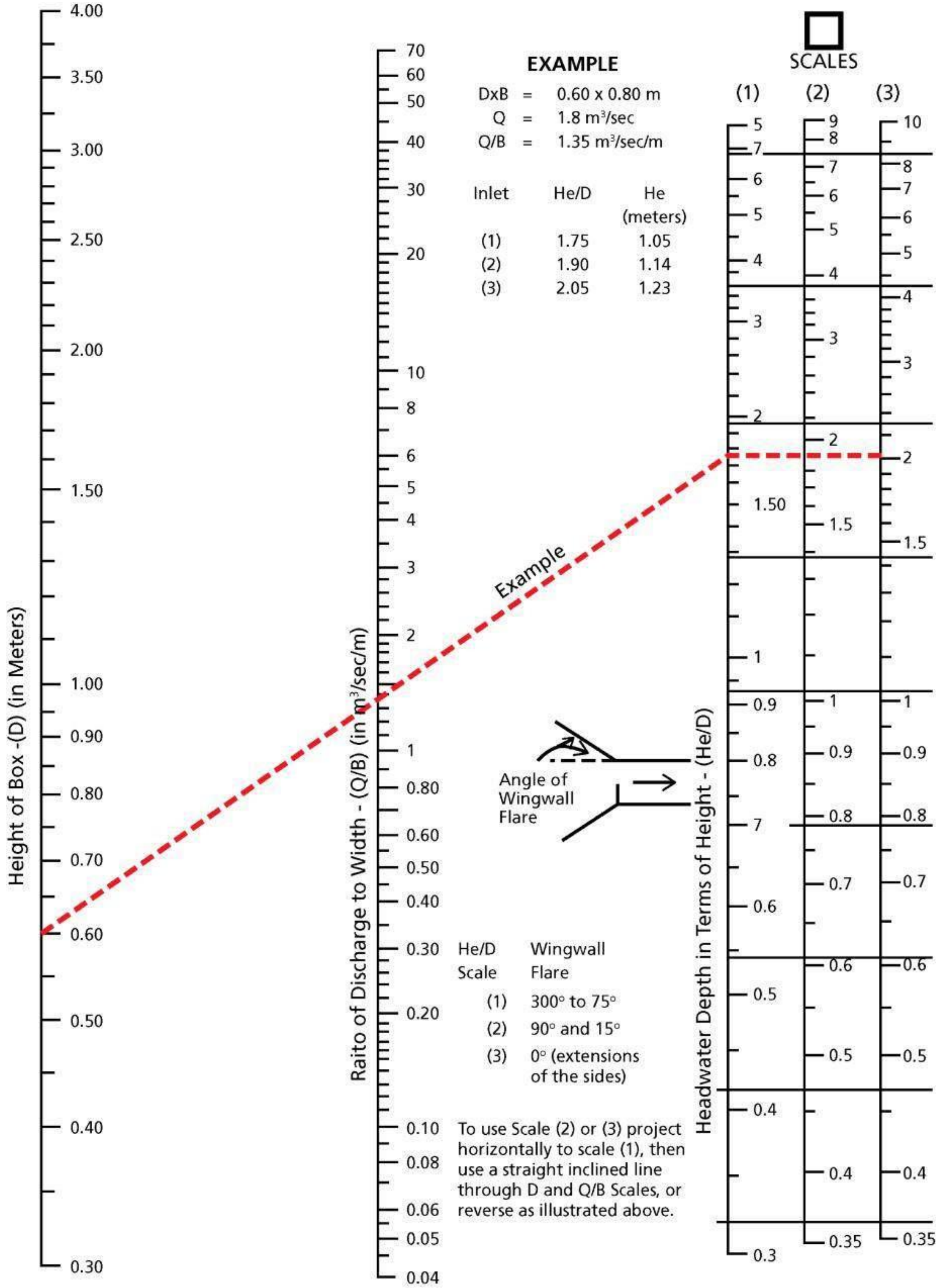
For example, in developing the data required as shown in Figure 4, assume a pipe culvert is needed to accommodate a Q_{10} peak flood flow of 4.4m^3/s. A 1000mm dia. pipe culvert is initially selected. While the minimum cover over the pipe is 500mm to the road surface, it is advisable to keep the wearing course from being saturated. The thickness of the pipe wall is 114mm, so the maximum headwater is 114mm + 500mm, or 614mm. This gives a HW/D of (614+1000)/1000, or 1.61. If the entrance is a square end with a headwall, the pipe can accommodate a flood flow of 2.2m^3/s, and a double-barreled pipe culvert can handle the flood flow of 4.4 m^3/s.

Figure 5 : Headwater depth and capacity for concrete pipe culverts with inlet control



Source: FHWA (2012).

Figure 6 : Headwater depth and capacity for concrete box culverts with inlet control



Source: FHWA (2012)

To minimize the effect of potential silting and deposition of debris in the culvert, **the slope/fall should be 3%-5%.**

4. SELECTED STRUCTURES

The selection of the size of the structure was governed not only by the flow, but by other considerations including proximity to the flood plain; ease of access for driveways and connecting roads and earthwork quantities.

For instance, a single-barreled box culvert with dimensions of 3m width by 3m height might be capable of handling the flow at a particular location, but would entail a high embankment fill and may present difficulties with access for adjoining roads and driveways. If it is deemed better to set the height at a workable 1.5 meters; this would necessitate the construction of a multi-barreled structure: eg- a triple-barreled 1.8mW x 1.5mH box culvert.

As this road follows a ridgeline alignment for most of its alignment, almost all catchment areas are small (8 hectares or less) and the flow can be handled through the use of pipe culverts. For catchment areas with Q_{10} flows of less than 3 m^3/s, a single barreled 1000 mmØ pipe culvert can handle the flow. Flows of up to 6 m^3/s are addressed by installing more than one pipe cross drain dividing the flow into smaller areas, especially at intervals down a gradient.

However, the following text addresses only those larger flow structures where the flow could not be addressed by a single pipe culverts of 1000 mm dia:

Table 7 : List of Major Structures for Kibuye-Karongi-Rushishi-Gisovu-Wisumo Road

ID	Chainage	Structures
1	0+280	1000 Dia_RCPC
2	0+780	1000 Dia_RCPC
3	2+940	2*800 Dia*RCPC
4	3+780	2*80Dia*RCPC
5	6+240	1000 Dia_RCPC
6	7+210	2*800 Dia*RCPC
7	0+150 (Spur)	2*1000Dia*RCPC
8	18+185	1000 Dia_RCPC
9	13+570	1000 Dia_RCPC
10	16+840	2*1000 DiasRCPC
11	17+310	1000 Dia_RCPC
12	21+100	1000 Dia_RCPC
13	22+560	2*80Dia*RCPC
17	**24+820**	**1RCBC_2.5mW*3.25mH**
18	25+300	1000 Dia_RCPC
19	27+110	1RCPC_1.5W*2H
20	28+790	1000 Dia_RCPC
21	33+950	1000 Dia_RCPC
23	**40+085**	**1RCBC_2.5mW*3.25mH**
24	41+450	RCBC_1.5W*2H

RCBC: Reinforced concrete Box culvert
RCPC: Reinforced pipe culvert

*Most existing structures **(as listed in the diagnosis report)** were silted. In all instances, we were also concerned with replacing structures which were of a width less than the new roadway width of 7 meters, with structures of the same width, allowing an additional width for the placement of structure rails and/or headwalls.*

Verification of Stream Channel Peak Flow Using Manning's Equation: It is generally advisable to check the flood flow values obtained through the use of the Rational Method against flood flow values obtained from historic flood height observations obtained from local residents and used in Manning's Equation to obtain flood flows. Before the selection of the structures, a factor of safety of 1.3 was applied to the obtain flood flows to ensure that the actual drainage structures discharge capacity is greater than the **Stream Channel Peak Flow obtained using Manning's Equation.** The verified list of cross drainages structures are presented here below:

Table 8: List of Diameter 80cm pipes

LOCATION OF 80DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD		LOCATION OF 80DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD		LOCATION OF 80DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD	
ID	**Chainage**	**ID**	**Chainage**	**ID**	**Chainage**
1	PK 18+350	22	PK 23+980	44	PK 28+960
2	PK 18+550	23	PK 24+100	45	PK 29+020
3	PK 18+780	24	PK 24+500	46	PK 29+130
4	PK 19+070	25	PK 24+990	47	PK 29+290
5	PK 19+280	26	PK 25+210	48	PK 29+380
6	PK 19+700	27	PK 25+580	49	PK 29+580
7	PK 20+100	28	PK 26+140	50	PK 29+740
8	PK 20+800	29	PK 26+370	51	PK 29+860
9	PK 20+980	30	PK 26+410	52	PK 30+000
10	PK 21+150	31	PK 26+580	53	PK 30+195
11	PK 21+250	32	PK 26+820	54	PK 30+300
12	PK 21+300	33	PK 26+960	55	PK 30+430
13	PK 21+290	34	PK 27+040	56	PK 30+670
14	PK 21+850	35	PK 27+310	57	PK 30+810
15	PK 22+000	36	PK 27+400	58	PK 31+095
16	PK 22+350	37	PK 27+270	59	PK 31+195
17	PK 22+700 (Double)	38	PK 27+660	60	PK 31+430
18	PK 22+950	39	PK 28+080	61	PK 31+595
19	PK 23+180	40	PK 28+330	62	PK 31+960
20	PK 23+540	41	PK 28+540	63	PK 32+200
21	PK 23+890	42	PK 28+750	64	PK 32+340
		43	PK 28+890	65	PK 32+450

LOCATION OF 80DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD	
ID	**Chainage**
66	PK 32+800
67	PK 33+080
68	PK 33+130
69	PK 33+370
70	PK 33+480
71	PK 33+595
72	PK 33+660
73	PK 33+880
74	PK 33+990
75	PK 34+140
76	PK 35+500
77	PK 36+060
78	PK 37+220
79	PK 37+450
80	PK 37+800
81	PK 38+600
82	PK 39+060
83	PK39+250

LOCATION OF 80DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD	
ACCESS ROAD TO KIZIBA REFUGEE CAMP	
ID	**Chainage**
84	PK 0+150 (Double)
85	PK 0+330
86	PK 0+610
87	PK 0+690
88	PK 1+300
89	PK 1+760
90	PK 1+880
91	PK 2+095
92	PK 2+140
93	PK 2+350
94	PK 2+520
JUNCTION TO GISOVU TEA FACTORY	
95	PK 0+200
96	PK 0+300
97	PK 0+600
98	PK 0+ 750

Table 9: List of Diameter 100cm pipes

LOCATION OF 100 DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD	
ID	CHAINAGE
1	PK 0+000
2	PK 0+150
3	PK 0+460
4	PK 0+640
5	PK 0+710
6	PK 0+800
7	PK 1+050
8	PK 1+450
9	PK 1+550
10	PK 1+780
11	PK 2+060
12	PK 2+172
13	PK 2+300
14	PK 2+760
15	PK 2+980 (Double)
16	PK 3+180
17	PK 3+370 (Double)
18	PK 3+580
19	PK 3+680
20	PK 4+ 390
21	PK 4+ 710
22	PK 4+850
23	PK 5+110
24	PK 5+260
25	PK 5+520
26	PK 5+550
27	PK 5+730
28	PK 5+950

LOCATION OF 100 DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD	
ID	CHAINAGE
29	PK 6+115
30	PK 6+310
31	PK 6+750
32	PK 6+890
33	PK 7+050
34	PK 7+240 (Double)
35	PK 7+400
36	PK 7+700
37	PK 7+800
38	PK 8+360
39	PK 8+890
40	PK 9+020
41	PK 9+110
42	PK 9+415
43	PK 9+505
44	PK 9+730
45	PK 9+990
46	PK 10+110
47	PK 10+260
48	PK 10 +410
49	PK 10+605
50	PK 10+720
51	PK 10+900
52	PK 11+030
53	PK 11+330
54	PK 11+430
55	PK 11+770
56	PK 11+885

LOCATION OF 100 DIA RCPC FOR KIBUYE GISOVU-UWISUMO ROAD	
ID	CHAINAGE
57	PK 12+ 200
58	PK 12+280
59	PK 12+ 510
60	PK 12+750
61	PK 12+920
62	PK 13+250
63	PK 13+380
64	PK 13+550
65	PK 13+780
66	PK 14+260
67	PK 14+520
68	PK 14+710
69	PK 14+880
70	PK 15+220
71	PK 15+400
72	PK 15+710
73	PK 15+870
74	PK 16+040
75	PK 16+210
76	PK 16+430
77	PK 16+600
78	PK 16+725
79	PK 16+910
80	PK 17+090
81	PK 17+200
82	PK 17+380
83	PK 17+650

Table 10: List of Reinforced Concrete Box Culvert

LOCATION OF RCBC FOR KIBUYE GISOVU-UWISUMO ROAD		
ID	Chainage	Dimensions
1	24+820	SINGLE BARREL 1RCBC_2.5mW*3.25mH
2	27+110	SINGLE BARREL 1RCBC_1.5W*2H
3	40+085	SINGLE BARREL 1RCBC_2.5mW*3.25mH

4	41+450	SINGLE BARREL RCBC_1.5W*2H

RCBC: Reinforced concrete Box culvert
RCPC: Reinforced pipe culvert

5. Side Ditches

Existing masonry ditches: Irrespective of the conditions of existing masonry ditches (good to poor condition) conditions, they will be demolished in order to achieve the required paved way width of 7 m and shoulders (min 3 m) and new longitudinal drainages will be constructed.

Dimensions of new Ditches. The intent is for ditches at all gradients to be paved at bottom using concrete to limit the existing erosion problem. The longitudinal ditches are provided on one side for the cut slope side, on both sides in centers or as the terrains dictates where they will be covered, and serve as walkways.

Figure 7 : Typical drawings of masonry ditches

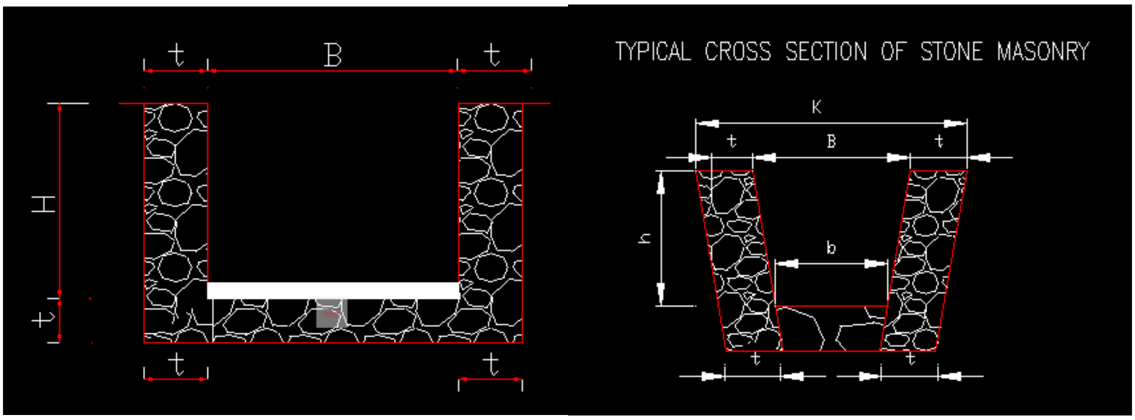


Table 11 : Dimensions of typical masonry channels

Types of ditch section	B (m)	b(m)	h(m)	t(m)
Trapezoidal TYPE 1	0.80	0.40	0.60	0.3
Trapezoidal TYPE 2	0.80	0.50	0.60	0.3
Trapezoidal TYPE 3	0.80	0.50	0.70	0.3
Rectangular TYPE 1	0.70	-	0.70	0.4
Rectangular TYPE 2	0.80	-	0.80	0.4
Rectangular TYPE 3	0.80	-	0.80	0.4
Rectangular TYPE 4	1.00	-	1.00	0.4

The road follows a ridgeline alignment for most of its alignment which is confirmed by very small sub-catchments that resulted into Sides ditches TYPE1 80*60*40 for one side of the road. Table below gives the chainages for Kibuye-Gisovu-Uwisumo road where masonry ditches will be provided on both sides of the road. The designed masonry ditches corresponding to the runoff flow of the sub-catchments is presented here below.

Table 12: Masonry ditches listing

SECTIONS WITH MASONRY DITCHES ON BOTH SIDES			
ID	**Chainage**	**Length (m)**	**Ditch dimensions**
1	PK 8+890-9+560	670	TYPE 3 80*70*50
2	PK 11+885-12+280	395	TYPE3 80*70*50
3	PK 12+280-12+510	230	TYPE3 80*70*50
4	PK 12+510-12+920	410	TYPE3 80*70*50
1	PK 14+000-14+200	200	TYPE1 80*60*40
2	PK 15+400-12+710	2,690	TYPE1 80*60*40
4	PK 16+430-16+600	170	TYPE1 80*60*40
5	PK 16+910- 17+200	290	TYPE1 80*60*40
7	PK 17+760-17+830	70	TYPE1 80*60*40
5	PK 17+900- 18+550	650	TYPE3 80*70*50
8	PK 18+960-19+130	170	TYPE1 80*60*40
7	PK 19+900-22+650	2,750	TYPE3 80*70*50
8	PK 22+780-23+050	270	TYPE3 80*70*50
9	PK 23+180-23+490	310	TYPE3 80*70*50
10	PK 23+750-24+100	350	TYPE3 80*70*50
11	PK 24+900-25+210	310	TYPE3 80*70*50
12	PK 25+210-25+580	370	TYPE3 80*70*50
11	PK 26+480-26+630	150	TYPE1 80*60*40
12	PK 27+400-27+590	190	TYPE1 80*60*40
13	PK 27+660-27+880	220	TYPE1 80*60*40
14	PK 28+000-28+150	150	TYPE1 80*60*40
15	PK 28+200-28+330	130	TYPE1 80*60*40
13	PK 29+100-30+000	900	TYPE3 80*70*50
16	PK 30+000-30+120	120	TYPE1 80*60*40
17	PK 30+430-30+660	230	TYPE1 80*60*40
18	PK 30+810-31+000	190	TYPE1 80*60*40
14	PK 31+000-31+900	900	TYPE3 80*70*50
19	PK 34+010-34+700	690	TYPE1 80*60*40
16	PK 37+450-37+650	200	TYPE3 80*70*50
17	PK 38+000-38+250	250	TYPE3 80*70*50
18	PK 38+420-39+060	640	TYPE3 80*70*50

6. Outlet Erosion Control

As per the detail drawings, all pipe culverts include a stone masonry apron at both the inlet and outlet for a length of approx. 1.5 meters. Similarly, all box culverts have an apron at inlets and outlets of 15-20 meters in length, depending on the height of the box.

Figure 8 : Outlet requirement to the valley.

Exception: Mahama Refugee camp, a rectangular outlet of 1m*1 m was designed to discharge the water from the camp and from the road to a safer downstream place for a length of 325 m.

The Consultant has noted that for most of the cross-drainage structures, there is no present evidence of significant erosion, and therefore a decision was made in the interests of economy to not uniformly spend scarce resources on further armoring culvert outlets when the necessity for such armoring has not been readily established.