4. HYDROLOGICAL STUDY ON SEBEYA RIVER CATCHMENT

By

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4. HYDROLOGY

4.1 Introduction

Since 2010, Sebeya river is causing frequent and serious destructive floods that are affecting mainly its downstream part causing too many damages. With the changes of occupation and utilization of land use in the basin between 1988 and 2009, we assume that the Sebeya regime has been changed and the minimum rates dropped in favor of the maximum flow. This is remarkable from floods observed more frequent in surrounding villages of Mahoko center, heading towards the upstream of the river.
The water retaining pond consists of the new Sebeya storage pond at Mwali site (Annex 1) to reduce the speed of Sebeya river and avoid its negative impact to the life and properties of surrounding people and reduce flooding at Mahoko Center. This water retaining pond is proposed to be constructed at a location on the confluence of Bihongora and Sebeya streams, further downstream at a distance of approximately 100 m and at 3 Km from the main road Musanze - Rubavu at Mahoko center. Thus, a much larger catchment is formed, which reaches 200,5 km^2, taking advantage of inflows from those significant two tributaries. The new pond location is between two hills namely Kaje and Mwali and is determined by the following UTM coordinates: E 0430040, N 988447 at the altitude of approximately 1918 m.
In the present report all main aspects of the water retaining pond design are addressed, so that its safety and normal performance are ensured. The most important design criteria or other design parameters issues are set, in order to avoid delays in the next stage caused by vagueness in relation to them. Preliminary calculations are carried out in order to approach a reliable sizing of the particular pond structures and a respective cost estimate, which is used for the determination of the project feasibility. This report is detailed the new hydrology approaches that were undertaken for the location of the Mwali-Kaje water retaining pond based on site visits and investigations that were done in the meantime. These are explained in detail in the following chapter of the report.
From this point of view the issues that are addressed by the present report fall into the following categories.
Desk study of the data required to carry out the hydrological survey; site investigation of potential location; completion of the hydrological survey for the potential site including the determination of the floods to be considered for pond design; determining the main morphological and hydrological characteristics of the catchment area (field characteristics, area, rainfall runoff, precipitation rate, runoff coefficient); determining the annual input of the retaining basin, accounting for evaporation; Helping to understand the

hydrological system of the Sebeya river network through the calculation and description of different catchments parameters for all Sebeya river branches existing upstream Mahoko Center; calculate all hydrological flows (flood flows, Dry season flows, mean flows, …) for all branches entering the Sebeya river and those for the Sebeya river itself at different points meant to host different ponds, meaning calculation of flow of the river, flood peak flows, 100 year flood, floods duration; 5 and 10 years floods are also calculated to serve in designing the river diversion during construction period; and finally estimating solid transport corresponding to different flows and catchments.
This study aims at suggesting and designs the dam at the outlet of the catchment but also at the outlet of each of the tributaries. The objective is to delay flow in dams and release it once flood events finish. The expected results are normal flows in Sebeya river beds downstream of the proposed Sebeya main dam which would boost the reduction of economic and human losses and increase agricultural production which was hammered by those floods.

4.2 Catchment Location of Sebeya river at the Dyke site and Characteristics

Over geological time, the collapse of the pit of Lake Kivu and the riser of the Congo-Nile process occurs on the base flattened prior to the cretaceous tertiary then determining the entry into operation of the chain of volcanoes. The erection of the Congo-Nile rushed erosion, clearing the hills and expanding new vulnerabilities in different valleys in opposition to the flow of rivers, which in plains and lakes (E. Bernard, 1952 and Schmitz, 1971). These volcanic phenomena distinguished themselves and intensified since the beginning of the quaternary where mountain forests enter between 2000 and 3000m like Gishwati, which started to develop on recent lava on coarse volcanic ash, and from these brown soil. This study is in this geographical region of high altitude mountain forest where Sebeya River and its tributaries were formed in a catchment altitude.
Sebeya river catchment is located in north-western part of Rwanda and covers the Rutsiro, Ngororero, Nyabihu and Rubavu District. It is drained by a number of small rivers but main ones are Bihongora, Gatare and Karambo upstream and further downstream Pfunda river. For this study, Pfunda river modelling was not considered since it enters Sebeya river just some distance before it empties in Lake Kivu and downstream the confluence no flood events were recorded.
In sebeya catchment, flooding typically occurs in flat areas between the steep parts formed by rift formation located predominantly in the flat area around Nyundo which acts as a natural retention buffer for floods. Sebeya is a small scale catchment (~365 km^2) with fast rainfall runoff reaction, so the flood is flash flood type. The population testifies that flooding after heavy rain storms occurs within a period 20 minutes to 3 hours.

The catchment of the river Sebeya extends to its upstream branch, on one part of Rutsiro and Ngororero Districts on an area of 180 km² and its downstream arm extends over an area of 40 km ² and then till the site of Nyundo bridge in Rubavu District.

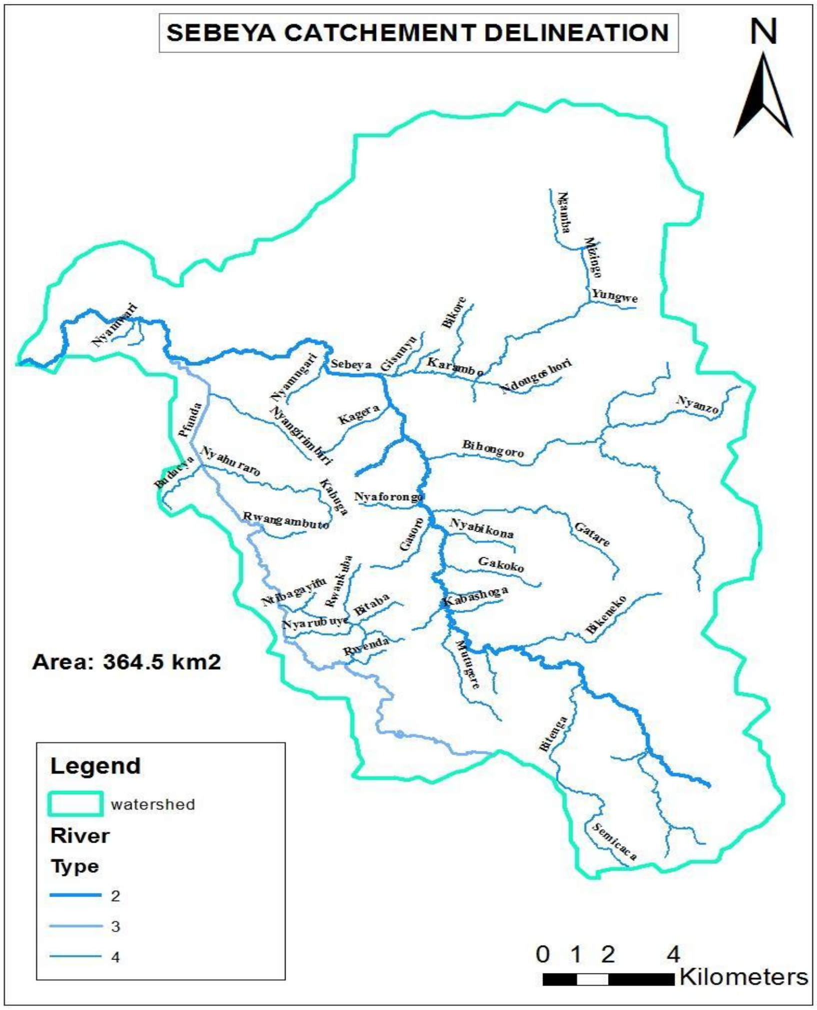

Figure 1. ***Hydrological network of Sebeya catchment***

As mentioned in the above introduction part, the applied methodological approach in this study is based on hydrological and climatological analysis of the available data in the region. According to the history of the river Sebeya, it seems that the river flowed through Sebeya natural forest Gishwati from upstream to downstream with clean water until 1968. After this time, population growth, deforestation, land watersheds through Agri-livestock and expoloitation mines have caused and accelerated the phenomenon of catchment erosion, causing denudation of soil and subsequently triggering heavy sedimentation of the river Sebeya and its tributaries.

4.3 Hydro-meteorology of the drainage basin

4.3.1 Climatology of the study area

This study focuses on the collection of climate data such as annual rainfall, monthly and annual evaporation data as well as humidity and temperature data from stations such as Gisenyi Airport, Pfunda, Rambura, Kanama and other surrounding stations.
The study then focuses on the processing and frequency analysis of the data in the first phase with little data to know the occurrence of events. The example is given below in Tables 1 and 2.
The study area has as a reference climate station, Gisenyi nearest Airport, with the coordinates: longitude 29° 15' south latitude and 1° 40' at an altitude of 1554m. The length of the data series is 1961-1990 at Gisenyi Airport with the climate characteristic showing the presence of two wet seasons and two dry seasons as follows:
- A small rainy season from mid-September to mid-December;
- A short dry season from mid-December to mid-February;
- A great rainy season from mid-February to May;
- A long dry season from June to mid-September.

The average temperature of the region is 20° C with a maximum of 30° C and a minimum of 9 degrees Celsius. The relative humidity is 82% in the rainy season and 60-70% during the dry season. The daily evaporation is estimated at 2.7 mm, the wind speed of 1 to 2 m/s and the daily exposure varies around 5 hours/day.

These are parameters that characterize the climate of the region near the Sebeya river catchment. The data presented above and in the following table show the basic fundamental climate system of the study area.

Table 1 Monthly average rainfall in and near Sebeya river catchment

Station / Month	Gisenyi Airport (1554 m)	Kanama	Rambura (2300m)	Muramba	Pfunda	Murunda (1875 m)	Crête Congo Nil (2700 m)
January	81.8	131.9	98.3	97.8	107.7	128.3	124.2
February	97.5	147.6	118.3	120.1	116.7	126.8	138.5
March	130.7	142.6	129.4	135.0	173.4	149.4	197.3
April	171.7	257.0	198.4	204.5	161.2	174.1	182.3
May	104.3	97.6	190.6	173.1	137.4	136.2	101.9
June	40.4	48.7	52.5	43.2	42.9	57.4	23.5

July	21.9	16.8	29.1	12.5	20.6	24.5	8.5
August	69.9	49.0	62.5	48.1	50.0	51.7	52.7
September	115.0	102.2	120.0	96.0	138.4	112.5	99.3
October	127.7	144.4	143.8	142.2	135.5	121.2	182.6
November	140.2	163.3	158.0	163.0	154.9	134.5	175.2
December	84.4	112.2	114.7	114.3	111.9	129.9	187.9
Total annual	**1185.4**	**1338.0**	**1415.7**	**1350.0**	**1319.0**	**1344.7**	**1393.7**

Source : Rwanda Meteorological Service

Some stations such as Gisenyi Airport and Muramba, Murunda, Rambura and Congo-Nile present rainfall with remarkable influences of the Environment such as Lake Kivu and its thermal heat for being on Lake Kivu shore and the rain forest Gishwati is found on the Congo-Nile with very high rainfall.

Reading the above Table 1 shows this in sufficiency. Much of climatic influences on Sebeya at Nyundo and its catchment are coming at the level of the water balance, at Rutsiro District and that of Ngororero which are characterized by high rainfall in the Congo-Nile.

The Table 2 below can help us to calculate rainfall / discharge extreme of Sebeya at Nyundo, but we prefer to reject on the profit of data observed in the Sebeya River itself.

Table 2 Maximum rainfall in 24 hours at Gisenyi Airport station (1976-2007)

Years	Maximum rainfall in 24 hours (mm)
1976	93.1
1977	49.4
1978	62.0
1979	38.2
1980	49.1
1981	41.5
1982	85.9
1983	51.6
1984	36.9
1985	40.5
1986	78.1
1987	42.6
1988	78.0
1989	43.7
1990	62.6
1991	58.8
1992	44.2
1993	41.8
1994	-
2002	59.0

2003	45.5
2004	63.5
2005	40.7
2006	90.8
2007	70.8

Source : Rwanda Meteorological Service

4.3.2 Hydrological data

Dated 27th March 2014 and 20th May 2014, field missions have enabled measurements of flow on the Sebeya river at Nyundo and Karambo rivers located near the local market. Flows are respectively 2.5 m^3/s and 1.91m^3/s at Sebeya river with a water level of 1.35m, and

0.624 m³/s and 0.704 m³/s at Karambo river. This allows us to conclude that there are not too far below the average and yet there is a strong retention puddles everywhere in the streets and foundations of houses moistened. This is probably due to a strong saturation of soil moisture in relation to the frequency of rain and a lack of sanitation agglomerations by stormwater drains.

4.3.3 Flood discharge analysis

To get insight in the rainfall-runoff response, the hydrographs of Sebeya-Nyundo gauging station is analysed together with rainfall collected from Gisenyi station. In general dry periods are interrupted by rainfall events during which a rapid increase in discharge occurs, followed by a somewhat less rapid decrease after the rainfall ends. These peaks in the hydrograph are called stormflow events, which take place in March and April (Table 1). From June to October, a period of baseflow takes place (see Table 1).

Extreme value distributions have been widely used in hydrology. They form the basis for the standardized method of flood frequency analysis in Great Britain (Natural Environment Research Council, 1775). Storm rainfalls are most commonly modeled by the Extreme Value Type I distribution (Show, 1953; Tomlinson, 1980).

The annual peak flows were found to be fitting well to the Extreme Value type I (Gumbel) Probability distribution when data were plotted on a Gumbel Probability paper (Fig. 3). From this distribution, floods expected at different return period were processed and analyzed in accordance with the laws of statistics of extremes. Flow measurement of mean water allows the establishment of the rating curve (Relation water level / discharge) below in Figure 2.

It is noted, however, that the measured flow during this study on 27 March 2014 (2.5 m^3/s) and 20 May 2014 (1.91m^3/s) is less than that should have on theoretical rating curve, this being, it seems that sand mining in the river bed disrupted downward flows of Sebeya river. This is why using the maximum and minimum flows observed on Sebeya River for 23 years (see Table 3), it was conducted a study and a calculation of the maximum and minimum rates for 2, 5, 10, 20, 50 and 100 years of return period (Table 4). However, a table of illustration and calculation according to the Gumbel distribution, is found in this report as well.

Figure 2 below shows the relation between water level and flow measured at Nyundo station on Sebeya river and the curve is in the form of an exponential function $Y=0.926\ e^{1.013\ X}$ representing the H/Q related to highly significant correlation. This curve is an expression of the steady flow in water average. The flow of the flood level is estimated at $Q=0.926*2.76^{1.013*2.5}=$**12m³/s**. However, flow measurements made on 27 March 2014 (2.5 m^3/s) and 20 May 2014 (1.91m^3/s) during this study as well as flow measurements conducted by RNRA on 25 February 2012 (0.82m^3/s); on 21 February 2014 (0.28m^3/s); on 28 April 2014 (1.67m^3/s) and on 18 August 2014 (0.64m^3/s) gave flow rates on down and we can think that this is due to continuous disturbance of the bed of the river Sebeya by sand mining activities.

	H(m)	Q(m³/s)
26//8/80	0.59	1.24
12/5/1988	1.2	4.58
11/6/1988	0.65	1.73
11/8/1988	0.7	2.15
1/12/1988	0.63	2
11/12/1988	0.64	1.94
11/5/1989	0.76	2.72
18/9/89	1.4	3
13/10/89	0.85	2.1
30/3/90	0.8	2.45
27/12/90	0.97	1.76
21/2/92	0.8	2.21
25/3/92	0.86	2.14
12/8/1992	0.57	1.74

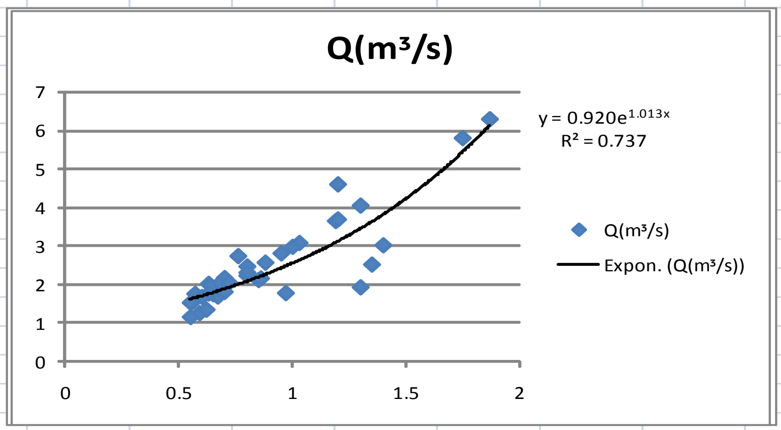

Figure 2. ***Rating curve of Sebeya river at Nyundo***

Table 3 Frequency analysis and extreme flow discharge of Sebeya River

		Débits Extrêmes de la Rivière Sebeya								
		et analyse fréquentielle								
N^{o}Série	**Années**	**Qmax.**	**Qmin.**	**Fréquence**			**Freq.**	**Qmax.**	**Qmin.**	
1	1997	4,07	0,66	0,021739			2	4,07	0,66	
2	1984	5,4	0,82	0,065217			6,5	5,4	0,82	
3	2008	5,58	1,07	0,108696			11	5,58	1,07	
4	1973	5,8	1,6	0,152174			15	5,8	1,6	
5	1974	5,98	1,6	0,195652			20	5,98	1,6	
6	1987	6	1,7	0,23913			24	6	1,7	
7	1995	6,27	1,75	0,282609			34	6,27	1,75	
8	1988	6,48	1,9	0,340909			34	6,48	1,9	
9	1977	6,7	1,93	0,369565			37	6,7	1,93	
10	2009	6,8	2	0,413043			41	6,8	2	
11	1976	7	2,1	0,456522			46	7	2,1	
12	1980	8	2,1	0,5			50	8	2,1	
13	2011	8,39	2,2	0,543478			54	8,39	2,2	
14	1986	8,4	2,29	0,586957			59	8,4	2,29	
15	1978	8,9	2,49	0,630435			63	8,9	2,49	
16	1982	8,9	2,5	0,673913			67	8,9	2,5	
17	1981	9,2	2,7	0,717391			72	9,2	2,7	
18	1975	9,31	2,7	0,76087			76	9,31	2,7	
19	1983	10,8	2,8	0,804348			80	10,8	2,8	
20	2010	11,26	2,8	0,847826			85	11,26	2,8	
21	2012	11,26	2,83	0,891304			89	11,26	2,83	
22	1985	14	2,9	0,977273			98	14	2,9	
23	1979	14,8	3,1				98,5	14,8	3,1	

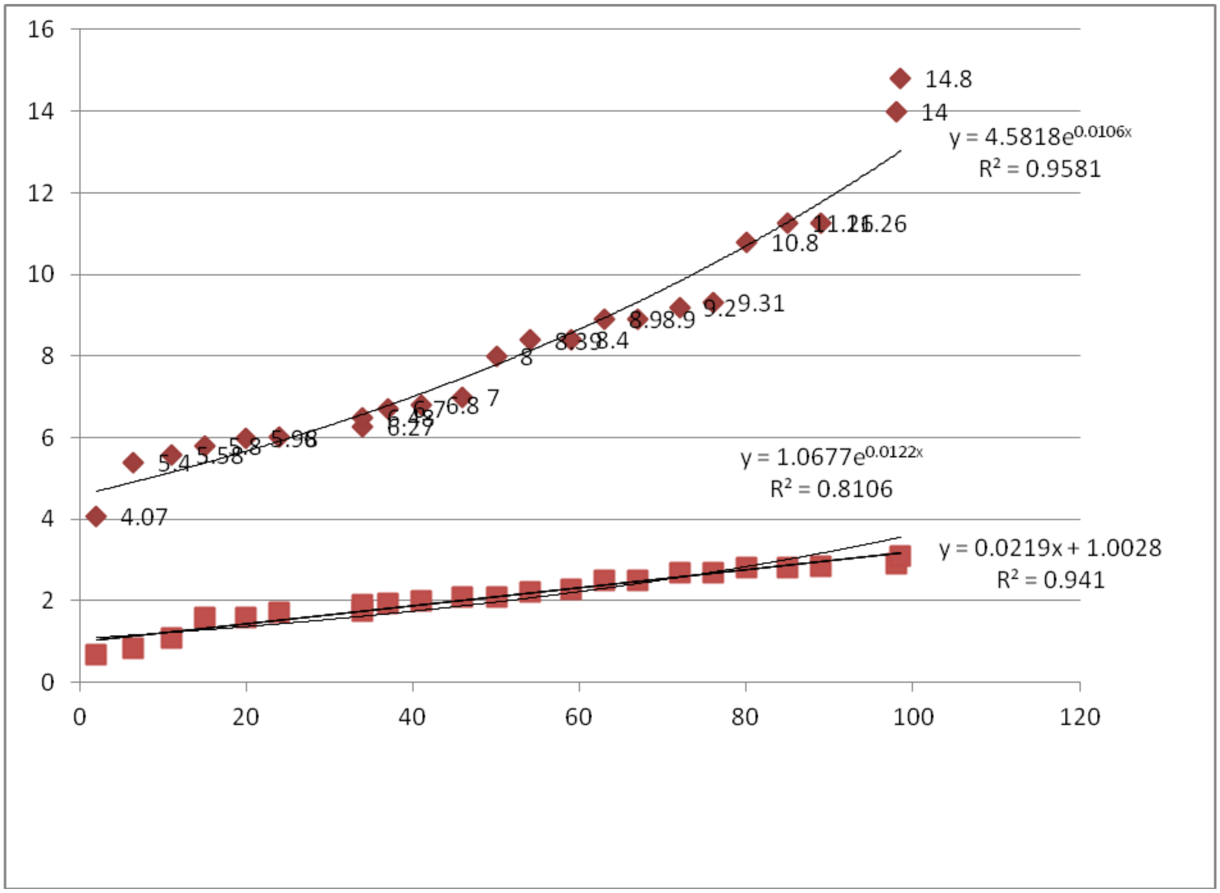

Figure 3 ***Peak and low discharge based on Gumbel distribution in Sebeya***

Figure 3 shows two curves, the result of a frequency analysis of peak and low flows in the Gumbel extreme flows. As regards the rating curve (Fig. 2), the water level heights are presented on the X-axis and the flow on the Y-axis (ordinate).

These curves are the graphic expression of Table 4 which calculates the frequency rates of return period of 2, 5, 10, 20, 50 and 100 years by law Gumbel extreme. These flood flows and low flows allow optimal reservoir management and possible irrigation in the swamp. From the Gumbel distribution floods expected at different return period were obtained and are shown in Table 4.

The Gumbel distribution is a double exponential of the form: $F(Q)= e^{-e^{-u}}$. Here, $U_T=a\ (Q_T - Q_0)$ is the reduced Gumbel variable and represents the fitted line at same Author law. The parameters a and Q_0 are scale and form parameters, respectively. Their calculation is based on the knowledge of the value of the mean $\bar{Q}$ and standard deviation δ of the data series. The average value of the series of maxima is 8.23 m^3/s and a standard deviation of 2.68 while the average minimum is 2.11 m^3/s with a standard deviation of 0.67. The formulas used to calculate parameters a and Q_0 are: a=1/(0.780*δ) et Q_0= $\bar{Q}$-(1/a)*0.577 where $\bar{Q}$ is the average daily maximum flow and 0.577 is constant of Euler.

Series of maxima and minima give as equation: for maxima: $U_T = 0.475\ Q_T - 7.045$ and for minima: $U_T = 1.91Q_T - 3.457$.

Using these formulas and knowing that U_T= -ln (-ln T/T-1), it is easy to calculate the different values of Q_T rates for different values of return period T. In calculating the minimum, the values of U_T are negative.

To take account of extreme flows of Karambo and Gatare rivers, we shall take frequency rate 1/4 of flow rate of return period corresponding to Sebeya river at Nyundo.

Table 4 Expected floods at the pond for different return periods in Sebeya river and rainfall

	Peak inflow rate (m^3/s)		**Low inflow rate (m^3/s)**
Q_2=	7.816849	Q_2=	1.62
Q_5=	10.20379	Q_5=	1.025
Q_{10}=	11.7835	Q_{10}=	0.63
Q_{20}=	13.29982	Q_{20}=	0.25
Q_{50}=	15.2584	Q_{50}=	0.0
Q_{100}=	16.7326	Q_{100}=	0.0

Table 4 shows the peak and low inflows which have been calculated using Extreme Value type I (Gumbel) Probability distribution for the adopted measured peak flow of 16.73 m^3/s for 100 years return period.

4.4. Modelling the Sebeya dam using NBDSS

4.4.1 Introduction

The Nile Basin Decision Support System (NBDSS) is a comprehensive analytic framework designed to meet the requirements of complex water resources

assessment and planning. It provides diverse toolsets for data processing, modeling, scenario management, cost-benefit analysis, optimization and multi-criteria decision making. It offers tools for integrating environmental, social and economic objectives thus greatly facilitating multi-sector water resources planning at river basin level. It provides unique toolset for supporting multi-stakeholder dialogue on water resources planning. With its Multi-criteria decision making tool, the DSS becomes key in supporting informed decision making in water resources. It uses Mike Hydro as modelling tool and PostgreSQL as database manager.
MIKE HYDRO is an integrated modeling version of the MIKE by DHI Water Resources model systems. This tool is used for a variety of model applications covering Integrated Water Resources Management (IWRM), water resources assessment, water allocation, **reservoir operation** and other types of analysis, planning and management model studies. The size of these may range from local project scale to international river basin scale.

4.4.2 Model set up (Mike HYDRO)

The model was built in Mike HYDRO whereby the Sebeya River, its tributaries, corresponding catchments and the proposed dam sites are represented as in the Figure 4 below. Figures for the following dam characteristics were populated as input data: catchments areas, runoff time series, reservoirs operation rules such as initial water levels, level area volume relationships, characteristic levels (bottom levels, dead zone levels and crest levels), flood control levels (level at which the water overflows the dam), and the minimum release time series (to enable continuous flow downstream the reservoirs).

We opted to use continuous flow data for Sebeya River for the period of 1974 to 1988 as they have proved to be consistent and accurate.

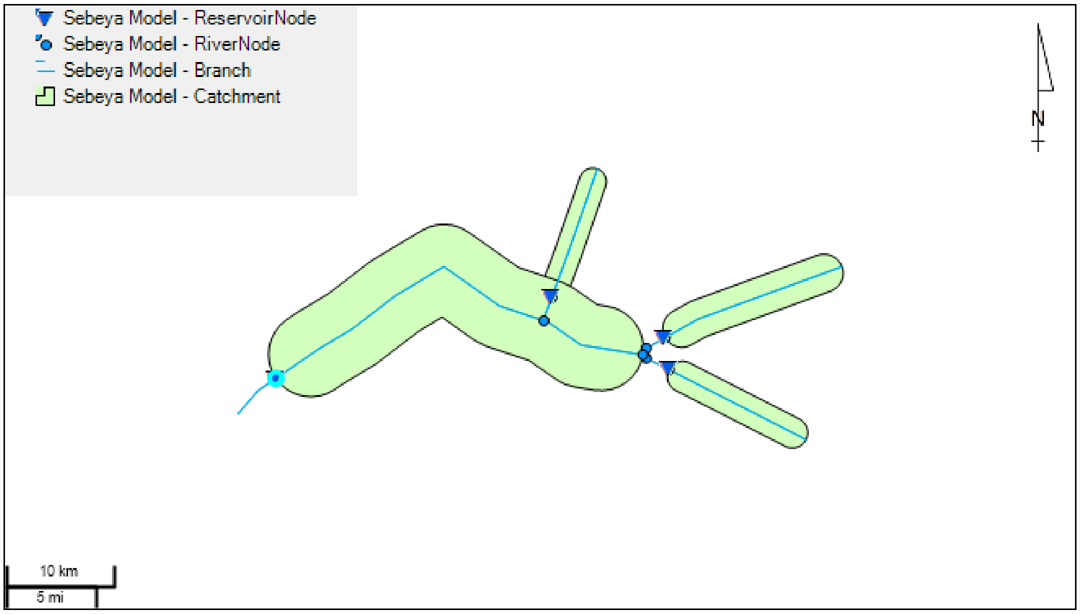

Figure 4 ***Sebeya River model with its tributaries, corresponding catchments and the proposed dam sites***

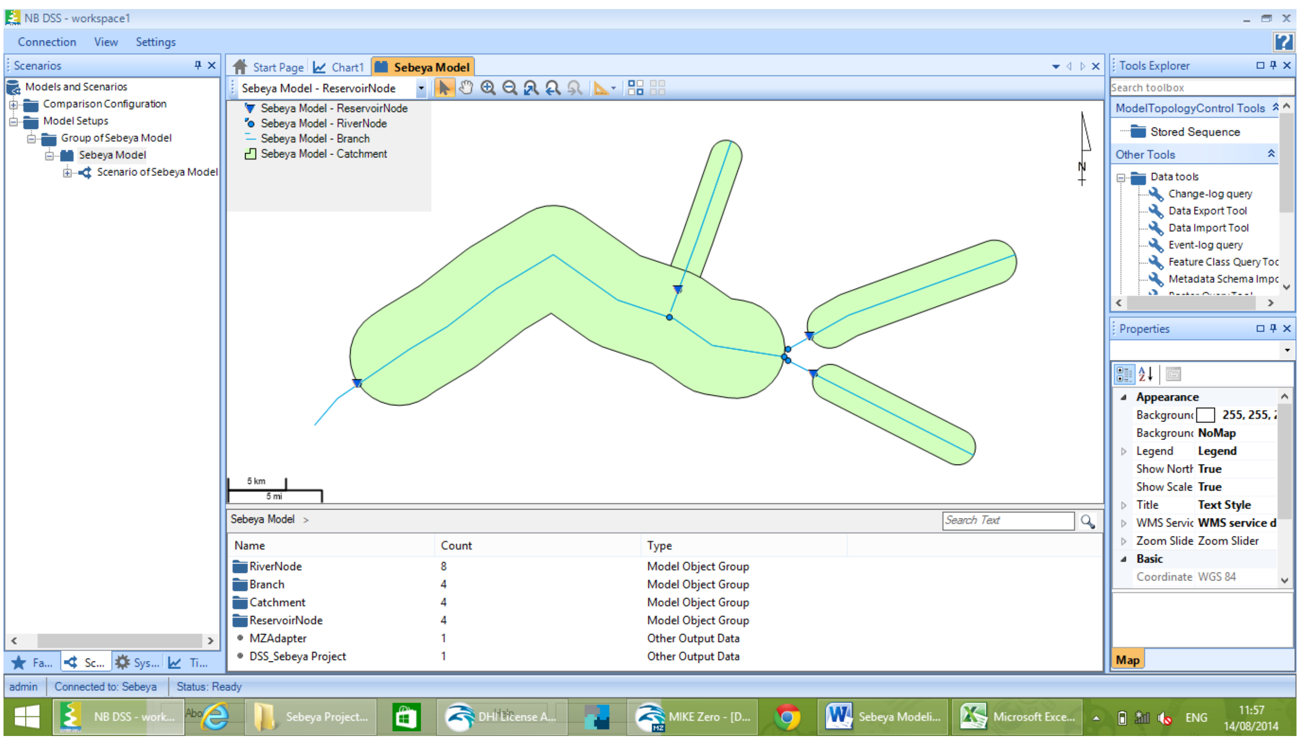

Figure 5 ***The model setup in NBDSS with each sub-catchment***

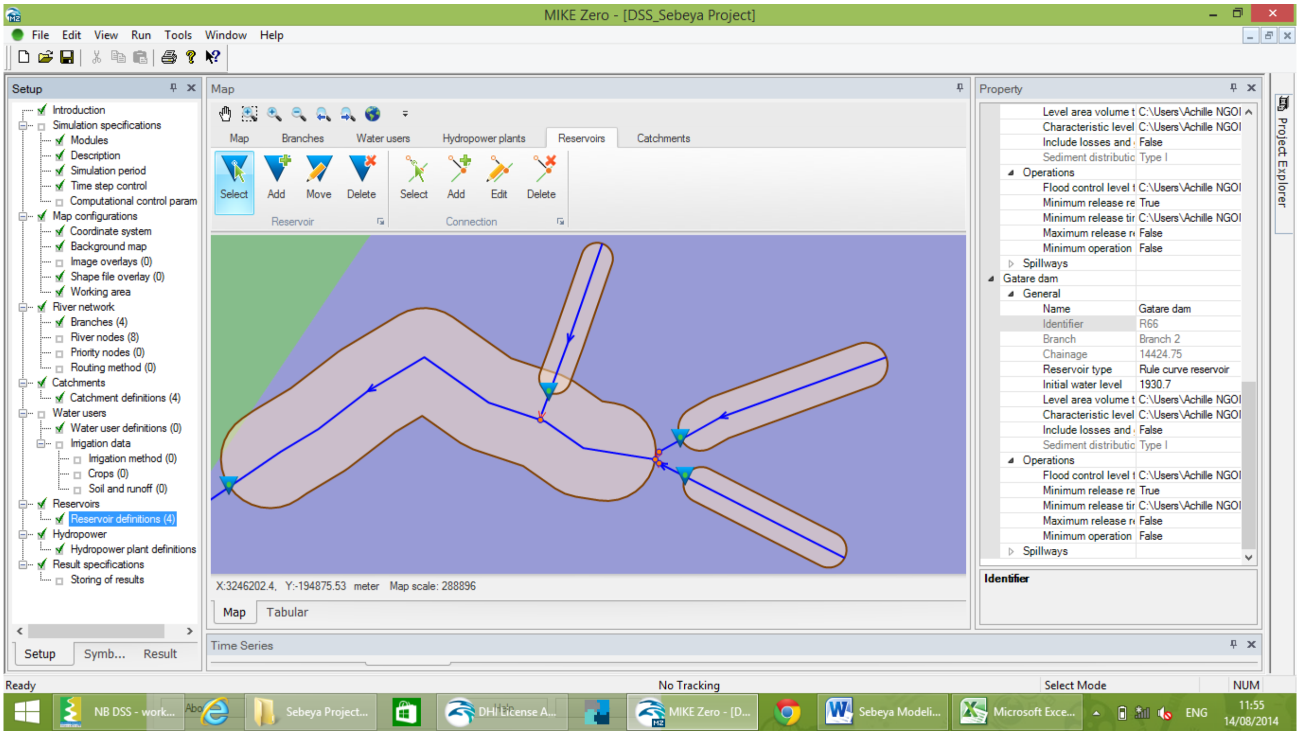

Figure 6 ***Model setup in Mike Hydro***

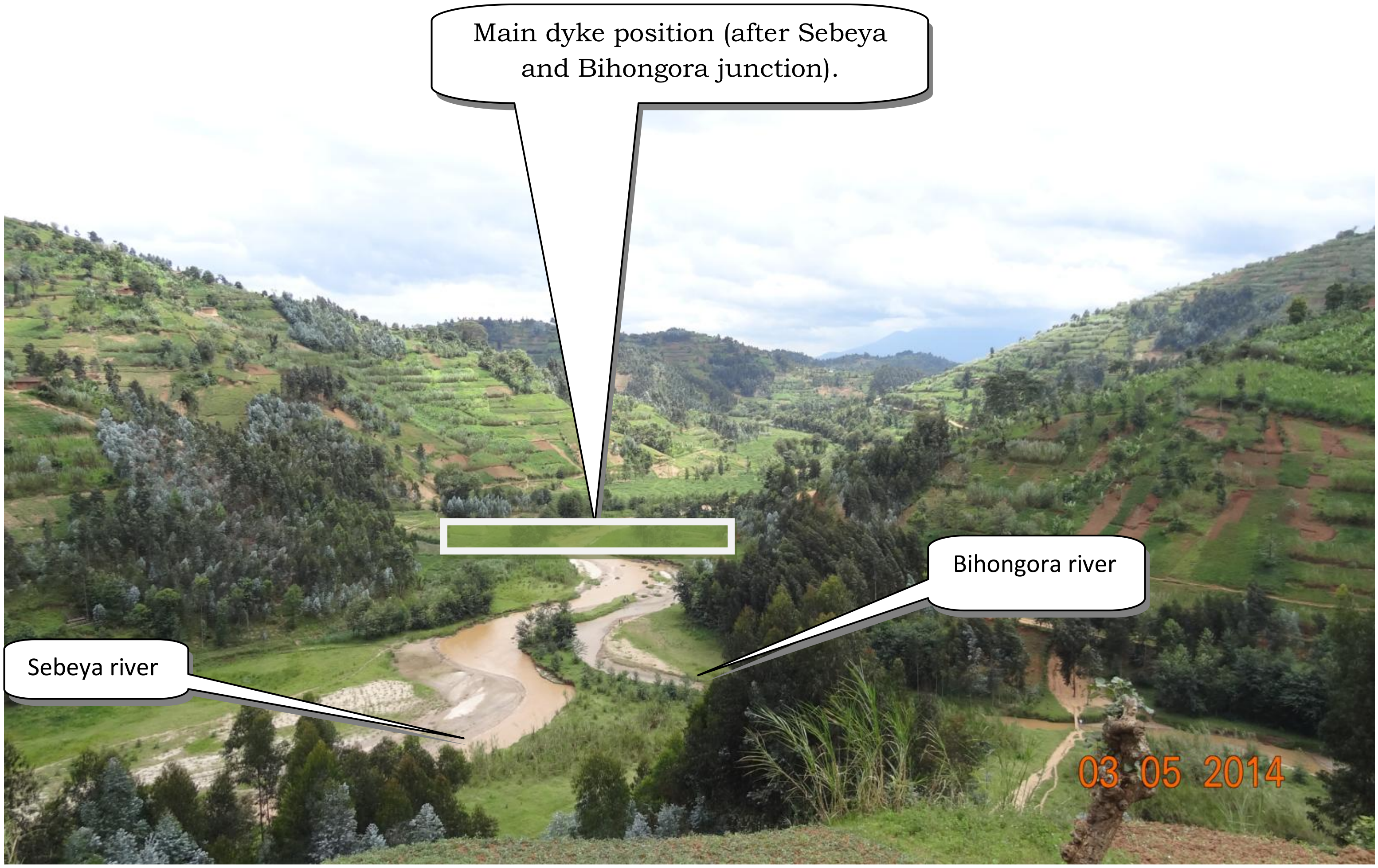

Figure 7 ***Location of main dam in the study area***

4.4.3 Dykes design characteristics

Table 5 Level area volume

DAM	LEVEL (m)	RESERVOIR AREA (km²)	VOLUME (10⁶m³)
Sebeya main dam	1900	0	0
	1901	0.0042	0.0021
	1902	0.0204	0.0204
	1903	0.0607	0.0910
	1904	0.0812	0.1624
	1905	0.0970	0.2425

	1906	0.0990	0.2850
	1907	0.1067	0.3735
	1908	0.1216	0.4864
	1909	0.1326	0.5967
	1910	0.1460	0.7300
Bihongora	1916	0	0
	1919.5	0.00196	0.0035
Karambo	1995.8	0	0
	1999.3	0.000657	0.00118
Gatare	1930.7	0	0
	1934.2	0.002	0.0039

Table 6 Characteristics levels

DAM	BOTTOM LEVEL (m)	DEAD STORAGE LEVEL (m)	DAM CREST LEVEL (m)
Sebeya main dam	1900	1900.3	1910
Bihongora	1916	1916.2	1919.5
Karambo	1995.8	1996	1999.3
Gatare	1930.7	1930.9	1934.2

MAIN MODEL ASSUMPTIONS

The calculation of the flow of each sub catchment was done by deducting it from sebeya flow by using catchment areas because the subcatchments are not gauged.

The flood control level was fixed at the top of the reservoir which means that once the dams fill, it will overflow downstream. Though, a continuous flow was provided to help dams to empty continuously to avail space for the incoming

storm. This was fixed to 8m^3/s for Sebeya main dam (even if this flow happens when it is about to flood after a while) and to 1m^3/s for the other three small dams. An adopted continuous flow with peak flow of 8m^3/s will not cause any flood at Sebeya river after construction of main dam as it was proved that the flood is observed once the flow reached to 12m^3/s (see Sect 4.3.3). In normal reservoir operation rules, this flow is considered as release required for supporting environmental flows in the river downstream of the reservoir but also helps to empty the reservoir while preparing potential flooding. Note that this release takes place as long as the water level is above the Dead zone level (Top of dead storage) (Table 6).
After all, the model was run to find out the impact of the reservoirs on downstream flow and on alleviating the flood issues in adjacent areas.
After that the model runs successfully, the model is registered into NBDSS to manage different scenarios which are baseline (normal flow without dams) and sebeya flow with main dam plus 3 small dams on Bihongora, Gatare and Karambo tributaries.
The model results are presented and interpreted in the following chapters.

4.4.4 Model results

After that the model was run, the daily inflow and outflow of each dam was computed and summaries in the table below (Table 7) in order to identify the impact of all dams on flood control in the catchment. This shows that the 3 small dams upstream have greater impact because the initial peak discharge was 16.73m^3/s and the inflow to Sebeya main dam is 14.55 m^3/s which corresponds to the reduction of 2.19m^3/s. Then the impact of **Sebeya main dam** which has a **height of 10m** and the volume of 730,000m^3 was found to be reduction of 5.88m^3/s on the peak flow. This means that the outflow of Sebeya main dam is **8.66m^3/s** (Table 7).

Table 7 daily inflow and outflow of each dam

DAM	PEAKS FLOW (M^3/S)		PEAK FLOW REDUCED BY EACH DAM(M^3/S)	TOTAL FLOW REDUCED BY ALL DAMS (M^3/S)
Sebeya main dam	Inflow	14.55	5.88	8.07
	Outflow	8.66		
Karambo	Inflow	3.42	0.60	
	Outflow	2.82		
Bihongora	Inflow	2.50	0.44	
	Outflow	2.06		
Gatare	Inflow	6.52	1.15	
	Outflow	5.38		

Overall, the role of four dam structures on Sebeya River and three small triburaties is estimated to be reduction of the peak flow from 16.73 to 8.66m³/s as shown in Table 7 this figure can't cause floods according to the morphology and record of the Sebeya River as well as calculations made in Section 4.3.3.

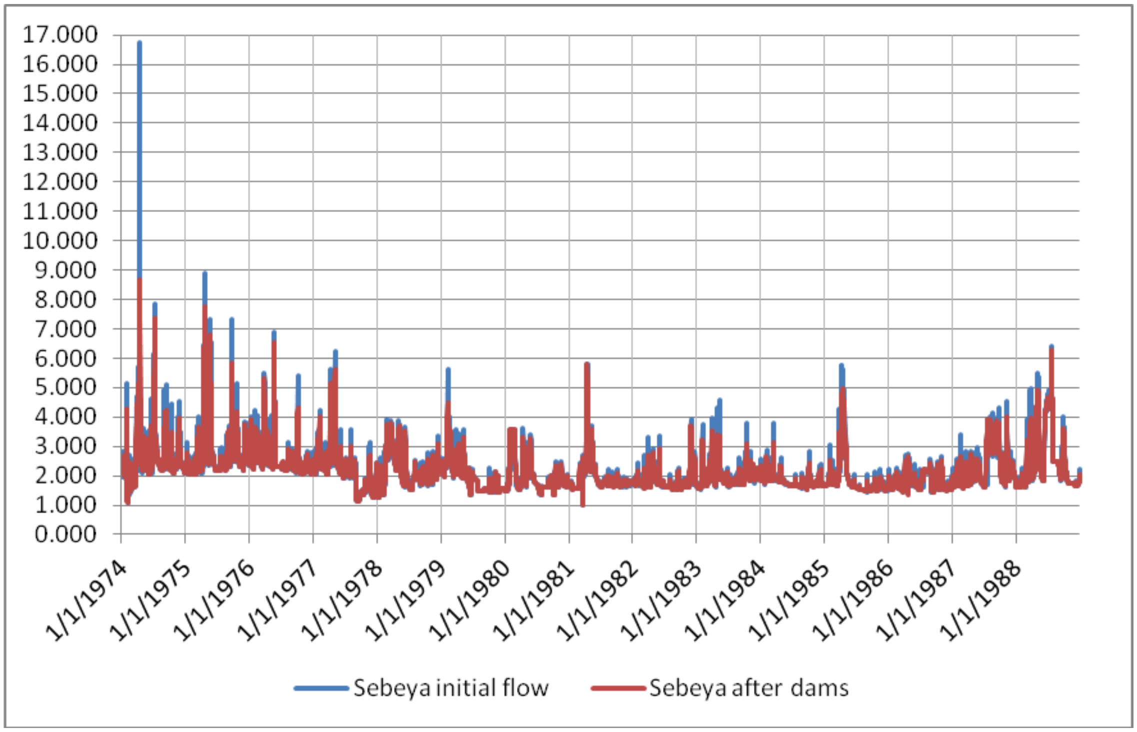

Figure 8 ***Graphs of daily discharge for each scenario***

As we know the construction of 4 dams implies much effort for monitoring and maintenance.
In case of budget constraint, the construction of Sebeya main dam only could be efficient as the flow would be around 10-11m³/s which is also good in terms of flood control.

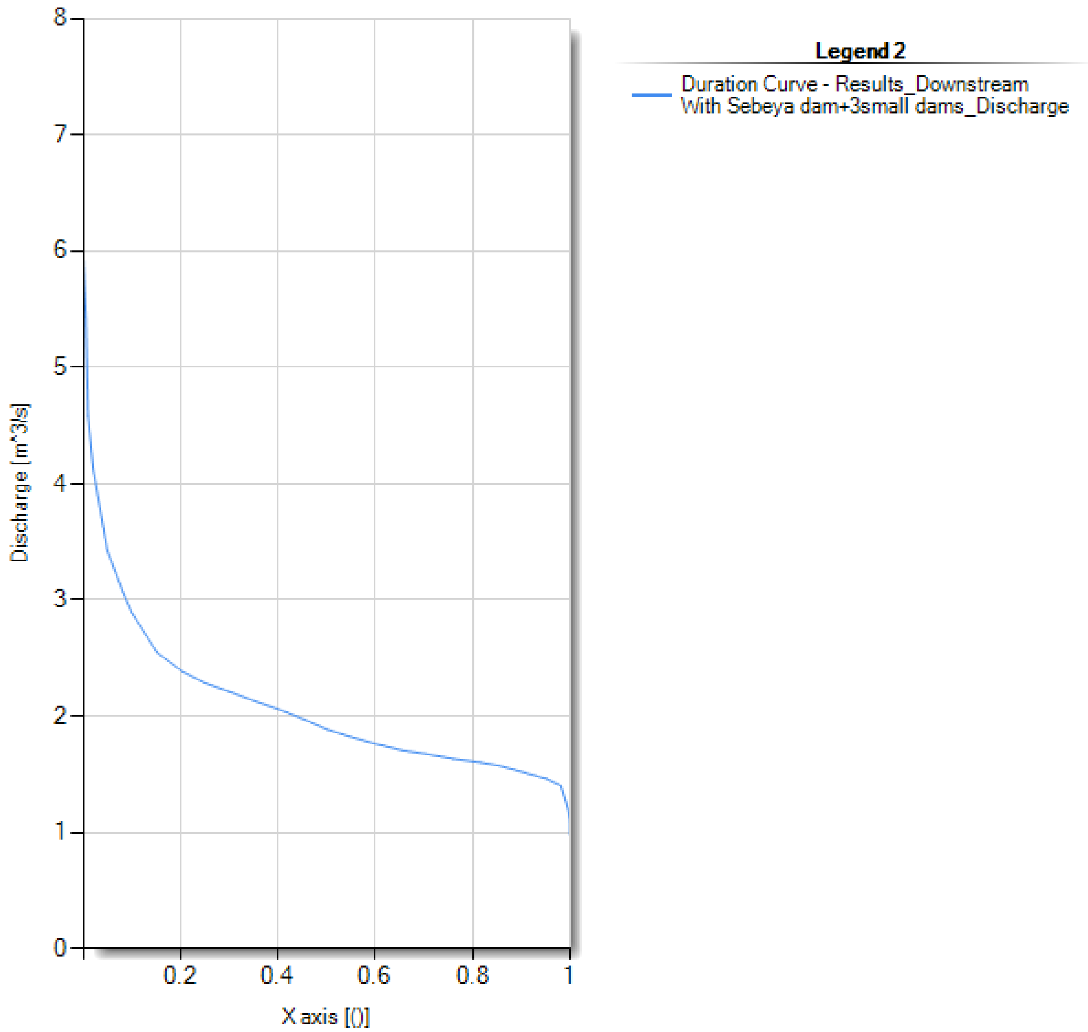

Figure 9 ***Flow duration curve of sebeya river flow with flood control dams.***

4.5 Reservoir Sedimentation

The two main rivers (Bihongora and Sebeya) located at Sebeya downstream at Mwali site (Annex 1), which are contributing to the project catchment are suffering from different kind of morphological changes, especially erosion. It was a question of assessing the state of pollution by sediments transported by the bed of the river Sebeya (see Table 8). It is noted that the said river is polluted mainly by human activities in relation to mining and agriculture and livestock. In addition to the natural increase of Bihongora and Sebeya floods resulting from climate changes. To combat these morphological changes, better understanding of the sediment transport movement is crucial.

While there are different techniques to evaluate the sediment transport, e.g., tracer techniques (fluorescent, dye-market sand or color sand), study of sediment physical features (sand size analysis and mineral decomposition), and the usage of large scale sediment traps (groins and inlets). These methods still have some limitations and difficulties (Mostafa and Tajima, 2012). However, estimates of sediment yield are extremely uncertain, even more so for small catchments like Mwali (MINAGRI, 2011b).

Table 8 Liquid flow rates and total sediment load of Sebeya River and its tributaries.

Dates	Rivers	Coordinates	Flows m³/s	Flow max. m³/s	Turbidity mg/ℓ	Total sediment load g/sec.
15/10/08	Sebeya downstream	Alt. 1930m Lat. 1°45'S Long. 29°20'E	0.867	2	1240	1075
15/10/08	Nyaforongo tributary	Alt.1932m Lat. 1°45'S Long. 29°20'E	0.011	0.05	119	1.31
16/10/08	Sebeya upstream (Maya)	Alt.1940m Lat.1°45'S Long.29°22'E	0.395	1.2	6288	2483.8
16/10/08	Bitenga tributary	Alt.1945m Lat.1°46'S Long.29°25'	0.086	0.2	-	-
16/10/08	Affluent Nyamugali	Alt.1943m Lat.1°44' Long. 29°26'	0.05	0.15	-	-
16/10/08	Gakoko tributary	Alt.1956m Lat.1°47'S Long.29°25'E	0.015	0.06	-	-
16/10/08	Kinyamise tributary	Alt.1935m Lat.1°46' Long.29°19'	0.011	0.05	-	-
17/10/08	Gasoro tributary	Alt.1935m Lat.1°47' Long29°28'	0.005	0.02	-	-
17/10/0	Pfunda at Gahembe (downstream)	Alt. 1480m Lat. 1°44'S Long. 29°17'E	0.334	1.1	4888	1632.6
17/10/08	Gatare tributary	Alt. 1930m Lat. 1°45'S Long. 29°19'E	0.258	1.05	1023	263.9
17/10/08	Sebeya source	Alt. 2417m Lat. 1°45'S Long. 29°21'E	0.001	0.003	2	0.002
17/10/08	Mpomboli tributary	Alt. 2300m Lat. 1°46'S Long. 29°22'E	0.01	0.04	5	0.05
21/10/08	Sebeya Karumbi	Alt. 2298m Lat. 1°46'S Long. 29°22'E	0.024	0.1	883	21.2
23/10/08	Nyatubindi tributary	Alt. 2320m	0.06	0.3	10	0.6

It was noted that close to the measurement site on Sebeya river at Nyundo place called Sebeya downstream, in the middle of tea growing areas, quantities of measured sediments were evaluated at 1075g/s (Table 8). If we consider that the sediments represent 1kg/s at Sebeya-Nyundo station, the annual evaluation of the quantities of sediment passing the station are estimated at 31,536 tons per year. It will be necessary to take into account this figure for good pond reservoir management and control.
Sediment control by terracing a large proportion of the catchment at hillsides, however, may well reduce sediment yield by over 50% (MINAGRI, 2011). In addition, sediment that will be deposited at the head of the pond reservoir should be periodically removed. These two actions are significant anti-soil erosion initiatives that take place in the vicinity of the reservoir and should be considered as of significant importance. Such interventions should be continued and be supplemented by measures that prevent or reduce the rate of sediment transport.

Most of the identified adverse impacts can be mitigated through specific measures and may be reduced to insignificant residual impacts. The positive impacts will also be maximized to optimize performance. However, the effectiveness of this mitigation of adverse impacts or positive impacts amplification requires the effective implementation of the proposed program for surveillance and monitoring.