Military Technical College

Kobry El-Kobbah,

Cairo, Egypt

10th International Conference on Civil and Architecture Engineering

ICCAE-10-2014

Determination of Grand Ethiopian Renaissance Reservoir (GERR) Life Span Using Remote Sensing Techniques

Ashour S. A. Ashour, Osama M. Moussa , Fawzy Al-Tohame, Hossam E. M. El-Hanafy

Abstract

The Blue Nile Basin is located in the Eastern region of the African Continent and covers most of the Ethiopian plateau highlands with an elevation of 2000 to 3000 meters above Mean Sea Level. The climate of the Ethiopian highlands is based on atmospheric circulation which follows the tropical division (Hurst et al., 1931). The main objective of this research is to determine the life span of GERR by using remote sensing techniques and by the aid of hydrological model Watershed Storm Hydrograph Model (WASHMO) that was established by Andy Ward, 1986. Hydrological parameters were extracted from Digital Elevation Model (DEM) of Shuttle Topographic Radar Mission (STRM). Other parameters that concerns rainfall, soil characteristics and land covers were collected and inserted in the mentioned model in order to determine water discharge and sediment yield from the Blue Nile Watershed.

1. Introduction

Grand Ethiopian Renaissance Dam (GERD) or Taehige, formerly known as the Millennium Dam and sometimes referred to as Hidase Dam, is a gravity dam on the Blue Nile River in Ethiopia currently under construction. It is in the Benishangul-Gumuz region of Ethiopia, about 40 km (25 mi) east of the border with Sudan. The dam is of a 170 m (558 ft) height; 1,800 m (5,906 ft) long gravity-type composed of and will have two power houses, each on either side of the spillway. The dam's reservoir will have a volume of 63 billion cubic meters (51 million acre feet).

Sediment – yield from the uplands and the stream channel can be determined either by using mathematical models which contain component for computing overland flow and in channel flow or by using regression models which determine the relationship between the measured suspended sediment load and the measured water discharge (Vanoni, 1975).

Most of the mathematical models were based on the Universal Soil Loss Equation (USLE). In Order to determine the water inflow and sediment yield from small catchment for the Blue Nile watershed we will use the new version of the USLE (WASHED model) which is modified by Ward 1986.

2. Physical Description of the Study Area

The study area is located in the Eastern region of the African continent (extended from 7° 30`N to 13° 00` N and from 34° 00` E to 40° 00` E). This area covers most of the Ethiopian plateau highlands at an elevation of 2000 to 3000 meters above mean sea level, see Figure 1.

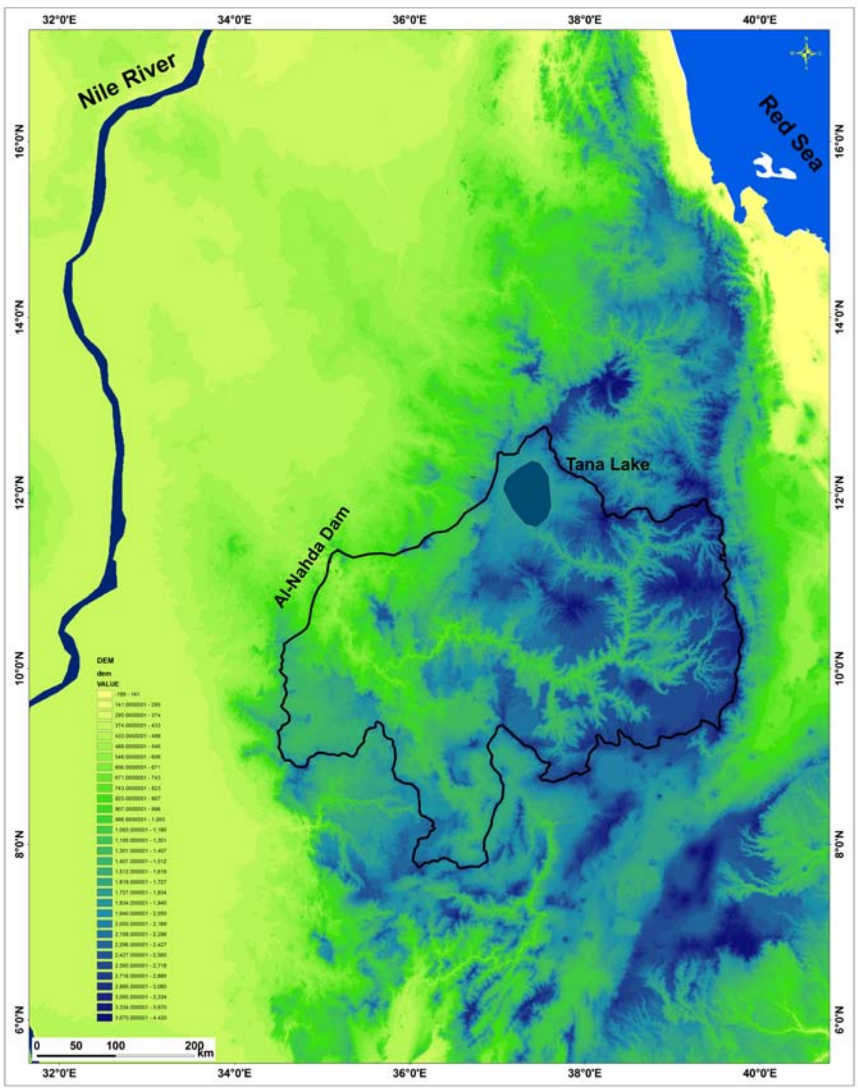


Figure 1: Location of the study area.

2.1 Topography

The Blue Nile and its tributaries all rise on the Northern Ethiopian Highland, or plateau, at heights of 2000 to 3000 meters above Mean Sea Level. Most of the Northern Ethiopian plateau is hilly with grassy downs, swamps valleys, and scattered trees. The highest point in this plateau is the peak of Simien Mountains, 4620m above sea level(Hurst,1950). Huffnagle (1961) describes the Northern Ethiopian plateau with respect to its topographic variation. This variation ranges from hilly and mountainous to broad rolling and nearly level plains. The Ethiopian plateau is cut up by the deep ravines or canyons in which the rivers flow. In some places the Blue Nile flows into a channel that is about 1300m below the level of this plateau on either side.

2.2 Hydrology

The Blue Nile Basin, including Lake Tana and its Basin, has an area of 324530 square km. The source of the Blue Nile is a small spring at a height of 2900 m and at about 100 Km South of lake Tana. From this spring the little Abbai flows down to lake Tana, 1829m above Mean Sea Level. Lake Tana is described by Shahin (1985) as a freshwater body which is situated in Norh-central Ethiopia. Its maximum length is 78 Km, width 67 Km and depth 14m. Relatively important feeders to lake Tana other than the little Abbai are the Rivers: Reb, Gumara, Magetch, Gelda and Unfraz.

2.3 Rainfall

The Abyssinian Plateau’s climate varies with latitude, altitude and exposure or slope. The rainy season is extended from June until September (Hurst et al., 1931). The West of Ethiopia receives higher amount of rainfall than does the remainder of the country. Highland rainfall normally peaks in August in the administrative regions of Welo and Northern part of Shewa (Figure 1). Rains decreases over much of the highlands during September (Henricksen, 1986).

2.4 Soil Types

The composition of the volcanic materials, particularly in the Ethiopian North Central Highlands, which cover most of the study area have a major importance for engineers and hydrologists. This is due to severe erosion which is caused by continuous events of storms during the rainy season. Two main soil types had been distinguished by Huffnagle (1961) : the red to reddish brown clayey loams and black soils. The red soils bare the specific latosols characteristics and they have an excellent permeability. The black soils which are derived from disintegration of dolerites are found in the lower parts (

depressions) of the study area. This soil type has tendency to dry out quickly and to crack. In wide deep valleys the black soil may have been intermingled with alluvial material (Huffnagle, 1961).

The soil's structure for different soil types in the Blue Nile Basin varies from fine granular (Cambisols dystric) to medium or coarse granular (Cambisols humic, Cambisols eutric, arenosols cambic and nitosols eutric). The corresponding permeability classes are slow to moderate for the fine granular and very slow for the medium or course granular.

2.5 Soil Erodibility Factor, K.

Direct measurement of the soil erodibility factor, K, is costly as well as time consuming. To achieve a better determination of soil erodibility factor for different soil types, the use of field-plot rainfall simulators had been recommended by Wishmeier and Smith (1978) in at least 12 different stations to obtain comparative data on numerous soils. The value of K is varied from a specific kind of soil to another according to the different properties of soil itself. Silt fraction content, percent of sand in soil, soil structure, organic matter content and permeability class are the most common properties that have been used to determine such factor either from empirical equations, tables or from soil erodibility nomographs.

Values of soil erodibility factors for different soil types vary during the year. Dickinson et al., (1982) determined the variation of K from season to season due to the change of the shear values for surface soils. Mutchler and Carter (1983) found that values of annual average soil erodibility by storm varied for Mississippi and Minnesota erosion plot data with the variation of the air temperature (Ulsaker and Onstad, 1984). The plant coverage strongly affects some of soil properties such as, infiltration and organic matter content. It increase infiltration as plant roots open up the soil and increases the organic content of the soil (Mogran,1980).

2.6 Vegetation

The study area land cover includes agricultural crops, coffee forests, grazing grounds, closed forests, open woodlands, open brush and scrub, as well as lakes and rivers. The important resources for the study area are fertile and climatic conditions which are favorable for cultivating a variety of crops and raising livestock. The cultivated area in Ethiopia are mostly on the highlands, in low valleys and on river plains which have sufficient rainfall or allow a form of irrigation (Huffnagle, 1961).

3. Model Description

The WASHMO (Watershed Storm Hydrograph Multiple Option) model was developed by Ward et al., (1979) at the University of Kentucky, Department of Agricultural Engineering. WASHMO had been used to determine volume of water runoff and sediment yield from watershed.

This model consists of two models. The first model describes the hydrology of the watershed and determines a design storm hydrograph. The second model describes the associated detachment, transport and deposition along with sediment yield from the watershed. Detachment occurs when a soil particle is dislodged from the soil surface and/or from the aggregate to which it was attached. When the soil surface is exposed, bare soil, the impact of falling rain drop is sufficient to detach soil particles from the soil mass. As far as the infiltration, percolation and saturation processes take place, and rainfall intensity exceeds the infiltration capacity, some of the excess water may be intercepted as surface storage in depressions, and the remainder becomes surface runoff. The soil particles can be easily transported by water, surface runoff. When the available energy is insufficient to transport soil particles, they will deposit either at a few millimeters of the detachment site or several kilometers downstream in rivers(Ward et al., 1979).

Sediment yield (in tons) was determined by using the modified version of the Universal Soil Loss Equation (USLE) which developed by Hann and Barfield (1978). This modified equation was written in the form :

$$Y_s = 95 \, (Q \, q_p)^{0.56} K L_s \, S_f \, C \, P_r \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Y_s is the sediment yield in tons from a storm, Q is the volume of runoff in acre-ft, q_p is the peak runoff rate in cfs, K is the soil erodibility factor, L_s is the slope - length factor, C is the ground cover factor and P_r is the reclamation practice factor.

4. Data Acquisition

Data preparation consists of creating main streams and tributaries from digital elevation model (DEM) with the aid of Arc-Map software. The other hydrological parameters such as Soil Conservation Factor Curve Number (SCS-CN), soil erodibility factor (K), Conservation Practice factor (CP).

4.1 Digital Elevation Model

A 30 m resolution of Digital Elevation Model (DEM) provided by Shuttle Radar Topography Mission (STRM) for the study area is used to describe the elevation of the Blue Nile watershed as shown in Figure 2.

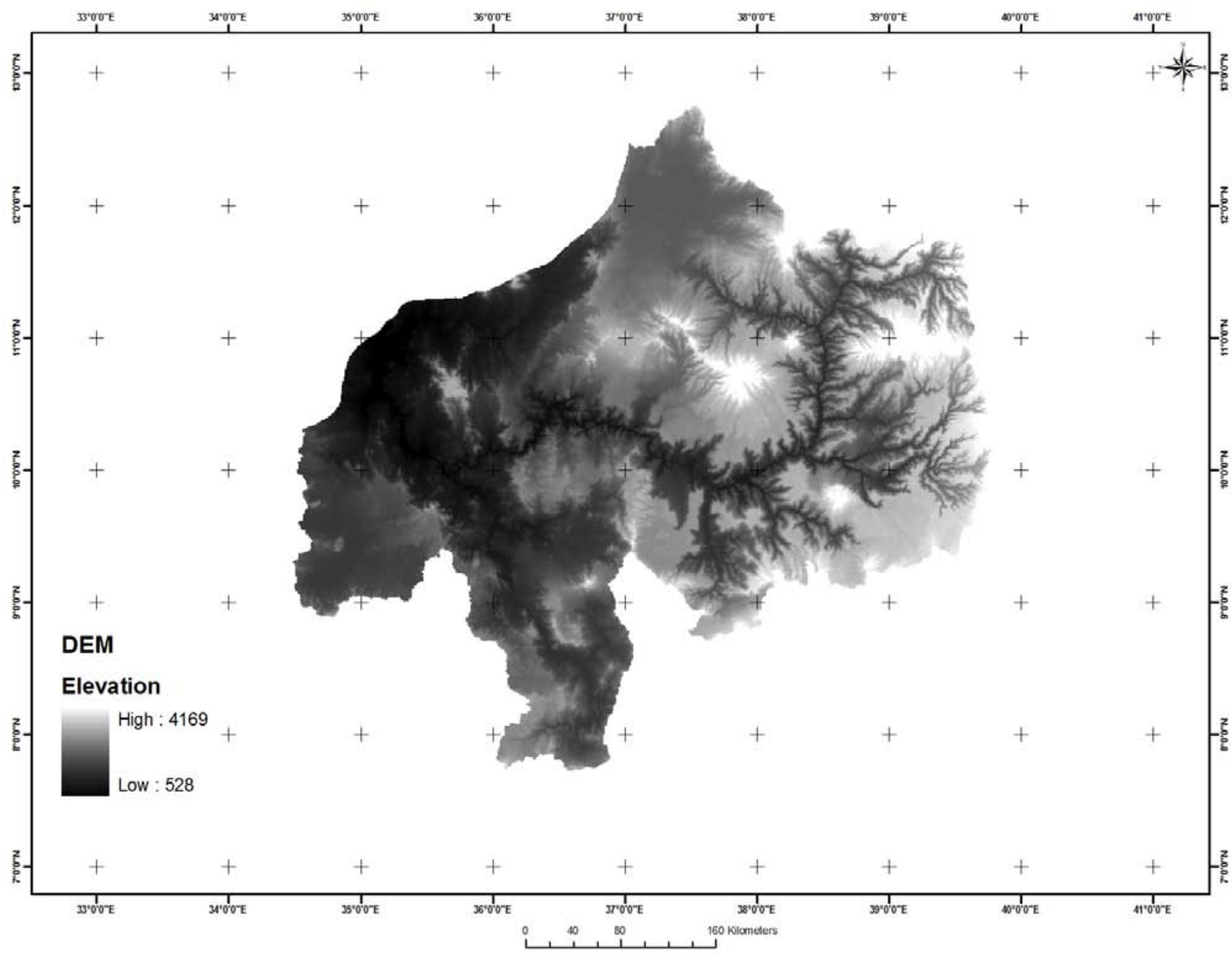


Figure (2) Digital Elevation Model for the study area.

4.2 Sub-watersheds extraction

Main stream and tributaries were extracted from DEM by using Arc-Map software. Sub-watersheds had been determined from both DEM and the drainage pattern of each catchment as shown in Figure 3.

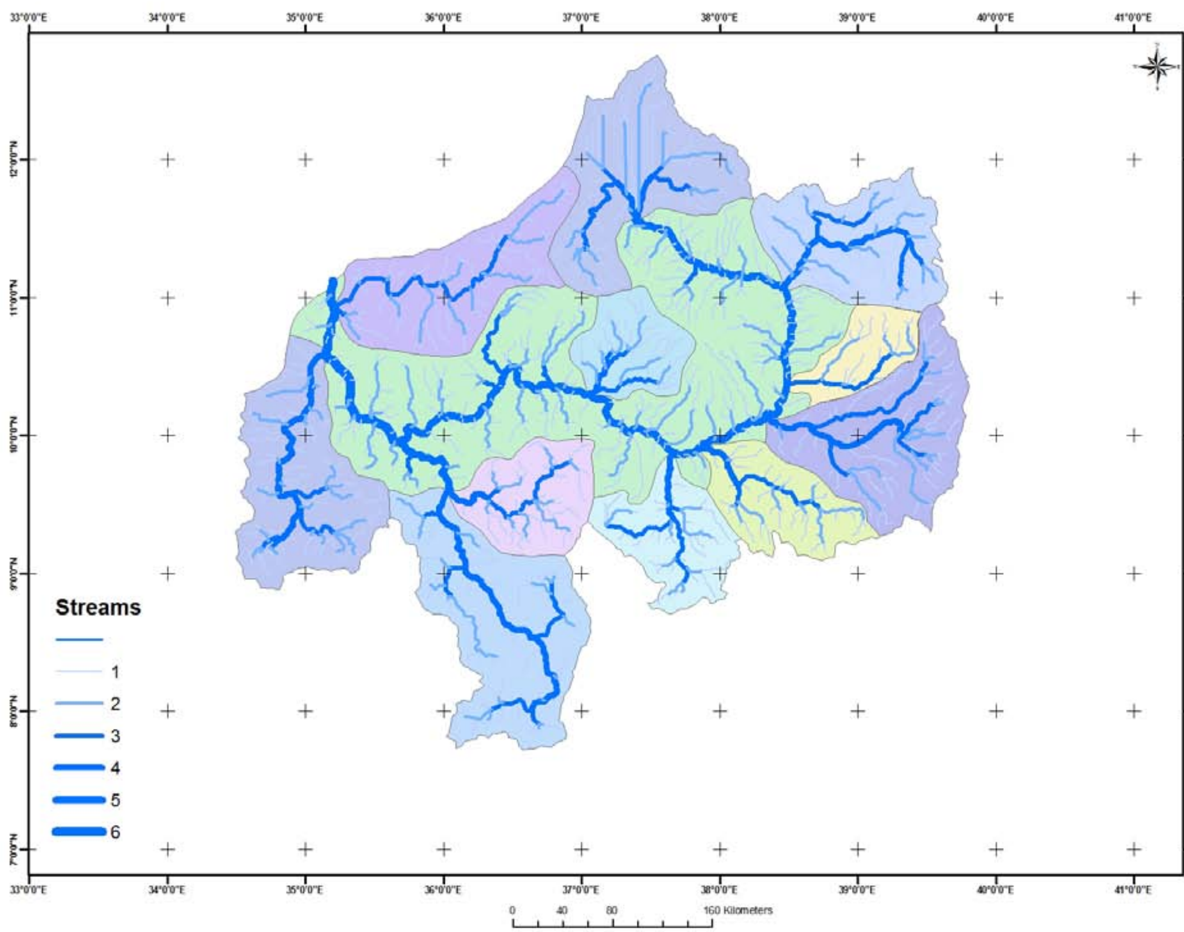


Figure 3: Sub-watersheds of study area.

4.3 Hydrological Parameters

The area of the watershed and its sub-watersheds, the lengths of main streams and their slopes and overland flow lengths and their mean slopes were extracted from the Arc-Map software. These values were tabulated in Table 1.

Table 1: Hydrological and Land coverage parameters that been extracted from Arc-Map Software.

Sub-Watersheds	Hydrological Parameters					
	Area (ha)	Hydraulic Length (m) and Slope	Overland Flow Length (m) and Slope	Land coverage %		
				Agric.	Forest	Grass Land
Sub-1	1390890.3	294270.3 and 4 %	47113.7 and 19 %	70.6	2.6	13.3
Sub-2	1513389.7	132132.1 and 6%	51126.2 and 9 %	21.8	9.5	25.9
Sub-3	1216737.2	201417.7 and 10%	62339.6 and 22 %	40.0	10.0	50.0
Sub-4	1487747.5	222609.1 and 7.5%	92098.8 and 17.4 %	38.4	24.6	37.0
Sub-5	793876.8	196735.2 and 9 %	35760.4 and 35.5 %	26.8	39.7	33.5
Sub-6	826636.4	157079.8 and 9 %	58213.3 and 18.3 %	40.0	10.0	50.0
Sub-7	813247.1	183101.0 and 8 %	40886.7 and % 15	78.7	3.7	17.6
Sub-8	1836815.9	339079.1 and 4 %	49927.5 and 15 %	83.4	0.0	16.6
Sub-9	1530389.1	260910.6 and 4 %	40363.0 and 8.4 %	47.0	2.3	11.8
Sub-10	623622.1	108361.0 and 12 %	40977.5 and 19.3	40.0	10.0	50.0
Sub-11	462513.3	153106.4 and 12 %	34626.9 and 18.4 %	40.0	10.0	50.0

Regarding to the land use and soil characteristics for the study area, Soil Conservation Service – Curve Number (SCS-CN) which represents the runoff potential of an area for each sub-watershed was determined by using Hann and Barfield (1978) approaches, see tables 2 and 3. The hydrologic soil groups that are given in Table 3 are based on the infiltration rate, depth, drainage and texture of different types of soil. The weighted mean value of the CN was used as a combined value for different kinds of vegetation coverage in each small catchment, when more than one type occurred. CN was found to be 42. The vegetation coverage percentage for each catchment was determined from Atlas of

Ethiopia. The description of different types of land cover was discussed widely by Huffnagel (1961).

Table 2: Definition of SCS hydrologic soil groups.

Soil Type	Description
A	These soils with high infiltration rate are chiefly deep, well-drained sands or gravel (Low runoff potential).
B	These soils with a moderate infiltration rate when thoroughly wet, are chiefly moderately deep, well-drained soils of moderately fine to moderately coarse texture.
C	These soils with a slow infiltration rate when wet are chiefly moderated deep, well-drained soils of moderately fine to moderately coarse texture.
D	These soils with a very slow infiltration rate, are chiefly clay soils with a high swelling potential, soils with a permanently high water table , soils with a clay pan at or near the surface and shallow soils over nearly impervious materials (high runoff potential).

Table 3: Runoff Curve Number for selected agriculture. (Antecedent rainfall = 1.4 – 2.1 inches).

Land use description	**Hydrological soil group**			
	A	**B**	**C**	**D**

Cultivated Land: * Without conservation treatment. ** With conservation treatment.	72 62	81 71	88 78	91 81
Pasture or range land: * Poor condition. ** Good condition.	68 39	79 61	86 74	89 80
Meadow: good condition.	30	58	71	78
Wood or forest land: * Thin stand, poor cover, no mulch ** Good cover	45 25	66 55	77 70	83 77

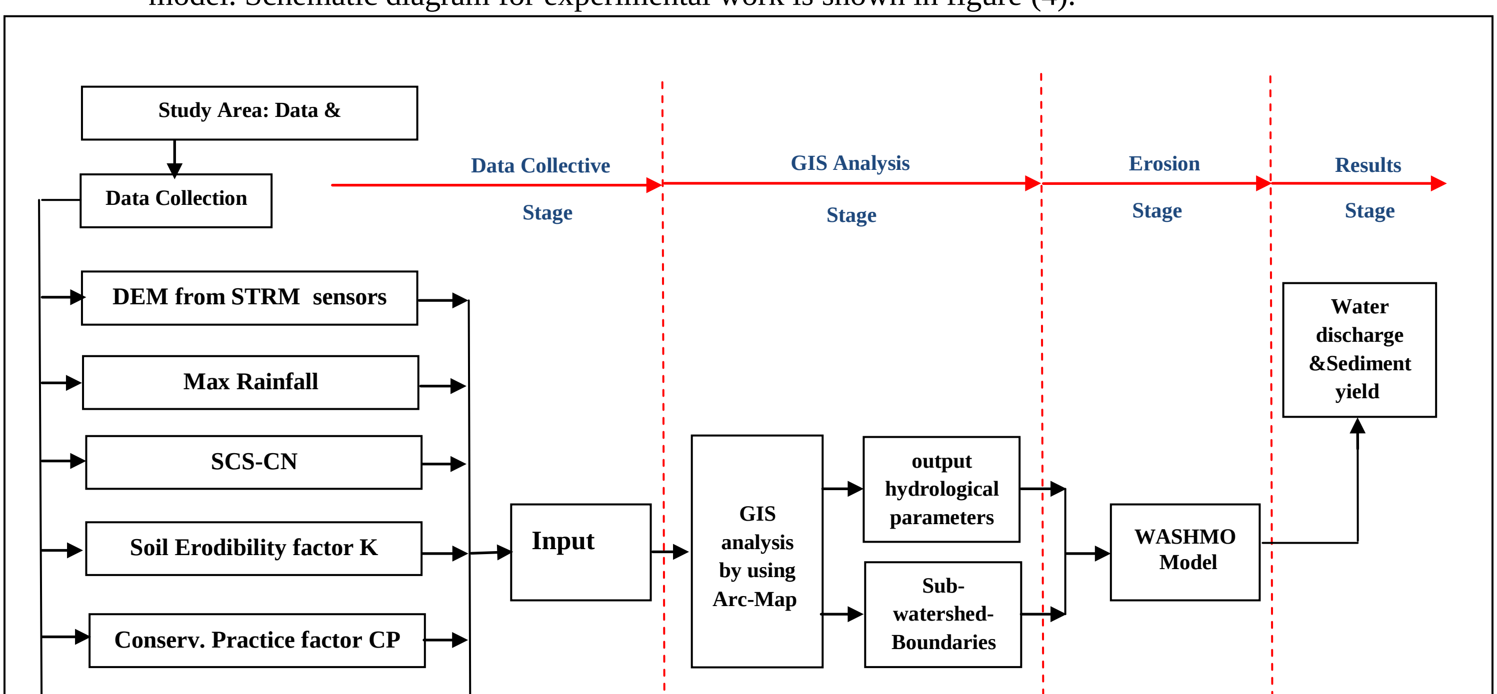
The soil erodibility factor, K, was found to be 0.20. This factor was determined by using soil erodibility nomograph given by Wischmeier and smith (1978). Percentage of agriculture, forest, and grass land coverage for the each Sub-Watershed was tabulated in table 1. The maximum rainfall amount was extracted from the Debre Markos station and found to be 164 mm and the time duration was assumed to be 24 hours. Sieve analysis of soil samples was studied and the particle size distribution of sediment flow was found to be as follows:

Particle size (mm)	0	0.002	0.05	0.1	2.0
% Finer	0	48.1	77	82	100

Conservation Practice factor (CP) was found to be 0.05 (Wischmeier and smith ,1978).

5. Methodology:

Data acquired from the previous subtitles were used as the input data of WASHMO model. Schematic diagram for experimental work is shown in figure (4).



Figure(4): Schematic Diagram of experimental work.

6. Results and Analysis

The input data of the hydrological model, "WASHMO" had been collected and determined carefully for each watershed area, these input data are:

- The area of every sub watershed by Hectares (Ha).
- The Hydraulic length of every sub watershed by meter (m)
- The percentage of every sub watershed that is Forest area (%).
- The percentage of every sub watershed that is Agriculture area (%).
- The percentage of every sub watershed that is Grass Land area (%).
- The percentage of the Overland Flow Slope for every sub watershed (%).
- The percentage of the Chanel Slope for every sub watershed (%).
- The Chanel Length from sub watershed to the outlet station of the watershed (m).
- The Cover or Conservation Practice factors for the watershed was determined from tables.
- The Specific Gravity of sediment particles.

The resulted water discharge in m^3/sec and sediment yield in tons for the first sub-watershed is shown in the following manuscript:

```
*******************************************************

*                         *

*   H Y D R O L O G I C A L   S Y S T E M S    *

*                         *
```

```
****************************************************
*                                *
*     PROGRAM  -  WASHED              *
*                                *
*     WATERSHED MODELLING              *
*                                *
*   PROGRAM TO DETERMINE RUNOFF HYDROGRAPHS    *
*   AND SEDIMENTGRAPHS FOR SMALL CATCHMENTS    *
*                                *
****************************************************
```

COMPANY DOING ANALYSIS :   MTC

ENGINEER   :   ASHOUR

DATE   :   30.4.2014

CLIENT   :   MTC

PROJECT DESCRIPTION   :   SEDIMENT CALCULATION

MAJOR WATERSHED NAME   :   AL-NAHADA WATERSHED

THE INPUT DATA FILE IS   :11

THE FLOOD HYDROGRAPH AND SEDIMENTGRAPH

IS STORED IN FILE   :11HYD

==

****

WATERSHED CONDITIONS AT AL-NAHADA WATERSHED

****

GLOBAL PARAMETERS

RAINFALL (mm.) : 164.00

INITIAL ABSTRACTION (mm.) : .00

-- will default to the SCS method

TIME INCREMENT OF HYDROGRAPH FROM START OF RUNOFF : .20

RAINFALL DISTRIBUTION SELECTED :SCS TYPE 2 CURVE

==

==

****

SUBWATERSHED CONDITIONS AT SUB1

****

RAINFALL PARAMETERS

SCS CURVE NUMBER : 42.00

UNIT HYDROGRAPH SELECTED : DOUBLE TRIANGLE

MAP PARAMETERS

AREA (ha.) :1390890.00

HYDRAULIC LENGTH (m.) : 294270.30

PERCENT FOREST (%) : 2.60

PERCENT AGRICULTURE (%) : 70.60

PERCENT GRASSLAND (%) : 13.30

OVERLAND FLOW SLOPE (%) : 19.00

CHANNEL SLOPE (%) : 4.00

CHANNEL LENGTH FROM SUBWATERSHED (m.) : 22313.55

TYPE OF CHANNEL FROM SUBWATERSHED : A NATURAL STREAM

CORRECTION FACTOR FOR IMPERVIOUS AREA : 1.00

CORRECTION FACTOR FOR CHANNEL IMPROVEMENTS : 1.00

AREAL REDUCTION FACTOR : 1.00

SEDIMENT PARAMETERS

SOIL ERODIBILITY PARAMETER K : .20

OVERLAND FLOW LENGTH (m.) : 47113.68

OVERLAND FLOW SLOPE (%) : 19.00

COVER OR CONSERVATION PRACTICE FACTOR : .05

SPECIFIC GRAVITY OF THE SEDIMENT PARTICLES : 2.65

EXPONENT OF THE FLOW SEDIMENT LOAD RELATIONSHIP: 2.00

PARTICLE SIZE DISTRIBUTION OF SEDIMENT FLOW

PART. SIZE mm.	% FINER %
.000	.0
.002	48.1

.050	77.0
.100	82.0
2.000	100.0

==

********** STORM HYDROGRAPH GENERATED FROM START OF RAINFALL ***********

TIME *	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
4.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
5.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
7.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
11.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
12.0 *	.2	.4	.8	1.1	1.5	1.9	2.3	2.7	3.2	3.7
13.0 *	4.2	4.8	5.3	5.9	6.5	7.2	7.8	8.5	9.2	10.0

14.0	*	10.7	11.5	12.3	13.1	13.9	14.7	15.5	16.4	17.2	18.1
15.0	*	19.0	19.9	20.8	21.7	22.6	23.5	24.5	25.4	26.4	27.3
16.0	*	28.3	29.3	30.3	31.3	32.3	33.4	34.4	35.5	36.5	37.6
17.0	*	38.7	39.8	40.9	42.0	43.1	44.2	45.3	46.5	47.6	48.8
18.0	*	50.0	51.2	52.4	53.6	54.8	56.0	57.2	58.4	59.7	60.9
19.0	*	62.2	63.5	64.7	66.0	67.3	68.6	69.9	71.2	72.6	73.9
20.0	*	75.2	76.6	77.9	79.3	80.6	82.0	83.4	84.8	86.2	87.6
21.0	*	89.0	90.4	91.8	93.2	94.6	96.1	97.5	98.9	100.4	101.8
22.0	*	103.3	104.8	106.2	107.7	109.2	110.7	112.2	113.6	115.1	116.6
23.0	*	118.1	119.7	121.2	122.7	124.2	125.7	127.3	128.8	130.3	131.8
24.0	*	133.4	134.9	136.5	138.0	139.5	141.1	142.6	144.2	145.7	147.2
25.0	*	148.8	150.3	151.9	153.4	154.9	156.5	158.0	159.6	161.1	162.7
26.0	*	164.2	165.7	167.3	168.8	170.4	171.9	173.4	175.0	176.5	178.1
27.0	*	179.6	181.1	182.7	184.2	185.8	187.3	188.8	190.4	191.9	193.5
28.0	*	195.0	196.5	198.1	199.6	201.2	202.7	204.2	205.8	207.3	208.9
29.0	*	210.4	211.9	213.5	215.0	216.6	218.1	219.6	221.2	222.7	224.3
30.0	*	225.8	227.3	228.9	230.4	232.0	233.5	235.0	236.6	238.1	239.7
31.0	*	241.2	242.7	244.3	245.8	247.4	248.9	250.4	252.0	253.5	255.1
32.0	*	256.6	258.1	259.7	261.2	262.8	264.3	265.8	267.4	268.9	270.5
33.0	*	272.0	273.5	275.1	276.6	278.2	279.7	281.3	282.8	284.3	285.9
34.0	*	287.4	289.0	290.5	292.0	293.6	295.1	296.7	298.2	299.7	301.3
35.0	*	302.8	304.4	305.9	307.4	309.0	310.5	312.1	313.6	314.1	294.1
36.0	*	249.0	244.5	239.8	235.1	230.2	225.4	220.3	215.4	210.4	205.5
37.0	*	200.4	195.5	190.4	185.6	180.6	175.9	171.1	166.5	161.8	157.4

38.0 *	152.9	151.0	149.1	147.2	145.2	143.3	141.4	139.5	137.6	135.7
39.0 *	133.7	131.8	129.9	127.9	126.0	124.1	122.2	120.2	118.3	116.4
40.0 *	114.5	112.6	110.7	108.8	106.9	105.0	103.1	101.2	99.3	97.4
41.0 *	95.6	93.7	91.9	90.0	88.2	86.4	84.5	82.7	80.9	79.1
42.0 *	77.3	75.6	73.8	72.1	70.3	68.6	66.9	65.2	63.5	61.8
43.0 *	60.2	58.5	56.9	55.3	53.7	52.1	50.5	48.9	47.4	45.9
44.0 *	44.3	42.9	41.4	39.9	38.5	37.0	35.6	34.2	32.8	31.5
45.0 *	30.2	28.9	27.5	26.3	25.0	23.8	22.6	21.4	20.2	19.0
46.0 *	17.9	16.8	15.7	14.6	13.6	12.6	11.5	10.6	9.6	8.7
47.0 *	7.8	6.9	6.0	5.2	4.4	3.6	2.8	2.1	1.4	

INITIAL ABSTRACTION = 70.15 mm.

ROUTED FLOW TIME FROM THE SUBWATERSHED = 5.10 hours.

TIME TO PEAK OF UNIT HYDROGRAPH = 46.85 hours.

THE DEPTH OF WATER ON WATERSHED = 1.15 mm.

VOLUME OF RUNOFF = 15925.98 thousand cu.m.

PEAK RUNOFF RATE = 314.37 cu. m./sec.

TIME TO PEAK RUNOFF = 35.75 hours.

==

******* STORM SEDIMENTGRAPH GENERATED FROM START OF RAINFALL ***********

TIME *	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
1.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
2.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
3.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
4.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
5.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
6.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
7.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
8.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
9.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
11.0 *	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
12.0 *	.1	.2	.3	.4	.6	.7	.9	1.0	1.2	1.4
13.0 *	1.6	1.8	2.0	2.2	2.4	2.7	2.9	3.2	3.4	3.7
14.0 *	4.0	4.3	4.6	4.8	5.1	5.4	5.7	6.1	6.4	6.7
15.0 *	7.0	7.3	7.7	8.0	8.3	8.7	9.0	9.4	9.7	10.1
16.0 *	10.4	10.8	11.1	11.5	11.9	12.3	12.6	13.0	13.4	13.8
17.0 *	14.2	14.6	15.0	15.4	15.8	16.2	16.6	17.1	17.5	17.9
18.0 *	18.3	18.8	19.2	19.6	20.1	20.5	21.0	21.4	21.9	22.3
19.0 *	22.8	23.3	23.7	24.2	24.7	25.1	25.6	26.1	26.6	27.1
20.0 *	27.6	28.0	28.5	29.0	29.5	30.0	30.5	31.0	31.6	32.1
21.0 *	32.6	33.1	33.6	34.1	34.6	35.2	35.7	36.2	36.7	37.3

22.0	*	37.8	38.3	38.9	39.4	40.0	40.5	41.0	41.6	42.1	42.7
23.0	*	43.2	43.8	44.3	44.9	45.4	46.0	46.6	47.1	47.7	48.2
24.0	*	48.8	49.4	49.9	50.5	51.0	51.6	52.2	52.7	53.3	53.8
25.0	*	54.4	55.0	55.5	56.1	56.7	57.2	57.8	58.3	58.9	59.5
26.0	*	60.0	60.6	61.1	61.7	62.3	62.8	63.4	64.0	64.5	65.1
27.0	*	65.6	66.2	66.8	67.3	67.9	68.4	69.0	69.6	70.1	70.7
28.0	*	71.3	71.8	72.4	72.9	73.5	74.1	74.6	75.2	75.7	76.3
29.0	*	76.9	77.4	78.0	78.6	79.1	79.7	80.2	80.8	81.4	81.9
30.0	*	82.5	83.0	83.6	84.2	84.7	85.3	85.9	86.4	87.0	87.5
31.0	*	88.1	88.7	89.2	89.8	90.3	90.9	91.5	92.0	92.6	93.2
32.0	*	93.7	94.3	94.8	95.4	96.0	96.5	97.1	97.6	98.2	98.8
33.0	*	99.3	99.9	100.5	101.0	101.6	102.1	102.7	103.3	103.8	104.4
34.0	*	104.9	105.5	106.1	106.6	107.2	107.8	108.3	108.9	109.4	110.0
35.0	*	110.6	111.1	111.7	112.2	112.8	113.4	113.9	114.5	113.3	103.7
36.0	*	90.4	88.7	87.0	85.3	83.5	81.7	79.9	78.1	76.3	74.4
37.0	*	72.6	70.8	69.0	67.2	65.4	63.7	61.9	60.3	58.6	57.0
38.0	*	55.5	54.9	54.2	53.5	52.8	52.1	51.4	50.7	50.0	49.3
39.0	*	48.6	47.9	47.2	46.5	45.7	45.0	44.3	43.6	42.9	42.2
40.0	*	41.5	40.8	40.1	39.5	38.8	38.1	37.4	36.7	36.0	35.3
41.0	*	34.6	34.0	33.3	32.6	32.0	31.3	30.6	30.0	29.3	28.7
42.0	*	28.0	27.4	26.7	26.1	25.4	24.8	24.2	23.6	23.0	22.4
43.0	*	21.7	21.1	20.5	20.0	19.4	18.8	18.2	17.7	17.1	16.5
44.0	*	16.0	15.4	14.9	14.4	13.8	13.3	12.8	12.3	11.8	11.3
45.0	*	10.8	10.4	9.9	9.4	9.0	8.5	8.1	7.6	7.2	6.8

46.0 * 6.4 6.0 5.6 5.2 4.8 4.4 4.1 3.7 3.4 3.0

47.0 * 2.7 2.4 2.1 1.8 1.5 1.2 .9 .6 .4

SEDIMENT YIELD = 8626861.00 tonnes.

PEAK SEDIMENT CONCENTRATION = 113.32 mg/l.

TIME TO PEAK SEDIMENT CONCENTRATION = 35.75 hours.

==

==

The resulted water discharge in m³/sec and sediment yield in tons for the Blue Nile watershed is shown in the following manuscript:

==

STORM HYDROGRAPH FOR WATERSHED AL-NAHADA WATERSHED

==

TOTAL AREA OF THE WATERSHED = 12495865.70 ha

THE DEPTH OF WATER ON WATERSHED = .24 mm.

VOLUME OF RUNOFF = 29901.79 thousand cu.m.

PEAK RUNOFF RATE = 570.41 cu. m./sec.

TIME TO PEAK RUNOFF = 40.90 hours.

TIME INCREMENT OF NEW HYDROGRAPH = .20 hours.

NUMBER OF RUNOFF VALUES = 155

******* STORM HYDROGRAPH GENERATED FROM START OF RUNOFF *******

.2	.8	1.5	2.3	3.2	4.2	5.3	6.5	7.8	9.2
10.7	12.3	13.9	15.5	17.2	19.0	20.8	22.6	24.5	26.4
28.3	30.3	32.3	34.4	36.5	38.7	40.9	43.1	45.3	47.6
50.0	52.4	54.8	57.2	59.7	62.2	64.7	67.3	69.9	72.6
75.2	78.0	81.5	85.1	89.0	93.0	97.2	101.5	106.0	110.6
115.4	120.3	125.4	130.5	135.8	141.1	146.4	151.9	157.4	163.0
168.7	174.4	180.2	186.0	191.9	197.8	203.8	209.9	216.0	222.1
228.3	234.6	240.9	247.3	253.7	260.1	266.6	273.1	279.7	286.3
293.0	299.7	306.4	313.2	320.0	326.9	333.8	340.7	347.6	354.6
361.6	368.7	375.8	382.9	390.0	397.1	404.3	411.5	418.7	425.9
433.2	440.4	447.7	455.0	462.3	469.6	476.8	484.1	491.4	498.7
506.0	513.2	520.5	527.8	535.1	542.4	549.6	556.9	564.2	570.4
509.5	504.5	499.1	493.5	487.7	481.9	476.2	470.6	465.2	460.1
455.4	455.8	456.2	456.5	456.9	457.2	457.6	457.9	458.3	458.6
459.0	459.4	459.8	460.2	460.6	461.1	461.6	462.1	462.6	463.2
463.8	464.5	465.2	466.0	466.8					

==

==

STORM SEDIMENTGRAPH FOR WATERSHED AL-NAHADA WATERSHED

===

TOTAL SEDIMENT YIELD = 66404073.00 tonnes.

PEAK SEDIMENT CONCENTRATION = 71.15 mg/l.

TIME TO PEAK SEDIMENT CONCENTRATION = 40.80 hours.

********* STORM SEDIMENTGRAPH GENERATED FROM START OF RUNOFF ********

.1	.3	.6	.9	1.2	1.6	2.0	2.4	2.9	3.4
4.0	4.6	5.1	5.7	6.4	7.0	7.7	8.3	9.0	9.7
10.4	11.1	11.9	12.6	13.4	14.2	15.0	15.8	16.6	17.5
18.3	19.2	20.1	21.0	21.9	22.8	23.7	24.7	25.6	26.6
27.6	28.5	29.2	29.9	30.5	31.1	31.7	32.3	32.8	33.4
33.9	34.4	34.9	35.4	35.9	36.4	36.9	37.5	38.0	38.5
39.1	39.6	40.2	40.7	41.2	41.8	42.3	42.8	43.4	43.9
44.4	45.0	45.5	46.0	46.6	47.1	47.6	48.2	48.7	49.2
49.8	50.3	50.8	51.4	51.9	52.5	53.0	53.5	54.1	54.6
55.2	55.7	56.3	56.8	57.4	57.9	58.5	59.0	59.6	60.1
60.7	61.3	61.8	62.4	63.0	63.5	64.1	64.7	65.3	65.8
66.4	67.0	67.6	68.2	68.8	69.4	70.0	70.6	71.1	70.4
53.7	51.3	48.9	46.5	44.2	42.0	39.9	37.9	36.1	34.5

33.1 32.6 32.1 31.6 31.2 30.7 30.3 30.0 29.6 29.3

29.0 28.8 28.6 28.4 28.3 28.1 28.0 28.0 27.9 27.9

28.0 28.0 28.1 28.2 28.3

=======================================

PARTICLE SIZE DISTRIBUTION OF SEDIMENT

=======================================

WEIGHTED SPECIFIC GRAVITY = 2.65

PART. SIZE mm.	% FINER %
.000	.0
.002	48.1
.050	77.0
.100	82.0
2.000	100.0

7. Conclusion and Recommendation

The max rainfall at debre Markos station (164 mm) with duration of 24 Hours gives volume of water = 29901.79 X 10^3 m^3 and 66404073 tones sediment as shown in the previous manuscript. Since the capacity of the GERR was estimated by the Ethiopian Government by the value of 63 billion m^3, then the following conditions (or Assumptions) will be taken in our consideration:

1- The Grand Ethiopian Renaissance dam will retain sediment into GERR.
2- No water losses from evaporation.
3- Effect of permeability is minimum.
4- No consumption of the stored water behind the reservoir for public use or irrigation purposes.

According to the resulted values of water volumes and sediment weight (weight in tones should be converted to volume) and under the mentioned conditions, the required filling time is found to be:

I) In case of filling of water and sediment :
Since the reservoir capacity is 63X10 ^{9} m^3
And the total volume of water and sediements per year equal 3.0 X10 ^{9} m^3/yr
The required filling time of the reservoir is (63X10 ^{9}) / (3 X10 ^{9}) = 21 year

II) In case of filling of sediment only, the life span (LS) will be as follows:

Since the reservoir capacity is 63X10 ^{9} m^3
And the total volume of sediements per year equal 1.4 X10 ^{9} m^3/yr
The estimated life span of the reservoir is (63X10 ^{9}) / (1.4 X10 ^{9}) = 45 year

The area of GERR is shown in Figure 5.

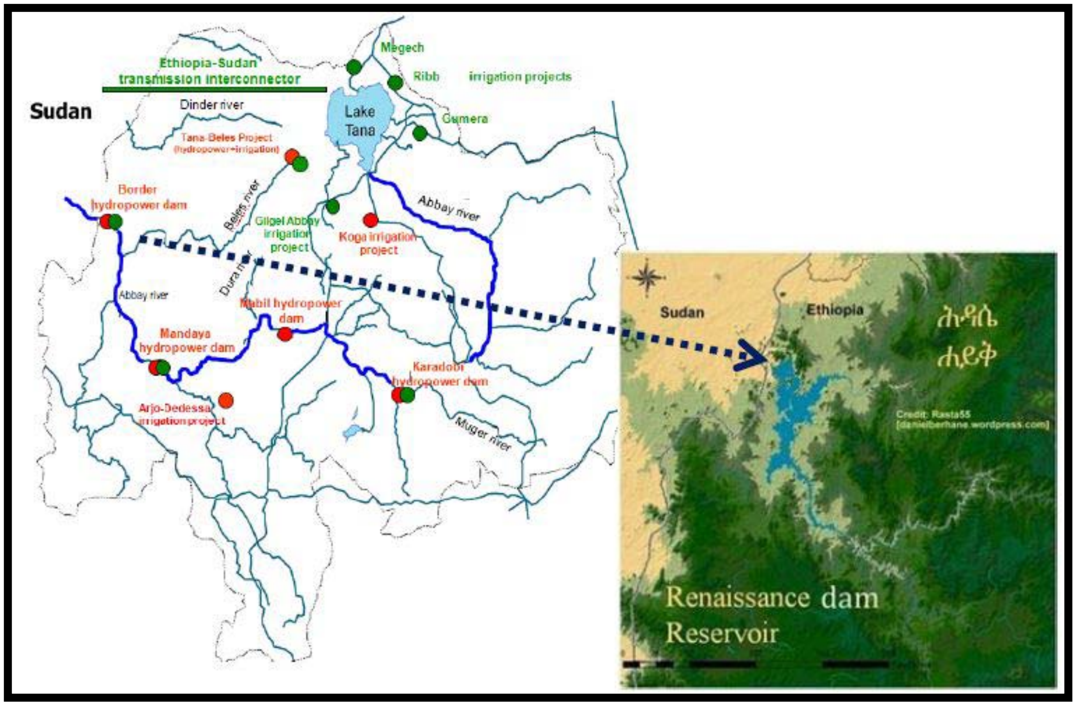


Figure 5 The area of Grand Ethiopian Renaissance Reservoir (GERR)

We **recommend** to use actual rainfall storm event and the actual number of these events and percentage of evaporation and infiltration that been neglected in our calculation. Also, we should take in future work the stored water behind the reservoir for public use or irrigation purposes.

Refernces:

- Dickinson et al., 1982, “ The great Salinity anomaly in the Northern North Atlantic 1968-1982”, Robert R Dickson, Jeno Meincke, Svend-Age Malmberg, Arthur J. Lee.

- Henricksen, B.L., 1986,"Reflections on drought": Ethiopia 1983-1984, International Journal of Remote Sensing. Vol. 7, No. 11, Nov. 1986, pp. 1447-1451.

- Hurst, H.E., 1952 The Nile , A General Account of the River and the Utilization of its Waters, Constable Publisher, London.

- Hurst, H.E.,1950, The Nile Basin. The Hydrology of the Sobat and the Topography of the Blue Nile and Atbara Vol. VIII, Government Press, Cairo, Egypt.

- Hurst, H. E., and Philips P., 1931," The Nile Basin Vol. **V.** The hydrology of the Lake Plateau and Bahr el Jabel. Physical Department paper No. 35, Schnidlers Press, Cairo, 235 pp.

- Huffnagle, H.P., 1961. Agriculture in Ethiopia, Food and Agricukture Organization of United Nation, Rome, 1961.

- Murphy H.F.,1986, "A Report on the fertility status and other data on some soils of Ethiopia, Jumma, Ethiopia" , College of Agriculture, Haile Sellassis University, Experiment Station Bulletin No. 44.

- Mutchler and Carter, 1983 , "Seasonal Soil Loss and erodibility variation on a Miamian Silt Loam Soil " .

- Shahin, M.,1985. Hydrology of the Nile Basin, International Institute for Hydraulic and Environmental Eng., Netherlands, Elsevier Science Publisher B.V.

- Ulsaker, L.G. and Onstad,C.A. 1984, "Reality Rainfall Erosivity factors to Soil loss in Kenya".

- Wishmeier W.H. and Smith, D.D. 1978, " Predicting rainfall Erosion Losses" , A guide to conservation planning. Science and Education Administration, United States Department of Agriculture Hyattsville, Maryland, pp58.

- Ward, A.D., Hann, C.T. and Tapp, J.S. ,1979, " The DEPOSITS Sedimentation Pond Design Manual ", Institute for mining and minerals Research Office of Informational Services, University of Kentucky, Lexington, Kentucky.

- Hann, C.T. and Barfield, B.J., 1978. Hydrology and Sedimentology of Surface Mined Lands. Office of Continuing Education and Extension College of Engineering. University of Kentucky, Lexington, Kentucky.