Hydrological Data Processing and Management System

Case Study: (Upper Awash Sub-Basin Flow Data Processing for Koka Reservoir Management)

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Abstract:- This case study is mainly focused on the determination of hydrological river flows using data processing techniques in the upper Awash basin that would be used for Koka reservoir management. The geographically located of the basin is between 38^{0}56'E – 39^{0}17'E longitude and 8^{0}34'N – 9^{0}05'N latitude, which is about 70km^2 south east of Addis Ababa in the Rift valley.

The main objectives of this case study are to determine seasonal river flows of Mojo, Awash at Hombole and Awash below Koka Dam Rivers and to analyse flow hydrographs for the management of Koka reservoir. The methodologies adopted in this case study were data collection, data processing and data analyses sections. In data collection section, data were collected using the gauge books, flow measurement, automatic recorders, radar sensor and telemetry. In data processing section data error correction, data entry, pre-processing activities were carried out and rating curves were developed. In the last section, data analyses and hydrographs were developed.

The finding from this case study shows that the maximum and minimum flows of each river in m^3/s are 511.2 and 0.0 for Mojo River, 803.1m^3/s and 0.04m^3/s for Awash River at Hombole and 718.0m^3/s and 0.76m^3/s for Awash River below Koka dam respectively. These flows were determined from the flow rating curves. The flow measurement parameters for each station were determined as shown in the data processing section. In addition, seasonal and annual flow hydrographs for each river are also presented in the annex. The flows to (Hombole and Mojo river flows) and from (below Koka river flow) would be used for the analysis of dam management during flooding seasons, dam safety and its efficient use in hydropower generation and irrigation demands. The flows were estimated both manually and using HYDATA software.

***Keywords:** Hydrology, data processing, flows, reservoir, Ministry of Water and Energy, Addis Ababa.*

1.0 INTRODUCTION

1.1 Koka Reservoir

The Koka reservoir is implemented in 1959 for developing hydroelectric power for Ethiopia. The Awash and the Mojo rivers supply the inflow to the reservoir. During the flood season both rivers are heavily loaded with suspended matter. Sedimentation in the Koka reservoir has been surveyed three times: in 1969 spot levels of the reservoir bed were taken and in 1973 and 1981 contour surveys were done. The total sediment deposited in the Koka reservoir in the period 1961-1981 has been estimated at 0.34 km^3, yielding an average of 17Mm^3 per year. A certain sediment prediction formula yielded 0.362 km^3 and 18 Mm^3 per year, respectively (Imru, 1992).

During the rainy seasons, from June through September, about 80% of the rains are received. Heavy downpours are common in most parts of the country and large scale flooding is rare and limited to the lowland areas where major rivers cross to neighbouring countries. However, intense rainfall in the highlands causes flooding of settlements close to any stretch of river courses. The Koka Reservoir operation has traditionally been responsibility of the Ethiopian Electric Power Corporation (EEPCo). Downstream of the dam there are three hydroelectric power plants, which are the main source of electric supply for the country. In the Awash valley below the dam there also is irrigation of close to 70,000 ha depending on water supply from the reservoir. A Koka Reservoir Operational Committee, composed of representatives from the Electric Board and Ministry of Water and Energy, establishes operation schedules for the reservoir to be followed for each rainy season. This schedule takes into account irrigation water requirement, flood security for developments downstream as well as power generation. A close follow-up of the operation by this committee has made it possible to prevent significant damages by floods and has rendered improved water supply for developments.

Objective

- Prepare hydrological yearbook for users
- Sustain surface and ground water study based on the available technologies and update the information on timely basis
- Develop flood control and early warning systems using hydrological models and provide real time information for users to reduce and manage flood risks in different parts of the country
- Collect water level, flows, sediment sample, and water quality from different hydrological stations and available data for development and research activities.

1.2 Study Area

The study area is located within the main Ethiopian rift valleys and mostly affected by the southerly and easterly Indian Ocean air currents as a result the air currents supply rain with bimodal characteristics. According to stream flow data that obtained from the area signify that there is high peak of rainfall from June to September, low from March to

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May and dry from October to February (please refer the hydrographs in the annex, Annex 1, 2, 3, 4, and 5 for each station).

2.0 Data processing

Data processing is a system of changing row data or unprocessed data in to a recognizable format that has been collected and encoded from the given gauge station. In other words, it is the process that starting from data acquisition from the field to database management in the office where the data will be given for users and stored in the database. Hydrological data are valuable in that they are relatively expensive to collect, are irreplaceable and have the potential to have very high value following certain events.
Error correction and data entry

Before entering the raw data in to computer the data should be corrected if there are errors such as, data missing during data recording at the station. Once the error is corrected throughout the series, then the corrected data are entered to the computer to get processed and analysed data and/ or information for different applications.

2.1 Developing Rating Curve

Once the discharge measurement and water level are plotted, for low and high flow points; (G_1, Q_1) and (G_2, Q_2) were identified in order to determine the flow parameters. This means, Q_3 is computed using $Q_3 = \sqrt{Q_1 \times Q_2}$ then G_3 is read from the corresponding readings of Q_3 on the plot. Finally the zero gauge height (G_0= e), the slope (b) and the flow coefficient (c) would be determined using the following empirical equations.

$$G_0 = \frac{G_1 \times G_2 - G_3^{\,2}}{G_1 + G_2 - 2G_3}$$

$$b = \frac{LOGQ_2 - LOGQ_1}{LOG(G_2 - e) - LOG(G_1 - e)}$$

$$C = \frac{Q_2}{(G_2 - e)^b}$$

Discharge is calculated by using the relationship established in the first part. If the stage-discharge relationship doesn't change with time, it is called permanent control. If the relationship does change, it is called shifting control. Shifting control is usually due to erosion or deposition of sediment at the stage measurements. Bed rock-bottom parts of rivers or concrete structures are often, though not always, permanent controls.

The relationship between G and Q is expressed by a single valued straight-line equation:

$$Q=c * (G-e)^{\wedge b}$$

Where: G is stage height in meter and Q is for discharge in m^3/s, c is constant number, e is zero-gauge height, and b is slope of the river reach.

2.2 Flow determination

Once the rating curves are developed, flows were computed from the river water levels. The developed rating curves for the three hydrological gauging stations were determined. The nature of developed rating curve which data points condense to the curve is more accurate, while that has dispersed data points decrease its degree of accuracy. The other point which one considers that the data extremely far from the fitting curve is considered as outliers and are not considered in the computation.

Therefore, for each rating curve, three parameters were determined for the three gauging stations. Accordingly, the parameters for Awash River at Hombole are c=23.82, e=0.35, and b=2.3417. For Mojo River, these parameters are c=29.52, e=-0.46, and b=1.688. Similarly, these parameters are c=51.18, e=-0.218 and b=1.418.

Table 1 Daily time series flows

	Mojo	Awash Hombole	Awash below Koka dam
Date	**Q, m3/s**	**Max Q, m3/s**	**Max Q, m3/s**
01-Jan-98	0.303	15.003	114.69
02-Jan-98	0.303	15.384	116.482
03-Jan-98	0.303	15.384	116.482
04-Jan-98	0.303	15.768	116.482
05-Jan-98	0.259	16.944	114.69
…	…	…	…
30-Dec-08	0.489	20.255	90.495
31-Dec-09	0.489	20.684	88.004

Table 2 Annual maximum and minimum time series flows

	Mojo		A. Hombole		B. Koka	
Date	Max Q, m3/s	Min Q m3/s	Max Q, m3/s	Min Q m3/s	Max Q, m3/s	Min Q m3/s
1998	396.255	0.277	788.21	13.53	345.02	111.13
1999	360.22	0.277	813.07	11.77	367.94	120.09
2000	219.656	0.171	469.51	8.85	250.3	51.74
…	…	…	…	…	…	…
2008	475.208	0.05	547.36	9.79	447.73	85.33
2009	197.062	0.011	661.55	9.16	100.66	51.74

The rating curves were also developed using HYDATA software. Since the dataset is many in number it is difficult to assess and estimate the error manually. However, this might be handled easily using software. Here the manually developed and HYDATA software developed rating curves were compared and the results are presented in the annex, please refer the attached figure.

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Figure 1. Rating curve for Mojo River

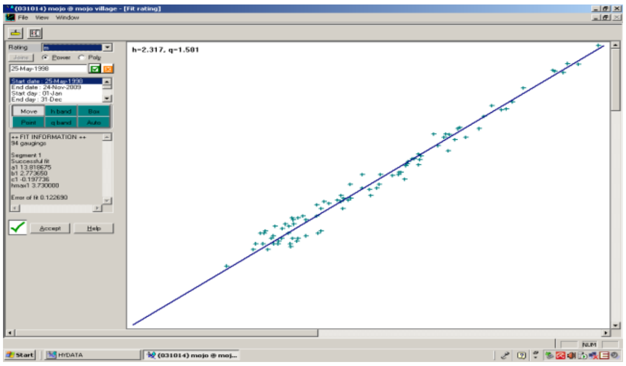


Figure 2. Rating curve for Awash River at Hombole

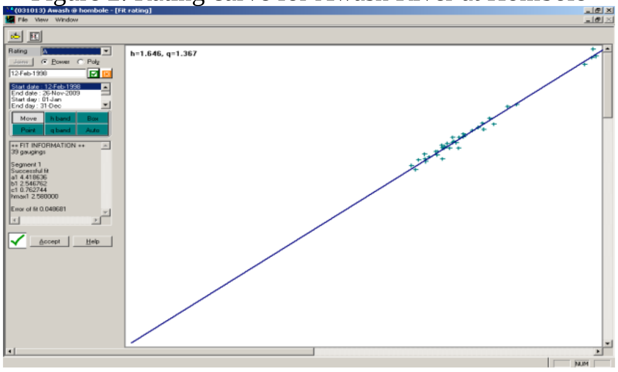
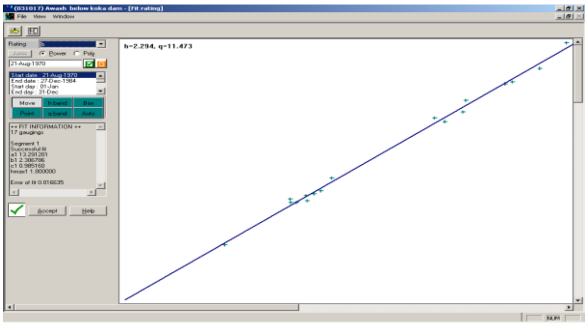


Figure 3. Rating curve for Awash River below Koka dam



3.0 DATA ANALYSIS

3.1 Hydrographs

It can observe this seasonal flow curve the variation of flows in different seasons by the effect of South Atlantic Ocean winds therefore, the most Ethiopia's river are perennial. During high flow or main rainy seasons (from June through September), ITCZ is moves northwards to red sea. At this time many parts of Ethiopia receives rain. Small to medium flows are also obtained when ITCZ moves in southern part of Ethiopia which brings rainfall to south and south western part of the country (from February through May). During dry seasons (from October through January), ITCZ is located further south and brings low flows rain to extreme south and south eastern Ethiopia.

Figure 4. Seasonal flow hydrograph of Mojo River

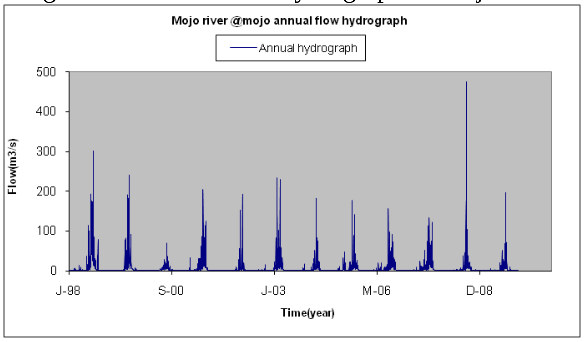


Figure 5. Annual flow hydrograph of Mojo River

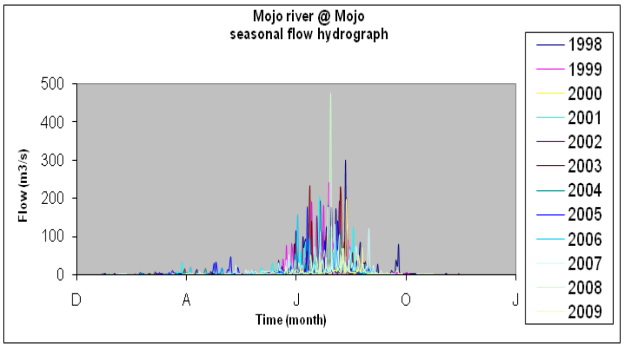


Figure 6. Seasonal flow hydrograph of Awash River at Hombole

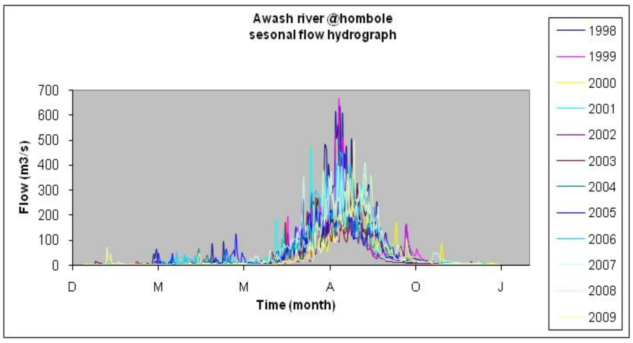


Figure 7. Annual flow hydrograph of Awash River at Hombole

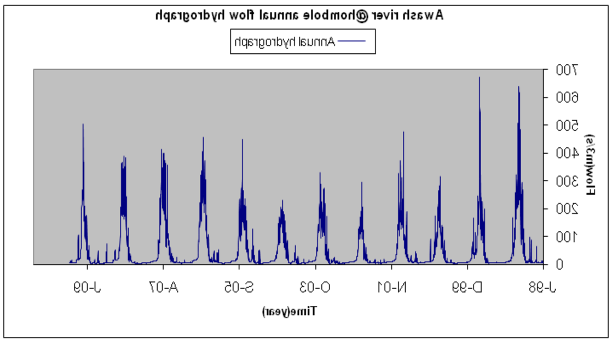


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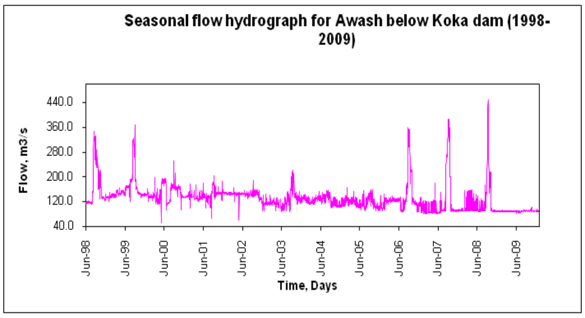
Figure 8. Seasonal flow hydrograph of Awash River below Koka dam



3.2 Reservoir management

Koka reservoir storage capacity is required to be maintained to absorb foreseeable flood inflows to the reservoirs, so far as they would cause excess of acceptable discharge spillway opening. Storage allows future use of the flood water retained. Koka reservoir had an original storage capacity of 1650 Mm3 at full reservoir level of 1590.7m above sea level (or 110.30m reduced level). When the dam was made operational in 1960 the capacity of the reservoir at 100.4 m (minimum operating level) was 180Mm3.

The mean rate of silt deposition in the reservoir is estimated at 13-20 Mm3 per year (MoWR, 1999), which is in the order of 1800 ton/Km2/year. Using the original capacity of the reservoir and the mean annual inflow of Awash River upstream of koka dam (29478Mm3 at Hombole station) the trap efficiency is estimated at 78.38 %.

Soil erosion in turn causes serious downstream negative multiple effects with high social and economical effects. The Metallitia earth dam near the Mojo River, for instance, filled with 96000 M^3 of sediments in two years, largely due to sediments from intense gullies (PRDE, 1989). Sedimentation of Koka reservoir has also been an ongoing problem since its impoundments.

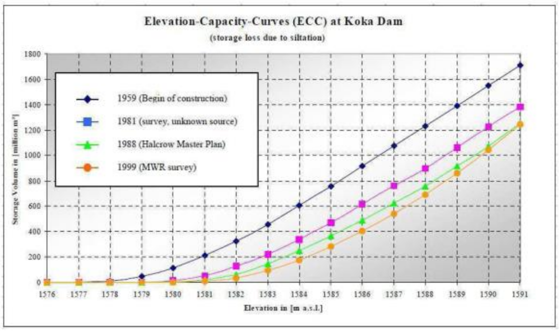


Figure 1 Koka reservoir area-capacity curve

3.3 Data storage and dissemination

All available and qualified hydrological datasets are being maintained in well-defined and computerized databases using the HYDATA v4.2 database management system for surface water and ENGIDA database for groundwater. Some of the most hydrological data types stored in the database are description that shows geographical and space-oriented data on catchments, location oriented data of observation stations and water quality laboratory results, processed results and rating questions, etc. Hydrological data are therefore disseminated for different users as per their requests from Hydrology and Water Quality Directorate, Ministry of Water And Energy for free.

4.0 RESULTS AND DISCUSSIONS

As indicated in the objective section, the main aim of this case study work is to determine flows to and from Koka reservoir and to study the current status of koka dam and its reservoir management system. The condition of the water in the area is explained based on climate and hydrology of flow data collected from gauging found upstream and downstream of the reservoir.

The developed rating curves for the three hydrological gauging stations were determined. For each rating curve, three parameters were determined for the three gauging stations. Accordingly, the parameters for Awash River at Hombole are c=23.82, e=0.35, and b=2.3417. For Mojo River, these parameters are c=29.52, e=-0.46, and b=1.688. Similarly, these parameters are c=51.18, e=-0.218 and b=1.418.

In the first step the relationship between stage and discharge is established by measuring the stage and corresponding discharge were plotted on log paper. And in the second part, the discharge was calculated by using the relationship established in the first part. From the rating curves the following straight line result was gained on the three gauging stations and also the curve characteristics exactly shows that the base sediment load patterns on the area increase time to time.

Results show that the flows were estimated using rating curve solution using a 12 years data, 1998 to 2009 for Awash Hombole, Mojo and Awash below Koka Dam Rivers. It is also presented graphically in the analysis section. Therefore, the average annual flows of Mojo River is about 341.06Mm^3, Awash River at Hombole is 1440.58Mm^3 and Awash below Koka dam is about 1520.19Mm^3. These flows are higher in rainy seasons, in contrast, the data pointed to a decrease in stream flow during low flow periods. Increased evaporation during these dry years could also have contributed to the low flows.

The seasonal flow hydrographs presented above, shows high flows (from June to September) during rainy seasons, Medium flow (from February to May) during small rainy seasons, and Low flow (from October to January) during dry seasons.

Estimates for soil erosion based on the sediment curve at Mojo gauging station and on an average sedimentation rating in Koka reservoir are an order of magnitude higher at 15-25 ton/ha/yr (MoWR, 2008). The fundamental causes of soil erosion in the study area are the severe impact of human activities (i.e. cultivation and grazing) on natural resources.

This is due the rapid increase in human and livestock population which is greater than the carrying capacity of the natural resource. This has resulted in fast spread of gullies and an irreversible degradation of natural resource (MoWR, 2008).

5.0 CONCLUSIONS

The study area, the upper Awash River Basin, covering 1506 Km^2, within the Ethiopian Rift valley, is located between 8.5N to 12N. The Awash River Basin is divided in to four major physiographic division; High land, Central plain, Rift floor and Escarpment.

According to the result, the seasonal flows of each river were affected by seasonal rainfall distribution. This means, the flow was maximum during Kiremt season and minimum during Bega season where as in the Belg season it is relatively medium. This shows that the seasonal flow variation of each river arise from the seasonal change of rainfall distribution characteristics of Ethiopia. The other point observed from the result was that the flows show continuous flows throughout the year like Perennial Rivers even though its flows are very small in dry season.

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