Genale Dawa III Dam Threatens Somalia's Water and Food Security

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Executive Summary:

Juba river is one of two perennial rivers in Somalia that accounts for majority of the country's agricultural output. Juba river also known as Genale Dawa river in Ethiopia, originates from the Ethiopian highlands. Three tributaries in Ethiopia converge near the Somalia national boundary to form the Juba river. The three tributaries are Genale, Dawa and Gestro rivers. Approximately 70% of the basin area for the Juba river lies within Ethiopia. The Ethiopian highlands originate about 90% of the precipitation forming the Juba river in Somalia. The Ethiopian Ministry of Water Resources (MoWR) has been conducting several high level feasibility studies of the potential hydropower of the country in order to harness the energy and grow their economy. Some of those studies were completed and are currently at implementation stage while others are ongoing.

The studies that the MoWR has been conducting include Genale Dawa III (GD-3), Genale Dawa V (GD-5) and Genale Dawa VI (GD-6) as cascading system. The GD-3 is currently in construction and will be completed in early 2018; while the GD-5 is still unknown whether it has been abandoned or is part of a long term vision. Two British firms were awarded the contract to design and construct GD-6 dam, the first quarter of 2017. Ethiopia has the rights to develop their country and deploy its available natural resources; however, there is an urgent need for transboundary coordination between the upstream and downstream bordering counties. Somalia which relies heavily on the Juba river could feel the devastating impacts of the water imbalances.

This brief whitepaper was prepared to assess the preliminary impacts of the proposed Ethiopian dams on Juba river. In particularly, it focuses on the impacts of the first completed hydropower project along the Genale Dawa river, GD-3. The GD-3 is expected to yield the total installed capacity (maximum output of all the generators combined under ideal conditions) of 254 MW. Based on historical streamflow data, the construction of GD-3 will have a significant impact on the Juba river in Somalia., the GD-3 dam will require to store a minimum of 260 million cubic meters to operate and has a capacity of 2.5 billion cubic meters. The annual volume of runoff in Juba at the most upstream point of Luuq is 5.8 billion cubic meters. Historical streamflow data at Luuq from 1963 – 1990 was used as the baseline along with data from the feasibility study for GD-6 completed by the MoWR of Ethiopia. Detailed hydrologic and hydraulic study of the Genale/Juba basin is crucial to fully quantify and assess the impacts from GD-3 and GD-6.

Based on historical streamflow data and the assumption that the current streamflow matches data collected pre-civil war, the construction of GD-3 will have a significant impact on the downstream communities. The construction of GD-3 results in a reduction of 24%-33% of the total streamflow at Juba River without taking the various other losses into account (i.e. evaporation, infiltration, transmission losses).

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1. Introduction

Within the last decade, the Ethiopian Ministry of Water Resources (MoWR) has been exploring the hydropower potential of the Juba/Genale Dawa River to provide energy supplies to rural communities in the Somali and Oromia regions of Ethiopia. The Genale Dawa Dam III (GD-3) is the first dam out of four other cascading dams to be constructed on the Juba/Genale Dawa River, and the estimated completion date for GD-3 is early 2018. The MoWR is exploring the remaining two cascading dams downstream of GD-3 to harness the potential energy resources. Therefore, the objective of this paper is to summarize the impacts of GD-3 to the downstream communities along the Juba river in Somalia, particularly during the draught seasons "Jillal".

Juba river along with Shabelle river are the only perennial rivers in Somalia and they provide lifelihood to numerous communities along the river banks. Communities along the Juba river are one of the most important agricultural regions in Somalia. The communities that rely on the Juba river include Doolow, Luuq, Garbahaarey, Baardheere, Saakow, Bu'aale, Jilib, and Jamaame (See **Figure 1** and **Table 1**). Juba River or Webi Juba is also known as Genale Dawa River within the Ethiopian national boundary. Three tributaries/rivers originating in the highlands of Ethiopia merge at the point south of the Somali national boundary (Doolow) to form the Juba River. Juba river ultimately combines with Shabelle River prior to emptying into the Indian Ocean, few kilometers east of the city of Kismaayo.

Table 1: Populations along the Juba Basin in Somalia

Region	Capital City	Region Population[1]
Gedo	Garbahaarey	508,000
Bay	Baydhaba	792,182
Bakool	Xudur	367,226
Lower Juba	Kismaayo	362,921
Middle Juba	Bu'aale	489,307
Total		2,519,636

[1] The population data is from the UNFPA report "Population Estimation Survey 2014 for 18 pre-war regions of Somalia".

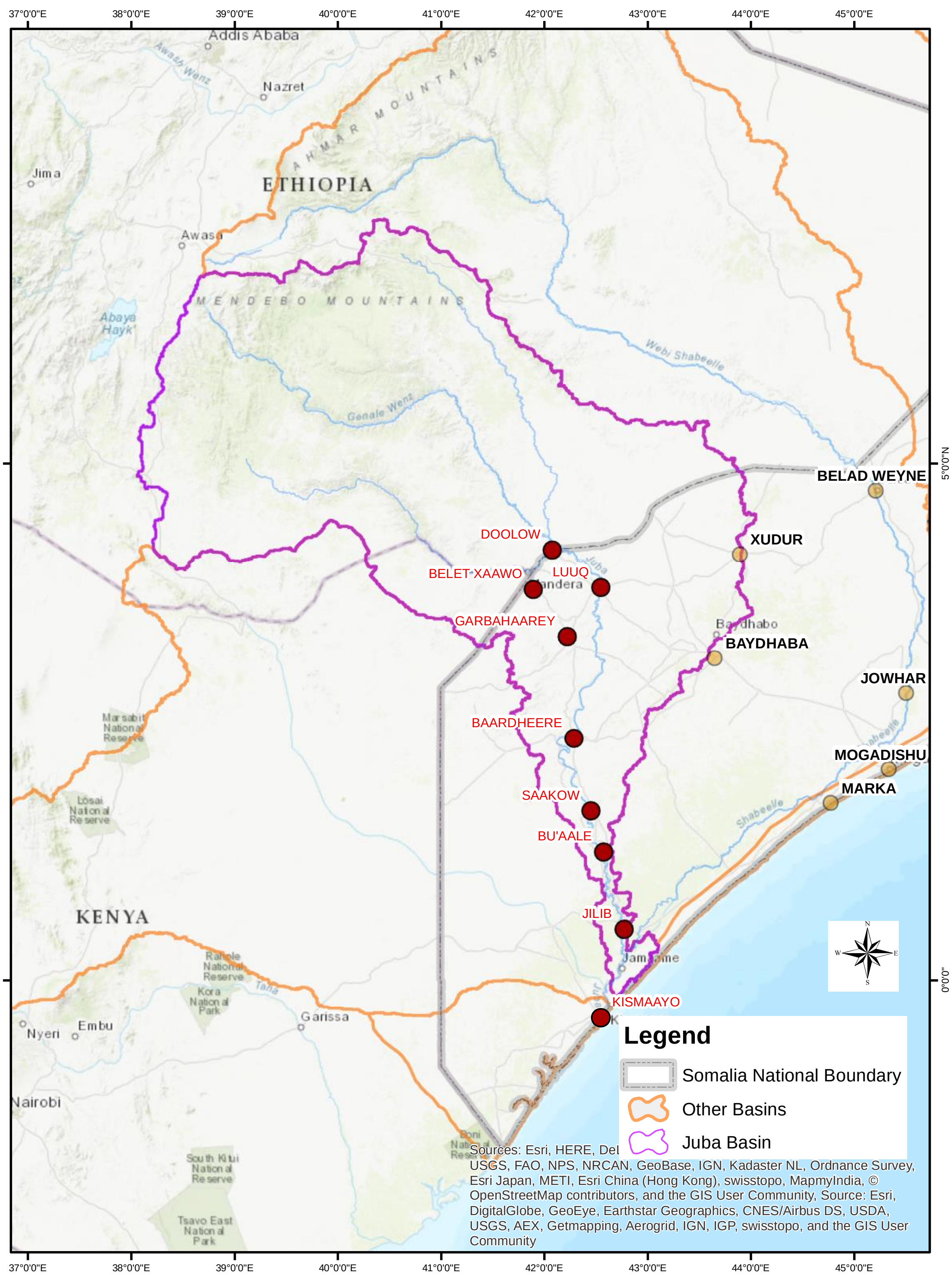

Figure 1: Location Map

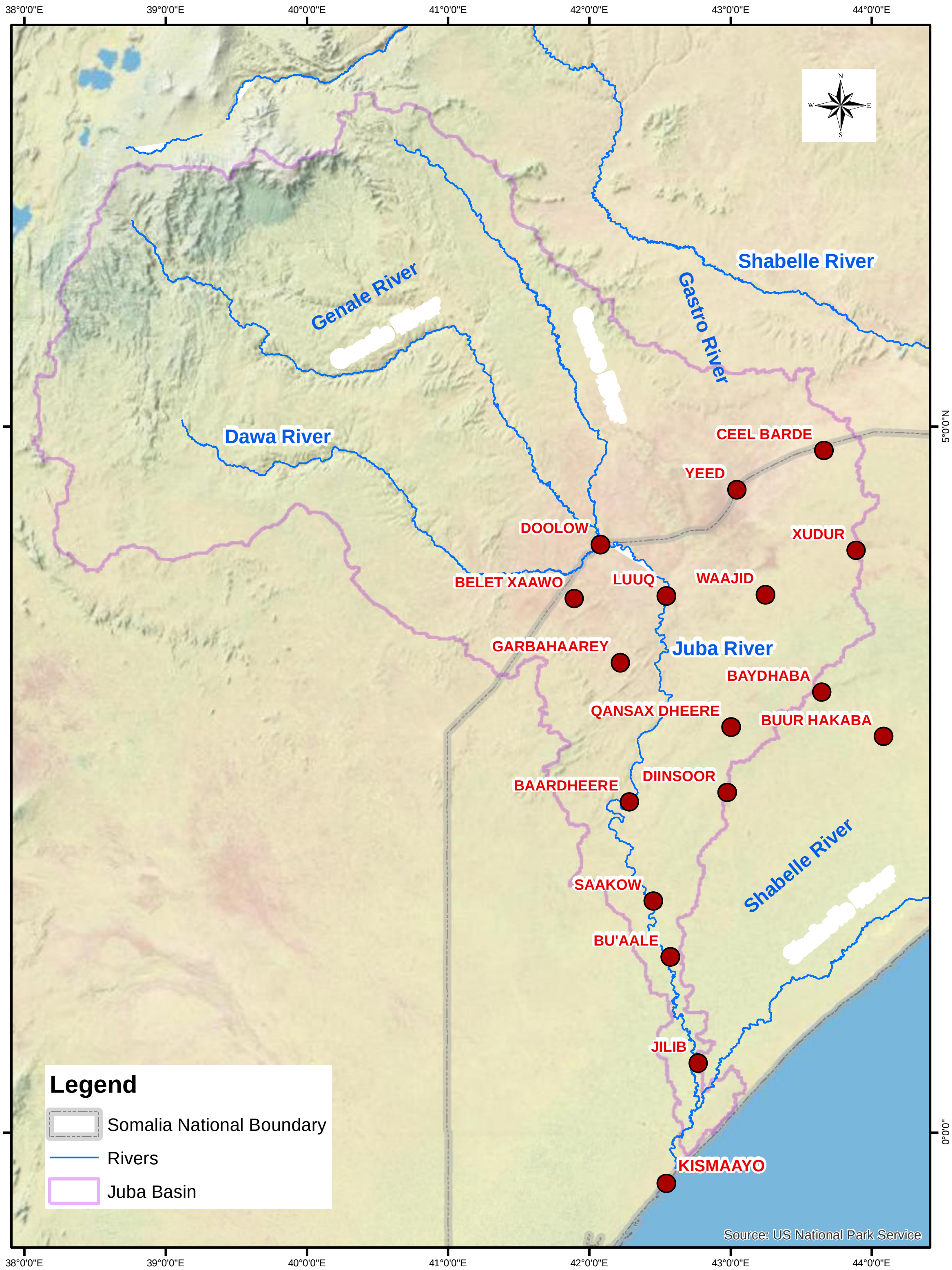

Figure 2: Vicinity and Physiography Map

2. Basin Characteristics

The contributing basin to the Juba basin is 221,000 km^2 at the mouth of the river near Kismaayo (Goobweyn) and 168,738 km^2 at Luuq, which is just south of the combination point at Doolow (location where Genale, Gastro and Dawa rivers combine, see **Figure 2**). The total length of the Juba river is 1,808 km out of which an approximately 1,004 km lie within Somalia's national boundary. About 30% of the contributing basin to the Juba is located within Somalia (**Figure 1**, purple boundary), while majority of the basin area is located within Ethiopia. **Table 2** below summarizes key parameters of the three tributaries feeding into Juba River.

Table 2: Juba River Basin and Tributaries

Basin	***Area (km^2)***	***Length (km)***	***Mean Elev. (m)***	***Max Elev. (m)***	***Volume (m^3) x 10^6***
Dawa River Sub-basin	24,860	755	982	4,337	
Genale River Sub-basin	57,044	714	1,254	4,373	
Gestro River Sub-basin	59,020	772	1,130	3,078	
Combination Point - Luuq	**168,738**	**874**			**5,878**

The river profile varies from the mountainous zone within Ethiopia to the alluvial plains within Somalia. The bed slope within the Somali boundary is uniform. The upstream of Luuq the slope is approximately 0.3% and downstream of the flatter regions where the river spreads out, the bed slope is 0.1%. Somalia Water and Land Information Management (SWALIM), a unit of FAO that serves the various non-governmental agencies that operate in Somalia and the Somali government, has conducted several qualitative studies that focused on the Juba basin. SWALIM has compiled data including aerial photography and a recent report titled "W-13 Hydraulic Analysis of Rivers Juba and Shabelle in Somalia" included a hydraulic analysis and HEC-RAS modeling. According to SWALIM the bed slope is closer to 0.02% for all the cross sections surveyed. The cross sections were based on a Digital Terrain Model (DEM) from the aerial survey conducted on January 2008. The differences in bed slope between the original studies completed by the Somali government of 0.1% and the recent SWALIM study of 0.02% could be due to many factors.

3. Rainfall and Climate

The climate of the Juba basin (within Somalia) and southern Somalia in general is arid to semi-arid. The seasonal variations are influenced by the northward and southward movement of the Intertropical Convergence Zone (ITCZ). The first half of the year the ITCZ moves northwards while the second half of the year towards the south. This intertropical movement of the ITCZ is the main cause of the seasonal weather patterns in the Juba Basin. There are four seasons in Somalia; Jilaal, Gu, Xagga and Dayr. The main rainy season in Somalia is the Gu season, which is between April and June. The intertropical front enters southern Somalia around March moving northeasterly and the Gu season occurs behind the intertropical front between April and June. The second rainy season is Dayr and runs from October to November. Seasonal precipitation varies with altitude. The majority of the rainfall for the Juba basin occurs in the Ethiopian portion of the basin (e.g. ~1500 mm/year in Ethiopia's mountainous region vs. 300 mm/year within Somalia). Historical studies have shown that approximately 90% of the precipitation that forms the river flow originates in the Ethiopian mountainous region.

Table 3: Rainfall Summary for the Various Seasons

Season	***Goba – Ethiopia*** [2]	***Negele – Ethiopia*** [2]	***Luuq***[3]	***Jammame***[3]	***Kismaayo***[3]
Jiilaal	140	100	34	28	10
Gu	280	385	136	237	242
Xagaa	325	55	5	124	115
Dayr	160	225	96	46	35
Annual Total	**905**	**765**	**271**	**435**	**402**

Rainfall over the Somali portion of the basin is sparse and majority of the rainfall occurs during the Gu season. There are minor showers during the Dayr season. **Table 3** summarizes the average rainfall from various sources using historical data. Goba in Ethiopia has the highest elevation of 2700 meters above sea level (m.a.s.l.) while Kismaayo is at sea level. A review of the historical data shows that although Gu season is the mean rainy season for majority of the Juba basin, after certain altitude the Xagaa season becomes the dominant rainy season, see **Table 3** Goba. This seasonal shift in precipitation also contributes to the variability of flow in the river. It is also important to note that although Gu produces the most precipitation across the basin, Dayr produces the peak flow rate.

3.1 Rainfall Losses

For this whitepaper, rainfall losses were not analyzed or reviewed in detail. Evaporation is a major loss for the Juba basin since the mean annual temperature is around 30 ^{o}C. SWALIM indicated that evapotranspiration is generally larger than the average rainfall for the Juba basin. There are also other factors that contribute to losses such as infiltration and transmission losses in the channel which will vary based on geology and the soil physical properties. For this analysis only the percentages of the streamflow data were used and no losses were considered.

[2] The Juba Environmental and Socioeconomic Studies (JESS) Project by USAID and the government of the Somali Democratic Republic, August 1987.
3 FAO SWALIM Long Term Mean Monthly Rainfall Summary.

4. Genale Dawa Dam III

Genale Dawa III (GD-3) Hydroelectric dam is 95% complete and authorities predict that it will be completed on schedule during the first quarter of 2018. The GD-3 impounds the Genale River in Ethiopia, which is the primary tributary to the Juba River in Somalia. Several feasibility studies commissioned by the Ethiopian Ministry of Water Resources have been concluded. The studies concluded that the potential environmental impacts downstream are significant. These studies also indicated that the impacts were manageable.

The GD-3 dam has a contributing area of 10,440 km^2 (See Table 2) while the total Genale basin is 57,000 km^2. The GD-3 dam is located at an elevation of 1020 m.a.s.l. along the Genale river approximately 250 km from the top of basin, and the approximate slope for this reach is 1.2 m/km. Downstream of GD-3 the elevation drops to 900 m.a.s.l and the slope steepens.

GD-3 is 110 meters high and the crest length is 465 meters. The hydropower dam is comprised of 3 vertical Francis turbine generators, each with generating capacity of 84.7 MW resulting in the total installed capacity of 254 MW. The outlet is 680 meter release tunnel with radial gates. There is also a 60-meter-high intake structure with vertical sliding gates. Water returns to the river through an 820 meter long tailrace tunnel and 480 meter long open channel[4].

Figure 3 below illustrates the relationship between the reservoir elevation, reservoir surface area and the resultant storage capacity. LRWL and HRWL represent the lowest and highest regulated water levels. At elevation 1080 meters (LRWL), the reservoir has a storage capacity of 260 million cubic meters. At the HRWL elevation, the reservoir's 100% capacity of 2.5 billion cubic meters is reached.

The average inflow to GD-3 is 95.8 m^3/s and the average outflow from the dam according to a feasibility study is 83.9 m^3/s. The maximum discharge at GD-3 is 116 m^3/s. In order to accurately quantify the impacts of GD-3, the operations of the dam need to be reviewed and analyzed. The operations of the dam will need to include the seasonal considerations and the bypass flows during flood stages.

[4] Details of the Hydropower Dam were obtained from the Stantec Description of the project. https://www.stantec.com/en/projects/united-states-projects/g/genale-dawa-3-gd-3-hydropower-project

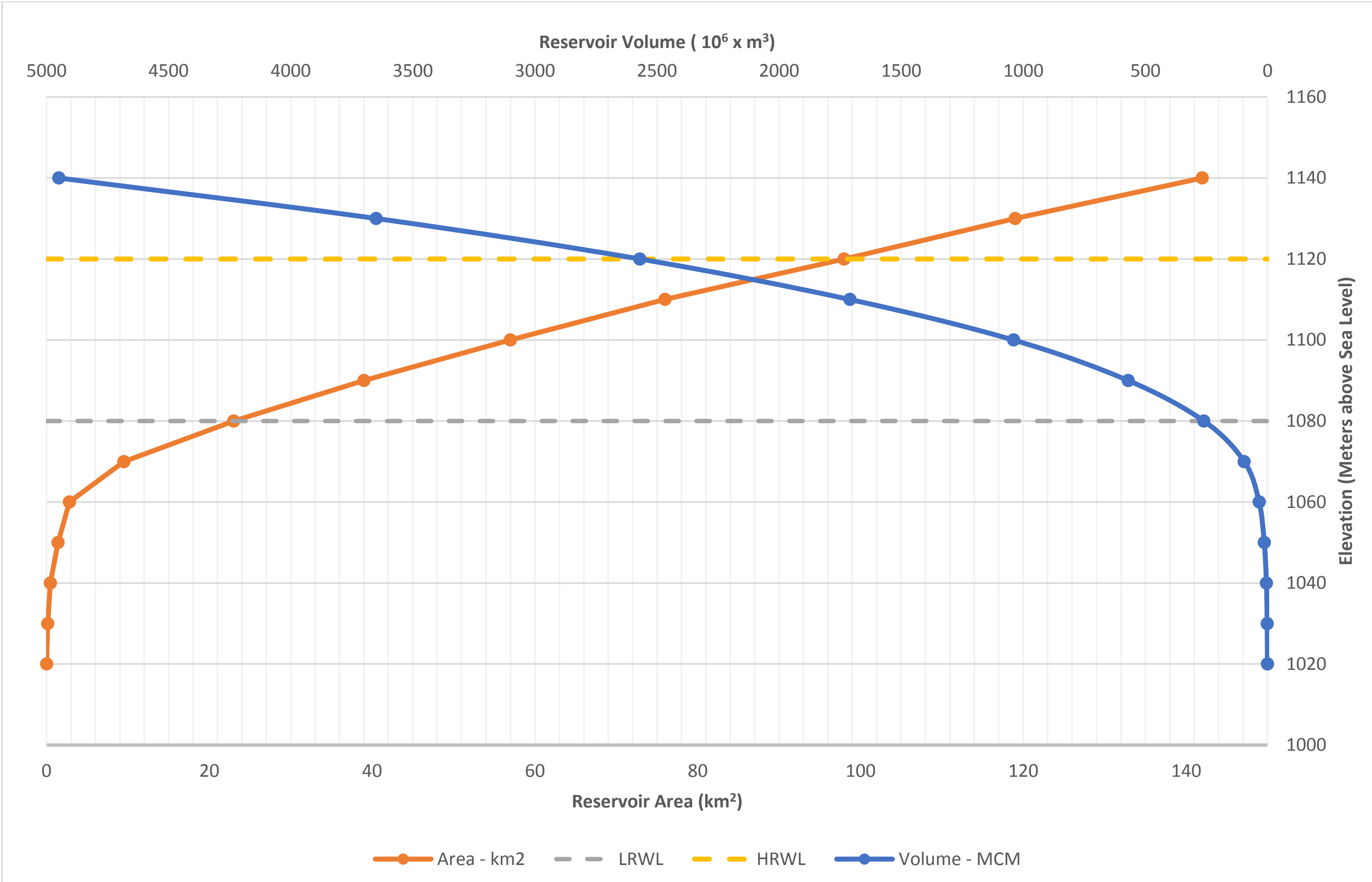

Figure 3: Elevation-area and Elevation-Volume curves

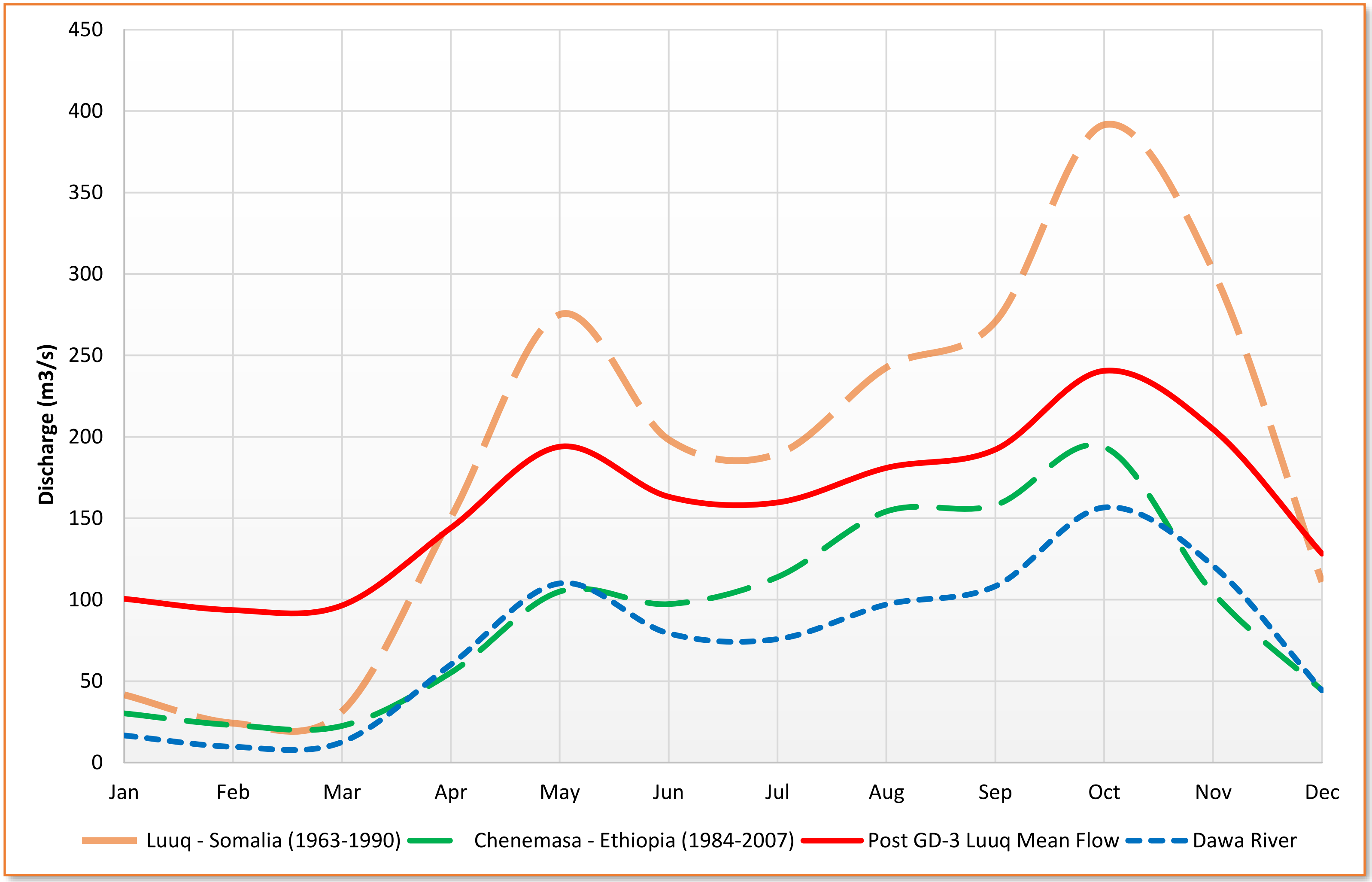

Figure 4: Mean Annual Transboundary River Flow

Figure 4 summarizes the monthly differences between Luuq, Chenemasa station in Ethiopia and outflow from the GD-3 dam. Chenemasa gauging station is located just upstream of the GD-3 at an elevation of 1120 m.a.s.l. Historical studies indicate that the Genale basin accounts for more than 50% of the runoff to the Juba river, while Dawa basin contributes to approximately 40% of the flow downstream of the confluence. The annual volume at Luuq is 5.8 billion cubic meters as stated in **Table 2** and the annual volume at Chenemasa gauging station is approximately 2.9 billion cubic meters based on the mean annual discharge from historical data (note, GD-3 reservoir is 2.5 billion cubic meters). The reliability of the data depends on the measurements in the field, cross section layout and rating curve development. To get the exact numbers for design purposes, the rating curves along with assumptions should be reviewed. Also, the entire data for the gaging stations downstream such as Helwei and Kole Bridge should be reviewed.

The red line in **Figure 4** shows the regulated outflow from the GD-3 downstream based on the assumption that during low river flows the minimum operating flow is 83.9 m^3/s and during the flooding season the maximum operating flow rate of 116 m^3/s is initiated. Based on this assumption, GD-3 dam will result in a reduction of streamflow of at least 24% between May and November. This estimate does not include other irrigation projects or evaporation loss/transmission losses, therefore the reduction in flow could be significantly higher.

It is also noteworthy that during the Jilaal season (from December to March) the flow rate at Luuq is comparable to the average monthly flow at Chenemasa gaging station. Without hydrometric data from Dawa River and Gestro River, it will be difficult to fully analyze the streamflow for the two reaches. The seasonal distribution of the flow along to the two reaches would also be critical to analyze the impact of the GD-3.

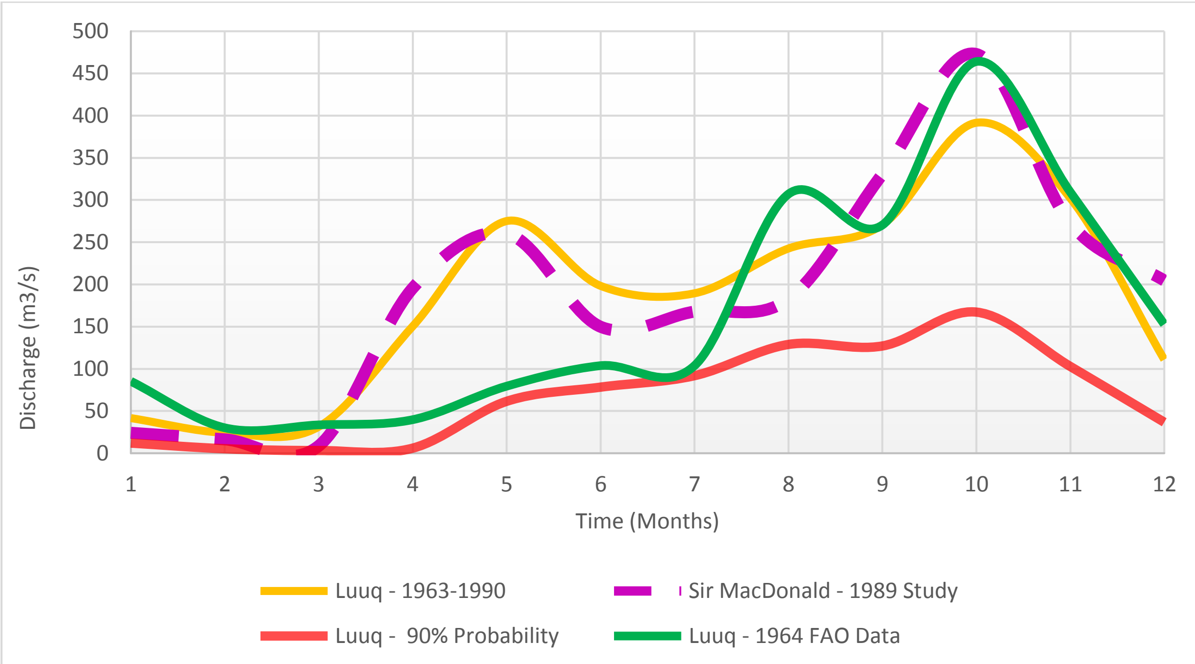

Figure 5: Comparison of Annual River Flow at Luuq Station

A comparison of historical data is provided in **Figure 5**. Annual data from 1964 and 1989, conducted by different consultants were plotted against the mean annual flow at Luuq from 1963 – 1990 (orange line). There are some variabilities during the Gu and Jilaal seasons but overall the shape of the hydrograph matches the mean. The Sir MacDonald study (purple) included flow data for the entire year and the median for each month was used. The red line indicates the 90% probability flow based on historical data (i.e. flow received at Luuq station 90% of the time from 1963 – 1989).

5. MoWR of Ethiopia's Grand-Plan

The MoWR has embarked an ambitious hydropower generation project along the Genale river that could have a potential catastrophic consequence to the downstream communities in Somalia. The impact on Juba river could manifest as early as Gu' 2018. Feasibility studies completed by MoWR of Ethiopia also indicate the plans to construct other cascading dams downstream of GD-3, see **Figure 6** below.

The cascading dams will utilize the outflow from GD-3 to GD-5 and ultimately to GD-6 dam. The MoWR has performed feasibility studies for the dams and coordinated with the Kenyan Ministry of Energy to determine the optimum design of the dams. Kenya will be the main client to harness the energy generated by the Genale Dawa system.

GD-6 has been studied in detail by the MoWR, and on Q1 of 2017 two British companies have jointly bid on the project. The new proposed dam will be at a lower elevation, approximately at 650 m.a.sl. and the height of the dam is approximately 60 meters from the feasibility study. The exact location of the dam will be finalized during the final design stage. The reservoir for GD-6 will be in the range of 140-180 million cubic meters.

The incremental increase in inflow (i.e. contributing area between GD-3 to GD-6) is 6.5 m^3/s. The average outflow from GD-3 is 83.9 m^3/s and the maximum turbine discharge is 116 m^3/s. The proposal for GD-6 is to operate with a turbine discharge between 118-124 m^3/s. To gain a complete understanding of the system, coordination with MoWR of Ethiopia is vital.

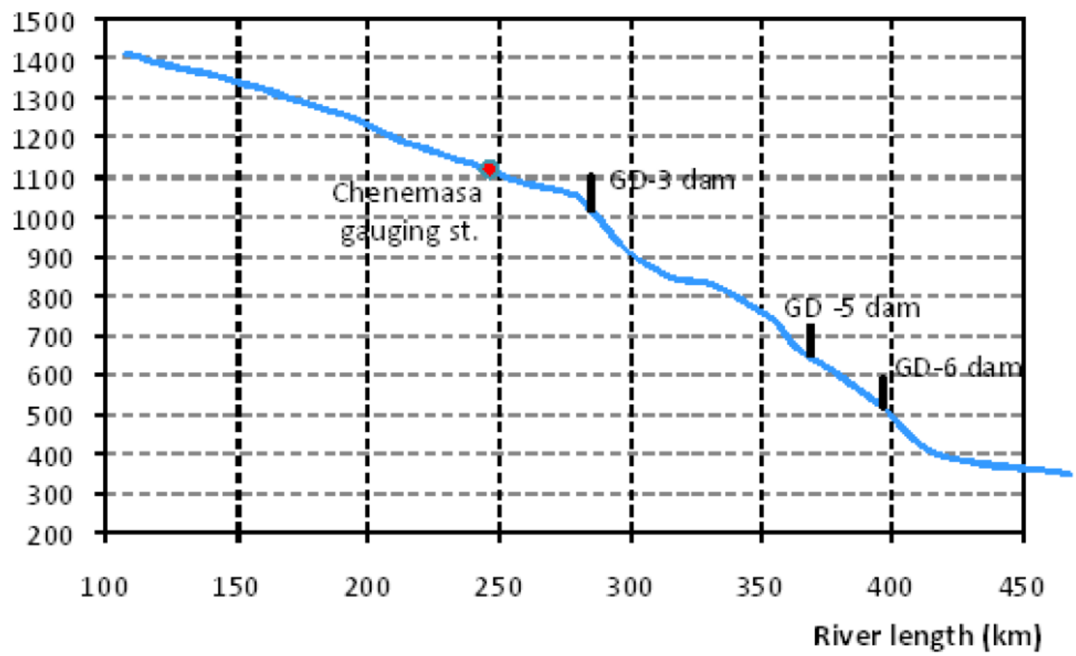

Figure 6: Genale River Cascading dams downstream of GD-3

6. Conclusion

Based on historical streamflow data and the assumption that the current streamflow matches data collected pre-civil war, the construction of GD-3 will have a significant impact on the downstream communities. A preliminary review of historical data indicated the following points:

- Genale River basin accounts for more than 50% of the flow in the Juba River downstream. This is supported by a review of historical streamflow data at Chenemasa gaging station (upstream of GD-3) where the annual average streamflow is 2.9 billion cubic meters. A review of the historical data for Helwei and Kole bridge stations is vital to support this assumption.
- Approximately 90% of the flow rate in Juba River originates from the Ethiopian portion of the Juba basin. GD-3 regulates and impounds half of the total flow into Juba river. The available water in Juba River will be reduced from 5.8 BCM to 4.8 BCM due to this

impoundment. Water balance for the Juba basin based on current and future needs is required to fully quantify the impacts to crop, livestock and domestic water demand.

- During draught periods, the flow rate at Luuq is equal to the streamflow at Chenemasa gaging station. This finding could be a coincidence, or it could mean that precipitation on the highlands of the Genale river solely contribute to the Juba river downstream. Further analysis of the hydrometric data for Dawa and Gastro rivers will shed some light into the seasonal precipitations to perform an accurate water balance.
- GD-3 estimated completion date is March 2018 and it will be crucial to determine the initial filling of the reservoir. Filling the reservoir immediately (as of February 20, 2018) will result in the extension of the draught season (Jilaal) to the Gu season to reach the minimum operating levels. If the reservoir filling has started in late 2017, current dry conditions in Luuq could be explained by this condition. During initial filling, entire rainfall from the Ethiopian highlands will be captured in the reservoir with no release.
- The construction of GD-3 results in a reduction of 24%-33% of the total streamflow at Juba River without taking the various other losses into account (i.e. evaporation, infiltration, transmission losses). Evaporation losses are amplified as one gets closer to the Somali national border. Therefore, the impoundment due to GD-3 could result (much more than the 24-33% estimate) in much higher impacts to the total volume of Juba river. A detailed hydrologic model will shed some light onto the total losses due to evaporation/transpiration and infiltration. It is also important to note that all the streamflow data summarized above is from 1963-1990 for Juba River, in other words recent irrigation project completed by the MoWR of Ethiopia along the Genale Dawa river are not considered. Recent streamflow data along Juba within Somalia is vital to make accurate predictions. Historical evaporation measurements or hydrometric data within Ethiopia will clarify the preliminary results.
- The construction of GD-3 along with the upcoming two projects (GD5 and GD6) in 2020 will likely diminishes the construction of Baardhere Dam in the future in Somalia and extension of exiting irrigation projects as included in Baardhere study. Similarly, GD-3 Dam will significantly decrease the water availability at Fanoole Barrage, Mogambo irrigation project, and Saakow Dam.
- The Draught Impact Needs Assessment (DINA) completed on October 2017 by the Somali government, various NGOs and the international partners must be reevaluated based on the completion of GD-3. The framework and the long term solutions will have to incorporate the impacts of the dam on the agricultural communities along the Juba valley.
- New bathometry survey, cross sections and revised rating curves are a must for Juba and Shabelle rivers. The data currently generated by SWALIM/FAO is based on pre-war analysis that established the rating curves. During the last 28 years, the river profile and geometry has changed, and the pre-war rating curve data is no longer applicable.