SWALIM

Water Resources of Somalia

Project Report No W-11
October 2007

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Funded by the European Union and implemented by the Food and Agriculture Organization of the United Nations

Disclaimer

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The document should be cited as follows:

Basnyat, D. B. (2007), Water Resources of Somalia. Technical Report No W-11, FAO-SWALIM, Nairobi, Kenya

Acknowledgement

I would like to acknowledge with gratitude the close support and guidance during the preparation of this report provided by Dr. Zoltan Balint, SWALIM Chief Technical Advisor and Dr. Hussein Gadain, SWALIM Water Coordinator.

I would also like to thank and put on record the support provided by the entire SWALIM team for the completion of this report.

The excellent information management system, including documentary, time series and spatial (GIS) data available at SWALIM, was useful in accessing all past work and data at one location and in a short period of time. This report has used extensively the data and analyses carried out by SWALIM and partner agencies over the past years. The various technical reports on water and land resources are referred to specifically and used in this report.

Last but not the least; I would like to thank FAO, Rome and FAO-SWALIM for giving me this opportunity to undertake this water resources assessment study for Somalia.

Executive Summary

Introduction

Water and land development need reliable data and information on available resources. Somalia Water and Land Information Management (SWALIM) are trying to recover lost information from all available sources and re-establish data collection networks. The purpose of this report is to prepare a comprehensive water resource assessment of Somalia based on data collected by SWALIM and partner agencies over the past years. The report is intended to assist decision makers, donors and investors.

The specific objectives of the report are:

- To assess the surface water and groundwater resources and the potential for meeting domestic, livestock and irrigation water supply demands in the whole of Somalia;
- To assess the water resources of the Juba and Shabelle river basins with special focus on water resources development constraints and potential;
- To identify major problems and priority areas within which more detailed investigations may be carried out.

As water and land resources of a river basin are inter-related and form a unit, a river basin is widely recognized as a natural unit for water resources planning and management. In this context, the water resources assessment of Somalia was carried out on the basis of a major river (drainage) basin. Although the surface water divide (catchment boundaries) may not follow strictly the groundwater aquifer boundaries, they are, however, seen to coincide generally with the major drainage basins. The general approach followed was to assess the water, land and related resources in each river basin. The assessment is based on the following major drainage basins:

1. Gulf of Aden basin
2. Darror basin
3. Tug Der/ Nugal basin
4. Ogaden basin
5. Shabelle basin
6. Juba basin
7. Lag Dera basin
8. Lag Badana basin
9. Central Coastal basin

Climate and Rainfall

Based on the agro-ecological zones of Somalia, the climate varies from desert in the north-eastern parts of the coastal areas of the Gulf of Aden basin and some areas in the Darror basin in the north-east; to arid and semi arid in much of the Gulf of Aden, Nugal and Ogaden basins in the central and northern regions; and to moist semi-arid in most of the Juba-Shabelle river basins in the south and in the mountainous areas of the Gulf of Aden in the north-west.

The long-term mean annual rainfall varies from 93 mm in the Darror basin to 549 mm in the Lag Badana basins. While the maximum annual rainfall in the Ethiopian and Kenyan parts of the Juba and Shabelle catchment reaches 1100 to 1350 mm, the maximum annual rainfall within Somalia is a high of about 700 mm in areas around Mareere in the lower parts of the Juba and Lag Badana basins. The minimum annual rainfall is around 20 mm in parts of the northern coastal locations in Gulf of Aden. In some parts of the Darror and Nugal basins it is as low as 66 and 80 mm, respectively.

Annual Potential Evapo-transpiration (PET) is between 1500 to 2000 mm in the southern river basins but exceeds 2000 mm in the northern basins (and is as high as 3000 mm in the northern coastal regions of the Gulf of Aden basin). In most locations, PET exceeds rainfall in all months of the year. In the southern basin areas, the monthly rainfall exceeds 0.5 PET in the *Gu* and *Deyr* seasons giving “growing periods” which allow some rainfed agriculture. However, in the case of the northern basins, except for few locations in the extreme north-west Somalia, even 0.5 PET exceeds rainfall in all months giving zero values for the longest growing period (LGP) in most of the areas. This is why most areas in the northern basins are not suitable for agriculture.

Hydrological Analysis of the Juba and Shabelle Rivers

The Juba and Shabelle are the only perennial rivers in Somalia. They are also the only rivers where long-term hydrological data are available. Based on streamflow data from 1963 to 1990, the long-term mean annual flow volumes in the Juba river at Luuq (catchment area-166,000 km^2) and at Jamama (268,800 km^2) are 5.9 billion cubic meter (bcm) and 5.4, respectively. The annual flows in the Shabelle river at Belet Weyne (207,000 km^2) and at Awdegle (280,000 km^2) are 2.4 bcm and 1.4 bcm respectively. The annual runoff-rainfall ratios (runoff-coefficient) are about 6.5% in Juba at Luuq and 2.1% in Shabelle at Belet Weyne. Annual flows decrease as the river flows downstream. This is mainly due to various factors such as: not much contribution to flows from the Somali catchment areas; frequent occurrence of bank full condition and spilling of flood into the flood plains and natural flood relief channels;river diversions for irrigation both during low and high flow periods; and losses due to evaporation and infiltration/recharge of the groundwater along the river. It is also evident that the flow in Juba is more than the flow in Shabelle although the catchment area of the latter is larger than the former.

There are considerable flow variations within a year as well as from one year to another. As the reliability of flow available is important for the design and planning of water resources, flow duration curves for the locations where long-term data are available have been prepared for all locations with long-term data. For example, the flows exceeding 50% and 90% of the time in Juba at Luuq are 152 m^3/s and 12 m^3/s, respectively. In the most downstream gauged location in Juba at Jamame, the 50% and 90% flows are 144 m^3/s and 10.3 m^3/s. In Shabelle river at Belet Weyne, the 50% and 90% flows are 61 m^3/s and 7.4 m^3/s, respectively. And in the most downstream gauged location in Shabelle at Awdegle, the 50% and 90% flows are 45.7 m^3/s and only 0.26 m^3/s. This shows that the water in Shabelle river is diverted most extensively in the dry seasons.

High floods in the Juba and Shabelle are known to cause frequent problems. Flood frequency analyses of annual daily maximum streamflow values were carried out using different probability distribution functions. The 5-year, 10-year, 50-year, 100-year and 1000-year flood estimates based on the Gumbel distribution for Juba at Luuq are 1,117 m^3/s, 1,338 m^3/s, 1,825 m^3/s, 2,031 m^3/s and 2,710 m^3/s, respectively. These estimates for Shabelle at Belet Weyne are 337 m^3/s, 395 m^3/s, 522 m^3/s, 576 m^3/s and 754 m^3/s, respectively. Flood values in Juba are more than that in Shabelle although the catchment area of the latter is larger than the former. This is due to higher rainfall intensities as well as denser drainage networks in the upper catchments of Juba.

The flood volume is not very large compared to the catchment areas of the two rivers. However, various natural and man-made causes have aggravated the flood problems in the two river basins. These may be summarized as:

- River bed levels rising higher than adjacent land, due to sediment deposition;
- People breaching levees to irrigate land in dry seasons;
- Encroachment of natural flood plains;
- Unplanned closures of natural flood relief channels;
- Total break down of the existing irrigation infrastructure;
- A total lack of central or local governance managing the river basin.

The problem of drought is also a recurrent problem in the two river basin areas. The low flow analyses of streamflows were carried out to plan for the worst condition of flow availability. Annual one-day, seven-day, 10-day, 15-day and monthly low flows were calculated, using the daily flow data in the two rivers. The lowest flows in the two rivers reach very low values close to even zero in some years. And as the river flows downstream, the low flows are extensively diverted for irrigation and other uses and the minimum flows in the lower reaches dropped to zero in many years. Due to the very high variability and zero or near zero flow values in some years, low flow frequency analysis was reasonable in the two upstream locations of the two rivers only. Even in the two locations, the low flows beyond a 10-year return period were mostly zeros, using the standard probability distribution functions.

Water quality of the two rivers is a matter of concern since both the human and livestock populations use the river water for direct consumption. There was very little water quality data available for the two rivers. The only available long-term data was for Juba at Mareera where electrical conductivity (EC) values were available for the period, 1977 to 1990. It is observed that the salinity in the river rises during the *Jilaal* season and peaks during *Gu* flood season. There is also a slight rise during the *Deyr* flood season, but it never reaches the peaks of *Jilaal* and *Gu* seasons.

Very little sediment observation has been made in the two rivers. Based on 53 samples of suspended sediment observations data from November 1989 to November 1990 in Shabelle at Afgoi, the total suspended sediment load is calculated to be about 6.9 million tons per year during the one year period. This is a preliminary estimate and it should be used with caution as there are various other factors that affect soil erosion and sediment transport.

Surface Water in other Major Basins

Surface water is limited in all the other drainage basins. There is no river with perennial flows. In the case of the northern basins especially that of the Gulf of Aden, there are a number of small streams (*toggas*) which are mostly ephemeral that originate from the mountainous areas in the north-west (above 2000 m elevation) and flow to the coastal areas of the Gulf of Aden. Other *toggas* draining the Nugal, Bokh and Darrror Valleys and other minor valleys move towards the Indian Ocean. However, there is practically no surface water that reaches the ocean as the rainfall falling in these catchments is lost through evaporation and infiltration.

No long-term surface water monitoring is done in these streams. Some limited monitoring was done in the late fifties and in 1980 and 1981 in some catchments in the Gulf of Aden basin. The catchment areas of these *toggas* were in the range of 3000 km^2 to 4800 km^2. Perennial springs are located along these *toggas* where the groundwater tables are intersected by the rocky outcrops. These *toggas* carry very high flood flows and debris after intense rainfall. Such surface runoff lasts for a few hours to a few days. Flash floods as high as 2500 m^3/s have been observed in *toggas* with a catchment area of 3,660 km^2. There were 12 flood events observed in one year in the same *togga*, out of which four were between 900 m^3/s and 2200 m^3/s. In such *toggas,* the annual runoff-rainfall ratio (runoff coefficient) are estimated to be between 3% and 6%.

Surface Water Storage

Wars (also called *bailey*, water pan, ponds or dams) and *berkads* are commonly used to collect surface (storm) water from small catchments of 2 to 3 km^2. *Wars* are more common than *berkads* in southern drainage basins mainly because of the favourable soil type (clayey) for the construction of *wars*. From the distribution of water points in the old 1:100,000 topograhical maps, we can see that percentage of rainwater ponds/reservoirs (87% in Shabelle, 91% in Juba, 79% in Lag Dera and 98% in Lag Badana) is larger compared to groundwater sources in the southern river basins than in the central and northern drainage basins (25% in Gulf of Aden, 28% in Darror, 39% in Nugal, 77% in Ogaden and 39% in central coastal basins).

Rainfall and climate regime is important for designing the *wars* and *berkads* and in estimating the amount of rainfall that can be harvested. Some studies in the past (***Kammer and Win, 1989***) show that in catchments of 2.5 to 4 km^2, storms of less than 15 mm rainfall did not produce runoff unless the antecedent moisture content was high. This would mean a threshold daily rainfall value of 20 to 30 mm, and there were only 9 to 16% of the rainfall days which exceeded this threshold values. Daily rainfall data have been analysed as part of this study in some locations to calculate the number of days and amount of rainfall with daily rainfall exceeding different threshold values. The results show that there are few days with rainfall exceeding threshold values of 20 mm and that 24-hour maximum rainfall is sometimes close or even higher than the long-term annual rainfall.

Groundwater Resources

Southern Somalia, which is traversed by the two perennial rivers, has the best hydro-geological conditions for finding groundwater such as along the major *toggas* in the alluvial deposits and weathered basement. In the areas covered by the Gulf of Aden, the Darror and the Nugal Drainage basins, groundwater movements start in the mountainous areas and move in two directions. The first is from the south to the north from the mountainous regions to the coastal areas of the Gulf of Aden. The second is from the north to the south towards the Haud and Sool plateaus. The hydro-geological divide also mostly coincides with the surface drainage divide.

The areas of good groundwater potential are as follows:

- Baydhaba Plateau, Buur, Waajid, Damassa areas in the Juba and Shabelle basins;
- Alluvial plains along the Juba, Shabelle and Lag Dera rivers;
- Shallow aquifers in the sand dunes in the central coastal belt and the northern coastal regions (freshwater lenses), in the Galkayo and Dhuusamarreb Ancestral drainage systems in the Mudug-Galgaduud Plateau, along the *toggas* in the mountainous areas and sloping plains of Northern Somalia;
- Deep aquifers in the Mudug-Galgaduud Plateau with wells of 100m to 250 m depths;
- Shallow aquifers in the Galcayo and Dhuusaarreb ancestral drainage and Coastal belt along the Gulf of Aden;
- Upper catchment area of the mountainous zone in the Gulf of Aden and Darror basins where many springs and underground/surface dams and infiltration galleries could be constructed;
- Plateaus and valleys in northern Somalia (Sanaag region, Haud Plateau and Darror Valley).

Groundwater Use

While surface water sources are limited to the riverine areas in the Juba and Shabelle basins and in *toggas* in the northern basins, groundwater sources such as dug wells, boreholes, springs, sub-surface dams and infiltration galleries are predominantly used to meet the human and livestock needs.

Dug wells are extensively used along the *toggas*, sloping plains and the coastal areas (freshwater lenses) with depth ranging from 2 or 3 m to 10 m. Water quality is a problem in these wells due to poor construction and since they provide common outlets for both livestock and humans. Boreholes are a permanent source of water for most of the people. In the southern river basins, average depth varied from 90m to 220 m in Bakool region, 60 to 70 m in Bay region, 60 to 125 m in the Hiraan region and 50 to 100 m in Gedo region. The average yield was around 10 to12 m^3/hr. Borehole depths ranged from 90 to 220 m (with static water levels from 80 to 130 m) in the north-western regions of Somalia (Somaliland). The estimated yield was from 3 to 30 m^3/hr. Water levels in Bari, Nugal, Eastern Sanaag and Mudug regions in central and north-eastern Somalia were estimated to be around 30 m, 160 m, 120 m and 230 m, respectively. Many boreholes have been abandoned due to the unsustainable draw down of static water levels.

Many natural springs exist in the Juba, Shabelle and Lag Dera basins (about 1 to 3% of the identified water points in the topographical maps) and in the mountainous areas of the Gulf of Aden basin, Darror basin and Nugal (about 10% of the water points). Perennial spring sources are found across the mountainous areas and a number of thermal springs are found along the coast in the Gulf of Aden basin.

Water for Human and Livestock

Sufficient quantity and quality of water for human needs is considered a basic human right. Access to safe water is said to be limited to only about 20.5% of the population, of which 53.1% live in urban areas and 4.1% in rural areas (*World Bank*, 2006, cited by IUCN, 2006). The present per capita consumption is said to be lower than the basic need standard of 20 lpcd.

Data on water used across regions and socio-economic profile is not available. However, given the scarcity of water, 20 lpcd and 50 lpcd are considered the average water consumption (basic requirement) in most regions Based on these figures and the current population estimate of 7.5 million, the total basic water requirement for the whole country is estimated to be 240,000 m^3/d.

Water for livestock is crucial as the livelihood of the majority of the population depends on livestock. Considering the 25 litre, 1.6 litre and 25-35 litre per head per day (lphd) requirements of cattle, sheep/goats and camels, respectively, water demand for livestock in the country is about 230,000 m^3/day (based on the livestock population of 4.7 million in 1988).

Recent population estimates show that there is a general trend towards urbanization in the country as the internally displaced population returns to the towns. Urban water supply will therefore be an important issue. Most such towns are rehabilitating the old piped water system. Various management models based on public-private-participation (PPP) are now in place in these towns. Boreholes are the predominant source of water for such systems.

Water for Agriculture

The crisis of food security linked to flood and drought is a striking feature of life in Somalia. Crop production is largely limited to the alluvial plains of the Juba and Shabelle rivers and inter-riverine area of Bay region where 90% of production is undertaken. In northern regions, where pastoralism is predominant, crop cultivation is mostly confined to the alluvial plains and slopes along the *toggas* in the northern basins and in natural oases where groundwater is available. Production is mostly smallholder and subsistence based.

Given the climatic regime of the country with its erratic and irregular rainfall pattern and the high potential evaporation losses, the water requirements of the crops are generally high. The cropping patterns for the irrigated agriculture in the Juba and Shabelle river basins consist of fruit trees, maize and groundnuts in the *Gu* and *Deyr* periods and tomatoes, sesame, cow peas and vegetables in the *Deyr* and *Jilaal* seasons. Based on a standard cropping pattern covering the above crops and representative cropping areas, irrigation water requirements were estimated, using climatic conditions of Jilib (in Juba basin) and Jowhar (in Shabelle basin). The irrigation water requirements (considering 65% field application efficiency only) for the representative copping patterns were an average of 0.36 l/s/ha or 11,400 m^3/ha and 0.37 l/s/ha or 11,800 m^3/ha, respectively.

Considering the 80% dependable flow (flows exceeding 80% of the time) available in Juba at Bardheera and in Shabelle at Mahadey Weyne, it is estimated that 50,000 ha of land could be irrigated year-round in Juba basin, while seasonal irrigation for a second crop of maize and sesame could be provided in much more land (up to 170,000 ha). In the case of Shabelle river, irrigation could be provided for up to 25,000 ha in the *Gu* season and it can be increased to 80,000 ha for the *Deyr* crops. These figures are preliminary estimates and are based on unregulated flow in the two rivers.

In the case of the mountainous regions in north-west Somalia, small pockets of land which are less than 1 to 2 ha are irrigated and cultivated along the *toggas*. Due to the high PET values and low rainfall, water required to meet the net irrigation requirement (effective rainfall minus crop requirement) for one crop of maize and sorghum during about four months growing period each is in the range of about 6000 m^3 and 5500 m^3 per ha (for the agro-climatic condition of Hargeisa). If 65% irrigation efficiency is considered, about 9230 m^3 and 8460 m^3 of water would be required per ha.

Recommendations for Future Activities

The following are some of the recommendations for future activities that would help improve water resources management in Somalia.

Meteorological Network

- The rainfall stations in the Juba, Shabelle, Gulf of Aden and Nugal Drainage Basins in Somalia are within the recommended network density of World Meteorological Organization (WMO). However, the network densities in other basins are sparse. It is recommended that network density be installed in the following basins: an additional three in Lag Dera, two in Lag Badana, one in Darror, five in Ogaden and five in the Central Coastal basins. This would bring the total rainfall stations in the country to 86 from the currently operational 70 stations.
- None of the above rainfall stations is the automatic recording type nor does any one of them measure other agro-climatological parameters. It is recommended that the ‘tipping bucket’ type automatic rain gauges be installed in 15 stations, covering at least one in each major basin, and some additional ones installed in the northern mountainous regions and in the central coastal basin areas.
- Pan evaporation, wind, relative humidity, water and air temperature and sunshine hours are other agro-climatological parameters that are required for water and agricultural development and management. WMO recommends one evaporation station in 50,000 km^2 in hilly and coastal areas and one in 100,000 km^2 in arid regions. It is recommended that 19 evaporation stations be installed covering all the major drainage basins.
- Apart from the meteorological stations within Somalia, it is important that rainfall data are available from the upper catchment areas of the Ethiopian and Kenyan highlands and

other areas in the catchment both for flood forecasting as well as runoff estimation using rainfall-runoff models.

Hydrometric Network

- Daily staff gauge readings are observed in each of three hydrometric stations in the Juba (Luuq, Bardhere and Bualle) and Shabelle rivers (Belet Weyne, Bulo Burti and Jowhar). There are eight other stations, four in each riverine area, mostly in the downstream stretch of the two rivers that were operational before 1990 but have not been re-established yet. The currently operational stations in the upper stretches of the rivers are appropriate for the estimation of the flows available in the river. The stations in the lower reaches should be rehabilitated in the future, especially after the irrigation infrastructure in the downstream areas are rehabilitated and start functioning again.
- The other small streams in the northern basins do not have perennial flows but are known to generate flash floods during the rainy season. It is recommended that discharge measurement and river gauging be carried out in at least five such *toggas* in the north. These may be T. Durdur (north-eastern Gulf of Aden), T. Hodomo (north-central Gulf of Aden), T. Dhut (Darror basin), T. Nugal (Nugal basin) and the *togga* contributing flows to the Xingalool internal drainage basin. These can be useful for designing early flood warning systems.
- The presently operational hydrometric stations observe daily gauge readings. Since no discharge measurements have been made after their rehabilitation, rating curves have not been developed. It is recommended that direct discharge measurements be started as soon as possible so that the rating curves can be developed.
- SWALIM is installing automatic water level recorders in four locations, Luuq and Bualle in Juba river and Belet Weyne and Jowhar in Shabelle river. Although the water level variations within a day are not expected to be much, these water level recorders would help derive the flood hydrographs and they would also be useful to observe any variations in the irrigation and other diversions within a day.

Surface water quality and sediment measurements

- The Juba and Shabelle rivers are extensively used by the people and livestock to meet their water needs in the riverine areas. While water salinity is a major concern, other parameters related to human and aquatic health (microbiological analysis, dissolved oxygen (DO) and minerals) are also important. It is recommended that water quality observations be carried out in at least two locations each in the two rivers, Luuq and Bualle in Juba and Belet Weyne and Jowhar in Shabelle. As urbanization and agricultural development increase along the river course, the water quality observations should be carried out in key locations in the downstream areas of the river, especially after the gauging stations in the lower reaches are rehabilitated.
- It is recommended that sediment sampling be undertaken in at least two locations in each river, Luuq and Bualle in Juba and Belet Weyne and Jowhar in Shabelle. As the soil erosion is found to be high during the first rainfall period sediment sampling should be done as frequently as once every week during March to June and once in two weeks during other months.
- The other rivers and *toggas* are also central in meeting the water needs of the people and livestock of the areas. Water quality monitoring in such rivers should also be carried out, taking into consideration agricultural and human interventions in these *toggas*.

Groundwater monitoring

- It is recommended that hydro-geological investigations be carried out in the future to update past studies and to estimate the renewable groundwater available including the potential recharge areas. This will require a detailed assessment of the topography, geology and hydrology of the areas, including some sub-surface investigations. While this activity needs to be carried out in the long term, it is recommended that the groundwater monitoring of some key bore holes be done in the short term.
- Based on the data collected in SWIMS by SWALIM, a selected number of bore holes covering different river basins and aquifer systems should be monitored. The monitoring should include: yield tests, observations of seasonal variations of the water level, water quality tests (especially the salinity and its seasonal variation but including other physical (temperature, colour, turbidity, odour and taste), chemical and bacteriological analyses (coliform etc).
- The shallow wells (dug wells) and springs should also be monitored to test its suitability for human and livestock consumption.

Runoff characteristics of small catchments

- Selected catchments like those of *toggas* in the north and small catchments that are used to collect storm water in the *wars* and *berkads* spread across the country should be monitored for one to two years. A meteorological station should be installed as required, equipped with automatic rain gauges and taking observations of other parameters like pan evaporation, wind, air temperature, relative humidity, sunshine hours and automatic surface water recording facility (gauges in a river or a *war*, *berkad* or pond). A simple water balance - taking into consideration rainfall, evaporation¸ infiltration and other losses, soil moisture content and runoff - can then be used to develop the rainfall-runoff relationships in different catchment and physiographic conditions.

Survey of water demand for humans and livestock

- There is little data available on the water consumption pattern of households and livestock. Factors such as the socio-economic profile, quantity and quality of water sources available, cost of water, climatic conditions are essential for designing interventions to improve access to safe water. Hence, it is recommended that users' surveys of water sources covering different regions/basins, rural and urban, be carried out to better understand the water consumption characteristics and the water needs of different regions. This should also include nomadic communities who move with their livestock from one place to another. Such a survey should be done on a water source basis (consumers using one source) and community basis (community and livestock using different sources).

Optimising Water Input to agriculture

- Water use for agriculture consumes the maximum amount of water. The crop yield of the major crops grown such as maize and sorghum are seen to be low and, as expected, the yield is higher in irrigated areas than in rain-fed areas. While crop yield depends on many types of inputs such as climatic conditions, soil, seeds, and fertilizers, it is also a matter of interest to optimise the water input to agriculture. Better water management through the forecast of climatic conditions (forecast of on-set and expected amount of rainfall) and water availability may assist the farmers to improve the agricultural productivity. A study linking water availability, rainfall forecasting and selection of cropping patterns and types may be carried out. This will require an integrated water, land and agricultural resources approach.

Water resources development

- Water resources development potential exists especially in the Juba and Shabelle basins and in some of the watersheds in the mountainous areas of the northern basins. Such development should assist in better management of the water resources in the basins to address the problems of “too much”, “too little” and “too dirty” water. The planned water resources development in the Juba and Shabelle rivers includes rehabilitation of the old irrigation infrastructure such as barrages and canals. Some inter-basin diversion, off-stream storage and reservoir projects (e.g. Berdheere in Juba) were planned in the past. These should be reassessed, based on the data collected and the assessment and studies carried out on the water and land resources by SWALIM, including this one.
- In the case of the flooding problem in the Juba and Shabelle rivers, it is seen that integrated flood management would help alleviate many of the problems presently attributed to floods in the areas. Even a small flood event that occurs once in every five years is known to create major problems. Various strategies of integrated flood management can be undertaken, such as reduction of flooding, reduction of susceptibility to damage, mitigating the impacts and preserving the natural resources of flood plains (WMO and GWP, 2004). It is recommended that an integrated flood management plan be developed for the two river basins, based on a river basin approach.

Data Gaps

- There were major data gaps in some regions (southern regions in Lad Dera and Lag Badana basins) due to security concerns and data gaps in some sectors such as water for other uses like industry, environment and wetlands (swamps).
- It is recommended that efforts are made to collect data on the above so that water resources management can be carried out in a holistic manner.

Glossary of Somali Terms

Balli	Small surface water harvesting ponds
Berkad	Underground reservoir, lined or un-lined, excavated to store surface runoff
Deyr	October to November, minor wet season
Elmi Jama	Sorghum variety grown in Northern Somalia
Gu	April to June, major wet season
Hagaa	July to September dry and cool season
Jilaal	Dry season from December to March
Mugciid	Underground reservoir storage well with an average depth of 15 meters
Togga	A non-perennial (seasonal) stream which is deep and narrow
Wadi	A non-perennial (seasonal) stream which is wide and shallow
War	Unlined dug-out (dam), usually 2 to3 m deep

List of Abbreviations

AEZ	Agro-ecological zones
AMC	Antecedent moisture content
CV	Coefficient of variation
DD	Drainage density
DEM	Digital Elevation Model
EC	Electrical Conductivity
EC	European Commission
EV1	Extreme value type 1 distribution
FAO	Food and Agriculture Organisation of United Nations
FSAU	Food Security Analysis Unit
FSAU	Food Security Analysis Unit- Somalia
GEV	General Extreme value distribution
GWP	Global Water Partnership
Ha	Hectare
IDPs/IDP	Internally Displaced People /Internally Displaced Person
IDWA	Inverse Distance Weighted Average
ITCZ	Inter tropical Convergence Zone
IWRM	Integrated Water Resources Management
KS	Kolmogorav-Smirnoff goodness-of-fits tests
l/s/ha	Litre per second per ha
LGP	Length of Growing Period
LN2	Log-normal distribution
LN3	3-parameter Log-normal distribution
LP3	Log-pearson type 3 distribution
Lpcd	Litre per capita per day
Lphd	Litre per head per day (livestock)
LUT	Land utilization type
MDGs	Millennium Development Goals
NOAA	Northern Oceanic Atmospheric Administration
PET	Potential Evapotranspiration
PPP	Public-private participation
PSAWEN	Puntland State Agency for Water, Energy and Natural Resources
RC	Runoff coefficient
RFE	Rainfall Estimates
RH	Relative Humidity
SWALIM	Somalia Water and Land Information Management
SWIMS	Somalia Water Source Information Management System
UNCEF	United Nations Children's Fund
UNDP	United Nations Development Programme
UNESCO	United Nations Education, Science and Cultural Organization
WHO	World Health Organization
WMO	World Meteorological Organization

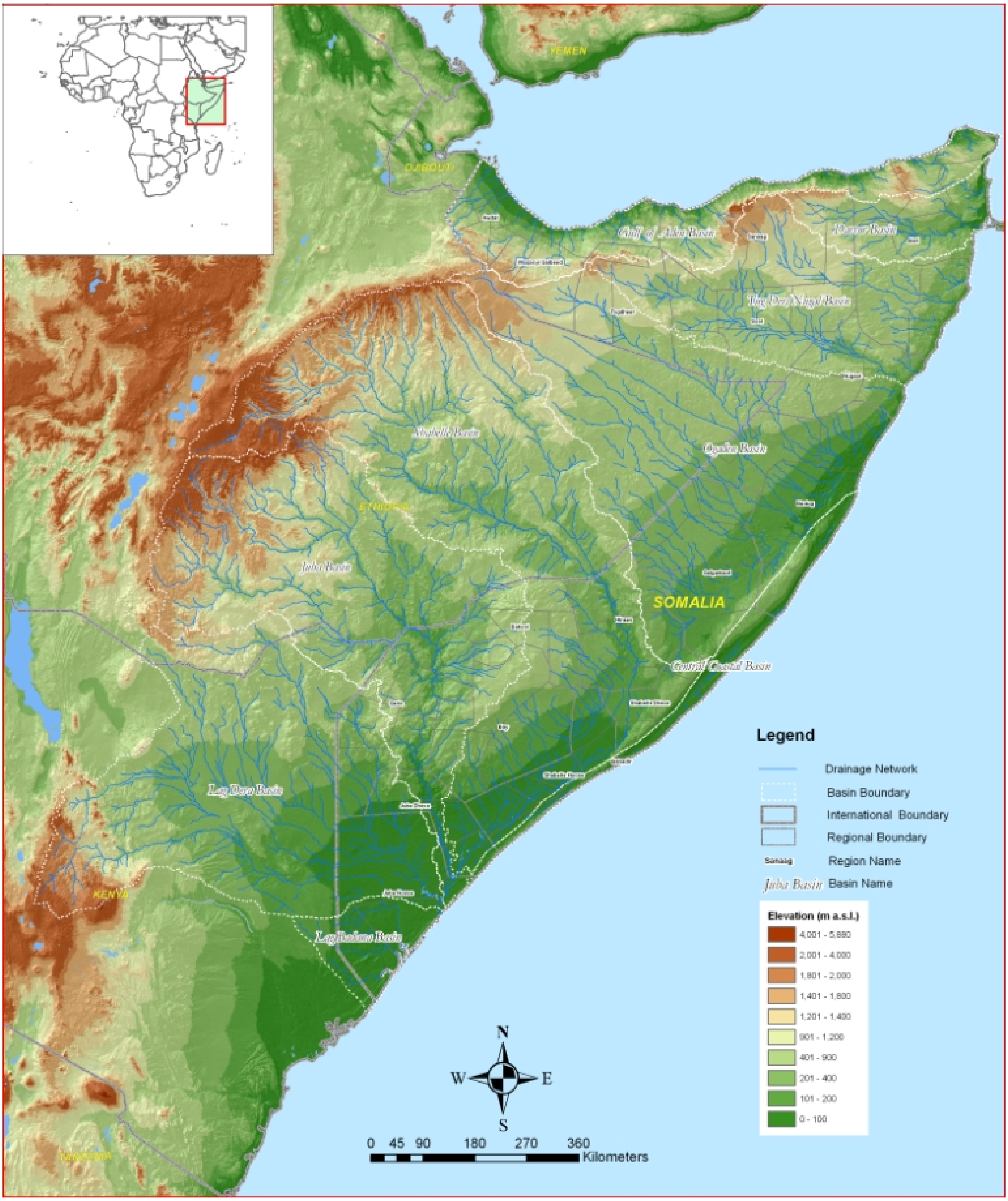
Table of Contents

Annexes

List of Figures

List of Tables

List of Maps



Map 1-1 : Major Drainage Basins of Somalia

1 Introduction

1.1 Purpose and scope of this report

Water and land development need reliable data and information on the available resources. For planning purposes, raw data has to be turned into information to enable informed decision making. Somalia Water and Land Information Management (SWALIM) is in the process of attempting to recover lost information from all over the world and at the same time re-establish data collection networks in collaboration with partner agencies. Hence, the preparation of this report on water resources of Somalia is based on the assessment of the data collected by SWALIM over the past years.

The purpose of this report is to prepare an overall water resource assessment of Somalia. It is intended to assist decision makers, donors and investors. Water resource is defined as the "water available or capable of being made available, for use in sufficient quantity and quality at a location and over a period of time appropriate for an identifiable demand" (*WMO and UNESCO, 1997*). Water resources assessment is further defined as "determination of the sources, extent, dependability and quality of water resources for their utilization and control".

The specific objectives of the report are:

- to assess the surface water and groundwater resources and the potential for meeting domestic, livestock and irrigation water supply demands in the whole of Somalia;
- to assess the water resources of the Juba and Shabelle river basins with special focus on water resources development constraints and potential;
- to identify major problems and priority areas within which more detailed investigations may be carried out.

The scope of the report covers the following:

- Review of existing materials, literature, data and knowledge related to the surface water and groundwater resources of Somalia, covering both quantity and associated water quality.
- Evaluation of the hydro-meteorological monitoring networks and available water resources information and databases (time series, rating curves, etc.) and recommendations for future development for integrated water resources management purposes.
- Assessment of the spatial and temporal variability of surface water and groundwater in terms of quantity and quality, including periods of groundwater stresses, as well as identification of zones with high groundwater salinity and poor water quality.
- Analysis of available water quality and sedimentation data and preparation of a preliminary system for future measurements.
- Assessment of the hydrological characteristics of the main catchments and rivers, including extreme events and long-term trends, and estimation of the water resources potential of meeting irrigation and other water demands.
- General assessment of the balance between available water resources versus the demand for suitable land for irrigation, considering topographical and available socio-economic characteristics
- General assessment of the water sources used for human and livestock needs as well as other needs.

1.2 General approach and methodology

As water and land resources of a river basin are inter-related and form a unit, a river basin is widely recognized as a natural unit for water resources planning and management. It is also widely accepted that the water resources available in a river basin should be managed on the basis of integrated water resources management (IWRM). The Global Water Partnership (GWP) defines IWRM as a process which promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems.

In this context, the water resources assessment of Somalia was carried out on the basis of a major river (drainage) basin. Although the surface water divide (catchment boundaries) may not strictly follow the groundwater aquifer boundaries, they are, however, seen to generally coincide with the major drainage basins in Somalia. Somalia can be divided into the following major drainage basins (Map 1-1(NB.-names of basins on Map are barely legible – Ed)

1. Gulf of Aden basin
2. Darror basin
3. Tug Der/ Nugal basin
4. Ogaden basin
5. Shabelle basin
6. Juba basin
7. Lag Dera basin
8. Lag Badana basin
9. Central Coastal basin

This assessment is based on secondary data available from past studies (mainly before 1990) and recent studies carried out by SWALIM. The general approach followed was to assess the water, land and related resources in each drainage basin. All available data on the surface water and groundwater resources was analysed to assess their temporal and spatial variations.

As the availability and use of the surface water and groundwater is dependent on various topographic and physiographic factors such as geology, geomorphology, soil, land use and land cover, a brief assessment (description) of these land characteristics for each basin was carried out, based on relevant literature. In particular, SWALIM undertook the land suitability assessment for various land use such as rainfed agriculture, irrigated agriculture, pastoralism (extensive grazing) and forestry. As agricultural water use, both rain-fed and irrigated, is a major consumptive use of surface water and groundwater, general cropping patterns for different basins were adopted based on relevant data and studies that were available. Historical data on areas of major crops cultivated in different regions and their yield were also collected and assessed in terms of their variations in the different regions (basins).

As the water needs for human and livestock are vital in an arid country like Somalia, data on population (rural, nomadic and urban) was collected from the best available source. There has been no population census since 1988 in the country so the population estimates that are available have to be used with caution. Similarly, recent data on livestock population was not available and the water needs for livestock was estimated using data of 1988 only. No reliable data on water consumption patterns for domestic and livestock are available and general standards were used to estimate the demand. Data on water demand for other uses such as industry, in-stream water demands of the aquatic ecosystems and wetlands, and wildlife were not available.

The assessment was based on the following specific types of analyses:

- Analysis of the climatological data to define the general climatic regime (rainfall, potential evaporation, temperature, relative humidity, wind speed) in each basin;
- Hydrological analysis (especially of the Juba and Shabelle rivers) including long-term monthly and annual flows, flow duration curves, flood frequency analysis, low flow analysis, water quality and sediment;
- Assessment of the hydrological regime of small ephemeral stream (*toggas*) in the northern drainage basins;
- Assessment of the surface water storages (*wars*, *berkads*) and the description of the important climatic and hydrological regime for catchment storm water harvesting;
- Assessment of the groundwater aquifers and potential groundwater development areas for future development, based on past studies;
- Assessment of technologies used for groundwater use – dug wells, boreholes, springs;
- Assessment of the main water demand -- domestic (rural and urban), livestock and irrigation;
- Assessment of interventions that may be required to improve the utilization of the available water resources in the different basins.

1.3 Assumptions and limitations

The civil war that erupted in 1990 has destroyed totally the hydro-meteorological data collection network as well as all major water resources infrastructures including barrages and canals to other water sources such as boreholes. Governance at the central and local levels is yet to be re-established. In this context, data on the water resources of the country is scattered and missing over a period of many years. As little climatological and hydrological data are available after 1990, most of the analysis was carried out using the pre-war data (before 1990). It is assumed that the hydro-meteorological regime is still valid.

Some of the limitations of this study are:

- Limited data is available on all sectors after 1990. SWALIM is rescuing the historical data and re-establishing the hydro-meteorological network in cooperation with partner agencies. However, due to security reasons as well as differing priorities of partner agencies, data gaps still exist in some regions of the country.
- Daily rainfall data is only available for some stations, so some analyses requiring short duration rainfall intensities could not be carried out. Similarly, only long-term average monthly values of other climatological parameters are available and time series data are available for only a few stations.
- Current socio-economic and population (human and livestock) data are not available. Demand estimation had to be based on old data and/or the best estimates made by different agencies.
- Hydrological flow data are available for the two main rivers only, the Juba and Shabelle. No long-term hydrological data is available for other rivers. The small streams (*toggas*) in the northern basins have high flows during high intensity rainfall. There are, however,

very limited data available (one or two years of data in the 1950s and 1980s) for a few of such *toggas*.

- The six stations established for the Juba and Shabelle rivers after 2002 are observing gauge height readings on a daily basis. However, as no discharge measurements have been made, new rating curves have not been developed and the validity of the old rating curves can not be confirmed.
- Groundwater is an important source of water for most of the country. Limited data is available on the aquifer system and their characteristics. Data on the yield and water level variations in the boreholes are also limited.
- SWALIM has started a collecting data on the water sources (*berkads*, *wars*, dams, dug wells, bore holes, springs etc) but this database is incomplete due to time and other resource constraints. Hence, a full assessment of the water use from these various water sources was not feasible.
- Lack of governance has led to the collapse of the water resources infrastructure and institutions. Any data collection is therefore based on the activities of international agencies or NGOs. Despite the best efforts by SWALIM to collect them together, there is still much to be done to rescue old data and manage new data to make it accessible to all.

1.4 Literature Review

There are certain past studies and work that can be considered crucial to assess the water resources of Somalia. Among them, the key literatures are briefly discussed below.

A little outdated but comprehensive study of the agriculture and water resources of Somalia is presented in a six-volume series report by UNDP/FAO (1968). The six volumes of the report were titled: *General, Water Resources, Landforms and Soils, Livestock and Crop Production, Engineering Aspects of Development*, and *Social and Economic Aspects of Development*. Although the report is old, it provides the setting for water resources and agriculture development in Somalia.

A comprehensive agro-climatological assessment and description of the whole of Somalia has been undertaken by Hutchinson and Polishchouk (1988). The report elaborately describes the climate of Somalia, including the general atmospheric circulation system affecting Somalia's climate. The report gives a thorough analysis of the variation of climatological parameters especially dealing with agriculture and also provides climatic classifications, growing season computation and crop potential and actual yield of major crops. Although there are other studies and reports prepared on the climate of specific locations of the country after that date, a complete description of the climate of Somalia has recently been prepared by SWALIM (*SWALIM Technical Report No. W-01, 2007*). The SWALIM study also uses the data collected from various sources (mainly from FAO database). Apart from the temporal variations of the various climatic parameters, spatial variations of the parameters over the whole of Somalia have been derived using the Inverse Distance Weighted Averaging (IDWA) Interpolation Method and presented in maps. The updated climate classification, agro-climatic zoning and Longest Growing Period (LGP) analysis have also been carried out.

The report by Kammer (1989) provides a general description of the nine major basins of Somalia and also describes each river basin's topography and physiography, climatic variations and surface water availability. As this report was focused on surface water resources only, it did not present any data or information on groundwater resources. Since the catchment areas and other physiographic characteristics must have been derived using maps and data available in the late 1980s, they need to be updated using new higher resolution (DEM) data than those that have been done in this report. Kammer (1989) has named the eastern coastal drainage systems -- consisting of small drainage flowing into the Indian Ocean -- as the Indian Ocean Basin. The present report has renamed it the Central Coastal Basin.

The Hydrometry Project-Somalia Report (*MacDonald and Institute of Hydrology, 1990*) is a comprehensive report on the pre-war hydrological data and analysis of the Juba and Shabelle rivers. The report provides the hydrometric data collected for all stations up to 1990. Analysis on hydrographs and flow forecasting is also carried out. Data on river water quality and suspended sediments are included in the report.

A description of the hydro-geological basins is provided by Johnson (1978). While the report presents a general description of the groundwater system, quantitative figures on the recharge and the yields of these aquifers are not available. It should be noted that the hydrogeological basins broadly follow the surface water drainage basins. A more detailed description of the aquifer systems and the potential groundwater development areas across Somalia is presented by Faillace and Faillace (1987). This report is divided into three sections covering the Northern, Central and Southern regions. The water quality (mainly electrical conductivity) and the water depths for shallow and deep bore holes are also provided. Again, however, the description on water movement, safe yield and recharge areas are not included.

Irrigation facilities in the Juba and Shabelle rivers are important for Somalia. The details of the irrigation infrastructure and the gross irrigated areas and cropping patterns are described in specific project reports (mainly feasibility studies). Henry (1979) provides a broad framework for irrigated agriculture in the Juba and Shabelle river basins. An estimation of the irrigation potential in the two river basins is also provided in his report. For details on the irrigation infrastructure, there are a number of project feasibility studies that deal with the irrigation potential and the related infrastructure development e.g. Mogambo Irrigation Project (*MacDonald, 1979*); Genale-Bulo Marerta Project (*MacDonald, 1978*); and Juba Master Plan Juba Master Plan (*Agrar-Und Hydrotechnik GMBH, 1990*).

An important source of water for the majority of the population is the groundwater wells (dug wells and boreholes). UNICEF has undertaken a number of inventories in 1999 on the water sources in Bay Bakool, Hiraan, Sool and Sanaag, Puntland and Somaliland. SWALIM, with the help of partner agencies, is also collecting data on the water sources and the database is called the Somalia Water Source Information Management System (SWIMS). Data on the monitoring of these sources, such as the water level variations in different seasons and the draw downs, if any, would be useful for planning purposes.

Another important source of water in Somalia is the catchment water (storm water) harvesting in *berkads* and *wars* (dams/reservoirs). As the climate is arid with erratic rainfall patterns and very high potential evaporation, most streams or drainages remain dry and there is adequate flow in them only at times of heavy rainfall. The hydrological regime of such small catchments from where the water is collected in these *wars* or *berkads* is important. Kammer and Win (1989) have carried out a case study of four small catchment areas from where the storm water is collected. The study presents the catchment and rainfall conditions for runoff generation. The research study reflected in this report is useful for the design of rainwater harvesting systems based on catchment runoff.

The above-mentioned consist of the main literature that set the background information for further assessment of water resources in Somalia. The most up-to-date data and information available on these individual topics are the more recent series of studies and reports prepared by SWALIM on the water and land resources of Somalia. The SWALIM Water Technical Reports that have been quite extensively used and/or referred to in this report are:

W01: *The Climate of Somalia*
W02: Somalia Rainfall Observers' Manual
W03: Inventory of Hydrometeorological Data for Somalia
W04: Development of River Gauge Network
W05: Status of Medium to Large Irrigation Schemes in Southern Somalia
W06: SWIMS Manuals; Volumes I and II
W07: Urban Water Supply Assessment - Monitoring Progress of Urban Somalia towards Millennium Development Goals
W08: Rural Water Supply Assessment
W09: Potential of Rainwater Harvesting in Somalia – A Planning, Design, Implementation and Monitoring Framework
W10: Improving Flood Forecasting and Early Warning in Somalia

In addition, the land resources reports prepared by SWALIM provide the most up-to-date data and status in Somalia. These are the following SWALIM Land Technical Reports:-

L-06: Land Suitability Assessment of selected study area in Somaliland
L-09: Land Suitability Assessment of the Juba and Shabelle riverine areas in Southern Somalia
L-12 Land Resources Assessment of Somalia

1.5 Structure and contents of the report

An Executive Summary is prepared for the benefit of readers, giving a brief summary of the water resources of Somalia and an outline of the report. The main report is divided into five chapters. An introductory chapter (this one) describes the purpose and content of the study, assumptions and limitations and the key literature available on the water resources of Somalia. Chapter 2 provides the country context and describes the socio-economic setting on which the water resources management and utilization will be based. This chapter also deals with an account of the issues and topics relevant to water resources management on a country-wide basis.. Chapter 3 deals with the water resources assessment of the two main river basins in Somalia, the Juba and Shabelle. In addition, the chapter covers two other southern basins, the Lag Dera and Lag Badana, and also describes the general surface water and groundwater availability as well as their current and potential uses. As the Juba and Shabelle are the only two rivers with perennial flows in the country, detailed hydrological analyses of the two rivers are presented. This chapter also presents an estimate of water supply demand and the irrigation demand under various scenarios. Chapter 4 covers the water assessment of the other major basins including Gulf of Aden, Darror, Tug Der/Nugal, Ogaden and Central Coastal basins. As surface water is limited and occurs only after high rainfall, the hydrological regime of these basins is different. Groundwater is an important source of water in these basins. Finally, the conclusions and recommendations are presented in Chapter 5. References of the literature reviewed and cited are provided in Chapter 6.

A number of annexes are attached at the end of the report containing selected data and sample figures and tables.

2 Country Context

2.1 Geography

Somalia is situated in the Horn of Africa and covers an area of 637,660 km^2. It has the longest coastline in Africa, being bordered by the Gulf of Aden to the north and the Indian Ocean to the east. The country is bordered by Kenya in the south, Ethiopia in the west and by Djibouti in the north-west. The country can be divided in five distinct physio-geographic zones differentiated by topography (*FAO, 2005*):

- the northern coastal plains;
- the Golis mountain range in the north;
- the central coastal plains;
- the broad limestone-sandstone plateau covering all of central and southern Somalia;
- the flood plains of the Juba and Shabelle rivers in the south, which provide the highest agricultural potential.

Somalia is often broadly divided into three states, politically as well as administratively. They are Somaliland, Puntland and South-Central Somalia. The country is further divided into 18 regions with 74 districts within them (Map 2-1).

2.2 Socio-economic features

Population Estimates

Water for human needs is considered a basic right of each individual. Population estimates for Somalia vary from 6.8 million, according to Somalia Watching Brief (*UNDP and World Bank, 2003*), to 7.5 million according to the UNDP (*Draft estimate, 2005*). The population estimation figures according to district are presented in Annex A. About 65% of the population is rural. Majority of the people are nomadic, either pastoralist or agro-pastoralist. Agriculture is the second most common occupation of the people. Somalia's agro-pastoralists and settled farmers live in villages or small settlements where water resources are reliable, while the nomadic pastoralists are constantly on the move with their livestock, the year round in search of pastures and water.

The last population census carried out in Somalia was in 1988 (*Ministry of National Planning, cited by Musse, 1997*). Figure 2-1 presents the population distribution in different regions of Somalia in 1988 and 2005. The diagrams show that there has been an increase in the percentage of population in the north-west regions and Banadir from 1988 to 2005. This is perhaps an effect of a relatively peaceful situation in the north-west, mainly Somaliland. However, as the southern region is the bread basket of Somalia, a higher percentage of people live in the South (mainly Juba and Shabelle riverine areas) than in other regions, with more than 40% in 1988 and an estimated 35% at present. Banadir region, where Mogadishu is located, is considered fully urban although some rural areas exist within it.

Map 2-1 : Administrative Map of Somalia

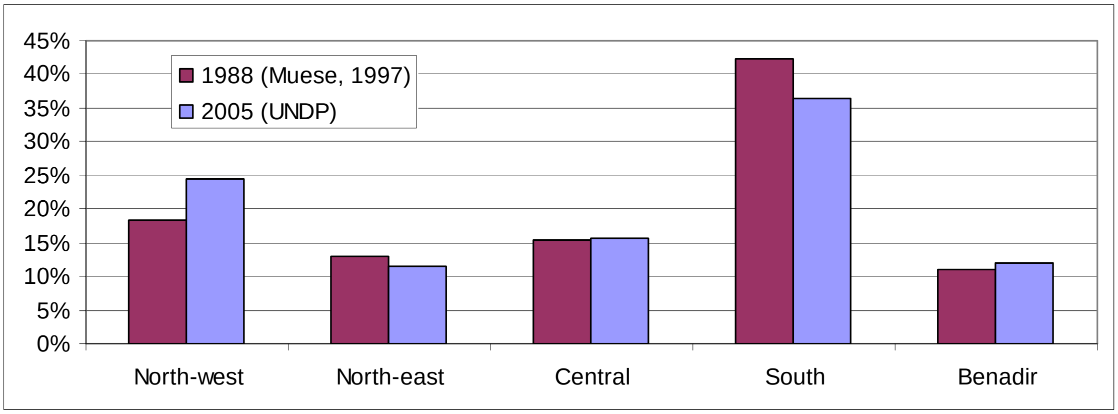


Figure 2-1 : Population Distribution within different Regions of Somalia

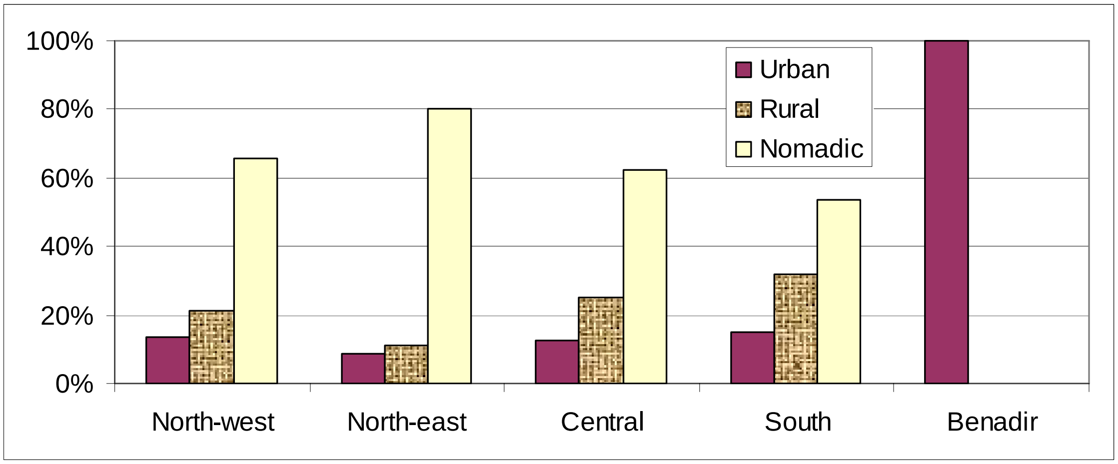


Figure 2-2 : Percentage of Urban, Rural and Nomadic Population (1988)

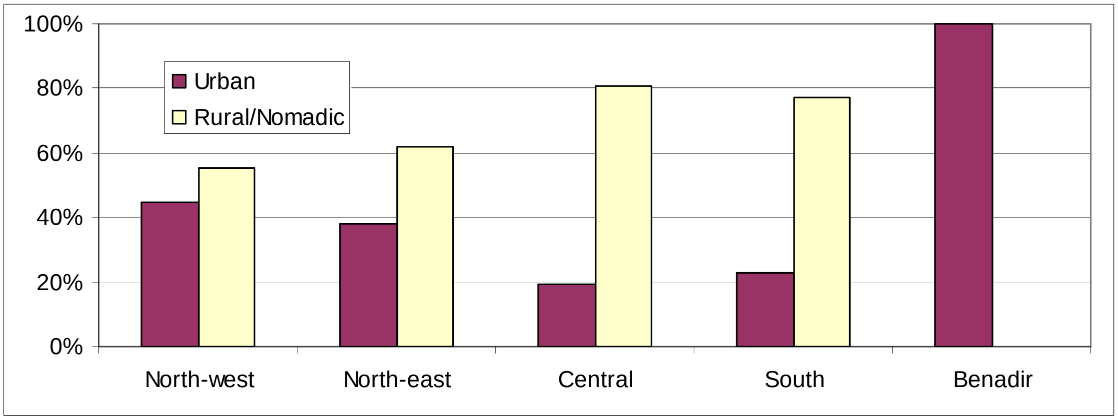


Figure 2-3 : Percentage of Urban and Non-urban Population (2005 estimate)

In terms of water requirements for domestic use, the water use pattern varies among the rural, nomadic and urban populations. Hence, the population dynamics in terms of rural and urban areas are important. Figure 2-2 and Figure 2-3 give the percentage of rural and urban population in different regions of Somalia in 1988 and in 2005. In the case of 2005, the population estimates have been categorised as urban and non-urban. From the available estimates, it is seen that, in general, population in urban areas is increasing, mainly due to migration of people from rural to urban areas and because the internally displaced people (IDPs) opt to return and settle in urban areas.

Livestock Population

Of the estimated population of 7.5 million people, about 65% live in rural areas where livelihoods are largely dependent upon livestock and agriculture. Livestock production is the predominant occupation in Somalia, with an estimated three-quarters of the population obtaining their subsistence needs from camels, cattle, sheep, and goats. Seasonal migration patterns of the nomadic herders are determined by the availability of grazing and water, based on a complex system of traditional land and water rights.

No recent estimate of the livestock population is available for Somalia. In order to present an overview of the livestock population of the country, data of the census in Somalia (1988) is presented in Table 2-1 and Figure 2-2

Table 2-1 : Livestock Population in Different Regions of Somalia in 1988

Region	**Cattle**	**Camel**	**Sheep**	**Goats**	**Total**	**%**
Northern Region	336,650	1,751,400	7,862,110	8,307,280	18,257,440	44%
Central	882,440	1,878,850	2,504,250	7,270,970	12,536,510	30%
Southern	924,970	1,207,810	706,320	1,828,470	4,667,570	11%
Trans Juba	2,037,210	1,406,210	740,920	2,045,850	6,230,190	15%
Total	4,181,270	6,244,270	11,813,600	19,452,570	41,691,710	100%

Source:Ministry of Livestock, Forestry and Rangeland, Department of Planning and Statistics, Mogadishu (cited by Musse, 1997)

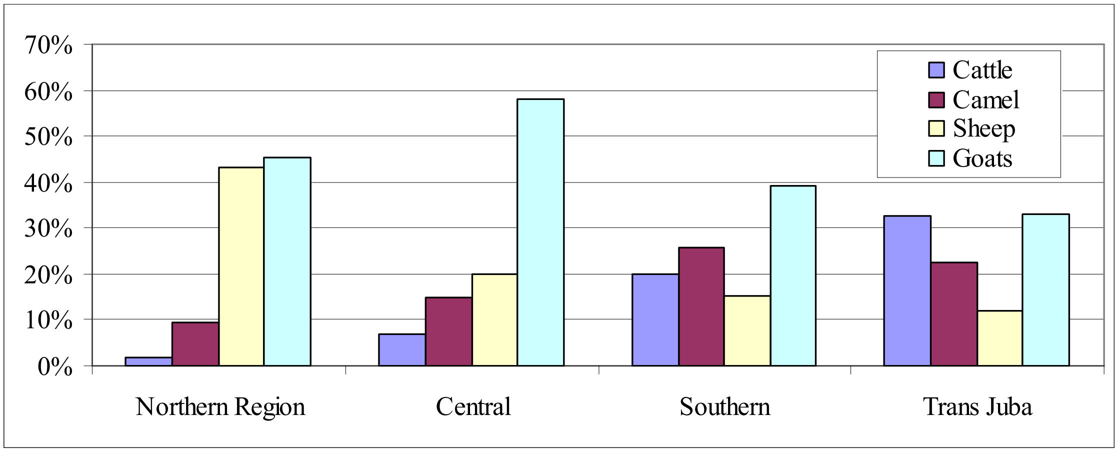


Figure 2-4 : Livestock Percentage in Different Regions of Somalia (1988)

2.3 Land resources

Data on geology, geomorphology, soil, land use and land cover are critical for water resources assessment and development. These are needed to assess the hydrological and climatological regime. In addition, these data combined with climate and hydrological information can be used to assess the land suitability of various purposes, including rain-fed and irrigated agriculture. SWALIM has undertaken a land suitability assessment of a selected study area in Somaliland (*Technical Report L-06, 2007*) and the riverine areas of Juba and Shabelle rivers (*Technical Report L-09, 2007*). Both reports were based on various land resources surveys carried out by SWALIM in the catchment areas of the Dur Dur Watershed in North-west Somaila and the Juba and Shabelle rivers. The results of these surveys are documented in SWALIM Technical Reports nos *L-02 (Landform*), *L-03 (Land cover*), *L-07 (Land use*), and *L-08 (Soils*), respectively.

Agro-ecological zones (AEZ) are land resource mapping units, defined in terms of climate, landform and soils, and/or land cover, having a specific range of potentials and constraints (*FAO, 1996*). Agro-ecological zones for Somalia have been defined and mapped through a combination of "Length of Growing Period (LGP)" Zones and "Aggregated Soil Groups".

The Length of Growing Period (LGP) is a period (in days) that moisture supply exceeds half potential evapotranspiration[1] (P > 0.5PET). The LGP is calculated over a whole year and may consist of one or more "normal" or "intermediate" Growing Periods (GP), whereby a normal GP is a period in which P exceeds full PET (P>PET) and an intermediate GP a period in which P exceeds half PET, but is less than PET (0.5PET<P<PET).

The resulting AEZ map (Map 2-2) shows 29 Zones defined by a combination of LGP and soil, and an additional three "inter-zonal" mapping units defined by landform (i.e. Dunes, Floodplains and Mountains).

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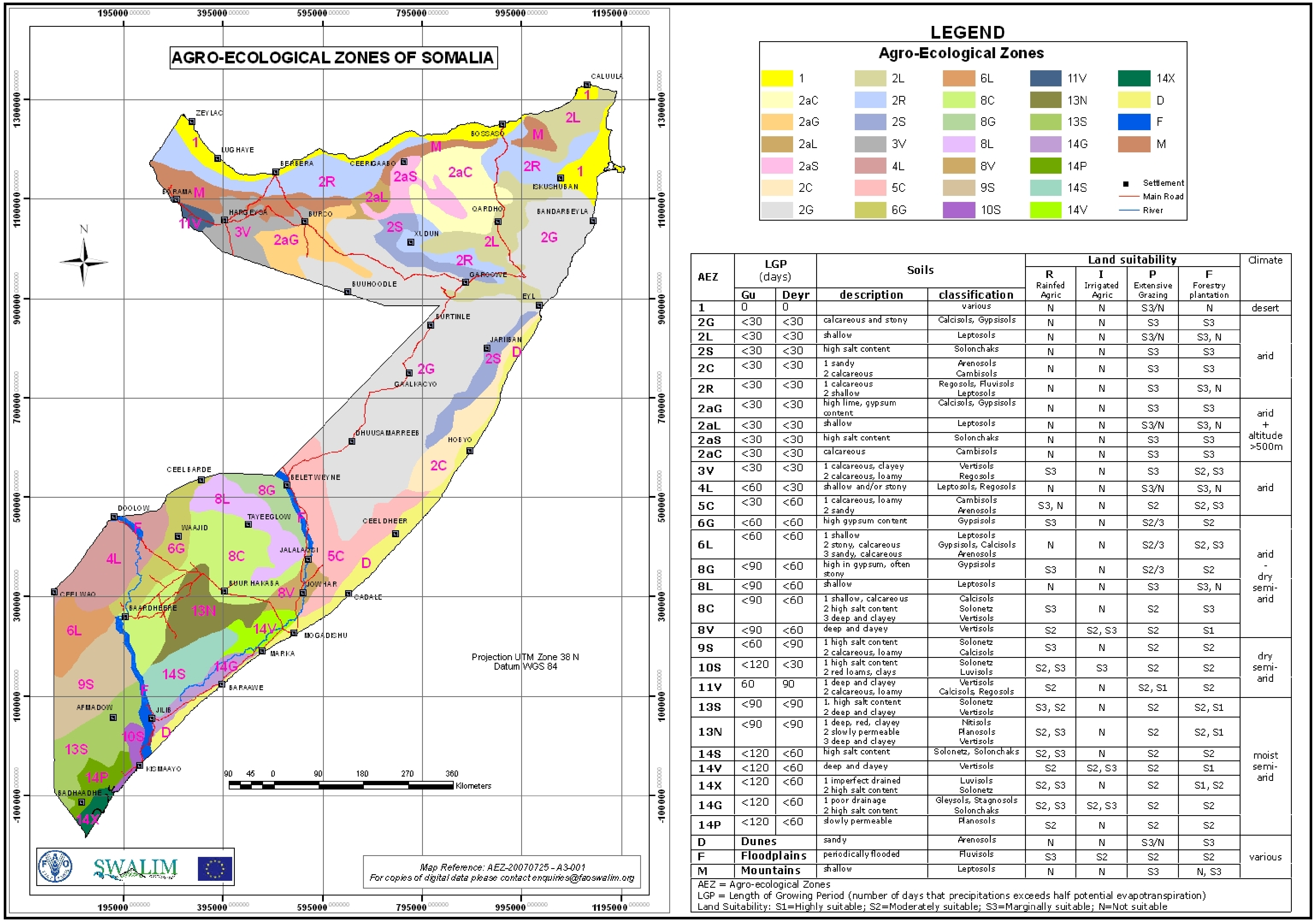
[1] It also includes the time required to evapotranspire up to 100 mm of stored soil moisture. This soil moisture storage has not been included in the present assessment, as all growing periods in Somalia are of an "intermediate" nature in which full water requirements are rarely met and little moisture is stored in the soil.



AEZ	LGP (days)		Soils		Land suitability				Climate
	Gu	Deyr	description	classification	R Rainfed Agric	I Irrigated Agric	P Extensive Grazing	F Forestry plantation	
1	0	0		various	N	N	S3/N	N	desert
2G	<30	<30	calcareous and stony	Calcisols, Gypsisols	N	N	S3	S3	arid
2L	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2S	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2C	<30	<30	1 sandy 2 calcareous	Arenosols Cambisols	N	N	S3	S3	
2R	<30	<30	1 calcareous 2 shallow	Regosols, Fluvisols Leptosols	N	N	S3	S3, N	
2aG	<30	<30	high lime, gypsum content	Calcisols, Gypsisols	N	N	S3	S3	arid + altitude >500m
2aL	<30	<30	shallow	Leptosols	N	N	S3/N	S3, N	
2aS	<30	<30	high salt content	Solonchaks	N	N	S3	S3	
2aC	<30	<30	calcareous	Cambisols	N	N	S3	S3	
3V	<30	<30	1 calcareous, clayey 2 calcareous, loamy	Vertisols Regosols	S3	N	S3	S2, S3	arid
4L	<60	<30	shallow and/or stony	Leptosols, Regosols	N	N	S3/N	S3, N	
5C	<30	<60	1 calcareous, loamy 2 sandy	Cambisols Arenosols	S3, N	N	S2	S2, S3	
6G	<60	<60	high gypsum content	Gypsisols	S3	N	S2/3	S2	arid - dry semi-arid
6L	<60	<60	1 shallow 2 stony, calcareous 3 sandy, calcareous	Leptosols Gypsisols, Calcisols Arenosols	N	N	S2/3	S2, S3	
8G	<90	<60	high in gypsum, often stony	Gypsisols	S3	N	S2/3	S2	
8L	<90	<60	shallow	Leptosols	N	N	S3	S3, N	
8C	<90	<60	1 shallow, calcareous 2 high salt content 3 deep and clayey	Calcisols Solonetz Vertisols	S3	N	S2	S3	
8V	<90	<60	deep and dayey	Vertisols	S2	S2, S3	S2	S1	
9S	<60	<90	1 high salt content 2 calcareous, loamy	Solonetz Calcisols	S3	N	S2	S2	dry semi-arid
10S	<120	<30	1 high salt content 2 red loams, clays	Solonetz Luvisols	S2, S3	S3	S2	S2	
11V	60	90	1 deep and clayey 2 calcareous, loamy	Vertisols Calcisols, Regosols	S2	N	S2, S1	S2	
13S	<90	<90	1. high salt content 2 deep and clayey	Solonetz Vertisols	S3, S2	N	S2	S2, S1	moist semi-arid
13N	<90	<90	1 deep, red, clayey 2 slowly permeable 3 deep and clayey	Nitisols Planosols Vertisols	S2, S3	N	S2	S2, S1	
14S	<120	<60	high salt content	Solonetz, Solonchaks	S2, S3	N	S2	S2	
14V	<120	<60	deep and dayey	Vertisols	S2	S2, S3	S2	S1	
14X	<120	<60	1 imperfect drained 2 high salt content	Luvisols Solonetz	S2, S3	N	S2	S1, S2	
14G	<120	<60	1 poor drainage 2 high salt content	Gleysols, Stagnosols Solonchaks	S2, S3	S2, S3	S2	S2	
14P	<120	<60	slowly permeable	Planosols	S2	N	S2	S2	
D	**Dunes**		sandy	Arenosols	N	N	S3/N	S3	various
F	**Floodplains**		periodically flooded	Fluvisols	S3	S2	S2	S2	
M	**Mountains**		shallow	Leptosols	N	N	S3	N, S3	

AEZ = Agro-ecological Zones
LGP = Length of Growing Period (number of days that precipitations exceeds half potential evapotranspiration)
Land Suitability: S1=Highly suitable; S2=Moderately suitable; S3=Marginally suitable; N=Not suitable

Map 2-2 : Agro-ecological Zones of Somalia

Source: SWALIM Technical Report L-12, 2007

2.4 Climatological data

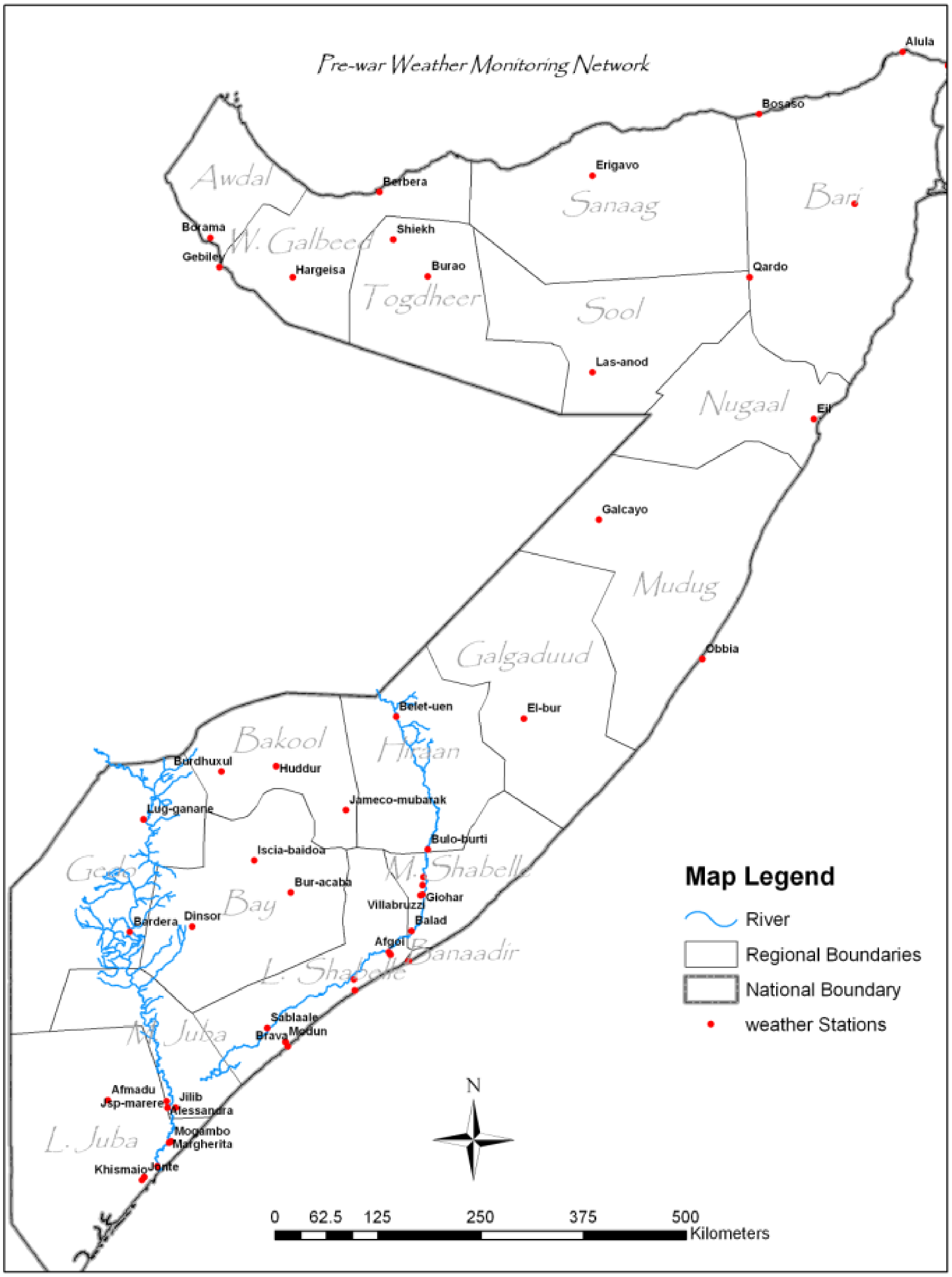
The requirements for the meteorological station network depend on the specific purpose the climatological data is used for. For water resources assessment purpose, its application is mainly to define the agro-climatic conditions for agriculture (both rainfed and irrigated), estimation of streamflows using rainfall-runoff relationships and models, for flood and low flow estimates (both prediction and forecasting) and for estimating erosion and sediment load. Streamflow in the rivers is the "catchment response" to the climate (rainfall, evaporation) in the catchment. The main climatological data of interest for water resources assessment are precipitation (hourly, daily, maximum rainfall for different durations), temperature, relative humidity, evaporation, wind speed, sunshine hours. Potential evapo-transpiration (PET) is an important parameter for estimating the water balance and for the estimation of crop water requirements.

SWALIM Technical Report No. W-01 provides an overview of the climate of Somalia. It also provides a description of the data available and general characteristics of the climatological parameters in Somalia. In addition, inventory of hydro-meteorological data for Somalia (SWALIM Technical Report No. W-03) provides an overview of data availability.

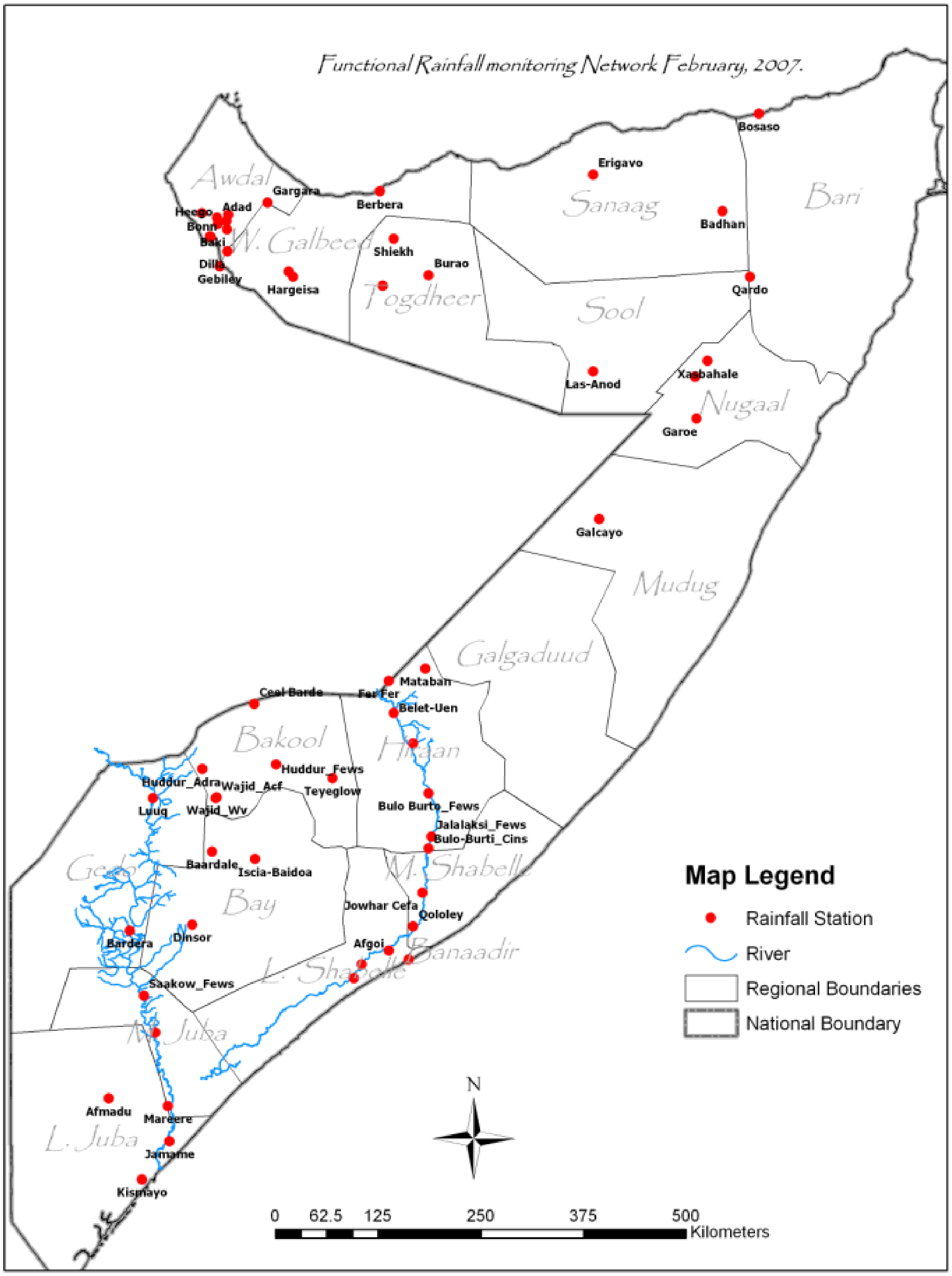
The internal civil strife in Somalia has led to the collapse of the hydro-meterological station network after 1990. There has been some effort to re-establish this vital information network recently, since 2002, by SWALIM in cooperation with other partner agencies active in Somalia. Hence, the meteorological stations and their data have been categorized as pre-war (before 1990, Map 2-3) and post-war periods (after 2002, Map 2-4). SWALIM has taken a lead to re-collect all datasets that are now scattered and those available in different conditions from various agencies.

Times series data are only available for rainfall and temperature in a few stations. Time series data of other climatology variable such as relative humidity, wind speed, sunshine hours, and evaporation are not existent. Database of FAO such as FAO Clim2, New LocClim and AgroMet Shell have been used to estimate other climatic parameters such as relative humidity, sunshine hours, temperature and potential evapotranspiration.

Apart from the rainfall data available from ground stations, remote sensing methods have also been used to estimate rainfall using satellite images of cloud cover, temperature and other atmospheric parameters over regions of interest. SWALIM has also acquired daily rainfall estimates (RFE) from 1995 onwards from NOAA's Climate Prediction Center. These are derived using RFE 2.0 model which uses satellite data and WMO GTS data for about 1000 stations (for calibration and validation purpose). The grids are 8.0 km grid and are in Albers equal area (conic) projection. Validation of these estimates with data from the ground stations within SWALIM was not encouraging. The reason for this is perhaps because NOAA does not include any rainfall data from stations within Somalia to calibrate and validate their model for RFEs.



Map 2-3 : Pre-war Rainfall Network in Somalia



Map 2-4 : Present Rainfall Network in Somalia (April, 2007)

2.5 Surface water resources

For the purposes of surface water resources assessment, Somalia can be divided into the following major river basins:

1. Gulf of Aden basin
2. Daroor basin
3. Tug Der/ Nugal basin
4. Ogaden/Central basin
5. Shabelle basin
6. Juba basin
7. Lag Dera basin
8. Lag Badana basin
9. Indian Ocean basin

A significant portion of water resources of Somalia comes from the river basin areas outside Somalia. The entire areas covering all the river basins contributing surface water in Somalia is shown in Map 1-1. It is bordered to the west by the East African Rift Valley and to the south by the Tana river basin, while to the north and east are the Gulf of Aden and the Indian Ocean, respectively. The areas include the Ethiopian part of the Juba and Shabelle river basins and parts of the Ogaden desert in Ethiopia and Somalia and northeast Kenya.

The Juba and Shabbele are the only two perennial rivers where there is a flow throughout the year. Other rivers and drainages have surface water only after periods of heavy rainfall. There are, however, some small streams called *toggas* originating from the plateaus and mountains in northern Somalia that have perennial flows in some stretches and at other stretches have a complex surface-water groundwater interaction where there is groundwater recharge as well as the existence of springs in the mountainous areas.

Most attention of surface water resources is given to the Juba and Shabelle rivers as there is a potential of irrigating the vast riverine areas of the two rivers. Juba and Shabelle rivers are also affected by intermittent floods. Even a small flood event of one in a 5-year period is known to cause flooding problems. The small *toggas* in the northern mountain areas also are known for the flash floods that have very high flows. The areas along the *toggas* are cultivated and irrigation is provided to small plots of 2 to 3 ha each through surface water and groundwater

Chapters 3 and 4 of this report contain a detailed analysis of the surface water resources of the major basins.

2.6 Hydro-meteorological database

The hydro-meteorological data available and collected for Somalia has been stored and managed, using the HYDATA systems originally developed by the Institute of Hydrology (IH), Wallingform (now the Center of Ecology and Hydrology). SWALIM is updating all historical and current data on this system.

As time series data on the climatological parameters such as temperature, relative humidity, sunshine hours, wind speed, potential evaporation etc. are not available for Somalia, estimates for these parameters have been made by using FAO's world wide database. These include New LocClim 1.10 – Local Climate Estimator (*Grieser, J, 2006*), FAOCLIM- World-wide agroclimate database (*Version 2.02*) and AgroMetShell (*FAO, 2006*).

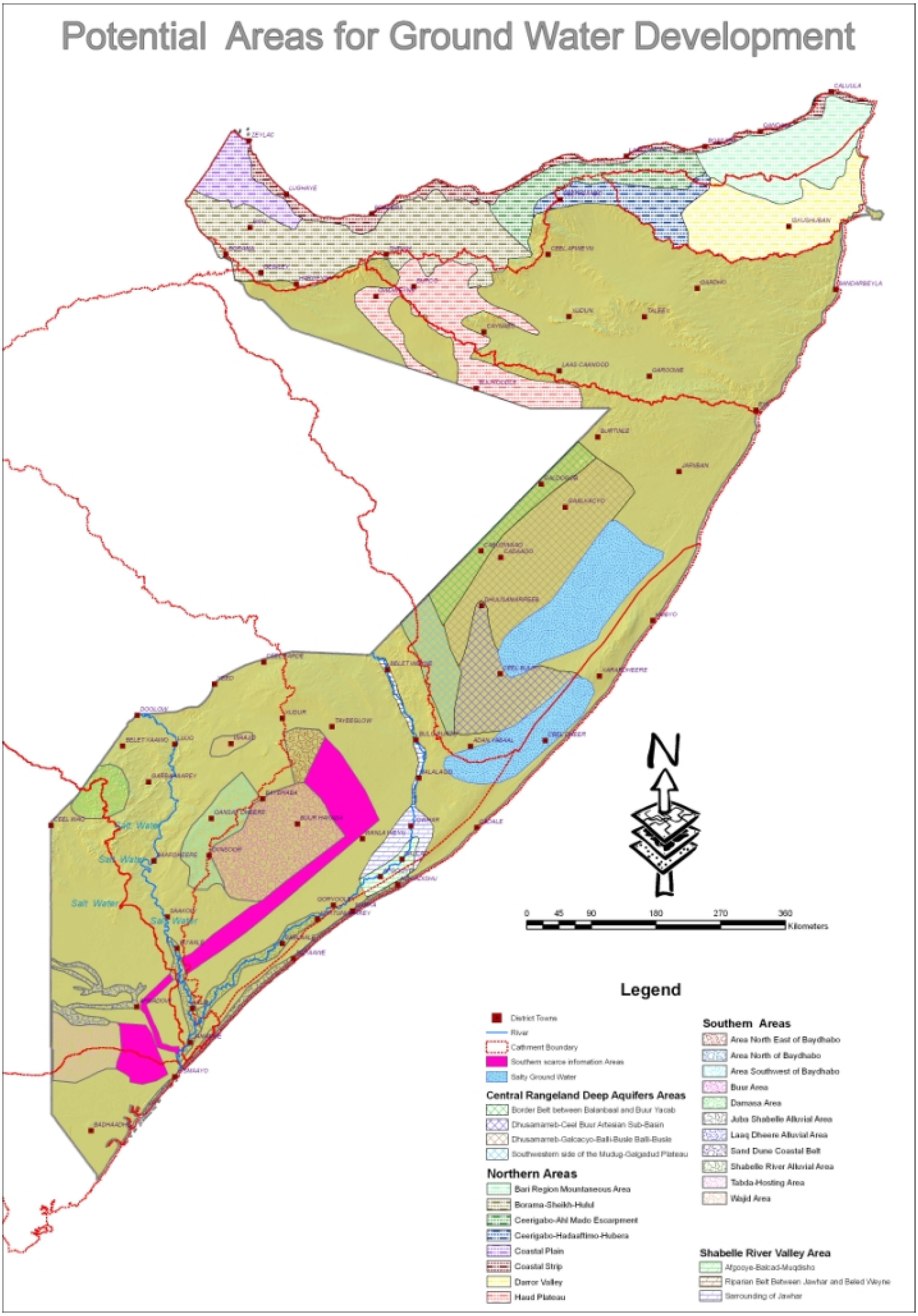
2.7 Groundwater resources

Groundwater is the main source of water for the majority of the people in Somalia. Except for the population residing along the Juba and Shabelle rivers, which also use surface water to meet their water needs, groundwater from dug wells, bore holes and springs are the primary sources of water for the population in the most of the country. Groundwater is harnessed by the rural and urban population to meet domestic and livestock water needs as well as for small scale irrigation.

Data on the aquifers and groundwater systems in Somalia are scattered and scarce. Investigations and groundwater explorations have been carried out for specific locations by different agencies (e.g. by TAMS (1986) for Bay and central rangeland, by Petrucci (2006) for some areas of NW Galbeed and Awdal regions of the Haud Plateau, Somaliland, by Sogreah (1982) and Groundwater Survey (2006) for Dur Dur watershed in Awdal region). But country-wide data are lacking. The best source of information on groundwater aquifers and potential areas for further development is the data collected and analysed by Faillace and Faillace (1987). The areas with good groundwater potential are presented in Map 2-5 (*adapted from Faillace and Faillace, 1987*).

Major water sources using groundwater are as follows:

- Shallow wells (hand-dug wells) – these are usually unlined, open with logs and stone arranged around the mouth. Their depth range is from a few meters to appr. 20 m;
- Boreholes – these are usually machined drilled and lined with steel casings. They are located mainly in major trading centres and towns. Depth of boreholes vary from 40 to 175 m or as high as 400 m and they yield in the range of 5 -10 m^3/hr . They are found to be either drilled by the government or donor agencies.
- Springs – these may be perennial as well as seasonal and are mostly located in mountainous regions. They are used both for livestock and domestic purposes.
- Sub-surface dam – these intercept and store the underflow in permeable *togga* beds. They are normally of two types. The first type uses a clay or masonry wall made in a trench, using the existing materials. The other type uses a masonry wall above an impermeable valley bottom, which are raised in several steps after every flood. Water is then collected from wells in the river beds or by using an infiltration galley connected to a pipe, conveying water to the community or a water point.
- Infiltration galleries – these are permeable collectors for interflow/sub-surface flow. They are normally laid horizontally across the river bed and conveyed to a central collector or well. In some instances, a downstream impermeable layer is constructed to raise the subs-surface flow.



Map 2-5 : Potential Groundwater Development Areas in Somalia

Source: Adapted from Faillace and Faillace (1987)

As groundwater sources are important in meeting the water needs of the population and livestock across the country, the following water quality acceptance (electrical conductivity based) are proposed by different sources (Table 2-2).

Table 2-2 : Recommended EC values for Water for Human and Animal Consumption

Use	**EC (μS/cm)**	
	WHO	**TAMS (1986)**
Domestic use	≤ 5,000	≤ 3,500
Cattle, goats and sheep	≤ 8,000	≤ 7,500
Camels	≤ 12,000	≤ 10,000

2.8 Water Use

2.8.1 Water for human and livestock

Domestic water demand is the most basic and fundamental need of humans for survival. Domestic water demand depends on various factors such as the climate, socio-economic conditions, and availability of fresh water. The demand is for both quantity and quality of water. In the case of the various types of users/groups their needs also varies. Pastoralists, for example, are concerned more about the quantity of water available for their animals, while in the urban and peri-urban areas water quality is a major consideration. The pastoralists obtain water mainly from shallow wells and *berkads* where sanitary services are limited, while the urban areas are supplied with water from boreholes and shallow wells. Water chlorination is practised in many of the urban water supplies.

Domestic water demand varies for rural, peri-urban and urban consumers. While the rural population, including pastoralists, agropastoralists and sedentary farmers, rely on common water points and public facilities, the urban population are normally supplied by various means: ranging from piped water supply, often metered and paid by volume of consumption, to public standposts and wells. The per capita demand for these different categories varies. In the case of most settlements in Somalia, actual water consumption is very small, mainly due to the water availability constraints that are normal in an arid climate. Although the minimum basic human consumption as recommended by WHO is 20 litres per capita per day (lpcd), most consumers survive with much less (between 2-16 lpcd). The Millennium Development Goal (MDG) defines access to water as water being available from an improved water source within 200 m of one’s place of residence. In the case of Somalia, people undertake a return journey of up to 20 km or more in dry seasons in search of water. Water fetched from elsewhere can only last a couple of days, meaning several trips are made every week. An estimate of the minimum water requirements for humans and livestock is given in Table 2-3. These rates are the bare minimum and do not represent the demand in the case of unconstrained availability.

Table 2-3: Daily Water Consumption for Humans and Animals

	Consumption per head/person (litres per day)
Cattle	20-25
Sheep, goats	1.3-1.6
Camels *	9-12
Human (domestic use)	5-20

* Water taken weekly, meaning around 80 litres per week.

Source: UNDOS Study in Nugal Region (cited in MWH and Parsons Brinckerhoff, 2004)

The demand for the urban population will be higher as the socio-economic conditions of the consumers are different and demand in terms of household connection ranges from 50 to 100 lpcd for domestic use.

2.8.2 Water for agriculture

Food security crisis linked to flood and drought is a striking feature of life in Somalia. Crop production is largely limited to South Somalia's alluvial plains and inter-riverine area of the Bay region where 90% of production is obtained. In northern regions, where pastoralism is predominant, crop cultivation is mostly confined to natural oases where groundwater is available. Production is mainly smallholder and subsistence based.

The exploitation of natural resources for agricultural production is limited due to insecurity; displacement of communities; degraded irrigation infrastructure; and lack of technical support, inputs, marketing and market access. Food Security Analysis Unit (FSAU) estimates that after the civil war that lasted through most of the 1990’s, the annual cereal production was about 300,000 tonnes covering 50% of the annual requirements (590,000 tonnes) and before the break of the civil war in 1990 it was 62% of the average production (480,000 tonnes).

Both rain-fed and irrigated agriculture is practised, depending on the agro-climatic conditions and the water availability of the area. As most of the country lies in an arid climatic belt, agriculture is limited to small areas in the north-west along the alluvial plains of the small *toggas* and in the Juba and Shabelle riverine areas where surface water is available for irrigation. Other areas with favourable climatic conditions such as the Buur escarpment between Juba and Shabelle have rain-fed agriculture with some irrigation, supplemented by groundwater.

As the potential evapotranspiration (PET) is higher than the rainfall in all months in most parts of the country, the irrigation requirement to meet the crop water requirement is quite high. This is more so in the north where PET levels are higher than the south. Hence, the yield of crops grown in these regions remain very low as the rainfall and irrigation water, if any, does not meet the crop water requirement.

There is conflicting data available on the actual areas presently being irrigated in Somalia. Table 2-4 and Table 2-5 present the land under cultivation and irrigated land in 1988.

Table 2-4 : Land Under Cultivation in Somalia in 1988

Region	**Land Under Cultivation**		**Potential Cultivable Land**[2]	**% of Potential Cultivable Land**
	Ha	**%**	**Ha**	**%**
North	132,000	13.2	139,500	94.6
Central	121,150	12.1	432,800	28.0
South	748,300	74.7	1,243,000	60.2
Somalia	1,001,450	100	1,815,000	55.2

Source: Somalia Agricultural Sector Survey,1988

Table 2-5 : Actual Irrigated Areas in Somalia in 1988

Region	**Flood Recession Cropping (Ha)**	**Controlled Irrigation (Ha)**	**Total (Ha)**
Juba	24,200	22,600	46,800
Shabelle	21,600	40,150	61,750
Bay	0	800	800
Center	0	1,600	1,600
North	0	2,000	2,000
Total	45,800	67,150	112,950

Source: Somalia Agricultural Sector Survey, 1988

2.8.3 Other water uses

Apart from the domestic, livestock and agricultural water use, other important uses of water include industry and the environment. There is no data available on these uses.

One vital consideration for the use of the river flows in Juba and Shabelle is the environmental water requirements that need to be maintained in the river for aquatic as well as other environmental uses. The swamps that the Shabelle river feeds would have an important ecological value in terms of sustaining the ecosystem as well as recharging the groundwater aquifers of the area. The many small fresh water lenses and shallow wells along the dunes and eastern coastal areas are likely to be affected if there any changes in the flows to the swamps.

The present study did not include these water needs mainly due to unavailability of data. However, any future study or investigation should consider these water requirements.

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[2] Total land suitable for cultivation, which includes land currently under cultivation and land that is yet to be opened up for cultivation.

2.9 Enabling environment

Somalia is in a transitional phase with a Transitional Federal Government (TFG) recognized by the international community. There are two autonomous regions in the north, Puntland and Somaliland, which have been managing their resources, including water resources, independently. The presence of the national government is limited to certain areas and there is very little central government presence in the central and southern regions of the country.

Management of natural resources like water resources is not possible without a strong enabling environment. It includes an institutional framework that focuses on the integration of various sectors while practising decentralization and decision making at the local level. What is urgently needed are water resources policies and acts that support integrated water resources management (IWRM) based on the principles of economic efficiency, equity and environmental sustainability.

The Ministry of Water and Mineral Resources of Somaliland has prepared a Somaliland National Water Policy 2004. Water Resources Strategy and Acts based on the policy have also been formulated. Similarly, the Puntland State Agency for Water, Energy and Natural Resources (PSAWEN, 2001) has prepared a “Water Supply Policy Green Paper”. These policies are based on the IWRM principles and river basins are considered fundamental planning units.

There is however a lack of relevant policy and regulatory framework in the southern regions. It would be difficult to undertake any irrigation infrastructure rehabilitation and flood management interventions in the Juba and Shabelle river basins without the necessary enabling environment.

3 Major River Basins in South-Central Somalia

3.1 General characteristics

The alluvial plains of the two perennial rivers of Somalia, Juba and Shabelle, are the food basket of the country. Shabelle joins Juba before Juba flows to the Indian Ocean, but it is only during major flood seasons that flows from Shabelle reach Juba. Similarly, flows from the seasonal rivers of north-east Kenya to Lag Dera, itself a seasonal river, only occur during extreme rains, and it is very rarely that flows reach Juba. Hence, technically both Shabelle and Lag Dera rivers are tributaries of Juba.

In addition to the three rivers, Juba, Shabelle and Lag Dera, another group of small ephemeral streams in the southern-most region of Somalia drains into the Indian Ocean. This river system has been collectively called the Lag Badana Basin. The Lag Badana Basin has a sparse network of poorly defined seasonal water courses but the catchment receives one of the highest rainfalls in Somalia. The water resources of Southern Somalia and the southern part of Central Somalia (parts of the Hiraan and Middle Shabelle) are based on these four river basins.

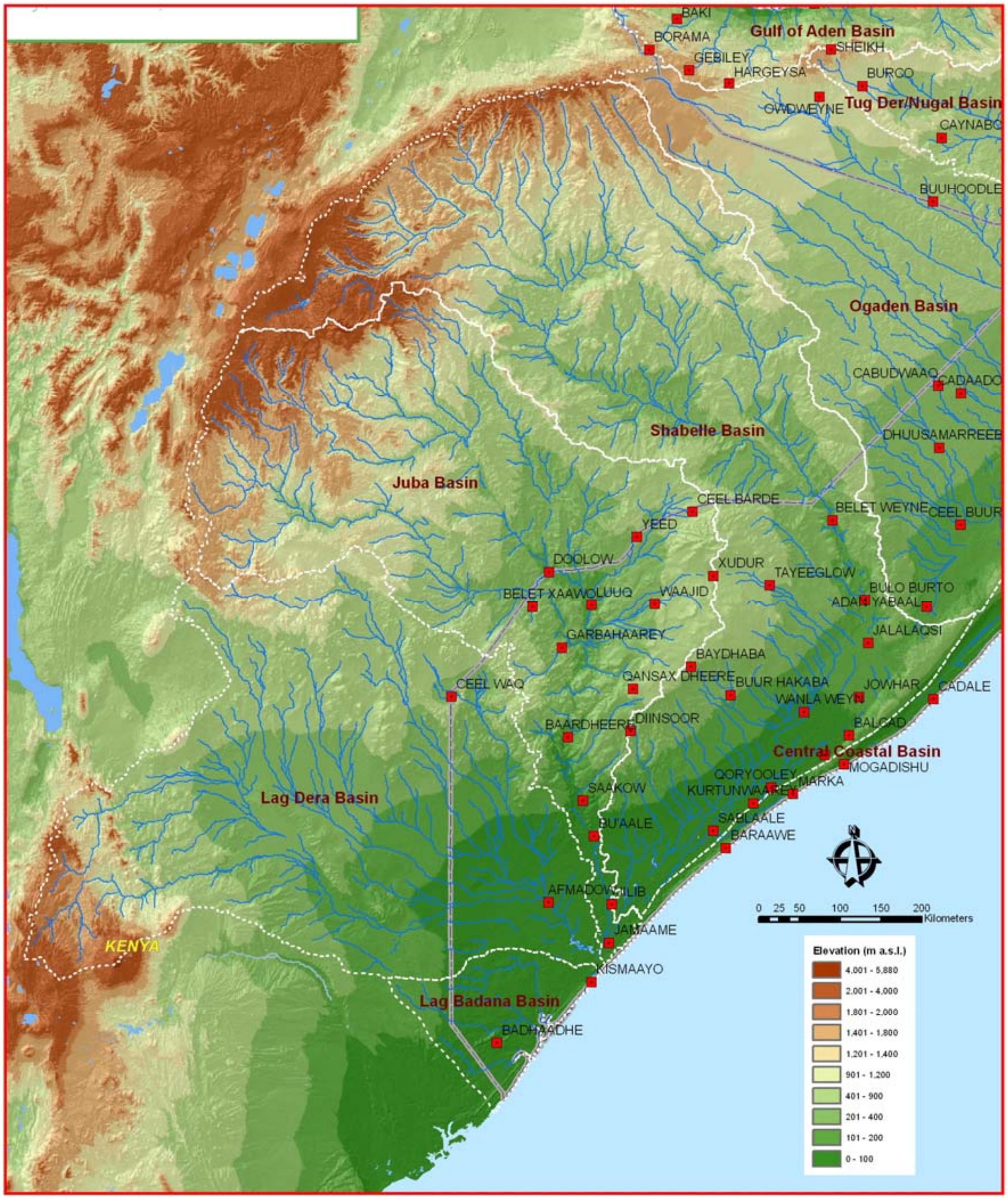
This chapter covers the water assessment of the above four drainage basins in South-Central Region of Somalia (Map 3-1).

3.1.1 Location

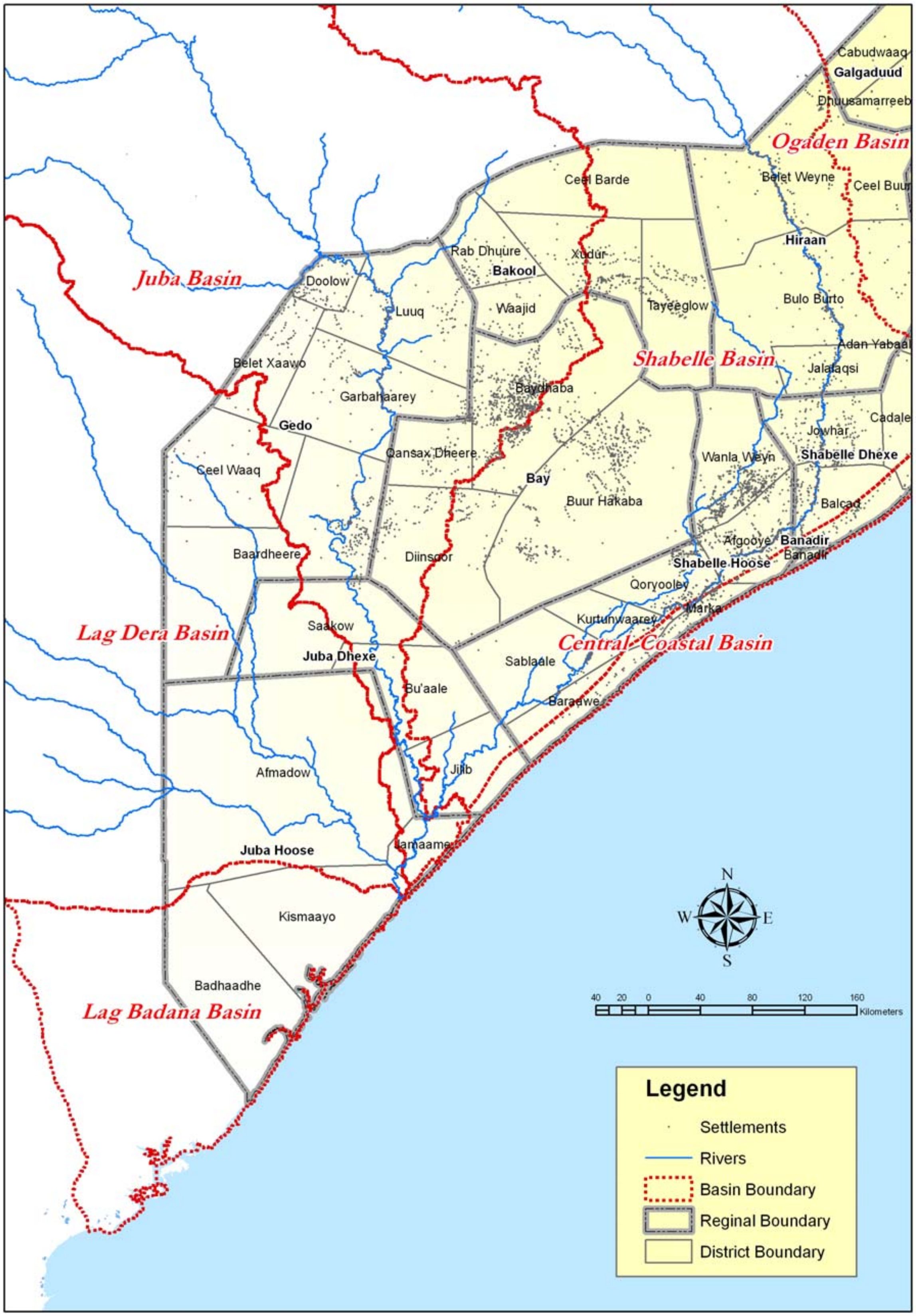
About two-thirds of the catchments of both the Juba and the Shabelle basins lie outside Somalia, mostly in Ethiopia, with a part of the Juba catchment in Kenya. Similarly, about three-quarters of the catchment of the Lag Dera Basin lie in Kenya. The catchment of the Lag Badana Basin lies within Somalia in the extreme south of the country.

Juba Basin

The Juba Basin within Somalia is spread over five regions and 20 districts within them (Map 3-2). The regions and districts (in brackets) that are covered by the Juba Basin are Bakool (Ceel Barde, Xudur, Rab Dhuure, Waajid), Bay (Baydhaba, Qansax Dheere, Dinsoor), Gedo (Luuq, Doolow, Belet Xaawo, Garbohaarey, Baardheere, Ceel Waaq), Middle Juba (Saakow, Jilib, Bu'aale), Lower Juba (Afmadow, Jamaame, Kismayo) (Map 3-2). As administrative boundaries of regions and districts do not necessarily match the basin boundaries, the river basin covers only parts of some of these regions and districts. The whole basin lies roughly between 38° 1' and 46° 0' east of the Prime Meridian and between 0° 15' and 7° 28' north of the Equator. The most important towns lying within the Juba basin are Luuq, Garbohaarrey, Baardheere, Bu'aale, Jilib, Jamaame and Kismayo.



Map 3-1 : Drainage Basins of Southern Somalia



Map 3-2 **:** Regions and Districts in Juba, Shabelle, Lag Dera and Lag Badana Basins

Shabelle Basin

The Shabelle basin, within Somalia, is spread over six regions and 22 districts within them. The regions and districts (in brackets) covered by the Shabelle basin in Somalia are Hiraan (Belet Weyne, Bulo Burto, Jalalaqsi), Middle Shabelle (Shabelle Cadale, Balcad, Jowhar), Lower Shabelle (Afgooye, Qoryooley, Marka, Kurtuwaarey, Sablaale, Baraawe, Wanla Weyne), Middle Juba (Jilib, Bu'aale), Bay (Diinsoor, Buur Hakaba, Baydhaba) and Bakool (Ceel Barde, Xudur, Tayeeglow) (Map 3-2). The whole basin lies roughly between 38^o 40' and 46^o 9' east of the Prime Meridian and between 0^o 15' and 9^o 38' north of the Equator. The most important towns lying within the Shabelle Basin in Somalia are Ferfer, Belet Weyne, Buulobarde, Mahadday Weyne, Jowhar, Balcad, Afgooye, Marka, Baraawe and Haaway.

Lag Dera Basin

The Lag Dera Basin, within Somalia covers two regions and five districts. The regions and districts (in brackets) are Gedo (Ceel Waaq, Baardheere, Saakow) and Lower Juba (Afmadow, Kismayo). The basin lies roughly between 36^o 12' and 42^o 35' east of the Prime Meridian and between 0^o 20' south and 4^o 35' north of the Equator. There is no major town located in this basin.

Lag Badana Basin

The Lag Badana Basin lies entirely within two districts, Kismayo and Afmadow, in the Lower Juba region (Map 3-2). The basin lies roughly between 41^o 0' and 42^o 15' east of the Prime Meridian and between 1^o 38' and 4^o 30' north of the Equator, with no major town located in it.

3.1.2 Topography and drainage network

Juba Basin

The Juba river has three main tributaries (Webi Gestro, Genale and Dawa) in its upper catchment which all flow south-eastwards. The three main tributaries have catchments of approximately 27,000 km^2, 57,000 km^2 and 60,000 km^2, respectively. Gestro and the Genale unite to form the Juba river just north of Dolo in Ethiopia, and the Dawa joins the Juba river at Dolo, having formed the Kenya-Ethiopia border and the Somalia-Ethiopia border in the area west of Dolo. The total catchment area of the Juba basin at the mouth of the river near Kismayo is about 221,000 km^2 (based on catchment delineation in SRTM 30m from USGS). 65% of which is in Ethiopia, 30% in Somalia and 5% in Kenya. The catchment areas of Shabelle and Lag Dera are not included, although both of them are technically tributaries of Juba, as explained earlier.

The basin extends from sea level at its mouth where it flows into the Indian Ocean in Somalia to well above 3000m in the northwest in Ethiopia. About 42% of the catchment area is below 500 m, 43% between 500 and 1500 m, 14% between 1,500 and 3,000 m and 1% above 3,000 m (Figure 3-1 and Table 3-1). The catchment area within Somalia is below 700m (Figure 3-2). Slopes in the upper part of the catchment in Ethiopia and Kenya are generally steep with a well developed drainage network. In the middle and lower part of the basin below 500m, the slopes are gentle and the drainage network is less dense. There is little flow contributed in the basin area within Somalia as the network is not well developed and there is no major tributary.

The total length of the Juba river is about 1808 km (measured on the longest tributary), of which 804 km lies in Ethiopia and 1004 km lies in Somalia (based on SRTM 30m derived streams from USGS). The total length of the longest tributary (the Genale) from its source to the confluence with the Gentro and Dawa is about 550 km. After entering Somalia, the river continues to flow south-easterly until it reaches the town of Luuq (also called Lugh Genale), from which point it flows towards south and into the Indian Ocean. The gradient of the river is steep in the upper reaches but slopes gently in the lower reaches, especially within Somalia.

Shabelle Basin

The Shabelle river rises on the eastern flanks of the eastern Ethiopian highlands (the highest point being 4230 m). The total catchment area of the Shabelle river at its confluence with the Juba river is about 297,000 km^2 (based on catchment delineation using SRTM 30m from USGS), two-thirds (188,700 km^2) of which lies in Ethiopia and the rest (108,300 km^2) is in Somalia. The elevation of the basin varies from about 20m above sea level in the south to more than 3000 m on the eastern Ethiopian Plateau. About 47% of the basin is below 500 m, another 41% is between 500 and 1,500 m, 12% is between 1,500 and 3,000 m and less than 1% is above 3000 m (Figure 3-1 and Table 3-1). Within Somalia, the catchment area is below 700 m (Figure 3-2).

The river and its tributaries in the eastern Ethiopian highlands are deeply incised and the slopes are steep. The total length of the main course of the river from the source to the Somalia border is about 1290 km and it traverses to additional distance of 1236 km within Somalia before it meets the Juba river. Its main tributaries in Ethiopia are the Fanfan (northern part of the basin) and the Far Depression. The flows in the former are intermittent and flows from it reach the Shabelle river only during heavy rainfall periods. The drainage network in the Ethiopian part of the catchment (especially in the western part) is dense to very dense except in the bordering region with Somalia and east of longitude 44^o E.

The Shabelle river flows south-eastwards to the Somalia border at the border town of Ferfer. There, it turns south to Balcad near Mogadishu, where it turns southwest and continues roughly parallel to the coast from which it is separated by a range of sand dunes. Half way along the coastal stretch, it runs into a series of swamps. Downstream of the swamps the river resumes a defined channel, but the flows are very much reduced and the Shabelle discharges into the Juba only in times of exceptional floods. The swamp areas (wetland) which are fed by Shabelle could have high ecological value in terms of habitat for flora and fauna as well as recharge areas of the groundwater aquifers lying in the area. Unfortunately, no data is available on these swamps. However, it could be safely said that the swamps sustain the freshwater available in the aquifers which meets the water needs of the coastal towns and settlements in the south. Further study, however, would be required to assess the hydro-geological conditions of the area.

The drainage network in the Somalia part of the basin is thin and virtually non-existent. The small streams with small catchment are of ephemeral type, where there is a flow only during heavy rainfall. A number of streams are found in Buur escarpment which is fed by springs.

Lag Dera Basin

The total catchment area of the Lag Dera river at its confluence with Juba is about 231,000 km^2 (based on SRTM 30m derived catchment delineation from USGS), out of which 80% is in Kenya. Its elevation ranges from sea level to over 2000 m in the northwest and to well over 3000 m in the southwest. The highest point in Kenya is Mount Kenya (5195m). About 73% of the basin area is below 500 m, 33% is between 500 and 1000m and the remaining areas are mostly below 3000 m, with a small percentage above 3000 m (Figure 3-1 and Table 3-1). Within Somalia, the catchment area is all below 700 m (Figure 3-2). Slopes are steep to very steep in the mountains in the southwest and along the western boundary.

Much of the drainage network is ill defined and thin. It consists of seasonal water courses of different lengths and carries runoff only after heavy rainfall. The larger of the seasonal streams are Lag Kutula in the northeast, and Lag Bor and Lag Bogal in the centre of the basin. Much of the rainfall evaporates or infiltrates in the flat lands and the broad shallow valleys. The flows from Lag Dera rarely reaches Juba as virtually all water disappears in Deshek Wamo, a large natural depression in the south of the basin. This natural depression could be of high ecological significance. However, no data is available on the hydrology of the basin or on the depression area and the wetlands within it.

Lag Badana Basin

The Lag Badana basin in the extreme south of the country is relatively flat and has a thin network of poorly defined seasonal water courses. The entire area of 16,600 km^2 within Somalia is below 200m above sea level (Figure 3-2 and Table 3-1). Surface water resources in the area are scarce and localized runoff occurs only during periods of heavy rainfall. Little water reaches the ocean although the seasonal streams receive seawater from the tidal estuaries. This area is assessed to receive a fair amount of rainfall based on data of rainfall stations in the neighbouring areas in Lag Dera basin (one station) and in the Kenyan side. No rainfall and surface water gauging is done in the basin.

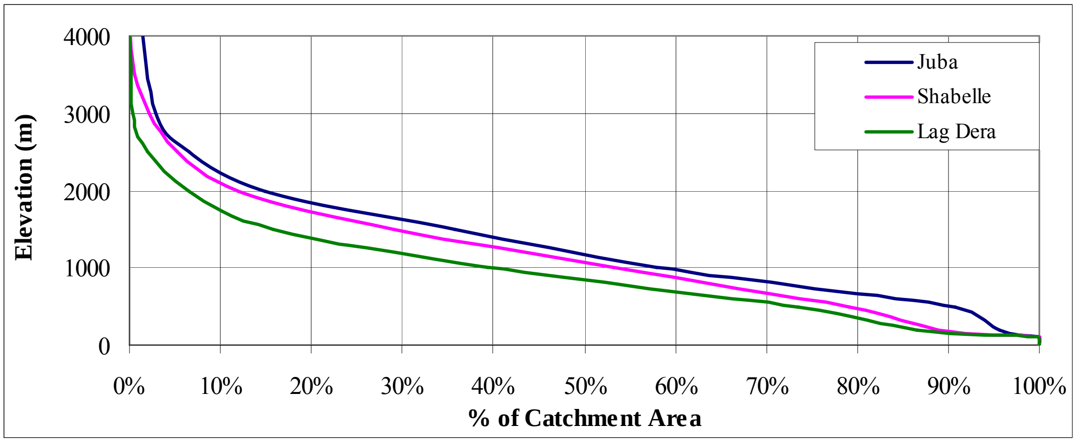


Figure 3-1 : Hypsometric Curves of Full Basin Areas
(based on 90m SRTM DEM data)

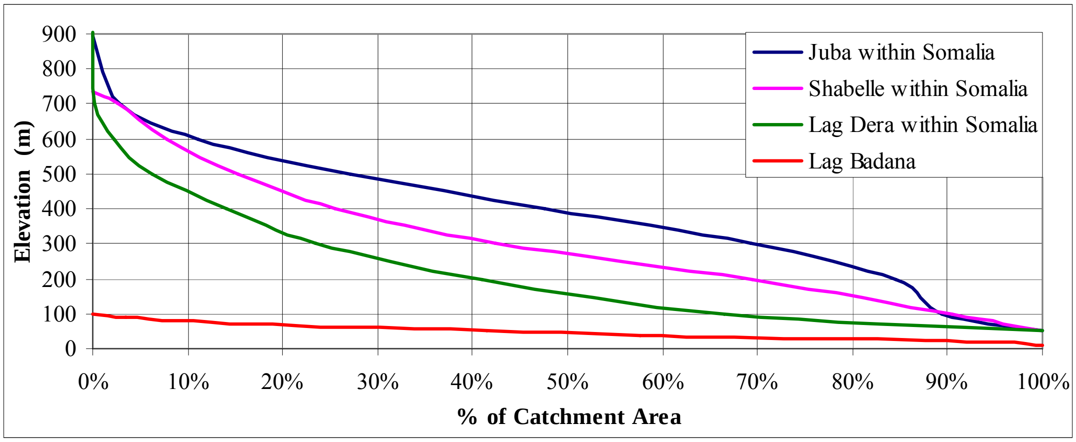


Figure 3-2 : Hypsometric Curves of Catchment Areas within Somalia
(based on 90m SRTM DEM)

3.1.3 Land resources

SWALIM has undertaken a land suitability assessment of the riverine areas of Juba and Shabelle rivers (*Technical Report L-09, 2007*). These were based on various land resource surveys carried out by SWALIM in the catchment areas of the Juba and Shabelle rivers. The results of these surveys are documented in SWALIM Technical Reports nos. L-02 (Landform), L-03 (Land cover), L-07 (Land use), and L-08 (Soils), respectively.

The main lithologies drained by the two rivers in the Somali part of their drainage are limestones, gypsum formations, sandstones and then silty clays, gravels and sandy deposits along the Shabelle river, with mainly limestones, gypsum formations, sandstones, and clays and sands in more than half of the Juba river. Between the two rivers lies a huge outcrop of crystalline rocks belonging to the African basement which is formed by granite, marbles, quartzite, gneiss and paragneiss (so called Buur region).

Table 3-1: Topographic and Drainage Characteristics of the Major River Basins in South-Central Somalia

	Catchment Area (km^2)		% of Catchment Area under different elevation levels (m)								
Basin	**From 30m DEM**	**From 90m DEM**	**<100**	**100-200**	**200-500**	**500-1000**	**1000-1500**	**1500-2000**	**2000-2500**	**2500-3000**	**>3000**
Juba	220,872	210,010	4%	5%	33%	22%	21%	8%	4%	2.1%	0.9%
Shabelle	296,972	283,054	11%	10%	26%	24%	17%	7%	3%	1.6%	0.6%
Lag Dera	231,639	218,645	26%	13%	34%	24%	9%	5%	2%	0.4%	0.2%
Catchment Area within Somalia			**<50**	**50-100**	**100-200**	**200-300**	**300-400**	**400-500**	**500-600**	**600-700**	**>700**
Juba	64,744	61,395	10%	5%	15%	22%	20%	16%	8%	2.8%	0.3%
Shabelle	108,295	102,806	9%	21%	27%	17%	10%	8%	5%	2.5%	0.1%
Lag Dera	46,335	43,789	34%	26%	18%	9%	8%	4%	2%	0.1%	0.01%
Lag Badana	16,575	15,619	73%	27%							

Based on SRTM 30m and 90m DEM; for catchment areas within Somalia, the catchments derived by 30m SRTM are clipped by national boundary

The main soil types present on the hillslopes and plains of the Somali portion of the Juba and Shabelle river basins are Eutric Vertisols, (deep clayey soils with >30% of clay that expand when wet and shrink upon drying), Haplic Calcisols (typical soils with accumulation of secondary carbonates in a calcic horizon), Haplic Solonetz (typical soils with "much" sodium absorbed at its exchange complex), Lithic Leptosols (very shallow soils limited at maximum of 25 cm deep by hard rock), Petric Gypsisols (soils with substantial secondary accumulation of gypsum ($CaS0_4$,$2H_2O$), and in this case the gypsum is strongly cemented or indurated).

The landcover of the flood plains and alluvial plain of the two rivers in Somalia consists of 66% wooded vegetation (mainly open shrubs), 18% rangeland (mainly closed to open savannah), 15% agriculture (mainly rainfed agriculture) and 1% of other types of cover.

A major type of land use is the subdivision of rural land use such as rainfed agriculture, irrigated agriculture, forestry etc. A land utilization type (LUT) is land use defined in more detail, according to a set of technical specifications in a given socio-economic setting. Major kinds of land use and land utilization types (LUTs) included in the land suitability assessment of the study area (*SWALIM Technical Report No. L-09*) are given in Table 3-2. The evaluation was done on a wide variety of tree species, including suitable species not currently under cultivation in the study area such as cotton, *Acacia nilotica* (maraa), etc.

Table 3-2: Major Land Use Types in South-Central Somalia

Major Kind of Land Use		**Land Use Type (LUT)**	
R	Rainfed Agriculture (crops)	Rc	Rainfed cowpea; short GP (80 days); low-medium input
		Rk	Rainfed cotton; GP 160-180 days; medium input
		Rm1	Rainfed maize; short GP (80-90 days); medium input
		Rs1	Rainfed sorghum; short GP (90-100 days); medium input
I	Irrigated Agriculture (crops)	Ir	Flood irrigation of paddy ice; medium input
		Ic	Gravity irrigation of citrus and other fruits, medium input
		Is	Gravity irrigation of sugarcane, medium to high input
P	Pastoralism (extensive grazing)	Pc	Extensive grazing of cattle; low input
		Pd	Extensive grazing of camels; low input
		Pg	Extensive grazing of goats; low input
		Ps	Extensive grazing of sheep; low input
F	Forestry (tree plantation)	Fai	*Azadirachta indica* (neem)
		Fan	*Acacia nilotica* (maraa)
		Fat	*Acacia tortilis* (qurac)
		Fce	*Casuariana equisetifolia* (shawri)
		Fcl	*Conocarpus lancifolius* (damas, ghalab)
		Fdg	*Dobera glabra* (garas)
		Fti*	*Tamarindus inidica* (raqai)

The land suitability was further classified into the following four classes:

S1 = highly suitable

S2 = moderately suitable

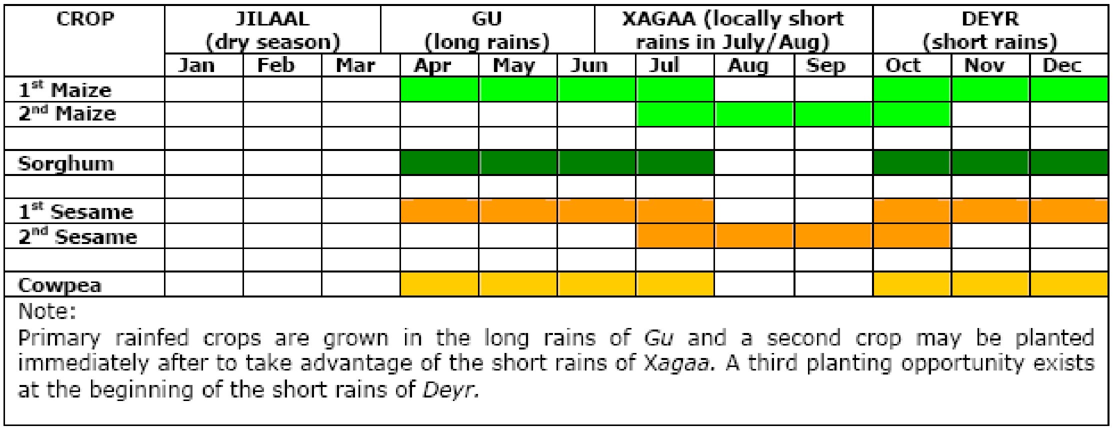
S3 = marginally suitable

N = not suitable

Land Suitability for Rainfed Agriculture

The main rain-fed crops grown in the Southern Somalia are maize, sorghum, sesame and cow peas. Other crops such as cotton are also suitable for the region (Table 3-2), but not commonly cultivated. As rain occurs mainly in the *Gu* (April-June) and *Deyr* (October-November) seasons, the crop calendar also follows the two seasons as seen in Table 3-3. There are three crops grown under rainfed agriculture in this region: the first crop is grown in the long rains of *Gu*, the second crop planted immediately after to take advantage of the short rains of *Hagaa* (July-September), while the third crop is planted at the beginning of the short rains of *Deyr*.

Table 3-3 : Crop Calendar for Main Rainfed Crops in South-Central Somalia



CROP	JILAAL (dry season)			GU (long rains)			XAGAA (locally short rains in July/Aug)			DEYR (short rains)		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st Maize				🟩	🟩	🟩	🟩			🟩	🟩	🟩
2nd Maize							🟩	🟩	🟩	🟩		
Sorghum				🟩	🟩	🟩	🟩			🟩	🟩	🟩
1st Sesame				🟧	🟧	🟧	🟧			🟧	🟧	🟧
2nd Sesame							🟧	🟧	🟧	🟧		
Cowpea				🟨	🟨	🟨	🟨			🟨	🟨	🟨

Note:
Primary rainfed crops are grown in the long rains of *Gu* and a second crop may be planted immediately after to take advantage of the short rains of *Xagaa*. A third planting opportunity exists at the beginning of the short rains of *Deyr*.

Source: SWALIM Technical Report No. L-09 (2007)

The study area has no land which is suitable (class S1) for the four rainfed crops which have been analysed. This is largely due to the fact that even in areas with relatively high mean annual rainfall (lower Shabelle and coastal zone), long-term average crop yields will remain below their biological potential, mainly because of rainfall variability (both seasonal and annual), flooding hazard, low soil fertility (alkaline soils) and/or high soil sodicity. Although some of these limitations can be overcome by improved management and increased inputs, this would mean increased costs that are unlikely to be off-set by increased production.

Roughly 10 to 25 % of the study area is moderately suitable (class S2) for one or all of the four crops analysed. Most of the moderately suitable land is made up of the floodplains of the middle Shabelle south of Jowhar. Another area moderately suitable for rainfed cropping is that of the upland plateaus in the Juba catchment around Baydhaba, Qansax Dheere and Xudur. One of the main limitations for cowpea and maize in the alluvial plains of both the Juba and Shabelle is the alkalinity (high pH) of the soil. Locally high sodicity and salinity also act as a limitation. Where such conditions exist, tolerant crops such as cotton, and to a lesser extent sorghum, are expected to do better. It is for this reason that some of the alluvial plains of the lower Juba and Shabelle are classified as moderately suitable for cotton, and marginally suitable or unsuitable for cowpea, maize and sorghum.

Around 35% of the study area is unsuitable (class N) for all four LUTs, and almost 55% is unsuitable for maize (Rm1), which is the most demanding crop. Severe limitations to rainfed cropping exist in the coastal dunes and plains because of the low moisture holding capacity of the soil. Short and unreliable growing periods, often in combination with shallow stony soils, pose a severe limitation in the hills and pediments in the northern parts of both the Juba and

Shabelle catchments. High salinity makes some of the alluvial plains unsuitable for cowpea and maize.

Land Suitability for Irrigated Agriculture

Somalia has a long history of irrigated agriculture on the alluvial plains of the Juba and Shabelle rivers. In 1988 about 67,150 ha was under controlled irrigation and 45,800 ha under flood irrigation (*SWALIM Project Report No W-05, 2006*). Large commercial schemes of irrigated sugarcane, rice, banana, citrus and other fruit crops used to operate in the Shabelle below Jowhar and in the Juba near Jilib. Since the early 1990s much of the irrigation infrastructure has deteriorated. Opportunities exist to revive old schemes or to grow the same crops in smaller schemes. Hence, three LUTs were defined and selected for the suitability assessment:

Ir: **Rice.** Flood irrigation of paddy rice, small-scale, low-medium input (NPK fertilizer, irrigation management and infrastructure);

Ic: **Citrus.** (Also other fruits). Controlled irrigation, medium-high input (seedlings, fertilizer, pesticides, irrigation management and infrastructure);:

Is: **Sugarcane**. Controlled irrigation, medium-high input (fertilizer, pesticides, irrigation management and infrastructure).

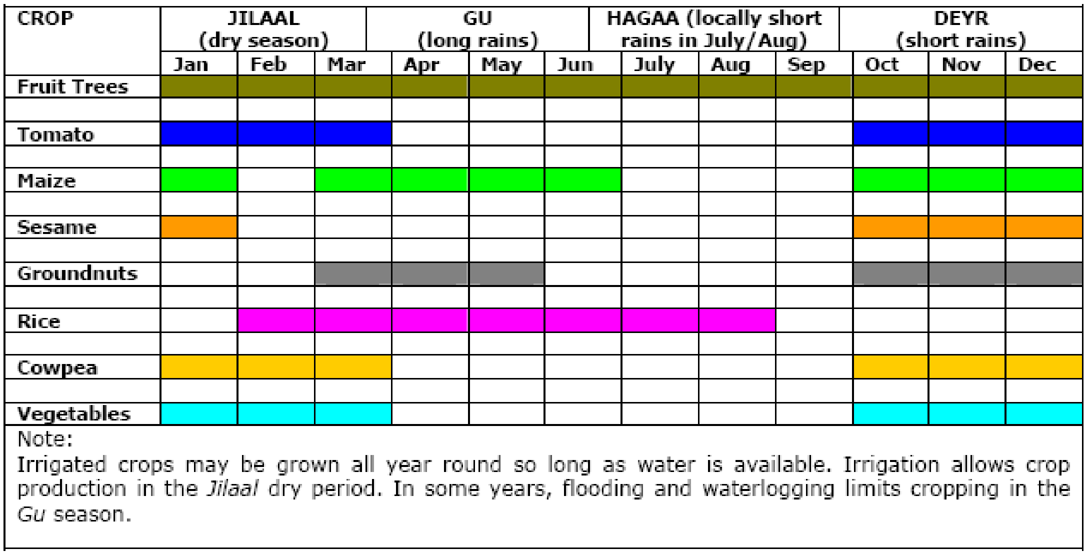
The land suitability evaluation carried out by SWALIM mainly concentrated on the suitability of the land (notable soils and topography), so that irrigation in these areas will be possible only if irrigation water can be provided from the Juba and Shabelle rivers. Table 3-4 gives the areas found suitable for irrigated agriculture, based on land resource information in Juba and Shabelle riverine areas.

Table 3-4: Land Suitability for Irrigated Agriculture in Riverine Areas of Juba and Shabelle

	Ic (citrus)		**Is (sugarcane)**		**Ir (rice)**	
	area (ha)	**%**	**area (ha)**	**%**	**area (ha)**	**%**
S1	0	0	85,813	1	0	0
S2	177,689	2	667,016	8	91,876	1
S3	3,239,716	37	2,6645,76	30	2,948,051	34
N	5,374,900	61	5,374,900	61	5,752,378	65
Total	8,792,305	100	8,792,305	100	8,792,305	100

The major crops grown where irrigation is available are fruit trees, tomatoes, maize, sesame, groundnuts, rice, cowpea and other vegetables. Flooding and water logging can hamper crop production in the *Gu* season in some years.

Table 3-5 : Crop Calendar for Some Irrigated Agriculture along the Juba and Shabelle River Basins



CROP	JILAAL (dry season)			GU (long rains)			HAGAA (locally short rains in July/Aug)			DEYR (short rains)		
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Fruit Trees	■	■	■	■	■	■	■	■	■	■	■	■
Tomato	■	■	■							■	■	■
Maize	■		■	■	■	■				■	■	■
Sesame	■									■	■	■
Groundnuts			■	■	■					■	■	■
Rice		■	■	■	■	■	■	■				
Cowpea	■	■	■							■	■	■
Vegetables	■	■	■							■	■	■

Note:
Irrigated crops may be grown all year round so long as water is available. Irrigation allows crop production in the *Jilaal* dry period. In some years, flooding and waterlogging limits cropping in the *Gu* season.

Source: SWALIM Technical Report L-09 (2007)

3.1.4 Socio-economics

Human Population

The more recent draft population estimates for the regions lying in the four basins are presented in Table A.1, Annex A. The most important towns found in the areas covered by the four basins, and their estimated populations are: Baardheere (25544), Jilib (29951), Jamaame (22415) and Kismayo (89333), in the Juba valley and Belet Weyne (30869), Jowhar (36844), Balcad (28106) and Afgooye (21602), in the Shabelle valley. Mogadishu (pop. unknown) and Marka (63900) are located along the coast, slightly off the Shabelle basin. The two (which two? -Ed) towns do not get water directly from the river. The Lag Dera and Lag Badana basins do not have major towns lying within their area.

Population estimation in Somalia is a very sensitive issue for various reasons. As the majority of people are pastoralists and agro-pastoralists, they lead a nomadic life and are always on the move in search of water and pasture for their livestock. About 48% of the population in the central and southern regions lying in the four basins are nomadic (pre-war period, year 1988) with 24% urban and 28% rural (Table 3-6). Hence, many areas have a moving population. These figures are based on the last official census in Somalia as there has been no census carried out since the outbreak of conflict in Somalia. However, according to the best available recent population estimate, 38% of the population in the regions is urban. Comparing the urban population in 1988 and the recent estimates (2005), there is a growing trend for more people to live in urban centres (see Table 3-6 and Figure 3-3).

Table 3-6: Population Dynamics in Southern Somalia for 1988 and 2005

	1988 Census[1]			**2005 Estimate**[2]	
Region	**% Urban**	**% Rural**	**% Nomadic**	**% Urban**	**% Non-urban**
Hiraan	15	17	68	21	79
Shabelle Dhexe	15	44	40	19	81
Benadir	100			100	0
Shabelle Hoose	17	60	23	20	80
Juba Hoose	22	27	51	32	68
Juba Dhexe	13	43	44	23	77
Gedo	12	20	68	25	75
Bay	16	30	54	20	80
Bakool	9	11	80	20	80

Note:

[1] Based on Ministry of National Planning, Central Statistics Department, Mogadishu (cited by Musse, 1997)

[2] Based on UNDP estimate (the estimates have been categorized as urban and non-urban only, non-urban included both rural and nomadic)

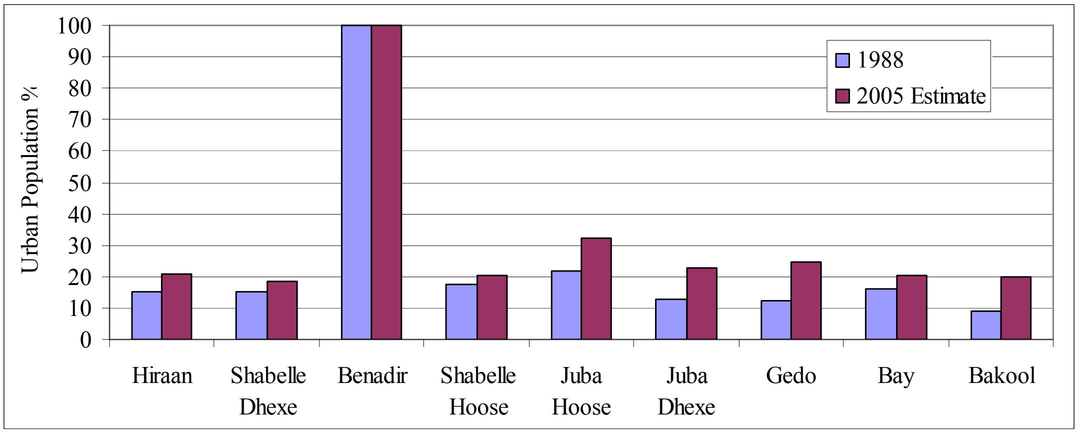


Figure 3-3 : Urbanization Trend in Southern Somalia

<u>Agriculture and Crop Production</u>

The riverine areas of the Juba and Shabelle rivers are mostly suitable for irrigated agriculture in Somalia. According to pre-war statistics, crop production accounted for just over 20% of the foreign exchange. About 110,000 ha of land were under recession cropping and 112,950 ha under full control irrigation schemes in the Juba-Shabelle basin (*SWALIM Project Report No W-05, 2006*). Civil war, aided by the El Nino floods in 1997-98, has led to the collapse of all large irrigation schemes and agricultural exports are now almost zero. However, even in the present context, 70% of the country's cereal production is from Juba-Shabelle basin. Some 60% of the country's maize is produced in the Lower Shabelle primarily by small holders' farmers.

Maize and sorghum are the two main crops grown in most of Somalia, which are cultivated both in rain-fed and irrigated areas. The annual area, production and yield of maize and sorghum for Somalia (based on FSAU data) are available in the <u>Dynamic Atlas (2007)</u>.

Annual cultivated areas, their production and yield for selected districts are presented in Figure 3-4 and Figure 3-5. The districts lying in the riverine areas (Jilib, Jowhar, Afgooye) have more areas cultivated with maize and the yields are higher than those in the districts (Huddur, Ceel Berde, Afmadow and Buur Hakaaba) that are mostly based on rain-fed cultivation. In the case of sorghum, as expected, districts away from the riverine areas (e.g. Buur Hakaaba) have more areas under sorghum cultivation.

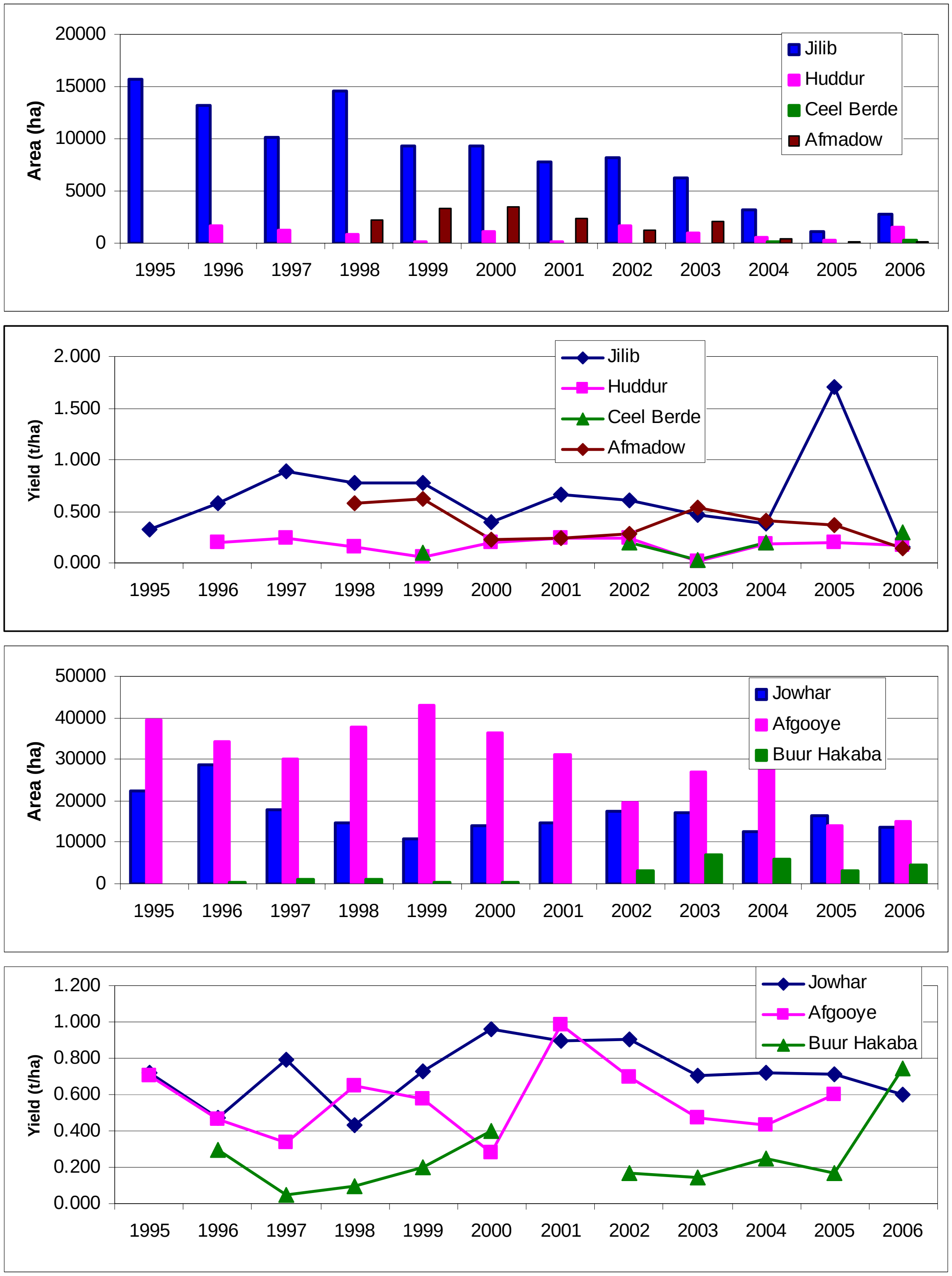
Farmers in the Juba and Shabelle river basins are sedentary, practising animal husbandry in conjunction with crop production. Lactating cattle, a few sheep and goats are kept near the homes, while non-lactating animals are herded further away. Most people in the riverine areas practise rural crop production and animal husbandry. Livestock population in 1988 numbered around 13.5 million in the regions of the four basins (see Table A.2 of Annex A). Again, although these figures are outdated, it gives an indication of the livestock population that used to be present in these regions.

3.1.5 Trans-boundary issues

The Juba and Shabelle rivers both originate from the Ethiopian highlands and their main contributing catchments lie close together. Lag Dera originates from the highlands in Kenya. While much of the runoff of the Juba and Shabelle rivers (estimated to be more than 90%) is generated from the catchments in Ethiopia and Kenya, very little flows from catchments of north-east Kenya ever reach the Somali parts of the Lag Dera river except during the high flood periods. The discharge along the river starts decreasing from well within the river reaches in Ethiopia and Kenya, due to – among other reasons -- river diversions, losses due to evaporation and seepage and over bank spillages,. However, little data is available on the stream flow gauging and water use in the Ethiopian and Kenyan catchments. Some limited climatological data are available for the stations in the two countries through the FAO Database, as well as information on other water use, especially in Ethiopia.

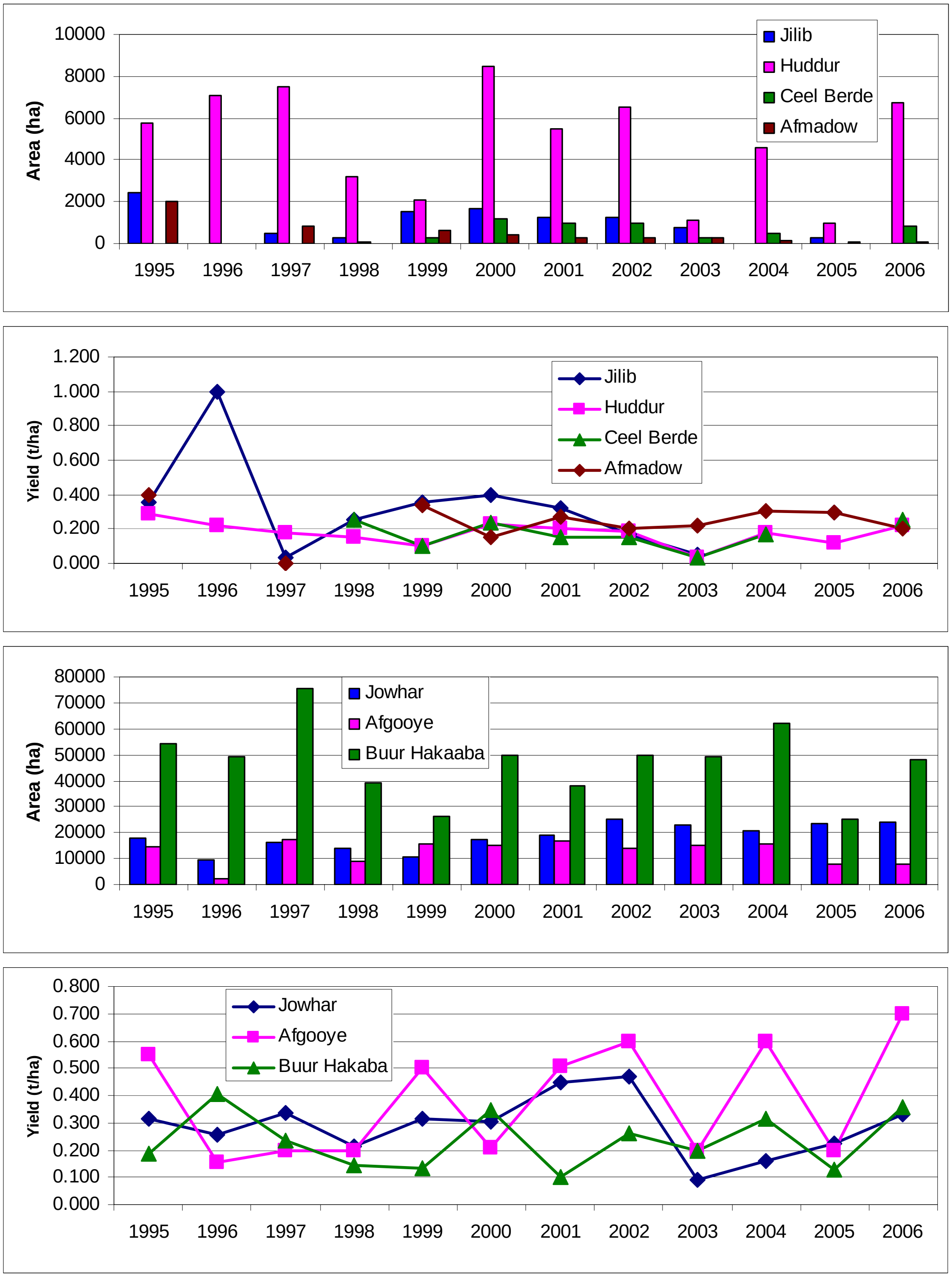
The Melka Wakana Dam for hydropower generation was built in the upper reach of the Shabelle river in Ethiopia in 1988. Since this is used for a non-consumptive purpose and the water storage provides regulation to increase the dry season flows, this project should not have any negative impacts on Somalia. There are some indications that another large dam has been constructed for irrigation in the Shabelle river. Any water diverted for consumptive uses like irrigation in the upstream reaches will reduce the flows in the river stretches in Somalia. This can have adverse impacts on the utilization of the river water, especially in the low flow periods. In Juba river, Baardheere Dam was planned to irrigate 175,000 ha of land and generate hydropower. Later, the project was downsized to irrigate 50,000 ha (*Gomes, 2003*), but it did not materialize due to Somalia's internal problems.

Recent reports (e.g. *Min. of Water Resources, Ethiopia et al, 2004*) mention that a Water Resources Master Plan of the Webi Shabelle Basin (referring to the Shabelle river basin within Ethiopia) has been prepared. A similar master plan was under preparation for the Genale Dawa basin (Juba river basin within Ethiopia) in 2004, as reported in the referred document. Both of these plans were not available for this study. These master plans should be consulted while planning and managing the water resources of the Juba and Shabelle basins in Somalia.



Data source: FSAU (Dynamic Atlas, 2007)

Figure 3-4 : Maize Cultivated Area and Yield in Selected Districts of Somalia



Data source: FSAU (Dynamic Atlas, 2007)

Figure 3-5 : Sorghum Cultivated Area and Yield in Selected Districts of Somalia

No international agreement on the sharing or utilization of the Shabelle and Juba rivers among the co-riparian countries of Ethiopia, Kenya and Somalia is known to have been signed to date. Ethiopia, being an upper riparian country, does not share information or data on the existing and proposed water projects in the Juba and Shabelle rivers.

3.2 Climate

3.2.1 Network analysis

SWALIM's Technical Reports Nos. W-01 and W-03 contain the data and inventory related to climate in Somalia. In the case of the Juba, Shabelle and Lag Dera basins, a substantial part of the upper catchment areas lie in Ethiopia and Kenya. The Ethiopian and Kenyan parts of the catchment also receive more rain than the areas within Somalia, but the potential evaporation in the Somalia catchment is greater than that of the catchment areas in Ethiopia and Kenya. Hence, in terms of generation of streamflows in rivers, the contribution of rainfall within Ethiopian and Kenyan catchment is much more significant. Hence, the climatological data of stations in the upper catchment areas outside Somalia is more critical in estimating stream flows in the rivers. However, in terms of the agro-climatological parameters influencing both rainfed and irrigated agriculture, the climatological data of stations within Somalia is of considerable importance.

Mean monthly time series data is mostly available only for rainfall whereas long-term mean monthly data are available for other climatogical variables. There were 28 stations within the four river basins within Somalia for the pre-war periods. Of these, limited daily rainfall data is available for only four stations (before 1986 with many missing values). Rainfall observations in 31 stations (19 new and 12 old) are presently being made by SWALIM and partner agencies in the areas of the four basins. An inventory of the station network (in Somalia, Ethiopia and Kenyan parts of the catchments) is given in SWALIM Technical Report No. W-03. The rainfall stations in different river basins are given in Table 3-7. It should be noted that there is only one rainfall station at Afmadow within Lag Dera basin in Somalia and none in Lad Badana basin.

Table 3-7 : Rainfall Station Network in South-Central Somalia

Basin	**Basin Area (km^2)**	**Pre-war Stations**			**Present Network**	
		No. of Rainfall Stations	**Density (km2/ station)**	**Range of Areas (Thiesen Polygon) (km^2)**	**No. of Rainfall Stations**	**Density (km^2/ station)**
Shabelle within Somalia	108,295	17*	6,350	34 – 12,700	23**	4,700
Shabelle within Ethiopia	188,677	14	14,200	100 – 33,700	-	-
Juba within Somalia	64,744	14*	5,000	130 – 14,300	13***	5,400
Juba within Ethiopia/Kenya	156,128	7	21,600	20 – 29,000	-	-
Lag Dera within Somalia	46,335	1	46,335	230 – 24,600	1	46,335
Lag Badana	16,575	0	NA	10 – 7,500	0	NA

* Including 4 stations in the basin border of Juba and Shabelle
** Including 12 new and 11 old stations
*** These include 6 in old locations, 3 of which are in the border region of Juba and Shabelle basin

WMO (1994) recommends a minimum network density of one rainfall station in 10,000 km^2 in arid areas. Based on this criterion, the rainfall station network density is within the recommended density in Juba and Shabelle river basins within Somalia. However, it is advisable to add about three stations within the Lag Dera basin and two stations in Lag Badana basin.

At present, there is neither an automatic rain gauge nor a climate station (observing rainfall, evaporation, maximum and minimum water and air temperature, wind movement and relative humidity, sunshine hours) in operation in the areas of the four basins. WMO (1994) recommends a minimum of one recording rain gauge and one evaporation station per 100,000 km^2 for arid regions. Rainfall intensity of shorter durations is important to estimate the storm runoff characteristics that are so essential for catchment water harvesting through *wars* and *ponds* in Southern Somalia. Other climate data such as evaporation, air temperature, wind movement, relative humidity and sunshine hours are important for water management. SWALIM is in the process of installing two automatic weather stations each in the Juba river basin (Luuq and Bualle) and in the Shabelle river basin (Belet Weyne and Jowhar). These stations will observe all the above climate parameters. In addition to these, it is recommended that at least one each of the automatic rain gauges and evaporation stations be installed in the Lag Dera and Lag Badana river basins.

Time series data for other climatological variables, apart from rainfall, are not available. There are only two stations with some monthly temperature time series data, namely Mogadishu (1928-1987) and Kismayo (1933-1960) in the vicinity of the areas of the four basins. Mean monthly estimation of other climatological data are available for a limited number of stations (Table 3-8). These are derived from FAO Global Climate Datasets (*FAOCLIM and LOCCLIM*).

Table 3-8 : Stations with Long-term Mean Agro-climatological Estimates (within Somalia)

Basin	**Basin Area (km^2)**	**Stations with Estimates of Mean Monthly Agro-climatological data**	
		No. of Stations	**Density (km^2/ station)**
Shabelle within Somalia	108,000	9*	12,000
Juba within Somalia	70,000	7*	10,000
Lag Dera within Somalia	46,335	1	46,335
Lag Badana	16,575	0	NA

* Including two stations lying in the boundary area of Juba and Shabelle basins (Huddur and Baidoa)

3.2.2 Rainfall characteristics

Rainfall in the four basins is low and erratic with a bimodal annual pattern. The Kenya-Ethiopia highland in the upper catchment area receives more rain. The middle catchment areas around Somalia and Ethiopian border, being in the leeward side of the highlands, receive less rain. There is an increase in annual rainfall as one moves towards the coast. Based on the annual average rainfall pattern, the southern parts of Somalia, including the four river basins, has an arid to semi-arid climate. Orographic and coastal influences also lead to a high variation in rainfall in the region.

3.2.2.1 Temporal variation of rainfall

The temporal rainfall variation in the four distinct seasons in different catchment areas within Somalia (based on Thiesen Polygon Analysis) are summarized in Table 3-9 and variations of some representative stations are presented in Figure 3-7.

Table 3-9 : Seasonal Rainfall Variation in the Major Basins of South-Central Somalia

Basin	**% of Annual Rainfall**			
	***Jilal* (Dec-Mar)**	***Gu* (Apr-Jun)**	***Hagaa* (Jul-Sep)**	***Deyr* (Oct-Nov)**
Shabelle Basin within Somalia	6%	53%	12%	29%
Juba Basin within Somalia	9%	51%	7%	33%
Lag Dera within Somalia	11%	43%	13%	33%
Lag Badana	6%	56%	24%	15%

Gu season is the primary cropping season as it is the major rainy season (more than 50% of the annual rain, except for Lag Badana). It also is to be noted that although 25 to 30% of the rain falls in the *Deyr* season in inland areas of the basins, the southern areas near the coast (e.g. Kismayo, see Figure 3-7) do not receive much rain in this season. The amount of rainfall in the four different seasons is also seen to be correlated with elevation in the areas of interest in Southern Somalia (Figure 3-6). As the elevation decreases, the trend is for a higher percentage of rain in *Gu* and a lower percentage of rain in *Deyr*. Similarly, there is more rain (30% of annual) in *Hagaa* for lower elevations (less than 75 m). This can be beneficial for rain-fed crops extended even after the *Gu* season.

There is a trend for higher *Hagaa* rainfall in lower elevation, particularly below 100m, and a decrease in *Deyr* rainfall as elevation decreases (see Figure 3-6). The trend in *Gu* season is not very well defined, though as the figure shows it is similar to that of *Hagaa*.

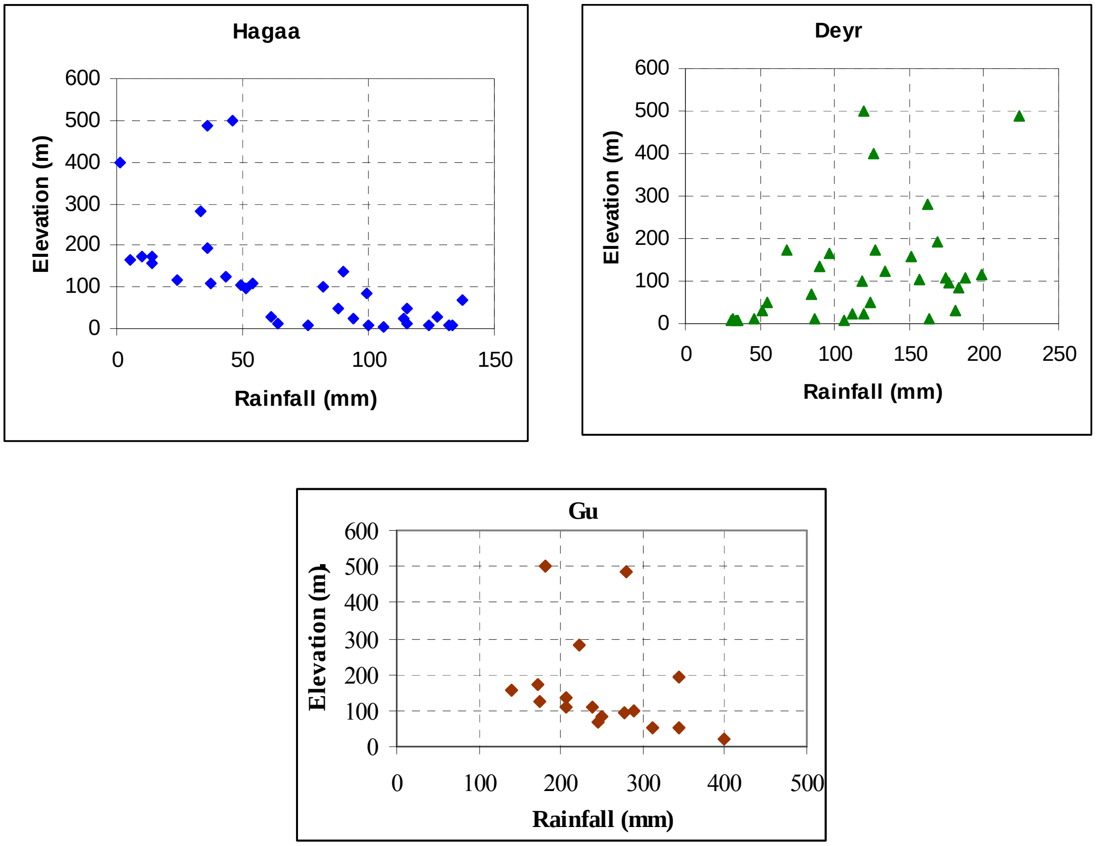


Figure 3-6 : Rainfall Variation with Elevation in *Hagaa, Deyr* and *Gu* Seasons

3.2.2.2 Spatial rainfall variation

There is a significant spatial variation in the rainfall in the catchment areas of the four basins. Upper catchment areas of Juba and Shabelle rivers in the Kenyan-Ethiopian highlands receive annual rainfall as high as 1270 mm whereas it decreases to as low as 280-300 mm in the central part of the basin in the Ethiopian-Kenyan border areas. The middle and lower Juba and along the coastal areas of mid-Shabelle river receive about 700-800 mm annually. The areas around the Shabelle and Juba basin boundaries (in the Baydhabo plateau and Buur areas) receive about 500-700 mm annually.

Map 3-3 presents the annual rainfall map prepared using the Inverse Distance Weighted Averaging (IDWA) method for the full catchment areas of the four basins lying in Somalia, Ethiopia and Kenya. A Thiesen polygon method was also used to estimate the areal rainfall in each basin. The polygons showing the influence of different stations are shown in Map 3-4.

The areal rainfall in the different river basins is given in Table 3-10. There is some difference in the areal rainfall estimated using the IDWA and Thiesen Polygons. This is also due to the scarce network of rainfall stations.

Table 3-10 : Annual Areal Rainfall (mm) for River Basins in South-Central Somalia

	Areal Annual Rainfall (mm)		**Based on IDWA Method (Annual Rainfall-mm)**	
Basin	**IDWA**	**Thiesen**	**Maximum**	**Minimum**
Shabelle Basin (full catchment)	**543**	**520**	**1129**	**266**
Shabelle- North-West (Ethiopia)	644	-	1129	266
Shabelle- North- East (Ethiopia)	439	-	730	319
Shabelle- South (Somalia)	460	452	651	279
Juba Basin (full catchment)	**595**	**566**	**1275**	**239**
Juba within Ethiopia/Kenya	669	-	1275	239
Juba within Somalia	427	-	704	279
Lag Dera (full catchment)	**534**	**501**	**1355**	**279**
Lag Dera within Somalia	478	499	571	332
Lag Badana	**549**	**496**	**704**	**452**

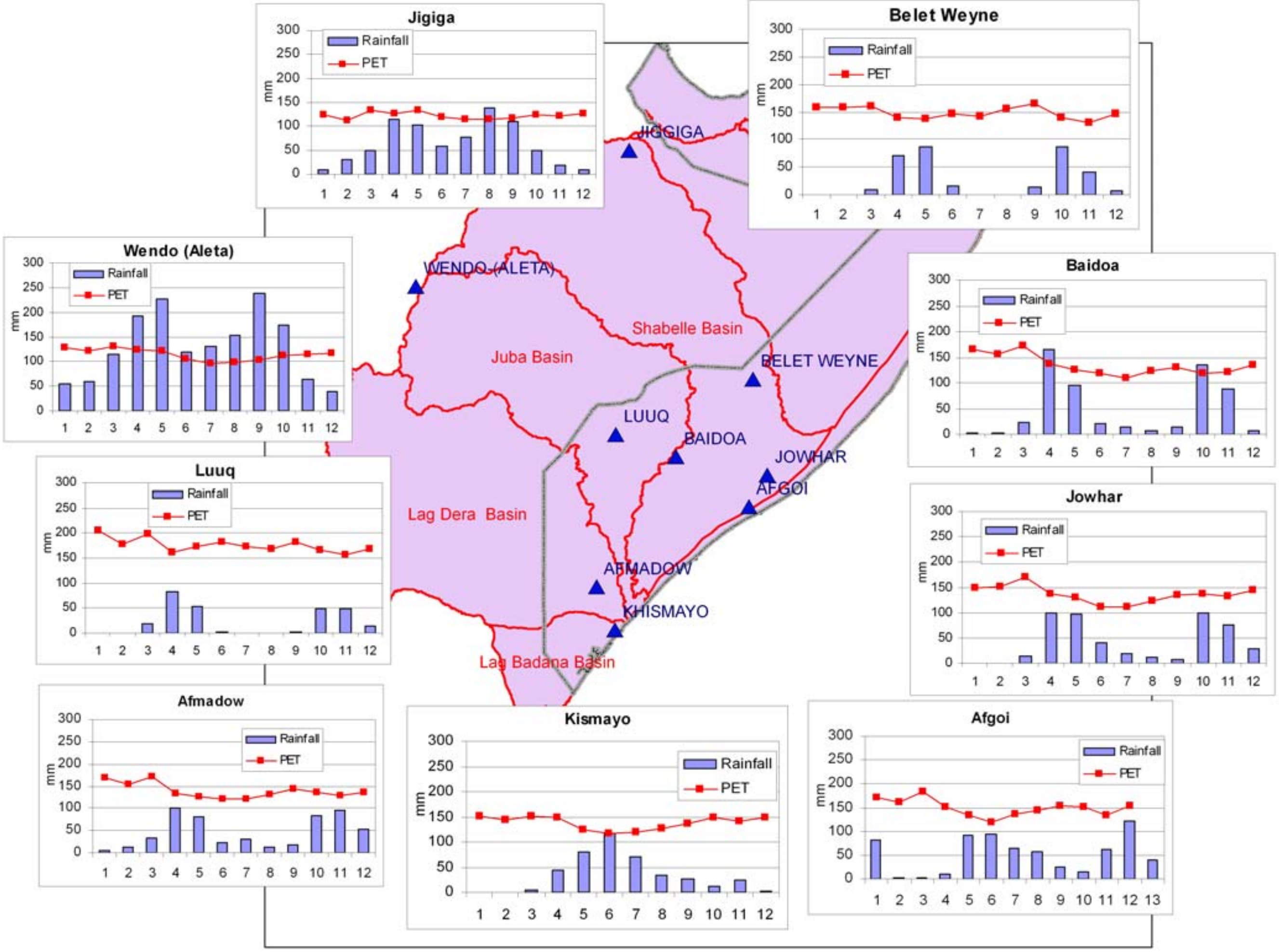
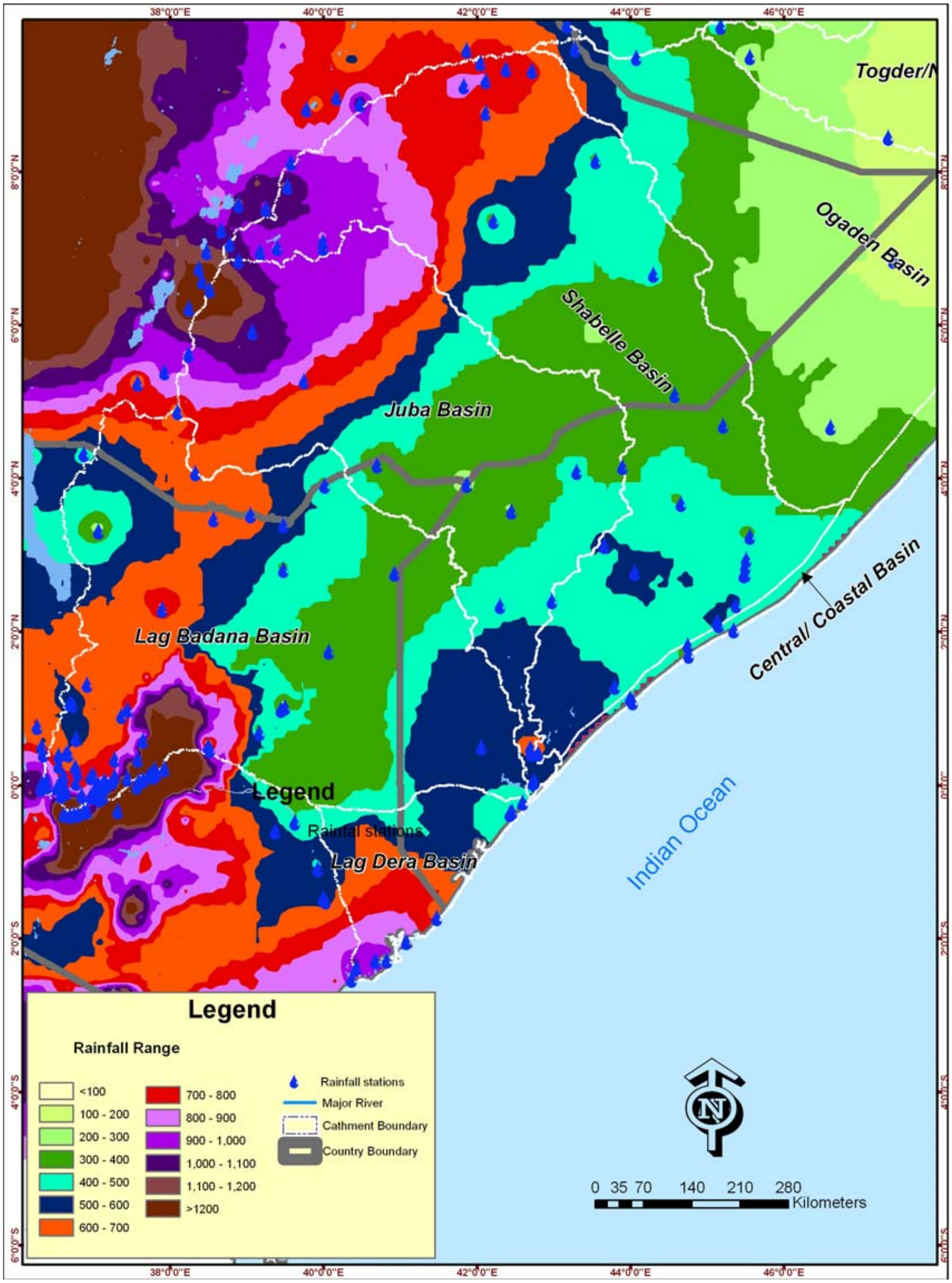
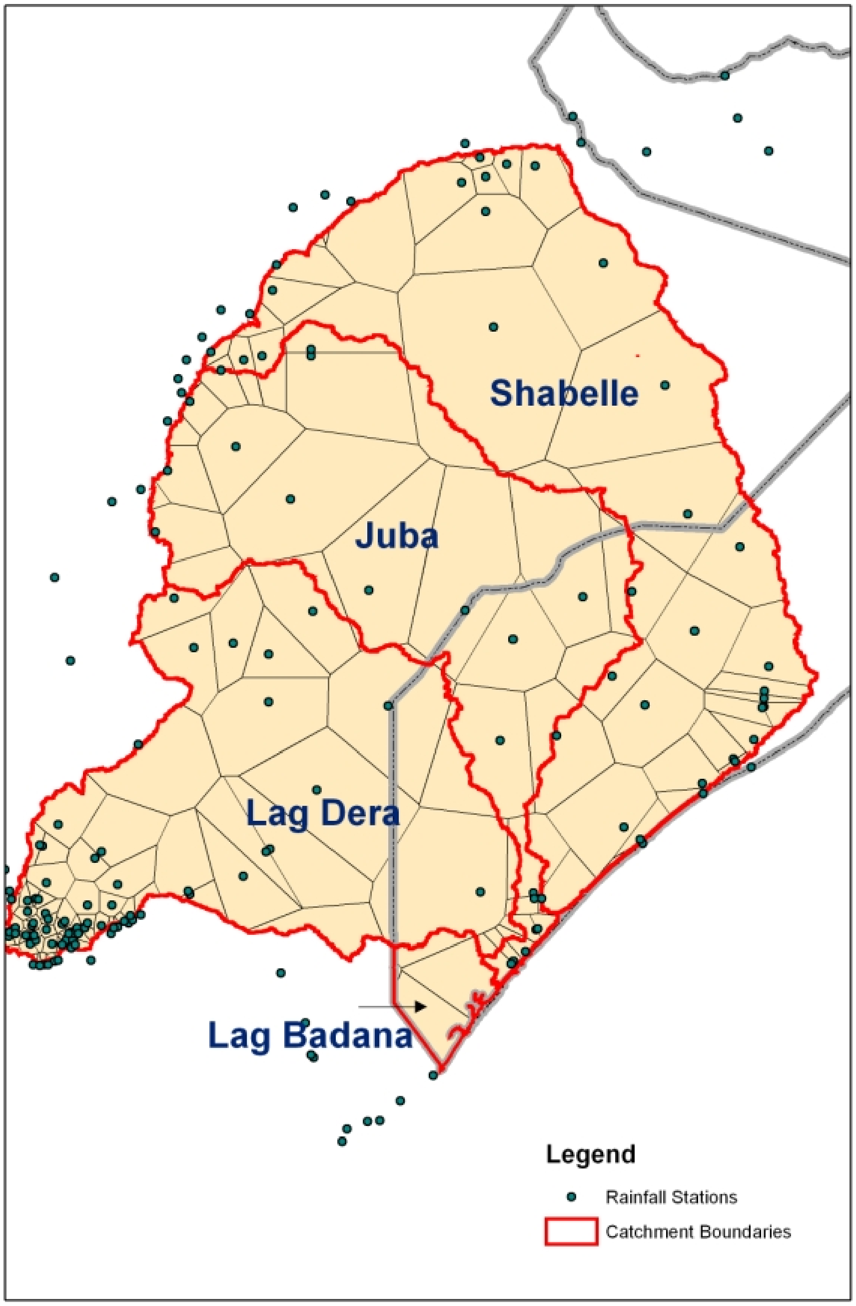


Figure 3-7: Monthly Rainfall and PET Variations of Selected Stations



Map 3-3 : Annual Rainfall Map for South-Central Somalia



Map 3-4 : Thiesen Polygons for Juba, Shabelle, Lag Dera and Lag Badana Basins

3.2.2.3 Rainfall variability

The variability of rainfall from one year to the other is a matter of prime concern for water utilization. The reliability of available water influences agricultural productivity as well as the design of water resources systems. Rainfall variation is quite high in the case of Somalia, including the areas of the four basins in Southern Somalia. The coefficient of variation (CV) of annual rainfall is found to vary more for locations with lower rainfall (Figure 3-8). The CVs of monthly rainfall is also greater during dry seasons compared to the two rainy seasons as seen from box plots presented in Annex B.

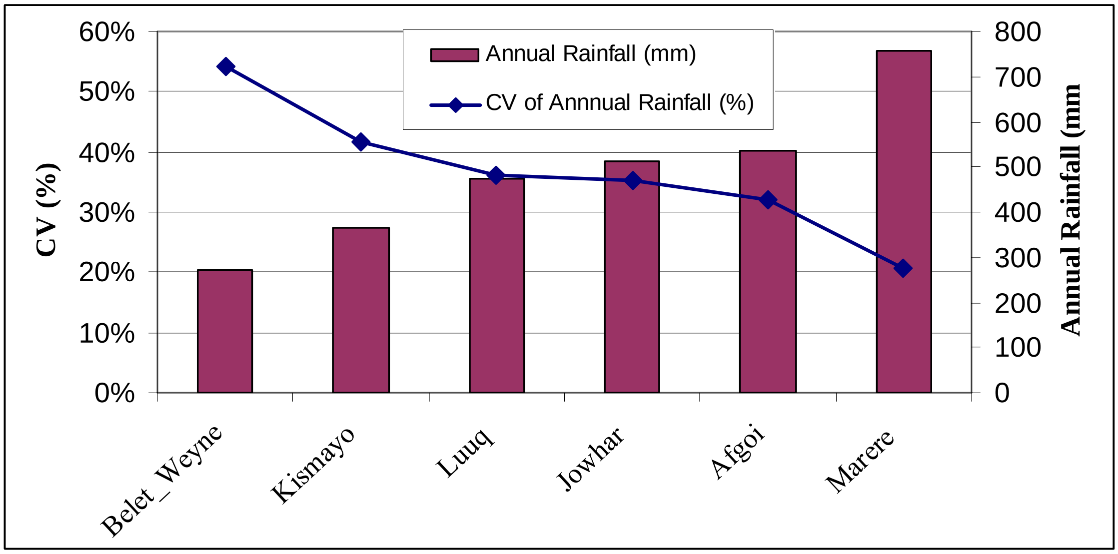


Figure 3-8 : Coefficient of Variation of Annual Rainfall for Representative Stations

3.2.2.4 Long-term Monthly and Annual Rainfall

The long-term mean monthly and annual rainfall for stations within Somalia in the catchment areas and vicinity of the four basins are given in SWALIM Technical Report No. W-01. Table 3-11 presents the 80% dependable monthly rainfall in stations with more than ten years of monthly time series data. It should be noted that the 80% dependable rainfall is mostly zero in the dry months of *Hagaa* and *Jilaal* for most locations.

It is to be noted also that for locations (Jowhar, Balad, Afgoi, Mareera, Jilib and Jamame) in the riverine areas of lower Juba and lower Shabelle, the 80% dependable rainfall is higher than other areas even in the months of July and Aug (begining of *Hagaa*). This is beneficial for crops extending beyond the *Gu* season. These values are important for estimating the irrigation water requirements.

Table 3-11 : 80% Dependable Monthly Rainfall in Selected Stations (mm) in South-Central Somalia

Stationa	Data Period	Years of Annual Data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Belet_Weyne	1922-1990	59	0.0	0.0	0.0	17.0	20.1	0.0	0.0	0.0	0.0	25.6	1.0	0.0	155.4
Huddur	1922-1990	28	0.0	0.0	0.0	65.6	13.8	0.0	0.0	0.0	0.0	56.4	4.0	0.0	233.0
Baidoa	1922-1990	54	0.0	0.0	0.0	86.0	24.9	0.0	3.0	0.0	0.0	63.7	12.9	0.0	380.5
Bur-Acaba	1922-1986	13	0.0	0.0	0.0	12.0	6.8	0.0	0.0	0.0	0.0	29.9	0.0	0.0	347.4
Jowhar	1922-1990	33	0.0	0.0	0.0	56.4	23.0	13.2	7.2	2.4	0.0	34.1	30.7	3.6	358.3
Balad	1922-1990	20	0.0	0.0	0.0	28.2	26.3	15.6	7.4	0.0	0.0	7.0	28.5	14.0	338.9
Genale	1929-1990	31	0.0	0.0	0.0	32.3	29.8	33.9	32.5	10.4	0.6	2.5	22.3	2.9	331.6
Jilib	1930-1986	19	0.0	0.0	0.0	63.0	73.7	31.1	26.3	6.2	0.3	7.5	28.1	13.6	478.6
Dinsor	1953-1990	10	0.0	0.0	0.6	39.6	18.7	6.2	0.8	0.0	0.0	19.0	48.0	0.0	307.2
Afgoi	1922-1990	40	0.0	0.0	0.0	25.1	36.5	17.2	20.1	5.0	0.0	11.2	25.2	0.0	414.6
Khismaio	1930-1986	33	0.0	0.0	0.0	2.7	19.2	41.6	23.3	3.8	0.4	0.0	0.0	0.0	226.2
Mareere	1977-1990	11	0.0	0.0	0.0	70.1	91.0	26.8	18.8	5.9	5.1	13.9	64.1	13.0	623.4
Allessandra	1930-1990	23	0.0	0.0	0.0	62.9	70.7	29.0	21.3	6.5	0.0	5.2	31.7	6.0	465.9
Luuq/Genale	1929-1990	31	0.0	0.0	0.0	32.3	29.8	33.9	32.5	10.4	0.6	2.5	22.3	2.9	331.6

Note: the 80% dependable rainfall has been calculated using data of different periods and duration. The years of annual data used are the years of data for all months in a year. There are many missing values and these were not filled (estimated) as the network density was sparse.

3.2.2.5 Daily Rainfall Analysis

Rainfall intensity data of periods less than 24 hours are not available. There are some stations with long-term daily data such as in Luuq, Jilib, Baidoa, Jowhar, and Belet Weyne. These data were analysed to see the variations in the daily rainfall patterns. As 20 mm is estimated by some past studies as the threshold daily rainfall for surface runoff generation in small catchments, an analysis of the number of days of rainfall exceeding 20 mm was calculated for selected stations (Table 3-12). There are not many days in a year where rainfall exceeds 20 mm so there is very little surface runoff generated. Figure 3-9 and Figure 3-10 present the daily rainfall in Baidoa for 1983 and 1923, the lowest and highest annual rainfall years.

Table 3-12 : Number of Days with Daily Rainfall > 20 mm for Selected Stations

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dev	Annual
Jilib	Mean	0.0	0.0	0.0	2.5	2.3	0.8	0.5	0.0	0.3	0.9	0.9	0.3	7.8
	Max	0.0	1.0	1.0	5.0	5.0	3.0	1.0	1.0	2.0	3.0	3.0	2.0	14.0
Jowhar	mean	0.1	0.0	0.1	1.1	1.2	0.5	0.1	0.0	0.1	0.3	1.0	0.2	4.2
	max	2.0	1.0	1.0	4.0	4.0	3.0	2.0	0.0	2.0	4.0	5.0	2.0	15.0
Baidoa	Mean	0.0	0.0	0.2	1.8	1.4	0.1	0.0	0.0	0.1	1.7	1.0	0.1	6.6
	Max	1.0	1.0	6.0	6.0	6.0	1.0	1.0	1.0	2.0	7.0	9.0	1.0	20.0
Luuq	Mean	0.0	0.0	0.2	1.1	0.5	0.0	0.0	0.0	0.0	0.4	0.6	0.1	2.8
	Max	0.0	0.0	2.0	6.0	3.0	0.0	0.0	0.0	0.0	4.0	7.0	2.0	10.0

Note: the mean values are in fraction because it is the average of days over different years

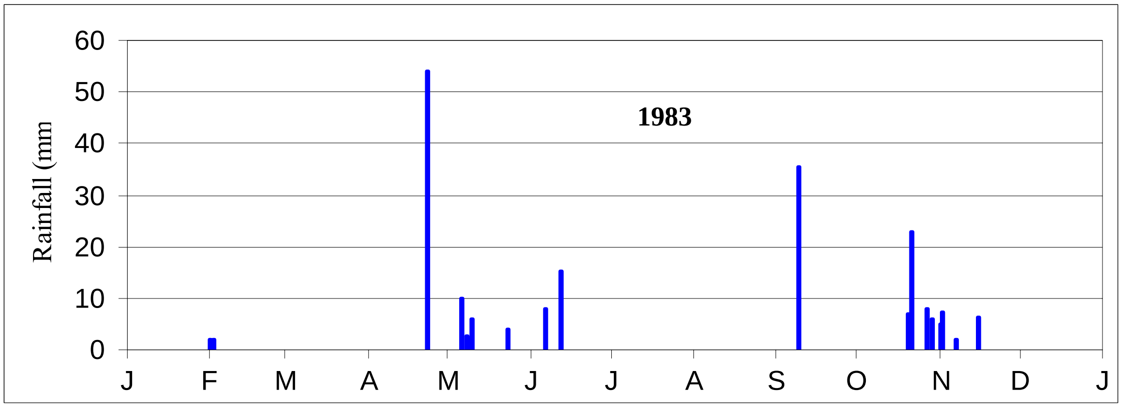


Figure 3-9 : Daily Rainfall in Baidoa (1983, low rainfall year)

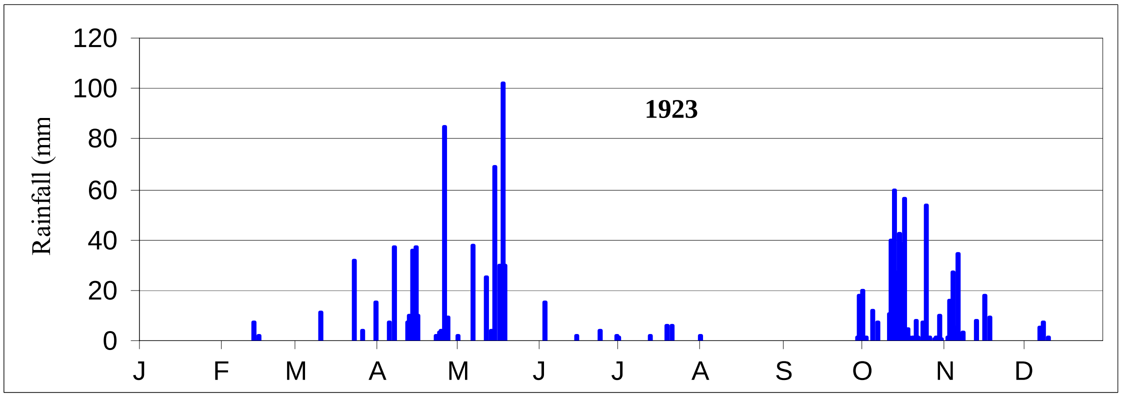


Figure 3-10 : Daily Rainfall in Baidoa (1923, high rainfall year)

3.2.2.6 24-Hour Maximum Rainfall

A frequency analysis of 24-hour maximum rainfall for Baidoa, using 44 years of intermittent data (from 1922 to 1986) was analysed to estimate the maximum 24-hour rainfall. The maximum 24-hour rainfall for 2-year, 5-year, 10-year, 20-year, 50-year and 100-year return periods based on Gumbel Distribution were 74 mm, 101 mm, 118 mm, 135 mm, 157 mm and 173 mm, respectively (Figure 3-11).

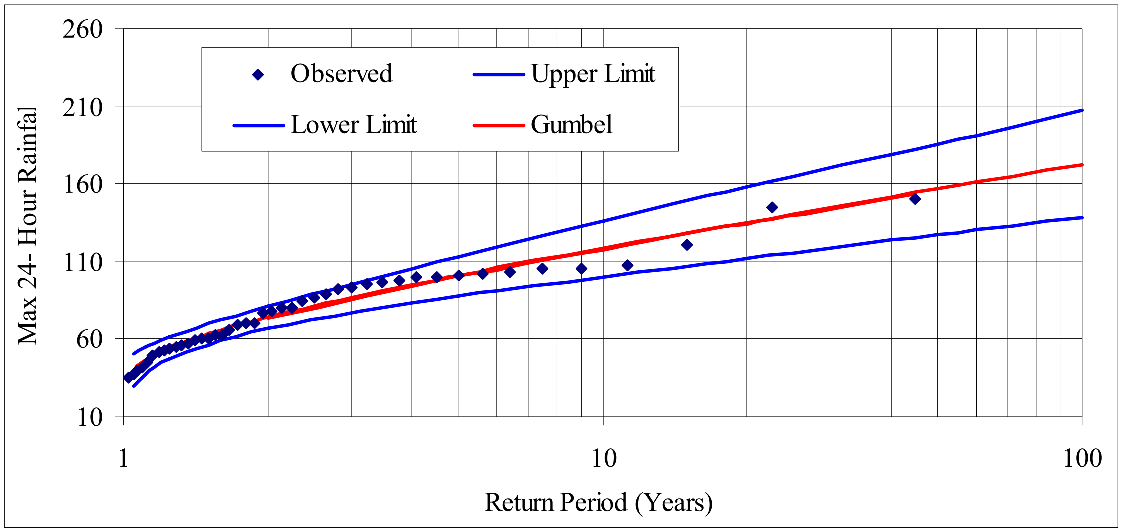


Figure 3-11 : 24-Hour Maximum Rainfall Frequency Analysis Results (Baidoa)

3.2.3 Potential Evapotranspiration

No time series data are available for evaporation for Somalia. Potential Evapotranspiration (PET) data were obtained from the FAO Global Database. Long-term monthly PET values are available for 49 stations within Somalia. SWALIM Technical Report No. W-01 gives the PET data for 49 stations. PET in the Juba-Shabelle basin area is lower than in the northern region. It ranges from about 1500 to 2000 mm per annum in the region (Figure 3-12 and Table 3-13). PET in selected stations within Shabelle and Juba basins are presented in Figure 3-13 and Figure 3-14, respectively. It can be seen that the PET increases as one moves inland to upstream areas of the basins (e.g. from Sablaale to Belet Weyne and Kismayo to Luuq, respectively). Highest monthly PET values are in March and September.

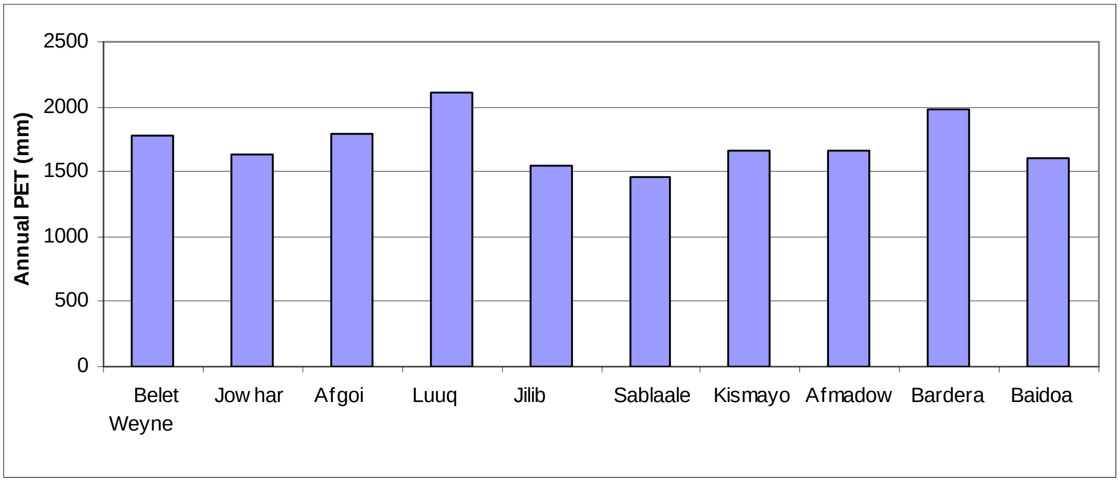


Figure 3-12 : Annual PET in selected stations in Juba and Shabelle Basins

Table 3-13 : Annual PET of Selected Stations in Juba and Shabelle Basins

River Basin	**Station Name**	**Longitude (°E)**	**Lattitude (°N)**	**Elevation (m)**	**Annual PET (mm)**
Shabelle	Belet Weyne	45.2	4.7	173	1778
	Jowhar	45.5	2.8	108	1631
	Afgoi	45.1	2.1	83	1796
Juba	Luuq	42.5	3.6	165	2113
	Jilb	42.8	0.43	23	1611
	Sablaale	43.8	1.3	50	1459
	Kismayo	42.4	-0.4	8	1657
	Afmadow	42.1	0.5	29	1669
	Bardera	42.3	2.35	116	2094
	Baidoa	43.7	3.13	487	2094

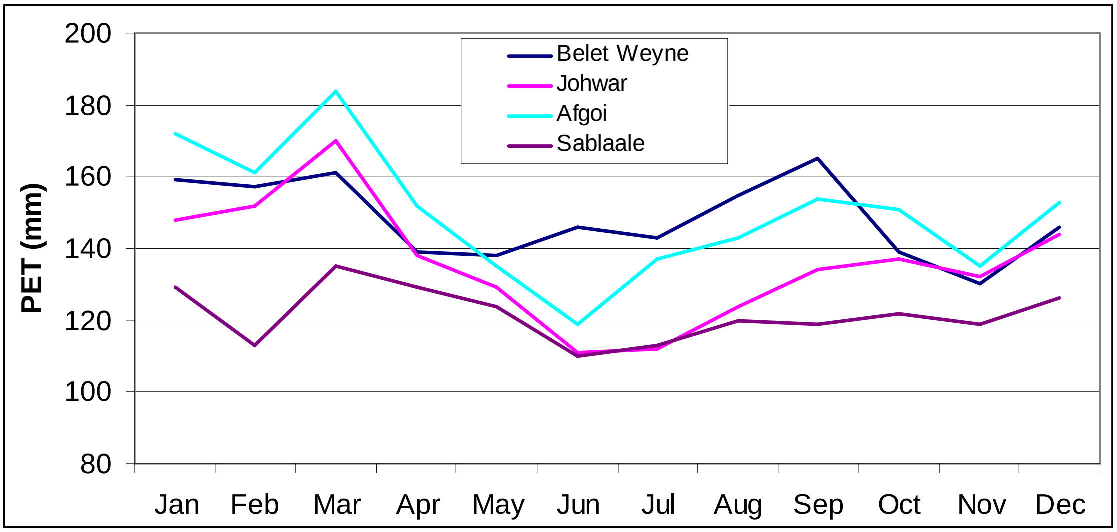


Figure 3-13 : PET in Selected Stations within Shabelle Basin

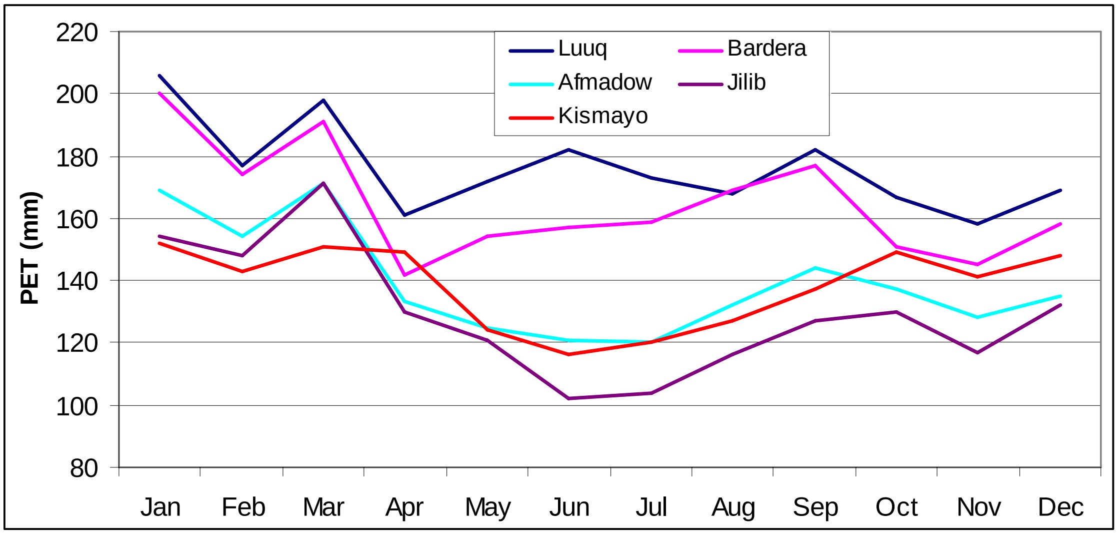


Figure 3-14 : PET in Selected Stations within Juba Basin

It should be noted that annual PET is more than monthly rainfall all over Somalia (Figure 3-7). There is therefore a water balance deficit. On a monthly basis some areas (stations) within Juba and Shabelle basins and in the vicinity have surplus water balance e.g Jilib, Mareere and Bur Acaba in the months of April and May.

SWALIM has calculated the “Length of Growing Period” (LGP) for all the stations with rainfall and PET data. LGP, as defined by FAO, is the period (in days) during a year when precipitation exceeds half the potential evapotranspiration, plus a period required to evapotranspire an assumed 100mm of water from excess precipitation stored in the soil profile. According to this assessment, the Juba and Shabelle basin areas and in the vicinity have the longest LGP values and are more suitable for cultivation.

3.2.4 Air Temperature

The mean air temperatures are generally high in the Juba-Shabelle river basin region. Average monthly temperatures reach as high as 31-33^{o} C in March in Bardheera, Luuq and Afmadow, in the Juba basin area of South Somalia. It is the hottest in the months of December to March. It is the highest in the Kenya-Somalia and Ethiopia-Somalia border areas (>30^{o} C) and it decreases toward the coastal areas. July and August are the coolest months. It can be seen from Figure 3-15 and Figure 3-16 that the stations in the inland areas (e.g. Belet Weyne amd Luuq) near the border with Ethiopia and Kenya are hotter than the stations nearer the coast (e.g. Kismayo and Afgoi). The long-term monthly temperature (mean, maximum and minimum) values are given in SWALIM Technical Report No. W-01. Greaterr differences occur in daily minimum and maximum temperature inland compared with temperatures near the coast.

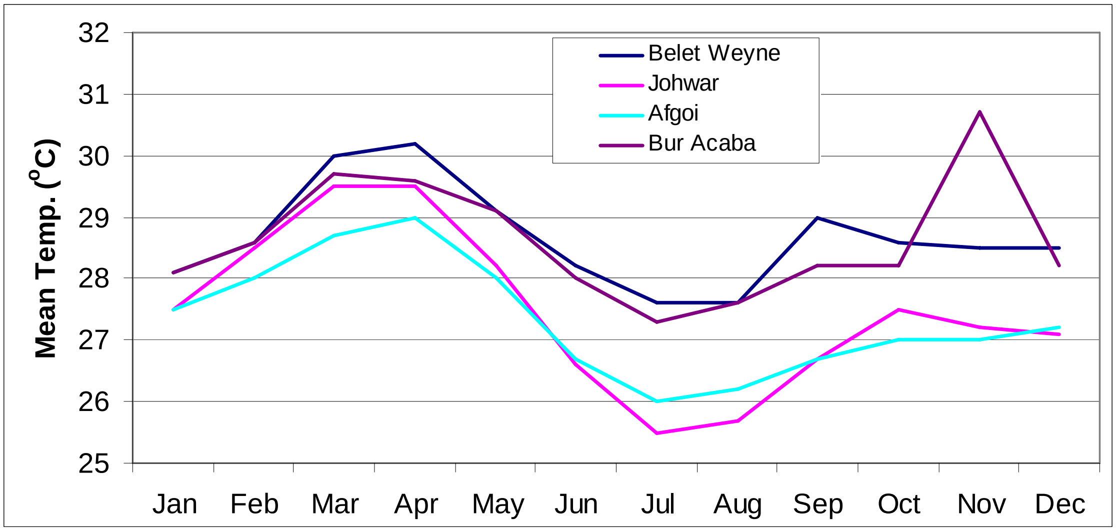


Figure 3-15 : Mean Monthly Temperature in Selected Stations within Shabelle Basin

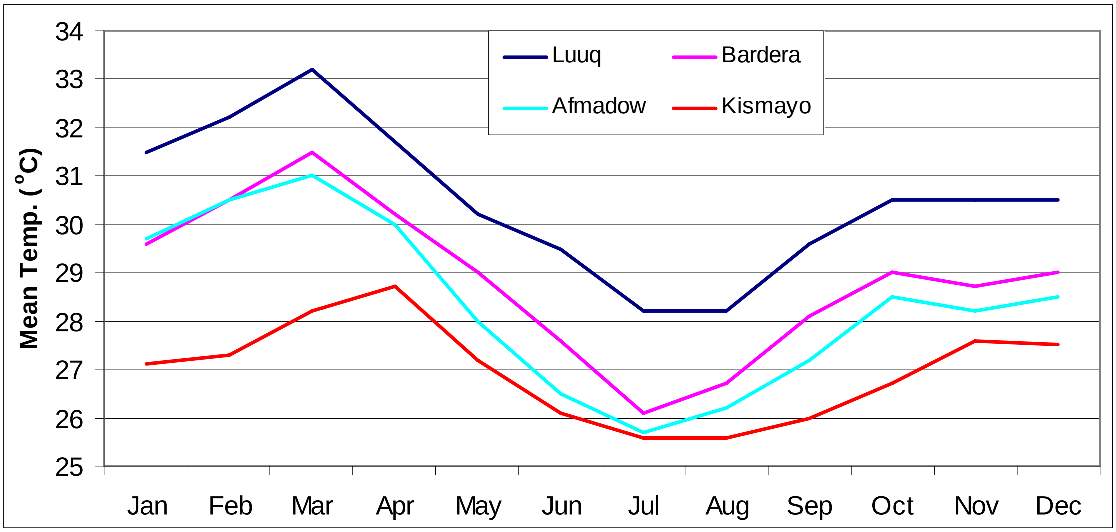


Figure 3-16 : Mean Monthly Temperature in Selected Stations within Juba Basin

3.2.5 Relative Humidity

Data on relative humidity is scarce in Somalia with only a few stations recording some observations. The monthly relative humidity data for stations in Somalia are given in SWALIM Technical Report No. W-01. These have been compiled by SWALIM from various sources. The relative humidity (RH) in the reaches of Juba and Shabelle rivers are higher than in other places and ranges from 70% to 80%. It is also higher near the coastal areas and downstream areas of Juba and Shabelle rivers. For example, RHs in Belet Weyne and Bur Acaba, inland areas, are lower than Balad and Afgoi, which are near the downstream areas of Shabelle river (Figure 3-17). Similarly, Luuq has lower RH than Kismayo for the same reason (Figure 3-18).

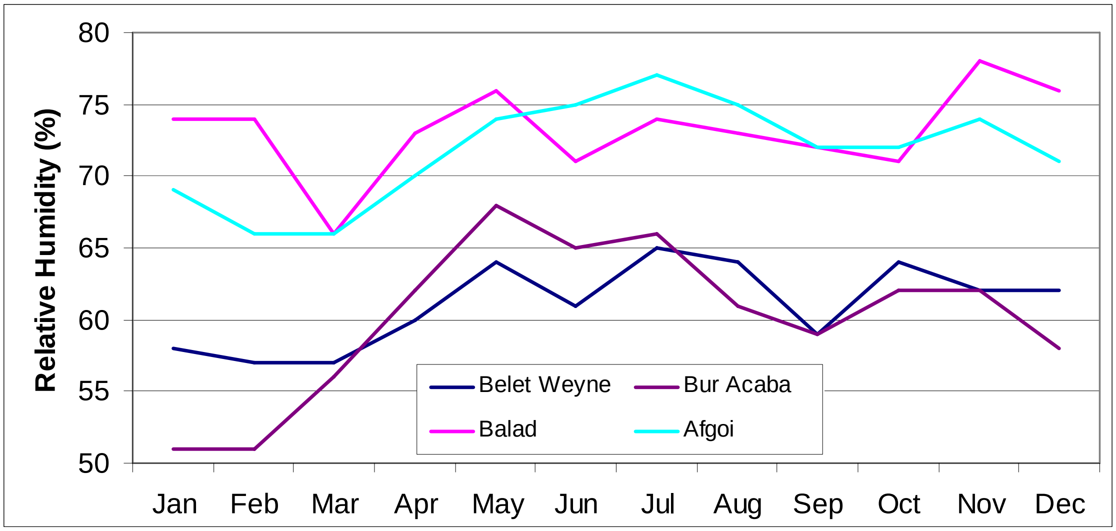


Figure 3-17 : Relative Humidity in Selected Stations within Shabelle Basin

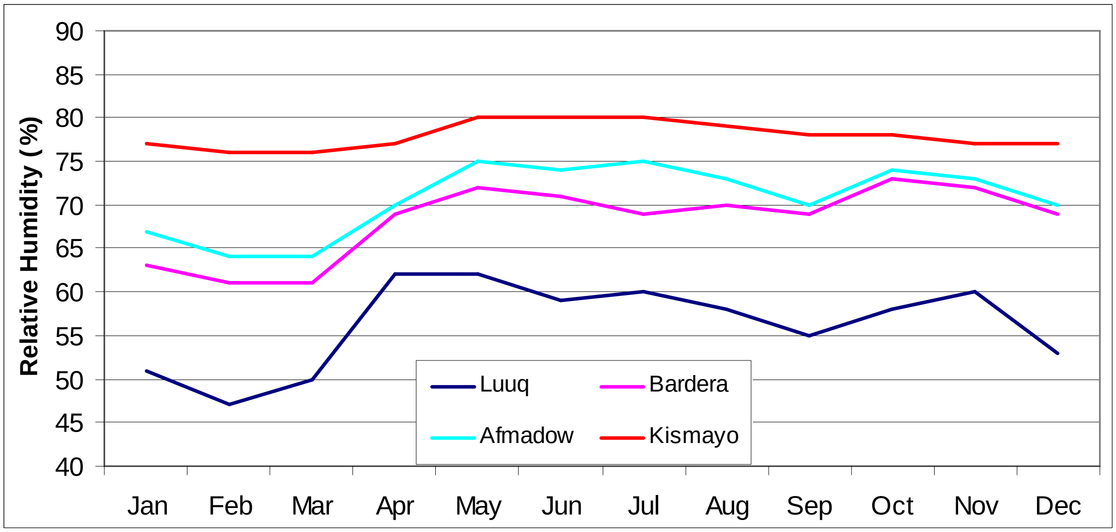


Figure 3-18 : Relative Humidity in Selected Stations within Juba Basin

3.2.6 Wind Speed

Wind speeds are generally from 0.2m/s to 8.5m/s on average in Somalia. The values however do vary greatly within the year from season to season. Low values of wind speed (0.2m/s to 4m/s) are observed in most parts of southern Somalia excluding areas around the south of lower Juba (5 m/s to 7 m/s) e.g. Kismayo. Figure 3-19 and Figure 3-20 present the monthly variation of wind speed in different stations in Shabelle and Juba basins. SWALIM Technical Report No. W-01 gives the monthly values of wind speed data derived from the FAOClim database. These are based on data taken from a limited number of years and hence it should be used with caution.

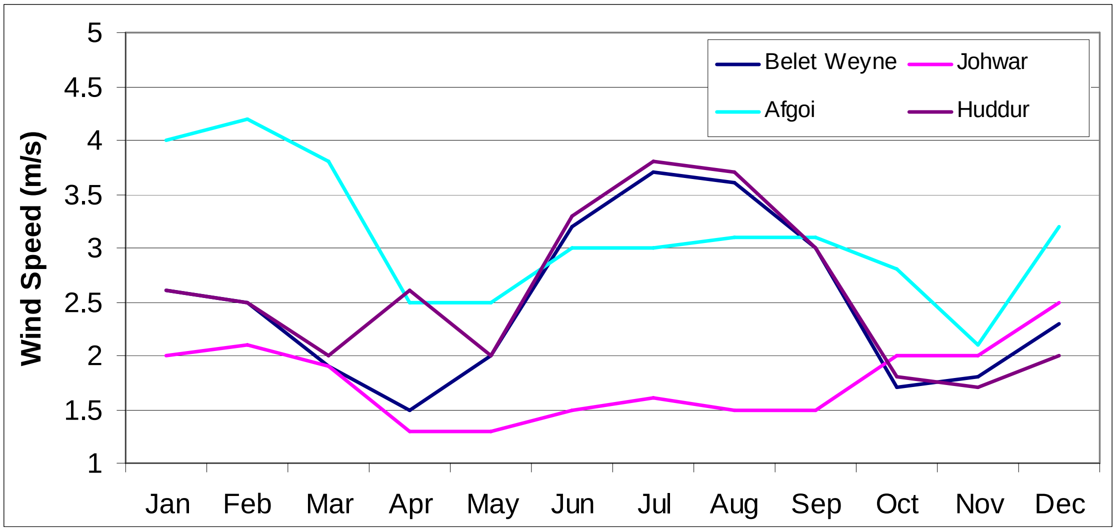


Figure 3-19: Wind Speed in Selected Stations within Shabelle Basin

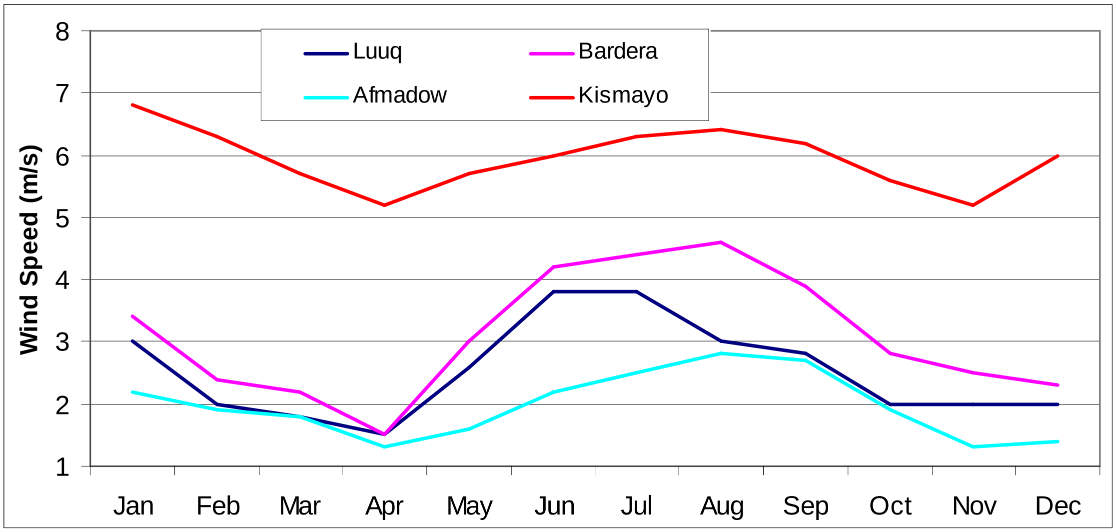


Figure 3-20 : Wind Speed in Selected Stations within Juba Basin

On an average the lowest values of wind speed occur in the months of April and November in the country, coinciding with the peaks of the two rainy seasons, *Gu* and *Deyr*, respectively.

3.3 Surface water resources

In the headwaters of the Juba and Shabelle river basins, where rainfall is generally high and losses are relatively low, surface water resources are abundant. In the middle sections, as rainfall decreases and becomes less frequent, losses increase and runoff is highly localised and seasonal, the rivers themselves still carry considerable volumes of water during most of the year. Downstream of the border, discharges reduce progressively, the flow being reduced by evaporation, infiltration, consumptive use, and by over-bank spillage when the stage is high.

Although Shabelle has a substantially larger catchment area than the Juba, the flow in the Juba is about three times larger, partly due to higher average annual rainfall, but also due to a much better developed drainage network in the upper part of its basin, with three major tributaries. River flows are highly variable from year to year, reflecting the great spatial and temporal variability in climate.

The general pattern of river flow is similar on the two rivers. Both rivers have two flood seasons, the *Gu* and the *Deyr*, reflecting the rainfall patterns. During the flood seasons, it is normal for downstream stations on both rivers to reach a sustained peak and display flat-topped hydrographs because of over-bank spillages upstream. The rivers also have slow response times, with significant changes in flow occurring over days, rather than hours.

3.3.1 Hydrological networks

There are gauging stations only in the Juba and Shabelle rivers. At present, three gauging stations with staff gauges are operational in each basin, although historical daily water levels and daily flows are available for six locations in each of the two rivers (Map 3-5). From the standpoint of water resources assessment and future development of water resources in the river basins, the following are recommended.

- In addition to the six operational gauging stations, additional gauging stations should be installed considering major water diversion locations.
- SWALIM is undertaking activities to make regular discharge measurements in order to develop up-to-date rating curves for the gauging stations in operation.
- Sediment load in the two rivers are an important factor for future water resources development in the two river basins. Regular sediment concentration observations should be undertaken in these gauging stations so that the sediment load of the rivers can be monitored. Sediment-discharge rating curves of these rivers can then be developed.
- Automatic gauge recording equipment should be installed in at least two stations in each river (one at an upstream location near the Ethiopian-Somalian border and one at a downstream location within Somalia). This would help develop flood hydrographs that would be needed for the design of water resources projects including flood management in the two river basins.
- Although the Lag Dera and Lag Badana rivers are ephemeral in nature, gauging of these rivers during the wet seasons at appropriate locations would assist water resources assessment and development in these two basins as well.

3.3.2 Streamflow

The Juba and Shabelle rivers are the only gauged rivers in Somalia. Before the out-break of the civil war, there were six gauging stations each in operation in Juba and Shabelle rivers within Somalia. River gauges (staff gauge readings) and discharge measurement records are available for these stations up to 1990 (Map 3-5). From the end of 1990 to 2000, these river gauging stations were not monitored and no data is available for this period. SWALIM in cooperation with other partner agencies are now collecting data from three gauging sites each in the Juba and Shabelle rivers. A complete inventory of the stream flow data availability is presented in SWALIM Technical Report No. 01.

3.3.3 Rating curves

Rating curves have been developed for the gauging stations based on direct discharge measurements in the rivers. Since no discharge measurements were made after 1990, there is no rating curve developed for these stations for the period after that year. There are one or two rating curves per station for more than 20 years. This signifies that the hydraulic control in the stations did not change frequently during the period. However, the sediment load in the rivers is considered to be quite high and the river cross section and hydraulic control of the stations could have changed between 1990 and now. So even though, staff gauge reading observations have been restarted in several stations, these have not been of much use as no discharge measurement data are available to develop the rating curves. SWALIM Technical Report No. W-03 gives the details of the rating curves. Standard power equations of the following form have been used to define the rating curves. The maximum heights (h_{max}) up to which the ratings are valid are also given.

$$Q = a(H + c)^b \qquad \text{valid up to } H_{max}$$

Where,

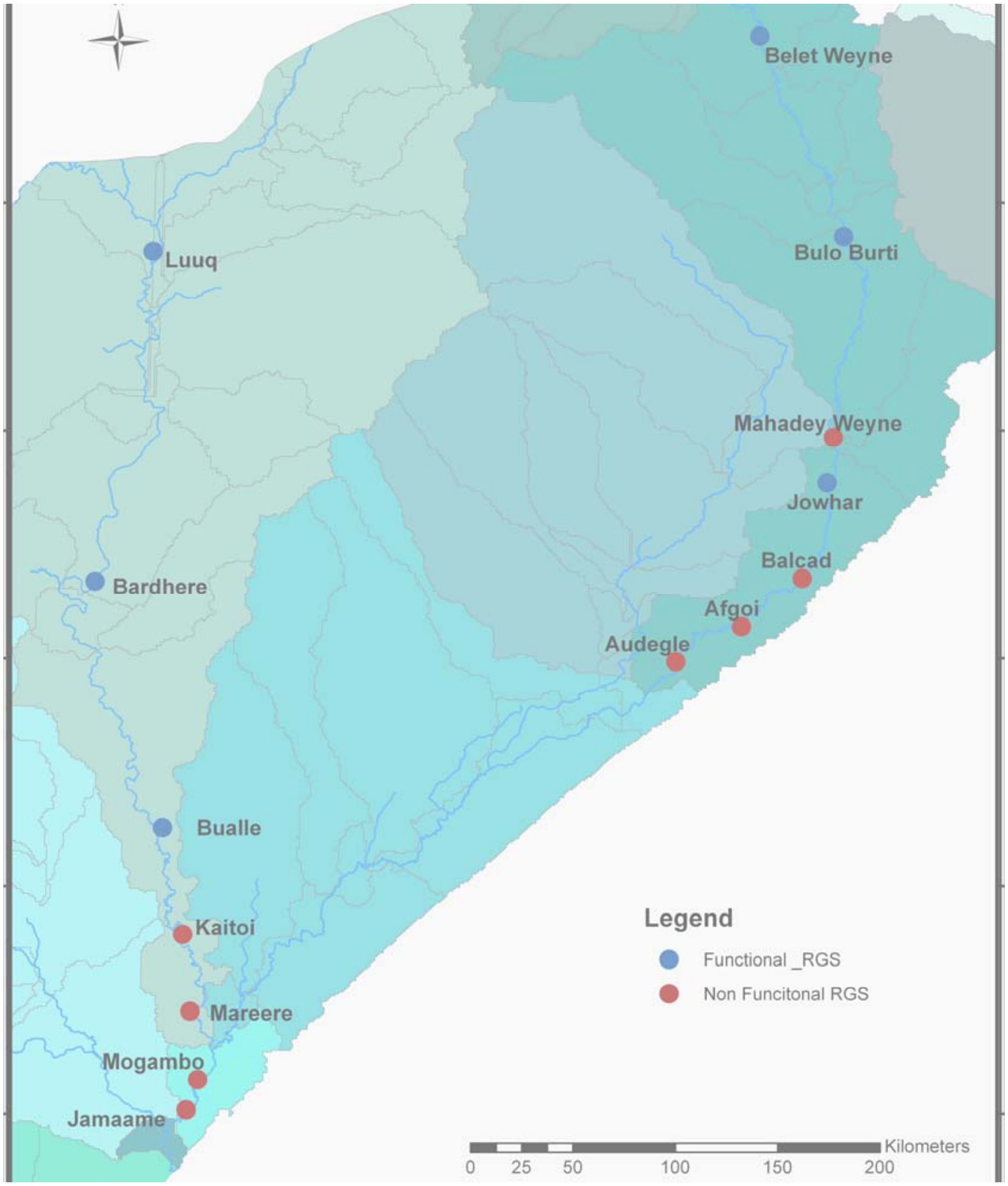
Q = discharge in m^3/s

a, b and c = constants,

H = staff gauge height (m)

H_{max} is the highest river level for which the relationship is valid.

The Juba and Shabelle rivers both have a very gentle gradient and the stage-discharge relationship may not be a single-valued function (hysteresis). This will lead to what is commonly also known as the “loop rating curve”, where the relationship differs during the rising and falling flow conditions. Data for developing such a rating curve was not available but this could be further explored so that the flow estimations are more accurate. SWALIM Technical Report No. W-10 on improving flood forecasting and early warning in Somalia provides a brief methodology for developing such a rating curve.



Map 3-5 : Location of the Hydrometric Gauging Stations along Juba and Shabelle Rivers

3.3.4 Monthly and annual flows

Daily flow data for each of the stations are available, that have been derived by applying the above rating curves to the daily observed gauge readings. These daily discharge data are given in SWALIM Technical Report no. W-01 and can be accessed through the SWALIM's website (www.faoswalim.org). The long-term flow data are available from 1951 for Belet Weyne and Luuq in the Shabelle and Juba river basins, respectively. These two stations are the most important ones and both are in the most upstream stretch of the two rivers within Somalia. They are also found to be less influenced by human and other interventions in Somalia. The flow data of other stations are available from 1963 or later until October 1990. Long-term flow statistics are derived using data from 1963-1989 (or available data during this period of stations with less data) as the gauge readings, discharge measurements and rating curves were found to be more reliable during this period. Rainfall and other climatological data are also available from this period. A summary of the lon- term monthly discharge along the Juba and Shabelle rivers is given in Table 3-14 and Table 3-15. It can be seen that the average river flows along the river decreases from upstream to the downstream parts, although the catchment areas increase. These could be due to various factors, which include the following:

- There is little contribution from the catchment areas in Somalia, due to both arid climatic conditions and undefined drainage network and density. Only during high rainfall periods do the tributaries contribute flows to the main river.
- The bank full condition occurs frequently when flood waters spill over the river banks and flood the vast flood plains laterally as one moves downstream. The peak flows in the downstream areas thus reduces and hence the total annual volume. The river channel becomes wider as it flows downstream.
- During the low flow periods, there is significant water diversion to irrigate the lands in the riverine areas along the Juba and Shabelle rivers. And very little water returns to the river as return flow.
- As the river traverses through arid climate conditions, the potential evapotranspiration is very high compared to rainfall. The evaporation from water in the flood plains is high too. Since the river slope is also very gentle, there is a lag of 2 to 3 days for the water to travel from the upstream to downstream points, where evaporation is quite high.
- The river water is recharging the aquifers along the course of the river which reduces the flow downstream. And due to the topography and hydro-geological conditions, it can be safely said that there is very little base flow contribution from groundwater aquifers in the Somali catchments.

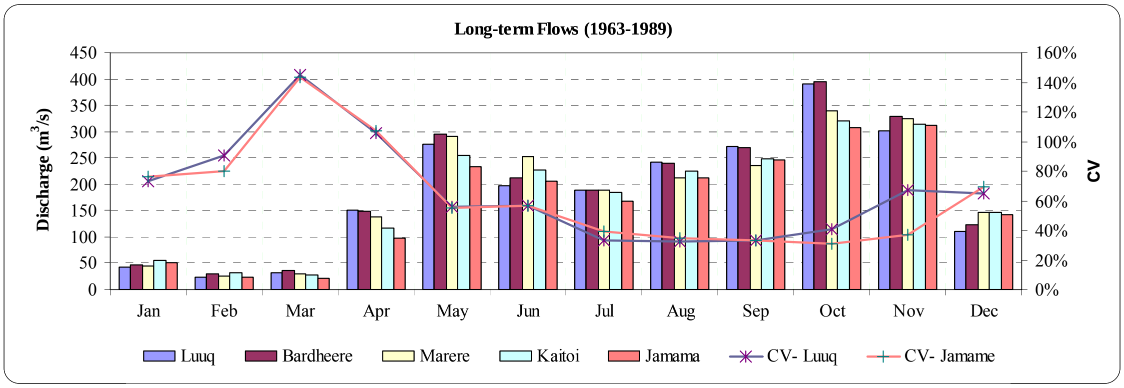


Figure 3-21 : Monthly Flow Variation along the Juba River

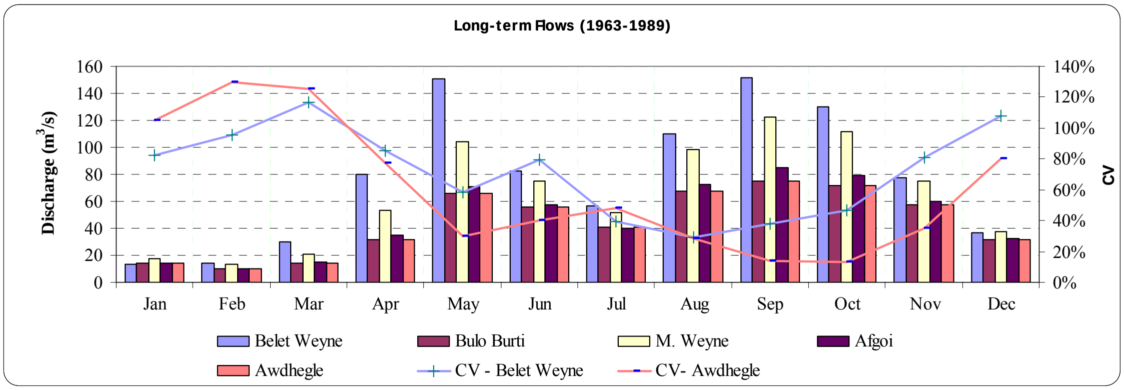


Figure 3-22 : Monthly Flow Variation along the Shabelle River

In terms of flows in the two rivers, there are more flows in Juba than in Shabelle although the catchment area of the former is smaller than that of the latter. The catchment area of Juba at Luuq is only 80% of the catchment area of Shabelle at Belet Weyne. The annual volume of discharge at Luuq is 4.13 billion m^3 (bcm) compared to the annual volume of only 1.63 bcm in Shabelle at Belet Weyne. These runoff values are only 4.2% and 1.3%. respectively, of the long-term average rainfall volume that falls in the two catchment areas. The Shabelle river has peak flows in May (middle of *Gu* season) and September (a month before the *Deyr* season), whereas in the Juba river the peak flows in *Gu* season are much less than those during October/November (*Deyr* season. The coefficient of variation (CV) in the low flow period is higher (80%-140%) than in high flow season (20%-50%).

It can also be seen from Figure 3-23 and Figure 3-24 that there is more reduction in flows in the Shabelle river than the Juba river from the most upstream to the most downstream gauging stations. The reduction in the Shabelle river occurs both in the wet months as well as the dry months. This implies that the high water reaches the bank full condition and spill to the flood plains and there is significant water diversion for irrigation to supplement the little rainfall that occurs. In the dry season, the reduction is more due to diversion and water use. The reduction in the Juba river is less, signifying that bank full condition occurs less as well as there is less diversion from the rivers.

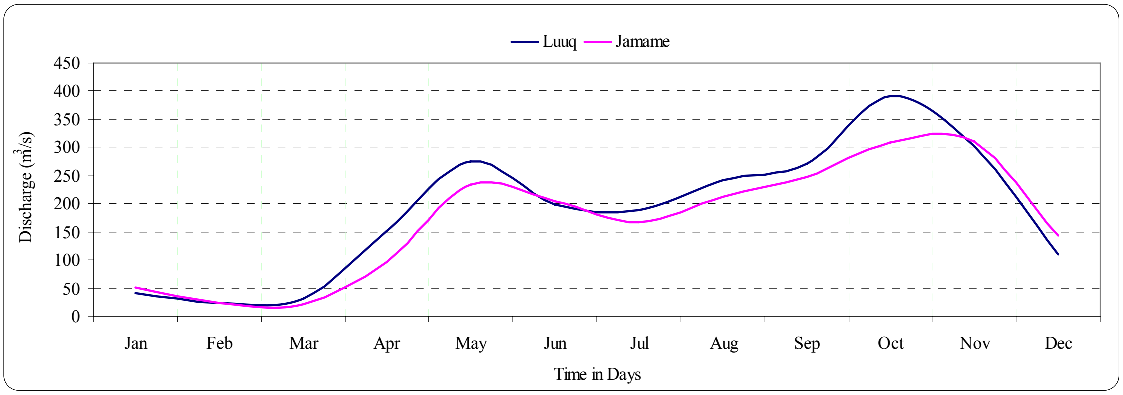


Figure 3-23 : Long-term Average Flows in the Juba River
(Most Upstream and Downstream Stations within Somalia)

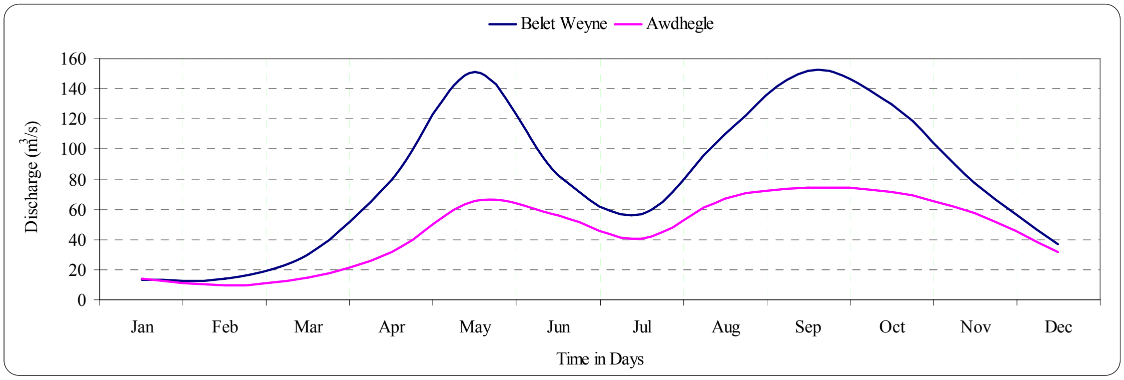


Figure 3-24 : Long-term Average Flows in the Shabelle River
(Most Upstream and Downstream Stations within Somalia)

Table 3-14 : Long-term Mean Monthly Discharge in Juba River (m^3/s)

Year	Area (km2)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Luuq	166,000	Mean:	41.6	24.2	31.4	150.4	275.1	198.3	189.5	242.6	270.7	391.6	302.1	110.9	186.4
		Std. Dv.	30.3	22.0	45.5	158.6	154.3	112.1	62.8	78.7	89.1	161.0	202.0	72.1	57.8
		C.V.	73%	91%	145%	105%	56%	57%	33%	32%	33%	41%	67%	65%	31%
Bardheere	216,730	Mean:	47.3	30.0	36.0	148.6	294.2	212.4	188.3	239.3	270.5	394.2	330.0	123.5	195.2
		Std. Dv.	29.5	20.8	46.1	158.0	180.0	132.2	63.5	77.1	88.6	161.4	200.9	77.9	59.4
		C.V.	62%	69%	128%	106%	61%	62%	34%	32%	33%	41%	61%	63%	30%
Marere	240,000	Mean:	45.3	25.9	30.4	137.3	290.2	253.0	188.7	212.3	236.4	339.9	325.7	146.3	186.0
		Std. Dv.	32.0	23.0	40.5	139.9	175.4	159.0	72.2	81.9	91.6	121.9	165.6	124.4	64.0
		C.V.	71%	89%	133%	102%	60%	63%	38%	39%	39%	36%	51%	85%	34%
Kaitoi	278,000	Mean:	54.3	31.6	28.4	117.3	254.9	227.1	183.8	224.9	248.0	319.8	313.5	146.5	178.1
		Std. Dv.	37.3	28.1	39.2	112.9	146.2	115.8	65.5	65.4	73.8	105.8	141.7	103.8	53.5
		C.V.	69%	89%	138%	96%	57%	51%	36%	29%	30%	33%	45%	71%	30%
Jamama	268,800	Mean:	50.5	23.4	21.7	96.7	233.2	205.2	167.4	211.3	247.1	308.8	311.0	142.8	169.5
		Std. Dv.	38.5	18.7	31.0	103.5	128.8	115.5	65.9	72.7	82.5	96.4	114.9	99.2	48.
		C.V.	76%	80%	143%	107%	55%	56%	39%	34%	33%	31%	37%	70%	29%

Table 3-15 : Long-term Mean Monthly Discharge in Shabelle River (m^3/s)

Year	**Area (km^2)**		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Belet Weyne	207,000	Mean:	13.5	13.8	30.0	79.8	151.2	82.7	57.0	110.0	151.8	129.6	77.5	36.9	75.0
		Std. Dv.	11.1	13.3	35.0	68.2	88.2	65.6	22.5	32.3	57.3	60.2	62.9	39.8	22.6
		C.V.	82%	96%	117%	85%	58%	79%	40%	29%	38%	46%	81%	108%	30%
Bulu Burti	231,000	Mean:	14.3	9.8	14.5	31.9	65.6	56.1	40.8	67.3	74.8	71.9	57.2	31.7	44.7
		Std. Dv.	15.0	12.8	18.1	24.7	19.7	22.4	19.7	19.3	10.3	9.5	20.1	25.5	10.7
		C.V.	105%	130%	125%	78%	30%	40%	48%	29%	14%	13%	35%	81%	24%
M. Weyne	255,300	Mean:	17.2	13.1	21.1	53.6	104.5	74.8	52.0	98.3	122.8	111.4	74.6	37.5	65.1
		Std. Dv.	12.9	12.0	25.4	38.1	39.0	40.7	25.5	27.9	26.9	27.8	37.4	33.7	15.3
		C.V.	75%	92%	121%	71%	37%	54%	49%	28%	22%	25%	50%	90%	23%
Balcad	272,700	Mean:	15.8	9.0	22.8	37.2	74.6	50.5	43.9	78.3	91.7	84.6	65.3	34.0	50.6
		Std. Dv.	13.0	6.5	23.9	24.4	20.9	21.7	19.0	22.4	9.4	9.1	18.9	22.1	10.0
		C.V.	82%	72%	105%	66%	28%	43%	43%	29%	10%	11%	29%	65%	20%
Afgoi	278,000	Mean:	14.2	9.6	14.7	34.7	70.9	57.4	40.0	72.8	84.8	79.2	60.4	32.4	47.6
		Std. Dv.	13.9	11.7	19.6	27.1	22.9	25.8	20.0	22.3	15.7	14.6	24.6	27.1	12.1
		C.V.	98%	122%	133%	78%	32%	45%	50%	31%	18%	18%	41%	84%	26%
Awdhegle	280,000	Mean:	14.3	9.8	14.5	31.9	65.6	56.1	40.8	67.3	74.8	71.9	57.2	31.7	44.7
		Std. Dv.	15.0	12.8	18.1	24.7	19.7	22.4	19.7	19.3	10.3	9.5	20.1	25.5	10.7
		C.V.	105%	130%	125%	78%	30%	40%	48%	29%	14%	13%	35%	81%	24%

3.3.5 Flow duration curves

Flow duration curves were prepared using daily flow data for the period between 1963 and 1989. The curves present discharge as a function of the percentage of time that discharge is exceeded. It provides a compact graphical summary of streamflow variability. The curves illustrate the dependability of flows and that the low flow dependability is important for the purpose of water resources planning. The flow duration curves for the Juba river at Luuq and the Shabelle river at Belet Weyne are given in Table 3-16 and Figure 3-25, and Table 3-17 and Figure 3-26, respectively. The monthly and annual flow duration curves and data for the other locations along the two rivers are presented in Annex C. A summary of the same is given in Table 3-18 and Table 3-19.

Table 3-16 : Flow Duration Curve for Juba River at Luuq (m^3/s)

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	102.2	76.2	170.2	494.8	651.8	472.8	355.2	418.9	448.6	847.8	674.6	288.6	508.4
10	79.8	58.3	67.0	390.5	550.4	357.3	282.6	379.6	409.1	734.7	506.9	239.8	404.0
20	60.6	36.2	36.4	216.7	418.7	271.7	248.9	326.6	368.7	560.0	412.6	174.0	297.5
30	49.5	27.5	19.2	166.6	335.0	223.9	222.7	282.1	330.4	483.7	339.1	120.8	237.4
40	35.3	20.4	13.8	126.8	265.9	197.9	197.3	249.7	291.5	397.3	287.3	98.3	192.9
50	30.0	16.0	10.3	91.1	222.3	169.9	182.8	227.9	263.7	327.9	244.2	81.6	151.8
60	25.5	12.3	8.4	52.6	182.2	142.7	166.8	205.8	239.2	287.9	208.3	66.7	106.2
70	21.6	9.9	7.1	34.4	146.4	119.0	151.3	186.9	213.3	253.4	164.4	54.8	62.1
80	17.3	6.4	5.5	15.3	102.1	96.0	122.0	161.1	170.8	217.4	135.1	46.0	30.9
90	12.0	5.3	3.2	6.0	61.5	78.3	91.9	128.9	127.1	167.2	102.8	36.7	12.1
95	9.0	2.2	1.3	4.6	34.5	58.5	69.4	107.9	112.0	147.0	85.0	30.0	6.4

Note: the % in the first column is the probability of flow exceedance

Table 3-17 : Flow Duration Curve for Shabelle River at Belet Weyne (m^3/s)

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	34.4	43.2	130.9	209.6	341.7	295.5	109.2	175.8	243.4	261.1	235.3	118.9	228.3
10	27.6	25.4	97.0	169.2	324.5	192.7	100.3	159.9	219.6	217.3	203.7	84.3	187.7
20	21.3	17.9	56.8	129.6	242.4	124.7	82.5	138.3	198.1	184.9	121.9	57.3	137.0
30	18.0	15.2	21.6	102.6	197.3	85.4	70.2	132.2	177.3	156.9	86.7	35.8	109.5
40	12.5	12.9	13.9	81.6	146.3	66.3	61.9	125.4	164.2	136.0	64.4	23.8	81.7
50	10.5	8.6	11.3	64.2	130.4	52.6	54.6	116.4	153.2	118.7	46.7	17.9	60.7
60	8.6	6.5	7.3	44.3	109.8	42.4	48.0	105.6	141.7	101.3	39.0	14.0	41.6
70	7.1	5.4	5.0	28.3	84.3	33.9	39.4	92.7	122.7	85.2	30.7	12.2	24.3
80	5.8	4.7	3.8	14.6	63.8	28.0	30.9	77.7	99.1	69.1	22.6	10.0	14.3
90	3.3	3.3	2.6	8.3	40.4	18.1	17.3	52.1	69.4	51.9	17.8	7.0	7.4
95	2.4	2.7	2.0	3.0	26.0	14.0	13.8	37.2	60.2	44.3	14.2	5.7	4.6

Note: the % in the first column is the probability of flow exceedance

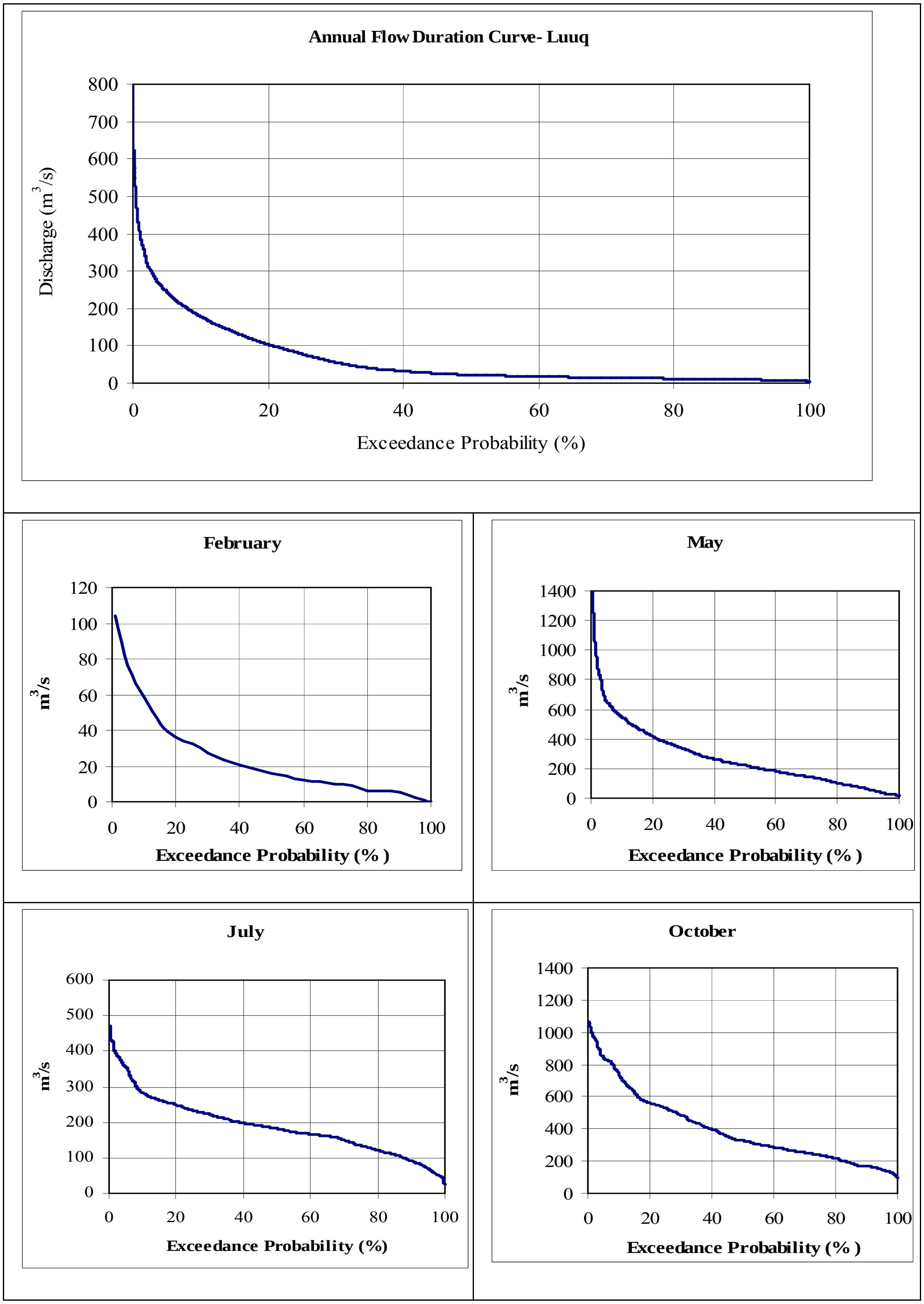


Figure 3-25 : Flow Duration Curve of Juba at Luuq

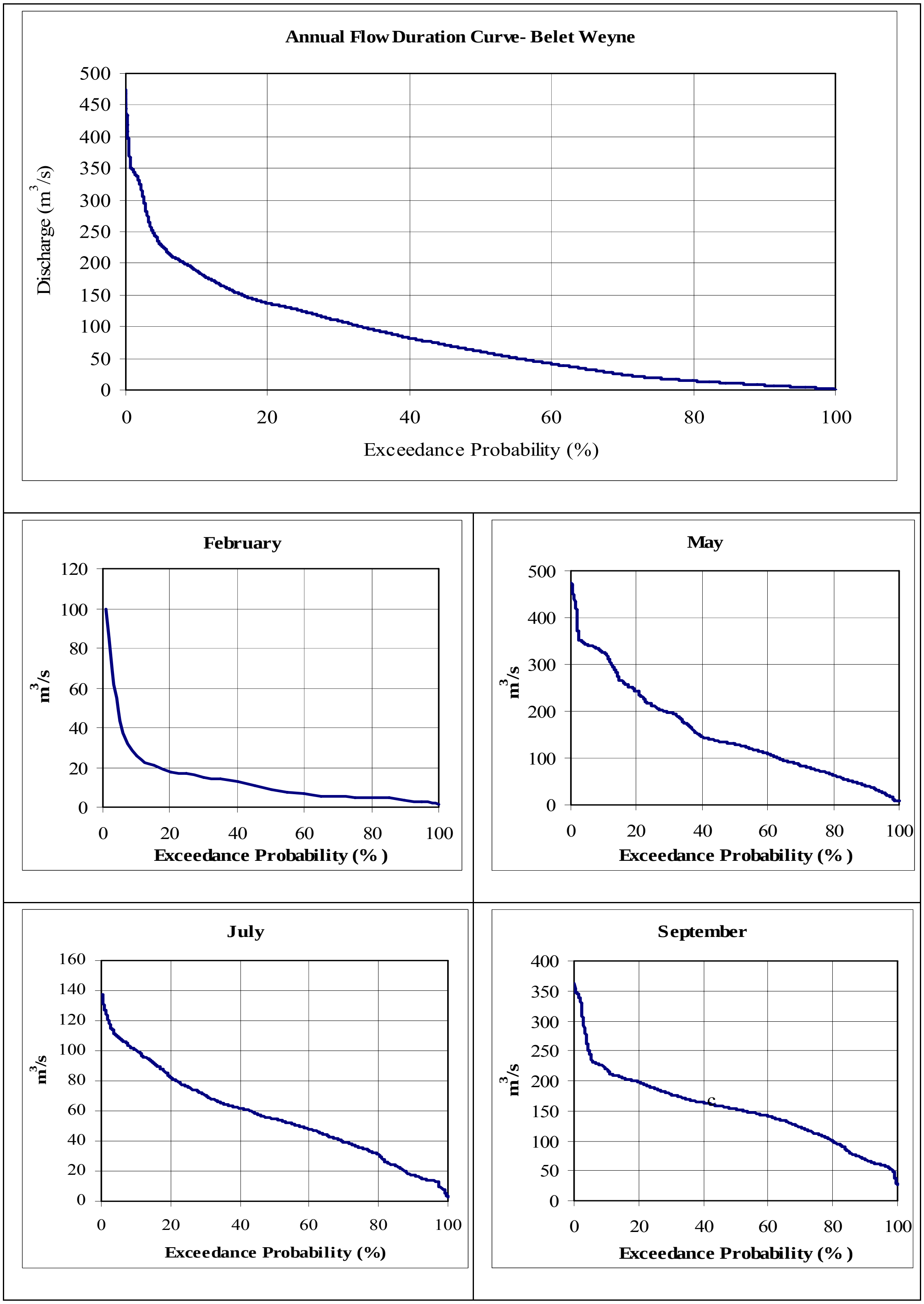


Figure 3-26 : Flow Duration Curve of Shabelle at Belet Weyne

.

Table 3-18 : Summary of Flow Duration Curve in Juba River (m^3/s)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Luuq	Mean	41.3	24.2	31.4	150.4	275.1	198.3	189.5	242.6	270.7	396.8	302.1	110.9	186.1
	20%	60.6	36.2	36.4	216.7	418.7	271.7	248.9	326.6	368.7	560.0	412.6	174.0	298.2
	50%	30.0	16.0	10.3	91.1	222.3	169.9	182.8	227.9	263.7	327.9	244.2	81.6	151.9
	80%	17.3	6.4	5.5	15.3	102.1	96.0	122.0	161.1	170.8	217.4	135.1	46.0	31.0
Bardheere	Mean	47.0	30.0	36.0	148.6	294.2	212.4	188.3	239.3	270.5	398.1	330.0	123.5	193.2
	20%	66.6	44.4	36.7	216.8	436.2	297.8	245.4	319.2	365.2	555.6	447.2	192.7	305.6
	50%	36.4	20.9	16.4	83.9	220.8	172.6	175.5	223.8	259.6	334.0	264.7	89.1	155.3
	80%	23.3	14.6	9.5	21.0	112.3	101.7	125.7	159.7	175.2	210.4	156.4	53.7	35.9
Marera	Mean	45.3	25.9	30.4	137.3	290.2	253.0	188.7	212.3	236.4	339.9	325.7	146.3	186.0
	20%	65.7	47.3	38.4	220.1	533.9	403.9	266.9	292.2	348.1	508.3	540.6	245.4	318.1
	50%	33.7	16.3	11.8	70.5	224.7	216.9	178.0	200.8	222.8	334.6	296.8	86.5	147.5
	80%	20.4	7.6	3.8	10.7	122.6	101.0	111.0	137.8	135.6	185.3	148.1	51.1	32.1
Kaitoi	Mean	55.2	32.2	29.1	119.3	252.4	209.1	181.7	235.6	253.7	334.2	310.8	145.1	179.9
	20%	77.9	52.4	37.6	215.2	477.0	314.8	238.7	313.4	335.3	472.0	455.0	238.2	301.0
	50%	44.2	24.5	14.2	42.4	191.8	178.7	168.9	216.4	250.4	303.7	280.6	100.0	154.7
	80%	27.2	8.7	3.3	9.0	100.5	99.8	115.1	163.9	174.4	203.7	158.8	59.0	36.1
Jamame	Mean	50.4	23.3	21.7	96.7	233.2	205.2	167.4	211.3	247.1	307.4	311.0	142.8	168.1
	20%	73.0	36.5	29.3	169.6	415.7	310.4	229.1	276.6	342.1	452.6	460.3	228.4	293.7
	50%	36.4	18.2	9.9	31.6	199.1	174.7	157.6	203.4	245.3	286.4	312.2	101.9	143.6
	80%	20.6	6.9	0.9	5.0	81.0	93.4	100.8	144.5	161.3	183.7	173.7	56.8	27.5

Table 3-19 : Summary of Flow Duration Curve in Shabelle River (m^3/s)

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Belet Weyne	Mean	14.3	13.8	30.3	80.5	152.8	82.8	57.0	110.7	152.0	130.2	77.7	37.2	78.3
	20%	21.3	17.9	56.8	129.6	242.4	124.7	82.5	138.3	198.1	184.9	121.9	57.3	137.1
	50%	10.5	8.6	11.3	64.2	130.4	52.6	54.6	116.4	153.2	118.7	46.7	17.9	60.8
	80%	5.8	4.7	3.8	14.6	63.8	28.0	30.9	77.7	99.1	69.1	22.6	10.0	14.4
Bulo Burti	Mean	13.3	10.5	20.8	61.3	132.8	78.8	49.9	99.5	136.4	122.9	76.1	34.3	69.7
	20%	21.2	16.0	21.8	110.1	209.1	115.9	75.5	127.2	173.5	173.3	118.4	46.9	121.6
	50%	8.8	6.4	7.2	42.0	111.5	50.7	47.6	104.2	138.5	108.7	51.0	16.0	49.7
	80%	3.9	2.0	1.1	5.5	53.9	21.8	22.8	68.7	97.1	70.6	24.1	8.3	10.0
M. Weyne	Mean	17.2	13.1	21.1	53.6	104.5	74.8	52.0	98.3	122.8	111.4	74.6	37.5	65.1
	20%	25.9	20.3	23.9	107.0	145.1	129.9	79.1	129.7	140.0	140.8	125.6	63.3	125.2
	50%	12.9	9.2	8.8	37.2	114.2	63.0	47.2	104.2	134.5	116.0	63.0	22.2	52.9
	80%	6.6	4.0	2.4	4.9	54.8	29.8	24.1	67.7	101.5	78.9	30.2	12.1	13.3
Afgoi	Mean	13.3	10.5	20.8	61.3	132.8	78.8	49.9	99.5	136.4	122.9	76.1	34.3	69.7
	20%	21.2	16.0	21.8	110.1	209.1	115.9	75.5	127.2	173.5	173.3	118.4	46.9	121.6
	50%	8.8	6.4	7.2	42.0	111.5	50.7	47.6	104.2	138.5	108.7	51.0	16.0	49.7
	80%	3.9	2.0	1.1	5.5	53.9	21.8	22.8	68.7	97.1	70.6	24.1	8.3	10.0
Awdhegle	Mean	14.3	9.8	14.5	31.9	65.6	56.1	40.8	67.3	74.8	71.9	57.2	31.7	44.7
	20%	26.4	17.1	26.9	72.8	85.2	83.0	64.5	84.6	83.3	81.9	81.4	62.1	77.7
	50%	8.1	4.1	3.0	19.8	74.0	63.5	39.1	74.0	77.4	74.0	62.7	22.0	45.7
	80%	1.7	0.0	0.0	0.0	42.7	28.4	17.9	49.2	70.0	63.8	32.7	7.3	8.7

3.3.6 High flow analysis

The high floods in the Juba and Shabelle rivers regularly inundate scarce cultivated land along the river course. From the date presented in Table 3-20, we can see that major floods occurred in 1977, 1981 and 1987 in Juba while, in the case of Shabelle, the peak flood in 1977 was not prominent. In 1997 and 2006 also there were high floods in the two rivers. The continuing deterioration of the flood control and river regulation infrastructure, coupled with unregulated settlement in flood plains and the recent practice of breaching river embankments to access water for wild flood irrigation, have increased the vulnerability of these communities to progressively smaller peak flows. The deposition of high sediment yield of the river course due to the mild slope and velocity of the rivers in Somalia has raised the bed level over the years. Hence, the river banks are regularly breached and the areas surrounding the river courses, both in the Juba and Shabelle rivers, are flooded every other year. The flood plains as well as some settlements located in them are also now relatively at a lower level than the river bed level. Any breach of the river banks therefore leads to the flooding of these settlements and precious agricultural areas. There is a loss of property and life, both livestock and human.

Floods are also a risk to a number of barrages and bridges along the course of the two rivers. Hence, a proper assessment of the floods and their likelihood of occurrence will benefit the design and management of these existing hydraulic structures and any planned in the future.

As far as the high flood data are concerned, there is no record of instantaneous maximum staff gauge readings or of the instantaneous discharge corresponding to them. But since the river profile is relatively mild sloped and the flood events are normally an outcome of high rainfall intensity in the upper catchment areas in Kenyan and Ethiopian highlands, there is likely to be little variation in the water level within a day, even for the high flows. There is also a considerable lag between the rainfall events in the upstream catchment areas and the flood events reaching the Somali territory. The flood hydrographs are thus estimated to be rather flat.

In the case of the Juba and Shabelle rivers, it is important to note that the floods in the lower reaches have been attenuated (peaks flattened) due to breaching of river banks and over-topping of them to flood the areas in the surrounding flood plains and beyond. Figure 3-27 and Figure 3-28 show the peak flow attenuation in the two rivers from the upstream to the downstream location in one of the high flood years. In the given year 1981, the high flood peaked in a single Gu season for Juba at Luuq while a smaller peak was also observed in the Deyr season in Shabelle at Belet Weyne. The upstream stations, Luuq and Belet Weyne, in the Juba and Shabelle rivers, respectively, are two locations which represent the flood estimates of the two rivers in Somalia. The flood estimates in the downstream reaches would then have to be estimated using flood routing methods, taking into consideration the hydraulic conditions such as over bank spillage into the flood plains. The annual peak floods from the observed gauge levels are given in Table 3-20. It can be seen that the flood peaks in Juba river at Luuq, although with a smaller catchment area, has larger flood values than that in Shabelle river at Belet Weyne.

Table 3-20 : Annual Maximum Discharge (m^3/s) for the Juba and Shabelle Gauging Stations

Year	Belet Weyne	B Burti	M Weyne	Afgoi	Awdegle	Luuq	Bardheera	Jamame	Mareera
1951	343.2					1080.5			
1952	NA					857.0			
1953	NA					770.3			
1954	258.5					916.3			
1955	174.5					619.3			
1956	377.8					NA			
1957	303.9					650.0			
1958	NA					NA			
1959	208.4					1113.5			
1960	138.5					NA			
1961	395.9					1181.0			
1962	NA					NA			
1963	351.4	306.2	135.4	96.8	74.7	689.0	642.4	459.2	
1964	226.5	195.0	136.7	92.0	75.3	839.8	790.4	473.2	
1965	226.1	197.3	134.9	88.8	77.1	1069.0	1035.9	477.2	
1966	190.9	160.8	143.2	87.4	72.2	484.8	547.6	477.0	
1967	284.6	231.7	140.6	98.2	74.0	NA	968.3	477.0	
1968	350.2	302.2	145.5	98.5	74.6	NA	NA	NA	
1969	199.7	175.9	147.1	97.9	74.0	NA	NA	NA	
1970	229.7	210.1	145.4	99.7	74.0	1119.1	1049.8	471.8	
1971	168.2	154.4	140.0	99.7	83.3	900.8	854.1	477.0	
1972	227.6	217.7	140.0	104.7	82.0	611.9	558.2	475.6	
1973	156.1	145.7	140.0	96.9	82.0	622.4	609.7	480.2	
1974	161.2	144.5	130.2	94.3	81.1	556.1	500.0	413.7	
1975	231.3	203.5	140.0	98.8	82.0	543.8	531.1	439.9	
1976	373.1	292.7	147.5	100.0	85.9	866.9	814.1	477.0	
1977	345.0	333.8	151.3	105.5	93.3	1822.8	1761.8	553.4	650.0
1978	255.3	218.4	140.0	108.6	93.6	828.8	809.1	477.0	595.0
1979	151.1	153.1	140.0	112.7	86.0	354.3	365.1	392.8	408.1
1980	164.5	168.7	148.4	89.5	80.4	249.7	439.7	240.8	201.4
1981	473.6	489.3	163.2	89.5	86.2	1431.1	1568.4	500.8	803.8
1982	245.4	228.9	156.8	95.5	90.3	851.4	1164.6	477.0	634.0
1983	361.8	317.8	155.5	96.6	90.3	677.7	680.9	510.5	634.7
1984	179.3	179.6	144.7	89.7	80.1	503.3	548.4	433.4	482.4
1985	352.9	307.5	166.3	81.1	82.0	641.4	1064.6	477.0	590.3
1986	165.8	179.2	156.1	89.0	89.1	543.9	562.9	477.0	513.5
1987	419.6	322.0	164.4	93.1	89.3	1475.2	1415.4	477.0	667.0
1988	226.9	199.4	172.3	85.5	89.7	855.8	962.9	477.0	536.5
1989	298.6	240.2	169.8	97.1	93.7	957.9	1296.4	477.0	593.2
1990	242.7	175.5	176.0	99.2	95.6	747.0		493.2	625.0

Note the high flows in 1977 and 1981.

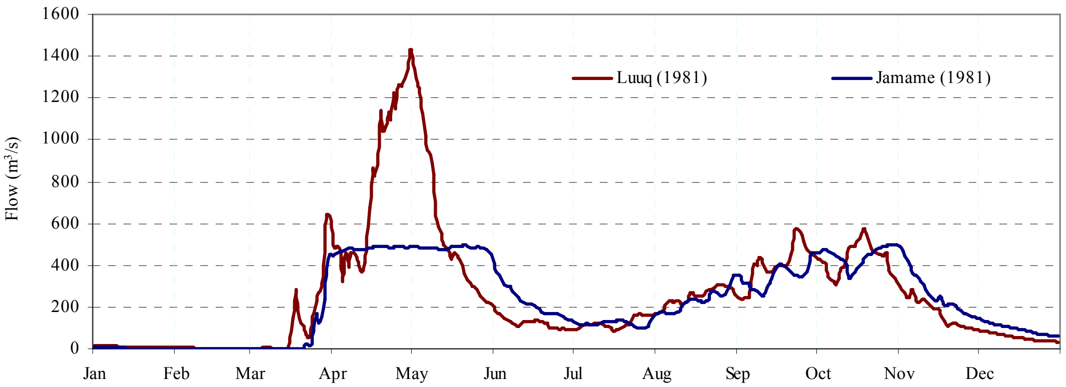


Figure 3-27 : Annual Hydrograph of the Juba River (1981)

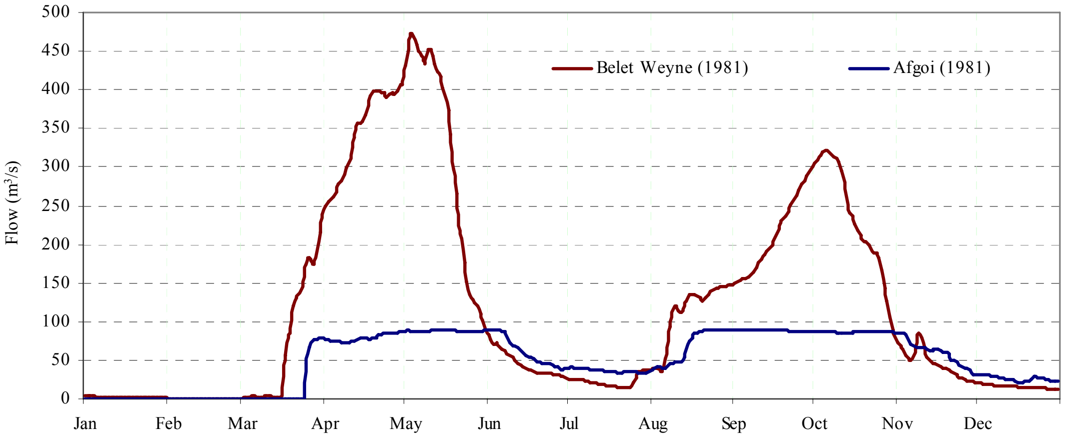


Figure 3-28 : Annual Hydrograph of the Shabelle River (1981)

Flood frequency analysis was therefore carried out using the maximum daily flow every year for the stations in the two rivers. Various probability distribution functions, namely Log-normal (LN), 3-parameter Log-normal (LN3), Log-pearson Type 3, Gumbel, Extreme Value (EV1) and General Extreme Value (GEV) were used and the best fit distribution was tested, using different goodness-of-fit tests. These included standard error, coefficient of correlation, chi-square and K-S tests. Outlier tests were applied to test for any high or low outliers. Data from 1951 to 1990 were utilized where available. One low outlier that was detected in Juba river at Luuq was removed and flood frequency analysis carried out. In both cases, Gumbel was found to be the best fit distributions from the view point of majority of goodness-of-fit tests. The flood estimates for the Juba river at Luuq are presented in Table 3-21, Figure 3-29 and Figure 3-30; for the Shabelle river at Belet Weyne estimates are presented in Table 3-22, Figure 3-31 and Figure 3-32.

The flood frequency analysis shows that the all the five frequency distribution are within the goodness-of-fit critical values. In the case of Juba at Luuq, the best fit distributions from the point of view of different tests were: GEV (standard error), EV1 and GEV (correlation coefficient), LN3 (chi-square) and LP3 (KS tests). In the case of Shabelle at Belet Weyne, while LN2 distribution was light better fit in terms of standard error and correlation coefficient, Gunbel distribution fitted the best in terms of the chi-square and KS tests. As the goodness-of-fit of all distributions are within the critical values and the variations of the flood predictions are also within each other, flood values determined by Gumbel distribution has been selected and recommended for planning purpose.

Table 3-21: Flood Frequency Analysis for Juba at Luuq (m^3/s)

Return Period (Year)	**Distribution**					
	LN2	**LN3**	**LP3**	**Gumbel**	**EVI**	**GEV**
2	771	799	794	783	777	775
5	1,084	1,090	1,090	1,117	1,082	1,079
10	1,296	1,266	1,267	1,338	1,284	1,283
20	1,501	1,425	1,424	1,550	1,477	1,481
50	1,771	1,620	1,610	1,825	1,727	1,740
100	1,978	1,761	1,740	2,031	1,915	1,935
500	2,473	2,073	2,014	2,506	2,349	2,395
1000	2,694	2,203	2,122	2,710	2,535	2,595
10000	3,475	2,630	2,450	3,389	3,154	3,273
Goodness of Fit						
Standard Error	44.599	54.271	54.255	49.322	40.533	39.505
Corr. Coeff., r	0.990	0.984	0.984	0.989	0.993	0.993
Chi-Square, χ^2	5.625	2.125	2.563	5.188	5.625	5.188
KS	0.086	0.066	0.059	0.067	0.075	0.079
Critical Value of KS for N= 36 and 95% confidence level						0.251
Critical Value of χ^2 for K= 7 (class) and 95% confidence level for 2 parameter distributions = $\chi^2_{0.95,4}$						9.4877
Critical Value of χ^2 for K= 7 (class) and 95% confidence level for 3 parameter distributions = $\chi^2_{0.95,3}$						7.8147

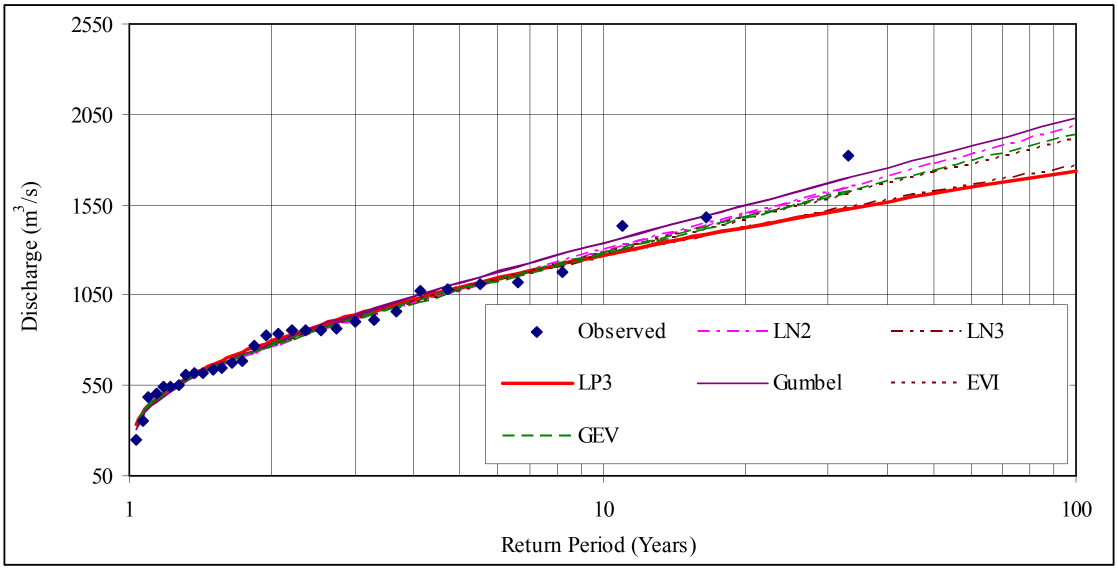


Figure 3-29 : Flood Frequency Analysis for Juba River at Luuq

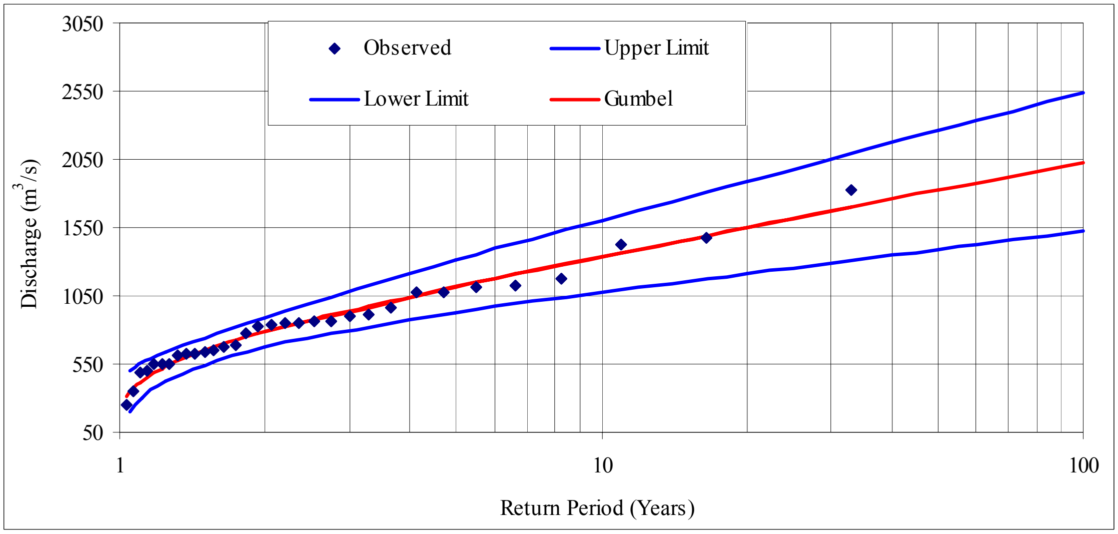


Figure 3-30 : Flood Estimates for Juba River at Luuq (Gumbel Distribution)

Table 3-22: Flood Frequency Analysis for Shabelle at Belet Weyne (m^3/s)

Return Period (Year)	**Distribution**					
	LN2	**LN3**	**LP3**	**Gumbel**	**EVI**	**GEV**
2	249	243	248	249	247	249
5	329	329	328	337	331	333
10	381	390	381	395	387	387
20	429	450	432	450	440	437
50	492	532	498	522	509	501
100	538	596	548	576	561	547
500	646	753	666	701	681	649
1000	693	826	718	754	732	692
10000	854	1,088	900	932	903	825
Goodness of Fit						
Standard Error	13.896	17.700	14.424	15.866	18.090	16.935
Corr. Coeff., r	0.985	0.978	0.984	0.984	0.980	0.982
Chi-Square, χ^2	5.611	5.222	5.611	2.889	4.056	4.056
KS	0.131	0.127	0.132	0.112	0.115	0.111
Critical Value of KS for N= 36 and 95% confidence level						0.230
Critical Value of χ^2 for K= 7 (class) and 95% confidence level for 2 parameter distributions = $\chi^2_{0.95,4}$						9.4877
Critical Value of χ^2 for K= 7 (class) and 95% confidence level for 3 parameter distributions = $\chi^2_{0.95,3}$						7.8147

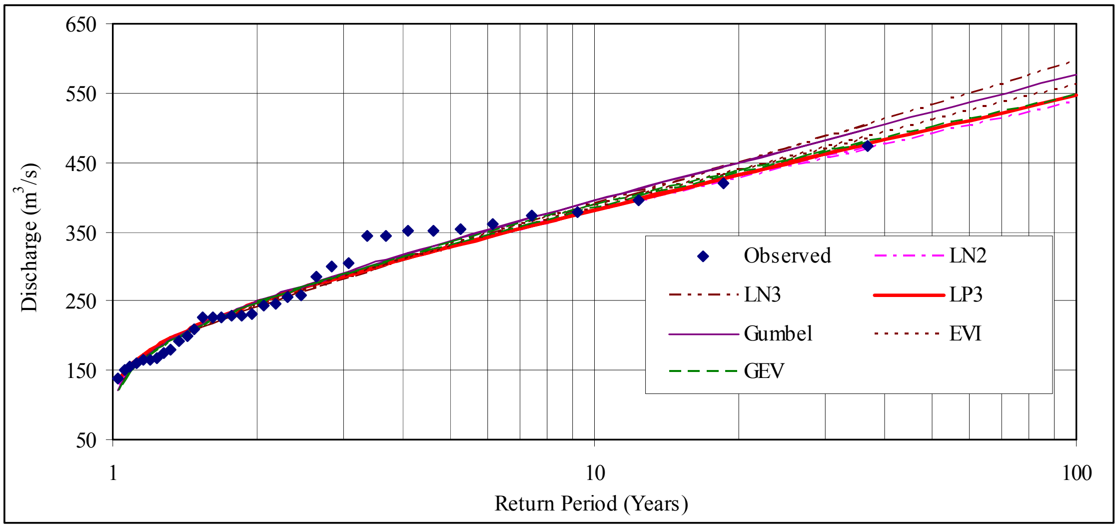


Figure 3-31 : Flood Frequency Analysis for Shabelle River at Belet Weyne

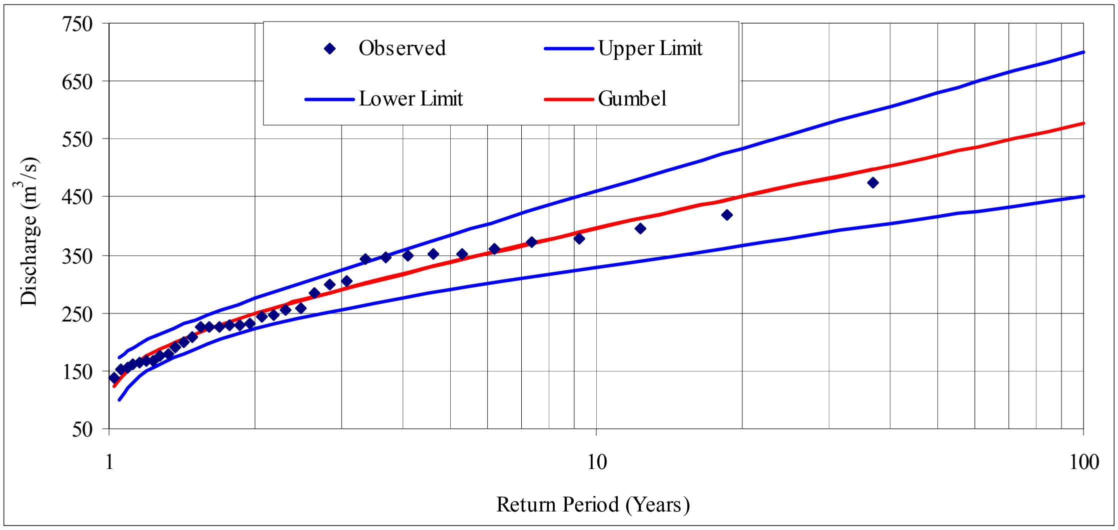


Figure 3-32 : Flood Estimates for Shabelle River at Belet Weyne (Gumbel Distribution)

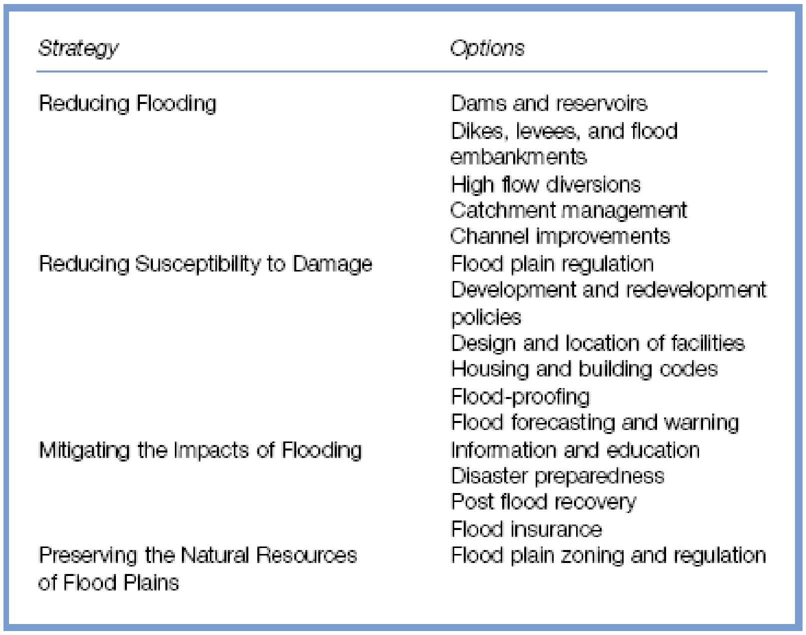
3.3.7 Low flow analysis

Low flow analysis of streamflow is important to plan for the worst situation of surface water availability. The capacity requirements of water storage facilities are often fixed, based on the low flow parameters to ensure the reliability of supply. The available daily streamflow data (1963-1989) of all gauging stations in the Juba and Shabelle rivers were used to derive one-day, 7-day, 10-day, 15-day and 30-day annual low flows by the moving average method. When most data for the low flow months were not available e.g. during January-March, such years were excluded from analysis (denoted by “NA” in the tables). The tables of annual low flows for Luuq (upstream) and Jamame (downstream) in Juba and Belet Weyne (upstream) and Awdhegle (downstream) in Shabelle are presented in Table 3-23, Table 3-24, Table 3-25, Table 3-26, respectively. The low flows at both Belet Weyne and Luuq (even zero for a 15-day average) are quite low in some years and it reduces to very low values in some years. As the river flows downstream, there is considerable reduction in low flows, as explained earlier, and the flows reach a low flow monthly average of even zeros (Table 3-24 and Table 3-26).

Box 3-1 : Floods in Juba and Shabelle

- Both the Juba and Shabelle rivers have extensive lengths of “levees” or flood embankments on both sides of the river banks.
- Six severe flood events occurred – Deyr of 1961, Deyr of 1977, Gu of 1981, Deyr of 1997, Gu of 2005 and Deyr of 2006. Although data are not available, the El Nino floods of 1977/78 are considered the worst in living memory.
- The flood peaks are of relatively low values (considering catchment area) e.g. floods of 100-year return period in Juba at Luuq (166,000 km^2) is about 2000 m^3/s and in Shabelle at Belet Weyne (207,000 km^2) is about 575 m^3/s.
- There is considerable lag time (more than 2-3 days) and the flood hydrographs (peaks) are substantially attenuated along the river due to, among other reasons, over-bank spillages onto flood plains, abstractions in flood relief canals (not operational at present), evaporation and infiltration.
- Various actions have aggravated the flood problems even in periods of low floods:
    - river bed levels rising higher than adjacent land due to sediment deposition;
    - people breaching levees to irrigate land in dry seasons;
    - natural flood plains have also been encroached;
    - unplanned closures of natural flood relief channels;
    - total break down of the existing irrigation infrastructure;
    - a total lack of central or local governance managing the river basin.
- SWALIM issues weekly flood warning bulletins during the flood season based on the water levels observed in the rivers. As bank full levels are reached almost 1 in 5 years, the two warning levels are adopted – orange (moderate flooding for 5-year flood events) and red (severe flooding for 10-year flood events and higher).
- An integrated flood management is recommended taking into consideration the various strategies and options, apart from haphazard control by levees.

Strategies and Options for Flood Management



Strategy	*Options*
Reducing Flooding	Dams and reservoirs Dikes, levees, and flood embankments High flow diversions Catchment management Channel improvements
Reducing Susceptibility to Damage	Flood plain regulation Development and redevelopment policies Design and location of facilities Housing and building codes Flood-proofing Flood forecasting and warning
Mitigating the Impacts of Flooding	Information and education Disaster preparedness Post flood recovery Flood insurance
Preserving the Natural Resources of Flood Plains	Flood plain zoning and regulation

Table 3-23 : Annual Low Flows in Juba River at Luuq (m^3/s)

Year	Daily Flow	3-day	7-day	10-day	15-day	30-day	Month
1963	9.6	9.8	9.8	10.0	10.8	12.7	14.1
1964	7.9	8.2	9.8	9.8	10.8	12.7	13.9
1965	4.6	4.7	4.9	5.1	5.4	6.4	9.1
1966	22.8	23.7	24.2	24.4	25.1	27.8	31.6
1967	5.4	5.4	5.4	5.5	5.5	5.6	5.6
1968	NA	NA	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA	NA	NA
1970	0.0	0.0	0.0	0.0	0.0	0.1	5.7
1971	3.1	3.2	3.4	3.6	3.8	4.9	5.3
1972	23.2	23.4	24.8	28.9	32.5	35.6	36.8
1973	4.2	4.2	4.3	4.4	4.5	4.8	9.6
1974	7.6	7.7	7.9	8.0	8.2	8.2	12.8
1975	0.8	0.8	0.8	0.9	1.1	1.7	3.1
1976	3.9	3.9	4.0	4.2	4.4	6.1	7.5
1977	11.9	12.5	14.6	14.8	16.6	21.2	23.7
1978	26.3	27.0	28.4	29.5	31.4	39.7	38.6
1979	32.9	34.9	38.7	40.8	42.3	51.6	52.4
1980	4.9	4.9	5.0	5.1	5.2	5.6	6.7
1981	1.5	1.5	1.5	1.5	1.7	2.2	2.7
1982	15.1	15.2	15.3	15.5	15.8	16.6	17.3
1983	24.2	26.9	29.3	30.3	31.4	32.4	40.0
1984	4.1	4.3	5.5	6.4	6.8	7.1	8.7
1985	0.7	0.8	0.9	0.9	1.1	1.2	1.6
1986	3.4	3.8	4.2	4.6	4.8	5.3	5.9
1987	2.9	3.2	4.1	4.7	5.1	6.3	7.7
1988	5.4	5.7	5.8	6.1	7.1	9.9	11.4
1989	6.2	6.2	6.6	6.8	7.2	9.1	10.7

Table 3-24 : Annual Low Flows in Juba River at Jamame (m^3/s)

Year	Daily Flow	3-day	7-day	10-day	15-day	30-day	Month
1963	9.7	9.9	10.0	10.2	11.0	12.9	14.7
1964	6.4	6.6	7.3	7.7	7.9	9.3	12.1
1965	2.6	2.9	3.3	3.3	3.5	4.6	7.6
1966	15.1	15.5	16.4	17.1	18.1	22.5	21.8
1967	12.3	12.3	12.3	12.3	12.4	12.4	12.5
1968	NA	NA	NA	NA	NA	NA	NA
1969	NA	NA	NA	NA	NA	NA	NA
1970	0.0	0.0	0.9	0.9	1.0	2.9	10.4
1971	0.0	0.0	0.0	0.0	0.0	0.3	1.6
1972	16.5	16.8	18.0	19.1	22.3	25.4	29.9
1973	2.0	2.2	2.5	2.8	3.2	4.1	4.5
1974	2.2	2.4	2.9	3.2	3.2	4.1	4.4
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.2
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	19.6	19.7	20.1	20.8	23.3	25.8	33.4
1978	33.1	33.4	33.8	33.8	34.0	38.6	45.2
1979	32.1	32.1	32.4	33.1	36.0	50.1	51.5
1980	0.0	0.0	0.1	0.1	0.1	0.2	1.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	5.7	5.8	6.4	6.9	7.8	8.4	9.4
1983	7.7	13.7	16.7	17.8	19.1	20.0	27.7
1984	2.6	3.2	4.6	4.9	5.3	7.2	9.4
1985	0.1	0.1	0.2	0.4	0.8	2.1	2.2
1986	2.7	2.8	2.8	2.8	2.8	3.0	3.5
1987	1.8	1.8	2.2	2.5	2.8	4.4	5.6
1988	11.3	11.8	12.6	13.2	13.5	14.1	14.2
1989	0.0	0.0	0.0	0.0	0.0	0.2	1.3

Table 3-25 : Annual Low Flows in Shabelle River at Belet Wyene (m^3/s)

Year	Daily Flow	3-day	7-day	10-day	15-day	30-day	Month
1963	NA	NA	NA	NA	NA	NA	NA
1964	NA	NA	NA	NA	NA	NA	NA
1965	NA	NA	NA	NA	NA	NA	NA
1966	2.7	2.8	2.9	3.0	3.1	6.8	6.1
1967	0.4	0.4	0.4	0.4	0.5	0.7	0.8
1968	12.5	12.5	12.8	13.2	13.8	15.3	15.7
1969	9.8	10.5	11.0	11.5	12.3	14.7	14.8
1970	7.1	7.3	7.5	7.8	8.1	8.8	9.0
1971	5.4	5.5	5.6	5.6	5.7	6.0	6.1
1972	6.8	6.8	6.9	7.0	7.4	8.6	11.5
1973	2.9	2.9	2.9	2.9	2.9	3.1	4.2
1974	NA	NA	NA	NA	NA	NA	NA
1975	NA	NA	NA	NA	NA	NA	NA
1976	NA	NA	NA	NA	NA	NA	NA
1977	NA	NA	NA	NA	NA	NA	NA
1978	10.6	10.6	10.6	10.7	10.9	12.2	12.6
1979	8.0	8.5	9.1	9.5	10.3	13.0	13.2
1980	2.2	2.3	2.4	2.5	2.8	4.7	5.3
1981	2.0	2.0	2.1	2.1	2.2	2.5	2.6
1982	7.0	7.0	7.1	7.1	7.5	8.7	9.2
1983	9.2	9.4	9.9	10.2	10.5	12.0	17.1
1984	8.0	8.1	8.4	8.7	9.5	9.8	11.0
1985	2.4	2.5	2.5	2.6	2.8	3.4	3.5
1986	4.0	4.1	4.2	4.3	4.5	4.7	5.0
1987	3.6	3.6	3.6	3.6	3.8	4.2	4.7
1988	2.3	2.3	2.3	2.3	2.4	2.5	2.6
1989	11.2	11.3	11.4	11.5	11.7	12.6	15.2

Table 3-26 : Annual Low Flows in Shabelle River at Awdhegle (m^3/s)

Year	Daily Flow	3-day	7-day	10-day	15-day	30-day	Month
1963	0.0	0.0	0.0	0.0	0.0	0.0	0.1
1964	0.4	0.5	0.6	0.7	1.0	1.9	4.6
1965	0.0	0.0	0.0	0.0	0.1	0.8	1.7
1966	0.0	0.0	0.0	0.0	0.0	1.0	1.5
1967	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1968	8.5	8.7	9.4	9.6	10.1	12.0	12.3
1969	8.2	9.1	10.5	11.0	12.3	15.4	15.8
1970	1.0	1.1	1.5	1.9	2.5	3.9	5.4
1971	0.9	0.9	0.9	0.9	0.9	0.9	1.1
1972	0.9	0.9	0.9	0.9	1.0	2.6	3.8
1973	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1974	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1975	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1976	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1977	4.8	4.9	5.3	5.9	6.2	7.6	10.1
1978	10.8	11.0	11.8	12.4	13.2	18.2	21.3
1979	2.5	2.8	3.6	4.1	5.0	8.5	8.9
1980	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	10.2	11.3	12.2	12.8	13.4	14.7	16.4
1983	19.1	19.3	20.9	21.2	21.5	23.2	29.4
1984	4.4	5.0	5.2	5.3	5.6	10.1	10.5
1985	0.0	0.0	0.0	0.0	0.0	0.2	0.2
1986	0.0	0.0	0.0	0.0	0.0	0.0	0.1
1987	0.0	0.0	0.0	0.0	0.0	0.1	0.1
1988	0.0	0.0	0.0	0.0	0.0	0.0	1.5
1989	3.8	5.3	9.2	9.2	10.1	10.8	11.3

A low flow frequency of these annual low flows were analysed by fitting them into standard probability distribution functions, namely Log-normal (LN2), 3-parameter Log-normal, Log Pearson Type 3 and Weibul distributions. Standard goodness-of-fit tests were also analysed. The 7-day and monthly low flows for different return periods for Juba at Luuq and Shabelle at Belet Weyne are given in Table 3-27 and Table 3-28. Figure 3-33 and Figure 3-34 give the details of 7-day and monthly low flow analysis for Juba at Luuq. Figure 3-35 and Figure 3-36 show the figures of 7-day and monthly low flows for Shabelle at Belet Weyne. The low flow distribution that best fits the low flow distribution is Weibul (from the point of most tests). However, in the case of some low flow values being equal to zero, LN2 and LP3 distributions could not be fitted due to their mathematical properties. As there is wide variation (high coefficient of variations) of low flows over the years (from maximum to minimum), the low flow frequency analysis results should be used with caution. The low flow prediction for return periods of more than 10 years gave very low or zero values. It is sometimes more advisable to use the flow duration values (% of time certain flow is exceeded in such cases).

Table 3-27 : Low Flow Frequency Analysis for Juba at Luuq (m^3/s)

Return	**Distributions**			
Period	**LN2**	**LN3**	**LP3**	**Weibul**
7-day Low Flow				
2	6.70	7.81	6.70	7.81
5	2.50	1.51	2.50	1.51
10	1.31	0.00	1.31	0.00
20	0.63	0.00	0.63	0.00
50	0.09	0.00	0.09	0.00
100	0.00	0.00	0.00	0.00
Standard Error	2.010	2.299	2.010	2.299
Corr. Coeff., r	0.977	0.970	0.977	0.970
Monthly Low Flow				
2	10.74	11.93	10.74	11.93
5	5.08	3.69	5.08	3.69
10	3.39	1.15	3.39	1.15
20	2.41	0.00	2.41	0.00
50	1.62	0.00	1.62	0.00
100	1.23	0.00	1.23	0.00
Standard Error	2.445	2.962	2.445	2.962
Corr. Coeff., r	0.979	0.971	0.979	0.971

Table 3-28 : Low Flow Frequency Analysis for Shabelle at Belet Weyne (m^3/s)

Return	**Distributions**			
Period	**LN2**	**LN3**	**LP3**	**Weibul**
7-day Low Flow				
2	4.80	6.04	4.08	6.04
5	2.37	2.99	2.37	2.84
10	1.64	1.48	1.93	1.33
20	1.21	0.27	1.69	0.21
50	0.86	0.00	1.50	0.00
100	0.68	0.00	1.41	0.00
Standard Error	1.865	0.701	3.153	0.684
Corr. Coeff., r	0.923	0.979	0.834	0.981
Monthly Low Flow				
2	6.73	8.01	5.85	8.31
5	3.45	4.17	3.44	4.02
10	2.43	2.41	2.79	2.00
20	1.82	1.07	2.42	0.51
50	1.32	0.00	2.13	0.00
100	1.06	0.00	1.99	0.00
Standard Error	2.321	0.902	3.808	0.864
Corr. Coeff., r	0.929	0.981	0.850	0.983

Note: The Chi-square and KS test results for all the distribution were similar mainly due to the problem of a high variation between high and low values. Hence, these are not present in the two tables above.

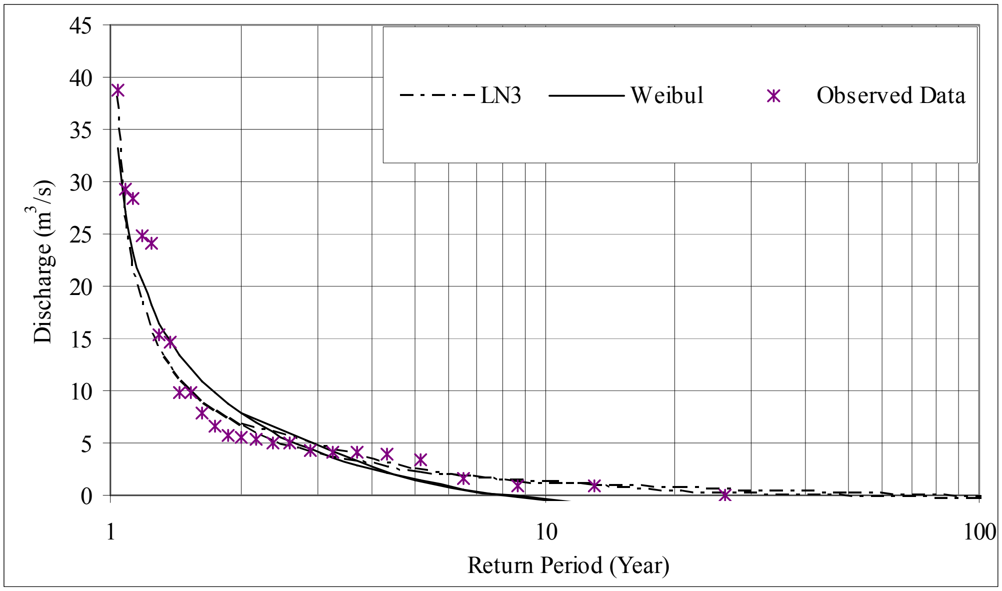


Figure 3-33 : 7-day Low Flow Frequency for Juba at Luuq

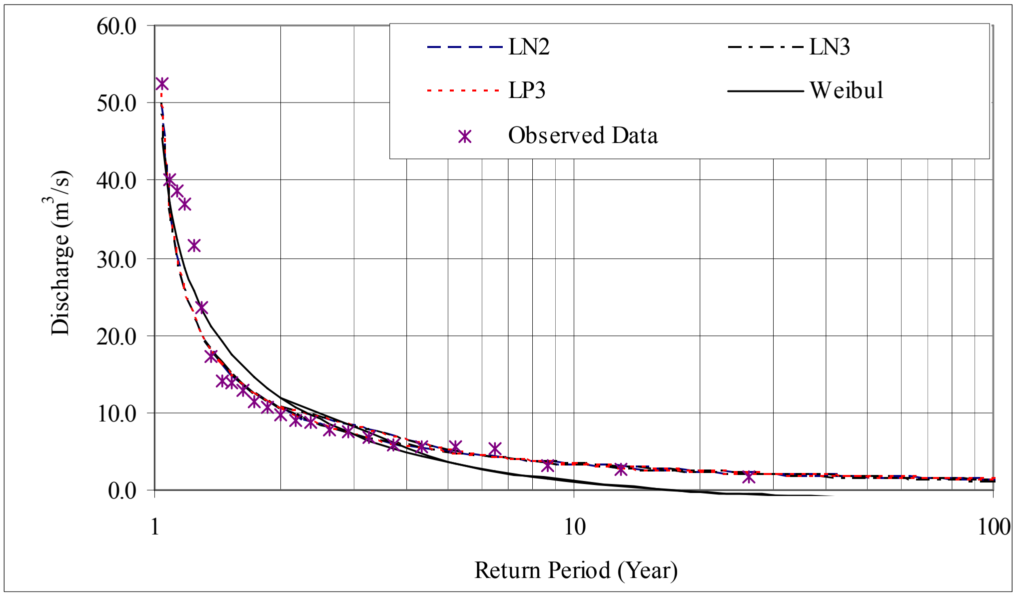


Figure 3-34 : Monthly Low Flow Frequency for Juba at Luuq

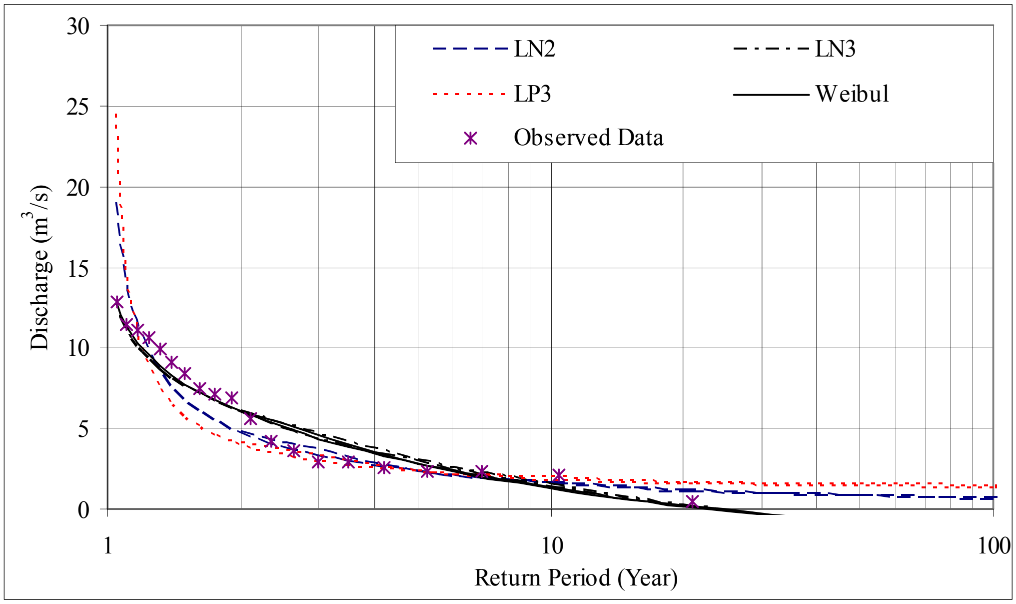


Figure 3-35 : 7-day Low Flow Frequency for Shabelle at Belet Weyne

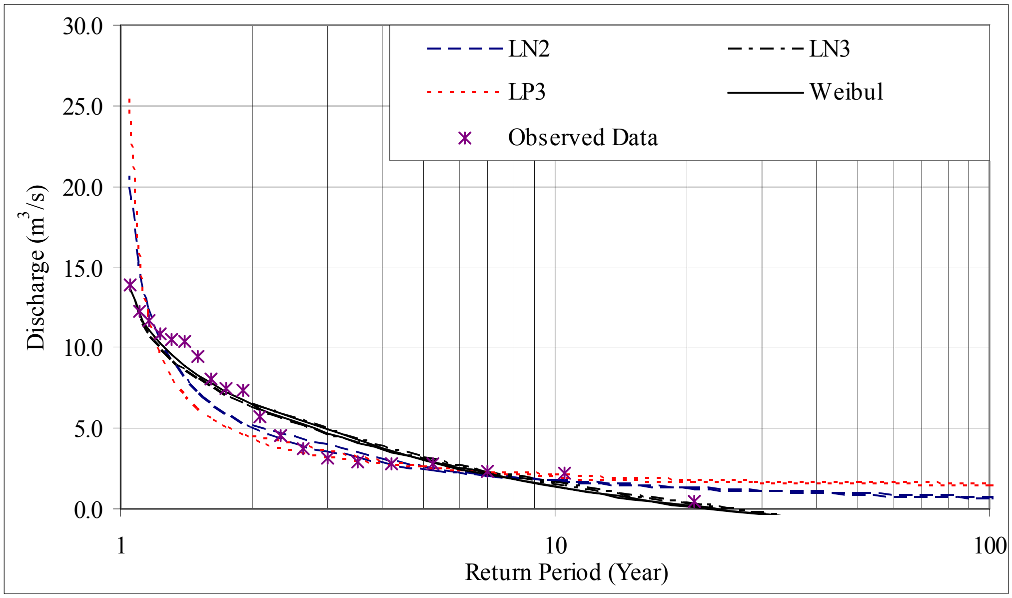


Figure 3-36 : Monthly Low Flow Frequency for Shabelle at Belet Weyne

3.3.8 Water quality and sedimentation

There has been very little work done regarding the quality of water in the rivers of Somalia. River water quality data (salinity) on a daily basis was collected for the Juba river at Mareera by the Juba Sugar Project (JSP) from 1977 to the end of November 1990. The data is presented in the Hydrometry Project Report (*MacDonald and IH, 1990*). Figure 3-37 and Figure 3-38 show the variation of the salinity during the year. The former figure presents the long-term monthly mean and medium salinity for the period from 1977 to 1990 and the latter presents the variation in some typical years (plotted, using daily salinity values). The figures demonstrate that the salinity in the river rises during the *Jilaal* season and the peak occurs during the *Gu* flood season. The figures also show that although there is a slight rise in the *Deyr* season, it never reaches the peaks of the *Jilaal* and *Gu* seasons.

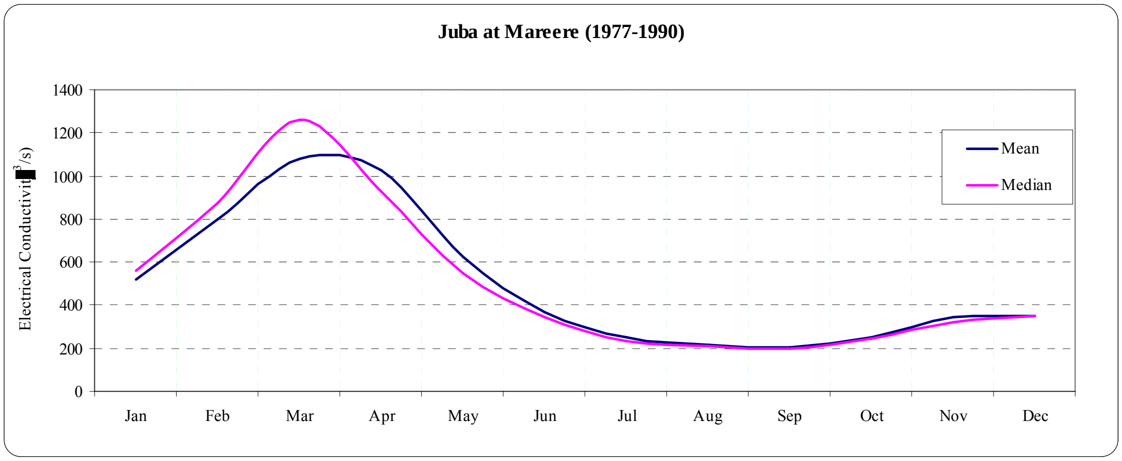


Figure 3-37 : Long-term Salinity (mean and median) for the Juba River at Mereere

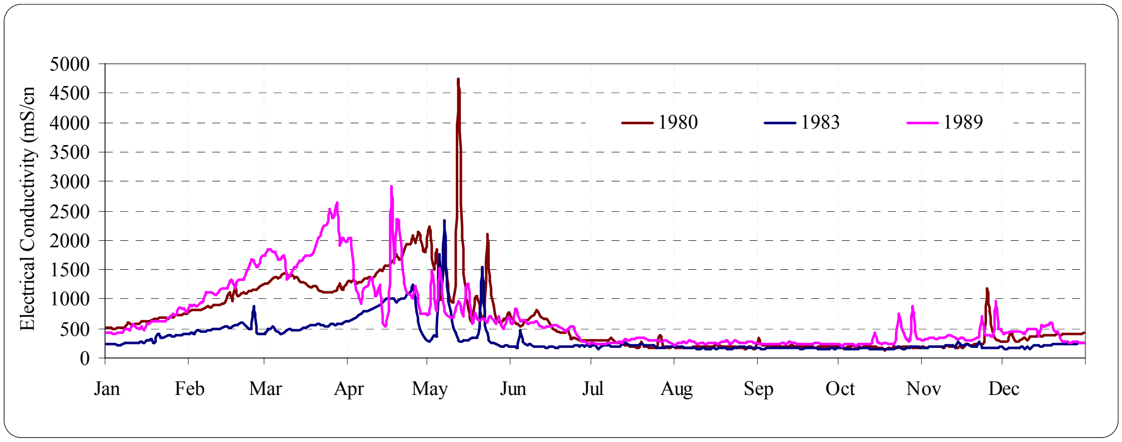


Figure 3-38 : Annual Variation of Salinity for the Juba River at Mereere

There is also very little data on the sediment load of the rivers. The Hydrometry Project (Phase 3) carried out by MacDonald and Institute of Hydrology (IH) (1991) presented some data collected by the project in the Shabelle river at Afgoi. Suspended sediment sampling using depth integrated method as well as salinity measurements were done by the project for one year from November 1989 to November 1990. There were 53 samples collected during this period and sampling was done at regular intervals throughout the year. The data are derived from the Hydrometry Project Report (*MacDonald and IH, 1990*). Although it would not be appropriate to draw strong conclusions from one year's data, a scatter plot of the suspended sediment concentrations and corresponding discharge at the time of observation over the one year period is presented in Figure 3-39. Higher values of sediment were observed during *Gu* period than in the *Deyr*. This supports the understanding that the *Gu* floods carry a higher sediment load than those in the *Deyr*.

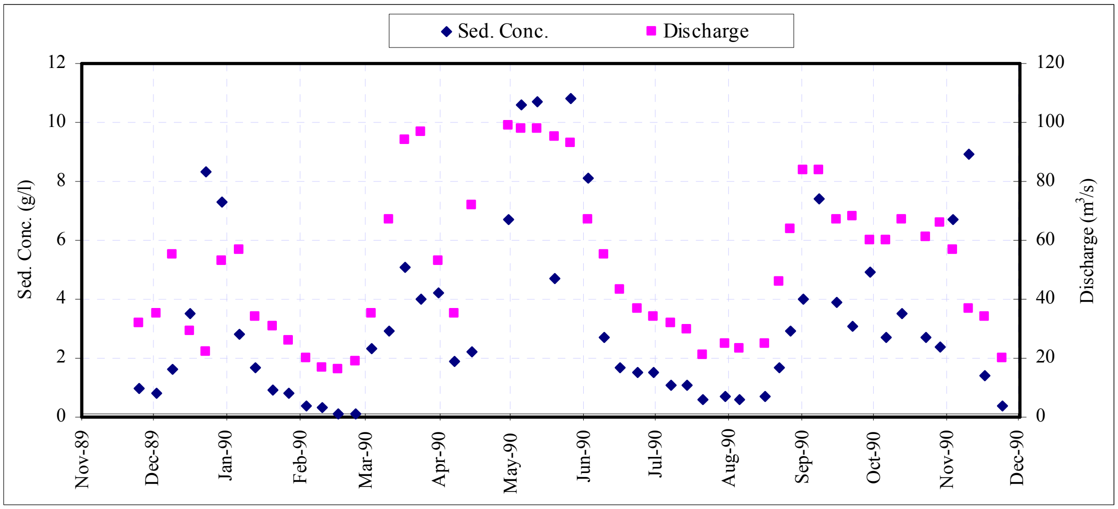


Figure 3-39 : Suspended Sediment and Discharge Data for the Shabelle at Afgoi

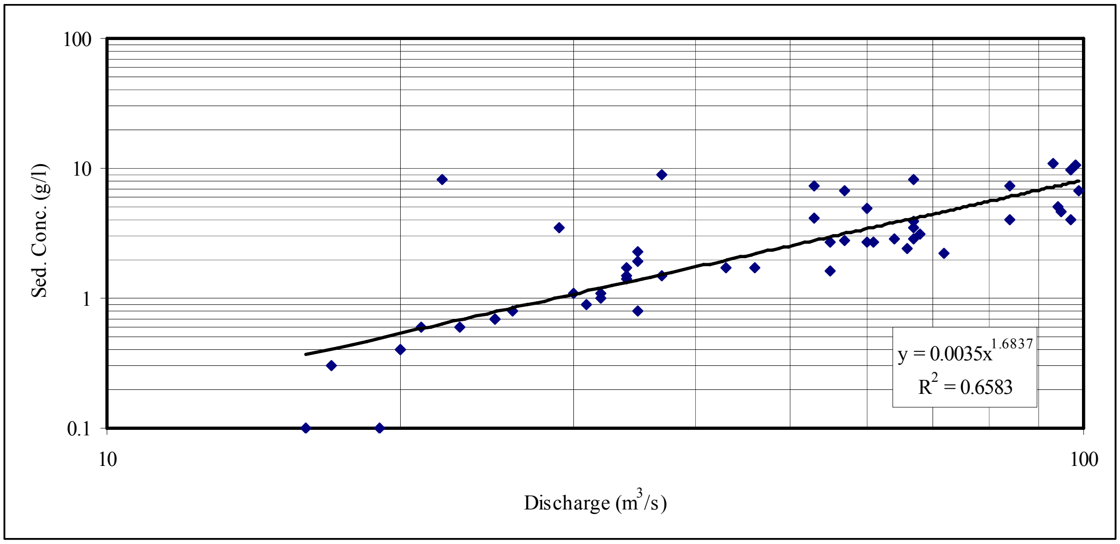


Figure 3-40 : Relationship between Discharge and Sediment Concentration

One sees a close correlation between sediment concentration and discharge (Figure 3-40). A power equation fits the data with a coefficient of determination (r^2) equal to 0.65. Again, developing a discharge-sediment concentration relationship using one year data may not be very reliable. However, the figure is presented here to demonstrate the possibility of developing sediment load and discharge rating curves. Such rating curves are useful in estimating the long-term sediment load using discharge data which are available for longer periods.

The total sediment load normally consists of suspended sediment load and bed loads. Given the topography and the very mild profile of the rivers, it is unlikely that there would be much bed load (sediments with large sizes) being carried by the Juba and

Shabelle rivers. Applying the sediment concentration — discharge rating curve derived in Figure 3-40 to the daily flow data for one year from 1 Dec, 1989 to 30 Nov, 1990 (discharge data for December 1990 was not complete, hence the December 1989 flows were used) -- the total suspended sediment load for a one-year period is estimated to be 6.9 million tonnes, This is just a one-year load calculated using sediment observation for one year period. Hence, it should not be taken in any way as a long-term estimate. It was carried out so as to get an idea of the likely magnitude of sediment load only. However, it does call for a concerted effort to undertake sediment data collection in the rivers in Somalia.

Salinity tests (electrical conductivity) were also carried out from the river samples collected during the sediment data collection in Afgoi. The variation of salinity in Shabelle at Afgoi (Figure 3-41) was also similar to that for the Juba river at Mareera (Figure 3-37). The higher salinity is observed during the *Jilaal* and *Gu* periods compared to the *Deyr*. In the case of Afgoi in 1990, salinity has decreased in a particular period in April, There could be various reasons for this, including that fact the water quality data at this location is also influenced by the discharge from the Jowhar off-peak reservoir.

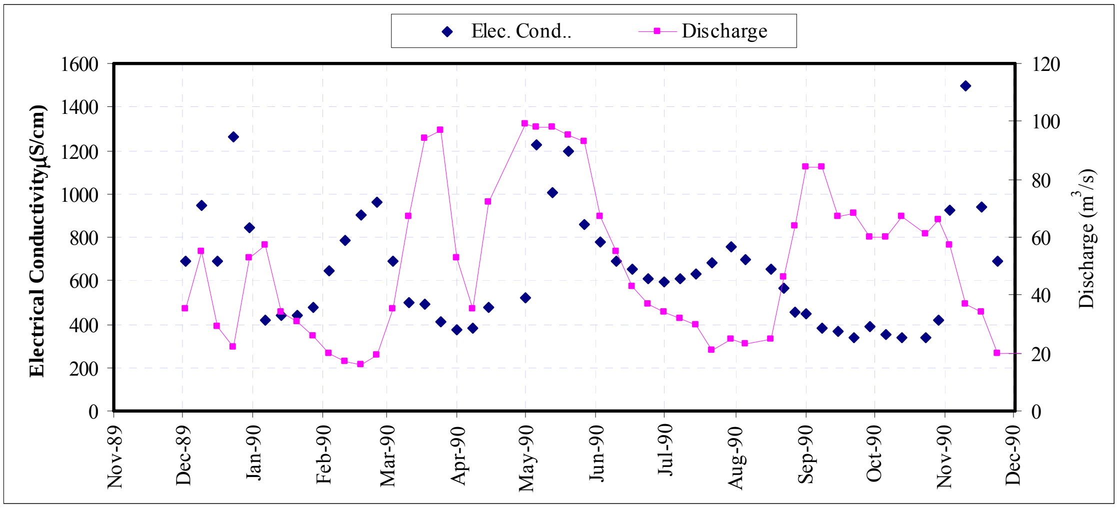


Figure 3-41 : Variation of Salinity in the Shabelle River at Afgoi
(Data Samples- 1989-1990)

Other water quality parameters are not observed in the rivers. As these rivers are used not only for irrigating the crops but also to meet the water needs of human and livestock populations in the area, the quality of water should be closely monitored.

3.3.9 Surface water storage - *Wars* and *Berkads*

Wars for rain water harvesting are more common than *berkads* in Southern Somalia. *Wars* are large ground natural or mechanically scooped water catchments for surface water collection and storage, mostly unlined, also called *bailey* or *water pan, ponds, dams*. The main reason for this is the favourable soil type (clayey) for the construction of *wars*.

The 1:100,000 topographical maps of Somalia, although prepared some decades ago, locate the water points in the country. There are many such water points located in the areas of the four river basins. As expected, due to higher rainfall in the region compared to other areas in the central and northern regions of Somalia, a majority of such points are categorized as rainwater ponds and reservoirs (91% in Juba basin, 87% of total water points in the Shabelle basin, 79% in Lag Dera basin and 98% in Lag Badana basin (Table 3-29). Similarly, there is a small percentage of water tanks located in these basins which could be filled also utilizing the surface water sources. The SWALIM water sources database (SWIMS) being compiled through cooperation with partner agencies, however, does not include any water sources using surface water. As this is just a start of the process of collection, the data available is not complete. *Berkads* are known to be used mainly in Hiran and Gedo regions for domestic storage.

Table 3-29 : Water Points Digitised from the Topographical Maps of Somalia

	Shabelle		**Juba**		**Lag Dera**		**Lag Badana**	
	No.	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Wells (WPW)	502	10.8%	190	7.2%	3,043	17.3%	29	1.6%
Wind Driven Wells (WPWW)	2	0.0%	3	0.1%	9	0.1%	0	0.0%
Motor Driven Wells (WPMW)	1	0.0%	1	0.0%	15	0.1%	0	0.0%
Rainwater ponds/reservoirs (WPRP_R)	4,051	86.8%	2,406	90.7%	13,907	78.9%	1,746	98.4%
Natural Springs (WPNS)	10	0.2%	36	1.4%	428	2.4%	0	0.0%
Man-made Springs (WPMS)	28	0.6%	11	0.4%	45	0.3%	0	0.0%
Water Tanks (WPT)	75	1.6%	6	0.2%	170	1.0%	0	0.0%
Total	**4,669**	**100%**	**2,653**	**100%**	**17,617**	**100%**	**1,775**	**100%**

Source: Digitised Data from 1:100,000 Topographical Maps

Berkads, classified under rainwater ponds/reservoirs in Table 3-29, have a capacity ranging between 10 and 100 m^3 (*ICRC 2002*). They are constructed mainly in areas where there are no dug wells. Water from the *berkads* is either used for domestic consumption or sold to outsiders. Where the water is sold, the *berkads* are better maintained with fencing to keep off animals, and in some cases covered with shrubs or iron sheets to reduce evaporation.

Box 3-2 : *Wars* - Rainwater Harvesting in Southern Somalia

(Source: Kammer and Win, 1989)

The former National Water Centre (NWC) of Somalia monitored four rural rain/catchment/storage facilities (*wars*) during 1989 in Southern Somalia. Although these data is quite old, it does, however, present representative characteristics including rainfall-runoff processes in small catchments which contribute to the harvesting of surface/storm runoff generated by rainfall in such catchments.

These storages (*balli*, *wars* and *berkads*) basically collect storm runoff that occurs when rainfall has sufficient intensity, duration and areal extent. Runoff-rainfall relationship (runoff coefficient), rainfall threshold (for runoff to occur) and effective rainfall (rainfall exceeding infiltration) depends on various physiographical factors of the catchments such as:

- Topography, slope and vegetation cover
- Soil characteristics and infiltration capacity
- Drainage density (DD) and drainage pattern

Physical details of catchments and reservoirs monitored

Name	**Xabaal Filley**	**Madax Maroodi**	**Fuud Dooro**	**Ribo**
Elevation (m asl)	85	110	183	358
Catchment Area (km^2)	2.5	2.8	2.7	3.0
Average slope (%)	0.20	0.24	0.75	0.86
Drainage density (m/km^2)	2200	3000	2100	2200
Vegetation	crops, shrubs	shrub, bush (medium density)	crops, shrubs	bush, shrubs (dense)
Soils	dark brown, grayish-brown clay	reddish-brown, medium to fine textured sandy loams	dark red to red coarse sands and sandy loams with quarts gravels	dark red to red coarse and sandy loams
Infiltration rate (cm/hr)	0.1-0.5	2.0-6.0	12.5-25.0	12.5-25.0
Reservoirs				
Max depth (m)	5.22	6.88	4.56	4.25
Max. volume (m^3)	25,300	29,300	18,200	19,200

Some of the key findings were:

- Most of the daily rainfall occurred in one storm event.
- Storms of less than 15 mm did not produce runoff unless the antecedent moisture content (AMC) was high (soil is very wet). Threshold rainfall value was between 20 to 30 mm depending on rainfall intensity and AMC. Only 9 to 16% of the rainy days had rainfall over this threshold values.
- Runoff coefficients (RC) varied considerably dependent on storm duration and/or intensity and AMC. They varied from 0.005 to 0.1 depending on the catchment physiographic (slope, DD and soil) as well storm characteristics, discussed above.
- Evaporation varied from 5 to 10 mm/day and seepage losses from 1 to 4 mm/day.

Clayey soils favour the construction of *wars*. However, sometimes they have to be lined up with plastic sheets to prevent water loss through seepage. The sizes of *wars* vary depending on the manpower available in the village for the construction. Water lasts for up to six months depending on the lining material used and consumption rate.

Wars are common in the Bakool, Bay and Hiraan regions. Their capacities vary from 1,500 to 50,000 m^3. Silting and seepage are the main problems with *wars*. The water lasts for two to three months after rain, but with proper lining using plastic sheets and clay material, the water can last for up to six months. On an average the settlements in the regions have two or three *wars* each.

Mugciids, which are underground reservoir storage wells with an average depth of 15 meters, exist mainly in the Bakool region. There are more than 1,700 *mugciids* in the region, mainly in Hoddur, Teyeglow and Wajid districts. Many of the *mugciids* are constructed in clusters, with each family owning two to three units. The depth of the *mugciid* varies from 7 to 17m with a diameter of 1 to1.5m. Water lasts for two to three months.

3.4 Groundwater

As the groundwater aquifers are recharged through infiltration from direct rainfall as well as from surface water from rivers and small *toggas*, the storage and movement of groundwater resources are likely to follow the rough boundaries of the major river basins. Hence, areas in Southern Somalia which are traversed by the two perennial rivers, Juba and Shabelle, have the best hydro-geological conditions for finding groundwater such as along the major *toggas* in alluvial deposits and weathered basements. In other areas, including the central rangelands where groundwater recharge is through direct rainfall, the amount of infiltration is estimated to be not more than 5% of the rainfall due to low and erratic rainfall which ranges from 100-250mm/year (*Faillace and Faillace, 1987*). Surface water from *toggas* and *wadis* can be trapped through infiltration galleries and check dams (gabion structures) to recharge the groundwater

3.4.1 Grounwater Aquifers[3]

The main hydro-geological basins/aquifers in Southern Somalia extend towards the north into Ethiopia and west into Kenya. These are:

- **Basement Complex** (also known as the "Buur Area") in the centre;
- **Xuddur-Bardheere Aquifer** to the north;
- **Coastal Aquifer** to the south in Southern Somalia;
- **Upper and Middle Shabelle Valley.**

Basement Complex Aquifer

The Basement Complex in the Buur Area is a well defined hydrogeological province, which due to its position and characteristics has an influence on the groundwater movement in Xuddur-Bardheere Aquifer. The rocks found in the basement complex are mainly granites, quartzite, micashists and marble. Mantle of red lateritic sand resulting from deep weathering

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[3] The description of the aquifer systems is adapted from Faillace and Faillace (1987)

of underlying rocks and alluvial formations deposited by numerous streams are also common. Recharge occurs mainly with rainfall and from runoff water along *toggas*. Little recharge occurs in large areas covered by black alluvial clay, and water found in such clays is usually salty. Much of the groundwater is found along the *toggas* in alluvial deposits and weathered basement where recharge conditions are good. Groundwater flows mainly along the major surface drainage pattern. The groundwater bodies are small and discontinuous, most of which are locally recharged. Small amounts of water can also be found in the rock fractures, though salinity of the water is generally high. The settlement density in this area, like those along the Shabelle and Juba rivers, is a testimony to the good groundwater resources available in the region (see Map 3-6).

Xuddur-Bardheere Aquifer

Recharge in this basin occurs along the Baydhabo escarpment through the joints of stratification and the Karstic areas through the dolines and sinkholes where rainfall and runoff water infiltrates rapidly (*Faillace and Faillace, 1987*). Recharge is good at the areas covered by the Baydhabo Jurrasic limestone, and almost zero at the areas covered by residual clay which is impermeable. Underground flow starts from the Baydhabo plateau and continues in the northeast and northwest direction. In the upper parts of the Juba valley, groundwater flow is from east to west, and from north to south.

There are numerous springs along the Baydhabo escarpment due to the draining of a narrow belt of the limestone formation cut by several small faults. Underground flow is locally inverted towards the escarpment by the small faults.

Two discharge zones are found in the Gedo region: one located in the western side of the Juba valley where groundwater seeps out through several small springs along the river bed of major *toggas*, and the other found in the north west of Garbaahaarrey draining the Cambar and Garbahaarrey formations.

Baydhabo Formation which surrounds the Basement Complex to the west, east and north has a high potential for groundwater. The depth of water increases from the edge of the escarpment towards the north. At Baydhabo, water level is 5m, whereas at the contact point with Canoole Formation the level is 50m. The levels are 70m and 120m for Ufurow and War Caasha respectively. Water quality in the Baydhabo is generally of good quality, with EC values ranging between 650 and 1500 µohms/cm. The other formations with water potential are Garbahaarrey, Cambar and the Main Gypsum Formations. The good groundwater potential in the area is also evident from the dense settlement in the area.

Coastal Aquifer

This groundwater aquifer system extends from the lower reaches of the Juba, Shabelle, Lag Dera and Lag Badhana river basins to the coastal areas in the South. Recharge of groundwater at the coastal basin occurs as a result of direct rainfall, Juba and Shabelle rivers, underground flow from Kenya, runoff and underground flow from the basement complex. Although little has been documented concerning the large swamps (wetlands) which the Shabelle and the Lag Dera rivers feed, it would be a potential source of recharge of the coastal aquifers which supply vital fresh water resources to the important towns located in the coastal areas in the south. Major recharge occurs only in certain areas where there are sand or sandy clay deposits. Flow in the Shabelle Valley area is influenced by the Bandar-Jalalaqsi fault. In Juba recharge mainly occurs in the areas of Liboy, Bilis Qooqani, Hosingo and south Hosingo. The recharge is good and groundwater is of fairly good quality. Sand deposits exist to a depth of 200m. Groundwater flow in the Shabelle is north to south, while in Juba valley it is north to south in the northern part and northwest to southeast in the southern area.

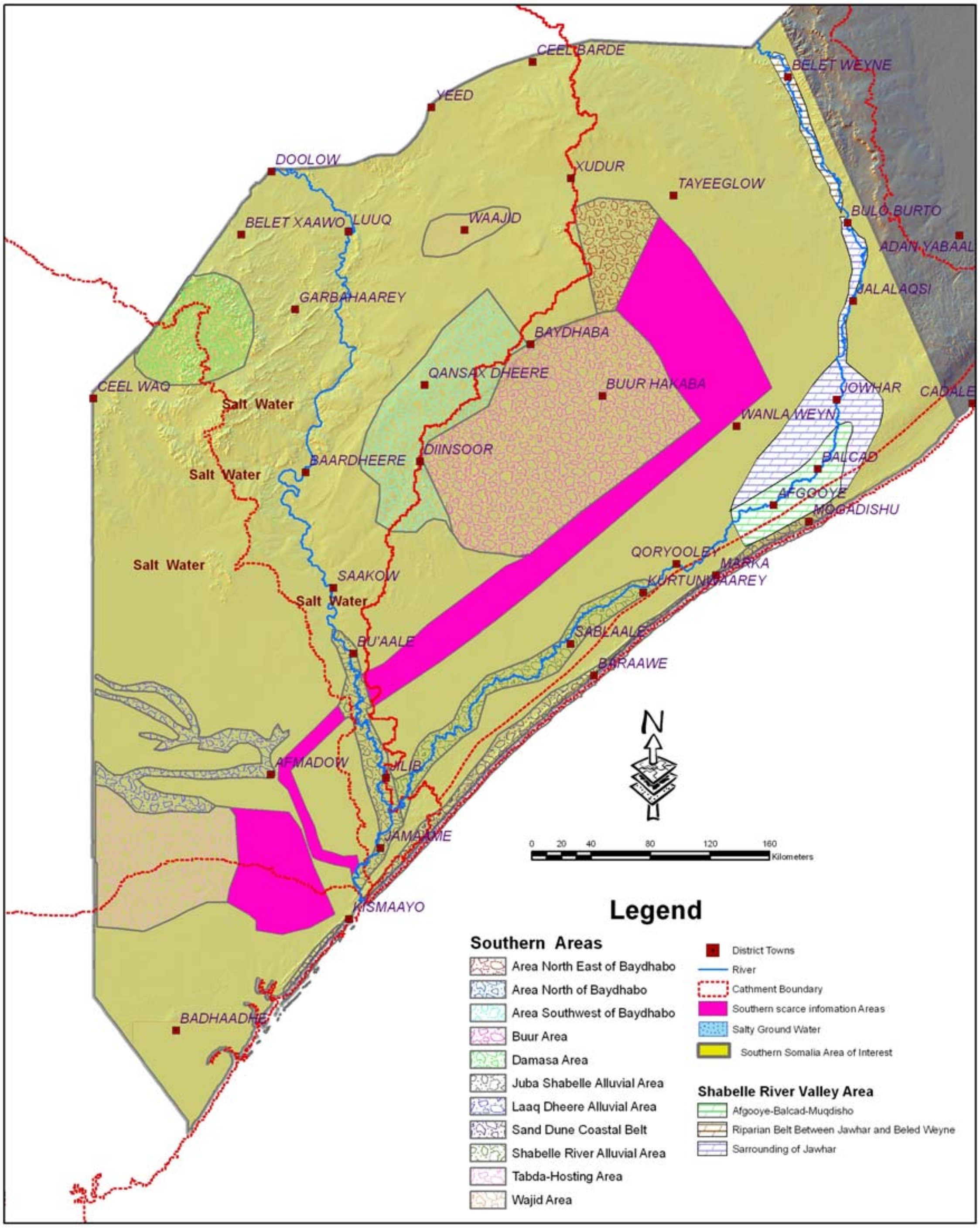
Upper and Middle Shabelle valley

Upper Shabelle is characterised by a broad valley delimited by geological formations composed of mainly limestone, gypsum, marls and sandstone. The Middle Shabelle valley consists mainly of clay and sandy clay overlaying gravel and clay layers. The groundwater movement in the riparian areas of the Shabelle river is along the river. The main formations are the Cretaceous Formations which supply water of marginal to salty quality, and the Alluvial Deposits which yield good to marginal quality water.

3.4.2 Potential groundwater development areas

Faillace and Faillace (1987) recommended certain areas that had good potential for groundwater development across the country. These are based on the hydrogeological and water quality suitability, using data of wells available at the time. Other factors important for groundwater development such as the potential for grazing, agriculture and population distribution were not included in the assessment of these areas.

These areas with good groundwater potential in the areas of the four basins are given in Table 3-30 and presented in Map 3-6. It should be noted that data on the nature, thickness and extension of aquifers are missing and only water quality information and descriptive information of the geological characteristics are available. The groundwater potential areas show that the well depths are in the range of 100-180 m. In addition to these deep wells that harness the deep aquifers in the region, water is also used from sub-surface layers at shallow depths along the various *toggas* and small streams.



Map 3-6 : Potential Groundwater Areas in Southern Somalia

(Source: Faillace and Faillace, 1987)

Table 3-30 : Areas with good Groundwater Potential in the Southern River Basins

No	Name	River Basin	Region	District	Electric Conductivity Range (µS/cm)	Well Depth (m)	Remarks
1	Baydhabo Plateau- Area north of Baydhabo	Juba	Bay	Baydhaba	650-250	100–150	Based on records of 15 drilled wells, good potential and can even be used for supplementary irrigation
2	Baydhabo Plateau- Area north-east of Baydhabo	Juba	Bay	Baydhaba	< 1,700	100-150	Based on well data along the perimeter of the area, additional wells required for further assessment
3	Baydhabo Plateau- Area south-west of Baydhabo	Juba	Bay	Baydhaba	900-6,500	100-150	Less favourable than areas 1.1 and 1.2 above
4	Waajid Area	Juba	Bakool	Waajid	252-4,200	60-80	Several faults, folds, karst holes and depressions provide fast recharge conditions
5	Damassa Area	Juba	Gedo	Goolow, Belet Xaawa	900	120-200	Pump test of one well = 28m^3/h for 54cm drawdown, additional 3-4 exploratory wells needed to assess, 2 wells in the area- best quality water
6	Tabda- Hosingo Area	Juba	L. Juba	Afmadow	1,700-5,520	120-180	Additionals wells recommended
7	Laaq Dheere – Laaq Bissic Alluvial Area	Lag Dera	L. Juba	Afmadow	NA	~ 10	Favourable for infiltration galleries, dug wells and shallow drilled wells

No	Name	River Basin	Region	District	Electric Conductivity Range (µS/cm)	Well Depth (m)	Remarks
8	The Juba River – Alluvial Area	Juba	M. Juba	Jilib, Bu'aale	NA	NA	Alluvial belt, from Dujuuma to Yoontay, has shallow groundwater table, good quality water
9	Shabelle River – Alluvial area between Buulo Mareeta and Homboy	Shabelle	L. Shabelle and M. Shabelle		NA	NA	Generally good water quality for dug wells and shallow drilled wells, water salinity increases towards the coast
10	Buur Area	Juba/Shabelle	Bay	Buur Hakaba	NA	NA	Good shallow aquifers along major *toggas* and drainage network good for recharge; surface water and groundwater dams can also be made to store water in stream beds, water quality varying from place to place
11	Afgooye-Balcad-Mogadishu	Shabelle	Shabelle Dhexe	Afgooye, Balcad and Mogadishu	NA	NA	Used for irrigation and water supplies of Balcad, Afgoye and Mogadishu, water of good quality
12	Jowhar and its surroundings	Shabelle	Shabelle Dhexe	Jowhar, Afgooye	NA	NA	Water table – 30-40 m deep, good to marginal quality
13	Shabelle Riparian belt between Jowhar and Beled Weyne	Shabelle	Hiraan	Jowhar, Beled Weyne,	NA	50-60	Shallow water table- dug wells and shallow drilled wells, Water table in 5-6 m

Source: Adapted from Faillace and Faillace (1987)

3.4.3 Groundwater use

Groundwater is harnessed by the rural and urban population to meet domestic and livestock water needs as well as for small scale irrigation. Major water sources using groundwater are shallow wells (hand-dug), boreholes, springs, sub-surface dams, and infiltration galleries.

An inventory of the water points is being collected and updated by SWALIM through coordination with agencies working in Somalia. The major groundwater sources that are used in the areas of the four basins are dug wells, drilled wells and others (springs). FAO-SWALIM database (SWIMS) contain 193 water sources listed in the three river basins (Table 3-31). No data has been received from Lag Badana river basin, mainly due to the security situation in the region. It is to be noted that the majority of these groundwater sources are dug wells although data on drilled wells were available in the Juba basin.

Table 3-31 : Water Sources from SWIMS Database

	Juba Basin	**Shabelle Basin**	**Lag Dera Basin**
Borehole	**31**	**4**	**2**
Urban	13	1	1
Nomad	3	0	1
Rural	4	0	1
Community owned	0	0	0
Dug Well	**24**	**97**	**4**
Urban	2	3	1
Nomad	8	0	2
Rural	9	81	1
Community owned	0	57	0
Other (springs)	**16**	**3**	**2**
Urban	1	0	0
Nomad	6	0	1
Rural	2	0	1
Community owned	0	0	0
Total Sources	**71**	**104**	**8**

Another database of water points, albeit a little outdated, digitised from the 1:100,000 topographical maps of Somalia, is also available for the whole country (Table 3-29). Interestingly, the majority of the water points are derived from the rainwater ponds and reservoirs. This is understandable given the fact that both rainfall and surface water is more available in this region than other parts of the country.

3.4.3.1 Dug Wells

Shallow dug wells are the most common sub-surface water sources in the area. Many of them, however, run dry during prolonged droughts. They are also known to have high organic contamination due to poor construction and common outlets for both livestock and humans. Data of this important source of groundwater has been collected by various sources. However, these are incomplete and data on the water consumption pattern, amount and purpose of use, are unavailable. FAO-SWALIM and partner agencies are collecting primary data on these water sources from the field for inclusion in the SWIMS Database.

In the Bakool region, a survey by UNICEF (1999) identified a total of 770 shallow wells, both permanent and seasonal. Only a small percentage of these water sources are functioning, as most of them have broken down. The average depth of the shallow wells in the district is 12m. Some are lined with concrete, but the majority have traditional timber logs for lining. In El Berde district only ten shallow wells were identified. The number is low because of the subsurface formation of fragile limestone intercalated with siltstones that tend to cave in with depth, making it difficult to construct dug wells.

The number of shallow dug wells in the Bay region is estimated to be 610, which includes 250 in Baidoa; 50 in Kansadere; 60 in Bardale; 90 in Burhakaba and 160 in Dinsor districts. The depth of the shallow wells vary across the districts, but is generally in the range of 8-10 m. Almost every household has a shallow well in the rural communities, whereas in the urban centres they are commonly constructed in clusters with the wells less than 300 m apart. The wells generally have stagnant water, cracked platforms and lacking proper drainage.

There are more than 200 shallow wells in the Hiran region, both communal and privately owned. Most of the wells are constructed either in limestone depressions in areas covered by gypsum, or along the river belt. Several shallow wells are also constructed along the main drainage system in Karstic limestone formation, though they tend to dry up during the dry period. However, most of the dug wells in the region have low recharge as a result of inadequate water column and caving in at the bottom due to upwelling of sands mainly along the tug beds and alluvial and sandy formations.

Gedo region has around 40 shallow wells (*ICRC, 2002*). The population served by these shallow wells is in excess of 140,000 families, both permanent and nomadic. Most of the wells are in a poor state, and need rehabilitation.

Construction technique used for the dug wells is poor, leading to cracked platforms that allow runoff water to seep back into the well. Many lack the well head, while those that have been rehabilitated have concrete lining only to a maximum depth of 10 m with the rest of the lining being either timber or natural stone.

3.4.3.2 Boreholes

Boreholes provide water throughout the year, and for communities living away from the major rivers they are the only source of water during prolonged drought periods.

A survey by UNICEF (1999) identified boreholes, along side shallow wells and *Mugciid*, as the main water sources in the Bakool region. There are a total of 31 boreholes in the Bakool region. However only three, representing 10% of the total boreholes, are functioning (Table 3-32)

Table 3-32 : Boreholes in Bakool Region

District	**Functioning Boreholes**	**Non-Functioning Boreholes**	**Boreholes Abandoned**	**Total No. of Boreholes**
Hoddur	0	0	11	11
Teyeglow	2	4	3	9
Rabdhure	0	2	2	4
El-Berde	0	0	1	1
Wajid	1	2	3	6
Total	3	8	20	31

Source: SWALIM Technical Report No. W-07

The average borehole depth varied from 90 m at Teyeglow district to 220 m at Hoddur. As a result of the civil strife in Somalia, many of the boreholes have been filled with stones and the power and pumping units have been looted. Both Rubdurre and El Berde districts have limited boreholes due to low yielding aquifers at great depths, leading to acute shortages of reliable water supply. Most structures accompanying boreholes -- water tanks, animal troughs and stand pipes -- were destroyed.

A total of 144 boreholes existed in the Bay region by the year 1999. The distribution of the boreholes per district is shown in Table 3-33.

Table 3-33 : Boreholes in Bay Region

District	Functioning Boreholes	Non-Functioning Boreholes	Boreholes Abandoned	Total No. of Boreholes
Baidoa	8	25	52	85
K/dhere	10	2	8	20
Bardale	9	6	5	19
B/khaba	0	2	5	7
Dinsor	1	3	9	13
Total	27	36	81	144

Source: SWALIM Technical Report No. W-07

The water table is fairly deep across the region. The average borehole depth is about 120 m. However, the static water level (SWL) varies from place to place. In Baidoa district, SWL is estimated at 63 m, while in Dinsor it is 73 m. In both cases the water yield is approximately 12m^3/hr.

In the Hiran region, borehole drilling started as early as 1915. A summary of the number of boreholes in each district is presented in Table 3-34.

Table 3-34 : Boreholes in Hiran Region

District	Functioning Boreholes	Non-Functioning Boreholes	Total No. of Boreholes
Belet Weyne	2	6	8
Bulo Burti	6	3	9
Jalalaqsi	4	2	6
Mahas	5	1	6
Mataban	1	4	5
Total	18	16	34

Source: SWALIM Technical Report No. W07 (2007)

The average depth of boreholes in the Hiran region is about 96 m, with the actual range identified as between 60 and 250 m. The average yield is estimated at 10m^3/hr.

According to ICRC (2002), there are six operational boreholes in the Gedo region. These boreholes serve a population of over 3,800 permanent families and 42,000 nomadic families. The average depth of boreholes in the region varies between 50 and 100 m. The depth increases with height above sea level. However, water quality according to ICRC is a major constraint, as large areas have water which cannot sustain people and livestock.

3.4.3.3 Springs

Both natural and man-made springs are also used for human and livestock water consumption. According to the data of water points derived from the 1:100,000 scale topographical maps (Table 3-29) there were 428 natural springs in Lag Dera basin, 38 in Juba basin and 10 springs in Shabelle basin. A number of man-made springs also exist in the region. Lag Badana basin did not include any identified springs.

3.5 Water demand

Water demand for human and livestock consumption is an important demand in any region in Somalia. A look at the topographical map with settlements show that settlements are mostly concentrated along the rivers and/or where there is good groundwater resource available. In the case of the areas covered by the four basins also, the riverine areas and the Buur area, where good groundwater resources are available, the areas are densely populated. As the Juba-Shabelle river basin is the food basket of the whole country, a good proportion of agricultural land is irrigated in this area. Hence, irrigation water is another major demand. Although these direct demands are important, one should not forget the water required to maintain the ecological balance. The aquatic life in the rivers as well as the flora and fauna in the swamps also requires water for their maintenance. The swamps which are fed by the Shabelle and Lag Dera rivers, as mentioned earlier, play a crucial role for the ecosystem as well as for recharging the aquifers in the region which are tapped by the many villages and towns. Hence, the environmental flow requirements cannot be ignored. As a good percentage of the population are nomadic, pastoralists and agro-pastoralists, there is a seasonal water demand pattern for most water sources, both surface water and groundwater.

3.5.1 Domestic demand

There is no household-level study on the water consumption pattern or water demand available for the region. Consequently, a rough estimate is made of domestic water demand, based on the UNDP draft population (2005). A per capita demand of 20 lpcd and 50 lpcd for rural and urban population is used. A total of 140,250 m^3 per day is required to meet the basic domestic water demand (Table 3-35).

Table 3-35 : Water Demand for Domestic Use in the Rural and Urban Areas of South-Central Somalia

Zone	**Region**	**Population Estimates**		**Water Demand Estimates (m^3/d)**		
		Urban	**Non-urban**	**Urban**	**Non-urban**	**Total**
Central	Hiraan	69,113	260,698	3,456	5,214	8,670
	Shabelle Dhexe	95,831	419,070	4,792	8,381	13,173
Benadir	Benadir	901,183		45,059	-	45,059
	Shabelle Hoose	172,714	677,937	8,636	13,559	22,194
South	Bay	126,813	493,749	6,341	9,875	16,216
	Bakool	61,438	249,189	3,072	4,984	8,056
	Gedo	81,302	247,076	4,065	4,942	9,007
	Juba Dhexe	54,739	184,138	2,737	3,683	6,420
	Juba Hoose	124,682	261,108	6,234	5,222	11,456
	Total	1,687,815	2,792,965	84,391	55,859	140,250

Note: [1] Only two regions (Hiraan and Shabelle Dhexe) are included from the Central region in this table.

Some urban towns in the region have piped water supply, utilities run by private, public or public-private partnership. However, they do not cover the total population of these towns. The water supply systems that were running before the civil war have been destroyed mostly and these are being slowly revived, but there is much still to be done. For example, the Jowhar water supply system that used to have 7000 household connections before the war is now connected to only 700 households through private connections (see Box 3-4)

Box 3-4 : Jowhar Water Supply System

Background

- Jowhar Town WS Sytem built in 1981-82 – vanadalized during the civil war.
- More than 30,000 people then relied on the low quality Shabelle river water.
- System rehabilitated in 1997 with support from EU and UNICEF.
- ‘Farjano’ (“Spring Heavan”) owned by 14 prominent business men representing a cross section of clans started operating and managing the system.

Salient Feautures of Water Supply System operated by Farjano

- Population of 13,000 served (23,256 users).
- Daily production – 300 m^3 from two new boreholes (yield > 70 m^3/hr) distributed without treatment.
- Hanti Wadaag Borehole ~ 60 m^3/hr supply to two 225 m^3 storage tanks in Horsed and Hanti Wadaag villages.
- Distribution system
    - Horsed Village Line – 7 public points (kiosks) and 99 private connections (~ 516 households (HHs));
    - Buulo Shiek Village Line – 5 kiosks and 27 private connections (~195 HHs);
    - Hanti Wadaag Village Line- 24 kiosks and 40 private connections (~2,483 HHs);
    - Kulmis Village Line – 6 kiosks and 29 private connections (~ 245 HHs);
    - Plus 5 international agencies;
    - 24-hour supply since 1997.
- Historical Tariff per m^3
    - 5000 SSh to water distribution operators and household consumers;
    - 6000 SSh to agencies.

Year	**Water Production (m^3)**	**Tariff**		**Total Revenue (US$)**
		So Sh	**US$**	
1997	14,671	5,000	0.66	9,683
1998	49,615	5,000	0.69	48,034
1999	37,103	5,000	0.63	23,375
			Total	**81,092**

- Current tariff and consumption (based on information provided in September 2007)
    - 1 US$ per m^3 in private connection (average consumption ~ 7 m^3 per household per month);
    - 0.5 US$ per m^3 to kiosks (currently 44 standpipes) privately operated and operators sell to consumers;
    - 1 kiosk supplies about 50 households (per household consumption about 60 litres per day);
    - Piped water supply mainly for drinking and cooking and secondary sources like shallow wells used for other purposes.
- Revenue enough to cover the Operation and Maintainance Cost and Farjano Company also runs school from its income.
- The present coverage includes 700 private connections (all metered with volumetric tariff) compared to 7000 before 1990.
- Clan members select the Board members of Farjano and there are four departments- Financial, Technical, Security and Personnel under a Chairmana and Vice-Chairman.

Source: UNICEF (1999) and Field Visit (2007)

3.5.2 Livestock demand

As livestock rearing is an important source of income for the people of the region, the demand for water for the livestock is considered vital. The people of the region practise a sedentary lifestyle. As they are involved both in agriculture and livestock rearing, the percentage of cattle is higher in this region compared to that of camels and sheep/goats than in the northern region of Somalia. The livestock are taken often to the rivers for watering. In fact, during the dry season, there occasions of conflicts between the nomadic populations who bring their livestock to the rivers and the local people living in the riverine areas, because the livestock destroy or eat the crops that are grown in the riverine areas.

Water demand for livestock has been based on 1988 data (*Ministry of Agriculure, cited by Musse, 1997*). The water demand for cattle, sheep/goats and camels have been taken as 25, 1.6 and 12 litres per head per day (l/h/d). A total of 114,000 m^3 per day of water is required for the livestock in the region (Table 3-36).

Table 3-36 : Water Demand for Livestock in South-Central Somalia in 1988

	Cattle		**Camel**		**Sheep/Goats**		**Total Demand (m^3/day)**
Region	**Head**	**m^3/day**	**Head**	**m^3/day**	**Head**	**m^3/day**	
Shabelle Dhexe	443,420	11,086	235,140	2,822	1,348,380	2,157	16,065
Shabelle Hoose	43,940	1,099	336,070	4,033	374,210	599	5,730
Benadir	25,530	638	1,140	14	32,430	52	704
Bakool	116,080	2,902	220,230	2,643	458,750	734	6,279
Bay	296,000	7,400	415,230	4,983	321,020	514	12,896
Gedo	612,900	15,323	899,270	10,791	1,566,160	2,506	28,620
Mid Juba	424,860	10,622	252,300	3,028	968,160	1,549	15,198
Low Juba	999,450	24,986	254,640	3,056	252,450	404	28,446
Total	2,962,180	74,055	2,614,020	31,368	5,321,560	8,514	113,937

3.5.3 Irrigation water use

The Juba and Shabelle river basins are considered the breadbasket of Somalia. They have considerable potential for irrigation development. It is estimated that up to 265,000 ha of land could be irrigated in these two basins if the pre-war irrigation infrastructure were brought back in operation. Based on the conclusions and recommendations of the "Banana Sector Study" (*EC, 2003*), efforts are being made by various donor agencies, including the European Community (EC), to restore the irrigation facilities and revive the agricultural sector for about 19,000 to 31,500 hectares, most of them on the Middle and Lower Shabelle. Private entrepreneurs are also investing to rehabilitate and maintain formerly irrigated plantations.

There are two major distinctions of river water use for agricultural production in the Juba and Shabelle river basins. Irrigation water is diverted to the irrigated areas either by pumps or by gravity flow through canals. In addition, cultivation is also carried out in flooded areas utilizing the moisture in the soil after flood recession; such areas are called "*deshek*".

The pre-war irrigation schemes are now in a state of disrepair, with most of the barrages and canals silted up and the gates and intakes inoperable due to lack of maintenance as well as due to intentional destruction of the structures during the conflict. In the 1920s, the Italian colonizers introduced controlled irrigation to grow a wide range of commercial crops such as cotton and bananas. Since then, a number of irrigation schemes were developed in the Juba and Shabelle rivers. There were altogether ten barrages (one in Juba and nine in Shabelle) that were constructed to regulate flows to the canals supply irrigation water to these irrigation schemes (*SWALIM Technical Report No. W-05*).

In addition, there were around 125 pumps in 1990 with an average pumping capacity of 150 l/s in operation supplying irrigation water to banana plantations in Lower Juba Valley (between Jamame and Kismayo).

Based on the available schemes, about 23,000 ha could be irrigated in the Juba basin with a future potential of about 50,000 ha. Irrigation schemes in the Shabelle basin itself could irrigate up to about 135,000 ha with a future potential of 215,000 ha if extensions were to be made. The ground reality now is that only a fraction of this area is presently being irrigated mainly because of the destruction of the infrastructure during the war and lack of operation and maintenance of the structures (barrages, intakes and canals).

3.5.3.1 Cropping patterns

The cropping patterns for irrigated agriculture were proposed by the SWALIM Land Suitability Assessment and were presented in Table 3-5 earlier. Basically, it consisted of fruit trees, maize and ground nuts in *Gu* and *Der* periods, tomatoes, sesame, cowpea and vegetable in Deyr and *Jilaal* seasons. It should be noted that irrigation can be considered for both seasonal (during wet seasons) and year-round (irrigating in dry season too) cultivation. As the Juba and Shabelle are important perennial rivers, year-round irrigation of some areas should be planned.

Cropping patterns have also been proposed and discussed by various other studies especially dealing with feasibility studies of individual projects. Henry (insert full name –Ed) (1979) has summarized the cropping patterns for irrigation areas in various stretches of Juba and Shabelle rivers.

In terms of irrigation planning, deciding on the cropping patterns and cropped areas for each crop is an iterative process which is based on the water availability and other resource constraints. As the scope of the present assessment does not include these aspects, a simple cropping pattern is used, based on the main crops, to assess the water balance in the two major rivers using some sort of scenario analysis. A simple cropping pattern (CP1) is presented in Table 3-37 based on the Land Suitability Study undertaken by SWALIM to estimate the crop water and irrigation requirements to get the water balance for various scenarios.

Table 3-37 : Representative Cropping Pattern and % Areas within Juba and Shabelle Basins

Crop	% of Total Area				
	Gu		Deyr		Perennial
	% Area	Start	% Area	Start	% Area
Maize	60	Mid Apr	26	Mid Sep	
Groundnuts	2	Beg. Apr			
Sesame			35	Mid Sep	
Vegetable	5	Mid Apr			
Bananas					10
Citrus					7
Sugarcane					16

3.5.3.2 Crop water and irrigation requirement

CROPWAT Version 4.3 for Windows developed by FAO has been used to derive the crop water requirements using climatological data for two locations, one each in the Juba and Shabelle basins. CROPWAT uses the Penman Montieth Method to derive the Reference Crop Evaporation (ETo). The crop coefficients for the crops have also been taken from the CROPWAT database. Effective rainfall is also calculated using the long-term average rainfall data.

Irrigation water requirement is a function of efficiency of delivering the crop water requirements for the crops. The following irrigation efficiencies are used to estimate the irrigation water demand.

Field application	0.65
Distribution	0.60
Overall	0.39

The overall efficiency is 39% which is quite reasonable for the conditions in Somalia.

Based on the cropping pattern given in Table 3-37, the field crop water requirements and irrigation demand calculated are given in Table 3-38 and Table 3-39, using the above efficiency figures and climate conditions of Jilib (Juba basin) and Jowhar (Shabelle basin).

Table 3-38 : Irrigation Water Demand for Selected Cropping Pattern (Jilib)

Month	ETo (mm)	ETm (mm)	Effective Rainfall (mm)	Net Irrigation (mm)	Field Water Supply (l/s/ha)	Irrigation Demand (l/s/ha)	Irrigation Demand m^3/ha
Jan	52.1	16.8	0.2	16.6	0.30	0.49	1324
Feb	53.3	10.6	0.0	10.6	0.00	0.00	0
Mar	51.4	13.7	0.4	13.2	0.00	0.00	0
Apr	47.3	20.2	23.4	2.6	0.05	0.08	208
May	42.4	28.3	39.6	0.0	0.00	0.00	0
Jun	38.3	40.8	29.2	11.6	0.20	0.34	908
Jul	36.1	40.9	16.3	24.6	0.44	0.73	1964
Aug	36.3	30.7	7.9	22.8	0.41	0.68	1815
Sep	38.5	14.1	4.3	9.8	0.17	0.29	774
Oct	41.9	18.3	8.6	9.8	0.17	0.29	774
Nov	45.4	31.8	14.5	17.4	0.31	0.52	1384
Dec	42.0	34.0	9.2	24.8	0.51	0.85	2277
Annual	525.0	300.2	153.6	163.8	0.21	0.36	11428

Table 3-39 : Irrigation Water Demand for Selected Cropping Pattern (Jowhar)

Month	ETo (mm)	ETm (mm)	Effective Rainfall (mm)	Net Irrigation (mm)	Field Water Supply (l/s/ha)	Irrigation Demand (l/s/ha)	Irrigation Demand m^3/ha
Jan	41.6	13.4	0.2	13.3	0.24	0.39	1,056
Feb	42.9	8.5	0.0	8.5	0.00	0.00	-
Mar	42.1	11.2	0.6	10.6	0.00	0.00	-
Apr	39.7	17.0	19.5	1.9	0.03	0.06	149
May	36.8	24.5	25.8	2.4	0.04	0.07	193
Jun	34.5	36.7	13.3	23.4	0.42	0.69	1,860
Jul	33.4	37.8	6.1	31.8	0.57	0.94	2,530
Aug	34.0	28.7	0.9	27.8	0.50	0.83	2,217
Sep	35.7	13.1	0.2	12.9	0.23	0.38	1,027
Oct	37.8	16.5	15.5	2.4	0.04	0.07	193
Nov	39.5	27.6	19.5	8.1	0.14	0.24	640
Dec	34.8	28.2	6.7	21.5	0.44	0.73	1,964
Total	**452.7**	**263.4**	**108.4**	**164.5**	**0.22**	**0.37**	**11,830**

3.5.3.3 Water balance

In order to make an estimate of the water balance in the Juba and Shabelle rivers, 80% dependable monthly flows are considered at Berdheera in Juba river and Mahadey Weyne in Shabelle river.. As no seasonal regulation storage is available, the following irrigation scenarios are considered to assess the irrigation water potential of the two rivers.

Juba Basin

Scenario 1 – Irrigating 25,000 ha (based on the assumption that the pre-war irrigation infrastructure is rehabilitated to full operation);

Scenario 2 - Irrigating 50,000 ha (based on the assumption that some extension is made using the pre-war irrigation infrastructure).

Shabelle Basin

Scenario 3 – Irrigating 50,000 ha (approximately the present irrigated areas);

Scenario 4 – Irrigating 135,000 ha (based on the assumption that the pre-war irrigation infrastructure is rehabilitated to full operation);

Scenario 5 - Irrigating 215,000 ha (based on the assumption that some extension is made using the pre-war irrigation infrastructure).

The water balance for the above five scenarios and the estimate of the maximum land that could be irrigated based on the available flows in Juba at Bardheere and Shabelle at Mahadey Weyne are presented in Table 3-40 and Figure 3-42, and Table 3-41 and Figure 3-43 respectively.

It can be seen that the up to 50,000 ha could be irrigated year round with the available flow in Juba (Figure 3-42) whereas the crops (second crop of maize and sesame) would be cultivated in more than 170,000 ha of land.

In the case of Shabelle where the flow is lower, it is not possible to irrigate such a large area (as considered to be possible by the available infrastructure) year round. Irrigation could be provided to up to 25,000 ha in Gu season whereas it could be increased to about 80,000 ha for the *Deyr* crops. As the maximum limitation for irrigation in January and December is only about 17,000 ha, the % of areas with perennial crops has to be limited to that area (Table 3-41 and Figure 3-43).

The calculation presented here is for the purpose of an estimation of the available surface water for irrigation without regulation. However, if regulation is possible, a larger area could be irrigated. The change in cropping pattern could also lead to more areas being irrigated. It should be noted that the flows available in the rivers during February and March are quite low, so irrigated agriculture is not planned for this period. The requirement for minimum flow release for environmental and other purposes also need to be considered while planning the irrigation from the rivers.

Table 3-40 : Scenarios of Water Balance in Juba River

Month	**Irr. Water Demand**			**80% Dependable Flow at Berdheere**	**Max. Irrigation Possible**
	m^3/ha	**25,000 ha**	**50,000 ha**		
		mcm		**mcm**	**ha**
Jan	1,324	33	66	62	47,124
Feb	0	0	0	39	-
Mar	0	0	0	25	-
Apr	208	5	10	56	270,000
May	0	0	0	301	-
Jun	908	23	45	272	300,098
Jul	1,964	49	98	337	171,409
Aug	1,815	45	91	428	235,623
Sep	774	19	39	469	606,462
Oct	774	19	39	564	728,308
Nov	1,384	35	69	419	302,710
Dec	2,277	57	114	144	63,176

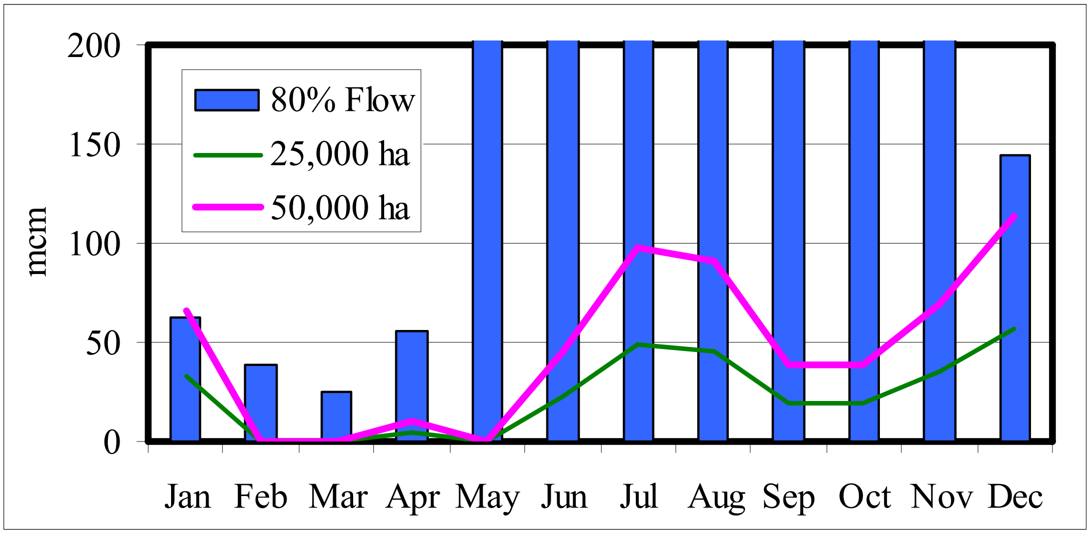


Figure 3-42 : Water Balance for different Irrigation Scenarios (Juba River)

Table 3-41 : Scenarios of Water Balance in Shabelle River at Mahadey Weyne

Month	Irr. Water Demand				80% Dependable Flow at Mahadey Weyne	Max. Irrigation Possible
	m^3/ha	50,000 ha	135,000 ha	215,000 ha		
		mcm			mcm	ha
Jan	1,056	53	143	227	18	16,641
Feb	0	0	0	0	11	-
Mar	0	0	0	0	6	-
Apr	149	7	20	32	13	87,660
May	193	10	26	42	147	759,115
Jun	1,860	93	251	400	80	42,869
Jul	2,530	127	341	544	65	25,504
Aug	2,217	111	299	477	181	81,728
Sep	1,027	51	139	221	272	264,819
Oct	193	10	26	42	211	1,092,711
Nov	640	32	86	138	81	126,431
Dec	1,964	98	265	422	32	16,480

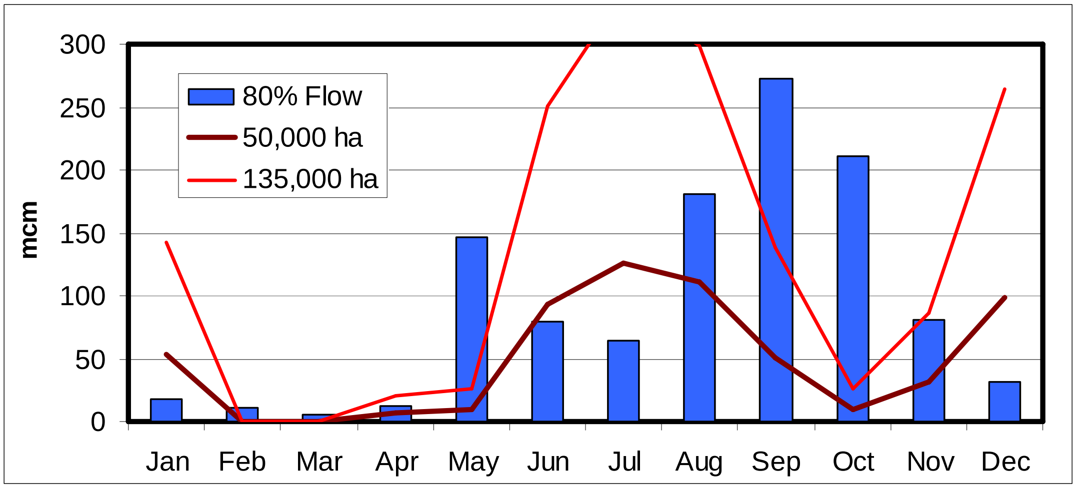


Figure 3-43 : Water Balance for different Irrigation Scenarios (Shabelle River).

4 Major River Basins in Central-North Somalia

4.1 General characteristics

The major drainage basins in the central and northern regions of Somalia are: the Gulf of Aden Basin, Darror Basin, Tug Der/Nugal Basin and Ogaden/Central Basin (*see Map 4-1*). Further sub-classifications of the northern drainage basins is presented in Map 4-2. In addition to these, the narrow strip of land along the Indian Ocean has short drainage networks and there is not much flow in these drainage channels that reaches the Indian Ocean. Unlike the Juba and Shabelle river basins which originate in the Ethiopian and Kenyan highland areas, these basins have little surface runoff and rainfall in the basins which are mostly lost through infiltration and evaporation. There are, however, some short streams (*toggas*) especially in the mountainous regions in the north that have flow through out the year in some stretches. There is a complex surface water-groundwater interaction along the *toggas,* whereby in some stretches there is surface runoff and in others there are mostly sub-surface interflows and recharging of groundwater aquifers. Natural springs are also common in the mountainous regions of the north where the rocky outcrops intersect the groundwater tables. Sub-surface flows along the *toggas* and groundwater available in springs (mountainous areas) and in shallow and deep aquifers are an important source of water for people and livestock in these drainage basins. Catchment rainwater harvesting through *wars* and *berkads* is also prevalent.

This chapter covers the water assessment of the above six drainage basins in Central and Northern regions of Somali.

4.1.1 Location

Gulf of Aden Basin

The Gulf of Aden basin, situated in the northern parts of Somalia, covers the areas drained by the small *wadis* and *toggas* that originate from the gently sloping plateau and passes through the mountain range extending in an east-west direction before reaching the coastal region to flow into the Gulf of Aden. The drainage area covered by these small seasonal streams, collectively known as the Gulf of Aden basin, is about 74,500 km^2 (based on the 90m SRTM DEM data). The drainage area is spread over five regions- Awdal, W. Galbeed, Togdheer, Sanaag and Bari and 15 districts within the regions (see Map 4-3). As administrative boundaries of regions and districts do not necessarily match the basin boundaries, the drainage basin covers only parts of some of these regions and districts. The drainage area lies roughly between 42^o 42' and 51^o 22' east of the Prime Meridian and between 9^o 28' and 12^o 1' north of the Equator. The most important towns lying within the drainage basin are Borama, Gebiley, Hargeisa, Berbera, Ceerigabo and Bossaso.

Darror Basin

The Darror basin mainly drains the Darror Valley and flows into the Indian Ocean. It covers an area of approximately 34,200 km^2 (based on the 90m SRTM DEM data) and is spread over the Sanaag and Bari regions and six districts within them (see Map 4-3). To its north lies the eastern part of the Gulf of Aden basin and to its south is the Tug Der/Nugal basin. The drainage area lies roughly between 47^o 52' and 51^o 15' east of the Prime Meridian and between 9^o 47’ and 11^o 35’ north of the Equator. The most important towns lying within the drainage basin are Gardho, Ishkushiban.

Tug Der/Nugal Basin

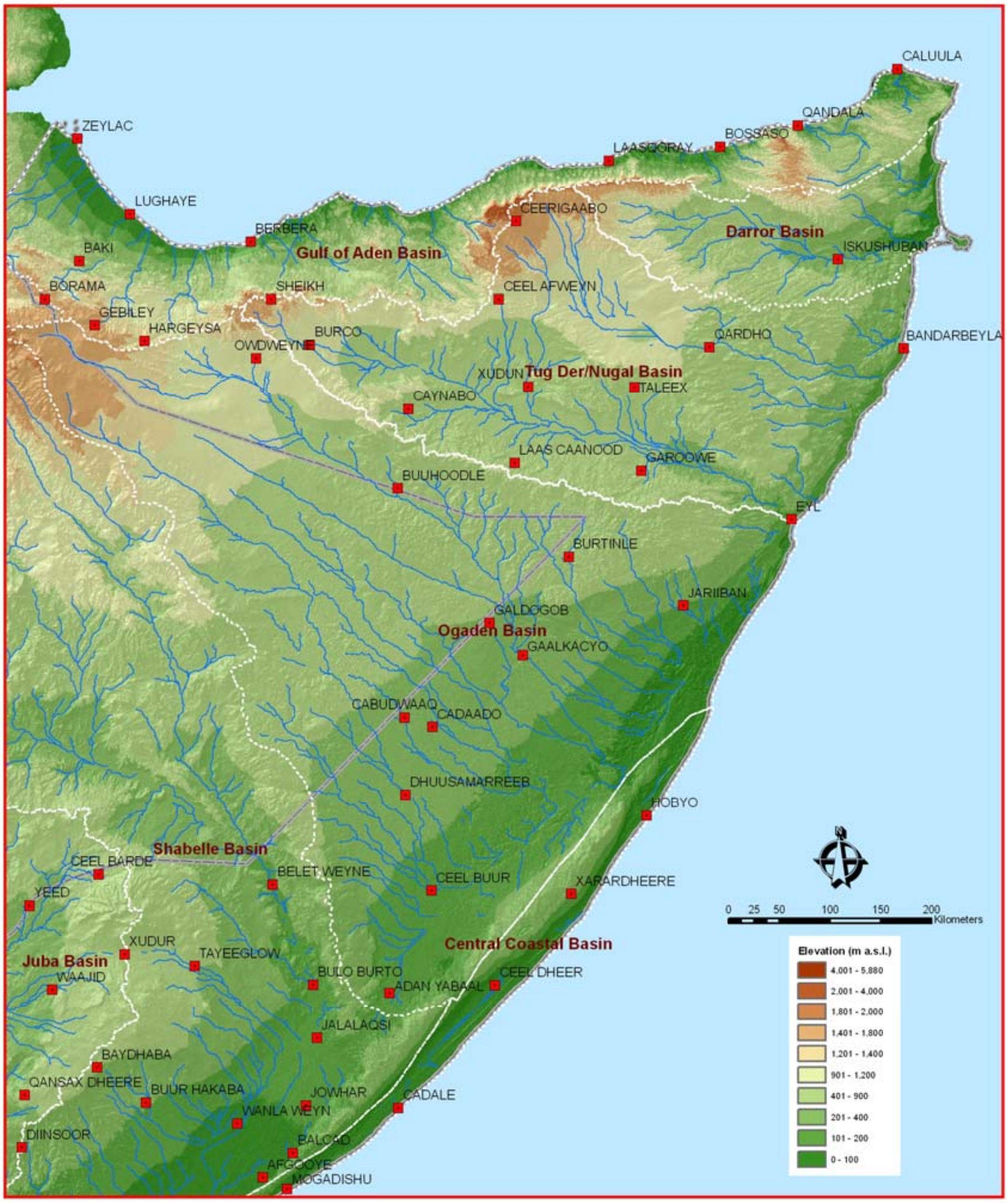
The Tug Der/Nugal basin lies to the south of the Darror Valley and the mountain range in the central part of north Somalia. It covers an area of approximately 112,200 km^2 (based on the 90m SRTM DEM data) and is spread over five regions- Togdheer, Sool, Sanaag, Nugaal and Bari and 16 districts within them (*see Map 4-3*). The drainage area lies roughly between 44^o 57’ and 50^o 59’ east of the Prime Meridian and between 7^o 55’ and 10^o 57’ north of the Equator. The most important towns lying within the drainage basin are Burco, Los Anod, Garoowe, Eyl.

Ogaden Basin

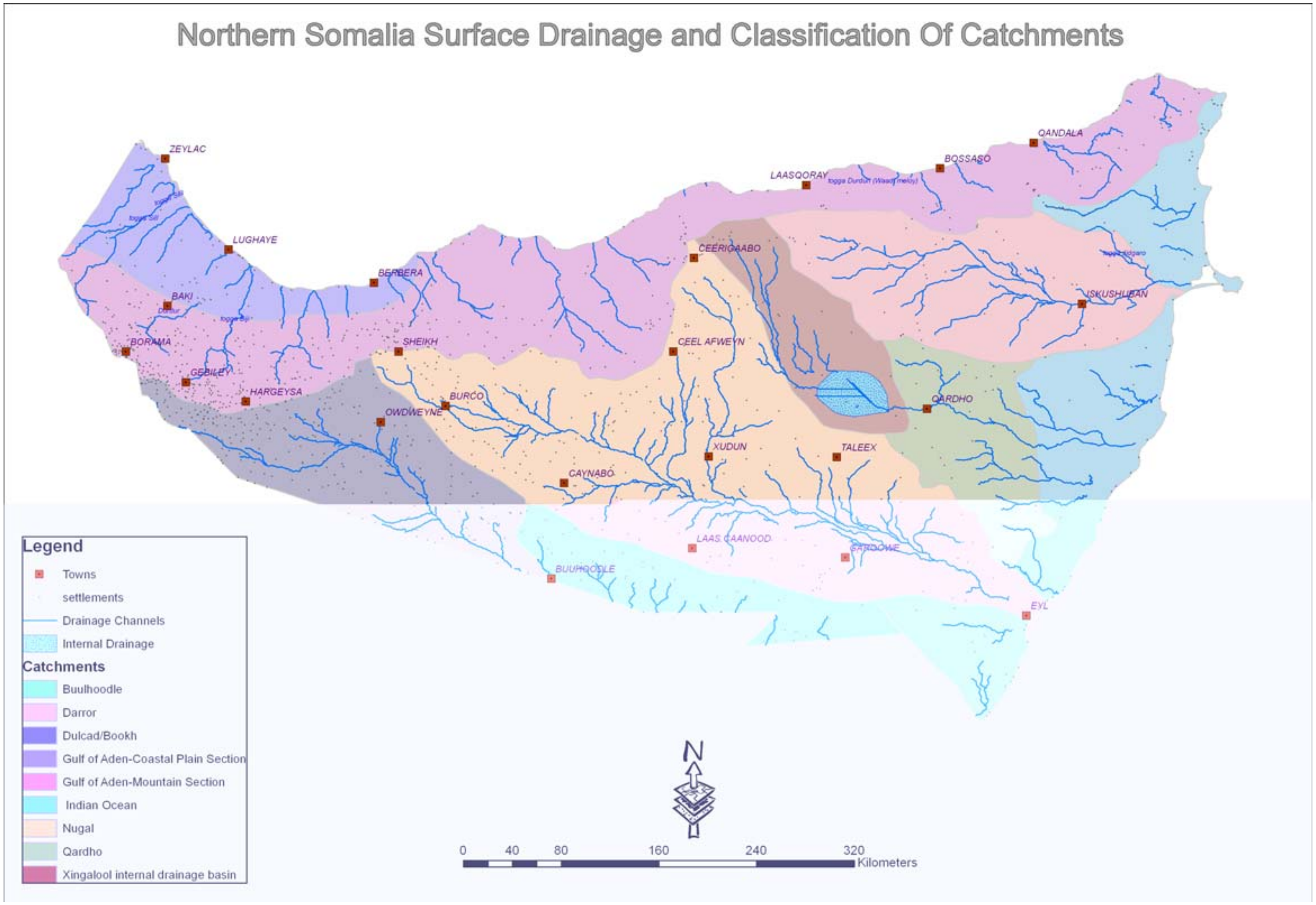
A major part of the central region of Somalia is drained by the extension of the Ogaden desert that can be considered to extend from the Ethiopian region northeast of the Shabelle river catchment area. As the area is mostly arid, with the least developed drainage network, localized runoff occurs during high rainfall but quickly dissipates through evaporation and infiltration. Virtually no water flows from one area to another, let alone any water reaching the sea. The total drainage area of the Ogaden basin extending from Ethiopia to coastal areas in Somalia is about 235,000 km^2 (based on 90m SRTM DEM data). Within Somalia, the area extends over seven regions and 20 districts within them (*see Map 4-3*). The drainage area lies roughly between 42^o 45’ and 49^o 55’ east of the Prime Meridian and between 3^o 32’ and 9^o 50’ north of the Equator. The only major urban centre (town) within the drainage basin is Galkayo.

Central Coastal Basin

The numerous small drainages, within the narrow strip of land along the Indian Ocean coast which flow towards the Indian Ocean, are collectively referred to as the Central Coastal basin. It stretches from just below the Equator to about 6^o north of the Equator. The inland boundary south of Mogadishu is formed by a range of sand hills of less than 150m in height. The drainage area stretches over the coastal areas of the five regions and ten districts within them (*see Map 4-3*). The drainage area lies roughly between 42^o 40’ and 49^o 7’ east of the Prime Meridian and between 0^o 15’ and 6^o 25’ north of the Equator. There are a number of coastal towns lying within the drainage basin including the capital of Somalia, Mogadishu.



Map 4-1 : Major Basin Location Map for Nothern Somalia



Map 4-2 : Classification of Catchments of Northern Drainage Basins

Map 4-3 : Regions and Districts Covered by the Central-Northern Drainage Basins

4.1.2 Topography and physiography[4]

Gulf of Aden Basin

The Gulf of Aden basin (drainage area 74,422 km^2) includes a variety of morphological features, such as accentuated reliefs, escarpment, steep slopes, coastal plains, internal plateaus and valleys. The high mountain range runs parallel to the shore of the Gulf of Aden. The highest peak is Mt. Surud, with an elevation of 2,408 m. The mountain range is constituted by crystalline rocks which are deeply incised by numerous *toggas* that flow towards the Gulf of Aden.

Many seasonal streams (*wadis* and *toggas*) originate from the gently sloping plateau (elevation ranging 1000 m and 1600 m) in the southern part of the western region of the basin. These streams then cut through the mountain range that extends in the east-west direction and flows to the coastal region of the Gulf of Aden. The area north of the mountain range is constituted by the sloping plain and the coastal range with elevation ranging from about sea level to 600 m. The drainage basin can be further classified into two sections, the coastal plane section and the mountain section (*Map 4-2*).

A number of large but seasonal streams, the *toggas*, flow in the western part of the Gulf of Aden basin. They include from east to west Tug Waheen (3000 km^2), Tug Durdur (3850 km^2), Tug Biji (3560 km^2) and Tug Silil (1930 km^2). Surface runoff occurs in these *toggas* only after heavy rainfall in the upstream (plateau) areas of the catchments which may last for few hours to a few days. The flow, however, may be perennial in the mountain range where bedrocks are exposed. However, in sandy wide channels of the streams, in valley bottoms and in the coastal plains, the surface runoff disappears through infiltration, evaporation and bank overflows to flood plains and little water, if any, is known to reach the sea.

The central region of the Gulf of Aden basin is marked by a high mountain range running west to east parallel to the coast and south to north along the 47^o E meridian (highest peak of 2410 m), The area is deeply incised with numerous *toggas*, the major ones being the Tug Jangarra (3700 km^2), Tug Hodmo (3800 km^2) and Tug Belgeabbili (4,800 km^2). The water from the *toggas* barely reaches the seas and infiltrates in the coastal plains.

The eastern part of the basin consists of a relatively narrow strip of land, bordered to the south by a mountain range varying in elevation from 500 m to well over 2000 m. The drainage network in this area is dense. Numerous short *toggas* dissect the escarpment facing the Gulf of Aden. Although short duration storms often generate brief spate flows, total runoff volumes are relatively small due to small catchments as well as limited rainfall in the area.

In terms of the elevation variation in the basin, the elevation varies from sea level in the coastal areas to over 2000 m in the mountain ranges that extend from the east to the west of the basin. The area slopes from the south to the north with the drainage flowing towards the Gulf of Aden, albeit very little, if an,y reaching the sea, as explained above. From Table 4-1, it can be seen that 42% of the area is below 500 m, 94% below 1500 m and 5% of the area lies between 1500 m to 2000 m. The hypsometric curves are presented in Figure 4-1.

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[4] The physiographic features have been adapted from Kammer (1989) and Faillace and Faillace (1989) but have been updated with new information, where available.

The Darror Basin

The Darror basin covers an area of 34,195 km^2 more than half of which is above 500 m (*Table 4-1*). To its north is the eastern part of the Gulf of Aden basin and to its south are the featureless plateaus separating it from the Tug Der/Nugal basin. This drainage basin is drained by a fairly dense network of seasonal streams. There are three main *toggas* that reach the Indian Ocean. The northernmost one is the Wadi Jeceyl which has a catchment area of over 3,800 km^2. Tug Dhut, also called Tug Jaceyl, downstream of Iskushuban, drains the Darror Valley and its western extension as far as Hadaaftimo. The Darror Valley is located south of the northernmost mountainous area and extends from west to east over a length of about 350 km with an area of over 25,000 km^2 with elevations varying from about sea level to 1,500 m. There are a number of small drainages north of the Darror Valley that flow from west to east towards the Indian Ocean, whose catchment does not contribute to flows in the main water course of the Darror Valley (*see Map 4-2*). For convenience of proximity of geography and climate, it has been grouped together while classifying the major drainage basin as the Darror basin.

The Tug Der/Nugal Basin

The Tug Der/Nugal basin lies to the south of the Darror Valley and the mountain range in the central part of north Somalia. The Tug Nugal drains the Nugal region and parts of the Togdheer and Sool regions. The Nugal valley extends over 600 km in length with elevations varying from about sea level in the east to 1,200 m a.s.l in the west. The Sool Plateau, a nearly featureless plain covered by limestone and marls, lies between the Darror and Nugal valleys. The elevations of the basin area vary from sea level in the west to over 2000 m in the mountain area of the north-east of the basin. The highest point is 2,233 m. About 24% lies below 500 m, 58% between 500-1000 m, 15% between 1000-1500 m, 3% between 1500-2000 m and a small part of the basin (<1%) is above 2000 m (*Table 4-1*). A large part of the drainage basin is made up of gently sloping plains such as the Sool Plateau, Sool Haud and Qardha Plateaus, and the Karman and Gubato plains.

Tug Der and Tug Nugal are two main drainage systems, which forms a large valley extending over 600 km in length in the southern and western parts of the drainage basin. The total catchment area of the drainage basin is about 112,231 km^2. An interesting part of this drainage basin is the Xingalol Internal drainage basin which receives water from the Sool Haud Plateau.

The Tug Der/Nugal drainage basin can be further sub-classified into four sections- Nugal Catchment, Xingalol internal drainage basin, Qarda Plateau Catchment and a ground of small streams in the east that flows towards the Indian Ocean (*Map 4-2*). The drainage network is relatively dense in the major valleys and on sloping areas but is less developed in the plateaus and the plains.

The Ogaden Basin

The Ogaden drainage basin is roughly triangular in shape and has a total area of about 149,559 km^2. Its elevation ranges from about sea level in the east to 1,563 m in the west. About 76% of the area is below 500m, 8% is between 500-1,000m, 16% is over 1,000 m (*Table 4-1*). The drainage network in most of the Ogaden region and central Somalia is very sparse and ill defined. The only reasonably well defined water course is in the Bokh Valley in northern Somalia which has a total length of about 180 km. In other areas, there is some occasional, localized surface runoff generated in the poorly developed seasonal streambeds, but this generally disappears quickly through evaporation and infiltration. No water reaches the Indian Ocean.

The drainage basin can be further classified into a number of sub-catchments. These include the Dulcad/Bokh catchment and Buuhoodle catchment that extends into both Somalia and Ethiopia (*parts of which are shown in Map 4-2*). Again, catchments of small drainages that flow directly into the Indian Ocean are included in the Ogaden drainage basin.

The Central Coastal Basin

The central coastal region drainage basin is defined as the narrow strip of land in the coastal areas of the Indian Ocean separated from the inland areas by a range of sand dunes (hills) which as generally less than 150 m high. North of Mogadishu the strip widens and the elevations along the inland boundaries increase to 452 m.

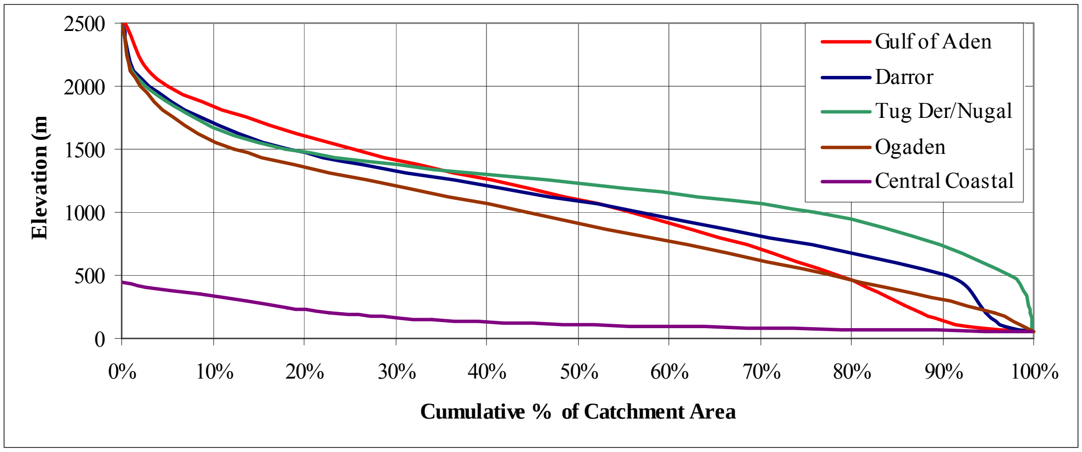


Figure 4-1 : Hypsometric Curves for Major Basins in Central-Northern Somalia (based on 90m SRTM DEM data)

Table 4-1 : Physiographic Characteristics of the River Basins in Central-Nothern Somalia

Basin	Catchment Area (km^2)	Max Elevation (m)	Catchment Area under different elevation levels (m)							
			<50	50-100	100-200	200-500	500-1000	1000-1500	1500-2000	2000-2500
Gulf of Aden	74,422	2,447	7%	5%	9%	23%	30%	20%	5%	0.4%
Darror	34,195	2,021	3%	2%	4%	34%	39%	15%	3%	0.0%
Tug Der/ Nugal	112,231	2,233	0.2%	0.2%	2%	21%	58%	15%	3%	0.04%
Ogaden	149,559	1,563	20.5%	0%	30.1%	25.4%	8.2%	15%	0.7%	0%
Central Coastal	27,638	452	40%	25%	16%	18%				

Note: the above physiographic characteristics are derived from the 90 m SRTM DEM

4.1.3 Land resources

The northern part of the country (northern Somaliland and Puntland), covering the Gulf of Aden, the Darror and the Tug Der/ Nugal basins, is characterized by an association of shallow and/or stony soils and somewhat deeper calcareous soils. A small area with deep, clayey soils is found south of Gebiley in the Gulf of Aden (south-western Somaliland). The central part of the country covering the Central Coastal and Ogaden drainage basins is dominated by sandy soils along the coast (Central Coastal basin) and moderately deep loamy soils with a high content of calcium carbonate and/or gypsum further inland (Ogaden basin) (*SWALIM Technical Report No. L-12, 2007*).

Based on the agro-ecological zones for Somalia that have been defined and mapped by SWALIM, all land areas lying in the five drainage basins of the central and northern regions are categorized as not suitable for irrigated agriculture. It should be noted, however, that some patches of areas along the *toggas* in the mountainous regions in North Somalia are suited for irrigated agriculture (e.g. Durdur and Gebiley watersheds described below). Some areas in the plateau areas in the northwest part of the country (around Hargeisa) are marginally suitable (S3) for rain-fed cultivation. However, these areas are mostly moderately (S2) or marginally (S3) suitable for extensive grazing and forestry plantation. SWALIM Technical Report No. L-12 (2007) presents the map and other details of the agro-ecological zones for Somalia.

SWALIM has undertaken a land suitability assessment in two main areas of interest, one in the north in the Dur Dur and Gebiley watersheds in the Gulf of Aden drainage basin in Somaliland (*Technical Report L-09, 2007*) and another in the riverine areas of the Juba and Shabelle rivers (*Technical Report L-09, 2007*). The latter was covered in Chapter 3. These were based on various land resources surveys carried out by SWALIM. The results of these surveys are documented in SWALIM Technical Reports Nos. L-02 (Landform), L-03 (Land cover), L-07 (Land use), and L-08 (Soils), respectively.

As land suitability assessment has been specifically carried out in the Durdur and Gebiley areas of the Gulf of Aden basin, the suitability of the land in these areas is presented in detail below.

Land Suitability for Rainfed Agriculture

Because of the arid and semi-arid conditions in the area, most of the attention has been paid to crops with a short Growing Period (GP). Four land utilization types (LUTs) were analysed, characterized by the production of individual crop varieties. They are: cowpeas (with short Growing Period(GP)), maize (with short GP), sorghum (with short GP) and sorghum (with long GP).

The study area has no land that is suitable (class S1) for the four rainfed crops which have been analysed. This is largely due to the fact that even in areas with relatively high mean annual rainfall (north-western plateau), long-term average crop yields will remain below their potential because of rainfall variability (both seasonal and annual), erosion hazard and low soil fertility. Although both erosion hazard and low soil fertility could be overcome by improved management and increased inputs, this would mean increased costs which are unlikely to be off-set by increased production.

About 14 % of the study area (185,000 ha) was found to be moderately suitable (class S2) for all four crop varieties analysed. Most of the moderately suitable land is found on the plateau, around Gebiley. In this area, relatively high rainfall (around 500mm) and moderate LGP (90 - 120 days) combine with deep soils (Vertisols) and gentle slopes to create favourable conditions for the cultivation of drought-resistant crops. Moderate limitations are posed by the variability in rainfall and LGP and by erosion hazard, preventing the realization of sustained high yields.

One-third of the study area is marginally suitable (class S3) for three of the four crop varieties analysed (cowpea, and the two sorghum varieties). For maize, which has somewhat higher moisture requirements, only 15% has been classified as marginally suitable. The main limitation is low moisture availability because of arid climatic conditions and/or shallow soils. Many of the main alluvial plains and floodplains have also been classified as marginally suitable because of the hazard of flooding.

More than 50% of the study area is unsuitable (class N) for the rainfed production of cowpea and sorghum, and more than 70% is unsuitable for maize. Most of the study area poses severe limitations for these types of land uses because of arid or desert climatic conditions and/or shallow and stony soils with poor rooting conditions and very low water holding capacity.

From the above, we can see that only the plateau area with relatively high rainfall is (moderately) suitable for rainfed crops. This area has two short growing periods (*Gu* and *Deyr*, respectively), separated by a short dry period (*Hagaa*). Farmers can follow two strategies: either grow a crop with a very short growing period in the *Gu* and/or *Deyr* period, or plant a drought resistant crop with a long growth cycle which can make use of both *Gu* and *Deyr*. Presently farmers in the area follow the latter strategy and grow a sorghum variety (*Elmi Jama*) with a growing period of 180 days. However, an improved early maturing variety is likely to give a better yield then the traditional late maturing variety. Also, any early maturing crop gives the farmer the opportunity to plant a second sequential or relay crop on the same land within a year (*SWALIM Technical Report No. L-06, 2007*).

The cropping calendar for some rain-fed crops is presented in Figure 4-2.

Land Suitability for Irrigated Agriculture (Orchards)

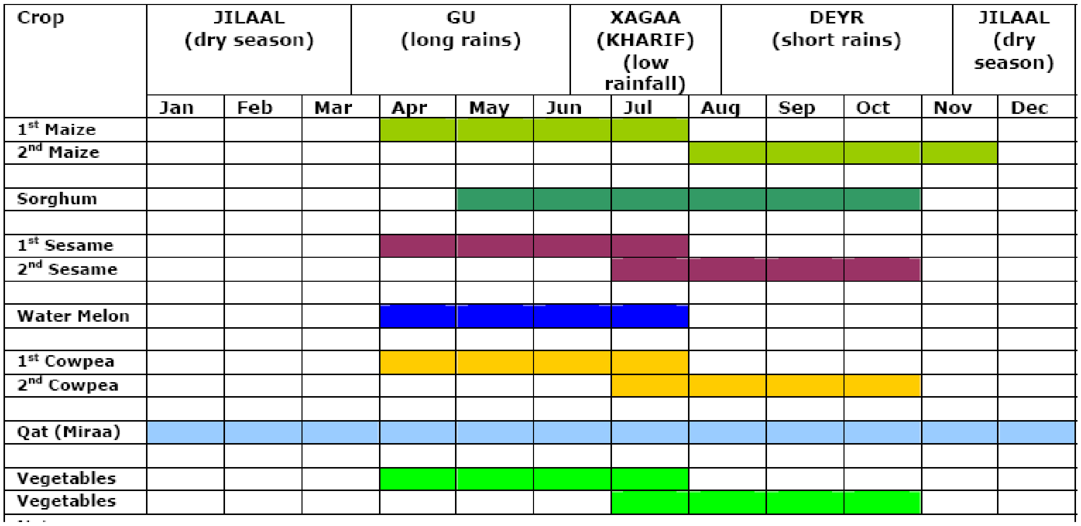
No systematic land evaluation has been carried out for irrigated agriculture. There is no water available for irrigation in most of the study area. Even the construction of storage dams or the application of water harvesting techniques would not solve the problem of general water deficit in the area. Potential evapotranspiration (PET) greatly exceeds precipitation throughout the year. Also there are no rivers bringing water from outside the study area and no known significant underground water reservoirs.

However, small surface water and underground water supplies exist locally along the major seasonal rivers (*toggas*), draining the mountains and the plateau. Small-scale irrigation is possible in these floodplains where water supplies occur close to pockets of deep soil. In fact, most of these areas are already used for irrigated gardens (orchards). Such scattered areas of irrigable land are usually not larger than half a hectare or less and used for the production of fruits (citrus, mango, papaya, guava) and vegetables.

Only a rough estimate was made of irrigable land due to the scale of the study, based on the estimation that roughly 30% of the braided river plains of the plateau, mountains and piedmont have suitable land. In this case, suitable land means gently sloping, slightly elevated land with deep soils along the main sandy and/or stony river beds.

About 10,500 ha of land (only about 0.8% of the total study area) consisting of braided river plains in the mountains and on the plateau was estimated to be suitable for irrigated agriculture. This figure should only been seen as an upper limit. The availability of water will be an important factor for irrigating this land. Also, because of land fragmentation, irrigation may be impractical or not cost-effective on some of the “suitable” land.

The 10,500 ha of estimated irrigable land refers to the total area of land near a water source and comprises a great number of the small patches of irrigable land in the narrow valleys in the mountain and plateau area. Although more detailed study is needed, it is likely that most suitable land is already used for irrigation and that future development of irrigated agriculture should focus on improved management of orchards, rather than expansion.



Crop	JILAAL (dry season)			GU (long rains)			XAGAA (KHARIF) (low rainfall)	DEYR (short rains)			JILAAL (dry season)	
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1st Maize				🟩	🟩	🟩	🟩					
2nd Maize								🟩	🟩	🟩	🟩	
Sorghum					🟩	🟩	🟩	🟩	🟩	🟩		
1st Sesame				🟥	🟥	🟥	🟥					
2nd Sesame							🟥	🟥	🟥	🟥		
Water Melon				🟦	🟦	🟦	🟦					
1st Cowpea				🟨	🟨	🟨	🟨					
2nd Cowpea							🟨	🟨	🟨	🟨		
Qat (Miraa)	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦
Vegetables				🟩	🟩	🟩	🟩					
Vegetables							🟩	🟩	🟩	🟩		

Source: SWALIM Project Report No. L-06 (2007)

Figure 4-2 : Crop Calendar for Some Rain-fed Agriculture in Durdur Catchment

4.1.4 Socio-economics

The four drainage basins in the central and northern regions of the country lie in the two autonomous regions of Somalia, namely Somaliland and Puntland. Although they have not been officially recognized by the international community, their existence and the water (? meaning not clear – Ed) governance related to them can not be ignored. Somaliland basically covers the north-western regions covering the Awdal, W. Galbeed and Togdheer regions and parts of the Sanaag and Sool regions. There are some territorial demarcation conflicts between Somaliland and Puntland in Sanaag and Sool regions. Puntland, on the other hand, covers the north-eastern regions including Bari and Nugaal and parts of Sool, Sanaag and Mudag. As mentioned earlier, the administrative boundaries do not necessarily match the drainage basin divides. Hence, the Gulf of Aden drainage, Darror, Tug Der/Nugal and Ogaden basins are spread over both the Puntland and Somaliland. The lower parts of the Ogaden basin are mostly in Central Somalia.

The majority of the population in the central and northern regions are engaged in nomadic livestock rearing. Table 3-6 presents the demographic change between the pre-war period in 1988 and that of 2005 estimates for the regions lying in the four basin areas in northern and central regions of Somalia. Figure 3-3 shows that more people are now living in urban towns. According to the last official census in Somalia, the majority of the population in these regions are nomadic, on an average around 72% of the population, with around 80% in the central-northern regions lying in Nugal and Ogaden Drainage basins. This is also due to the arid and semi-arid climatic conditions of the region where land suitable for cultivation is limited.

Based on the more recent estimates, the north-west zone of the country (Awdal, W. Galbeed, Togdheer, Sool and Sanaag regions) are estimated to have a population of 1.8 million (24% of the national population), 45% of which is urban and 55% rural. The north-east zone (Bari, Nugal and Mudug regions) has a population estimate of about 863,000 (12% of the national population), 38% of which is urban and 62% rural. Galgaduud region of the central zone which lies in the Ogaden drainage basin area has a mostly rural population (82%). The population estimates for 2005 are presented in Table A.1 of Annex A.

Population estimation in Somalia is a very sensitive issue for a number of reasons. As the majority of people are pastoralists and agro-pastoralists, they lead a nomadic life and are always on the move in search of water and pasture for their livestock. Hence, many areas have a moving population. No distinction has been made to identify the nomadic population in these estimates but it is assumed that most of the rural population in the regions are nomadic. These figures have to be used with caution.

Livestock is the biggest contributer to the national GDP from this region. Livestock exports from Berbera and Bosasso ports in 2005 were 1.6 million and 1.2 million, respectively (*Table 4-3)*

Table 4-2 : Population Dynamics for the Regions in Central-Northern Somalia (1988 and 2005)

	1988 Census[1]			**2005 Estimate[2]**	
Region	**% Urban**	**% Rural**	**% Nomadic**	**% Urban**	**% Non-urban**
Awdal	8	27	64	36	64
W. Galbeed	27	21	52	70	30
Togdheer	18	21	61	31	69
Sanaag	6	13	82	21	79
Bari	11	9	80	49	51
Nugaal	9	11	80	38	62
Sool	7	24	69	26	74
Mudug	8	13	80	27	73
Galgaduud	7	14	79	18	82

Note:

[1] Based on Ministry of National Planning, Central Statistics Department, Mogadishu (cited by Musse, 1997)

[2] Based on UNDP estimate (the estimates have been categorized as urban and non-urban only, non-urban included both rural and nomadic)

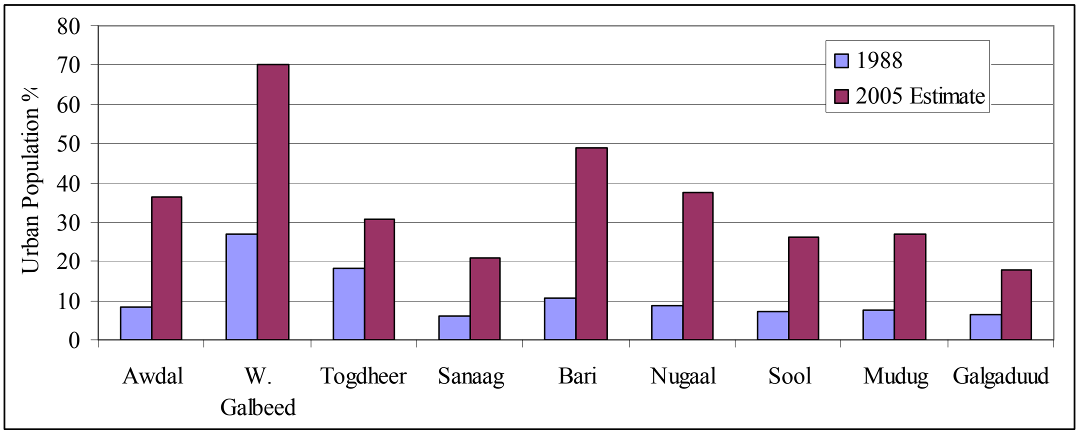


Figure 4-3 : Urbanization trend in Northern Somalia

Table 4-3 : Number of Livestock Exported in 2005 (heads)

Year	**Sheep/Goat**	**Cattle**	**Camel**	**Total**
Bosasso	1,487,101	90,544	7,833	1,585,478
Berbera	1,023,795	148,151	5,069	1,177,015

Source: Respective Port Authorities

Sorghum and maize are the two crops grown in some districts and regions in northern Somalia. Sorghum is normally planted at the end of April to coincide with the Gu rainfall, and harvested by the middle of October. Two crops of maize are planted, one from the end of April to mid June_and again from the beginning of August to the middle of October (*FSAU data from Dynamic Atlas, 2007*). Table 4-4 and Table 4-5 present the average production of maize and sorghum over the years. While the maize yield is seen have a reasonable yield of about 800 kg/ ha in 1999, it has decreased over the last few years, and was especially low during 2001-2005 during the drought. In the case of sorghum too, the yield in 1999 was 800 kg/ha while the yield decreased during 2001-2005 to about 400-600 kg/ha.

Degradation of the northern rangelands as a result of overgrazing is an issue that has been of concern. There have been various estimates of the regional carrying capacities based on estimates of annual rainfall, mean live weight of livestock and primary forage production. Such an assessment is beyond the scope of the present report. However, a land degradation study carried out by SWALIM indicated that development of water points in some areas have led to land degradation as a result of the nomadic population and pastoralists bringing their livestock for watering at the water points (*SWALIM Technical Report L-10*). This calls for a coordinated management of water and land (rangeland).

The most important towns in the areas covered by the four basins, and their estimated populations are: Boramo (82,921), Hargeisa (422,515), Burco (96,463), Laas Caanood (24,830), Ceerogaabo (31,098), Bossaso (107,181), Garoowe (33,395) and Gaalkacyo (54,800).

Table 4-4 : Area and Production of Maize in Northern Regions

Region	**Awdal**	**W. Galbeed**	**W. Galbeed**	**Togdheer**	**Togdheer**	**Togdheer**
District	**Borama**	**Hargeisa**	**Gebiley**	**Burco**	**Owdweyne**	**Sheikh**
Production (t)	797	743	1645	34	20	23
Area (ha)	1,891	1,799	3,630	85	52	58
Yield (t/ha)						
Average	0.421	0.413	0.453	0.400	0.385	0.397
1999	0.800	0.800	0.800		0.800	
2000	0.500	0.300	0.400		0.300	
2001	0.500	0.301	0.400		0.294	
2002	0.203	0.200	0.200			
2003	0.300	0.200	0.300		0.200	
2004	0.400	0.400	0.400	0.400	0.400	0.400
2005	0.450	0.450	0.450	0.400	0.400	0.400
2006	0.600	0.500	0.600	0.381	0.400	0.500

Source: FSAU Data (Dynamic Atlas, 2007)

Table 4-5 : Area and Production of Sorghum in Northern Regions

Region	**Awdal**	**W. Galbeed**	**W. Galbeed**	**Togdheer**	**Togdheer**	**Togdheer**
District	**Borama**	**Hargeisa**	**Gebiley**	**Burco**	**Owdweyne**	**Sheikh**
Production (t)	2315	1876	9168	125	444	126
Area (ha)	3809	3010	14815	218	816	240
Yield (t/ha)						
Average	0.608	0.623	0.619	0.573	0.544	0.525
1999	0.700	0.800	0.800		0.600	
2000	0.600	0.600	0.700		0.600	
2001	0.600	0.600	0.595		0.606	
2002	0.400	0.500	0.400		0.230	
2003	0.700	0.644	0.752		0.600	
2004	0.500	0.500	0.400	0.602	0.600	0.500
2005	0.700	0.600	0.650	0.552	0.600	0.600
2006	0.750	0.600	0.750	0.600	0.600	0.600

Source: FSAU Data (Dynamic Atlas, 2007)

4.2 Climate

4.2.1 Network analysis

The drainage basins dealt in this chapter are basins with relatively little, if any, surface water available. The climate is mostly arid and semi-arid in these basins. Rainwater harvesting through various means is common in these catchment areas. High short duration rainfalls are found to generate “spates” of runoff often lasting for a few hours to a few days. However, these may cause localized flooding and soil erosion in the steeper mountainous areas in the north-west parts of the Gulf of Aden basin and some parts of the Darror and the Tug Der/Nugal basins. Hence, the meteorological network requirements for these areas are for rainfall (intensity and amount) and other climatological data for flash flood forecasting and management, rainwater harvesting, irrigation water requirement in small patches of some mountainous areas, rain-fed agriculture in limited areas and supply or recharge of the groundwater and other water sources.

Mean monthly time series data are mostly available only for rainfall whereas long-term mean monthly values are only available for other climatogical variables. A detailed description of the meteorological network in Somalia is presented in SWALIM Technical Reports No. W-01 and No. W-03. There were 16 stations within or in the vicinity of the five drainage basins within Somalia for the pre-war periods. Three stations within Ethiopia can also be used to assess the areal rainfall in the Ogaden basin. Out of these, limited daily rainfall data is available only for four stations (before 1986 with many missing values). Rainfall observations in 41 stations (19 new and 22 old) are presently being made by SWALIM and partner agencies in the areas of the five drainage basins. An inventory of the station network (in Somalia and Ethiopian parts of the catchments) is provided in SWALIM Technical Report No. W-03. The rainfall stations in different drainage basins are given in Table 3-7.

Table 4-6 : Rainfall Station Network in Major Basins in Northern Central-Northern Somalia

Basin	**Basin Area (km^2)**	**Pre-war Stations**			**Present Network**	
		No. of Rainfall Stations	**Density (km^2/ station)**	**Range of Areas (Thiesen Polygon) (km^2)**	**No. of Rainfall Stations[1]**	**Density (km^2/ station)**
Gulf of Aden	74,400	11	6,764	950 – 15,500	17	4,376
Darror	34,200	6	5,700	102 – 17,800	2	17,100
Nugal	112,200	7	16,000	1,700 – 30,900	11	10,200
Tug Der/ Ogaden[2]	150,000	11	13,600	970 – 38,000	5	30,000
Central Coastal	27,600	18	1,500	30 – 9,300	2	13,800

Note:

[1] Considering stations strictly within basins boundaries

[2] Drainage includes the area within Somalia only

Time series data for other climatological variables apart from rainfall are not available. There are only two stations with some monthly temperature time series data, namely Mogadishu (1928-1987) and Kismayo (1933-1960) in the vicinity of the areas of the four basins. Mean monthly estimation of other climatological data are available for a limited number of stations (Table 3-8). These are derived from FAO Global Climate Datasets (*FAOCLIM and LOCCLIM*).

Table 4-7 : Stations with Mean Agro-climatological Estimates in Central-Northern Somalia

Basin	**Basin Area (km^2)**	**Stations with Estimates of Mean Monthly Agro-climatological data**	
		No. of Stations	**Density (km^2/ station)**
Gulf of Aden	74,400	3	24,800
Darror	34,200	2	17,100
Nugal	112,200	0	-
Tug Der/ Ogaden	150,000	3	50,000
Central Coastal	27,600	1	27,600

4.2.2 Rainfall characteristics

Rainfall in the five drainage basins is low and erratic. There is wide spatial and temporal variations in the rainfall patterns over most of the areas covered by the five drainage basins covered in this chapter. There is both a seasonal as well inter-annual variations in the amount of rainfall in the areas covered by these five basins. In order to assess the spatial variation of the rainfall over the catchment areas of the respective drainage basins, two methods were used: mainly the Inverse Distance Weighted Averaging (IDWA) and the Thiesen Polygon methods. The following subsections describe the spatial and temporal variations of the rainfall.

4.2.2.1 Temporal variation of rainfall

The temporal rainfall variation in the four distinct seasons in different catchment areas, based on the Thiesen Polygon weights, are summarized in Table 3-9 and a variation of some representative stations are presented in Figure 4-4.

From Table 3-9, it can be seen that the areal percentage of rainfall in *Deyr* is quite low in the Gulf of Aden drainage basin. The mountainous western region of the Gulf of Aden basin e.g Borama (*Figure 4-4*) receives a good amount of rainfall in *Hagaa* compared to *Deyr* and other seasons. Rainfall in *Gu* and *Hagaa* seasons is good for rain-fed agriculture in the area (as the length of growing period (LGP) is longer). The locations in the coastal regions (stations - Alula, Bossaso and Berbera, see Figure 4-4) receive very little rain.

In the case of other basins, about 50% and 30% of the annual rainfall occur in the *Gu* and *Deyr* seasons, respectively. In terms of the seasonal variations of the rainfall, it is interesting to note that there is an exponential correlation between elevations and *Hagaa* rainfall and inverse- exponential correlation between elevation and *Deyr* rainfall. In higher elevations especially in the north-western region of Somalia, there is more *Hagaa* rainfall than in other reqions and less of *Deyr* rainfall. However, no correlation was seen in the % of rainfall falling in *Jilaal* and *Gu* seasons (*see Figure 4-5*). This would be beneficial for rain-fed agriculture as seen from the length of growing period (LGP) analysis carried out by SWALIM (*SWALIM Technical Report Nos. W-01 and L-12, 2007).*

Table 4-8 : Seasonal Rainfall Variation for the Major Basins in Central-Northern Somalia

Basin	**% of Annual Rainfall**				**Areal* Annual Rainfall (mm)**
	Jilal **(Dec-Mar)**	***Gu*** **(Apr-Jun)**	***Hagaa*** **(Jul-Sep)**	***Deyr*** **(Oct-Nov)**	
Gulf of Aden	13%	39%	40%	8%	272
Darror	9%	53%	20%	18%	78
Tug Der/Nugal	9%	51%	20%	20%	168
Ogaden (total catchment)	8%	51%	12%	29%	247
Tug Der/ Ogaden (catchment within Somalia only)	9%	50%	11%	30%	212
Central Coastal	8%	52%	12%	28%	301

* Note: Areal rainfall estimated using Thiesen Polygon method gives slightly different estimates than the one estimated using the Inverse Distance Weighted Averaging (IDWA) method

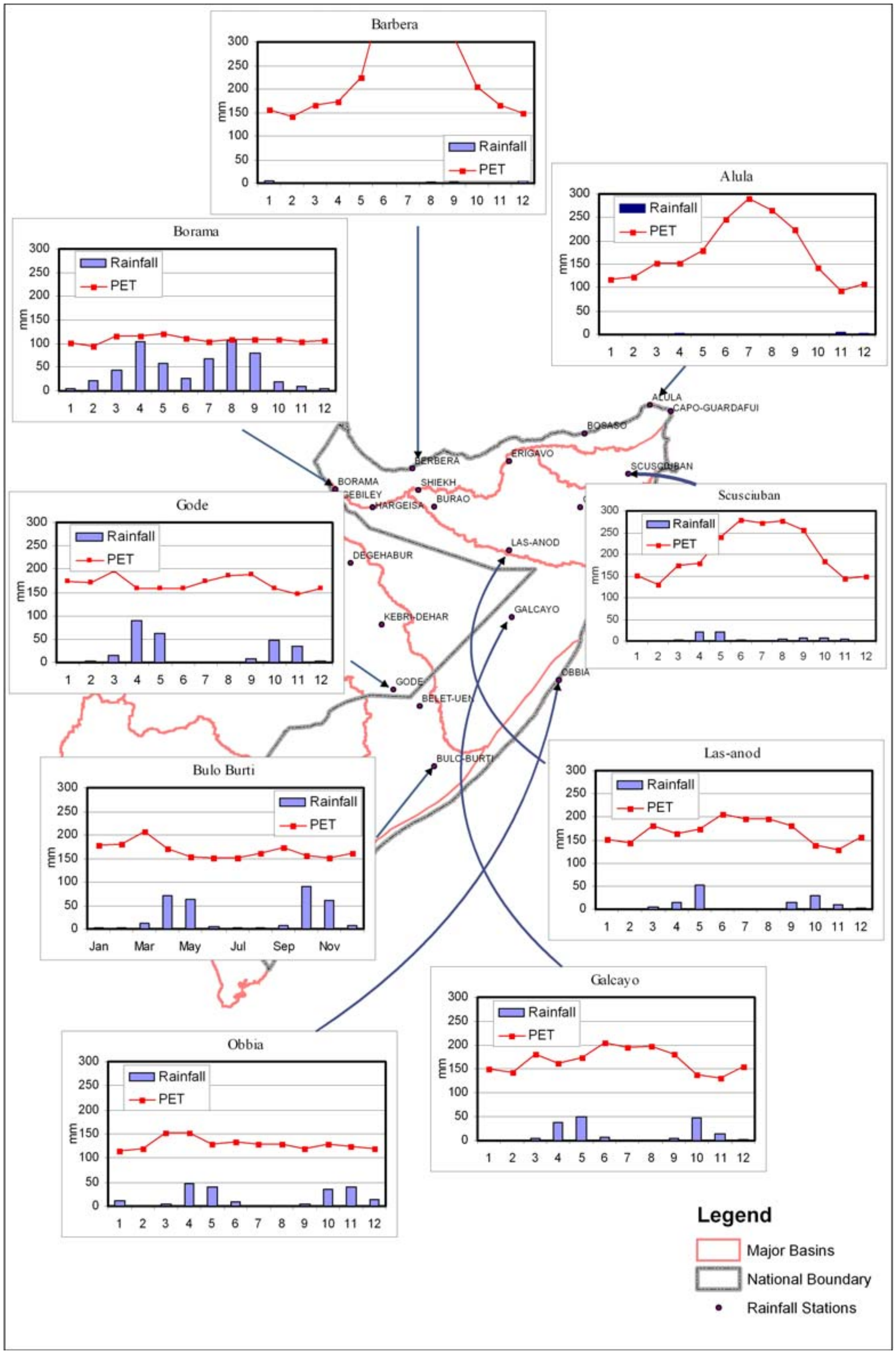


Figure 4-4 : Monthly Rainfall and PET Variations

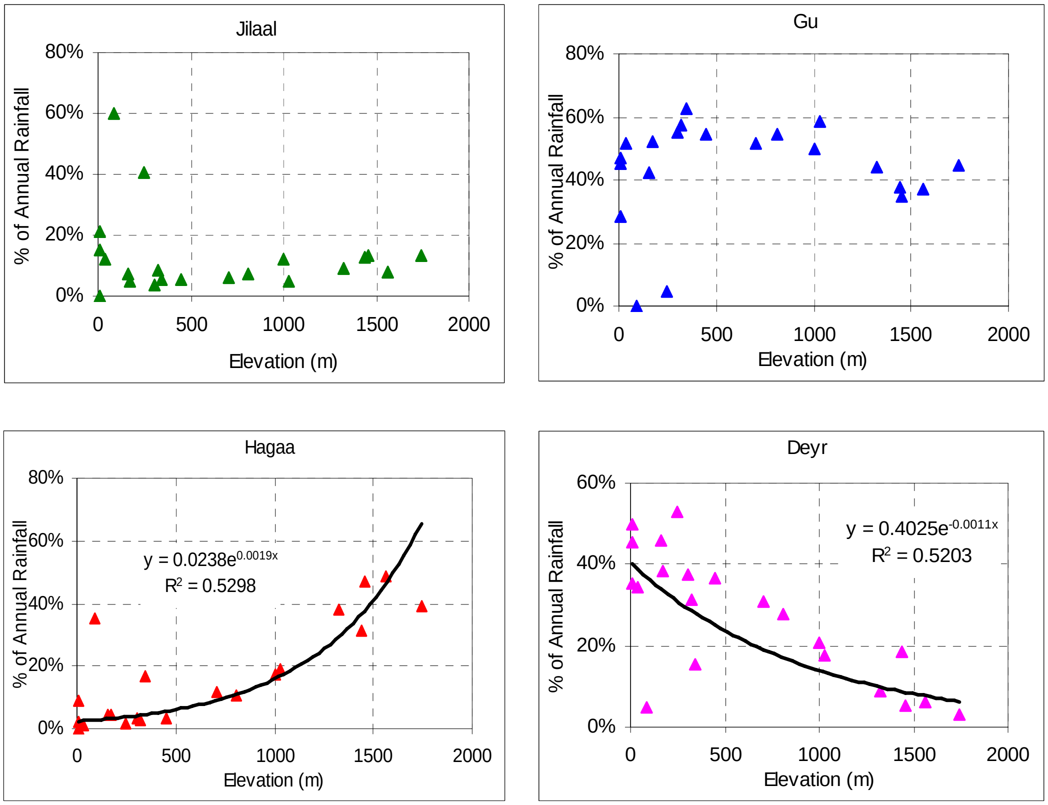


Figure 4-5 : Seasonal Rainfall Variation with Elevation in Central-Northern Somalia

4.2.2.2 Spatial rainfall variation

There is a significant spatial variation in the rainfall in the catchment areas of the five basins in the central and northern regions of Somalia. The mountain region in the western part of the Gulf of Aden basin receives more than 500 mm of annual rainfall e.g. Borama (543 mm) and in Sheikh (515 mm). However, the coastal areas in the northern part of the Gulf of Aden receive very little annual rainfall (less than 20 mm in Berbera, Alula and Bossaso as presented in Figure 4-4). The catchment areas in the Darror basin also receive little water e.g.,, Scusciuban (72 mm) The western part of the Nugal basin near the mountains receive about 240 mm (e.g. Burao) and further east it decreases to about 110 mm (e.g. Qardo). The Ogaden basin areas in Somalia receive from 205 mm (El Bur) to 170 mm (Galcayo). The rainfall in the central coastal area increases as you go south e.g. Obbia (206 mm) to Modun (486 mm).

There is no rainfall station located in the Ethiopian region of the Ogaden catchment, but some stations in the Shabbele river catchment in the vicinity receive 266 mm (Gode) to 467 mm (Kebri Dehar). These stations, however, may not really represent the rainfall in the Ogaden catchment, although the Thiesen Polygon method considers these locations to estimate the rainfall in the Ogaden catchment due to their vicinity. The areal rainfall in the different drainage basins based on the Inverse Distance Weighted Averaging (IDWA) (*see Map 4-4*) and the Thiesen Polygon (*see Map 4-5*) methods are given in Table 3-10. There is some difference in the areal rainfall estimated using the IDWA and Thiesen Polygon methods. Although both methods do not take into consideration the topographical variations, these differences arise due to the scarce rainfall network (*Table 3-7*).

Table 4-9 : Annual Basin Areal Rainfall (mm) for the Major Basins in Central-Northern Somalia

	Areal Annual Rainfall (mm)		**Based on IDWA Method (Annual Rainfall-mm)**	
Basin	**IDWA**	**Thiesen Polygon**	**Minimum**	**Maximum**
Gulf of Aden	228	272	27	531
Darror	93	78	66	159
Tug Der/ Nugal	164	168	80	465
Ogaden (Total)	280	247	133	651
Ogaden (Somalia)	-	212	-	-
Central Coastal	358	301	186	545

There is some correlation seen between elevation and annual rainfall (Figure 4-6) especially for location north of 8° N. Latitude.

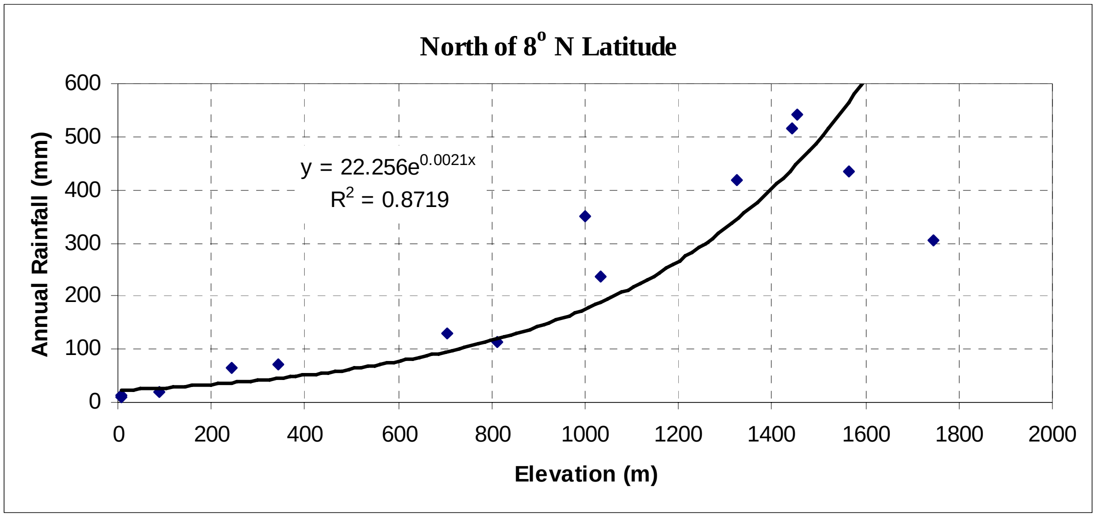
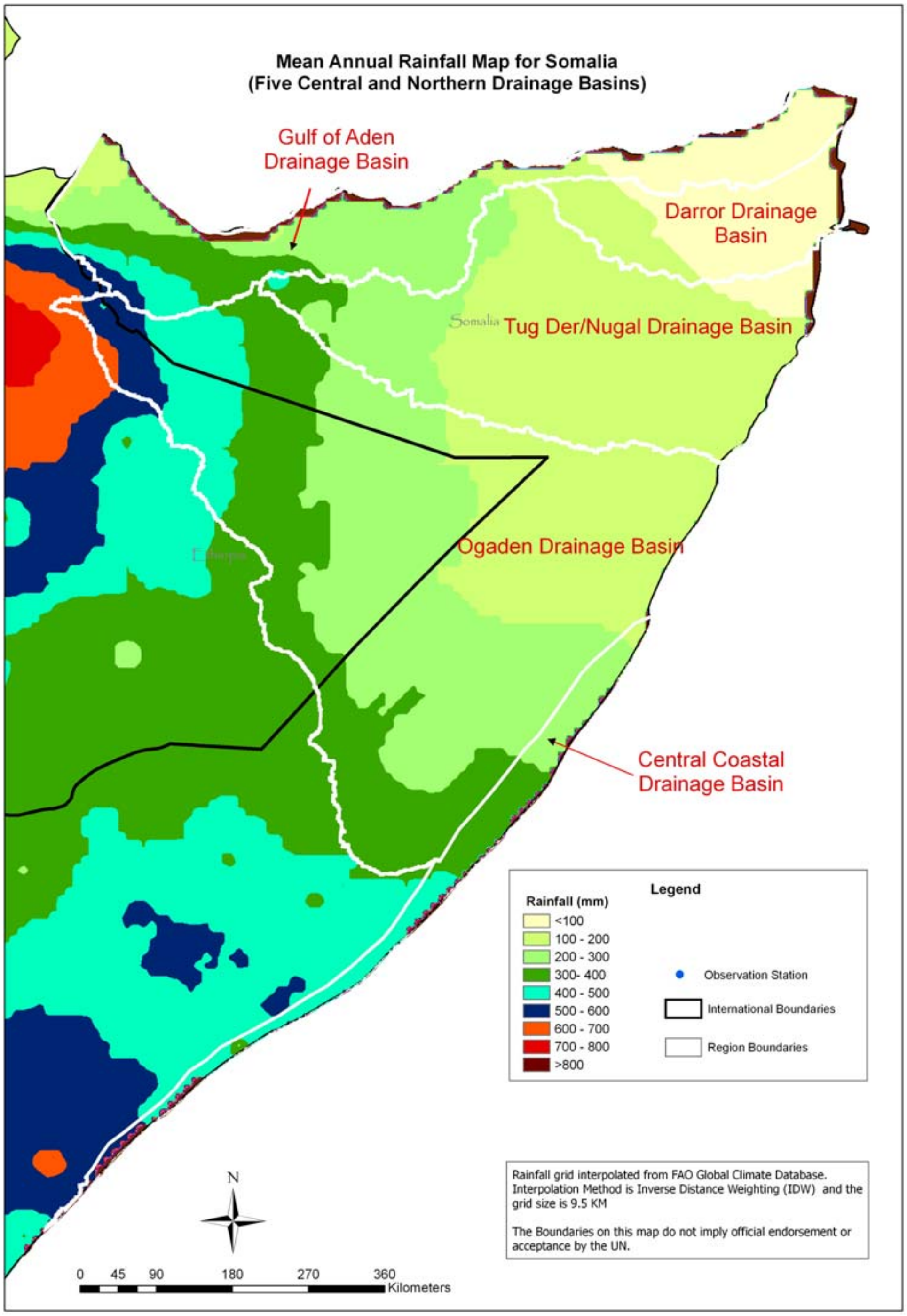


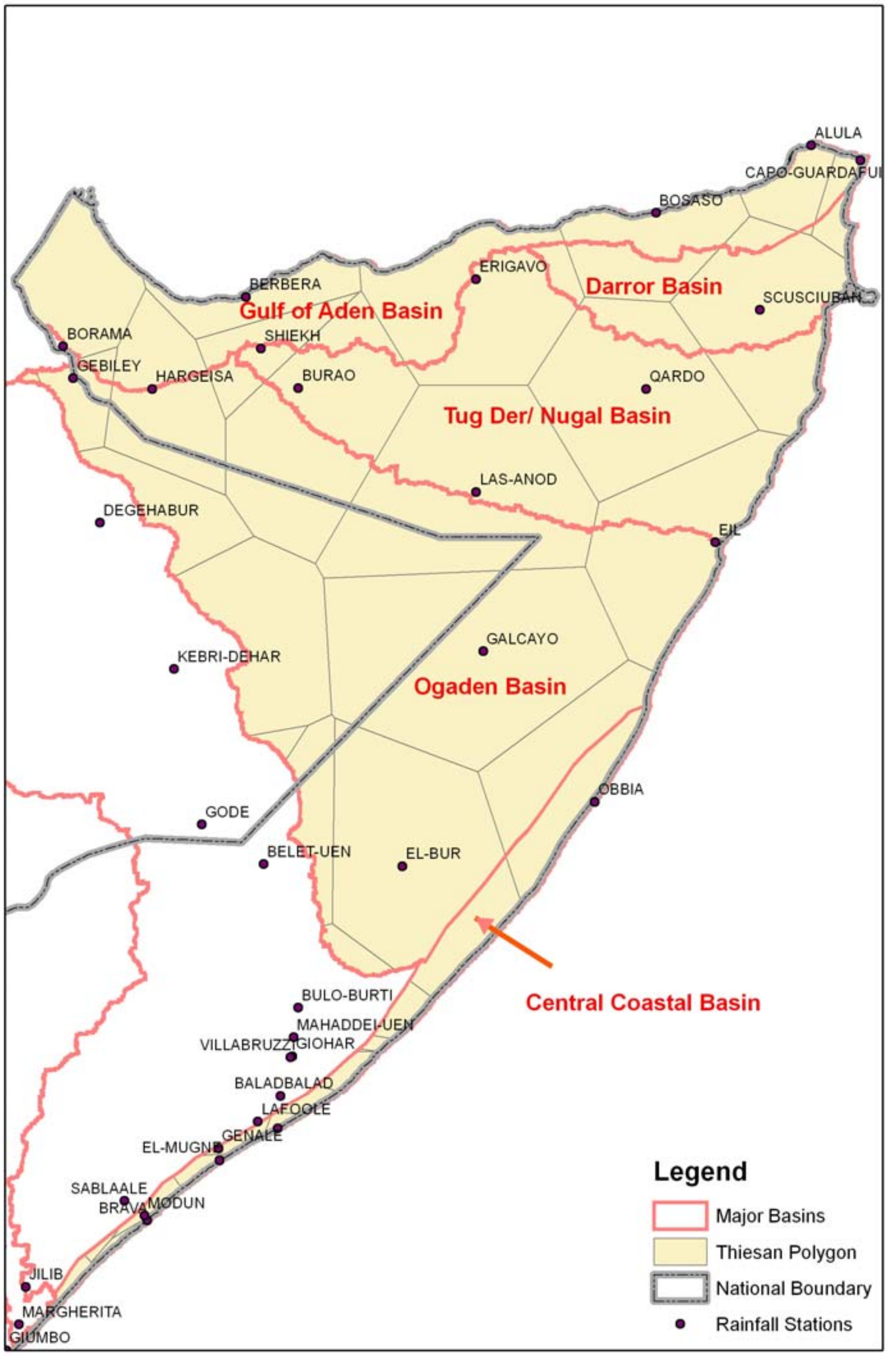
Figure 4-6 : Annual Rainfall Variation with Elevation (North of 8° N of Equator)



Rainfall grid interpolated from FAO Global Climate Database. Interpolation Method is Inverse Distance Weighting (IDW) and the grid size is 9.5 KM

The Boundaries on this map do not imply official endorsement or acceptance by the UN.

Map 4-4 : Annual Rain in Five Central and Northern Somalia Drainage Basins



Map 4-5 : Thiesen Polygons in Five Central and Northern Somalia Drainage Basins

4.2.2.3 Inter-annual rainfall variability

The variability of rainfall from one year to the next is a matter of prime concern for water utilization. The reliability of water availability influences agricultural productivity as well as the design of water resources systems. Similarly, as rainwater harvesting is quite common in meeting the domestic and livestock needs of the majority of the population in these basins, high variation (seasonal as well as inter-annual) is a matter of concern. The rainfall variation is quite high in the case of Somalia, including the areas of the five basins in Central and Northern Somalia. The coefficient of variation (CV) of annual rainfall is found to vary more for locations with lower rainfall (*Figure 4-7*). The CVs of monthly rainfall is also greater during dry seasons compared to the two rainy seasons.

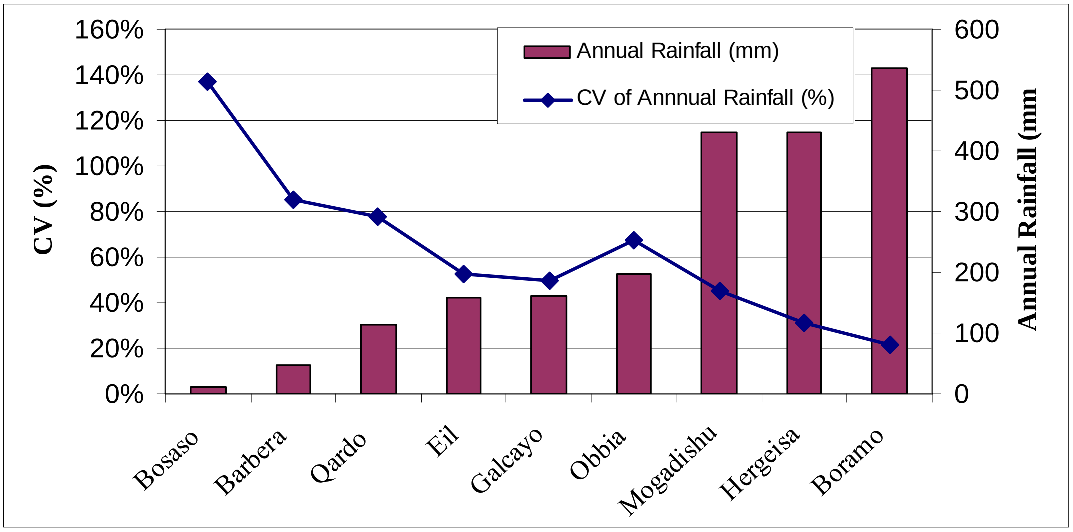


Figure 4-7 : Coefficient of Variation of Annual Rainfall for Representative Stations

Box plots of selected stations located in the five drainage basins of Central and Northern Somalia are presented in Annex B. The inter-annual variations of the monthly rainfall are quite high as seen from the box plots, which show the maximum, minimum, median and the quantile values of the monthly rainfall.

4.2.2.4 Long-term Monthly and Annual Rainfall

The long-term mean monthly and annual rainfall for stations within Somalia in the catchment areas and vicinity of the five basins are given in SWALIM Technical Report No.W-01. The data is also accessible through SWALIM's web site (www.faoswalim.org). Table 3-11 gives the 80% dependable monthly rainfall in stations with more than 10 years of monthly time series data. It can be seen that the 80% dependable rainfall is mostly zero in the dry months of *Hagaa* and *Jilaal* for most locations with low annual rainfall. However, it is useful to note that locations such as Borama, Brava, Gebiley and Hargeisa receive more rainfall in August-September than in October-November. Continuity of rainfall after the *Gu* season is good for rain-fed agriculture as such locations have longer growing period. It is also seen that the coastal regions of the Gulf of Aden receive practically no rainfall (less than 20 mm in Alula, Berbera and Bossaso) whereas the mountainous regions of the northwest Somalia receive more than 500 mm of annual rainfall (Borama and Sheikh).

Table 4-10 : 80% Dependable Monthly Rainfall (mm) in Selected Stations in Somalia

Station	Long. (^{o}E)	Latt. (^{o}N)	Alt. (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Berbera	45	10.4	89	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1
Borama	43.2	9.9	1454	0.0	0.0	0.0	31.4	21.4	12.6	45.5	85.3	45.4	0.0	0.0	0.0	418.0
Bosaso	49.2	11.3	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brava	44	1.1	6	0.0	0.0	0.0	6.2	11.8	32.5	10.1	4.1	0.0	0.0	0.0	0.0	235.5
Bulo-burti	45.6	3.3	158	0.0	0.0	0.0	76.0	10.0	0.0	0.0	0.0	0.0	53.5	13.6	0.0	328.4
Burao	45.6	9.5	1032	0.0	0.0	0.0	1.8	13.0	2.0	0.0	0.0	5.0	0.0	0.0	0.0	137.4
Eil	49.8	8	36	0.0	0.0	0.0	0.0	19.0	0.0	0.0	0.0	0.0	4.5	0.4	0.0	80.0
Erigavo	47.4	10.6	1744	0.0	0.0	0.0	7.6	13.0	9.0	0.0	9.4	46.0	0.0	0.0	0.0	236.0
Galcayo	47.4	6.9	302	0.0	0.0	0.0	0.0	11.0	0.0	0.0	0.0	0.0	5.1	0.0	0.0	104.8
Gebiley	43.3	9.6	1563	0.0	0.0	0.0	11.4	27.2	27.8	46.4	37.0	27.2	0.0	0.0	0.0	372.2
Hargeisa	44.1	9.5	1326	0.0	0.0	0.0	13.0	26.2	16.4	22.9	36.9	34.6	1.0	0.0	0.0	319.8
Las-anod	47.4	8.5	705	0.0	0.0	0.0	0.0	6.2	0.0	0.0	0.0	0.0	3.0	0.0	0.0	82.0
Mogadishu	45.4	2	9	0.0	0.0	0.0	7.6	15.0	25.8	27.2	9.3	2.2	1.1	3.7	0.0	271.3
Obbia	48.6	5.3	10	0.0	0.0	0.0	0.0	4.8	0.0	0.0	0.0	0.0	0.0	5.2	0.0	85.9
Qardo	49.1	9.5	810	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.4
Scusciub	50.2	10.3	344	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.3

Note: the 80% dependable rainfall has been calculated using data of different periods and duration. The years of annual data used are the years of data for all months in a year. There are many missing values and these were not filled (estimated) as the network density was sparse.

4.2.2.5 Daily Rainfall Analysis

As the rainfall pattern in northern Somalia is quite erratic and irregular, the rainfall analysis of shorter periods than a month is necessary. Unfortunately, daily rainfall data is available for only a few stations. These include Berbera, Borama, Hargeisa and Galkayo in the northern regions of Somalia. However, no data of short duration storms are available. Daily data of the post-war stations are availabl,e but for a few years only. High intensity rainfalls of short durations are known to occur, resulting in flash floods and heavy erosion in the mountainous areas in Northern Somalia. Most of the *toggas* as discussed in the later sections, are known to carry intermittent surface water (spates), e.g. in the Durdur catchment. Assessment and forecasting of such events require rainfall data of shorter duration which are not available. SWALIM is preparing to install automatic weather stations across the country to collect rainfall and other climatological data on a continuous basis.

Rainwater harvesting from roof catchments as well as from catchment harvesting of storm water (*wars* and ponds) is an important source of water in the northern drainage basins (*SWALIM Technical Report No. W-09*). It is noted that the minimum daily rainfall of 5 mm is required for rainwater harvesting and about 20 mm is required for the generation of surface runoff in small catchments. A daily rainfall analysis to estimate the number of rainy days, number of days with a threshold rainfall of 5 mm and 20 mm, and the rainfall volume with rainfall exceeding the 5 mm and 20 mm threshold rainfall was carried out. Sample results of Galcayo are presented in Annex A.

Box 4-1 presents salient features of the daily rainfall variations in Galcayo in the Ogaden drainage basin.

4.2.2.6 24-hour Maximum Rainfall

Analysis of some intermittent years of data in Berbera, Hargeisa, Borame and Galkayo show that the maximum 24-hour rainfall figures reach a high of 61 mm, 100 mm, 123 mm and 167 mm in these locations, respectively (*see Table 4-11*). These maximum rainfall figures are of interest in various water resources assessment, including soil erosion and flooding. In order to give an idea of the frequency of occurrence of the 24-hour maximum rainfall, a frequency analysis using the Gumbel distribution was carried out using 30 years of data available for Hargeisa and 25 years of data for Galcayo. Based on the Gumbel distribution, the 24-hour maximum rainfall figures in Hargeisa is estimated to be 70 mm, 80 mm, 94 mm and 104 mm for 10, 20, 50 and 100 year return periods, respectively (*Table 4-12 and Figure 4-8*). Similarly, the 24-hour maximum rainfall figures in Galcayo is estimated to be 122 mm, 149 mm, 184 mm and 210 mm for 10, 20, 50 and 100 year return periods, respectively (*Table 4-12 and Figure 4-9*).

Box 4-1 : Daily Rainfall Analysis – Galcayo

The rainfall pattern in Galgayo, located in the Ogaden drainage basin, is presented to illustrate the highly erratic and intermittent rainfall pattern in the region.

Some of the salient features of the daily rainfall pattern based on 25 years of daily data between 1944 and 1985 in Galcayo are:

- The long-term average annual rainfall is 159 mm but the annual variation is from a minimum 34 mm to a maximum of 406 mm per annum.
- The long-term annual rainfall, considering daily rainfall over the 5 mm threshold value, is 147 mm.
- The long-term annual rainfall, considering daily rainfall over the 20 mm threshold value, is 98 mm.
- The long-term average number of days with daily rainfall of more than 5 mm is only 7 days, varying from 2 to 13 days over the 25-year data period.
- The long-term average number of days with daily rainfall of more than 20 mm is only 2 days, varying from 0 to 5 days over the 25-year data period.
- The highest 24-hour maximum rainfall occurred in 1965 which was equal to 167 mm, more than the long-term annual average rainfall of the station.
- In four out of 25 years of data available, 24-hour maximum rainfall exceeded 100mm. The 5-year and 10-year return period 24-hour maximum rainfall is equal to 94 mm and 122mm, respectively.
- The rainfall variation in 1965 which received the highest 24-hour rainfall of 167 mm is presented in the figure below.

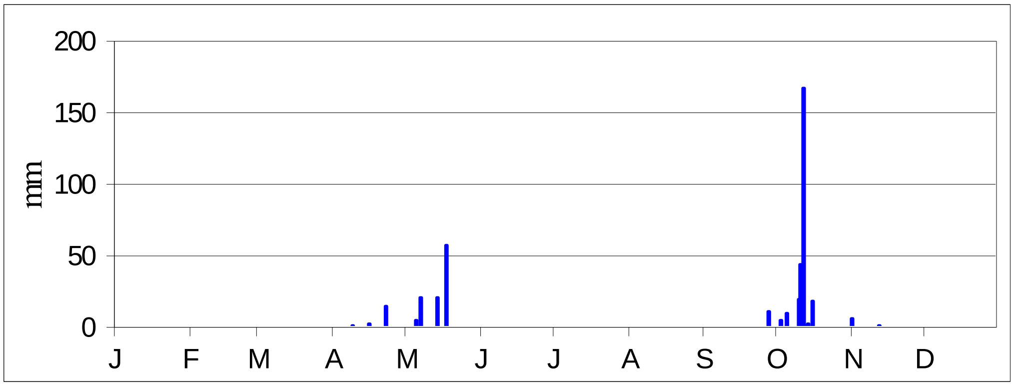


Table 4-11: Maximum 24-hour Rainfall of Selected Stations in Central-Northern Somalia

Year	Berbera	Hargeisa	Borama	Galkayo
1944	56	-	-	19
1945	22	-	-	51
1946	13	36	-	52
1947	1	57	-	51
1948	61	47	-	42
1949	-	37	-	10
1950	-	-	-	-
1951	-	70	-	-
1952	-	38	-	-
1953	-	-	-	-
1954	-	32	-	-
1955	-	36	-	-
1956	-	43	-	-
1957	-	-	-	-
1958	-	53	-	-
1959	-	38	-	-
1960	-	-	-	-
1961	-	-	-	113
1962	-	-	-	36
1963	-	100	-	-
1964	-	50	-	33
1965	-	27	-	167
1966	-	30	-	48
1967	-	44	33	36
1968	-	39	42	38
1969	-	38	-	44
1970	-	22	-	31
1971	-	34	36	38
1972	-	33	46	40
1973	-	32	-	166
1974	-	41	38	60
1975	-	60	56	27
1976	-	67	43	110
1977	-	65	34	-
1978	-	57	45	40
1979	-	-	46	-
1980	-	42	30	-
1981	-	-	34	94
1982	-	37	62	59
1983	-	-	78	-
1984	-	-	52	43
1985	-	-	123	-
1986	-	62	-	-

Table 4-12 : 24-hour Maximum Rainfall Frequency Analysis (Gumbel Distribution) for Hargeisa and Galcayo

Return Period (year)	Hargeisa	Galcayo
2	43	52
5	59	94
10	70	122
20	80	149
50	94	184
100	104	210

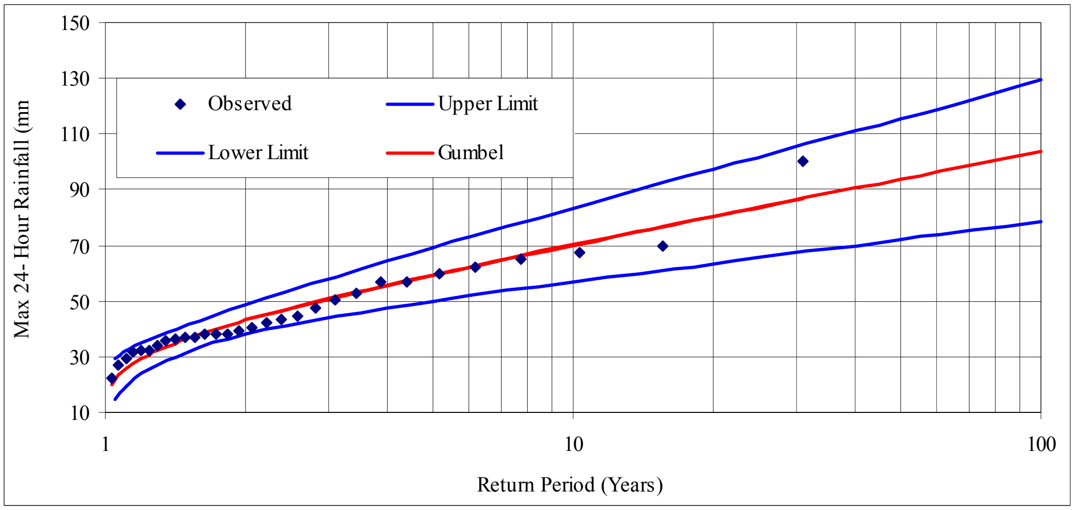


Figure 4-8 : 24-hour Maximum Rainfall Frequency Analysis Results (Hargeisa)

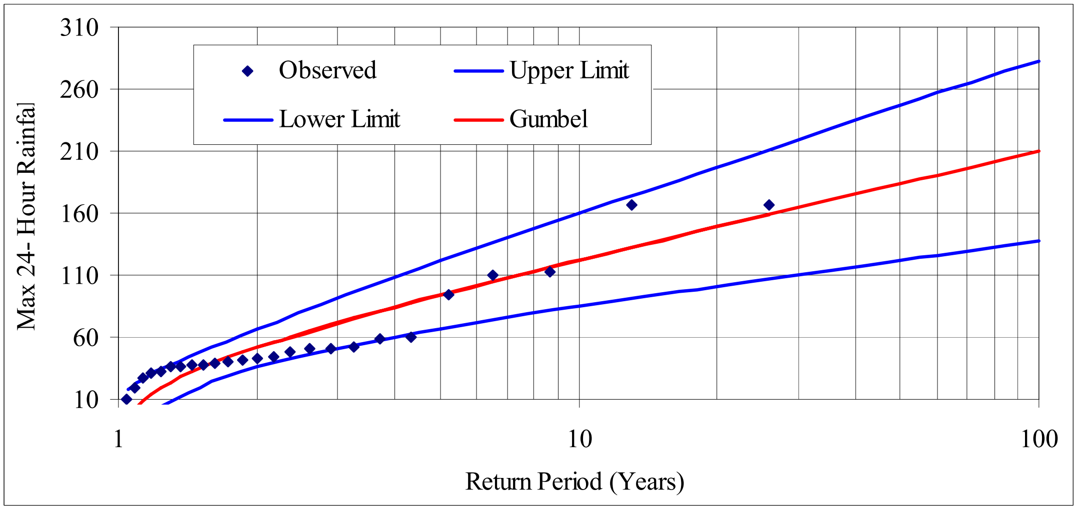


Figure 4-9 : 24-hour Maximum Rainfall Frequency Analysis Results (Galcayo)

4.2.3 Potential Evapotranspiration

No time series data are available for evaporation for Somalia. Potential Evapotranspiration (PET) data were obtained from the FAO Global Database. SWALIM Technical Report No. W-01 presents the PET data for 49 stations. PET in the northern areas, including the north-west mountainous regions, are higher than in the southern regions and in the eastern coastal regions. It ranges from about 2100 to 3000 mm in the north-east coastal regions (Alula and Berbera) whereas it is only 1460 to 1630 mm per annum in the central coastal region (*Figure 4-10* and *Table 4-13*). In the inland areas of the Darror, Tug Der/ Nugal and Ogaden basins, annual PET is between 2000 to 2400 mm.

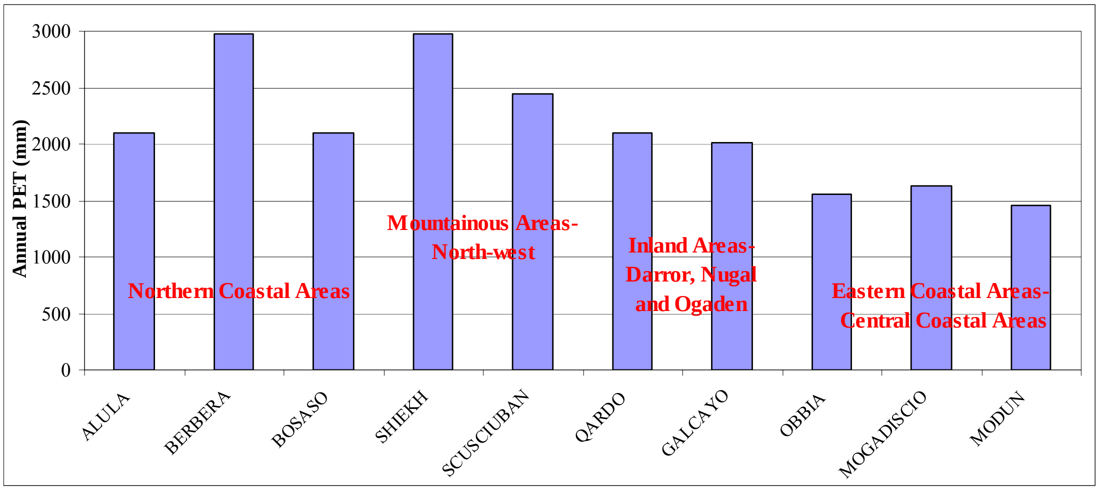


Figure 4-10 : Annual PET in Selected Stations across Somalia

Table 4-13 : Annual PET of Selected Stations across Somalia

Name	Longitude (°E)	Lattitude (°N)	Elevation (m)	Annual PET (mm)
ALULA	50.8	12.0	6	2094
BERBERA	45.0	10.4	89	2977
BOSASSO	49.2	11.3	6	2094
SHIEKH	45.2	9.9	1441	2977
SCUSCIUBAN	50.2	10.3	344	2440
QARDO	49.1	9.5	810	2094
GALCAYO	47.4	6.9	302	2014
OBBIA	48.6	5.3	10	1554
MOGADISCIO	45.4	2.0	9	1631
MODUN	44.0	1.2	50	1459

Monthly PET variation of selected stations in these basins are presented in Figure 4-11, Figure 4-12 and Figure 4-13. Highest monthly PET values are in May and September in the northern coastal areas whereas PET is more or less constant over the months in the eastern coastal areas (Central Coastal Basin) with a small peak in March.

It should be noted that monthly PET is more than the monthly rainfall all over Somalia (as was also presented in Map 4-4). While annual rainfall in central and northern Somalia ranges from almost zero to a maximum of 700 mm, annual PET is in the range of 1500 mm to more than 3000 mm. There is therefore a water balance deficit through out the year (*see Map 4-4*).

According to "Length of Growing Period" LGP assessment carried out by SWALIM, the catchment areas under the Gulf of Aden, Darror, Tug Der/ Nugal and Ogaden basins have the shortest LGP values and are not suitable for cultivation. Some areas in the mountainous regions in the north-western parts of the Gulf of Aden are marginally suitable for cultivation provided that the flows in the small *Tugs* can supplement the rainfall.

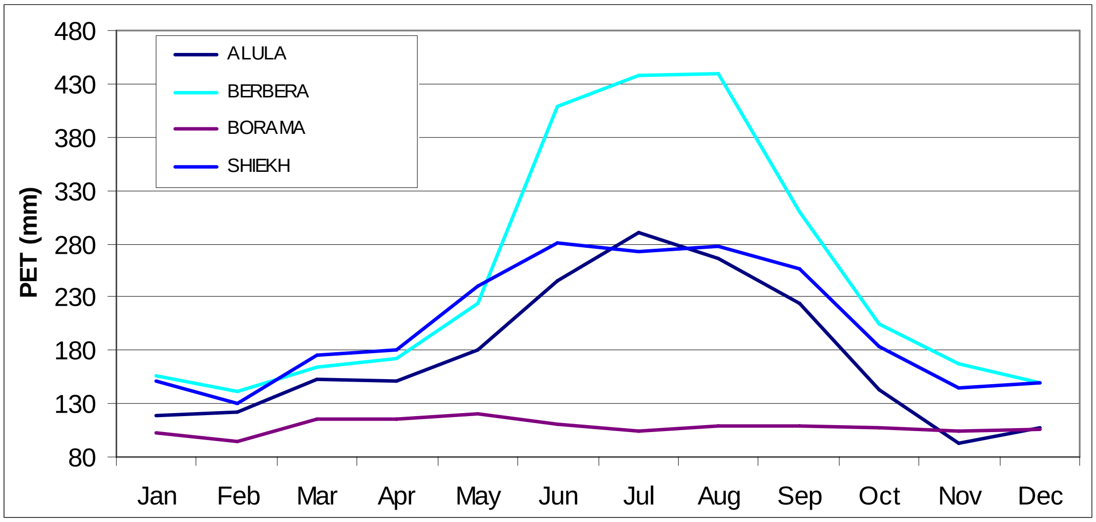


Figure 4-11 : PET in Selected Stations within Gulf of Aden Basin

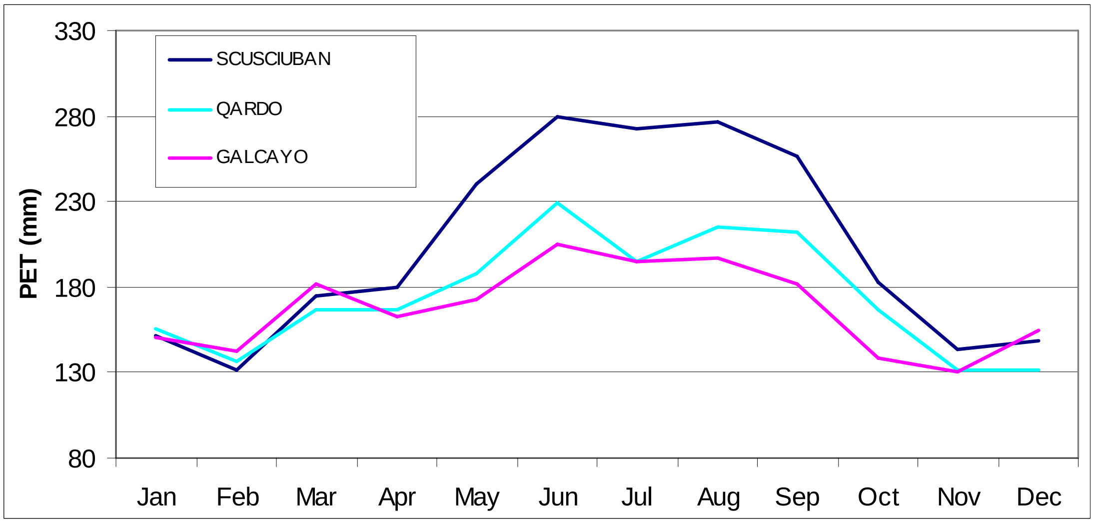


Figure 4-12 : PET in Selected Stations within Darror, Tug Der/ Nugal and Ogaden Basins

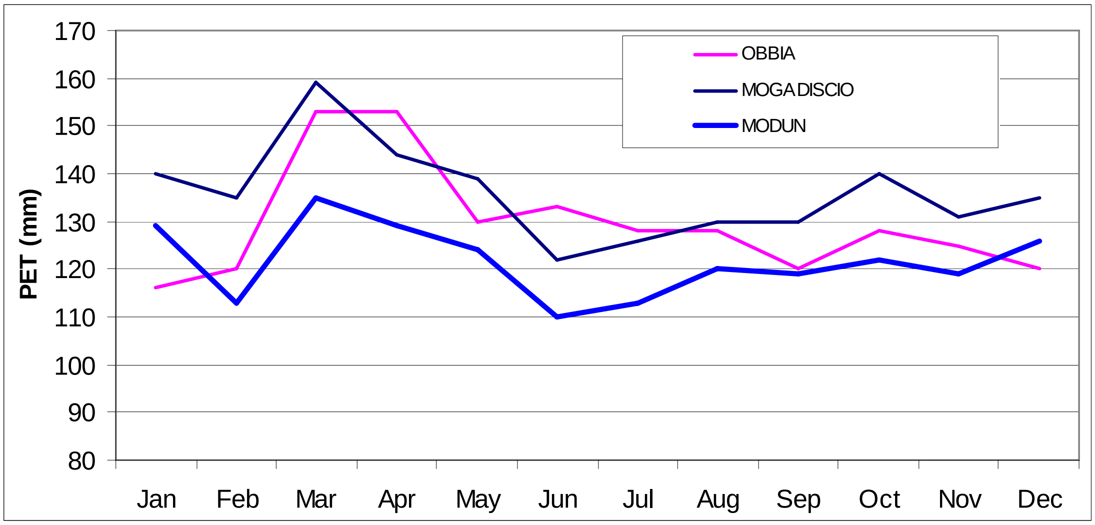


Figure 4-13 : PET in Selected Stations in the Eastern Coastal Areas

4.2.4 Air Temperature

The mean air temperatures are generally high in the drainage basins in central and northern regions of Somalia. Mean temperature is high in the range of about 25° C to more than 35° C in the northern coastal regions (e.g. Berbera and Bossaso) while it is cooler in the north-western mountain region (e.g. Shiekh) where it varies from about 15° C to about 23° C (*Figure 4-14*). In the inland areas of the Darror, Tug Der/Nugal and Ogaden basins, it varies between 22° C to about 33° C (*Figure 4-15*). The mean temperature is highest from June to August in the Gulf of Aden basin areas whereas the peak temperature occurs from May to September in the inland areas of the Darror, Tug Der/Nugal and Ogaden basins. In the eastern coastal areas of the Central Coastal basin, the mean temperature is cooler than the inland and northern coastal regions and is more or less constant between 25° C to about 28° C throughout the year (*Figure 4-16*).

The long-term monthly temperature (mean, maximum and minimum) values are given in SWALIM Technical Report No. W-01. Higher differences in daily minimum and maximum temperature occur inland compared to nearer the coast.

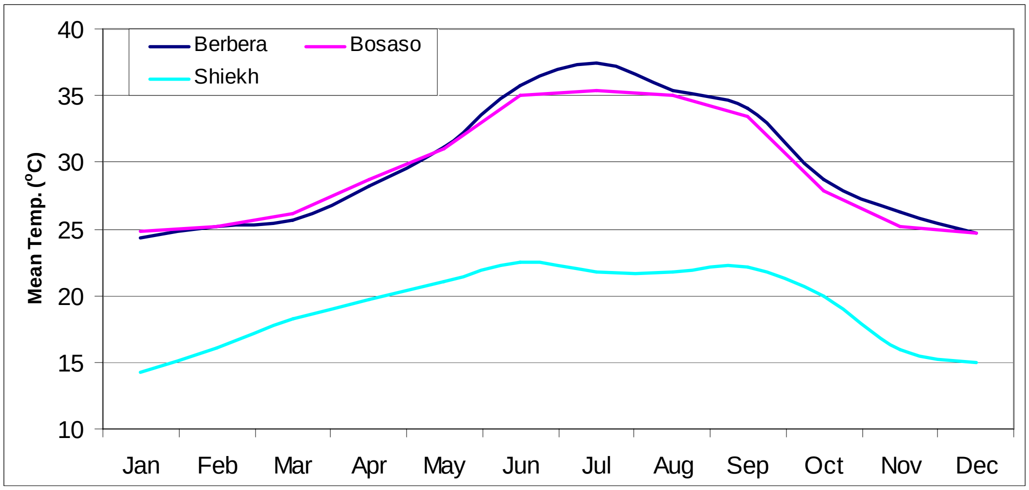


Figure 4-14 : Mean Monthly Temperature in Selected Stations within Gulf of Aden Basin

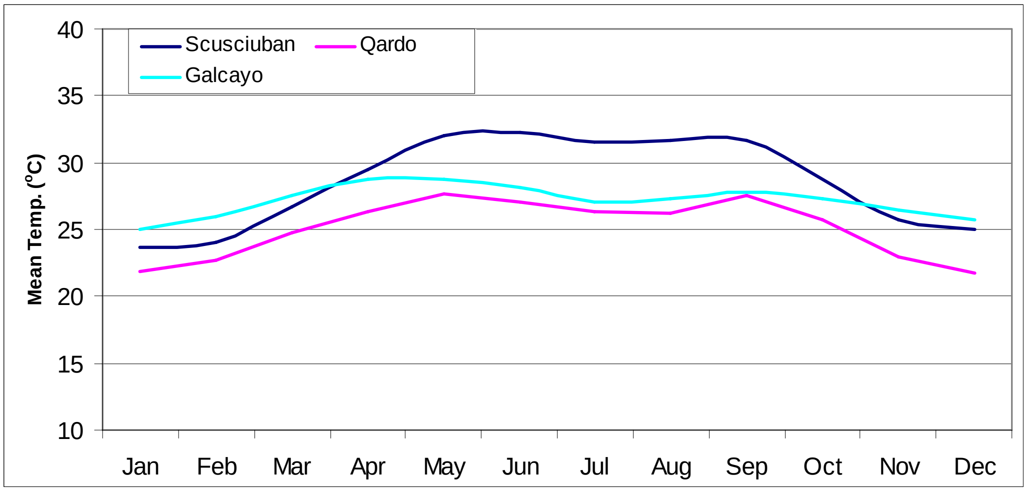


Figure 4-15 : Mean Monthly Temperature in Selected Stations within Darror, Tug Der/ Nugal and Ogaden Basins

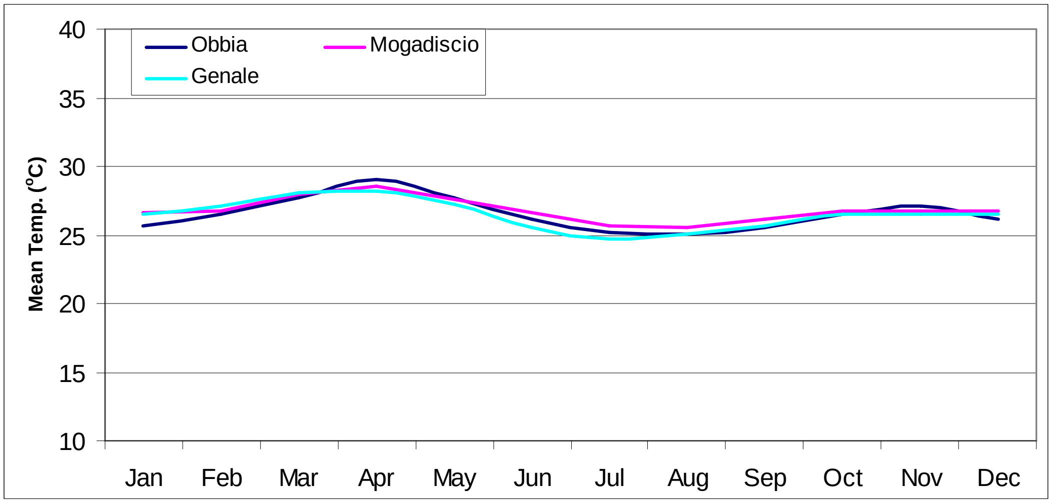


Figure 4-16 : Mean Monthly Temperature in Selected Stations in the Central Coastal Basin

4.2.5 Relative Humidity

Data on relative humidity is scarce in Somalia with only a few stations recording some observations. The monthly relative humidity data for stations in Somalia are given in SWALIM Technical Report No. W-01. The relative humidity (RH) is higher in the coastal regions than in the inland areas. In the case of the Gulf of Aden basin which has wide topographical variations, RH in the northern coastal region (e.g. Alula and Berbera) is higher (70-75%) than in the inland-mountainous regions (e.g. Borama and Sheikh) where it varies around 50-65% over the year (*Figure 4-17*). In the case of the inland areas in the Darror, Tug Der/Nugal and Ogaden basins, it is more or less constant throughout the year and varies from a low of 40% (in Susciuban) to around 70% (in Las Anod) (*Figure 4-18*). In the case of the coastal regions of the Central Coastal basin, it is constant through the year at around 75% to 80% (*Figure 4-19*).

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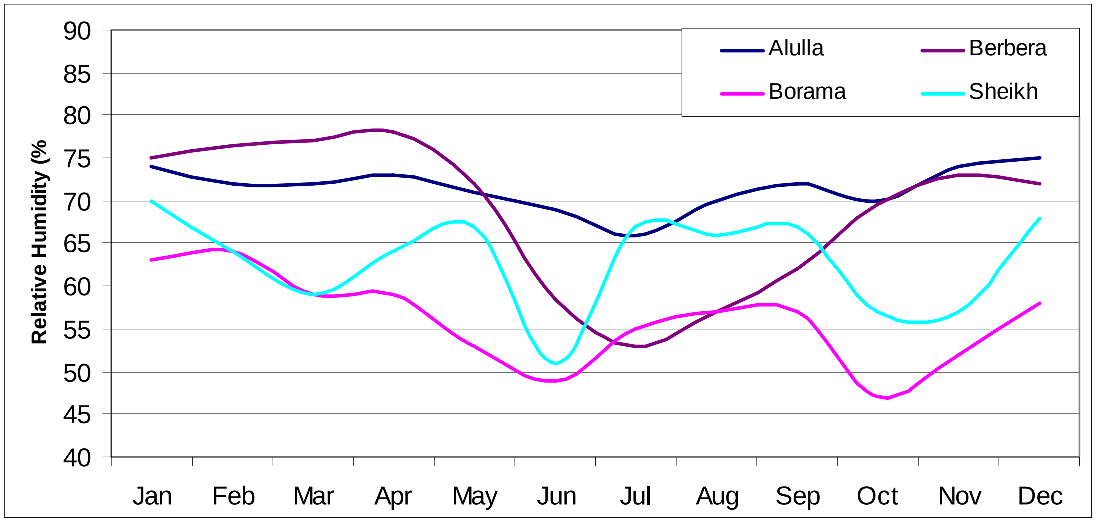


Figure 4-17 : Relative Humidity in Selected Stations in the Gulf of Aden Basin

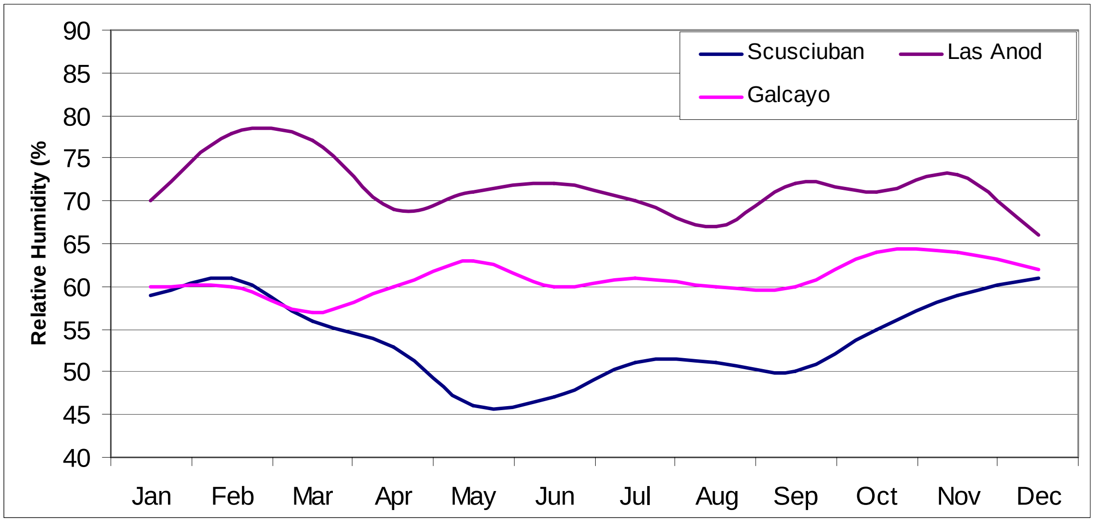


Figure 4-18 : Relative Humidity in Selected Stations in the Darror, Tug Der/ Nugal and Ogaden Basins

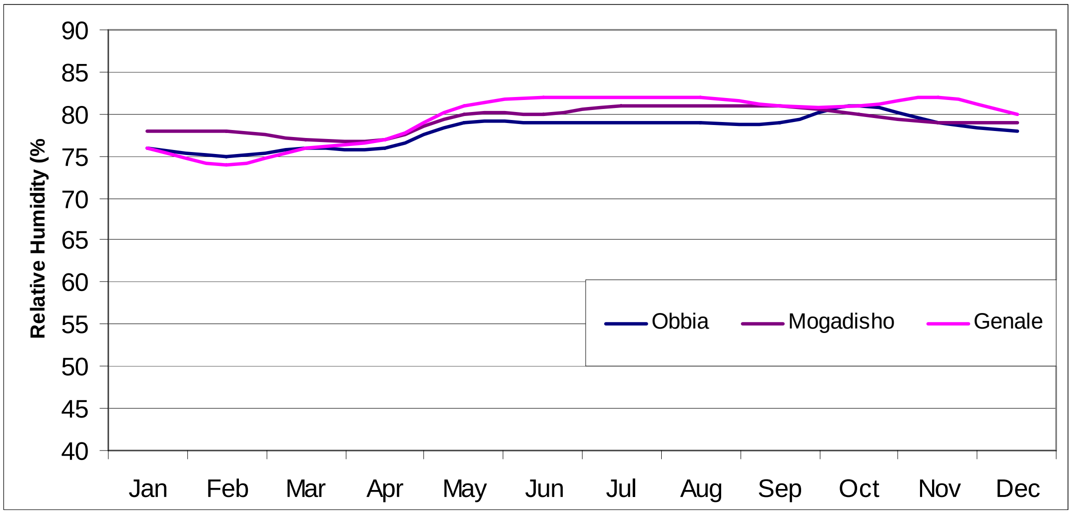


Figure 4-19 : Relative Humidity in Selected Stations in the Central Coastal Basin

4.2.6 Wind Speed

In the case of the Gulf of Aden basin, in the mountainous areas (e.g. Hargeisa) the wind speed is quite high, ranging from around 7 m/s to a peak wind speed of about 11 m/s during July and August. The northern coastal areas (e.g. Berbera and Bossaso) have wind speeds varying from around 4 m/s to a high of around 8 m/s during July and August (*Figure 4-20*) In the case of the inland areas of the Darror and Tug Der/Nugal basins, wind speeds vary from a low of about 3 m/s to a high of about 7.5 m/s. Wind speeds are higher during June to August (*Figure 4-21*). The inland areas of the Ogaden basin have lower wind speeds which vary from a low of about 2 m/s to a high of about 5 m/s (e.g. Galcayo, Figure 4-21). In the case of the Central Coastal basin, it is interesting to note that the wind speed increases as one moves from the south (Genale) to the north (Obbia) (*Figure 4-22*). At Genale, a coastal location in the southern part of Somalia, the wind speed is quite low and varies from 1 m/s to 2 m/s throughout the year. At Mogadishu, the wind speed varies from 3 m/s to less than 5 m/s over the year. At Obbia, further north in the eastern coastal region, the wind speed varies from about 6 m/s to 8 m/s.

SWALIM Technical Report No. W-01 gives the monthly values of wind speed data derived from the FAOClim database. These are based on data of a limited number of years and hence it should be used with caution. On an average the lowest values of wind speed occur in the months of April and November in the country coinciding with the peaks of the two rainy seasons, *Gu* and *Deyr*, respectively.

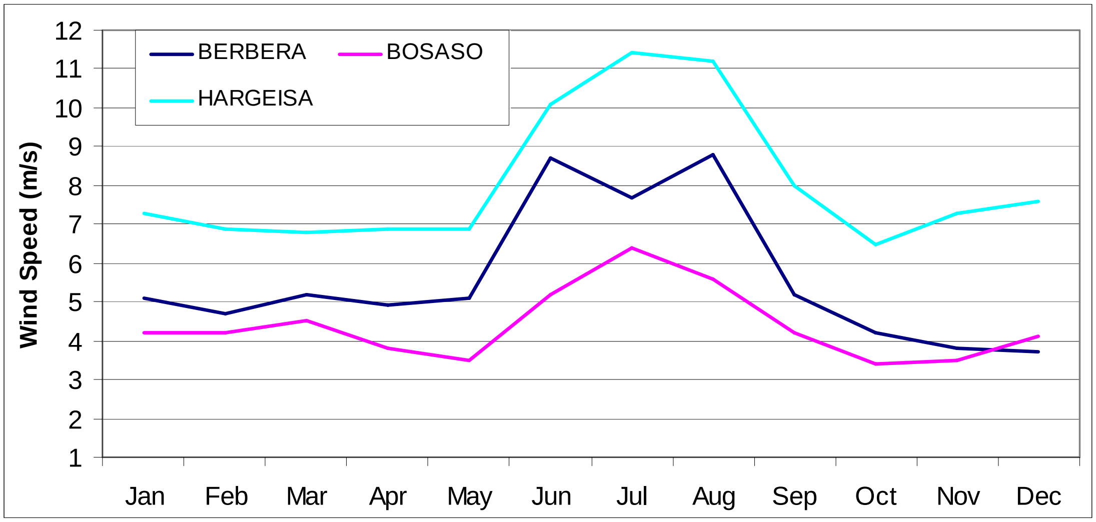


Figure 4-20 : Wind Speed in Selected Stations in the Gulf of Aden Basin

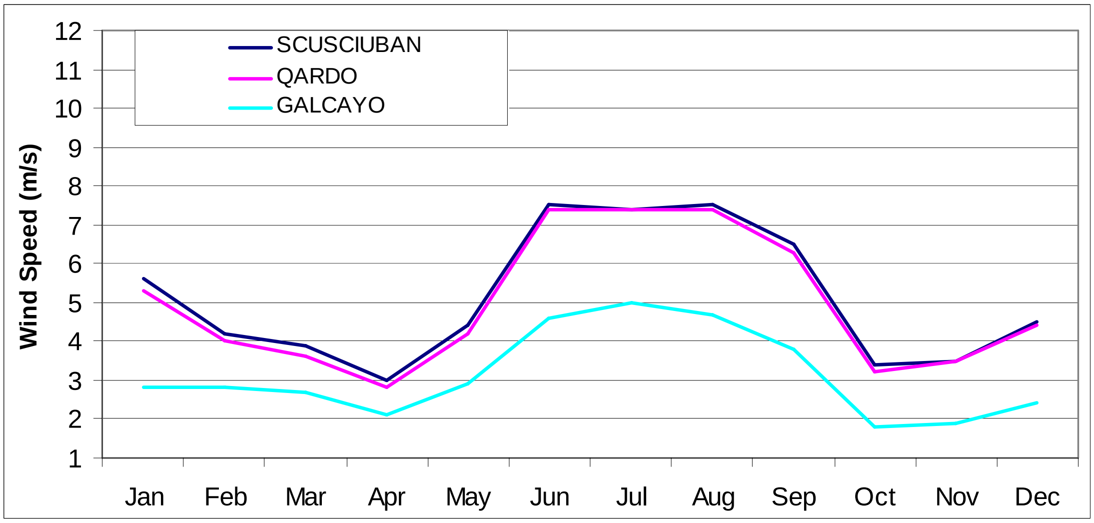


Figure 4-21 : Wind Speed in Selected Stations in the Darror, Tug Der/Nugal and Ogaden Basins

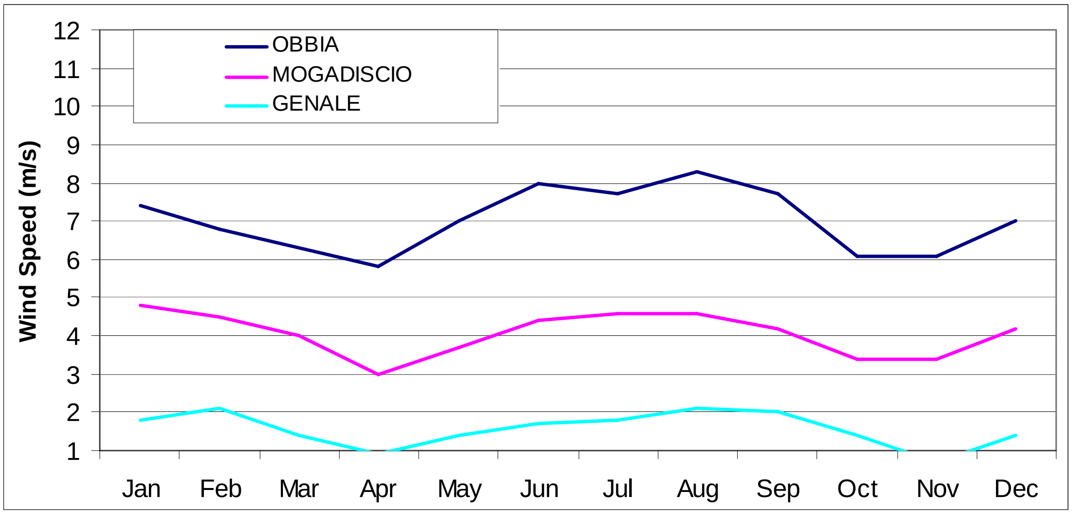


Figure 4-22 : Wind Speed in Selected Stations in the Central Coastal Basin

4.3 Surface water

The surface drainage of the northern regions of Somalia, in particular the Gulf of Aden, Darror and Nugal Drainage basins, can be further classified according to their surface drainage and catchments (*Faillace and Faillace, 1986*) (*see Map 4-2*). This area has a variety of geomorphological aspects: mountainous areas, valleys, plateaus, sloping plains, coastal hills and dunes. Many small *toggas* cross the escarpment facing the Gulf of Aden. Large *toggas* drain the mountain areas of Borama and Hargeisa as well as the areas from Sheikh and Ceerigabo and they flow to the coastal areas of the Gulf of Aden. All other *toggas* draining the Nugal Valley, the Bokh Valley, the Darror Valley and other minor valleys discharge into the Indian Ocean or into endoric basins. The Xingalool internal drainage basin and the Qardho Plateau catchment are two such endoric basins which do not flow out of the catchment to the ocean or to another river system. The northern-most part of the Horn of Africa is a mountainous area, the highest point being Mt. Bahaja at 2,135 m.

No perennial river of any importance exists in the five drainage basins covered in this chapter. The *wadis* and *toggas*, the seasonal streams, where drainage networks are developed, such as in the Gulf of Aden, Darror and Tug Der/Nugal basins, have surface runoff only after heavy rainfall. After intense rainfall, these small streams can carry high floods and debris. The surface runoff lasts from a few hours to a few days. In the Ogaden basin, the drainage networks are very thinly developed and most of the little rainfall that falls is lost through evaporation and infiltration. The main *toggas* in the drainage basins of Northern Somalia are given in Table 4-14.

No long term surface water monitoring has been done in any of these *wadis* and *toggas*. Some surface water observations were made in the small streams originating from the plateau in the western region of the Gulf of Aden basin by Sogreah in 1980 and 1981. Sogreah monitored 12 hydrometric stations, four with water level recorders and eight with staff gauge only in four main catchments in the Gulf of Aden drainage basin (north-western Somalia). In addition, nine stations were also installed in small catchments with drainage areas between 6 and 172 km^2. Based on the one-year programme carried out in 1980 and 1981, the surface water estimates made in the four *wadis* are presented in Table 4-15.

Table 4-14 : Main Toggas in the Drainage Basins of Northen Somalia

Major Basin	Name of Togga	Catchment Area (km^2)	Remarks
Gulf of Aden	T. Waheen	3,000	Western mountainous
	T. Durdur	3,560	Western mountainous
	T. Biji	4,185	Western mountainous
	T. Silil	3,930	Western mountainous
	T. Jangarra	3,700	Central part
	T. Hodomo	3,800	Central part
	T. Belgeabili	4,800	Central part
Darror Basin	Wadi Jecyl	3,800	Tributary of T. Dhut
	T. Dhut		main togga
Nugal Basin	T. Nugal		main togga

Sogreah (1981) also concluded that, on average, for unit drainage areas of 100 km^2 on the plateau, the runoff threshold is 24 mm and the corresponding runoff coefficient is 0.65. In the case of small catchment areas (2-3 km^2) used for rainwater harvesting, the threshold rainfall value for runoff generation was estimated as 15-20 mm.

In the Darror drainage basin, surface runoff in most of the drainage area is negligible as whatever rainfall that occurs in the basin area, which is low and irregular, is lost through evaporation and infiltration. Some *toggas* in the northern mountainous region do produce some surface rainfall after heavy rainfall. No data or observations exist in these small *toggas*.

In the Tug Der/Nugal drainage basin, some surface water records are available for Tug Der at Burai for six years during 1945 to 1950. During this period, an average of about 33 spates was recorded per year. About 85% of these occurred during the five months from May to September. It is estimated that an average runoff of 33 million m^3 (mcm) per year, equivalent to about 22 mm in the 1500 km^2 catchment, occurs in the area (runoff coefficient of 0.06) (*Kammer, 1989*). Although some mountainous areas in the basin contain some surface water, in other plain and plateau areas most rainfall is lost and little surface water ever reaches the Indian Ocean.

Table 4-15 : Hydrological Parameters of Four Catchments in Gulf of Aden Basin

	Waheen	**Biji**	**Dur Dur**	**Silil-Jidhi**
Catchment Area (km^2)	3,000	3,560	4,185	3,930
Potential Upstream Runoff (mcm)	130	100	160	89
Water lost by infiltration upstream of gorges (mcm)	90	56	120	85
Water passing gorges (mcm)	40	44	40	4
Infiltration in coastal plains (mcm)	40	44	40	4

Source: Sogreah (1981), cited by Groundwater Survey Ltd. (2006)

Box 4-2 **:** Typical Hydrological Regime of *Toggas* (Example: Tug Durdur)

Tug Durdur is a typical small stream (catchment area of 4,185 km^2) draining the north-western part of Somalia (Somaliland) which originates in the plateau and flows through the mountains to the Gulf of Aden. Even in this region with its semi-arid climate, surface water and groundwater resources available in catchments drained by *toggas* like Durdur can be and has been used for agriculture and for the domestic water needs of humans and livestock. Based on the study by Sogreah (1981) and by Groundwater Survey Ltd (2006), the water resources situation in the catchment is summarized below:

Water Availability

- Mean annual rainfall in the catchment is about 340 mm, with the upper catchment areas receiving around 500 mm per annum. Although the flows in most reaches of the stream are intermittent, there are certain stretches where there are perennial flows.
- Perennial springs are found in areas where groundwater recharges by the *toggas* are intersected by rocky outcrops. Discharge of such springs located in the upper catchment areas (e.g. region of Ruqi) were observed to be around 190 m^3/hr by Groundwater Survey Ltd (2006) while Sogreah (1981) has measured it as being 43 m^3/hr in 1981.
- Irrigation is carried out in such areas by pumping and water conveyance system. Irrigated orchards are found in the alluvium 2 to 3 m above the riverbeds.
- There are considerable groundwater-surface water interactions as the water tables and the rock outcrops intersect each other. Infiltration of runoff is high because of the gentle slopes of the river course, wide riverbeds and flood zones with large grained permeable soils. The *toggas* are often dammed up by rock barriers which stores large volume of water under the bed of the *toggas*. Vast green, fertile alluvial plains (e.g. at Qabri Baxar) are prevalent in such areas.
- Groundwater Survey Ltd. (2006) estimates an infiltration rate of about 36, 000 to 40,000 m^3 per km^2 in the valley areas of the *toggas* such as Durdur.

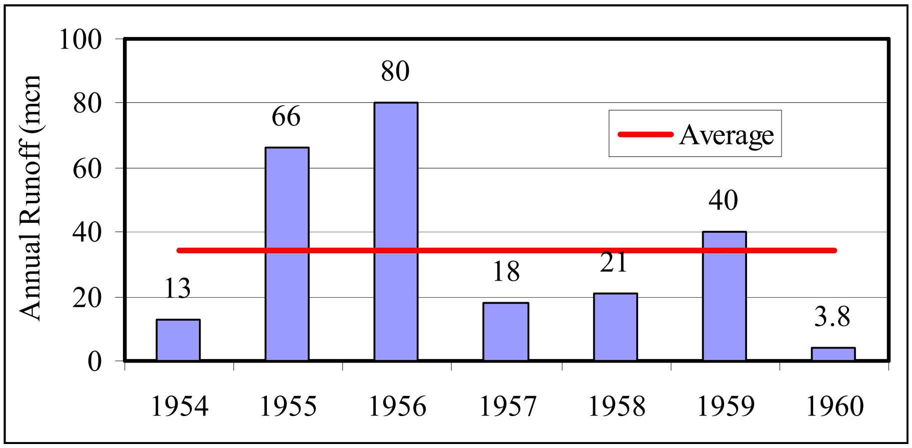
Flash Floods

The flash floods that originate from high intensity rainfall in the mountain areas are mostly infiltrated in sands and sandy clay deposits to contribute towards the groundwater recharge in the lower catchment. Hydrological observations were made for about a year during 1980 and 1981 in two locations in the Tug Durdur: one upstream at Ruqi on the Dibrawein (catchment area- 770 km^2, mean annual rainfall- 400 mm) and one downstream at Qabri Baxar on the Durdur (catchment area- 3660 km^2, mean annual rainfall- 350 mm) by Sogreah (1981).

- At Ruqi, 20 floods of 10m^3/s or above were recorded in 1980, with three about 60 m^3/s and one attaining 125 m^3/s. The latter was caused by heavy rains on the 20th and 21st October, 1980.

Togga Durdur (cont'd)

- At Qabri, ten flood events were observed in 1980, the heaviest being 2500 m^3/s and lasting for about 20 hours and another about 400 m^3/s lasting for eight hours. Total runoff was estimated to be about 27 mcm (million m^3).
- Again at Qabri, in 1981, 12 flood events occurred in March, of which four were between 900 m^3/s and 2200 m^3/s, total runoff volume being equal to 88 mcm. These floods were due to exceptional cyclonic rainfall.
- Based on data from 1954 and 1960, Mac Donald (1976) estimated the average annual runoff at Qabri Baxar as 34 mcm, 2.7 % of the mean annual rainfall of 350 mm. However the annual variation, as seen from the figure below, is very high.



Water Sources

- Data on the assessment of 12 boreholes (depth between 60 -125m) in Durdur show that: the downstream parts have higher yields (20 – 100 m^3/hr) compared to those in the upstream parts of (7 – 14 m^3/hr). Safe yield is much less.
- Shallow wells and springs located in the Durdur catchments are given below:

District	**Baki**	**Ruqi**	**Heego**	**Adaad**	**Hamarta**	**Horey**	**Total**
Shallow Wells	78	37	11	25	0	0	151
Av. water level (m)	5.9	9.4	4.5	3.3	0	0	5.8
Av. depth (m)	8	11.3	6.5	4.3	0	0	7.5
Av. discharge (m^3/d)	67	204	19.2	11	0	0	75.3
Springs	1	1	-	2	2	3	9

. Source: Groundwater Survey Ltd. (2006)

4.4 Surface Water Storage - *Wars* and *Berkads*

Wars and *berkads* (also called *bailey* or water pan, ponds, dams) used for rain water (catchment) harvesting are common in Northern Somalia. The 1:100,000 topographical maps of Somalia, although prepared some decades ago, locate the water points in the country. There are many such water points located in the areas of the five drainage basins (*Table 3-29* and *Figure 4-23*). The Ogaden drainage basin has a high percentage of rainwater ponds/reservoir (77% of water points) which is understandable because the groundwater potential in the areas is not much. In the other four drainage basins, there are between 25% to 40% rainwater ponds/reservoirs. Except for the Central Coastal areas (5% of total water points), there are not many water tanks ("*Berkads*") located in the topographical maps. The SWALIM water sources database (SWIMS) being compiled through cooperation with partner agencies, however, does include *Berkads* and Dams which harness surface water in all the drainage basins except for the Central Coastal region (*Table 4-17*).

Table 4-16 : Water Points from Topographical Maps of Major Drainage Basins in Central-Northern Somalia

	Aden		**Darror**		**Nugal**		**Ogaden**		**Central Coastal**	
Type of Water Point	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**
Wells (WPW)	393	42.9	97	62.6	408	49.5	861	23.2	459	55.8
Wind Driven Wells (WPWW)	0	0.0	0	0.0	0	0.0	0	0.0	2	0.2
Motor Driven Wells (WPMW)	7	0.8	0	0.0	6	0.7	0	0.0	0	0.0
Rainwater ponds/reservoirs (WPRP_R)	231	25.2	44	28.4	323	39.2	2838	76.6	319	38.8
Natural Springs (WPNS)	283	30.9	14	9.0	83	10.1	0	0.0	0	0.0
Man-made Springs (WPMS)	1	0.1	0	0.0	0	0.0	1	0.0	0	0.0
Water Tanks (WPT)	1	0.1	0	0.0	5	0.6	5	0.1	42	5.1
Total	**916**	**100**	**155**	**100**	**825**	**100**	**3705**	**100**	**822**	**100**

Source: Digitised Data from 1:100,000 Topographical Maps

Dams, ponds and dug outs (*Wars*) are commonly used in the Nugal and Darror valleys to collect storm water from small catchments. The *Wars* are unlined with surface areas of hundreds to thousands of m^2 and a depth of 2 to 3 m.

Berkads are major water sources in Haud Pleatau. There are many of them in Galbeed, Sool and Togdheer regions. Recently, they have been introduced in the Sanaag and Awdal regions too. They vary in their capacity, the ones in Togdheer, Sool and Sanaag are normally less than 300 m^3 while the ones in Awdal and Galbeed are more than 300 m^3 capacity. The main problems with *Berkads* are related to sanitary and hygienic conditions. More than 50% of the Berkads are non-operational due to cracks developed mainly as a result of faulty design and construction.

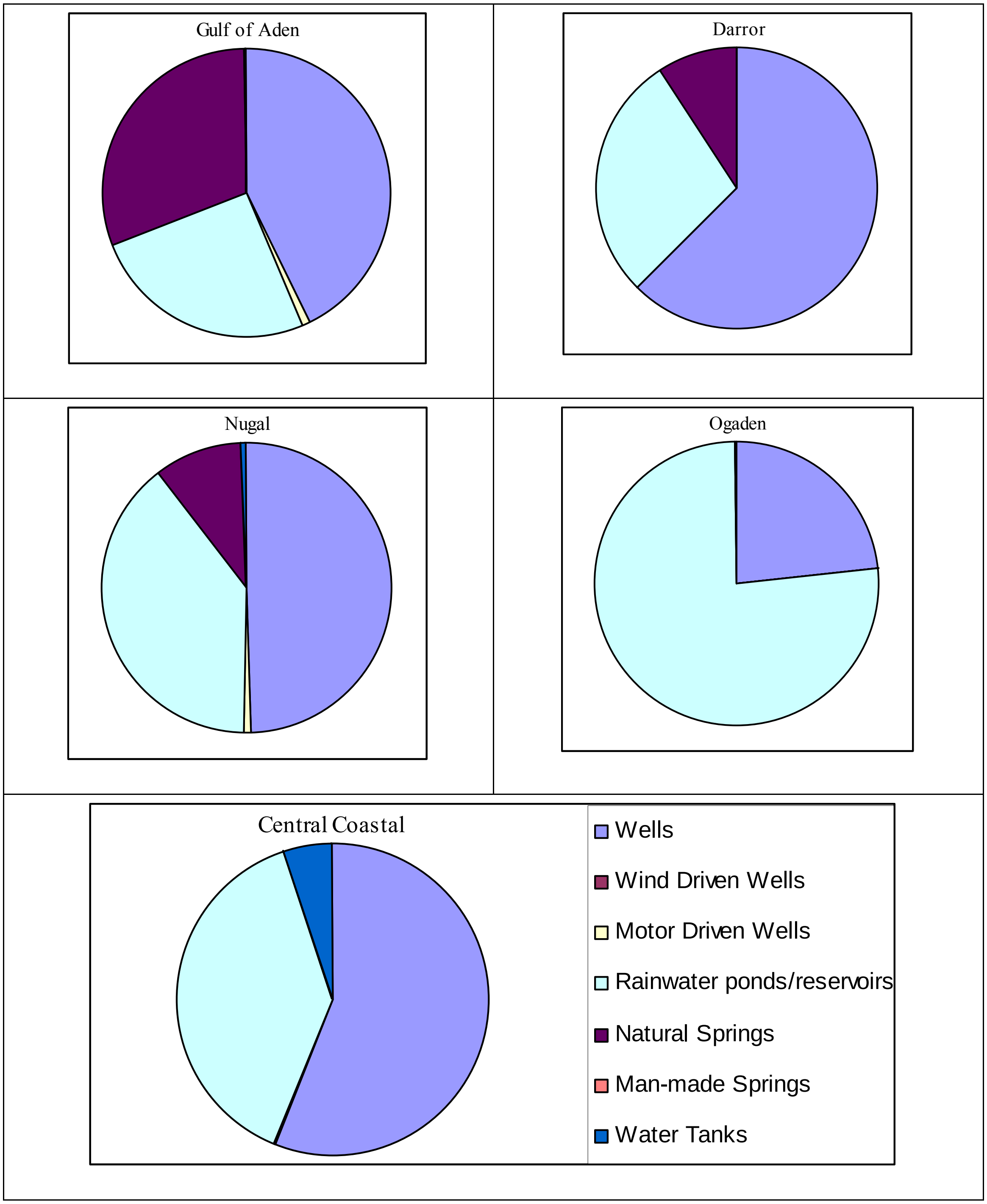


Figure 4-23 : Water Points from 1:100,000 Topographical Maps

Table 4-17 : Number of *Berkads* in Regions of Northern Somalia

Region	No. of Berkads
Togdheer	5000
Sool	2400
Awdal	100
Sanag	100
Woqooyi Galbeed	40[5]

Source: SWALIM Project Report No. W-08 (2007)

Mink (2007) estimated that the cost of *Berkad* construction was between US$1500 and 3000, depending on the size and construction materials. Major problems encountered with *Berkads* were: leakages due to seepage through cracks appearing as a result of bad construction technology used, high evaporation losses, and contamination due to poor sanitary conditions in rural areas.

Surface water dams from small surface water harvesting *ballis* to *wars* of larger sizes (up to 150,000 m^3 capacity) are common in Northern Somalia. The major problems identified with such dams are: high construction costs (US$ 80,000 – 100,000 for one), high losses through seepage due to adverse site conditions, the need for regular dredging to remove silts, over exploitation of the *wars* and the locating (meaning not clear – Ed) leading to land degradation and erosion due to over grazing by livestock of pastoralists and nomadic population. There were six high capacity dams constructed by the World Bank in rural Somalia in the 1980s. The cost of each of these dams ranged from US$ 80,000 to 100,000 each. Siltation was identified as one of the main problems in the *wars* and dams.

4.5 Groundwater

As there is little surface water available in the five drainage basins described in this chapter, groundwater is an important source of water to meet the needs of the human and livestock population. Data on the aquifers and groundwater systems are scattered and scarce. The following are some past studies/reports available for the areas discussed in this chapter: TA MS (1986) in the central rangeland, by Petrucci (2006) for some areas of NW Galbeed and Awdal regions of the Haud Plateau; Somaliland, by Sogreah (1982); and Groundwater Survey (2006) for Dur Dur watershed in Awdal region. The best source of information on groundwater aquifers and potential areas of further development is still the data collected and analysed by Faillace and Faillace (1987).

Groundwater movements in Northern Somalia, in the areas covered by the Gulf of Aden, the Darror and the Nugal drainage basins, start in the mountainous areas and move in two directions. The first is from the south to the north from the mountainous regions to the coastal areas of the Gulf of Aden. The second is from the north to the south towards the Haud and

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[5] Indicated data is only from current SWIMS database, no numbers were obtained from the ground; the actual number could be much more.

Sool plateaus. Thus the hydrogeological divide mostly coincides with the surface drainage divide.

In most of the areas covered by the five drainage basins, groundwater recharge is through direct rainfall, amount of infiltration is estimated to be not more than 5% of the rainfall due to low and erratic rainfall (*Faillace and Faillace, 1987*). Surface water from *toggas* and *wadis* can be trapped in the mountainous areas of the Gulf of Aden basin through infiltration galleries and check dams (gabion structures) to recharge the groundwater .

In the mountainous areas of the Gulf of Aden, Darror and Nugal basins and in the northern and eastern coastal areas, water tables are found with 5 – 20 m along the *toggas*. Whereas in the plateau areas, the water depth is quite deep and boreholes are drilled to a depth of 150 m to up to 400 m.

4.5.1 Groundwater Aquifers[6]

The main hydrogeological basins in the areas (*Faillace and Faillace, 1987*) covered by the five drainage basins are as follows:

- **Coastal Belt and Sloping Plain**, **Mountainous Zone** incised by numerous *toggas* in the Gulf of Aden basin
- **Plateaus and Valleys** which include the large undulated Haud and Sool plateaus and the Darror and Nugal valleys in the Darror and Tug Der/Nugal drainage basins
- **Mudug-Galgadud Plateau** in the Ogaden drainage basin
- **Coastal belt** in the Central Coastal basin

Northern Coastal Belt, Sloping Plain and Mountainous Zone

The coastal belt and sloping plains of the Gulf of Aden basin receive little rainfall (less than 50 mm/year) and has very high temperatures and evaporation. The alluvial deposits of the sloping plains and the coastal belt are recharged by run-off water from *toggas* flowing from the mountain range. The mountainous zone extends along the continuous belt from Borama to Hargeisa, Sheikh, Ceerigabo and Bosaso Districts. The northern side towards the Gulf of Aden consists of deep valleys, steep slopes, hills and mountain ranges. The southern side forms the edge of a large plateau which slopes gently towards south and southwest.

Plateaus and Valleys

The Haud Plateau, the Taleex Plateau and the Nugal Valley, the Sool Haud and Sool plateaus, and the Darror Valley are known to have interrelated factors. Geological and morphological aspects are similar and the groundwater conditions are interrelated.

In the Haud Plateau, groundwater is tapped by hand-dug wells along major depressions and by a few drilled wells. The water table in general is known to be deep, more than 300m in some regions. Economic exploitation of groundwater aquifers in the central and eastern parts of the Haud Plateau is doubtful.

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[6] Mainly adapted from Faillace and Faillace (1987)

The Nugal Valley is a large, flat-bottomed valley flanked by the Teleex, Sool Haud and Sool Plateaus. The Teleex Plateau rises gently towards the edge of the escarpment which constitutes the upper-most part of the T. Nugal catchment. Groundwater recharge by direct infiltration occurs mainly in the upper most part of the T. Nugal catchment. There are a number of hand-dug wells tapping water from the Teleex Formation and from gypsiferous alluvial deposits in the depressions along *togga* beds and in the flood plains.

The Sool Plateau is a sparsely populated area with very little water resources. The water table in the Sool Haud Plateau is at depths of more than 100m. In the flood plains of the Xingalool, the water table is at depths of 60m. Data from eight boreholes drilled by the Chinese in the 1980s in the Haud and Sool Plateaus are at depths from 113 m to 230 m, with yields ranging from 1.35 to 8.33 m^3/hour and specific capacity between 0.038 and 9.560 m^3/hr/m (Faillace and Faillace, 1989). Groundwater resources in the Sool Haud and Sool Plateaus seem to be scarce and high cost required for drilling deep bore holes makes it uneconomical.

The main water sources in the Darror Valley are located along the toggas, especially along T. Jaceyl, where water is found at shallow depths in different locations. In addition, springs are also found in small valleys in the mountain range. The central part of the valley does not show a good potential of freshwater at economical depths. However, possibilities of exploiting groundwater at reasonable depths are there in the terminal sections of the alluvial fans which extend along the mountain bordering the northern side of the Valley. Groundwater exploration should be further carried out in this region.

Mudug-Galgadud Plateau

The main aquifers in the Mudug-Galgaduud Plateau are the Yasooman Formation, Karkar Formation, Oligocene-miocene Suites and Plio-Pleistocene Gypsiferous Deposits. The Yasooman Formation marks the eastern edge of the Upper Shabelle Valley and forms as escarpment which corresponds to the southwestern limit of the Central Rangelands Plateau. Groundwater from this formation is known to be of good quality. There are limited well data but one artesian well drilled in 1985 had a water level 2.7 m above ground. The Karkar formation covers the northern part of the Mudug-Galgaduud Plateau. The boreholes drilled in this formation had to be abandoned due to cavities. The ones that were completed as production wells struck water of good to fair quality at depths over 100 m. The lower section of the Oligocene-miocene Suites is represented by dense karstified limestone (basal limestone) transgressive over the Yasooman Formation. Water quality in the limestones is known to be from fair to good. The upper section of the Oligocene-miocene suites consists of gypsiferous clay, sand, gypsiferous sand, gypsum, sandstone, and intercalation of thin layers of limestone (Mudug beds). Several wells drilled in the Mudug beds struck highly saline water. A shallow gypsiferous aquifers constituted by gypsum, calcrete, and gypsiferous clay is widespread in the central part of the Mudug-Galgaduud Plateau (Plio-Pleistocene Gypsiferous Deposits) and is related to the two major ancestral drainage systems: the Galkayo and Dhuusamarreeb systems. There is some underground flow along these ancestral drainage systems. The water level in hand dug wells and sinkholes are 20-25 m deep northeast of Gaalkacyo and it decreases to 2-3 m or less in the terminal flood plains.

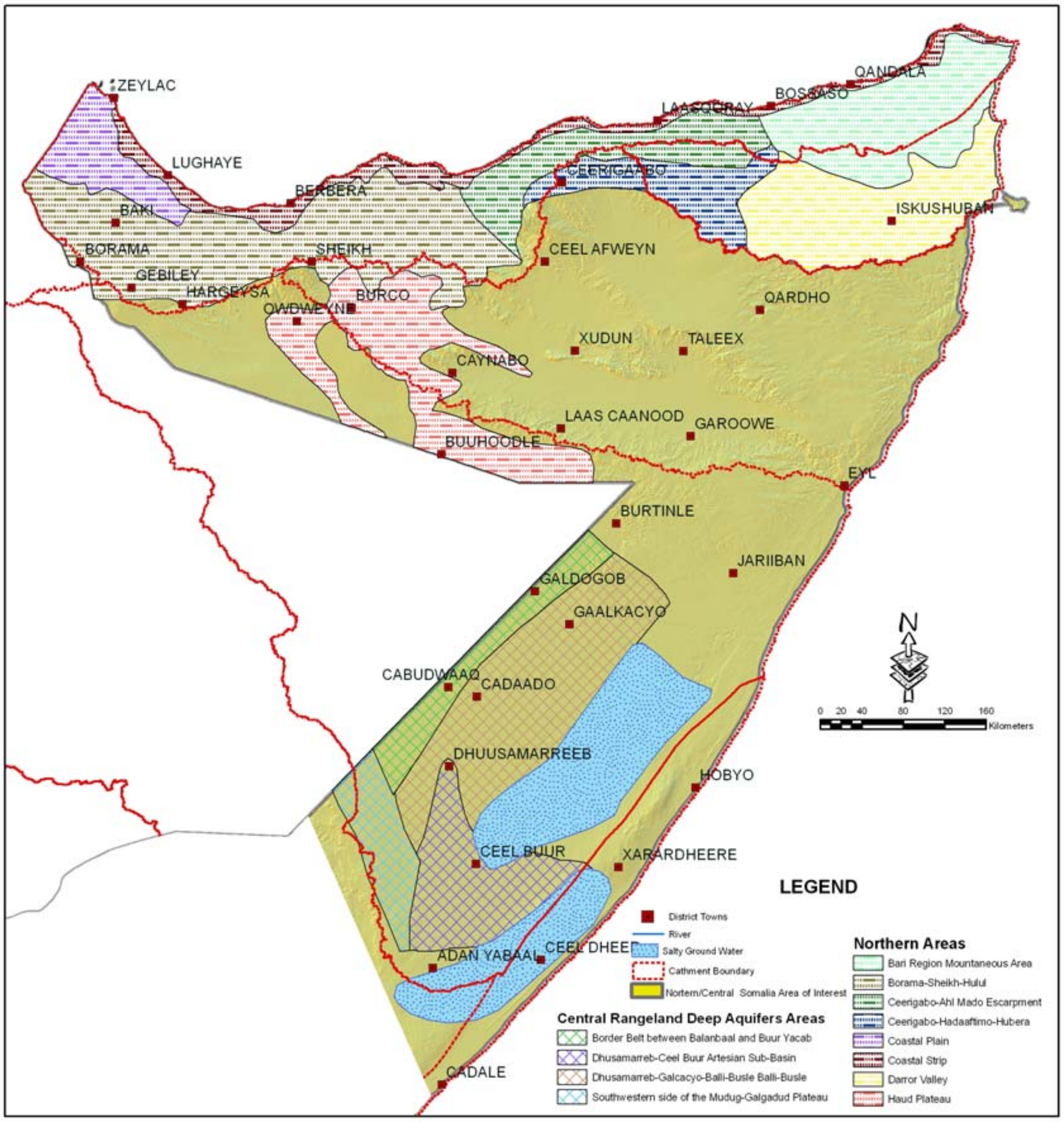
Indian Ocean Coastal Belts in Central Coastal Basin

The coastal best is constituted by a variety of rocks including limestone, sandstone, marls and clay, sand, coral limestone, and arenaceous sandstones dating from Oligocene to recent. The main water sources are the hand-dug wells used by the nomads and the few scattered villages. Pits and hand-dug wells along the coast tap water from beach sand and coral limestone. The freshwater lenses are very thin and deteriorate rapidly when withdrawn intensely. most of the hand-dug wells yield water with an E. C. between 2000 – 3000 S/cm, with exception of a few cases in the dunal belt at a certain distance from the coast which is of the bicarbonate type.

4.5.2 Potential groundwater development areas

Faillace and Faillace (1987) recommended certain areas that had good potential for groundwater development across the country. As also discussed in Chapter III, these are based on the hydro-geological and water quality suitability using data of wells available at the time. Other factors important for groundwater development such as the potential for grazing and agriculture, and population distribution were not included the assessment of these areas.

These areas with good groundwater potential in the areas of the five drainage basins are given in Map 4-6 and Table 4-18. It should be noted that data on nature, thickness and extension of aquifers is missing and water quality information and descriptive information of the geological characteristics are only available. The groundwater potential areas show that the well depths are in the range of 100 - 250 m. In addition to these deep wells that harness the deep aquifers in the region, water is also used from sub-surface layers at shallow depths along the various *toggas* and small streams.



Map 4-6 : Potential Groundwater Area in Northern Somalia

Table 4-18 : Areas with good Groundwater Potential in the Five Drainage Basins of Central-Northern Somalia

No	Name	River Basin	Region	District	EC Range (µS/cm)	Well Depth (m)	Remarks
1.	Sand dune Coastal Belt	Central coastal	L. Shabelle	Mogadishu, Marka	NA	NA	Water quality good depending on the thickness and shape of the freshwater lens, additional investigation recommended
Deep Aquifer Development in Mudug-Galgadud Plateau							
2	Southwestern Side of the Mudug-Galgadud Plateau	Ogaden	Galgaduud	Cabudwaaq, Galkacyo, Galdogob	NA	100-220	Yasoomman Formation, constituted by red sand and stand stone covering a large belt of 30-60 km along the western side of the Mudug-Galgaduud basin
3	Border Belt between Belanbaal and Buur Yaqab	Ogaden	Galgaduud	Ceel Buur	1,750–3,000	120-250	Unconfined aquifers with water level between 75-150 m
4	Dhuusamarreeb – Gaalkacyo-Balli Busle	Ogaden	Galgaduud	Dhussa - arreeb, Cadado, Galkacyo	NA	150-200	
5	Dhuusamarreeb-Ceel Buur Artesian Sub-basin	Ogaden	Galgaduud	Dhussa marreeb,, Ceel Buur	NA	NA	Deep confined aquifers overlain by basalt has high artesian pressure and well production is good, Wells in Ceel Buur can be used for small scale irrigation

No	Name	River Basin	Region	District	EC Range (µS/cm)	Well Depth (m)	Remarks
Central Somalia- Mudug-Galgadud Plateau – Shallow Aquifer Development							
6	Gaalkacyo and Dhuusa-arreeb Ancestral Drainage Systems	Ogaden	Galgaduud, Mudug	Dhussa marreeb, Galkacyo	NA	NA	Numerous shallow wells in existence - 70-80% of water for Mudug-Galgadud plateau, mostly used by nomads and hence grazing potential
7	Coastal belt	Central coastal	Galgaduud, Mudug	Ceel Dheer, Xarardheere, Hobyo	NA	NA	Freshwater lens limited to a few short sections along the coast, careful management required, dug well and shallow drilled wells with good to marginal quality water
Northern Somalia - Coastal belt and sloping plain							
8	Shallow aquifer development along the coastal belt	Gulf of Aden	Awdal, W. Galbeed, Sanaag, Bari	Coastal Districts in the north	NA	5–10	Continuous shallow aquifer recharged by numerous *toggas* from the mountains, sub-surface water flowing in alluvial deposits, water table is 2-3 m near the shore, date palms are cultivated along the coast
9	Sand- River and Alluvial Cone Aquifers Bordering the Sloping Plain	Gulf of Aden	Awdal, W. Galbeed,	Borama, Baki, Lughayen Hargeisa	3,000-6,000 (Waheen area)	NA	Areas covered by T. Waheen, Biji, Durdur, Silil Toggas have high yield, suitable for dug wells and shallow drilled wells

No	Name	River Basin	Region	District	EC Range (µS/cm)	Well Depth (m)	Remarks
Mountainous Zone- Northern Somalia							
10	Boorama Shiekh-Hulul Area	Gulf of Aden	Awdal, W. Galbeed,	Borama	NA	NA	Good rainfall and recharge conditions, many springs and underground/surface dams and infiltration galleries could be constructed
11	Ceerigabo-Ahlmado Escarpment	Gulf of Aden	Sanaag,	Ceerigaavo, Ceel Afweyn	NA	NA	30-40 springs yielding less than 1 l/s, small scale irrigation feasible
12	Bari Region Mountainous area	Darror	Bari	Qardho	NA	NA	"*Laas*" dug in the sandy beds of Dugahan, Balade and Merera Toggas, many springs occur and are used for small scale irrigation, Numerous wells around the town of Boosaso
Plateaus and Valleys- Northern Somalia							
13	Haud Plateau[7]	Ogaden, Nugaal	W. Galbeed, Togdheer	Hargeisa, Owdweyne, Burco	NA	NA	Best grazing potential, but limited water resources, Water table below 282 m at Salaleh, investigation for shallow aquifers

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[7] In 2005/2006, geophysical survey was carried out in some small areas NW Galbeed and Awdal regions of the Haud Plateau (Petrucci, 2006). A number of Vertical Eletrical Sounding (VES) were carried out in 6 villages. Groundwater potential were categorized as poor (less than 50 m^3/day/well), medium (50-100 m^3/day/well) and high (more than 100 m^3/day/well). Two of them had poor and four had medium to high potential.

No	Name	River Basin	Region	District	EC Range (μS/cm)	Well Depth (m)	Remarks
							required in T. Togdheer and other *toggas*
14	Margin of Sedimentary Basin in Ceerigabo, Hadaaftimo, and Hunerra in the Sanaag Region	Gulf of Aden and Darror	Sanaag	Ceerigaavo, Ceed Afweyn	NA	NA	Well drilled in Ceerigabo – 195m deep, with yield of 180m^3/hr with only 2.43 m drawdown
15	Darror Valley	Darror	Bari	Iskushuban	NA	NA	Shallow aquifers along T. Jaceyl, good potential springs, Iskushuban springs are used for irrigation, groundwater investigation along the base of the -ountains delimiting the northern side of the valley neededd

Source: Adapted from Faillace and Faillace (1987)

4.5.3 Groundwater use

Groundwater is harnessed by rural and urban population to meet domestic and livestock water needs as well as for small scale irrigation. A rural water supply assessment study carried out by SWALIM (Technical Report No. W-08) shows that the major groundwater sources such as dug well, bore holes and springs are extensively used in the region. SWALIM's database (SWIMS) contains a total of 538 water sources listed in the five drainage basins (Table 3-31). Out of which, 266 are groundwater sources, namely Bore holes, Dug Wells, Springs and Others.

Table 4-19 : Water Sources in Central-Northern Somalia from SWIMS Database

	Gulf of Aden	**Darror**	**Tug Der/ Nugal**	**Ogaden**	**Central Coastal**	**Total**
Berkad	**31**	**5**	**43**	**179**	**-**	**258**
Urban	6	1	6	7	-	20
Nomad	20	3	15	39	-	77
Rural	24	5	30	148	-	207
Community owned	4	-	2	16	-	22
Dam	**11**	**-**	**-**	**3**	**-**	**14**
Urban	-	-	-	-	-	0
Nomad	-	-	-	-	-	0
Rural	-	-	-	-	-	0
Community owned	1	-	-	-	-	1
Bore holes	**10**	**5**	**33**	**21**	**-**	**69**
Urban	6	1	20	5	-	32
Nomad	-	2	6	0	-	8
Rural	9	5	16	**13**	-	43
Community owned	-	-	-	1	-	1
Dug Well	**94**	**7**	**18**	**13**	**31**	**163**
Urban	24	-	4	1	3	32
Nomad	22	3	3	9	1	38
Rural	77	7	10	11	13	118
Community owned	5	-	3	1	15	24
Springs	**10**	**8**	**10**	**3**	**-**	**31**
Urban	-	2	3	-	-	5
Nomad	1	1	3	2	-	7
Rural	7	6	5	3	-	21
Community owned	2	-	1	-	-	3
Other	**-**	**-**	**3**	**-**	**-**	**3**
Urban	-	-	1	-	-	1
Nomad	-	-	1	-	-	1
Rural	-	-	2	-	-	2
Community owned	-	-	-	-	-	0
Total Sources	**156**	**25**	**107**	**219**	**31**	**538**

From the database of water points digitised from the 1:100,000 topographical maps of Somali (Table 3-29), we can see that except for Ogaden Basin, other drainage basins have a good percentage of groundwater wells. In the case of Gulf of Aden, 31% of the water points in the topographical maps are springs, which is quite understandable in the mountainous terrain in the western regions with small *toggas* interspersed in them recharging the spring water sources. The Darror and Nugal Basins also have about 10% of spring water points. Again, these are predominant in the higher elevation regions. Ogaden and the Central Coastal areas do not have springs identified, which is also quite obvious given their relative low elevation and flatter terrain. In the Ogaden Drainage Basin, 77% of the water points listed is rainwater ponds/reservoirs. This is understandable given the low groundwater potential in the areas and rainwater harvesting is one main source of water. The topographical maps did not have many water tanks ("*Berkads*") listed except for some 5% in the Central Coastal drainage basin.

4.5.3.1 Dug Well

Shallow dug wells are common sub-surface water sources in the area. many of them however run dry during prolonged droughts. They are also known to have high organic contamination due to poor construction and common outlets for both livestock and humans. As discussed in Chapter III, data of this important source of groundwater has been collected by various sources. However, these are incomplete and data on the water consumption pattern, amount and purpose of use, are unavailable.

Shallow wells are dug along the various *toggas* of the mountainous regions of the drainage basins in Northern Somalia. Shallow wells are also common in the northern coastal areas but the quality of water is a problem. In the plateau areas, the water tables are found to be lower and hence there are less of shallow dug wells found in these areas.

Information on shallow wells collected by SWALIM through field visits and interviews in the regions of Northern Somalia are given in Table 4-20. most of these were found to be unlined which was attributed to high costs of lining such wells.

Table 4-20 : Shallow Wells in Regions of Northern Somalia

Region	**Number**	**Locations**	**Average Depth (m)**	**Uses**
Awdal	300	Along dry beds of Toggas	5 - 6	Domestic, livestock and irrigation
W. Galbeed	465	Along dry river beds and backs	8	Domestic, livestock and irrigation
Sanaag	250	Coastal areas, along river beds	4	Domestic, livestock and irrigation
Togdheer	980	Dry beds of T. Dheer	3 – 8	Domestic, livestock and irrigation (10%)

Source: SWALIM Technical Report No. W-08.

Construction technique used for the dug wells is poor, which leads to cracked platforms which allow runoff water to seep back into the well. Many lack the well head, while those rehabilitated have concrete lining only to a maximum depth of 10 m with the rest of lining being either timber or natural stone. Average cost of shallow dug wells with concrete linings to about 6 m depth ranged from 1,800 – 2,200 US$.

4.5.3.2 Boreholes

Boreholes provide water through out the year and for communities living away from the major rivers they are the only source of water during prolonged drought periods. It is estimated that there were a total of 205 boreholes in the five regions of Somaliland before 1988. However recent estimates suggest that only about 25% of them are operational. Private boreholes are also drilled to irrigate private farms or for selling water through tankers to other users. As boreholes are the only permanent sources of water in most of the arid regions of Northern Somalia, they are quite useful to meet the water needs during the dry seasons. Private wells are known to charge an equivalent of between 0.05 to 0.1 US$ for a 20 litre jerrican and it is also supplied through tankers as far away as 50-60 km. The transportation costs add up to the cost of water and it can be as high 0.4 US$ for 20 litre of water. The cost of drilling boreholes in the region was about 120-200 US$ per m of drilling. For a 150 m deep borehole, it will cost 35,000 – 40,000 US$ including the casing and pumping tests.

Private boreholes are also now in operation. Fifteen private boreholes (with a depth of 145 m – 180 m; static water level – 95 m – 120 m) are in operation in Togdheer Region. These are mainly used for irrigating orchards, with one near Burao used for water bottle industry.

Details of some of the bore holes in operation in Somaliland are given in Table 4-21.

Table 4-21 : Data of Selected Boreholes in Somaliland

Name/Location	Depth (m)	Static Head (m)	Yield Estimate (m^3/h)	Remarks
Yuba Borehol	160	-	-	-
Darar Weyne	220	105	3	Operates 22 hours/day in Hagaa and Jilaal (0.15$ for 20 liter)
Lanqucuje	124	94	12	For Erigavo Town (0,08$ for 20 liter
Xingalool	114	60	6.5	0.3 $ for 200 liter barrel
Berahaga	200	130	-	-
Dhakar	170	-	30	-
El Bur	164	137	39	-
Kabadheere	186	90	10	5 km south of Burao
Jiifto	86	82	-	25 km from Berbera Town

Source: SWALIM Technical Report No. W-08.

From Table 4-21, we can see that the depth of bore holes in Somaliland (north-western regions of Somalia) ranged from about 90 m to 220m and the static water level was from 80 to 130 m below the surface. Survey by various sources estimate that the average water level in Bari, Nugal, Eastern Sanaag and Mudug regions are 30 m, 160 m, 120 m and 230 m respectively.

4.5.3.3 Springs

In the mountainous areas of the Gulf of Aden Drainage Basin and the Darror and the Nugal Valleys, groundwater moves quickly towards the lowland in fissures and faults and is discharged through a number of springs. Spring water generally flows in stream channels and infiltrates rapidly in boulders and gravel after short durations. This water is of relatively good quality. There are a number of thermal springs that flows from the base of the mountain areas and faulted rock outcrops along the coast.

Natural springs are found In the mountainous areas of Awdal, W. Galbeed and Togdheer regions. There are more 28 perennial springs in the Galbeed regions. UNICEF in 1999 located six springs in the Baki and Lughaya districts of Awdal region.

Both natural and man-made springs are also used for human and livestock water consumption. According to the data of water points derived from the 1:100,000 scale topographical maps (Table 3-29) there were 283 natural springs in the Gulf of Aden Basin, 14 in Darror Basin and 83 in the Nugal Basin. Ogaden and Central Coastal basins, as expected, did not have any springs due to their geological conditions.

4.6 Water demand

Water demand for human and livestock consumption is an important demand in any region in Somalia. UNICEF survey results for Puntland showed that 30% of people used Berkads, 35% used Boreholes, 10% used dug wells and 5% used springs as the main source of water supply for human and livestock needs.

4.6.1 Domestic demand

Although per capita water demand is based on various factors including water availability, price, socio-economic profile, climate etc, a rough estimate of the rural and urban water demand for regions lying in the four northern drainage basins is presented in Table 3-35. It is based on the UNDP draft population data and a per capita demand of 20 lpcd and 50 lpcd have been used for rural and urban water demand. These demand rates are considered average rates in the region considering the water availability and other factors. A total of about 96,670 m^3 of water per day is required for the regions under consideration. The water demand of the central coastal regions is not included here as population estimates are unavailable.

Table 4-22 : Rural and Urban Water Demand Estimate in Central-Northern Somalia

Zone	Region	Population Estimates		Water Demand Estimates (m^3/d)		
		Urban	**Non-urban**	**Urban**	**Non-urban**	**Total**
North-west	Awdal	110,942	194,513	5,547	3,890	9,437
	W. Galbeed	490,432	209,913	24,522	4,198	28,720
	Togdheer	123,402	278,893	6,170	5,578	11,748
	Sool	39,134	111,143	1,957	2,223	4,180
	Sanaag	56,079	214,288	2,804	4,286	7,090
	Bari	179,633	188,005	8,982	3,760	12,742
North-east	Nugaal	54,749	90,592	2,737	1,812	4,549
	Mudug	94,405	255,694	4,720	5,114	9,834
Central[1]	Galgaduud	58,977	271,080	2,949	5,422	8,370
	Total	**1,207,753**	**1,814,121**	**60,388**	**36,282**	**96,670**

Note:

[1] Only one regions (Galgaduud) is included from the Central region in this table.

Water consumption in five villages in north-east Somalia, in Togdheer and Galbeed regions of the autonomous region of Somaliland, is presented in Box 4-3. It is based on a house-hold level survey carried out by Caritas, Switzerland and Caritas, Luxembourg (Swiss Group) (Caritas, 2007). The survey was carried out in a sample size of 150 households (about 7% of 2235 households in the 5 villages) to survey on "Knowledge, Attitude and Practices (KAP) in Water, Sanitation and Hygiene" in the five villages. The discussion presented in the box is focused mainly on the water supply and sanitation (WATSAN) coverages, water sources, water consumption pattern, some coping cost and sanitation aspects although the survey carried out by Caritas had covered other aspects of hygiene. It would certainly be inappropriate to consider the case of these five villages as representative of the whole northern region. The regions also received more rainfall than other arid regions in the western and central-north regions of Somalia. However, it does give a snapshot of WATSAN situation in the rural villages of northern Somalia. Other similar studies and/or performance evaluations on WATSAN interventions by different agencies spread over different climatic and socio-economic regions of the drainage basins would be useful to plan and design future interventions in the WATSAN sector.

The urban water supply system in central and northern regions of Somalia, like in southern Somalia, is managed and operated by various public and private operators. As water is a scarce commodity in the arid and semi-arid regions of most of Somalia, consumers in the urban areas are willing to pay a substantial amount of money for access to water supply. must urban towns rely in a variety of water sources including water utility (privately owned or public-private), private tankers, private wells and hand-pumps. Tanker distribution is now common in many towns in Northern Somalia. Privately owned water distribution tankers are used to supply water to towns such as Galcio, Garowe, Bossaso and Gardo. SWALIM Technical Report No. W-07 presents the status and description of three urban water supply systems in Bosaso, Borama and Erigabo, all located in the northern region of Somalia.

A study by Hydroconseil (2002) for EC and UNICEF in the five urban towns in Somalia (including Berbera, Borama, Burao and Bosaso in Northern Somalia) show that the private sector plays an important role in meeting the water needs of these urban towns. However, the coverage of urban households by the water utility is quite low. Connection per 1000 inhabitants are about 30 for Berbera, 20 for Hargeisa, 10 for Bosaso and is less than 5 for Burao and Boroma. The scope of public-private partnership (PPP) to increase the coverage in these and other towns is considered good as people in Somalia are willing to pay for the water services they receive. Given the huge investment required for the water sector, it would be beneficial to attract private investment at least in the urban sector. Management of private utilities is also considered to be better than this of the public sector. Various models of PPP are in operation from concession (informal) in Baidoa, public autonomous in Berbera, Burao, Hargeisa and Borama, and lease contract in Bosaso.

Box 4-3 : WATSAN Situation in North West Somalia (Somaliland)- Togdheer and Galbeed Regions
(Source: Caritas, 2007)

Status

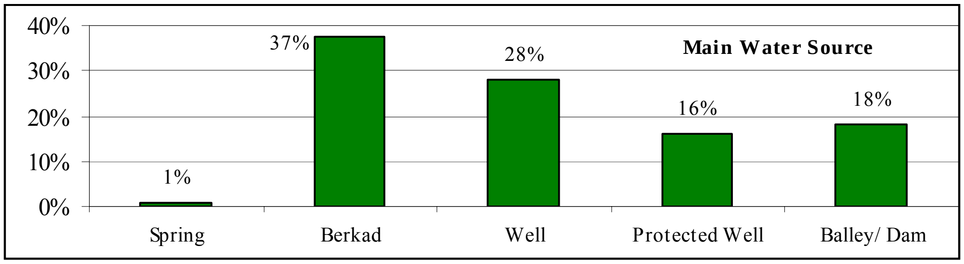
- About 69% of population lack access to safe drinking water in Somaliland
- 79% of rural and nomadic population have no access, total an unserved rural and nomadic population of about 723,000
- Latrine coverage (Sanitation) is 25.1% (urban) and 14.4% (rural)
- Caritas WASH project has rehabilitated more than 500 berkads and built 17 new berkads, over 100 wells and several sand storage dams
- Caritas has also provided latrine slabs and rubbish pits to enhance proper hygience
- Current population of Somaliland estimated as 3 million with 50% in Togdheer and Galbeed regions (including IDPs returning from Ethiopia and Djibouti)

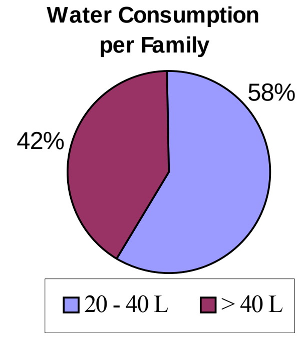
Results of Caritas Assessment in 5 Villages

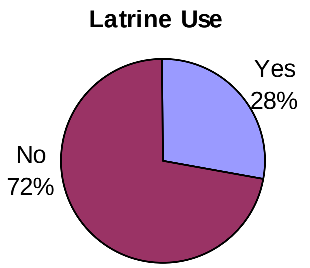
- 150 households in *Wajaale*, *Udaan*, *Qoryaale*, *Haahi* and *Qaloocan* Villages surveyed using structured questionnaires (out of total 2235 households with total population 11,865, with average house hold size of 7)

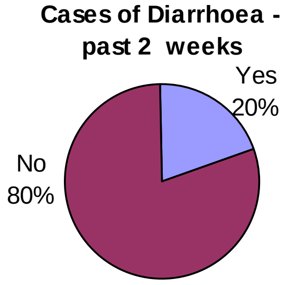
Main Sources of Water

Village	**Source of Drinking Water**				
	Spring	**Berkad**	**Shallow Well**	**Protected Well**	**Balley or Dam**
Haahi		25	3		2
Qaloocan		29	1		
Qoryaale			7	23	
Udaan	1		29		
Wajaale		2	2	1	25
Total	**1**	**56**	**42**	**24**	**27**

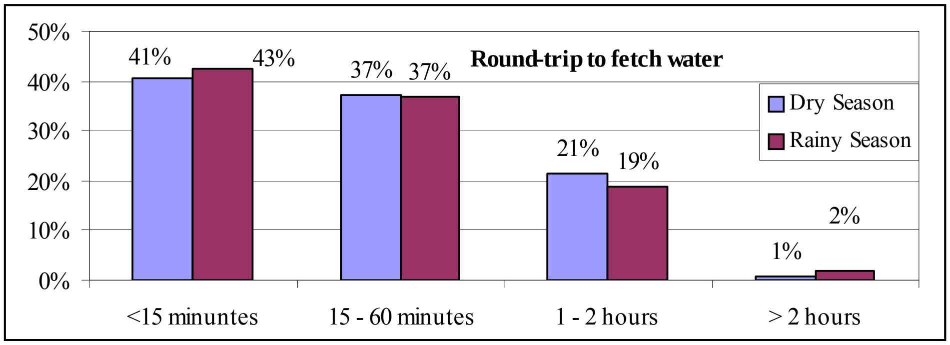


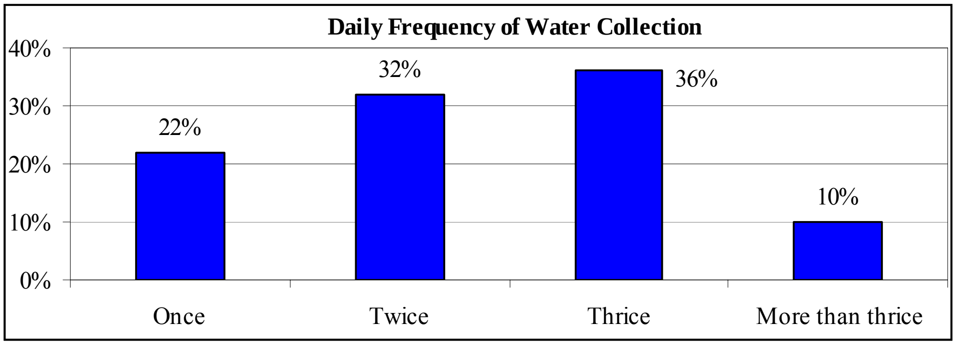


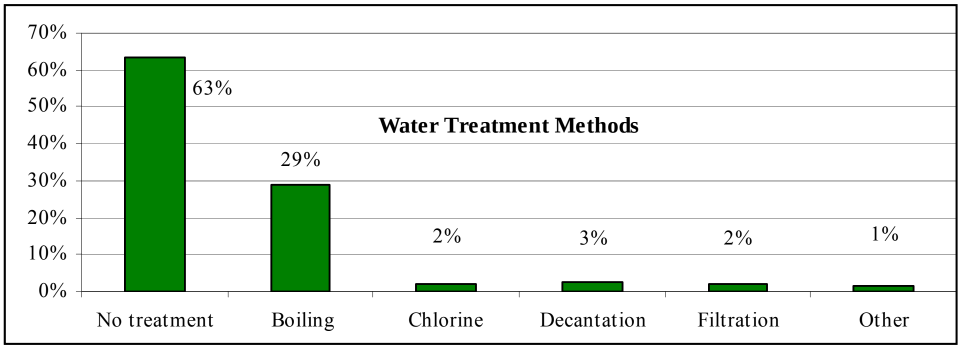




Box : WATSAN Situation in North West Somalia (Somaliland)- (oont'd)







Key Findings

- Majority lack access to improved water source
- Water consumption is very low (48% using less than 40 liter per household (HH) and 58% between 20 – 40 liter per HH.
- 72% do not have latrines, 20 % has diarrhoea in the last 2 weeks prior to survey
- About 60% spend more than 15 minutes to fetch water, with more than 20% spending more than 1 hours each time
- 63% do not use any water treatment at home

4.6.2 Livestock demand

As livestock rearing is the most important occupation and biggest export from Somalia, water demand for livestock is important. Water demand for cattle, sheep/goats and camels are 25, 1.3-1.6 and 9-12 litres per head per day (l/h/d). Camels have the unique ability to go for days without water and although its daily requirements can be 12 l/h/d, the water consumption can be 80 litres once every week. Hence, nomadic population travel long distances to feed and fetch water using camels to meet their domestic water requirements.

Using a water demand of 25 l/h/d, 1.6 l/h/d and 12 l/h/d water demand for cattle, sheep/goats and camels, an estimate of the livestock water demand based on the 1988 livestock population is calculated in Table 4-23. Total of 115,000 m^3 of water is required per day to meet the livestock water demand of the regions lying in the northern drainage basins.

Table 4-23 : Estimate of Livestock Water Demand in Central-Northern Somalia (1988 livestock numbers)

	Cattle		**Camel**		**Sheep/Goats**		**Total Demand (m^3/day)**
Region	**Head**	**m^3/day**	**Head**	**m^3/day**	**Head**	**m^3/day**	
W. Galbeed	168,310	4,208	695,100	8,341	5,608,030	8,973	21,522
Togdheer	51,070	1,277	367,410	4,409	2,250,690	3,601	9,287
Sanaag	85,930	2,148	235,370	2,824	2,758,180	4,413	9,386
Nugaal	13,930	348	177,960	2,136	3,004,190	4,807	7,290
Bari	17,410	435	275,560	3,307	2,548,300	4,077	7,819
Mudug	399,380	9,985	883,480	10,602	4,985,760	7,977	28,563
Galgaduud	282,310	7,058	464,410	5,573	2,923,720	4,678	17,309
Hiraan	200,750	5,019	530,960	6,372	1,865,740	2,985	14,375
Total	**1,219,090**	**30,477**	**3,630,250**	**43,563**	**25,944,610**	**41,511**	**115,552**

4.6.3 Irrigation demand

Although the areas covered by the five drainage basins in central and northern Somalia has very little surface water available, pockets of land along the *toggas* and other areas with good groundwater are irrigated. The main crops grown are vegetables and other cash crops. Some of the irrigated areas in the drainage basins dealt in this chapter are as follows.

Coastal Areas of the Gulf of Aden

Date palm cultivation is the major agricultural activity along the coast. Water for irrigation is obtained from hand-dug wells. The Sogreah (1981) study estimated an area of about 700 ha that could be irrigated in the coastal plains of the Durdur Catchment areas, in the western region. The shallow wells that are recharged by the Tug Durdur are used for irrigation. The best conditions for shallow wells exist within a 2 km width of the coastal belt, where water table is within a depth of 1-5 m. Another area along the sloping plains at the outlet of the major *toggas* is also suitable for date palm cultivation.

4.6.3.1 Cropping patterns and water requirements

The major crops grown in the northern regions of Somalia are maize and sorghum. According to Figure 4-2 (Dur Dur catchment in north-west Somalia) there are two crops of maize grown (first from April to July and second from August to November) and a single crop of sorghum from May to October. Other crops like sesame, cow peas, Qat (Miraa - an illegal crop still widely grown in the region.) vegetables and water melon are also grown but they are done so in limited areas. In order to estimate the crop water and irrigation requirements for the two major crops (two crops of maize) and sorghum, crop water requirements, Cropwat software was used with rainfall and climate data from Hargeisa. The net irrigation requirement and field water supply requirement (70% efficiency) is presented in Table 4-24.

Table 4-24 : Crop Water Requirement for Hargeisa Calculated using CropWat

Climate data used	**Hargeisa**
Calculation time step used	**10 days**
Irrigation efficiency	**70%**

Date	ETo	Crop Kc	ETm	Total Rain	Effect. Rain	Net Irrigation Req.	Field Water Supply
	mm/period		mm/period	mm/period	mm/period	mm/period	(l/s/ha)
Maize 1							
April	224.62	0.34	75.81	74.72	65.34	10.48	0.06
May	238.34	0.89	213.59	67.04	59.29	154.31	0.85
June	245.47	1.20	294.56	37.51	35.17	259.38	1.43
July	253.17	0.80	224.07	33.24	31.96	192.10	0.90
Total	**961.60**	**0.81**	**808.03**	**212.51**	**191.76**	**616.27**	**0.81**
Maize 2							
Aug	236.57	0.34	79.42	56.17	50.87	28.55	0.16
Sep	222.19	0.89	197.52	64.19	57.50	140.02	0.77
Oct	203.83	1.20	244.59	27.88	26.36	218.24	1.20
Nov	190.27	0.80	169.47	1.75	1.75	167.72	0.80
Total	**852.86**	**0.81**	**691.00**	**149.99**	**136.48**	**554.53**	**0.73**
Sorghum							
May	238.34	0.34	80.38	67.04	59.29	21.09	0.11
Jun	245.47	0.80	196.54	37.51	35.17	161.36	0.89
Jul	245.10	1.00	245.10	31.86	30.68	214.41	1.18
Aug	275.65	0.77	221.39	65.69	59.51	161.88	0.72
Total	**1004.56**	**0.73**	**743.41**	**202.10**	**184.65**	**558.74**	**0.73**

From the water requirements based on difference between the crop evaporation (ETm) and the effective rainfall, the net irrigation requirement is calculated. The field water requirement is then calculated using a field application efficiency (70% used here). If the irrigation water is conveyed through canals, water conveyance and distribution efficiency should also be applied while calculating the irrigation water requirement. It is seen that the ETm is always higher than effective rainfall, so cultivation without irrigation requirement would result in yield reduction.

In rainfed areas, the yield would be reduces according to any moisture shortage which the crop experiences. methods are available for estimating yield of crops based on rainfall and other meteorological variables. One method, which includes response to inadequate water supply is that of Doorenbos and Kassam (1979). The basic equation is:

$$\left(1-\frac{Y_a}{Y_m}\right)=k_y\left(1-\frac{ET_a}{Et_m}\right)$$

Where:

Ya = actual yield
Ym = theoretical maximum yield
Ky = yield reduction factor
Eta = actual evapotransipiration
ETm = crop required evapotranspiration

Hutchnison and Polishchouk (1988) has calculated the yield reduction for different crops due to water shortage for different locations in Somalia using agro-climatological data available then. According to their calculation, yield reduction due to water shortage in Hargeisa for both sorghum and maize is 26% of the ideal yield assuming optimal water supply.

If irrigation water is available, the irrigation requirement as per Table 4-24 would be needed. As an estimate of water requirement, the total volume of water required to meet the irrigation requirement (with 70% efficiency) in each cropping season for each crop is equivalent to about 8551 m^3, 7727 m^3 and 7708 m^3 per ha of crop cultivated for maize (*Gu*), maize (*Der*) and sorghum, respectively, as per the cropping calendar used in Table 4-24. In case, non-conventional methods like drip or sprinkler irrigation were to be used (with higher field application efficiency), the net irrigation water requirement would be 6163 m^3, 5545 m^3 and 5587 m^3 per ha of crop cultivated for maize (*Gu*), maize (*Der*) and sorghum, respectively.

The irrigation water requirement estimates made here can be used for general planning purpose.

5 Summary, Conclusions and Recommendations

5.1 Summary and conclusions

Based on the assessment of the water resources of the major river basins of Somalia, the following summary and conclusions can be drawn.

Physiography and Socio-economics

- As the water and land resources of a river basin are interrelated, a river basin or watershed should be taken as the unit for planning and management of water and land resources. It is also seen that the groundwater aquifers generally follow the surface water divide. The catchment areas of the major river basins are summarized in Table 5-1. The hypsometric curves are presented in Figure 5-1 and Figure 5-2 for the full catchments and catchments within Somalia, respectively. It can be seen that while the elevations of the Juba, Shabelle and Lag Dera River basins reach higher than 3000 m in the upper catchment areas in Ethiopia and Kenya, the elevations within Somalia for these basins are within 700 m. The highest elevations of the northern basins are above 2000 m.

Table 5-1 : Catchment Areas of Major River Basins in Somalia

Major Drainage Basin	**Catchment Area**		
	Total	**Within Somalia**	
	km^2	**km^2**	**% of total**
Juba	220,872	64,744	29%
Shabelle	296,972	108,295	36%
Lag Dera	231,639	46,335	20%
Lag Badana	16,575	16,575	100%
Ogaden	234,943	159,500	63%
Tug Der/Nugal	112,231	112,231	100%
Darror	34,195	34,195	100%
Gulf of Aden	74,422	74,422	100%
Central Coastal	27,638	27,638	100%

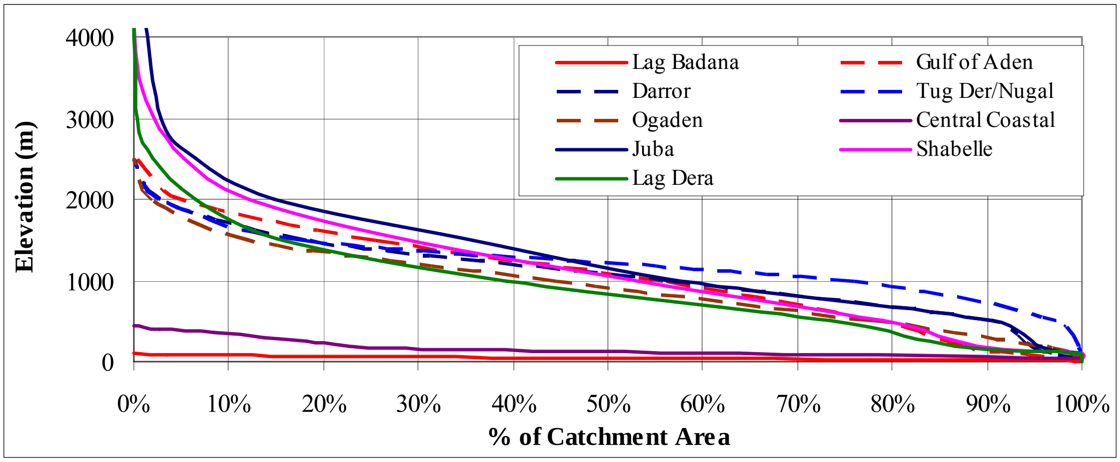


Figure 5-1 : Hypsometric Curves Major River Basins across Somalia

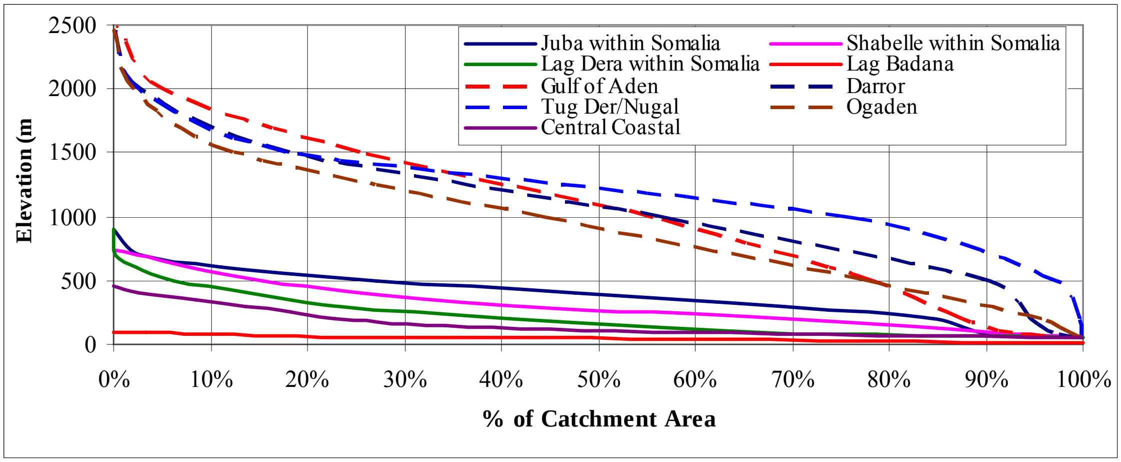


Figure 5-2 : Hypsometric Curves (catchment area within Somalia) of Major River Basins

- Based on the agro-climatic conditions and water availability, irrigated agriculture is practiced in areas within the riverine areas of the Juba and Shabelle Rivers and some patches of land along the *toggas* in the mountainous areas of north-western Somalia (e.g. Durdur watershed) and northern coastal areas. The areas in the Juba, Shabelle, Lag Dera and Lag Badana basins are either moderately or marginally suited for rain-fed agriculture. In the case of the northern basins (Gulf of Aden, Darror, Nugal and Ogaden), most of the land areas are not suitable for rainfed or irrigated agriculture. There are however some areas in north-west Somalia in Borama, Hargeisa, Gebiley, Burco, Owdweyne and Sheikh districts where rain-fed cultivation is done. Most of the areas in these basins are marginally and moderately suitable for extensive grazing and forestry plantation.
- The present population estimate is about 7.5 million. The population density, as expected, is higher in the areas where water availability is better. Such areas include the riverine areas of Juba and Shabelle, Buur area and the north-western mountainous regions in the Gulf of Aden Basin. Although 61% of the population live in rural areas where livelihoods are largely dependent upon livestock and agriculture, there have been a recent trend of increase in urban population mainly due to security situations and the internally displaced population returning to urban areas.
- There is no recent data available on livestock population. Livestock population in 1988 was about 42 million livestock, out of which 44% were in the northern region, 30% in the central region, 11% in the southern region and 15% in the trans Juba region. It is also seen that percentage of sheep/goats were higher in the northern and central regions compared to the southern and trans-Juba region. Cattle are more common in the southern basins while camels are more common in the northern basins.
- As the majority of the population are nomadic who are pastoralists rearing livestock as their main occupation, these people rely in rangelands for grazing their livestock. Water availability in these grazing lands is also an important need for the livestock. Hence, water sources management in coordination of rangeland management is an important consideration.

Climate and Rainfall

- Based on the agro-ecological zones of Somalia, the climate varies from desert in the northern coastal areas of the Gulf of Aden Basin and some areas in the Darror in the north-east; arid and semi arid in most of the areas within Gulf of Aden, Nugal and Ogaden Basin in the central and northern regions; and moist semi-arid in most of the Juba-Shabelle River Basins in the south and in the mountainous areas of the Gulf of Aden in the north-west.
- The areal annual rainfalls in the major basins based on the Inverse Distance Weighted Averaging (IDWA) Method are presented in Table 5-2. It varies from 93 mm in the Darror Basin to 549 mm in the Lag Badana Basins. While the maximum annual rainfall in the Ethiopian and Kenyan parts of the catchment reaches 1100 – 1350 mm, the maximum annual rainfall within Somalia reaches a high of 704 mm in some areas of Juba and Lag Badana Basins. The minimum annual rainfall is around 20 mm in some parts of the northern coastal locations in Gulf of Aden and the minimum in some parts of Darror and Nugal is as low as 66 and 80 mm, respectively.
- Annual Potential Evapo-transpiration (PET) is between 1500 to 2000 mm in the southern river basins but exceeds 2000 mm in the northern basins (and is as high as 3000 mm in Berbera and Sheikh). In most locations PET exceeds rainfall in all months of the year. In the southern basin areas, the monthly rainfall exceeds 0.5PET in the *Gu* and *Deyr* seasons giving some growing periods which allows some rainfed agriculture. However in the case of the northern basins, except of few locations in the extreme north-west Somalia (e.g. Borama and Gebiley), even 0.5PET exceeds rainfall in all months giving zero values for the longest growing period (LGP) in most of the areas. This is one of the main reasons why most areas are not suitable for agriculture.

Table 5-2 : Areal Annual Rainfall (mm) of Major River Basins in Somalia

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Basin	**Annual**	**Maximum**	**Minimum**
Shabelle Basin (full catchment)	543	1129	266
Shabelle Basin within Somalia	460	651	279
Juba Basin (full catchment)	595	1275	239
Juba Basin within Somalia	427	704	279
Lag Dera (full catchment)	534	1355	279
Lag Dera within Somalia	478	571	332
Lag Badana	549	704	452
Gulf of Aden	228	531	27
Darror	93	159	66
Tug Der/ Nugal	164	465	80
Ogaden (full catchment)	280	651	133
Ogaden within Somalia	257	558	133
Central Coastal	358	545	186
National (Somalia)	307	704	27

Hydrological Analysis of the Juba and Shabelle Rivers

- The water resources available in the Juba and Shabelle rivers provide the only opportunities for irrigated agriculture in the country. The wide variations in the river flows, in particular "too much" water in the rainy season and "too little" water in the dry season requires sound management of the available water resources. Hence, a detailed hydrological analysis was carried out for the streamflow in these two rivers that would assist in the water resources planning and management. The findings of these analyses are summarized below.
- The annual flow volumes along the two rivers are presented in Table 5-3, Figure 5-3 and Figure 5-4. It can be seen that the annual flows decrease as the river flows downstream. This is mainly due to various factors such as: not much contribution to flows from the Somali catchment areas, frequent occurrence of bank full condition and spilling of flood into the flood plains and natural flood relief channels, river diversions for irrigation both during low and high flow periods, and losses due to evaporation and infiltration/recharge of the groundwater along the river. It is also seen that the flow in Juba is more than the flow in Shabelle although the catchment area of the latter is larger than the former.

Table 5-3 : Annual Runoff Volume along the Juba and Shabelle Rivers

Location	Area (km^2)	Mean (mcm)	Std. Dv. (mcm)	C.V.
Juba River				
Luuq	166,000	5,878	1,823	31%
Bardheere	216,730	6,156	1,873	30%
Marere	240,000	5,866	2,018	34%
Kaitoi	278,000	5,617	1,687	30%
Jamama	268,800	5,345	1,514	29%
Shabelle River				
Belet Weyne	207,000	2,365	713	30%
Bulu Burti	231,000	1,410	337	24%
M. Weyne	255,300	2,053	483	23%
Balcad	272,700	1,596	315	20%
Afgoi	278,000	1,501	382	26%
Awdhegle	280,000	1,410	337	24%

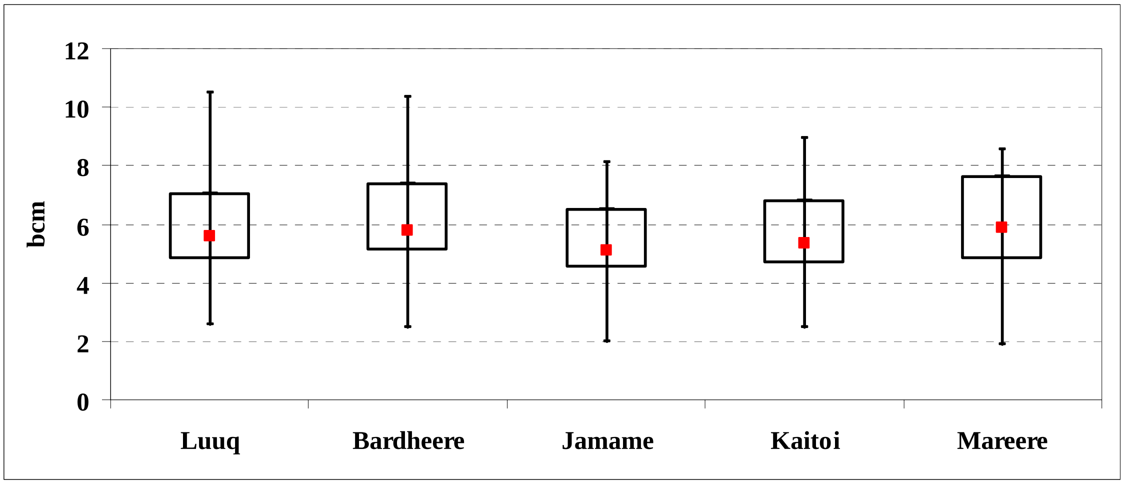

Figure 5-3 : Annual Runoff along the Juba River

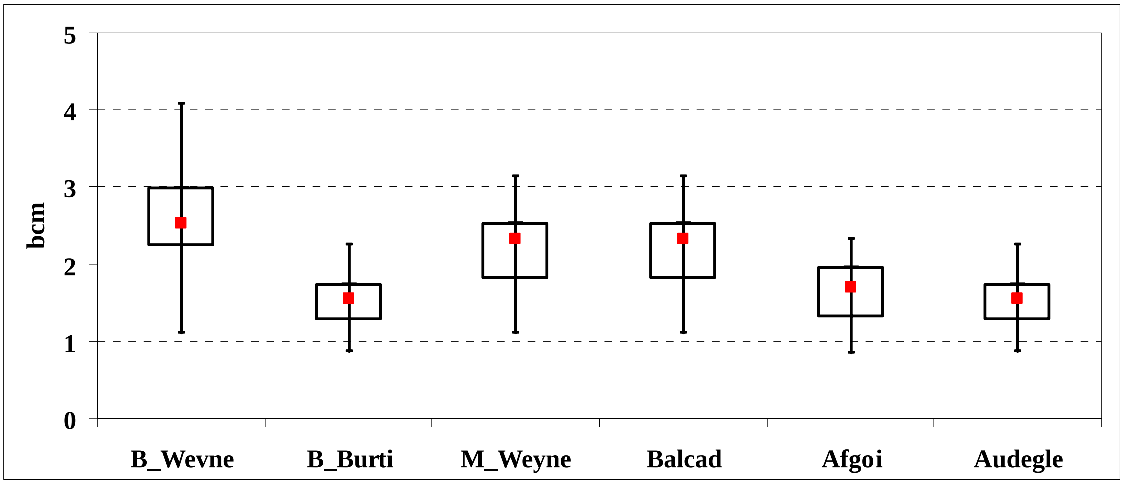

Figure 5-4 : Annual Runoff along the Shabelle River

- There are considerable flow variations within a year as well as from one year to another. As the reliability of flow available is important for water resources design and planning, flow duration curves for the locations where long-term data are available have been prepared. For example, the flow exceeding 50% and 90% of the time in Juba at Luuq are 152 m^3/s and 12 m^3/s, respectively. Similarly, it is 61 m^3/s and 7.4 m^3/s, respectively in Shabelle at Belet Weyne.
- High floods in the Juba and Shabelle are known to cause problems in the two river basins. Flood frequency analyses of annual daily maximum streamflow values were carried out using different probability distribution functions. As bank full conditions occurred during high flow periods as the two rivers flowed downstream, the maximum flood values observed in the lower reaches of the rivers were limited to the bank full values only. Hence, flood frequency analyses were more appropriate for the locations in the upstream reaches only. For estimation of the flood values in the lower reaches, it would be more appropriate to use flood routing methods. Various goodness-of-fit tests showed that the standard probability distribution functions used for flood analysis were all within the accepted critical values and the flood estimations by the different methods did not vary much. Hence, the Gumbel Method, which is a simple and widely used method, was selected as the best fit distribution. The flood estimates based on the Gumbel distribution for the two rivers are summarized in Table 5-4. It can be seen that the flood values in Juba are more than that in Shabelle although the catchment area of the latter is larger than the former. This is due to higher rainfall in the upper catchments of Juba.

Table 5-4 : Flood Frequency Analysis (m^3/s) for Selected Stations in Juba and Shabelle

Location	**Area (km^2)**	**Return Periods (years)**							
		2	**5**	**10**	**20**	**50**	**100**	**500**	**1000**
Juba at Luuq	166,000	783	1,117	1,338	1,550	1,825	2,031	2,506	2,710
Shabelle at Belet Weyne	207,000	249	337	395	450	522	576	701	754

- The flood volume is not very big compared to the catchment areas of the two rivers. However, various natural and man-made causes have aggravated the flood problems in the two river basins. These may be summarized as:
  - River bed levels rising higher than adjacent land due to sediment deposition
  - People breaching levees for irrigating land in dry seasons
  - Encroachment of natural flood plains
  - Unplanned closures of natural flood relief channels
  - Total break down of the existing irrigation infrastructure
  - Total lack of central or local governance managing the river basin
- The problem of drought is also a recurrent problem in the two river basin areas. The low flow analysis of streamflow was carried out to plan for the worst condition of flow availability. Annual 1-day, 7-day, 10-day, 15-day and monthly low flows were calculated using the daily flow data in the two rivers. It is seen that the lowest flow years in the Juba River at Luuq were 1970, 1975 and 1985 where even the 30-day low flow values were close to zero. In the case of Shabelle at Belet Weyne, the low flows in 1967 were seen to be the worst with less than 1 m^3/s of 30-day average low flows. And as the river flows downstream, the low flows are fully diverted and the minimum flows in the lower reaches reached zero in many years. Due to the very high variability and the flows being equal to or near zero in some years, low flow frequency analysis was reasonable in the two upstream locations of the two rivers only. Even in the two locations, the low flows beyond a 10-year return periods were mostly zeros using the standard probability distribution functions.
- Water quality of the two rivers is a matter of concern as the human and livestock population use the river water for direct consumption. There was very little data available for the two rivers. The only available long-term data was for Juba at Mareera where electrical conductivity (EC) values were available for a period of 1977 to 1990. It is observed that the salinity in the river rises during the *Jilaal* season and peaks during *Gu* flood season. There is also a slight rise during the *Deyr* flood season but it never reaches the peaks of *Jilaal* and *Gu* seasons.
- Very little sediment observation has been made in the two rivers. Based on 53 samples of suspended sediment observations made from November 1989 to November 1990 in Shabelle at Afgoi, the total suspended sediment load is calculated to be about 6.9 million tons per year during the one year period. Again, this is a very preliminary estimate and it should be used with caution as there are various other factors that affect soil erosion and sediment transport.

Surface water in other Major Basins

- Surface water is very limited in all the other drainage basins. There is no river with perennial flows. Data on Lag Dera and Lag Badana are very scarce. These two basins receive the maximum rainfall in Somalia (478 mm and 549 mm annual areal rainfall respectively in Lag Dera and Lag Badana). However, there is no surface water observation made in these river basins. It is generally believed that surface runoff only occurs after high intensity rainfall.
- In the case of the northern basins especially the Gulf of Aden Basin, there are a number of small streams (*toggas*) which are mostly ephemeral that originates from the mountainous areas in the north-west (above 2000 m elevation) and flows to the coastal areas of the Gulf of Aden. Other *toggas* draining the Nugal Valley, Bokh Valley, Darrror Valley and other minor valleys drain towards the Indian Ocean.

However, there is practically no surface water that reaches the ocean as the rainfall falling in these catchments is lost through evaporation and infiltration. There are only small stretches in *toggas* that have flow throughout the year.

- No long-term surface water monitoring is done in these streams. Some limited monitoring in the late fifties was done in 1980 and 1981 in some catchments in the Gulf of Aden Basin. The catchment areas of these *toggas* were in the range of 3000 to 4800 km^2. The main findings of these studies were:
    - Perennial springs are located along these *toggas* where the groundwater tables are intersected by the impermeable rock layers
    - Infiltration rate is estimated to be about 40,000 m^3/km^2 along these *toggas*.
    - These *toggas* carry very high flood flows and debris after intense rainfall. Such surface runoff lasts for few hours to few days. Flash floods as high as 2500 m^3/s was recorded in 1980 for T. Durdur at Qabri (catchment area – 3660 km^2). In 1981, there were 12 flood events observed, out of which four were between 900 m^3/s and 2200 m^3/s.
    - Mac Donald (1976) estimated an average annual runoff of 34 mcm in T. Durdur at Qabri, which was equivalent tof 3.2% of the mean annual rainfall of 350 mm in the catchment area.
- Based on limited data of six years in late 1940s, an average of 33 spates of surface runoff was recorded per year in Tug Der at Burai in Tug Der/Nugal Basin. Kammer (1989) estimated an average runoff of 33 mcm per year which was equivalent to 22mm of runoff depth in the 1500 km^2 catchment area and a runoff coefficient of 0.06.

Surface Water Storage

- *Wars, balleys*, water pan, ponds, dams and *berkads* are commonly used to collect surface (storm) water from small catchments of 2-3 km^2. *Wars* are more common than *berkads* in southern drainage basins mainly because of the favorable soil type (clayey) for the construction of wars. From the distribution of water points in the old 1:100,000 topograhical maps, we can see that percentage (out of the total water points) of rainwater ponds/reservoirs (87% in Shabelle, 91% in Juba, 79% in Lag Dera and 98% in Lag Badana) is larger compared to groundwater sources in the southern river basins than in the central and northern drainage basins (25% in Gulf of Aden, 28% in Darror, 39% in Nugal, 77% in Ogaden and 39% in central coastal basins).
- It is important to note that the rainfall and climate regime is important for designing the *wars* and *berkads* and in estimating the amount of rainfall that can be harvested. Some studies in the past (Kammer and Win, 1989) show that in catchments of 2.5 to 4 km^2, storms of less than 15 mm rainfall did not produce runoff unless the antecedent moisture content was high. This would mean a threshold daily rainfall value of 20-30 mm and there were only 9-16% of the rainfall days which exceeded this threshold values. Daily rainfall data have been analysed as part of this study in some locations to calculate the number of days and amount of rainfall with daily rainfall exceeding different threshold values.
- Average costs of *Berkads* was 1500 – 3000 US$ depending on their size and average cost of *wars* was 80,000 - 100,000 US$. Faulty design and bad construction has made more than 50% of the *Berkads* non-functional in the north-western regions. Siltation was a major problem for *wars*.

Groundwater resource

- Very little data is available on the groundwater potential and hydro-geological condition of the aquifer system. The best available data and study on a country wide basis is the one by Faillace and Faillace (1987) although other investigations have been carried out for specific locations. Southern Somalia which are traversed by the two perennial rivers have the best hydro-geological conditions for finding groundwater such as along the major *toggas* in the alluvial deposits and weathered basement.
- In the areas covered by the Gulf of Aden, the Darror and the Nugal Drainage Basins, groundwater movements start in the mountainous areas and moves in two directions. The first is from the south to the north from the mountainous regions to the coastal areas of the Gulf of Aden. The second is from the north to the south towards the Haud and Sool plateaus. The hydro-geological divide also mostly coincides with the surface drainage divide.
- The areas of good groundwater potential are as follows:
    - Baydhaba Plateau, Buur, Waajid, Damassa Areas in the Juba and Shabelle basins
    - Alluvial plains along the Juba, Shabelle and Lag Dera Rivers
    - Shallow aquifers in the sand dunes in the central coastal belt and the northern coastal regions (freshwater lenses), in the Galkayo and Dhuusamarreb ancestral drainage systems in the Mudug-Galgaduud Plateau, along the *toggas* in the mountainous areas and sloping plains of Northern Somalia,
    - Deep aquifers in the Mudug-Galgaduud Plateau with 100 – 250 m well depths
    - Shallow aquifers in the Galcayo and Dhuusaarreb Ancestral Drainage and Coastal belt along the Gulf of Aden
    - Upper catchment area of the mountainous zone in the Gulf of Aden and Darror Basins where many springs and underground/surface dams and infiltration galleries could be constructed
    - Plateaus and Valleys in northern Somalia (Sanaag region, Haud Plateau and Darror Valley)

Groundwater use

- Shallow wells (dug wells), boreholes, springs, sub-surface dams and infiltration galleries are used as groundwater sources.
- Dugwells are extensively used along the toggas, sloping plains and the coastal areas (freshwater lenses) with depth ranging from 2-3 m to 10 m. Water quality is a problem in these wells due to bad construction and common outlets for both livestock and humans. Average cost of dug wells with concrete linings to about 6m depth ranged from 1800 – 2200 US$.
- Boreholes are the permanent source of water for most of the people. In the southern river basins, average depth varied from 90-220 m in Bakool region, 60-70 m in Bay region, 60-25 m in the Hiraan region and 50-100 m in Gedo region. The average yield was around 10-12 m^3/hr. Borehole depths ranged from 90- 220 m (with static water level from 80-130 m) in north-western regions of Somalia (Somaliland). The estimated yield was from 3-30 m^3/hr. Water levels in Bari, Nugal, Eastern Sanaag and Mudug regions in central and north-eastern Somalia was estimated to be around 30 m, 160 m, 120 m and 230 m, respectively. There have been cases of many boreholes being abandoned due to unsustainable draw down of static water levels.

- The cost of drilling was about 12-200 US$ per m of drilling. For a 150 m deep borehole it would cost 35,000 – 40,000 US$ including casing and pumping tests.
- Many natural springs exist in the Juba, Shabelle and Lag Dera basins (about 1-3% of the identified water points in the topographical maps) and in the mountainous areas of the Gulf of Aden Basin, Darror Basin and Nugal (about 10% of the water points). Perennial spring sources are found across the mountain areas and a number of thermal springs are found along the coast in the Gulf of Aden Basin. They are however not found in Ogaden and the Central Coastal areas.

Water for Human and Livestock

- Sufficient quantity and quality of water for human needs is considered a basic human right. Recent data on access to water are not available. Access to safe water is said to be limited to only about 20.5% of the population, with the coverage of 53.1% in urban areas and 4.1% in rural areas (World Bank, 2006 cited by IUCN, 2006). The present per capita consumption is said to be lower than the basic need standard of 20 lpcd.
- Of the estimated population of 7.5 million people, about 61% of the population lives in rural areas where livelihoods are largely dependent upon livestock and agriculture. Livestock production is the pre-dominant livelihood, with an estimated three quarters of the population obtaining their subsistence needs from camels, cattle, sheep, and goats. Water for livestock is therefore an important need and nomadic population is known to travel long distances in search for forage and water sources. While surface water sources are limited to the riverine areas in the Juba and Shabelle basins and in the *toggas* in the northern basins, groundwater sources such as dug wells, boreholes and springs are predominantly used to meet the human and livestock needs. Catchment water harvesting in *wars* and *berkads* is also used where it is feasible and other sources are not available.
- The per capita water consumption is very low in the region. One study by a SWISS agency in five villages in Awdal and Galbeed regions showed that 58% of the households used 20-40 litre of water per family per day (about 3-6 lpcd) and 42% used more than 40 litre per family per day (more than 6 lpcd).
- Data on water used across regions and socio-economic profile is not available. However, given the scarcity of water, 20 lpcd and 50 lpcd are considered the average water consumption (basic requirement) in most region. Based on these figures the total basic water requirement for the whole country is estimated to be 240,000 m^3/d.
- Considering 25, 1.6 and 12 litre per head per day (lphd) demands of cattle, sheep/goats and camels, respectively, water demand for livestock in the country is about 230,000 m^3/day (based on the livestock population data of 1988).
- Recent population estimates show that there is a general trend of urbanization in the country as internally displaced population is returning to towns. Urban water supply will therefore be an important issue. Most such towns are rehabilitating the old piped water system. Various management models based on public-private-participation (PPP) are now in place in these towns. Bore holes are the predominant source of water for such systems.

Water for Agriculture

- Given the climatic regime of the country with very erratic and irregular rainfall pattern and the high potential evaporation losses, the water requirements of the crops are generally high.

- The cropping patterns for the irrigated agriculture in the Juba and Shabelle River Basins consist of fruit trees, maize and groundnuts in *Gu* and *Deyr* periods and tomatoes, sesame, cow pea and vegetables in *Deyr* and *Jilaal* seasons. Based on a standard cropping pattern covering the above crops and representative cropping areas, irrigation water requirements were estimated using climatic conditions of Jilib and Jowhar. The irrigation water requirement (considering 65% field application efficiency but without considering water distribution losses) for the representative copping patterns was an average of 0.36 l/s/ha or 11,400 m^3/ha and 0.37 l/s/ha or 11,800 m^3/ha. Considering the 80% dependable flow available in Bardheera and Mahadey Weyne in Juba and Shabelle Rivers, it is estimated that 50,000 ha of land could be irrigated year-round in Juba basin but seasonal irrigation for second crop of maize and sesame could be provided in much more land (up to 170,000 ha). In the case of Shabelle River, irrigation could be provided to up to 25,000 ha in the *Gu* season and it can be increased to 80,000 ha for the *Deyr* crops. These figures are preliminary estimates and are based on unregulated flow available in the two rivers.
- In the case of the mountainous regions in north-west Somalia, small pockets of land which are less than 1-2 ha are irrigated and cultivated along the *toggas*. Due to the high PET values and low rainfall, water required to meet the net irrigation requirement (effective rainfall minus crop requirement) for one crop of maize and sorghum during about four months each of the growing period is in the range of about 6000 m^3 and 5500 m^3 per ha (for the agro-climatic condition of Hargeisa). If 70% irrigation efficiency is considered about 8500 m^3 and 7700 m^3 of water would be required per ha.

5.2 Recommendations

5.2.1 Network density and hydro-meteorological data collection

World Meteorological Organization (WMO) recommended density of stations for minimum network (WMO, 1994) in the physiographic regions relevant to Somalia is presented in Table 5-5.

Table 5-5 : WMO Recommended Minimum Meteorological Network Densities

Physiographic Unit	Minimum density per station (area in km^2 per station)			
	Rainfall Station		Evaporation stations[1]	Streamflow Station
	Non-recording	Recording		
Coastal	900	9,000	50,000	2,750
Hilly	575	5,757	50,000	1,875
Arid	10,000	100,000	100,000	20,000

Note: [1] An evaporation station consists of a pan of standard national designs where daily observations of evaporation are made, together with daily observations of rainfall, maximum and minimum water and air temperatures, wind movement, and relative humidity.

The above network density is used as a guide only and various other factors such as accessibility and resources availability should also be considered. The following recommendations are made as regards to the hydro-meteorological network and data collection.

Meteorological Network

- The rainfall stations in the Juba, Shabelle, Gulf of Aden and Nugal Drainage Basins within Somalia are within the recommended network density by WMO. The network densities in other basins are however sparse. It is recommended that additional three in Lag Dera, two in Lag Badana, one in Darror, five in Ogaden and five in the Central Coastal basins be installed. This would bring the total rainfall stations in the country to 86 from the currently operational 70 stations.
- None of the above rainfall stations are of automatic recording type nor does any one of them measure other agro-climatological parameters. SWALIM is planning to install four automatic weather stations (observing all key climatological parameters) in two locations in Juba River Basin (Luuq and Bualle) and in two locations in Shabelle River Basin (Belet Weyne and Jowhar) soon. Three more in Baidoa (in the South, Juba/Shabelle Basin), Garowe (Tug Der/Nugal Basin) and Hargeisa (Gulf of Aden Basin) will also be installed in the near future. WMO recommends that about 10% of rainfall stations should be automatic recorders. It is recommended that ‘tipping bucket’ type automatic rain gauges be installed in 15 stations covering at least one in each major basin and some additional ones in the mountainous regions of north and in the central coastal basin areas.
- Pan evaporation, wind, relative humidity, water and air temperature and sun shine hours are other agro-climatological parameters that are required for water and agricultural development and management. WMO recommends one evaporation station in 50,000 km^2 in hilly and coastal areas and one in 100,000 km^2 in arid regions. It is recommended that 19 evaporation stations be installed in the following major drainage basins: Gulf of Aden (Borama, Berbera and Bosaso), Darror (Qardo), Nugal (Burao, Garowe), Nugal (Galcayo and El-bur), Shabelle (Belet Weyne, Jowhar, Sablaale, Baidoa and Buur Acaba), Juba (Luuq and Jilib), Lag Dera (Afmadow), Lag Badana (Badhadeedhe) and Central Coastal Basin (Mogadishu and Obbia).
- Apart from the meteorological stations within Somalia, it is important that rainfall data are available from the upper catchment areas in Ethiopian and Kenyan highlands and other areas in the catchment both for flood forecasting as well as runoff estimation using rainfall-runoff models.

Hydrometric Network

- Three hydrometric stations each are observing daily staff gauge readings in the Juba (Luuq, Bardhere and Bualle) and Shabelle Rivers (Belet Weyne, Bulo Burti and Jowhar). There are eight other stations, four in each river, mostly in the downstream stretch of the two rivers that were operational before 1990 but have not been re-established yet. As the flows contributions to the rivers is mostly from catchment outside Somalia, both in terms of low flows as well as high flows and there is no major tributary contributing flows to the two rivers, the pre-war station network can be considered adequate. The currently operational stations in the upper stretches of the rivers are appropriate for the estimation of the flows available in the river. The stations in the lower reaches should be rehabilitated in the future especially after the irrigation infrastructure in the downstream areas are rehabilitated and start functioning again.
- The other small streams in the northern basins do not have perennial flows but are known to generate flash floods during the rainy season. It is recommended that discharge measurement and river gauging be carried out in at least five *toggas* in the north. These may be T. Durdur (north-eastern Gulf of Aden), T. Hodomo (north-central Gulf of Aden), T. Dhut (Darror Basin), T. Nugal (Nugal Basin) and the *togga*

contributing flows to the Xingalool internal drainage basin. These can be useful for designing early flood warning systems.

- The present operational hydrometric stations observe daily gauge readings. Since no discharge measurements have been made after their rehabilitation, rating curves have not been developed. It is recommended that direct discharge measurements be started as soon as possible so that the rating curves can be developed. The discharge measurements should be made to cover the different flow conditions- low, medium and high flows. As the river profile is very mild and the possibility of a 'loop rating curve' being more appropriate as the water surface slope is likely to be different in the rising and falling flow conditions, discharge measurements should be made for both rising and falling water level conditions.
- SWALIM is installing automatic water level recorders in four locations, Luuq and Bualle in Juba River and Belet Weyne and Jowhar in Shabelle River. Although the water level variations within a day are not expected to be much, it is recommended that these water level recorders be installed so that the flood hydrographs can be generated. It would also be useful to observe any variations in the irrigation and other diversions within a day.

5.2.2 Surface water quality and sediment measurements

- The Juba and Shabelle Rivers are extensively used by the people and livestock to meet their water needs in the riverine areas. During dry seasons, 'nomadic' pastoralists also bring their livestock for watering to the rivers. The chances of the river water being polluted by geological, agricultural and human interventions are high. While water salinity is a major concern, other parameters related to human and aquatic health (bacterial content, dissolved oxygen (DO) and mineral (especially heavy metals)) are also important). Very few water quality observations mainly electrical conductivity (EC) for salinity have been made in the past. It is recommended that water quality observations be carried out in at least two locations each in the two rivers, Luuq and Bualle in Juba and Belet Weyne and Jowhar in Shabelle. As the urbanization as well as agricultural development along the river course increases, the water quality observations should be carried out in key locations in the downstream areas of the river, especially after the gauging stations in the lower reaches are rehabilitated.
- As the water quality is believed to be more critical in the dry (*Jilaal*) and beginning of first rainfall (*Gu*), the frequency of water quality observations should be about once a week from February to May and once a month in the other months. As the detailed planning of water quality observations is being undertaken by SWALIM under the river basin management project, it was not further assessed in the study leading to this report.
- Sediment load of the Juba and Shabelle rivers seem to be high as seen from the aggradation and siltation of the existing irrigation canals and the Jowhar offtake reservoir. Given the physiographic and river morphological characteristics, there is practically no bed load in the rivers and the sediment load is mostly of suspended type. It is recommended that sediment sampling be undertaken in at least two locations in each river, Luuq and Bualle in Juba and Belet Weyne and Jowhar in Shabelle. As the soil erosion is found to be high during the first rainfall period, the frequency of sediment sampling should be once every week during March to June and once in two weeks in other months. As sediments concentration can vary along the

vertical as well as horizontal direction within the cross-sectional area of the river, it is recommended three samples be taken in each cross section, i.e. at 25%, centre and 75% of the width of the river cross-section. Depth integrated samplers should be used with a sounding weight that is capable of reaching the bottom of the river. As the gauging sites are located in the bridges in the river, appropriate equipment capable of sediment sampling from the bridges should be used. SWALIM is preparing and undertaking a detailed work plan for sediment measurement under the river basin management project and it was therefore not assessed further in the study leading to this report.

- Although the Juba and Shabelle Rivers are extensively used, the other rivers and *toggas* are not less important to meet the water needs of the people and livestock of the areas. Water quality monitoring in such rivers should also be carried out taking into consideration agricultural and human interventions in these rivers and *toggas*.

5.2.3 Groundwater monitoring

While there are some preliminary information available on the hydrogeology and the description of different aquifers in the country (e.g. Faillace and Faillace, 1987), aquifer characteristics (storage coefficients, groundwater movements etc), recharge areas, thickness and its extension are not known. Data on the groundwater sources (dug wells, bore holes, springs) that are in use is being collected by SWALIM. While boreholes are the permanent sources of water both for rural and urban areas, majority of them are known to be non-functional or abandoned. There have been some evidence (e.g. Petrucci (2006), Groundwater Survey (2005)) that the discharge from some of these boreholes have been more than their safe yield and hence the water levels have gone down (unsustainable draw down). Water quality of some of the boreholes is also found to be not suitable for human and livestock consumption. Monitoring of these bore holes across the country, covering different agro-climatic regions as well as in different known hydro-geological basins (aquifers) would help understand the groundwater characteristics and estimate the annual recharge amount.

It is recommended that groundwater basin (aquifer system) investigations be carried out in the future to update the data from past studies and estimate the renewable groundwater available including the potential recharge areas. This will require a detailed assessment of the topographic, geologic and hydrologic including some sub-surface investigations. While this activity should be carried out in the long term, it is recommended that the groundwater monitoring through monitoring of some key bore holes be carried out in the short term.

The following is recommended for monitoring the groundwater sources:

- Assessment of the recharge areas fracturation and infiltration by a combination of satellite imagery analysis and field and laboratory analysis of rock samples (especially in the north-mountainous areas)
- Based on the data collected in SWIMS by SWALIM, selected number of bore holes in the following regions should be monitored:
  - Basement complex aquifer in the Buur Area (Bay region)
  - Xudder-Bardheere Aquifer in the Gedo region
  - Coastal aquifers in the south of the Juba and Shabelle river basins

  - Upper and Middle Shabelle valley (water quality is also a concern in the area as the geological formations are mainly limestone, gypsum, marls and sandstones in the Cretaceous Formations)
  - Mudug-Galgaduud Plateau area
  - Haud Plateau, Nugal Valley, Sool Plateau, Flood plains of Xangalool and Darror Valley
  - Northern coastal belt and sloping plains of the Gulf of Aden
  - Some urban towns where boreholes are used for town water supply (e.g Bossaso, Borama, Ergabo, Jowhar where SWALIM had already collected some baseline data, SWALIM Technical Report No. W-07)
- The monitoring should include the following:
  - Yield test (using a pumping test by observing the static water level and the draw down, and then estimating the discharge-draw down ratio)
  - Observations of seasonal variations of the water level
  - Water quality tests (especially the salinity and its seasonal variation but including other physical (temperature, colour, turbidity, odour and taste), chemical and bacteriological analyses (coliform etc)
- The shallow wells (dug wells) and springs should also be monitored to test its suitability for human and livestock consumption.

5.2.4 Runoff characteristics of small catchments

While the ongoing projects deal more with the management of the Juba and Shabelle River Basins which is understandable, some investigations on the rainfall-runoff characteristics of the smaller catchments generating runoff only after high intensity rainfall would be useful. This would particularly be useful for watershed management (of small *toggas* in the north) and for planning and designing catchment water harvesting systems such as the *wars* and *berkads*.

Selected catchments like the catchments of *toggas* in the north and small catchments that are used to collect storm water in the *wars* and *berkads* spread across the countries should be monitored for one to two years. The field monitoring methodology can be similar to the one used by Kammer and Win (1989). A meteorological station equipped with automatic rain gauges and taking observations of other parameters like pan evaporation, wind, air temperature, relative humidity, sun shine hours and automatic surface water recording (gauges in a river or a *war*, *berkad* or pond) facility should be installed as required. A simple water balance taking into consideration rainfall, evaporation¸ infiltration and other losses, soil moisture content and runoff into consideration can then be used to develop the rainfall-runoff relationships in different catchment and physiographic conditions.

5.2.5 Water for human and livestock

There is however very little data available on the water consumption pattern of the households and livestock. Factors such as the socio-economic profile, quantity and quality of water sources available, cost of water, climatic conditions etc are important for designing interventions to improve access to safe water. Hence, it is recommended that some users' surveys covering different regions/basins, rural and urban, water sources be carried out to better understand the water consumption characteristics and the water needs of different regions. This should also include nomadic communities who move with their livestock from one place to another.

Some past studies including the ones carried out by SWALIM (SWALIM Technical Report No. L-10) suggest that land-degradation has accelerated due to inappropriate construction of new water sources in the rangeland areas. It is recommended that an environmental impact assessment be made of the location of new development of water sources based on land and other characteristics of the areas.

The above may not directly fall under the mandate and objective of SWALIM but, as SWALIM has collected the baseline data on the water sources, concerned agencies such as UNICEF, UN-HABITAT and other NGOs working in the sector could partner with SWALIM to undertake such a study. Interventions based on such a study would be more successful.

5.2.6 Water for agriculture

Water use for agriculture consumes the maximum amount of water. The crop yield of the major crops grown such as maize and sorghum are seen to be low and it is, as expected, more in irrigated areas than in rain-fed areas. While crop yield depends on many types of inputs such as the climatic conditions, soil, seeds, fertilizers etc, it is also matter of interest to optimise the water input to agriculture. Better water management through the forecast of climatic conditions (forecast of on-set and expected amount of rainfall) and water availability may assist the farmers to improve the agricultural productivity. A study linking water availability, rainfall and water forecasting and selection of cropping patterns and types may be carried out. This will require an integrated water, land and agricultural resources approach.

Irrigation planning in the riverine areas of Juba and Shabelle needs to be based on the water availability. This study has assessed the water availability in different period including their reliability. Water use conflicts may develop between different uses (irrigation, water supply and environment) and between upstream and downstream users if integrated water resources management (IWRM) principles are not followed. A river basin approach should thus be taken while developing the irrigated areas in the two river basins.

5.2.7 Water resources development

Water resources development potential exists especially in the Juba and Shabelle basins and in some of the potential watershed in the mountainous areas of the northern basins. Such development should assist in better management of the water resources in the basins to address the problems of “too much”, “too little” and “too dirty” water.

In the case of the flooding problem in the Juba and Shabelle Rivers, it is seen that an integrated flood management would help alleviate many of the problems presently attributed to floods in the areas. Even a small flood event that occurs once in every five years is known to create major problems. Various strategies of integrated flood management such as reduction of flooding, reduction of susceptibility to damage, mitigating the impacts and preserving the natural resources of flood plains (WMO and GWP, 2004) can be taken. It is recommended that an integrated flood management plan be developed for the two river basins based on the river basin approach. SWALIM is undertaking a river basin management project that is geared towards this goal.

The planned water resources development in the Juba and Shabelle Rivers includes rehabilitation of the old irrigation infrastructure such as barrages and canals. Some inter-basin diversion, offstream storage and reservoir project may also be planned in the future. The data collected on the water and land resources and the assessment and studies carried out by SWALIM including this one should help the water resources development in the two basins.

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Annexes

Table A. 1 : Population Estimates for Somalia

Region	**District**	**Estimated population 2005 (mid-year)**		
		Total	**Urban**	**Non-urban**
North-west Zone		1,828,739	819,989	1,008,750
Awdal		305,455	110,942	194,513
	Borama	215,616	82,921	*132,695*
	Baki	25,500	8,577	*16,923*
	Lughaya	36,104	14,010	*22,094*
	Zeylac	28,235	5,434	*22,801*
W. Galbeed		700,345	490,432	209,913
	Hargeisa	560,028	422,515	*137,513*
	Berbera	60,753	42,070	*18,683*
	Gebiley	79,564	25,847	*53,717*
Togdheer		402,295	123,402	278,893
	Burco	288,211	96,463	*191,748*
	Buuhoodle	38,428	9,607	*28,821*
	Owdweyne	42,031	11,107	*30,924*
	Sheikh	33,625	6,225	*27,400*
Sool		150,277	39,134	111,143
	Laas Caanood	75,436	24,830	*50,606*
	Caynabo	30,702	6,676	*24,026*
	Taleex	25,354	4,371	*20,983*
	Xudun	18,785	3,257	*15,528*
Sanaag		270,367	56,079	214,288
	Ceerigaabo	114,846	31,098	*83,748*
	Ceel Afweyn	65,797	12,159	*53,638*
	Laasqoray	34,724	5,500	*29,224*
	Badhan	55,000	7,322	*47,678*
North-east Zone		863,078	328,787	534,291
Bari		367,638	179,633	188,005
	Bossaso	164,906	107,181	*57,725*
	Bandarbayla	14,376	5,400	*8,976*
	Caluula	40,002	13,000	*27,002*
	Iskushuban	45,027	8,508	*36,519*
	Qandala	42,502	15,600	*26,902*
	Qardho	60,825	29,944	*30,881*
Nugaal		145,341	54,749	90,592
	Garoowe	57,991	33,395	*24,596*
	Burtinle	34,674	8,669	*26,005*

Region	**District**	**Estimated population 2005 (mid-year)**		
		Total	**Urban**	**Non-urban**
	Eyl	32,345	7,086	*25,259*
	Dan Gorayo	20,331	5,599	*14,732*
Mudug		350,099	94,405	255,694
	Gaalkacyo	137,667	54,800	*82,867*
	Galdogob	40,433	7,067	*33,366*
	Hobyo	67,249	12,811	*54,438*
	Jariiban	39,207	6,341	*32,866*
	Xarardheere	65,543	13,386	*52,157*
Central Zone		1,174,769	223,921	950,848
Galgaduud		330,057	58,977	271,080
	Dhuusamarreeb	91,260	16,819	*74,441*
	Cabudwaaq	41,067	8,413	*32,654*
	Cadaado	45,630	9,326	*36,304*
	Ceel Buur	79,092	12,818	*66,274*
	Ceel Dheer	73,008	11,601	*61,407*
Hiraan		329,811	69,113	260,698
	Belet Weyne	144,345	30,869	*113,476*
		89,120	17,824	*71,296*
		46,724	10,279	*36,445*
		21,918	4,541	*17,377*
		27,704	5,600	*22,104*
Shabelle Dhexe		514,901	95,831	419,070
	Jowhar	218,027	36,844	181,183
	Adan Yabbal	62,917	7,200	55,717
	Balcad	120,434	28,106	92,328
	Cadale	46,720	10,800	35,920
	Warsheikh	15,573	2,635	12,938
	Mahaday	51,230	10,246	40,984
Banadir Zone/Region		901,183	901,183	
	Xamar Weyne	43,309	43,309	
	Hodan	71,590	71,590	
	Warddhiigleey	53,619	53,619	
	Boondheere	61,143	61,143	
	Xamar Jabjab	36,331	36,331	
	Waaberi	50,864	50,864	
	Wadajir	50,110	50,110	
	Kaaraan	123,171	123,171	

Region	District	Estimated population 2005 (mid-year)		
		Total	Urban	Non-urban
	Yaaqshid	128,488	128,488	
	Shibis	79,751	79,751	
	Cabdulcasiis	22,153	22,153	
	Hawl Wadaag	39,114	39,114	
	Shangaani	24,368	24,368	
	Heliwaa	43,420	43,420	
	Dharkenley	40,983	40,983	
	Dayniile	32,769	32,769	
South Zone		2,734,885	621,688	2,113,197
Shabelle Hoose		850,651	172,714	677,937
	Marka	192,939	63,900	129,039
	Afgooye	135,012	21,602	113,410
	Baraawa	57,652	15,413	42,239
	Kurtunwaarey	55,445	7,426	48,019
	Qoryooley	134,205	22,841	111,364
	Sablaale	43,055	8,011	35,044
	Wanla Weyn	155,643	22,016	133,627
	Aw Dheegle	76,700	11,505	65,195
Bay		620,562	126,813	493,749
	Baydhaba	227,761	59,107	168,654
	Buur Hakaba	125,616	25,123	100,493
	Dinsoor	75,769	12,154	63,615
	Qansax Dheere	98,714	16,743	81,971
	Bardaale	92,702	13,686	79,016
Bakool		310,627	61,438	249,189
	Xudur	93,049	19,110	73,939
	Ceel Barde	29,179	5,335	23,844
	Tayeeglow	81,053	16,221	64,832
	Waajid	69,694	14,439	55,255
	Rab Dhuure	37,652	6,333	31,319
Gedo		328,378	81,302	247,076
	Garbahaarey	38,017	11,650	26,367
	Baardheere	106,172	25,544	80,628
	Belet Xaawo	55,989	13,597	42,392
	Ceel Waaq	19,996	4,559	15,437
	Doolow	26,495	5,674	20,821
	Luuq	62,703	14,676	48,027
	Buur Dhuubo	19,006	5,602	13,404

Region	District	Estimated population 2005 (mid-year)		
		Total	Urban	Non-urban
Juba Dhexe		238,877	54,739	184,138
	Bu'aale	59,489	13,588	45,901
	Jilib	113,415	29,951	83,464
	Saakow	65,973	11,200	54,773
Juba Hoose		385,790	124,682	261,108
	Kismaayo	166,667	89,333	77,334
	Afmadow	51,334	7,122	44,212
	Badhaadhe	38,640	5,812	32,828
	Jamaame	129,149	22,415	106,734
		7,502,654	2,895,568	4,607,086

Source: UNDP (Draft, 2005)

Table A. 2 : Livestock Distribution in Somalia (1988)

Region	**Cattle**	**Camel**	**Sheep**	**Goats**	**Total**
Northern Region					
W. Galbeed	168,310	695,100	2,795,590	2,812,440	6,471,440
Togdheer	51,070	367,410	1,141,870	1,108,820	2,669,170
Sanaag	85,930	235,370	1,894,030	864,150	3,079,480
Nugaal	13,930	177,960	277,690	2,726,500	3,196,080
Bari	17,410	275,560	1,752,930	795,370	2,841,270
Sub-total	336,650	1,751,400	7,862,110	8,307,280	18,257,440
Central Region					
Mudug	399,380	883,480	1,414,670	3,571,090	6,268,620
Galgaduud	282,310	464,410	732,200	2,191,520	3,670,440
Hiraan	200,750	530,960	357,380	1,508,360	2,597,450
Sub-total	882,440	1,878,850	2,504,250	7,270,970	12,536,510
Southern Region					
Shabelle Dhexe	443,420	235,140	411,360	937,020	2,026,940
Shabelle Hoose	43,940	336,070	113,930	260,280	754,220
Banadir	25,530	1,140	7,720	24,710	59,100
Bakool	116,080	220,230	102,160	356,590	795,060
Bay	296,000	415,230	71,150	249,870	1,032,250
Sub-total	924,970	1,207,810	706,320	1,828,470	4,667,570
Transjuba Region					
Gedo	612,900	899,270	622,620	943,540	3,078,330
Mid Juba	424,860	252,300	31,130	937,030	1,645,320
Low Juba	999,450	254,640	87,170	165,280	1,506,540
Sub-total	2,037,210	1,406,210	740,920	2,045,850	6,230,190
Total	4,181,270	6,244,270	11,813,600	19,452,570	41,691,710

Source: Ministry of Livestock, Forestry and Rangeland, Department of Planning and Statistics, Mogadishu (cited by Musse, 1997)

Table B. 1 : Long-term Mean Monthly and Annual Rainfall (mm) for Weather Stations in Somalia

	Station	Longitude (^{o} E)	Latitude (^{o} N)	Elevation (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Afgoi	45.13	2.13	83	2.0	2.0	10.0	91.0	94.0	64.0	58.0	26.0	15.0	62.0	121.0	39.0	584.0
2	Afmadow	42.06	0.51	29	5.0	12.0	32.0	102.0	81.0	23.0	30.0	13.0	18.0	84.0	97.0	53.0	550.0
3	Alessandra	42.70	0.50	25	1.0	3.0	4.0	131.0	136.0	74.0	50.0	24.0	20.0	51.0	69.0	37.0	600.0
4	Alula	50.75	11.96	6	1.0	0.0	0.0	3.0	1.0	0.0	0.0	0.0	0.0	1.0	6.0	2.0	14.0
5	Balad	45.38	2.36	95	0.0	1.0	10.0	92.0	114.0	71.0	17.0	21.0	13.0	65.0	111.0	30.0	545.0
6	Bardera	42.30	2.35	116	3.0	6.0	27.0	117.0	71.0	10.0	11.0	5.0	8.0	82.0	116.0	17.0	473.0
7	Barro-Weyne	45.50	2.86	104	0.0	0.0	14.0	120.0	77.0	26.0	25.0	12.0	12.0	92.0	65.0	10.0	453.0
8	Belet-Weyne	45.21	4.70	173	0.0	0.0	9.0	72.0	86.0	15.0	0.0	1.0	13.0	86.0	41.0	7.0	330.0
9	Berbera	45.03	10.43	89	6.0	0.0	0.0	0.0	0.0	0.0	1.0	3.0	3.0	0.0	1.0	6.0	20.0
10	Borama	43.18	9.93	1454	4.0	21.0	44.0	104.0	57.0	27.0	67.0	107.0	80.0	19.0	9.0	4.0	543.0
11	Bosaso	49.18	11.28	6	0.0	0.0	0.0	4.0	1.0	0.0	0.0	0.0	1.0	2.0	3.0	0.0	11.0
12	Brava	44.03	1.10	6	0.0	0.0	3.0	46.0	81.0	96.0	66.0	23.0	17.0	14.0	20.0	10.0	376.0
13	Bulo-burti	45.56	3.25	158	3.0	3.0	11.0	70.0	64.0	5.0	3.0	3.0	8.0	90.0	61.0	7.0	328.0
14	Bur-acaba	44.06	2.78	194	0.0	4.0	9.0	202.0	130.0	13.0	12.0	6.0	18.0	112.0	57.0	4.0	567.0
15	Burao	45.56	9.51	1032	2.0	4.0	5.0	47.0	68.0	23.0	10.0	8.0	27.0	34.0	8.0	0.0	236.0
16	Burdhuxul	43.30	4.10	400	0.0	0.0	26.0	215.0	67.0	0.0	0.0	0.0	1.0	102.0	24.0	3.0	438.0
17	Capo-Guadaffi	51.25	11.81	244	8.0	1.0	7.0	3.0	0.0	0.0	0.0	1.0	0.0	2.0	32.0	10.0	64.0
18	Dinsor	42.98	2.41	280	3.0	0.0	30.0	138.0	70.0	15.0	11.0	11.0	11.0	64.0	98.0	19.0	470.0
19	Eil	49.78	7.95	36	5.0	5.0	5.0	27.0	57.0	0.0	0.0	0.0	2.0	41.0	15.0	5.0	162.0
20	El-bur	46.61	4.68	175	5.0	1.0	13.0	54.0	47.0	1.0	3.0	1.0	6.0	49.0	19.0	6.0	205.0
21	El-mugne	44.76	1.71	12	0.0	0.0	0.0	57.0	28.0	70.0	18.0	26.0	20.0	13.0	19.0	0.0	251.0
22	Erigavo	47.36	10.61	1744	10.0	8.0	22.0	39.0	59.0	38.0	8.0	31.0	80.0	4.0	5.0	1.0	305.0
23	Galcayo	47.43	6.85	302	0.0	0.0	4.0	37.0	50.0	6.0	1.0	1.0	4.0	48.0	15.0	2.0	168.0
24	Gebiley	43.28	9.61	1563	1.0	4.0	28.0	52.0	60.0	51.0	71.0	82.0	59.0	17.0	9.0	2.0	436.0
25	Genale	44.75	1.83	69	2.0	0.0	3.0	87.0	87.0	72.0	69.0	52.0	16.0	24.0	60.0	15.0	487.0
26	Jowhar	45.50	2.76	108	0.0	1.0	14.0	100.0	97.0	41.0	19.0	12.0	6.0	99.0	75.0	28.0	492.0
27	Giumbo	42.60	-0.21	30	0.0	0.0	1.0	41.0	113.0	105.0	71.0	44.0	12.0	29.0	23.0	3.0	442.0
28	Hargeisa	44.08	9.50	1326	2.0	11.0	25.0	85.0	65.0	33.0	39.0	55.0	65.0	29.0	8.0	1.0	418.0
29	Huddur	43.90	4.16	500	0.0	0.0	5.0	107.0	75.0	0.0	0.0	0.0	46.0	108.0	12.0	2.0	355.0
30	Baidoa	43.66	3.13	487	3.0	3.0	23.0	165.0	95.0	20.0	15.0	8.0	13.0	135.0	89.0	8.0	577.0

	Station	Longitude (^{o} E)	Latitude (^{o} N)	Elevation (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
31	J-Mubarak	44.66	3.68	135	0.0	0.0	1.0	113.0	80.0	13.0	58.0	29.0	3.0	55.0	35.0	3.0	390.0
32	Jilib	42.80	0.43	23	1.0	5.0	4.0	122.0	170.0	106.0	47.0	41.0	26.0	25.0	87.0	29.0	663.0
33	Jonte	42.46	-0.33	8	0.0	0.0	0.0	42.0	124.0	82.0	52.0	15.0	9.0	3.0	28.0	28.0	383.0
34	Mareere	42.71	0.43	12	2.0	4.0	33.0	148.0	167.0	89.0	47.0	41.0	27.0	49.0	114.0	45.0	766.0
35	Kismaio	42.43	-0.36	8	0.0	1.0	6.0	45.0	80.0	117.0	70.0	34.0	28.0	11.0	24.0	3.0	419.0
36	Lafoole	45.15	2.10	100	2.0	0.0	3.0	108.0	81.0	100.0	42.0	25.0	15.0	30.0	88.0	32.0	526.0
37	Las-anod	47.36	8.46	705	1.0	1.0	4.0	14.0	52.0	1.0	0.0	0.0	15.0	30.0	10.0	2.0	130.0
38	Luuq	42.45	3.58	165	1.0	1.0	18.0	82.0	52.0	2.0	1.0	1.0	3.0	48.0	48.0	14.0	271.0
39	Mahaddei	45.51	2.95	125	3.0	8.0	37.0	75.0	82.0	18.0	31.0	1.0	11.0	74.0	60.0	24.0	424.0
40	Jamame	42.73	0.05	10	2.0	3.0	5.0	60.0	99.0	78.0	68.0	24.0	32.0	27.0	19.0	18.0	435.0
41	Modun	44.00	1.15	50	0.0	0.0	0.0	115.0	103.0	93.0	30.0	69.0	16.0	22.0	33.0	5.0	486.0
42	Mogadishu	45.35	2.03	9	0.0	2.0	4.0	60.0	75.0	86.0	77.0	39.0	17.0	34.0	72.0	8.0	474.0
43	Mogambo	42.75	0.06	10	0.0	0.0	10.0	119.0	130.0	130.0	38.0	28.0	34.0	12.0	75.0	15.0	591.0
44	Obbia	48.56	5.33	10	11.0	1.0	4.0	47.0	41.0	9.0	0.0	0.0	5.0	34.0	39.0	15.0	206.0
45	Qardo	49.08	9.50	810	0.0	1.0	7.0	26.0	31.0	4.0	0.0	4.0	8.0	26.0	5.0	0.0	112.0
46	Sablaale	43.80	1.30	50	0.0	0.0	0.0	124.0	124.0	97.0	49.0	15.0	24.0	65.0	59.0	11.0	568.0
47	Scusciub	50.23	10.30	344	0.0	0.0	3.0	22.0	21.0	2.0	0.0	5.0	7.0	6.0	5.0	1.0	72.0
48	Shiekh	45.18	9.91	1441	5.0	13.0	33.0	79.0	76.0	38.0	33.0	53.0	74.0	71.0	25.0	15.0	515.0
49	Villabruzi	45.48	2.75	108	6.0	1.0	22.0	94.0	87.0	25.0	26.0	16.0	12.0	104.0	84.0	21.0	498.0

Source: FAO Climate Database (based on pre-war data)

Table B. 2 : Long-term Mean Monthly and Annual Rainfall (mm) for Stations in Ethiopia and Kenya Relevant to Juba and Shabelle Basins

	Station	Country	Longitude (^{o} E)	Latitude (^{o} N)	Elevation (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1	Abela	Ethiopia	38.90	6.85	2600	28	30	67	93	86	83	169	106	164	82	22	53	983
2	Adaba	Ethiopia	39.40	7.02	2485	27	39	56	75	64	72	169	190	82	26	5	6	811
3	Alemaya	Ethiopia	42.05	9.43	2125	9	38	71	92	100	84	111	190	104	45	29	7	880
4	Awash	Ethiopia	40.17	8.98	1052	21	52	59	70	57	31	118	135	63	22	15	11	654
5	Bokoji	Ethiopia	39.25	7.53	2850	30	43	75	81	100	114	198	174	91	55	19	10	990
6	Degehabur	Ethiopia	43.55	8.15	1000	6	1	34	79	68	28	5	12	43	61	12	1	350
7	Dire-dawa	Ethiopia	41.87	9.60	1146	15	33	67	103	55	20	80	117	60	19	17	8	594
8	Dixis	Ethiopia	39.58	8.13	2600	57	63	72	89	45	98	156	175	134	82	22	21	1014
9	Dodola	Ethiopia	39.18	6.97	2540	35	35	47	82	47	79	153	158	111	59	28	18	852
10	Funyan-bira	Ethiopia	42.38	9.35	2050	19	15	37	98	78	54	107	122	106	49	28	0	713
11	Galamso	Ethiopia	40.48	8.90	1829	28	29	79	199	105	129	237	165	184	69	51	19	1294
12	Goba	Ethiopia	40.00	7.02	2700	22	40	61	139	108	59	91	119	121	108	64	18	950
13	Gode	Ethiopia	44.58	5.10	320	0	3	16	89	63	1	0	0	8	48	35	3	266
14	Grawa	Ethiopia	41.83	9.13	2250	16	26	52	111	158	85	115	189	85	46	39	9	931
15	Hamaro	Ethiopia	42.22	7.37	750	6	9	23	80	102	12	1	2	26	37	10	2	310
16	Harer	Ethiopia	42.12	9.20	1856	13	30	55	97	126	99	145	121	94	42	28	9	859
17	Jiggiga	Ethiopia	42.72	9.33	1644	9	31	50	114	103	58	78	139	111	50	19	9	771
18	Kebri-dehar	Ethiopia	44.30	6.67	450	2	12	4	149	100	5	0	0	15	114	58	8	467
19	Kofele	Ethiopia	38.78	7.07	2680	28	60	114	148	90	110	145	149	143	98	61	24	1170
20	Metehara	Ethiopia	39.78	8.83	1062	15	45	44	63	34	21	120	122	46	9	3	2	524
21	Midagaloloa	Ethiopia	42.12	8.78	1428	14	23	49	72	92	87	80	66	101	64	13	4	665
22	Robe	Ethiopia	40.00	7.10	2450	22	41	67	129	72	59	88	109	119	67	36	14	823
23	Ticho	Ethiopia	39.53	7.82	2800	46	87	135	155	101	95	157	165	144	103	54	23	1265
24	Adola-(kibrem	Ethiopia	39.08	5.92	2170	20	21	84	214	135	42	31	50	60	160	78	25	920
25	Burji	Ethiopia	37.93	5.40	1960	41	36	100	176	137	52	43	37	69	155	84	31	961
26	Colaris	Ethiopia	38.48	6.97	1850	27	61	109	130	156	121	197	182	153	81	46	14	1277
27	Dila	Ethiopia	38.30	6.42	1670	35	48	99	174	150	105	129	102	167	158	65	21	1253
28	Gode	Ethiopia	44.58	5.10	320	0	3	16	89	63	1	0	0	8	48	35	3	266
29	Hagere-mariam	Ethiopia	38.25	5.63	2000	15	30	79	149	193	63	45	19	57	133	51	15	849
30	Hagere-selam	Ethiopia	38.52	6.47	2840	55	98	88	134	131	109	124	119	113	148	88	21	1228

	Station	Country	Longitude (^{o} E)	Latitude (^{o} N)	Elevation (m)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
31	Mega	Ethiopia	38.33	4.08	2215	34	52	70	149	103	16	22	10	11	120	74	11	672
32	Neghelli	Ethiopia	39.75	5.28	1455	13	32	58	225	168	9	7	6	44	180	60	10	812
33	Wendo-(aleta)	Ethiopia	38.42	6.58	1860	54	59	114	192	227	119	130	153	239	175	65	39	1566
34	Yabelo	Ethiopia	38.10	4.88	1740	44	33	71	162	71	14	16	3	58	76	20	11	579
35	Yirga-chefe	Ethiopia	38.25	6.23	1925	29	42	123	293	296	136	101	124	243	301	103	13	1804
36	Yirgalem	Ethiopia	38.38	6.75	1835	43	57	104	153	143	94	114	136	153	126	57	36	1216
37	El-roba	Kenya	40.02	3.92	1006	3	4	38	122	43	1	1	5	1	59	49	8	334
38	El-wak	Kenya	40.93	2.77	366	4	1	37	100	22	1	4	3	3	43	90	28	336
39	Mandera	Kenya	41.87	3.93	231	1	7	18	83	35	2	1	1	2	44	48	5	247
40	Murri	Kenya	40.70	4.18	1006	0	1	28	95	48	0	0	0	0	54	79	29	334

Note:

1. The long-term mean has been calculated with data of different periods
2. The relevant stations are based on the Thiesen Polygon analysis.

Source: FAO Climate Database

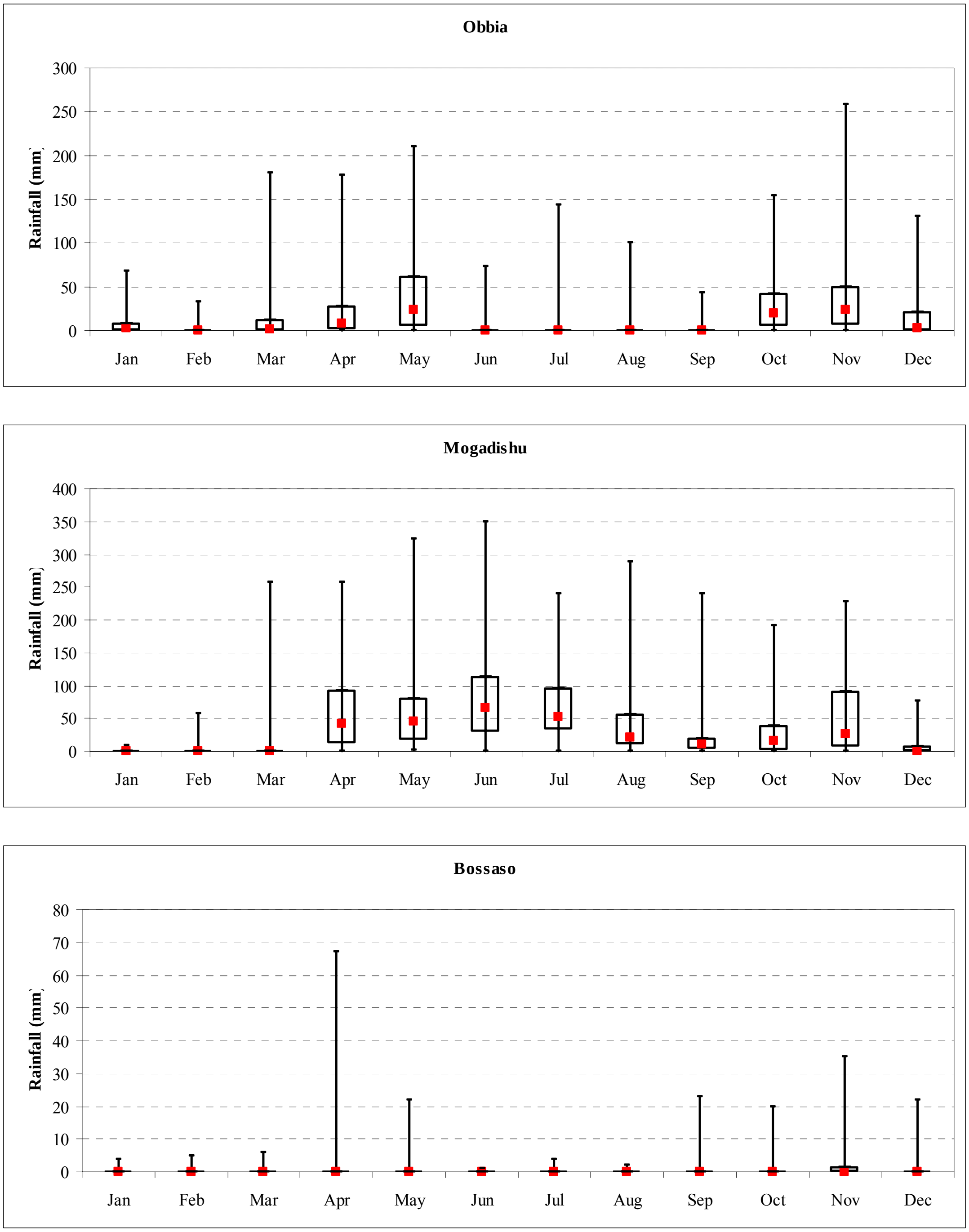
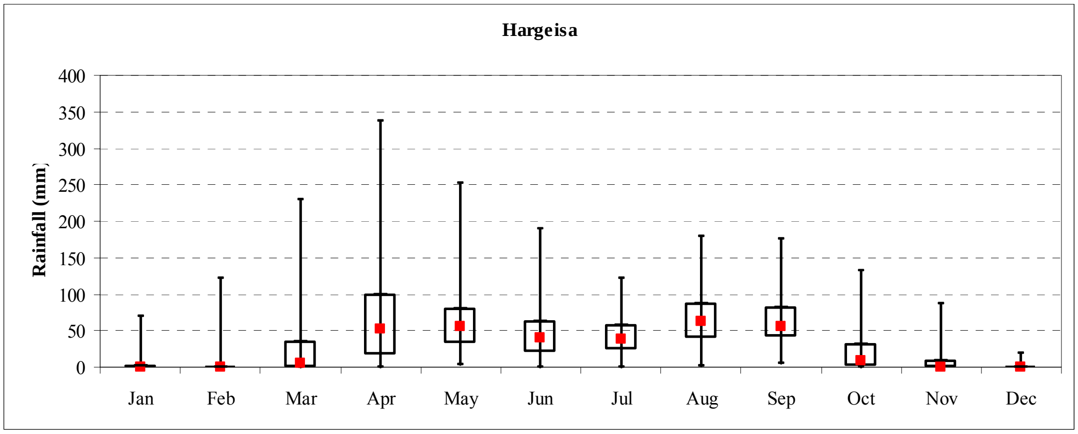
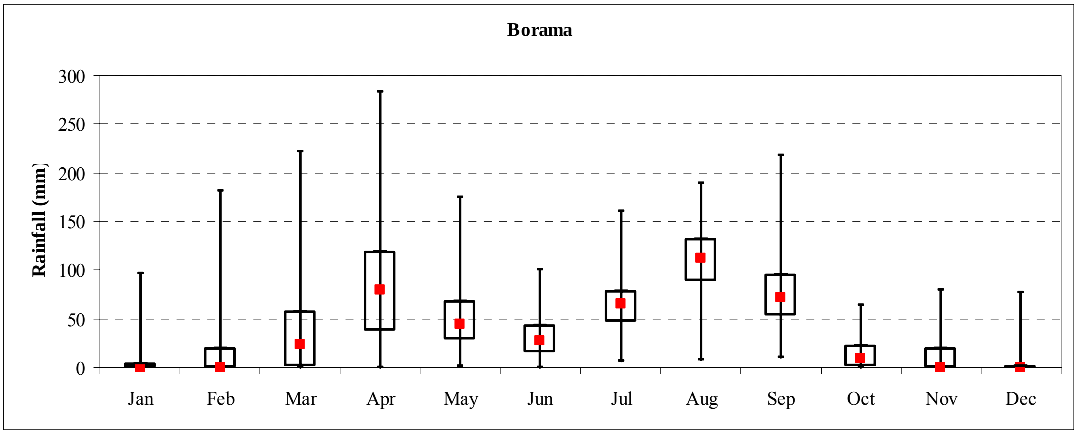


Figure B. 1 : Box Plots of Rainfall for Selected Stations in Somalia





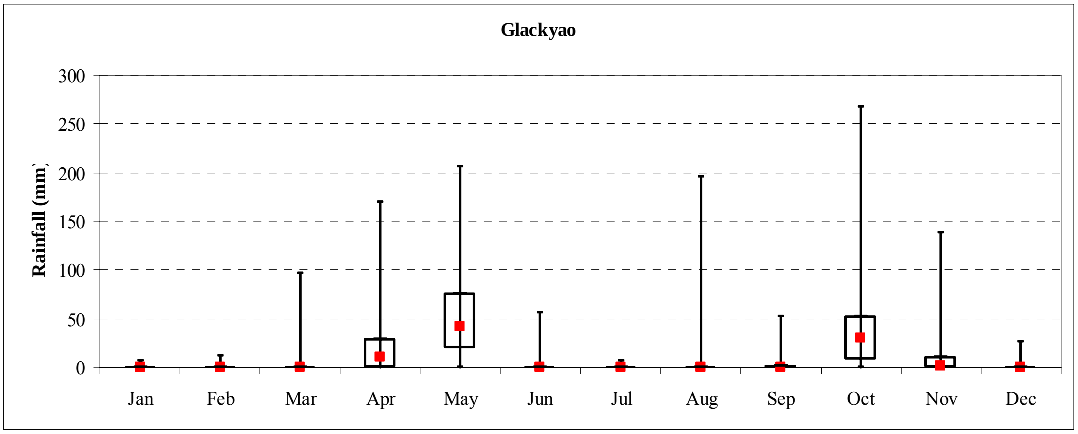
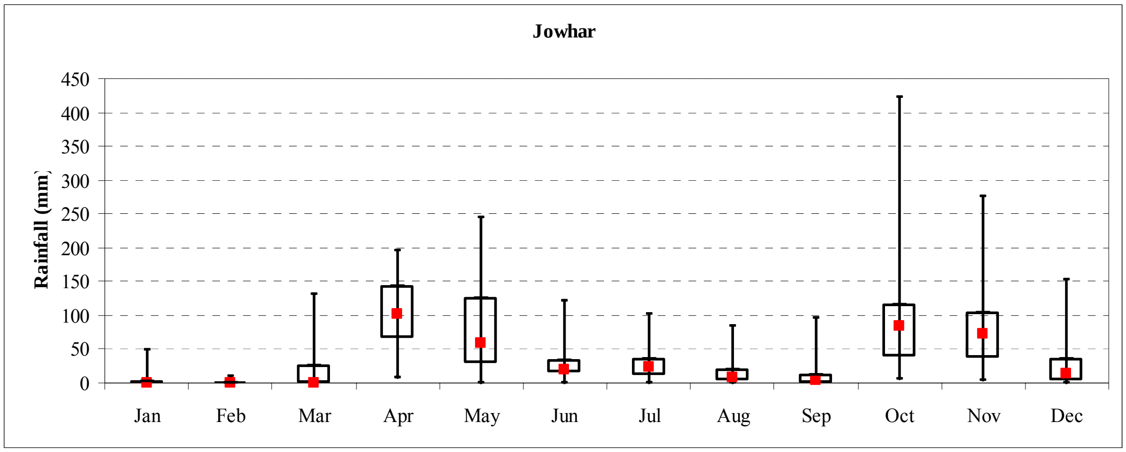
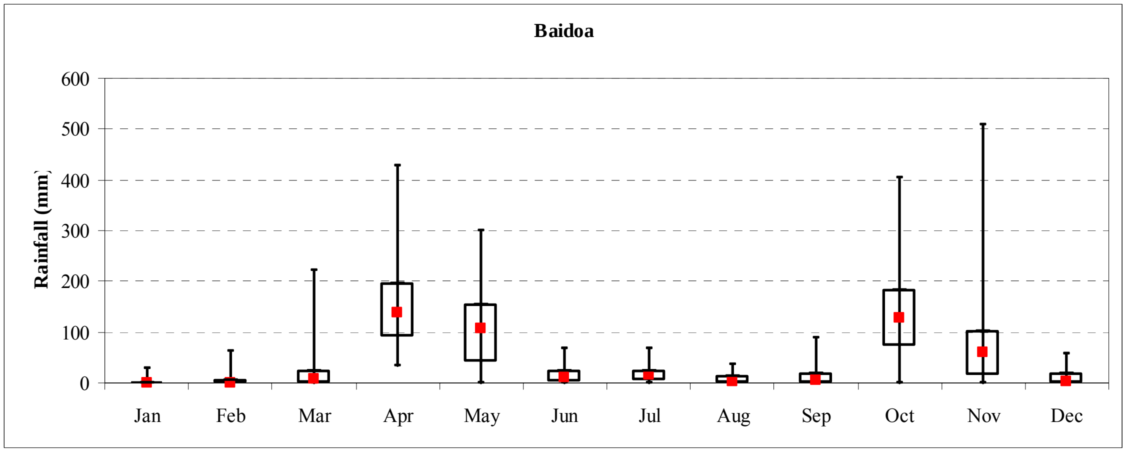


Figure B. 2 : Box Plots of Rainfall for Selected Stations in Somalia (cont'd)





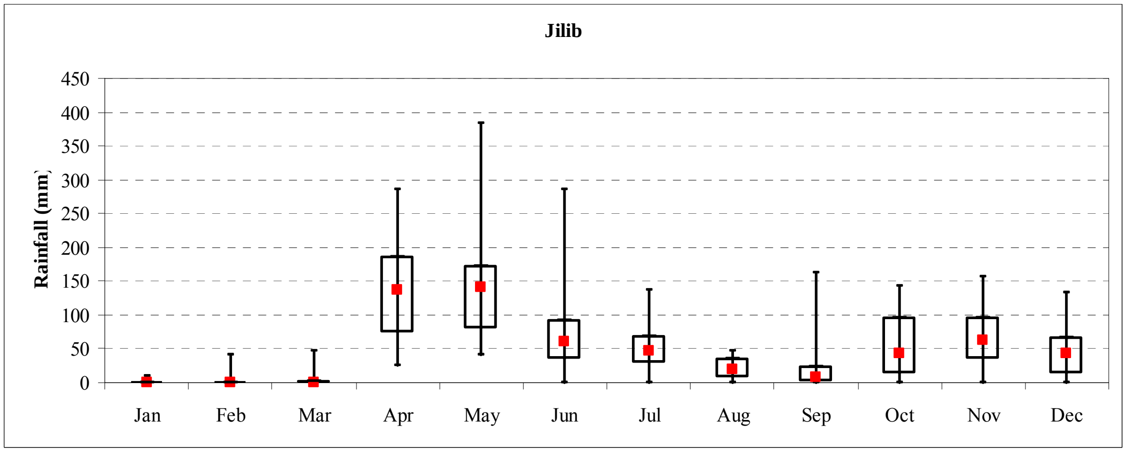


Figure B. 3 : Box Plots of Rainfall for Selected Stations in Somalia (cont’d)

Table B. 3 : Number of Days with Rainfall > 20mm (Galkayo)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann-ual
1944	0	0	0	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	1	0	0	0	0	0	0	0	1
1946	0	0	0	2	0	0	0	0	0	0	0	0	2
1947	0	0	0	0	1	0	0	0	0	1	0	0	2
1948	0	0	0	0	2	0	0	0	0	1	0	0	3
1949	0	0	0	0	0	0	0	0	0	0	0	0	0
1961	0	0	0	0	1	0	0	0	0	0	1	0	2
1962	0	0	0	0	1	0	0	0	0	2	0	0	3
1963	0	0	0	3	m	0	0	0	0	0	1	0	M
1964	0	0	0	0	0	0	0	0	0	1	0	0	1
1965	0	0	0	0	3	0	0	0	0	2	0	0	5
1966	0	0	0	0	0	0	0	0	0	3	0	0	3
1967	0	0	0	0	2	0	0	0	0	1	0	0	3
1968	0	0	0	2	0	0	0	0	0	0	0	0	2
1969	0	0	0	0	3	0	0	0	0	0	0	0	3
1970	0	0	0	1	1	1	0	0	0	0	0	0	3
1971	0	0	0	0	0	0	0	0	0	1	0	0	1
1972	0	0	0	0	1	0	0	0	0	1	0	0	2
1973	0	0	0	0	2	0	0	0	0	1	0	0	3
1974	0	0	0	0	1	0	0	0	0	0	0	0	1
1975	0	0	0	0	1	0	0	0	0	0	0	0	1
1976	0	0	0	2	1	0	0	0	0	1	0	0	4
1977	0	0	0	m	m	0	0	0	0	6	1	0	M
1978	0	0	0	0	2	0	0	0	0	0	0	0	2
1979	0	0	0	1	2	1	0	0	1	0	0	m	M
1980	m	m	m	m	m	m	m	m	m	m	m	m	M
1981	0	0	1	2	0	0	0	0	0	0	0	0	3
1982	0	0	0	1	0	0	0	0	0	1	1	0	3
1983	m	m	m	m	m	m	m	m	m	m	m	m	M
1984	0	0	0	0	1	0	0	0	0	0	0	0	1
1985	0	0	0	0	1	0	0	0	0	m	0	m	M
Mean	0.0	0.0	0.0	0.5	1.0	0.1	0.0	0.0	0.0	0.8	0.1	0.0	2.2
Max	0	0	1	3	3	1	0	0	1	6	1	0	5

Table B. 4 : Daily Rainfall > 20mm in Galkayo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1944	0	0	0	0	51	0	0	0	0	0	0	0	51
1945	0	0	0	0	51	0	0	0	0	0	0	0	51
1946	0	0	0	94	0	0	0	0	0	0	0	0	94
1947	0	0	0	0	51	0	0	0	0	20	0	0	71
1948	0	0	0	0	55	0	0	0	0	42	0	0	97
1961	0	0	0	0	29	0	0	0	0	0	113	0	142
1962	0	0	0	0	21	0	0	0	0	61	0	0	82
1963	0	0	0	117	m	0	0	0	0	0	35	0	M
1964	0	0	0	0	0	0	0	0	0	33	0	0	33
1965	0	0	0	0	98	0	0	0	0	231	0	0	329
1966	0	0	0	0	0	0	0	0	0	90	0	0	90
1967	0	0	0	0	70	0	0	0	0	21	0	0	91
1968	0	0	0	68	0	0	0	0	0	0	0	0	68
1969	0	0	0	0	103	0	0	0	0	0	0	0	103
1970	0	0	0	29	30	31	0	0	0	0	0	0	90
1971	0	0	0	0	0	0	0	0	0	38	0	0	38
1972	0	0	0	0	35	0	0	0	0	40	0	0	74
1973	0	0	0	0	188	0	0	0	0	23	0	0	211
1974	0	0	0	0	60	0	0	0	0	0	0	0	60
1975	0	0	0	0	27	0	0	0	0	0	0	0	27
1976	0	0	0	147	20	0	0	0	0	27	0	0	195
1977	0	0	0	m	m	0	0	0	0	186	27	0	M
1978	0	0	0	0	68	0	0	0	0	0	0	0	68
1979	0	0	0	48	81	45	0	0	32	0	0	m	M
1981	0	0	94	69	0	0	0	0	0	0	0	0	164
1982	0	0	0	54	0	0	0	0	0	54	59	0	167
1983	m	m	m	m	m	m	m	m	m	m	m	m	M
1984	0	0	0	0	43	0	0	0	0	0	0	0	43
1985	0	0	0	0	26	0	0	0	0	m	0	m	M
Mean	0	0	3	22	41	3	0	0	1	31	8	0	102
Max	0	0	94	147	188	45	0	0	32	231	113	0	329
Min	0	0	0	0	0	0	0	0	0	0	0	0	27

Table C. 1 : Hydrometric Station Inventory in Somalia

Site ID	Station Name	Time Series	Area (km^2)	Lat.	Lon.	Elevation (m)	Start Date	End Date	Missing data	Data Source
Jubba River										
1	Luuq	Stage and Daily flow	166,000	3:47:29	42:32:30	141	1951	To date	1968,1991-2000	IH, Care Somalia
2	Bardheere	Stage and Daily flow	216,730	2:20:30	42:17:00	89	1963	To date	1968,1990-2000	IH, Care Somalia
3	Jamame	Stage and Daily flow	268,800	0:01:10	42:41:00		1963	1990	1968	IH
4	Kaitoi	Stage and Daily flow	240,000	00:47;30	42:40:00	25	1963	1990	1965 - 1971	IH
5	Mareere	Stage and Daily flow	240,000	0:27:00	42:42:00	10	1977	1990		IH
6	Kamsuma	Stage and Daily flow	255,000	0:14:40	42:46:30		1972	1989	1977-1987	IH
7	Mogambo	Stage and Daily flow	260,000	0:09:00	42:44:00	14	1983	1989		
Shabelle River										
10	Belet Weyne	Stage and Daily flow	207,000	4:44	45:12:20	176	1951	To date	1953, 1991-2001	IH, ScUk-Somalia
11	Bulo Burti	Stage and Daily flow	231,000	3:51:20	45;34:20	133	1963	To date	1991-2001	IH,CINS
12	Mahadey Weyne	Stage and Daily flow	255,300	2:58:20	45:31:50	105	1963	1990		IH
13	Balcad	Stage and Daily flow	272,700	2:21:00	45:23:30	95	1963	1979		IH
14	Afgoi	Stage and Daily flow	278,000	2:08:40	45:07:30	77	1963	1990		IH
15	Audegle	Stage and Daily flow	280,000	1:59:10	44:50:00	70	1963	1990		IH
16	Kurtunwaarey	Stage and Daily flow		1:39:00	44:18:00					IH
26	Jowhar	Stage only					1999	2003		CEFA

Table C. 2 : Flow Duration Curve for Juba at Luuq

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	102.2	76.2	171.1	494.8	660.2	472.8	357.2	420.4	448.6	847.8	674.6	293.7	509.9
10	79.8	58.9	67.0	390.5	550.4	357.3	282.6	379.6	409.1	739.9	506.9	239.8	404.5
20	60.9	36.2	36.4	216.7	418.7	271.7	248.9	326.6	368.7	560.0	412.6	174.0	298.2
30	49.5	27.6	19.2	166.6	335.0	223.9	222.7	282.1	330.4	483.7	339.1	120.8	237.7
40	35.3	20.4	13.8	126.8	265.9	197.9	197.3	249.7	291.5	397.5	287.3	98.3	193.0
50	30.0	16.0	10.3	91.1	222.3	169.9	182.8	227.9	263.7	327.9	244.2	81.6	151.9
60	25.5	12.3	8.4	52.6	182.2	142.7	166.8	205.8	239.2	287.9	208.3	66.7	106.6
70	21.7	9.9	7.1	34.4	146.4	119.0	151.3	186.9	213.3	253.8	164.4	54.8	62.2
80	17.3	6.4	5.5	15.3	102.1	96.0	122.0	161.1	170.8	217.6	135.1	46.0	31.0
90	12.0	5.3	3.2	6.0	61.5	78.3	91.9	128.9	127.1	167.2	102.8	36.7	12.1
95	9.0	2.4	1.3	4.6	34.5	58.5	69.4	107.9	112.0	147.9	85.0	30.0	6.4

Note: % is the first column is the percentage of exceedance

Table C. 3 : Flow Duration Curve for Juba at Bardheere

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	106.3	76.3	157.8	505.8	740.7	501.9	363.6	410.9	457.1	881.0	762.7	317.3	532.8
10	85.6	64.1	66.5	386.5	600.1	382.1	304.3	375.5	419.1	747.3	579.1	261.7	413.6
20	66.6	44.4	36.7	216.8	436.2	297.8	245.4	319.2	365.2	555.6	447.2	192.7	305.6
30	53.8	32.5	23.6	162.6	339.9	228.9	214.0	280.3	322.2	487.4	383.5	132.9	241.5
40	43.3	26.9	19.8	125.4	270.2	198.8	192.6	253.2	284.1	401.7	320.5	110.5	192.6
50	36.4	20.9	16.4	83.9	220.8	172.6	175.5	223.8	259.6	334.0	264.7	89.1	155.3
60	31.5	18.6	14.7	49.5	181.8	155.4	159.6	197.0	236.3	287.5	226.1	73.5	112.5
70	26.7	16.2	12.1	30.6	152.7	126.2	142.3	182.0	208.4	252.1	183.1	65.8	69.0
80	23.4	14.6	9.5	21.0	112.3	101.7	125.7	159.7	175.2	210.6	156.4	53.7	35.9
90	18.5	12.2	7.0	11.7	71.2	77.7	96.8	132.8	129.0	165.7	125.3	43.2	18.4
95	15.1	10.5	4.2	6.4	45.3	61.3	80.5	108.7	113.0	148.7	99.5	36.9	12.8

Table C. 4 : Flow Duration Curve for Juba at Mareere

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	133.1	71.0	169.0	530.4	667.4	623.4	364.7	383.7	425.0	584.5	627.0	432.1	544.5
10	92.3	59.5	58.1	448.8	575.6	512.7	312.9	357.8	380.4	538.0	591.7	318.5	452.1
20	65.7	47.3	38.4	220.1	533.9	403.9	266.9	292.2	348.1	508.3	540.6	245.4	318.1
30	51.8	34.8	24.9	170.6	385.4	316.3	224.3	249.3	306.4	458.9	449.9	178.2	240.3
40	38.7	20.9	15.1	133.6	302.7	251.4	199.8	216.4	258.3	401.2	366.2	115.5	187.8
50	33.7	16.3	11.8	70.5	224.7	216.9	178.0	200.8	222.8	334.6	296.8	86.5	147.5
60	28.8	11.8	7.7	28.4	179.9	171.6	154.9	171.7	192.9	278.6	223.6	72.8	107.5
70	24.6	8.7	5.1	20.1	153.6	140.0	124.6	157.4	166.9	233.2	171.9	58.2	61.8
80	20.4	7.6	3.8	10.7	122.6	101.0	111.0	137.8	135.6	185.3	148.1	51.1	32.1
90	14.9	4.3	2.2	5.3	72.9	65.6	90.8	113.5	88.0	127.8	113.0	37.3	12.2
95	10.3	2.5	0.7	2.6	25.8	58.7	65.0	88.4	72.6	117.8	98.3	32.1	6.2

Table C. 5 : Flow Duration Curve for Juba at Kaitoi

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	139.8	94.4	101.5	483.4	556.9	456.0	349.2	403.9	402.1	590.7	613.0	369.8	477.0
10	109.9	77.2	63.7	325.7	486.3	406.1	296.2	361.9	373.5	518.0	503.2	309.2	406.7
20	77.9	52.4	37.6	215.2	477.0	314.8	238.7	313.4	335.3	472.0	455.0	238.2	301.0
30	60.1	34.6	23.8	162.3	340.8	254.5	206.5	271.1	306.8	421.2	407.6	160.3	235.5
40	50.3	27.9	19.9	108.9	247.7	215.2	186.4	236.8	278.7	354.0	353.4	121.6	191.9
50	44.2	24.5	14.2	42.4	191.8	178.7	168.9	216.4	250.4	303.7	280.6	100.0	154.7
60	39.1	20.1	11.5	22.8	170.3	151.1	150.0	202.8	225.8	269.2	222.2	79.6	111.3
70	32.7	16.2	7.7	18.0	146.7	122.9	132.7	183.2	202.9	233.1	184.7	67.4	70.0
80	27.2	8.7	3.3	9.0	100.5	99.8	115.1	163.9	174.4	203.7	158.8	59.0	36.1
90	18.7	5.3	1.2	5.8	50.9	78.0	89.6	139.6	126.7	169.7	130.9	50.4	16.2
95	11.1	1.4	0.0	3.7	29.2	70.8	74.7	115.6	105.1	135.5	112.6	43.9	6.5

Table C. 6 : Flow Duration Curve for Juba at Jamame

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	144.9	62.3	70.8	457.1	477.0	477.0	320.4	379.3	399.0	477.0	477.0	383.0	469.8
10	104.4	52.4	46.4	267.3	477.0	436.1	278.1	348.7	377.6	477.0	477.0	311.6	401.8
20	73.0	36.5	29.3	169.6	415.7	310.4	229.1	276.6	342.1	452.6	460.3	228.4	293.7
30	56.6	27.9	16.1	131.0	325.6	243.3	199.5	239.4	311.5	411.5	427.8	163.8	226.9
40	43.7	22.4	12.6	62.1	247.7	205.3	176.2	217.1	272.2	344.9	377.1	123.8	183.6
50	36.4	18.2	9.9	31.6	199.1	174.7	157.6	203.4	245.3	286.4	312.2	101.9	143.6
60	30.6	13.5	6.1	19.1	160.4	153.5	135.7	180.9	215.0	252.8	248.5	85.2	99.2
70	25.6	10.0	3.1	10.0	127.7	123.3	120.4	160.9	192.8	222.4	211.6	68.4	58.1
80	20.6	7.0	0.9	5.0	81.0	93.4	100.8	144.5	161.3	183.7	173.7	56.8	27.5
90	14.2	5.3	0.0	1.3	44.8	62.7	76.5	112.6	109.8	146.4	128.2	43.1	10.5
95	5.7	1.4	0.0	0.0	23.1	51.4	53.6	78.0	87.0	127.6	112.9	34.5	3.6

Table C. 7 : Flow Duration Curve for Shabelle at Belet Weyne

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	34.4	43.2	130.9	212.0	341.8	298.3	109.2	175.8	246.4	262.0	235.3	118.9	229.2
10	27.6	26.1	99.0	169.2	324.5	196.8	100.7	159.9	219.6	217.3	203.7	84.3	188.2
20	21.3	17.9	57.5	129.7	242.4	124.7	82.5	138.4	198.1	186.2	121.9	57.3	137.1
30	18.0	15.2	21.7	103.5	197.7	85.4	70.4	132.2	177.3	156.9	86.7	35.8	109.7
40	12.5	12.9	13.9	82.1	146.3	66.6	61.9	125.4	164.3	136.0	64.4	23.8	81.9
50	10.5	8.6	11.3	64.2	130.4	52.6	54.6	116.4	153.2	118.7	46.7	17.9	60.8
60	8.6	6.5	7.3	44.3	110.2	42.4	48.0	105.8	141.7	101.3	39.0	14.0	41.6
70	7.1	5.4	5.0	28.3	84.3	34.0	39.4	92.7	122.7	85.3	30.7	12.2	24.5
80	5.8	4.7	3.8	14.6	64.1	28.2	31.0	77.7	99.2	69.1	22.6	10.1	14.4
90	3.3	3.3	2.6	8.3	40.4	18.1	17.3	52.2	69.4	52.0	17.8	7.0	7.5
95	2.4	2.7	2.0	3.0	26.0	14.0	13.8	37.3	60.2	44.3	14.5	5.8	4.6

Table C. 8 : Flow Duration Curve for Shabelle at Bulo Burti

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	35.8	32.1	101.9	180.8	291.0	288.7	102.6	153.4	209.3	260.2	222.5	119.3	202.2
10	30.1	20.5	76.2	136.5	265.3	193.5	91.4	140.3	190.0	196.1	191.5	77.3	165.8
20	21.2	16.1	21.8	110.1	209.1	115.9	75.5	127.2	173.5	173.3	118.4	46.9	121.6
30	16.5	13.2	14.6	83.1	169.1	85.6	63.7	119.3	159.1	146.1	87.3	27.6	95.0
40	11.6	10.1	9.7	63.0	134.2	66.2	55.6	113.1	149.6	122.8	69.1	21.1	72.2
50	8.9	6.4	7.2	42.0	111.6	50.7	47.7	104.3	138.5	108.8	51.0	16.0	49.7
60	7.4	4.9	4.6	27.5	91.5	38.8	38.6	95.3	127.8	96.2	40.2	12.9	30.1
70	5.8	3.6	2.9	13.2	75.8	30.1	30.6	85.5	112.6	83.2	31.6	10.3	17.0
80	3.9	2.0	1.1	5.5	54.3	21.8	22.9	69.0	97.1	70.9	24.1	8.4	10.0
90	2.1	0.0	0.0	2.6	29.9	14.7	14.1	46.9	72.2	57.7	17.5	6.5	4.5
95	0.7	0.0	0.0	0.1	20.3	12.1	9.4	35.4	60.8	47.2	13.1	5.5	1.9

Table C. 9 : Flow Duration Curve for Shabelle at Mahadey Weyne

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	42.7	35.0	98.6	158.1	164.3	159.7	107.9	141.7	154.9	156.2	152.3	132.7	149.5
10	34.2	23.2	72.2	134.5	159.4	148.0	93.7	138.5	145.6	149.4	144.6	91.6	140.0
20	25.9	20.3	23.9	107.0	145.1	129.9	79.1	129.7	140.0	140.8	125.6	63.3	125.2
30	22.1	16.8	18.0	80.0	140.0	102.1	65.9	120.8	140.0	137.5	100.2	37.4	100.7
40	15.6	13.2	13.4	58.0	129.2	79.8	55.9	113.6	138.0	127.6	83.8	27.1	77.3
50	12.9	9.2	8.9	37.2	114.3	63.0	47.3	104.2	134.5	116.0	63.0	22.3	52.9
60	10.5	7.6	6.2	19.0	99.2	48.7	40.6	94.3	129.9	106.4	48.4	19.0	34.5
70	8.6	5.2	4.6	12.5	80.8	39.2	33.6	82.7	119.1	90.9	39.1	15.7	21.2
80	6.6	4.0	2.4	4.9	55.3	29.8	24.2	67.7	101.5	78.9	30.2	12.1	13.3
90	5.0	2.2	1.1	2.2	32.1	18.2	16.0	50.3	70.3	62.2	23.3	9.4	6.3
95	2.7	0.1	0.0	0.7	22.5	14.9	10.5	35.7	61.5	50.8	19.5	8.0	3.6

Table C. 10 : Flow Duration Curve for Shabelle at Afgoi

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	35.8	32.1	101.9	180.8	291.0	288.7	102.6	153.4	209.3	260.2	222.5	119.3	202.2
10	30.1	20.5	76.2	136.5	265.3	193.5	91.4	140.3	190.0	196.1	191.5	77.3	165.8
20	21.2	16.1	21.8	110.1	209.1	115.9	75.5	127.2	173.5	173.3	118.4	46.9	121.6
30	16.5	13.2	14.6	83.1	169.1	85.6	63.7	119.3	159.1	146.1	87.3	27.6	95.0
40	11.6	10.1	9.7	63.0	134.2	66.2	55.6	113.1	149.6	122.8	69.1	21.1	72.2
50	8.9	6.4	7.2	42.0	111.6	50.7	47.7	104.3	138.5	108.8	51.0	16.0	49.7
60	7.4	4.9	4.6	27.5	91.5	38.8	38.6	95.3	127.8	96.2	40.2	12.9	30.1
70	5.8	3.6	2.9	13.2	75.8	30.1	30.6	85.5	112.6	83.2	31.6	10.3	17.0
80	3.9	2.0	1.1	5.5	54.3	21.8	22.9	69.0	97.1	70.9	24.1	8.4	10.0
90	2.1	0.0	0.0	2.6	29.9	14.7	14.1	46.9	72.2	57.7	17.5	6.5	4.5
95	0.7	0.0	0.0	0.1	20.3	12.1	9.4	35.4	60.8	47.2	13.1	5.5	1.9

Table C. 11 : Flow Duration Curve for Shabelle at Awdhegle

%	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
5	46.5	36.4	71.5	83.8	90.1	88.6	81.1	89.0	88.1	84.4	88.1	82.7	87.1
10	35.4	25.8	48.2	75.6	88.2	86.2	73.5	88.0	85.7	82.4	85.7	74.0	83.3
20	26.4	17.1	26.9	72.8	85.2	83.0	64.5	84.6	83.3	81.9	81.4	62.1	77.7
30	18.6	13.9	16.8	54.4	81.7	74.0	53.3	82.0	82.0	79.8	74.0	42.5	74.0
40	12.0	8.5	9.9	37.5	74.5	69.9	44.2	79.5	81.1	74.5	72.9	29.5	64.1
50	8.1	4.1	3.1	19.8	74.0	63.5	39.2	74.0	77.4	74.0	62.7	22.0	45.7
60	5.8	1.5	0.1	13.8	71.9	51.3	34.0	73.6	74.0	73.3	49.6	17.7	31.2
70	3.4	0.4	0.0	1.1	61.9	39.8	26.4	61.7	74.0	69.6	40.1	12.1	18.3
80	1.7	0.0	0.0	0.0	42.8	28.4	18.0	49.2	70.0	64.1	32.7	7.6	8.7
90	0.0	0.0	0.0	0.0	24.7	16.5	12.1	33.8	57.9	53.7	22.4	3.7	0.3
95	0.0	0.0	0.0	0.0	18.0	11.3	5.4	24.7	45.6	46.8	16.6	0.0	0.0