EC Funded Project

German Agro-Action Somaliland

Inception Report of the Integrated Water Resource Management Plan

Community Based
Natural Resource Management
in the Dur-Dur Watershed,
Awdal Region,
Somaliland

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1. INTRODUCTION

1.1 General

The present project is a further development of an initial intervention by GAA in the Dur-Dur Valley[1]. This second phase seeks to contribute to the stabilisation and improvement of rural livelihoods in Awadal region based on the sustainable use of natural resources. The project area covers the entire Dur-Dur watershed, which is situated within the Districts of Borama, Baki and Lughaya See Appendix 2.

The project is designed to enable communities in the watershed to manage natural resources and farming systems increasingly in a sustainable, efficient and equitable manner.

A major investment of the project is to develop an Integrated Water Resource Management Plan (IWRMP) in close collaboration with land-users and administrative bodies.

The IWRMP is being developed through a contract between GAA and a Nairobi based private consultancy – Groundwater Survey (Kenya) Ltd. The process will include the following activities

- Preparation and Inventory of Data
- Field Reconnaissance
- Satellite Image processing
- Hydrologic Data Collection
- Inspection of Existing Water Supply Schemes
- Water Demand
- Water Resources Assessment of the Study Area
- Detailed Fieldwork/ Water Resources Inventory
- Participatory Meetings
- Detailed Site Investigations
- Environmental Assessment
- Data Evaluation
- Data Processing Using GIS
- Planning and Design

Progress to date.

- Data Inventory of all technical reports in the Dur Dur Watershed
- Initial meeting with FAO- LAWIP in Hargeisa by John Fox
- Reconnaissance Survey by Water Resources Assessment Team
- Field Visit by John Fox 13th to 21st March – longitudinal transect from Baki to Lughaya (185km); Transect from Baki to Bonn then traverse along water shed Bonn to Borama to Dilla to Hargeisa.
- Preparation of Inception Study Report.

1.2 Location

The project area is situated in the mountainous region to extreme west of Somaliland, Awadal region. It comprises of approximately 3600 km^2 and consists of the communities of Adaad, Heego, Horey, Harmata, Old Baki, Baki, Gargara, Garbaraho, Borama, Bown, Dilla, Halimale and Ruqi.

The altitude ranges from 250 m at coastal areas (Gargara) to 1000 m near Baki .The upper part of the water catchment is located in Dilla (1500 m) and Borama areas. Baki has an altitude of about 900 to

[1] Community Based Rehabilitation of Wadi Management in Baki District, Somaliland

1000m, however the mountains between Baki and Borama, on the highest tips, reach about 1200 to 1300m. The area is covered mainly by Basement System rocks and by limestone where streams have incised narrow valleys composed of mainly alluvial deposits. The community of Baki forms the centre of the middle part of the Dur Dur water catchment, covering the largest arable land currently cultivated. However, there are significantly larger arable areas (presently with limited cultivation) in the Garbaraho area, in the lower part of the Catchment. In Baki and Ruqi areas, irrigated agriculture is practiced along the banks of the main valleys of Dibra Weyn and Bira Toggas. The rest of the communities rely on Laasdhure, Daraso, Abassa, and Dur Dur, etc Toggas for irrigation farming. All these temporary watercourses extend from the south to the north where they flow, after having crossed the mountains and the costal plain into the Gulf of Aden. On the plateaus between the foot of Alog mountain range and the togas rain fed agriculture is practiced in the communities of Heego Northwest of Baki up to Ruqi in the southwest. However, main rain fed areas in the water shed is found in the Dilla and Borama areas).

1.3 Project Objectives

The specific objectives as described in the Terms of Reference provided by the Client are as follows:

'The consultants will be commissioned to work out an Integrated Water Resource Management Plan (IWRMP) for the entire Dur-Dur watershed. The IWRMP will be elaborated in a participatory manner with land-users, administrations at all levels including the Ministries of Agriculture, Water, Planning and Ministry of Environment and Pastoral Development, as well as other stakeholders'.

Specific tasks to be undertaken:

- Review and analysis of existing relevant data
- Comprehensive assessment of the quantity and quality of water resources (surveys of ground water and surface water)
- Comprehensive assessment of climate data (setting up of automated meteorological stations-AMS-).
- Evaluation of actual water consumption (irrigation, livestock, drinking and household water, wildlife)
- Analysis of the existing land use systems
- Participation of stakeholders and line ministries
- Presentation of a mid-term draft on a local workshop
- Data processing with Geographical Information Systems (GIS)
- Linkage to the FAO Water and Land Information Management Project.

The methodology will be developed in partnership with the FAO Water and Land Information Management Project and will be in accordance to FAO standards where applicable.

Two automatic meteorological stations will be set-up within the project area, one in Baki and one in Gargara/or Garbaraho area (depending on the area which shall meet the meteorological requirements as well as free from vandalism.) The climatic conditions differ significantly. Additional simple rain gauges will be installed at different locations to supplement the already existing gauges.

Up to two 40-meter drillings are planned in order to complete and update existing ground-water survey data from the 1980's. The Consultancy has already done additional geophysical and hydrogeological investigations in the whole of the Dur Dur Catchment. It is worth noting that apart from the recommended two borehole sites that are planned under this programme for environmental monitoring purposes, the Consultant shall give additional recommended borehole sites per village dependent on the projected water demand for domestic, livestock and irrigation after detailed evaluation of the geophysical/hydrogeological data and consultation with the relevant stakeholders.

Reading of the gauges will be done with an automated system. A local assistant will support the investigations for the IWRMP.

All data will be made available to the FAO Water and Land Information Management Project as well as other interested groups. The Consultancy shall produce maps for the project area with help of satellite images, Somalia 1:100,000 topographical maps and GPS mapping which shall be carried out during the investigations. Maps and satellite images have already been obtained from FAO, UNDP Somalia office in Nairobi and Regional Centre for Resource Mapping and Development, Kasarani, Nairobi. These maps shall be prepared in a format acceptable/compatible with the FAO standards and where necessary the Consultancy shall seek assistance from the FAO SWALIM Project. Furthermore the Consultancy has already collected Water Facilities and Sources software from the SWALIM project which shall facilitate the data inventory exercise during the fieldwork process.

It is expected that at the end of this study, the Integrated Water Resource Management Plan for the Dur-Dur watershed will serve as a model for other areas in Somalia and in the Horn of Africa.

1.4 Approach and Methodology

The study approach shall remain as discussed in the Consultant's Methodology, which was included in the Bid Proposal and subsequently in the Consultancy Contract.

1.5 Contract

The Contract for Consultancy Services between German Agro Action and Groundwater Survey (K) Ltd. was signed on 9th January 2004.

1.6 Commencement Date

It was agreed during the contract negotiations that the Commencement Date would be effected once the security situation in Somaliland improves. This was effected when GSK professionals conducted reconnaissance survey of the project area between 27th February 2005 and 20th March 2005. The draft inception report would be due on 25th March 2005.

2. KEY DOCUMENTATION BEING USED

The Consultant obtained a number of reports for review from various sources. These reports include the following:

I) **C Faillace & E.R Faillace, (1986)**. Water Quality Data Book of Somalia: Hydrogeology and Water Quality of Northern Somalia Vol. I & II.
II) **Chris Reij *et al* (1988)**. Water Harvesting for Plant Production. World Bank Technical Paper No.91.
III) **Chris Reij et *al* (1992).** Water Harvesting for Plant Production Vol. II – Case Studies and Conclusions for Sub Saharan Africa.
IV) **IUCN Eastern Africa Programme, (1997).** Environmental Impact Assessment Manual and Guidelines for the Somali Water Sector.
V) **IUCN Eastern Africa Programme, (1997).** Somali Natural Resource Management Programme – **Elaboration** of Practical Guidelines on Environmental Impact Assessment Methods for Rehabilitation and Development Planning in Somalia, with Particular Emphasis on the Water Sector.
VI) **UNDP – Somalia & WORLD BANK (2003).** Socio – Economic Survey 2002 Somalia – Report No.1 Somalia Watching Brief 2003.
VII) **Macfadyen, W.A, (1952).** Water Supply and Geology of Parts of British Somaliland
VIII) **TAMS, (1986).** Northwest Region Agricultural Development Project. Pilot Watershed **Management** for Soil and Water Conservation and Small Garden Development, Vol. 1. Background and Water Shed Management.
IX) **Well Drilling Investigation, Group of China (1986).** Investigation Report on the Feasibility of **Well** Drilling in the Four Northern Towns of Somalia.
X) **BCI Geonetics International, Inc. (1985).** Regional Groundwater Potential and Identification of Potential Test Drilling Sites in Fractured Bedrock Aquifers.
XI) **Critchely, W., Reij, C., Seznec**, A. Water Harvesting for Plant Production. Volume II: Case studies and Conclusions for Sub-Saharan Africa.
XII) **SOGREAH(1983).** North West Region, Agricultural Development Project, Feasibility Study and Technical Assistance; Hydro-geological Study Report.
XIII) Department of Statistics and Research, Ministry of National Planning and Coordination (MNP&C) 2003
XIV) **Ministry of Agriculture**: Strategic Plan for Agricultural Rehabilitation and Development 2004 and 2006,
XV) **PRA Community Mapping**, Historical Profiles and Problem Analysis for IlGorey; Baki; Horey; Qabribahar; Heego; Ruqi, Hamarta (GAA).
XVI) **Malte Sommerlatte and Abdi Umar, May 2000**: An Ecological Assessment of the Coastal Plains of North Western Somalia (Somaliland),
XVII) **CF Hemming, 1966**: The Vegetation of the Northern Region of the Somali Republic,
XVIII) **Doris Klughardt and Mohamed Eggeh Killeh, January 2002:** Community Based Rehabilitation of Wadi Management in Baki District, Awdal Region, Somaliland, Environmental Study.
XIX) **GAA/ EC Project Document, June 2003-June 2006**: Community Based Natural Resource Management in the Dur-Dur Watershed, (extended to September 2006 due to security issues in 2004)
XX) **GSK/ GAA Contract for IWRMP**: Development in Collaboration with FAO-WLIP.
XXI) **FAO –WLIP** Project Document.
XXII) FAO Topographic Mapping
XXIII) Republic of Somaliland: Somaliland in Figures, MP & C, Somaliland, Hargesia.
XXIV) IFAD-UNOPS-BSF (1999). Beyond Relief Programme, Somaliland; Geophysical Survey in North-West Galbeed and Awadal Regions.
XXV) **SHABA** (Shirkadda Adeegayada Bulshada Awadal (2004). Annual Technical Report.
XXVI) UNICEF Somalia(2002), Borama Water Supply Project, Test Pumping of Dhamug Wells.

However, the Consultant would like to access technical information for the projects done in the watershed by the following NGOs: **CARE, German Red Cross/ Somali Red Crescent, ADO and ARDA**, **FAO** documentation, **HABITAT.**

Faillace & Faillace (1986). Water Quality Data Book of Somalia – Hydrogeology and Water Quality of Northern Somalia.

These publications provide exhaustive information on the regional hydrogeology of the study area, which includes water quality data. Some of the references quoted in these publications, which give more detailed information were not available.

The conclusions contained in the reports reveal that the importance of the Jurassic limestone and its arenaceous basal sections outcropping in the Awadal Region is not properly understood and that the limestone aquifers which are thought to be discontinuous may indeed by continuous and somehow connected.

It is also stated that studies carried out by BCI Geonetics in the Awadal and N.W. Galbeed regions disclosed that the basement complex is intensively fractured and it appears that conditions for groundwater development by shallow drilling are more favourable than previously thought.

In section II of volume 1, the report contains a chapter on the hydrogeology of Borama town and its environs. Water quality and type are presented in Volume II of the same report. The geological formations are made up of Precambrian Basement, karstified Jurassic limestone and widespread alluvial deposits west of Borama. Water for Borama Town is obtained from Dhamuuq Spring from where it is piped to the Town. Other sources for Borama area include seepages from artesian well close to the spring and wells dug in the Togga. The quality of this water is good with EC ranging between 1150 and 2130 μS/cm.

It is recommended that further hydrogeological studies of the most important areas covered by the Jurassic limestone should be carried out with subsequent drilling of exploration/production wells. It is also recommended that hydrogeological studies of the important valleys selected for agricultural development and other purposes should be carried out.

Ministry of Water & Mineral Resources, (1998). Somaliland's National Water Resources Development Policy – Draft C

This Policy paper identifies water as the limiting factor to most of the development activities of Somaliland. The life pattern of the people revolves largely around the availability or absence of water. Water for human and animal consumption is a major constraint, especially for those who move far away from riverbeds. The main objective of this policy is therefore ***to promote the rehabilitation and construction of water facilities and to improve management of water resources within a context of environmental and economic sustainability in order to enhance accessibility to water.***

It is envisaged that to meet this objective, a two-fold commitment will be adopted. This includes:

- Decentralization a) delegation of authorities/responsibilities to the regional level and
  b) support for community and private sector operations of water facilities.

- Economic Sustainability of:
  a) the operations and maintenance of water facilities
  b) providing support to the Ministry for its supervisory activities.

This policy paper proceeds to outline the Water Policy Context, Policy Objectives and Principles, Water Sector Priorities, Authorities/Responsibilities for Water Resources Development and Maintenance, Formal Structure of Water Sector and Enhancing Capacity in the Water Sector in six separate sections.

Since this was a draft paper, it is expected that the paper is in its last stages of preparation and that there is now a definite policy of the same. If this is available, it will be incorporated in the study and the outcome outlined as per the policy paper. The Policy will be one of the guidelines to the study of Dur-Dur Watershed area.

Since this Report describes the general area west of Hargeisa, more emphasis will be paid to the under-developed and potential agricultural areas of Awadal Region.

2.1 Background Information on Hydrology/Hydrogeology of the Dur Dur Catchment

The Background information for Dur Dur watershed has been explored through literature review of the existing technical reports and all other relevant data available. It is noted that the previous studies only concentrated on the upper and lower parts of this catchment while little investigations were done in the middle part of the catchment. As part of the on going study the Consultant intents to fill the gaps on existing information as well as carry out detailed geological and hydrogeological studies in the whole of the Dur Dur catchment. The sections below give a summary of the background information on the Dur Dur Catchment.

2.1.1 Geology of the Upper Part of Dur Dur Catchment

In Dilla area, SOGREAH (1983) has subdivided the geology of this region into two very distinct sectors. To the north, are outcrops of the basement complex forming the escarpments; while to the south are the sedimentary formations of the Ogaden plateau, with a flat relief dropping gently to the south. The basement complex consists of granitic gneisses and psammitic metamorphic formations.

These formations are highly fractured, which indicates that they were subject to considerable tectonic activity. The strike of the psammite bands indicates that the granitic gneisses were introduced into the middle of the metamorphic formations.

Well-Drill Investigation Group of China (1986) has classified the geology of Borama area in three distinctive classes as follows: The metamorphic rock system of pre-sinian system, the sand conglomerate and limestone of Jurassic system and the loose alluvial accumulation of quaternary system.

Metamorphic rocks of the Preterozic have further been classified into three groups which comprise of Quartz Feldspar Gniess, Hornblende mica-schist/gneiss and the Psammite with uniform grain. Quartz feldspar gneiss occurs mainly in the east within the low and medium land. They are characterised by steep mountains whose lithology consist of light yellowish pink and light grey-yellow median and fine orthoclase and plagioclase including a few schistose and black minerals.

Hornblende biotite gneiss, the hornblende schist and hornblende mica-schist and other metamorphic complex rock surround Borama town. They have mainly grey-green and dark green colour. The gneiss and schist appear irregularly in the area. Between them the gneiss has rough crystal and contains minerals such as feldspar and quartz. The hornblende and mica are arranged in fixed direction and appear in gneiss structure. The schist has thin schistose structure and is foliate or schistose. The bedding plane is very flat. The stratification seems to be that of sedimentary rock and is regular we can measure the occurrence of the bedding plane. The components are fine. The hornblende content is high. The mica schist is on the schistosity plane. After weathering it becomes

brown-yellow or grey-brown. The occurrence trend of main schistosity is NE 10^0 - 20^0 degrees. The tendency is NW 280^0 - 290^0. The dip is very sharp, 50^0 - 60^0 in general, 68^0 - 75^0 degrees maximum.

The psammite with uniform grain is placed between the hornblende mica schist in strip and stretches to the south and the north approximately. Near Borama, there are 4 or 6 zones with a width of 200 - 500 m. It is light yellowish pink, grey-white and grey-yellow feldspar quartz granules of median or fine grain D. The variable gabbrite, the gabbrite and the hornblende:

The sand conglomerate and Limestone of Jurassic System:
In the north-west of Somalia, the straits of Jurassic system occur over large area. In the surrounding of Borama there is also some stratification of Jurassic system to outcrop in a small scope. Compared with the local stratification, it can be divided into two parts i.e. the Adigrat sandstone and sand conglomerate rock at the bottom, and the argillaceous limestone at the top. The outcrop is within a distance of 5 -10 km to the east of Borama.

The loose accumulation of Quaternary System:
The majority of alluvial deposition is located in the gentle ground and develops on the two sides of Damuk and Amud rivers. Because of the different source and origin, in horizontal direction and the vertical direction the accumulation of quaternary system varies obviously. It's difficult to find the typical section as a local representative in Borama Area.

2.1.2 Geology of the Middle Part of Dur Dur Catchment

The middle part of Dur Dur Catchment is composed mainly of Basement rocks and Jurassic Limestones. Near Baki area, there occurs Alog Mountain range which is composed of crystalline Basement rocks. However most of the Baki "Basin" comprises of mostly Quaternary deposition which is composed mainly of sandy clays, and alluvial sands close to the Bira and Debra Weyn Toggas. The most dominant rock formation in the middle part of the Catchment is Jurassic Limestones which have similar characteristics with earlier description for Borama town. There have been fewer investigations done in the middle part of the catchment both hydrogeological and hydrological. (See geological map in Appendix 2).

2.1.3 Geology of the Lower part of the Dur Dur Catchment

SOGREAH report has defined the geology of Lower Dur Dur catchment in three units:

- An upstream unit underlain entirely by Basement (Waraqadhigta);
- The central unit comprising Basement, Jurassic limestones and coastal plain alluvium (Qabri Baxar);
- The downstream unit, comprising Basement. Jurassic limestones and Nubian sandstones on the-west bank, and Jurassic limestones alone on the east bank (Gargara).

Waragadhigta unit comprises of granitoid gneisses containing muscovite-rich pegmatite veins which form the highest relief. A prominent SW-NE fault from Waraqadhigta to Gargara controls togga orientation. with an orthogonal fault - or suspected fault - controlling the alignment (SE-NW) of the *T.* Miridh (south east of Waraqadhigta), (SOGREAH 1983). To the Downstream near Gargara, Basement comprises foliated psammites oriented SE-NW, dipping at 30 to 65° to the North. While the Qabri Baxar unit is described as Basement outcrops on the west bank which underlie the Jurassic limestones. They comprise of granitoid gneisses and granulitic migmatite with a strike ranging from 35 to 70°. Basement granitoid gneisses underlie the west bank of the togga, with a foliation strike of 71^0. At Gargara, they constitute the northern-most rock barrier across the togga.

Jurassic limestones overlie Basement unconformably on both banks of the *togga.* They comprise banded limestones of total thickness 400m. Nubian Sandstone was reported to occur in the downstream area on the west bank of the togga (SOGREAH, 1983). They are composed of hard sandstones with large quartz pebbles, with bedding planes dipping at 15 to 20^0 to the south,

concordant with the Jurassic limestones they overlie. Similar outcrops have been noted on the south bank of the Togga Gargara, south of Gargara village.

Alluvium has been extensively deposited in the Gargara and Qabri Baxar areas. Two separate depositional episodes have been identified - recent togga alluvium (clayey sand), and ancient brown and red sandy clays. In the upper part (Waraqadhigta to Qabri Baxar) ancient alluvium is at least 100m thick and clay-dominated, though there may be palaeochannels of coarser material within it. The togga alluvium comprises coarse sand, pebbles and blocks along the togga centre-line, becoming finer with distance away from it. Togga alluvium is thickest immediately adjacent to the streamline at about 50m, thinning to 10m at the margins.

Alluvium in the coastal plain is universally distributed across a featureless plain, with a single basalt outcrop overlying the ancient red clay south west of Sabawanaag. Red and brown sandy clay alluvium covers most of the plain and is believed to be universally thick: downstream of Gargara it is at least 150m thick: The modern stream channels have developed in this older, clayey alluvium. Downstream and west of the rock bar at Gargara, sediments have formed a pronounced alluvial cone, between 40 and 46m thick comprising fine sands with local intercalations of clay and gravels. The cone extends at least 14km northwards, and is some 5km wide on the west bank of the T. Durdur.

2.1.4 Hydrology of the Dur Dur Catchment

In the upper part of the Dur Dur Catchment, (near Borama) there are three distinctive water causes which are described by the Well-Drill Investigation Group of China (1986) as follows:

1. Togga Lehelou: it takes its source at the north slope of the highland of 1780.6 m in Eagi which is 12 km away from the southeast of Borama. In its surroundings there are some small valleys which join it. In massica, the flood drains away to the north. The length of the river is about 12km. To the north of middle school, at a distance of 1.5km away, it joins with Dhaaua River and its lower reach is also called Amud River.

2. Togga Dhamaua: The upper reach is Garadesharo River. The reach which passes through Borama town and flow to the northwest, is called Togga Dhamaua. In the river at a place, which is 3 km away from Borama, there is emerging underground water to flood and make some fine stream from the river bed of the reach. The water source of the town of Borama is here. It is only river bed in which there is water all the year round (by the time the Chinese were carrying out investigations, 1986). On the two sides of the valley is the limestone having monoclinal occurrence. In the river bed there is some thin accumulation of Quaternary Period. The underground water floods at the edge of the river bed. The river goes to the northeast and joins with the Amud River.

3. Togga LaasDhiige: The river is 4km away from the north of Borama. It flows from the west to the east and joins with Dhamaua River near the highland of 1580m.

The three tributaries join to form Amud River which goes into mountain land and meanders towards the northeast where it joins Lass Dhuure Togga. Amud river is the big river near Borama. It stretches to the east of Borama. The local inhabitants sometimes call Lass Dhuur River as Amud River, too.

The middle part of the Dur Dur catchment is composed mainly of Dibra Weyn, Las Dhure, Bira, Daraso, and Abase Toggas which join up to form the Dur Dur Togga this flows to the lower part of the watershed. Debra Weyn Togga drains relatively a large area before it is joined by the Bira toga. The two Toggas have very good alluvial material which provides ancient pathways or groundwater recharge. The Dibra Weyn Valley has thick deposits of alluvium along the Togga beds, which provide significant long-term storage for groundwater.

In the lower part of the Durdur Togga flows about 10 km from SW to NE across the coastal plain. The SOGREAH report has divided this into upstream and downstream parts:

The upstream extend from Waraqadhigta to a rocky sill at Gargara village, (282m amsl). It falls from 520 to 280 m amsl. over a distance of 30km at a mean gradient of 0.8 to 1 %. This is the T. Coolfuul on the 1:100,000 scale topographic map. The main downstream reach (*T.* Gargara on the 1: 100,000 scale map) extends from Gargara to the coastal strip some 40km to the NNE; the main togga narrows from a broad and shallow 800 m to 50m adjacent to the sea. There are numerous minor toggas in this zone, all essentially branching from Gargara. The gradient is typically 0.7%.

The lower Durdur catchment receives less than 100mm of rainfall a year. In 1980 a gauge at Qabri Baxar measured an annual total of 86.4mm. Mean annual flow at Qabri Baxar (396m amsl) was calculated to be 34 MCM or 93,000 m^3/d (catchment area 3,000km^2, mean catchment rainfall 347mm). SOGREAH concluded that a relatively humid microclimate existed in the area, such that despite it remaining dry in the central mountain chain (at Hargeisa), localised storms of sufficient intensity occurred that flash floods resulted.

SOGREAH observed significant infiltration of flood flow into togga alluvium between Waraqadhigta and Gargara: in a single flood event discharge at Waraqadhigta was not less than 1,5001/s whereas in the togga north of Gargara (28km downstream) flow was less than 301/s.

2.1.5 Hydrogeology of the Dur Dur Catchment

Previous hydrogeological investigations have been carried out mainly in the upper and lower parts of the Dur Dur catchment. These include: BCI Geonetics International (1985), Well-Drilling Investigation Group of China (1986), SOGREAH (1983), TAMS (1986), IFAD-UNOPS-BSF, (1999), and UNICEF, 2002. The areas which detailed investigations were carried include: Borama, Dilla, Old Baki, Baki, Ruqi, and Gargara.

In general the definition of aquifer types in the Dur Dur Catchment can be classified dependent on the geology of the area. BCI (1985) have described the geology of the area in the following groups.

Jurassic Limestone Aquifers

The Jurassic limestone has the greatest potential for ground-water development of any rock type. Observations made in the study area indicates that this rock should be a significant aquifer where it is fractured or has undergone extensive karst development. "The most extensive karst development is in the study area near Borama where the limestone has probably been exposed continuously since the Jurassic. Karst development decreases toward the north probably because there was no hiatus between the Jurassic and the Cretaceous and because the Nubian sandstone deposited in this area has protected the limestone from karst development.

This limestone is more easily recharged in areas where the bedding is not horizontal. The greater the dip of the sediments, the greater the recharge capability. The lower section, which usually contains lenses of sandstones and conglomerates up to 90 m thick, may be less favourable.

In some areas, the limestone has weathered to a clay rich residuum which reduces the recharge capability of the aquifer. This residuum tends to accumulate in some of the alluvial valleys reducing the ability of a well in the bedrock to make use of the recharge from the overlying tug beds, would then represent a significant ground-water resource.

Tertiary Basalt Aquifers

The Tertiary basalts occur primarily as elevated plateaus and are generally unsaturated. In a few areas, such as Agabar and Las Dhure, they are found in the lowlands and appear saturated. Wells drilled in these areas have intersected water-bearing zones composed of sand lenses and weathered basalt. These wells are shallow and no exploration has been conducted to evaluate the water potential

in the entire thickness of these basalts. The possibility exists that thicker zones of alluvium might exist at greater depths, representing a significant groundwater resource.

Field observations made in stream channels indicate that there is paucity of vertical fractures in the basalt flows as might be expected; since these basalts are extremely young and have been subject to less tectonic disturbance than neighbouring formations. In certain areas, however, vertical fractures resulting from the cooling of the basalts might be expected. These areas probably represent primary recharge zones. This is perhaps supported by observations made where there is an extreme paucity of vegetation, no soil development and a very rubbly, gravely appearance. This apparently indicates that these flows are extremely permeable to recharge from precipitation. If this is the case, then these basalts may permit a considerable amount of recharge to the underlying basalt and alluvial layers which would then represent a significant groundwater resource.

Precambrian Granite Aquifers

The Precambrian granites in the study area are productive aquifers only where they have been fractured and faulted by tectonic activity. Remote-sensing interpretation, geologic mapping, and field observation indicate that the most productive fracture zones are probably related to the recent rifting in the Red Sea and the Gulf of Aden. These granites are fairly equi-granular and tend to form open fracture systems as the result of tectonic stress. The schist and gneisses, however, tend to have tectonic stress relieved by movement along crystal boundaries and foliation planes and are less likely to produce open water-bearing fracture systems. Since the granites do not have a significant amount of porosity or secondary permeability, except where there are well-developed fracture systems, there is not alot of ground water in storage within most of the granite. A weathered, granitic residuum can act as a significant reservoir for the storage of ground water. In the study area, however, it appears that the residuum has been largely removed by erosion resulting from rapid uplift of the Precambrian basement.

Precambrian Metamorphic Rock Aquifers

The Precambrian metamorphic rocks in the study area are quartzite, mica schists, gneisses, metamorphic volcanics, and metapelites. Tectonic stresses tend to be relieved by movement along foliation planes, which are developed to varying degrees in the rocks. Therefore, large water-bearing open fracture systems are not formed except in places where there has been very significant tectonic movement and a tremendous amount of stress. As with granitic rocks, large ground-water supplies cannot be developed unless there is an appreciable thickness or saturated permeable overburden overlying the well site.

Mafic and Ultramafic Crystalline Rock Aquifers

These rocks are similar to granites in that they are equi-granular and tend to fracture rather than relieve stress by movement along foliation planes. However, because the minerals of which they are composed break down more readily and completely than do the mineral constituents of more siliceous rocks, the weathering of mafic rocks results in a relatively large volume of weathering product. The weathering product, consisting primarily of clay and calcite, tends to plug existing fractures and prevents them from transmitting ground water. In general, therefore, mafic and ultramafic rocks are not considered good fractured-bedrock aquifers.

Surficial and Alluvial Aquifers

Although investigating alluvial aquifers was not within the scope of this project, the presence of permeable alluvial materials, as discussed earlier, is important in the site selection of fractured crystalline bedrock aquifers.

Part of our investigative scheme, therefore, has necessarily been to identify and delineate areas of significant alluvial material, which in the inland crystalline province, generally occurs in wide tugs or fairly large alluvial valleys.

Also, in many cases, areas with extensive fracturing have eroded to a greater extent than surrounding areas, thereby forming lowland with significant deposits of sand and gravel. These alluvial aquifers have been evaluated more for their storage and recharge capabilities for underlying bedrock aquifers than for direct ground-water extraction.

From the literature review of the previous hydrogeological investigation done within the Dur Dur basin, it can be concluded that the lower Durdur basin has substantial groundwater potential. A properly-designed wellfield upstream of Qabri Baxar and/or Gargara, and sited perpendicular to the direction of flow should be able to supply not less than 10,000m^3/d of water of good chemical quality (EC_{25} 625µ/cm), and possibly significantly more. 10,000m^3/d constitutes just over 10% of the estimated mean daily catchment flow at Waraqadhigta. Further downstream the alluvium becomes progressively more clayey and consequently less efficient as an aquifer.

2.2 Initial Observations by the Consultant on Ecology and Landuse Patterns

2.2.1 Climate Change

Somaliland like other countries has been in a state of ecological change for many decades if not hundreds of years, and practically all the changes have been towards a reduction in the vegetation cover (Hemming, 1966).

Field evidence suggests that the most recent process of climatic change has been one of decreasing rainfall and desertification has proceeded considerably in the last 500 years. It is known that reduction in rainfall has been greatest in semi-arid regions and along east coasts and Somaliland qualifies on both counts. Butzer (1961) has constructed a map indicating the percentage rainfall decrease during the period 1911-1940 and he places most of Somaliland between 20and 25% reduction.

Whilst the underlying, long term trend in climate change is lower rainfall amounts over the watershed it is very clear that current land use patterns and increased competition between the resource needs of herders and those of farmers (often the same people) is compounding the effect of the underlying climatalogical changes (see section 2.2.4) and that in turn these current changes may be having an impact of exacerbating reduced rainfall occurrence.

2.2.2 Average Rainfall incidence

Earlier work carried out during the 1940s and ‘50s gives a reasonable pattern of rainfall. This indicates a general reduction of rainfall by 20-25% from 1911 to 1940. By looking at more up to date figures we should be able to see if this trend is continuing. In any case it is likely that rainfall quantity is less than it used to be. Whilst it is not possible to derive a long-term trend over such a short period of 11 years, other data that covers the area for much longer periods of 50 years (Bonfilioni, 1992) supports the notion of this drying trend.[2]

2.2.3 Significant number of Skeletal Mountain Forms (i.e. Natural erosion processes complete)

Some of the mountains are steep rock forms where the erosion process is complete and regeneration is not feasible. All erosion processes are due to wind, water and gravity action. However for the last 20-30 years, the causes of this erosion have been accelerated by the increases in human and animal populations using the valleys resources. The detailed estimation of how much erosion is due loss of ground cover and how much of that is due to overgrazing is a very complex task. To our knowledge no extensive study has been specifically done for the Dur Dur valley on these issues. Although it is

[2] Details of the exact reference will be availed in the mid term draft presentation but all the evidence from the International Panel on Climate change-details will be given- are of reducing rainfall trends in the Horn of Africa over the last 40 years that increasingly falls below the long-term average for the region.

possible to provide a general assessment based on such tools for example, as the general soil loss equation and studies done elsewhere (we can seek assistance from FAO Land Cover on this). The study will seek to investigate these to give a general idea of what is likely to be the situation but a detailed assessment is beyond the capacity of this consultancy to undertake.

2.2.4 Most useable/ productive land is suitable for extensive livestock raising and natural fauna and flora.[3]

There are a number of areas, though small in area, suitable for rain fed and/ or irrigated crop production (horticultural and fruit production). It will be part of the consultancies task to define the aerial extent of these. However these are the most critical sites for the sustainability of the livestock production system. The pastoral system relies on access to three kinds of land area. Wet season grazing, dry season grazing and drought period reserve areas. The best land for crop production lie in the dry season and drought reserve areas of the pastoralists. Making these areas unavailable to pastoralists is placing serious stresses on the inter-season and inter-annual management of the pastoral production system and presently is forcing herders to graze/ browse more marginal areas on steeper slopes. This has the effect of accelerating soil erosion on the steep slopes and on open grazing land. Livestock Herds may have diminished in size over the last 30 years and particularly in the last 5 years or so. There are significantly fewer cattle because of the reduced availability of suitable grasses; there are fewer camels; numerically fewer sheep and goats. Proportionally herd composition has changed in favour of the number of goats and in other similar areas a steep increase in goat populations indicates a move towards rapid removal of vegetation and increased erosion rates. If there are no changes in management practice and control of natural resources it is foreseeable that the total productive capacity of the watershed will be significantly lower in the next twenty years than they are at present and that human and animal populations projected above will not be realised. The principal features of the watershed then would be characterised by increased poverty and serious conflict as different groups seek to survive on a diminishing resource base. To conclude whilst most erosion is naturally induced increased erosion is taking place in the upper catchment and in the riverine Togga's is increasingly due to the activities of local farmers and NGOs.

[3] It means we are dividing land up into different primary categories: i) land that is suitable for crop production, ii) land that can better be used for extensive livestock herding and iii) land that is best reserved as flora and fauna habitat. (category three means land that is essential to retain for long term biodiversity purposes for both plant and animal species.

3. PREPARATION ACTIVITIES

3.1 Anticipated Project Outputs

Based on TOR and the above mentioned observations, the following outputs will be provided:

The Integrated Water Resource Management Plan will comprise:

- Quantity and quality of the water resources, including ground-water (survey of the available natural resources)
- Land-use pattern
- Actual consumption and future needs for water (irrigation, drinking and household water, livestock, wildlife)
- Areas of intervention for irrigation farming, soil conservation and measures to protect the vegetation
- Sites of actual or potential conflicts about natural resources.

The Contractor will give an elaborate Integrated Water Resource Management Plan (IWRMP) for the Dur Dur watershed, Awadal Region, Somaliland. The IWRMP will be developed in a participatory manner with land-users, administrations at all levels including the Ministries of Agriculture, Water and Planning, Ministry of Environment and Pastoral development, as well as other stakeholders.

In a first phase, a Water Resources Assessment Survey will be carried out. Results will be presented in a comprehensive document, providing all background data, and with thematic maps on an appropriate scale (e.g. 1:60,000). This general assessment study considers the following aspects:

- Significant participation of the local community in all steps of plan development
- Water quantity and water quality (natural and man-induced contamination of surface and groundwater).
- Gender aspects (the traditional role of women being the providers of water are significant and as such women should have an important voice in the decision making process for water supplies in the village).
- Environmental aspects of further water development in the area
- Technical viability of proposed systems
- Analysis of investment costs.

In a second phase, village Water supply Planning Surveys will be conducted. These surveys will include detailed studies at community level to determine what the best possible options for water supply are (considering the needs of farmers and the needs of those still involved in nomadic livestock production in order to reduce Natural Resources Management based conflicts).

The results will be analysed and presented in a technical report (Community Water Supply Planning Document) covering all aspects and including all technical data for each village. The accompanying volume including all the maps will be “Community Water Supply Planning Atlas. It will also include the technical description of the selected options, as well as a standard design for the different types of water points and participatory proposals as to how work will be carried out.

The Community Water Supply Planning will contain the following elements:

- The General Map of the area indicating important features of the natural resources base
- Mapping that describes the pattern of land use and the definition of different community areas
- An analysis of land use practices and the level and causes of natural resources based conflicts.
- Maps indicating the water resources and the centre of demand
- A Map with existing and planned water points (scale 1:20,000)
- Summary of planning and costing in a planning sheet

- Site sketches at a much larger scale, showing the precise location of the selected water points
- General technical specifications for the works to be done, i.e. standard design and bills of quantities
- An outline Log Frame Analysis of how future work might be carried out.

3.2 Fieldwork Approach

Detailed field study has been divided into two phases. Phase one shall comprise of Detailed Water Resources Assessment study while Phase II will involve Water Supply Planning Surveys.

The Consultant proposes to spend a maximum of 6 weeks during the detailed water resources assessment investigations. This will involve geophysical investigations, condition assessment of the existing water sources, hydrological analyses, setting up of meteorological stations, GIS mapping,. GSK will split the Consultants into two teams. The first team will be headed by John Fox (Landuse Systems Analysis, Irrigation and Soil Conservation Team, Water Supply Planning Surveys) and the Second Team will be headed by Vincent Okello (Water Resources Assessment Team). In that respect therefore, two field assistants will be availed to the teams should it happen that they will be working simultaneously at different parts of the project area.

For ease of execution, the Water Resources Assessment Team will conduct their surveys as proposed below. It should be noted that this schedule is tentative and amendments may be made dependent on the site specific conditions for each of the sites. A total of 13 sites shall be investigated. However, due to logistical preferences, the sites have been classified into 5 groups of which time has been allocated for field investigations as summarised in the table below.

Group	Sites	Time Input (Weeks)
1	Baki and Ruqi	1.5
2	Old Baki, Borama, Dilla	1
3	Heego, Adaad, Bown, Halimale	1
4	Harmata, Horey	1
5	Gargara, Garbaraho	1.5

Table 3.1: Time Input for Water Resources Assessment Study[4]

After the Water Resources Assessment team have successfully completed their investigations and carried out preliminary analysis of the existing and potential water sources within the Dur Dur water shed, the second phase of this study will commence immediately. The results of the water resources assessment team shall be very critical for the landuse systems analysis, soil conservation studies, and especially more so for the Water Supply and development surveys for the study area. In this regard, the following time input for the second phase headed by John Fox is summarised below. It should be noted again that the table below is subject to change depend on the site specific conditions. (For more detailed time schedule chart please refer to Appendix 1).

[4] The Water Resources Assessment Study Fieldwork was completed by the time this Final Version of the Inception Study was being prepared.

Specific Activities	Timing	Balance
Total Input	2.8 months	84 Days
Field Reconnaissance	9 days completed	9
		75 balance
Activity 1	Detailed study of Qabre Behar/ Gargara	12 days
Activity 2	Detailed Study of Hermata sub Catchment. District Dialogue/ Planning workshop- Baki District Dialogue/ Planning workshop- Baki	12 Days
Activity 3	In depth Review of upper Catchment from Bonn – Borama-Dilla Discussion with leaders and Agencies working in the upper catchment Mid Term Report	12 days
Activity 4	Mapping/ GIS work	20 days
Activity 5	Final Planning and integration of findings.	19 days
Total of remaining Days		**75 days**

Table 3.2: Time Input for Water Supply Surveys and Development Study

Notes:

- Needs 3 return flights
- The planning workshops will include Training elements for both the Local Authorities and GAA staff. GAA staff will be involved as facilitators in planning and implementing each workshop.
- Not clear at present how many days will be required for mapping and planning.

3.3 Planning Approach

3.3.1 NRM Systems Approach

(- Natural System, Users System and Geopolitical System)

A Natural Resource Management Approach will be used in which three overlapping elements will be researched and analysed with respect to the priority aspects that are affecting the Dur-Dur watershed. These elements are the Natural System, the User System and the Geo-Political System

3.3.2 The Natural System

Somaliland like other countries has been in a state of ecological change for many decades if not hundreds of years, and practically all the changes have been towards a reduction in the vegetation cover (Hemming, 1966).

Field evidence suggests that the most recent process of climatic change has been one of decreasing rainfall and desertification has proceeded considerably in the last 500 years. It is known that reduction in rainfall has been greatest in semi-arid regions and along east coasts and Somaliland qualifies on both counts. Butzer (1961) has constructed a map indicating the percentage rainfall

decrease during the period 1911-1940 and he places most of Somaliland between 20 and 25% reduction.

The recent process of drying-out of the climate, together with over-grazing and concomitant erosion, has greatly reduced the forest cover in Somaliland.

Figure 3.1.below shows the rainfall map of Somaliland (Griffiths and Hemming, 1963).

In Hemming.

Vegetation Change

GAA commissioned an environmental study in 2002 (Community Based Rehabilitation of Wadi Management in Baki District, Awdal Region, Somaliland, Klughardt and Killeh, January 2002). This study focussed on the 800 km^2 (total catchment area is 3,600 km^2) of the GAA project area including Horey, Hamarta Ruqi, Baki, Heego and Adaad. This covers much of the middle catchment area and was carried out from August to November 2001.

They used a land degradation categorisation proposed by Bally and Melville (1973)[5] that distinguishes 4 stages of degradation and developed a framework of 10 characteristic habitat types for the area. **Seven out of the 10 characteristic types were assessed as grade 2-**

Where most grass is eaten off, shrubs are thinned out and much of the remaining grasses and herbs are found in the shelter of the bushes. Felling of trees for fuel and lopping for fodder contribute to the degradation. Trampling by sheep, goats and cattle loosens the soil, which is blown away by the wind or washed away by water. **Three out of 10 habitat types are classified as grade 3 –**

Where the remaining grasses have been killed of and in many areas, unpalatable Aloes colonise the bare ground among scattered bushes. These three habitat types include the Salvadora-Dobera- Acacia transition scrub of the Waraabley Valley in Horey area, the Accacia Bussei open woodland of Biyo-Humo in Horay area and the Acacia Bussei open woodland around Marodi-Ka-Dhac (elephant pass). All three are pastoral areas.

This assessment compares with Hemming's comments made 15 years earlier.

"The present day vegetation of Somaliland shows a great variety of effects of the heavy hand of man and his [live] stock. The main mode of action of overgrazing is the actual eating of the plants to such an extent that they either disappear or die. The young seedlings are also eaten, and the species are therefore unable to replace themselves. During the dry season, when the low plants offer poor grazing[6], it is common for Somali graziers to lop off large branches of *Acacia* trees, so that the goats and sheep may eat the leaves and fruit. Thus several years' growth may provide half an hours grazing for a few goats.

In addition to the direct feeding effects of livestock upon the vegetation, grazing herds cause erosion by loosening the soil and exposing to wind. Livestock also make distinct routes through the bush and these tracks of pulverised soil devoid of vegetation act as avenues along which water erosion begins. This disturbance of soil also causes the death of plants by exposing their roots to desiccation. In addition to branches being lopped off, the lateral roots are often dug up and used in the construction of portable houses and the bark is removed for rope making. As overgrazing continues, annual grasses and other low plants replace much of the perennial cover, but bare ground becomes increasingly more common. Bare ground, with the exception of loose sandy soil, generally absorbs less rainwater in the absence of vegetation than it would with a good vegetation cover. Thus the amount of water entering the soil and becoming available to plants is reduced and surface –rooted plants, notably *Acacia bussei*, die, and soil erosion becomes steadily more serious".

It is clear that the processes being observed by Hemming way are also being reported on in 2001 at a more advanced stage of continuing degradation.

[5] Report on the vegetation of the Somali Democratic Republic with recommendations for its restoration and conservation, Bally and Melville, 1973

[6] Note that Hemming makes no distinction between grazing (grasses) and browsing (trees) as we do today.

Water Resources[7]

The lower Durdur basin has substantial groundwater potential: a properly-designed wellfield upstream of Qabri Baxar and/or Gargara, and sited perpendicular to the direction of flow should be able to supply not less than 10,000m^3/d of water of good chemical quality (EC_{25} 625µ/cm), and possibly significantly more. 10,000m^3/d constitutes just over 10% of the estimated mean daily catchment flow at Waraqadhigta. Further downstream the alluvium becomes progressively more clayey and consequently less efficient as an aquifer.

3.3.3 The User System

The Dur-Dur area is part of an extensive pastoral and agro-pastoral network within which mobility is the key to the survival of all the clans and sub clans involved.

Movement is distinguished between migrations to areas where it has rained (and therefore fresh grazing and browse available) defined as wet season grazing areas; migrations from wet season areas when the grazing and available water is used up, to dry season grazing areas that provide secure water and grazing areas but not enough to allow the herds to remain all year round and; drought grazing reserves that are used when rain completely fails sometimes for two to three year periods.

The inhabitants of the Dur-Dur watershed are and have been for a long time the three sub-clans of the Gadabursi. The Gadabursi don't only live in the valley there are significant numbers living around the Harar area of Somali Region in Ethiopia. These relatives who are also agro-pastoralists have rights to seasonally pass through the watershed on their way to communal grazing lands in the coastal area. To the west (outside of the watershed) Issa Somalis from Shinile Zone in Somali Region, Ethiopia and from Djibouti also make a similar seasonal migration to the coast and back. To the east of the watershed Ishaaq clans move in a similar fashion to and from the coastal plain all herders have rights to graze and browse their animals.

Inside the watershed only Gaabursi groups dwell and migrate to the Qabre Baxar/ Gaargara area where there is sufficient water and browse/ grazing and sometimes to the coast when necessary.

Along the coastal area there are distinct communities of Gadabursi, Issa and Ishaq whose home range is along the coast. A specific feature of the Lughaye area is the large populations that are settled throughout the year along the coastal strip. Camels are grazed on the *Suaeda* salt bush[8] within short distances from the sea and many families have never moved more than 20 km away from their hamlets. The presence of a large population on the coastal plains of Lughaya excludes other pastoralists from grazing in the area during the dry season. However near Lughaya in land is the Kalawle borehole, the Garissa and the Gaargara areas which have permanent water and good grazing. So the Gaargara area acts as a dry season grazing area for all these groups.

Until thirty years ago transhumant pastoralism was the only livelihood system in the watershed then in the Ruqi area began to fence of land and to practice rain fed crop production. This led to other families doing the same thing and as this continued some farmers began to divert some of the river flow to farmland and so improved the productivity of the farms. Many of these families produce crops whilst continuing to herd livestock and so have become transhumant agro-pastoralists. However, there appears insufficient land that is suitable either for rain fed or for irrigated crop production whilst increased numbers of families are farming or farming/ herding others are dropping out of pastoral production without being able to take up farming. These groups are now trying to survive by manufacturing charcoal and selling it particularly in Borama. Mentioning Borama raises the whole question of population growth. On the rim of the watershed denoted by Bonn, Borama, Dilla and partly Gebely there are significant human urban centres growing up. Whilst there are a variety of non-land based jobs available in these centres, they represent markets for the produce and trade of watershed dwellers.

[7] Taken from GSK investigation team Report, March 2005

[8] *Sueada* shrubland occurs in a narrow strip all along the coast line from Loyada to Berbera on saline soils.

There are in fact four livelihood strategies operating in the watershed –agro-pastoralism, rain fed/ irrigated crop production, charcoal production and trading. These are often not distinct, with members of the same family being involved to some extent in each of these strategies. No studies have been done to our knowledge but there are probably a few wealth owners based in the towns that own significant numbers of livestock, land for farming, trading in charcoal and other goods. Many others will earn a living by working for these few or trading with them. Although GAA has done some good work using PRA tools in their project area but this is all limited to crop production and doesn't involve the other strategies. In Somaliland it is assumed that everyone is "poor" but clearly this is not the case. No wealth ranking exercises have been carried out. The most evident sign of poverty is engagement in charcoal production. A discussion held by the Medical Assistant based in Baki suggests there is malnutrition in the area and this tends to be in poor pastoralist families.

Human and livestock populations

Human population has increased significantly in the last thirty years. However there is apparently no definitive population data for the watershed (or indeed for Somaliland). In the absence of this Borama, Dila and Bonn are the largest towns that are situated on the divide of the Watershed. Borama has a population of some 150,000-200,000; Bonn perhaps 5,000; Dilla 6,000-7,000. In the Watershed Loqi/ ceel Berdale area may have up to 4,000 People, Baki some 2,000-3,000; Gabre Behar/ Gargare area maybe 4,000. Lughya 3,000. Making a total of 174,000-224,000. Given the need to plan for the future we could use a figure of 200,000 and apply a population growth Rate of 3.1%[9] (in 20 years equals 162%) Therefore a projected population would be 324,000 divided as 55% pastoral communities and 45% Urban dwellers (Somaliland in Figures) this would be 146,000 in urban centres and 178,000 pastoralists. There is a problem with this calculation. Pastoral communities generally have lower growth rates typically 2.1% whereas the urban growth rate might well be close to the official 3.1%. In any case there is no way that the watershed can sustain such numbers of people who are making a living from land/ water based livelihoods. Pastoral livelihoods are based on livestock numbers that are in turn based on rainfall/ vegetation parameters and there is some evidence that livestock numbers are falling so probably the pastoral community will not raise much above 100,000. This would give a total figure of about 250,000 by 2020.

A study carried out by IUCN reported in May 2000[10] involved an aerial survey of the coastal plain below the main watershed (carried out in November 1999). The livestock numbers counted are listed below:

Species	Population Estimate	Density (No./ km^2)	Species as % of Whole	Biomass as % of Whole
Camels	16,785	1.79	4.4	53.0
Sheep and Goats	358,201	38.2	94.5	40.2
Cattle	3,376	0.36	0.8	6.6
Donkeys	563	0.06	0.1	0.24
Total	**378,925**	**40.41**	**100**	**100**

Table 3.3 Livestock populations at the Coastal Plain

Remembering that these figures relate to the whole coastal area (about 10,000 km^2), the numbers coming from and returning to Dur-Dur catchment must be some smaller percentage of this total. If the density/ km^2 is assumed to be the same in the upper watershed compared with the coastal plain[11] then the middle and upper catchment (3,600km^2) might have as many as 144,360 of all species (or 6,400 camels, 137,520 sheep and goats and 1,300 cattle). It is pretty obvious that the number of cattle

[9] Somaliland in Figures page 5. MP&C, Republic of Somaliland, Hargeisa

[10] An Ecological Assessment of the Coastal Plains of North Western Somalia (Somaliland, Sommerlatte and Abdi Umar, May 2000.

[11] This may not be a fair assumption and ideally it would be necessary to carry out a livestock numbers survey to test the validity of the assumption.

has seriously fallen over recent years. A fact confirmed by discussion with herders who say that the total number of animals has fallen and that the number of cattle is much fewer than earlier whilst the number of goats relatively higher. The IUCN report identifies sheep and goats as one group but within the group of small-stock goat numbers are increasing relative to sheep. The implications of this are:

i. the amount of grazing in the watershed is no longer sufficient to support cattle therefore there are very few
ii. the number of goats, though fewer in total numbers are the dominant species (as they can access steeper slopes and browse vegetation in difficult places to extinction and
iii. the population density of all animals (40/ km^2) is considerably higher than the sustainable capacity of a watershed with such steep slopes and high erodibility. This more than anything else illustrates the unsustainability of current livelihood practices.

The long-term effect of overgrazing/ browsing would have occurred irrespective of the introduction of crop agriculture along the Togga beds. However, the introduction of rain fed crop production on the ridge area of the watershed (around Bonn, Borama, Dilla and Gabiley) and the more recent introduction of irrigated crop production in the middle and lower togga areas is:

i. accelerating the erosion processes and destroying potential farming land due to poor soil and water conservation management
ii. ii) Marginalizing herders from vital riverine dry season grazing/ browsing areas and forcing them to utilise steeper and more vulnerable slopes more extensively.

In conclusion, the use of arable/ irrigable land to grow cash crops compared with transhumant pastoralism is a positive progression that allows families the possibilities to improve their livelihoods instead of a declining subsistence existence based on livestock as crops (primary producers) generate more kilocalories per unit of land than livestock (secondary producers) do. Nevertheless in the Dur-Dur situation continued expansion of crop agriculture is forcing livestock to depend more and more on vulnerable slopes that will continue to remove both grasses and trees, increasing soil loss, accelerating soil erosion through the toggas and accelerating rainfall run-off that increases flooding in the farming areas. This in turn is removing significant amounts of fertile farmland soil reducing the areas suitable for farming. Economically this will drive more people into the charcoal business. This is a circular, no-win situation where all the livelihood strategies in the watershed are unsustainable and future generations will more likely seek a living in the rapidly growing towns elsewhere.

3.3.4 Geo-political System

On 18th May 1991, at a meeting in the town of Buraco, after 10 years of fighting against the military regime of Siyad Barre, the Somali National Movement (SNM) declared self-independence for the former northern regions of the collapsed Democratic Republic of Somalia.

At a subsequent meeting (January-May 1993) held in Borama, the SNM agreed to give power to civilian politicians. This laid the foundations of the new constitutional order in Somaliland. A two-chamber parliament was formed. The “upper house” called the “Gurti” was created and includes elders, Sheikhs and Sultans. The Gurti is responsible for keeping the peace between the clans. It also passes legislation, and authorises decisions from the lower house. The Lower House, composed of about 74 representatives of various Somaliland sub-clans passes legislation. The Borama conference also elected an executive President. The President chooses his cabinet, which, consists of technical Ministers who run ministries. The administrative divisions are regions called “Gobol” and Districts called “Degmo”.[12] There are six regions in Somaliland namely Togdheer,Sahil, Sanag, Sool, Galbeed and Awadal.

[12] Ibid

State Organisations
With respect to the Dur-Dur Planning process the Ministry of Planning and Cooperation (MP&C), the Ministry of Agriculture (MoA), the Ministry of Water and Mineral Resources (MoW&MR) and the Ministry of Rural Development and Pastoralists (MRD&P) are the main agencies of government concerned.

The Ministry of Agriculture has recently updated its third Strategic Action Plan (2004-2006) where it lays out the main strategic themes for the agriculture sector. These include:

1. Natural Resource Management
2. Technical Assistance for Institutional Capacity Building
3. Agricultural Training and Extension
4. Human Resource Development
5. Agricultural Research and Agricultural Resource Database Development.
6. Setting up an information centre
7. Farm produce marketing
8. Rural Finance.

Local Authorities
Three Districts in Awadal Region- Borama, Baki and Lughaya encompass the Dur-Dur watershed. Each has an elected council with a Mayor and a District Development Committee. These are elected bodies but are new to their role as local authorities and need considerable assistance in developing their perceptions and organisation capabilities. This will be particularly important in the development of an IWRMP.

International organisations
There are a number of organisations working with the government in agricultural development. The most important ones are listed below.

Organisation	Activities	Area of Operation
International		
IFAD 2001-2005	Rural Finance, Extension, Training, Marketing Feasibility Study, Tech. Support to MoA, Capacity building, feeder roads and Natural resource Management.	Gebilay area (Hargeisa and Awdal Region. (partly in Dur-Dur Upper Watershed.
WFP 2003-2005	Natural Resource Management	Area??
Habitat	Urban planning	Hargeisa, Borama.
Amoud University	Natural Resource Management Faculty	Borama
CINS 2004-?	Natural Resource Management, extension (seed multiplication), research (on-farm storage, IPM), farm inputs, Training, Marketing	Upper Catchment
DRC 2002-2005	Extension, Natural Resource Management	Lower Catchment
GAA 2004-2006	Irrigated/ rainfed extension, training, Natural Resource Management	Middle catchment
Drysdale 1 year	Cadastral Survey, Natural Resource Management	Upper catchment
VETAID 1 year	Pastureland agro-pastoral training	Hargeisa and Awadal Regions
Local		
Red Crescent	Sub surface dams for domestic water	upper catchment
ADO	Working with CARE, NED and UNHCR on Food for work, Capacity building of farmers associations, construction of shallow wells	Awadal, Hargeisa and Sahil
ARDA	Working with CARE and VETAID	
ARRO		

Table 3.4: NGO Activities in Dur Dur Watershed

3.4 Outline of the Integrated Watershed Management Plan.

a. The watershed should be divided into three specific zones-

- The upper catchment zone-starting from Bown to Borama, Dilla and parts of Gabilay district as shown on the watershed map below.
- The middle zone that corresponds with the six community areas where GAA are working now- Ruqi, Baki, Horey, Harmata, Heego and Adaad..
- The Lower Zone including Garbo Raxo, Gargara and the coastal plain.

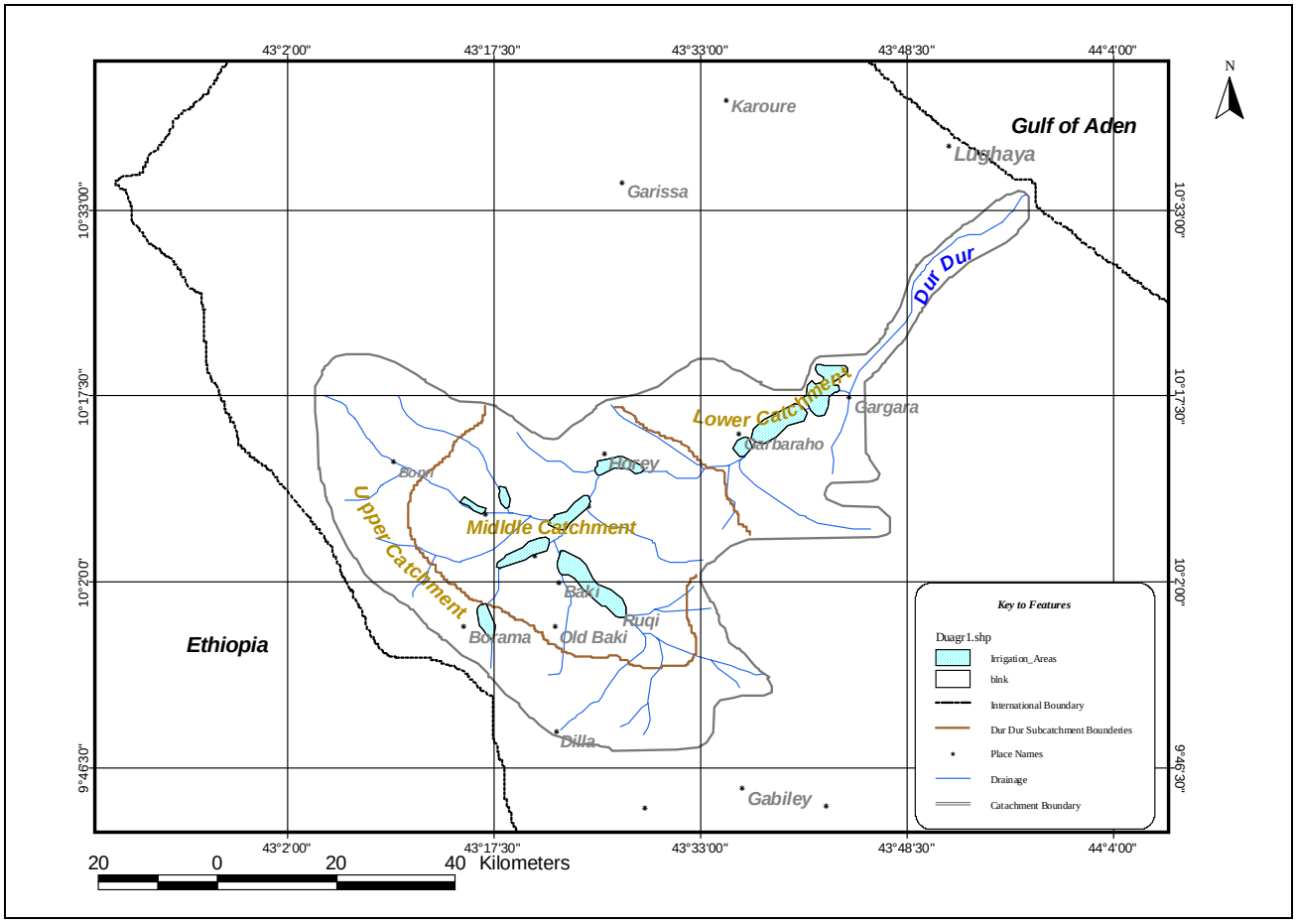


Figure 3.2: Dur Dur Catchment Zonation Map

b. Delineation of all potential arable/ irrigable land; Rangeland mapping- divided into wet season grazing areas, dry season grazing areas, and drought reserve areas,

- Potential habitat reserves for plants and wildlife;
- Potential forest reserves.
- Togga system mapping;
- Erosion mapping- worst areas, key areas (then remedial measures)
- Zonation of the valley according to land use and socio-economic practice

c. Interviews with all stakeholders involved in natural resource issues in the watershed
Formation of an "Interagency Watershed Management Forum" (IWMF), including Government Ministries, District Development Committees, University, International and Local Agencies

d. Detailed studies of most critical erosion sites- (e.g.) Il Gorey catchment, Bira Dibra Weyn, Gargara and outline design of remedial measures.

e. Participatory planning in thee zones- lower, middle and upper.
Bringing together of sub-plans at Interagency Watershed Management Forum. Discussion of sub plans and validation of Integrated Watershed Management Plan.

f. Description of basic strategies/technologies in each zone.

3.4.1 Upper Catchment Zone.

This zone can be divided into four parts:

i. the broad, farming/ wet season grazing areas that lie either side of the ridge line (often either side of the main road).
ii. the uninhabited mountainous areas surrounding Bown and between Borama and Gebilay and
iii. the upland Toga valleys that originate on the upper watershed and travel down to the middle zone
iv. Urban centres including Gebilay, Dilla, Borama Dilla and Bown.

The **broad farming/ herding wet season areas** need to have some delineation between farming and grazing areas. **The farming areas** already have some examples of on-farm soil and water conservation structures such as contour-bunds, contour stone-lines. These are thought to be constructed by IFAD, CARE/ local NGOs are well done but are not yet universal practice. There are no examples of live fencing around fields and there are no examples of tree shelter-belts or grass strips visible although close to Dilla there is a sign on the road advertising a tree nursery.

The **wet season grazing** season would need to become part of a strategy by users (from the watershed areas and perhaps from Ethiopia) within the framework and timing of wet season- dry season- emergency reserve area strategy (yet to be defined and debated).

The **Togga system** has some already eroding upper parts (e.g. the large erosion channel opening up to the south-west of the road leaving Borama that later turns across the road and down past the confluence of the two Toggas either side of Borama). Shallow wells used down stream have dried up following the development of boreholes well field that supplies Borama with domestic water. Red Crescent, in collaboration with German Red Cross have recently installed a sub-surface dam in Togga Abbasa below Bown that is a positive example of the main technology needed in these main toggas. It is clear that many plots have been already fenced in this major togga and in one case; close to the sub-surface dam one owner has cleared a sloping site with a bulldozer (sign of things to come). Sub-surface dams, check dams in minor toggas and maintenance of riverine vegetation along river banks should be the main strategy in these areas together with contour channels with multi-purpose

tree lines/ re-forestation above the future farm/ grazing areas. The main farming approach should be agro-forestry as GAA are promoting.

Urban centres. It will be necessary to make estimations of future domestic demand for the urban centres and to consider how this demand will be met and from what sources. Collaboration with Habitat might be the way to do this as these estimates might already have been made.

3.4.2 Middle Catchment Zone

The communities that GAA have focussed on during the first phase of the project and where the greatest concentration of irrigated farms represent this zone. It is also where the greatest problems of soil erosion and loss of water flows are and the main centre of charcoal production The structure of the main watershed is broken up into a series of well defined sub-catchments including the Ruqi-Baki area, Adaad, Heego, Harmata and Horey. There is a considerable amount of work to do in this area that relates to each of these communities. Whilst it will be necessary to map each of these the best approach would be to select one of them and to implement an integrated land-use and natural resource management plan as a demonstration of how all of them can be recovered for sustainable livelihoods. This sub-plan would involve i) direct action with farmers on promoting bank protection through not cutting existing vegetation or planting multi-purpose trees, ii) direct action with herders on developing a wet season, dry season and emergency reserve areas plan that includes creating exclosures in order to regenerate overgrazed hillsides over a period of four to five years then reopening these to controlled grazing whilst closing others for regeneration. Clearly this would involve developing a set of bye-laws that all potential users would agree to abide by and a system of monitoring and applying sanctions when these are contravened iii) when it is agreed which sub-catchment should act as the pilot an erosion control plan can be developed that includes check dams on minor togas, contour bunds that carry water along the contour and is able to infiltrate into the soil and multi-purpose trees that would be used for fodder, construction and mulch. These treatments can be supplemented by grass reseeding along and below the same contours. Lower down the sub-catchment similar treatments might be tried including establishing irrigated fodder production on farms. It may be possible to establish a crop rotation system on some farms especially those that are owned by herding families. In the main Togga's where soil eroded from higher up the main watershed has been washed down, and then scoured by flash floods the use of sand storage dams should be introduced (see Appendix 5). In the model catchment a series of these should be planed and implemented. Where there are steep banks in danger of being undercut by floods gabion walls need to be put in place similar to the one installed with support from IFAD in Bira Togga at Baki. It is suggested that the Il Gorey sub catchment might be a good candidate for the model in the middle catchment. In GAAs work with irrigated farming communities it may also be an idea to introduce stall-fed dairy goat production. This would involve using a few goats for milk production and manure that is integrated into the farming system with the intention of improving food security and encouraging the minimisation of free- range goats on the slopes.

3.4.3 Lower Catchment Zone

The Lower catchment starting from Wobley mountain range down through Gaarbo Raaxo, Gargara, and Lughaya involves two major Toggas joining the Dur-Dur channel at Gargara. Here there is a considerable amount of fertile soil that has been washed down from the upper and middle zones and is an important area for both the farmers and the agro-pastoralists from the upper and middle zone, from the coast and from elsewhere. The hydro-geological studies are confirming that there is a considerable amount of stored water in the area as well. Exploitation of this water without complementary development of sound natural resource management would likely lead to the destruction of the area and the loss of the soil and grazing/ browsing vegetation that it can produce. It is suggested that this area be a second model area that focuses on soil and water conservation measures whilst assisting both farmers and herders to develop crop and fodder production in an intensive way. The measures used in this area would to a large extent follow the same pattern as the middle zone but where feasible introduce macro-catchment fodder farming, alluvial fan water spreading, flood water diversion and micro-catchments for the regeneration of natural vegetation and

intensive fodder production. Likely these areas might become group farms where the rights to access are clearly defined.

3.5 GAA and its Activities

The current GAA project recognises the risks of continued expansion of irrigated farming in the watershed. However, they should take into consideration the inclusion of strong soil and water conservation measures and the development and strengthening of local institutions that understand the dynamics.

3.6 Work Permits/Visa

The GAA is organizing for (multiple) entry Visas for the nominated GSK staff who will be involved in the field investigations. These will include: Dirk van Enk, John E. Fox, Vincent Okello and Edwin Magati. Multiple entry visas might not always be available, however GAA has processes the visas for John, Vincent and Edwin.

3.7 Staffing Schedule

The work programme and staffing schedule needed to complete the project in a logical order, remains as outlined in our proposal. Time allocations for the staff shall remain the same as agreed on in the Contract.

3.8 Meetings with Relevant Authorities

John Fox will meet with the relevant stakeholders in the project area which include but not limited to the following to discuss the Integrated Water Resource Management Planning (IWRMP):

- Ministries of Agriculture
- Ministries of Water,
- Ministries of Planning
- Village Elders
- Ministry of Environment and Pastoral Development

However as earlier discussed, it should be noted clearly that GAA will participate in planning and facilitate the Workshop. GSK will not be responsible for funding for such Workshops, this is clearly stipulated in the Contract Agreement.

3.9 Communications

In general, communications with the Client (GAA) should be through GAA Area/Project Manager or his substitutes appointed with approval of the Client. Invoices should be submitted direct to the Client's Nairobi office, with copy and preferably with a copy to GAA Somaliland.

3.10 Office Accommodation and Transport

The Contractor will organize the work out of a field office in the Dur Dur area made available by GAA, with its principal office in Nairobi mainly for backstopping. GAA will arrange for transportation within Somaliland. Moreover, basic accommodation will be provided by GAA in Baki

and (Gargara) the Cabibahar area. In Hargeisa and Borama, accommodation will be paid by the Contractor.

3.11 Maps and Satellite Images

During the data inventory and inception study and visit, the Consultant obtained all relevant maps for the study area. The following maps have been obtained from the UNDP Somalia office:

1. NC 38-63
2. NC 38-64
3. NC 38-65
4. NC 38-66
5. NC 38-52
6. NC 38-51
7. NC 38-39
8. NC 38-40
9. NC 38-38
10. NC 38-50
11. NC 38-62
12. NC 38-73
13. NC 38-75
14. NC 38-76
15. NC 38-77
16. NC 38-78
17. NC 38-90
18. NC 38-89
19. NC 38-87

The Consultant has also obtained satellite images covering Dur Dur Catchment from UNDP Somalia office and Regional Centre for Resource Mapping and Development, Nairobi:

- P165R053 and P166R053 (01/02/1986 and 09/03/1985 respectively)
- Data and Information Management Unit, Environmental CD 3
- Data and Information Management Unit, Environmental CD 1

The Consultant also has managed to obtain FAO Water Sources Information Software and Manuals from Somalia Water and Land Information Management Project (SWALIM).

Image processing has already been performed on the satellite scenes. Images covering the Dur Dur Catchment have been produced. The images were edge enhanced in order to perform lineament interpretation and identify open faults that are likely to be associated with fractured aquifer systems. The consultant shall also use the satellite images in planning field work activities as well as interpretation and mapping of the soils, geology and landuse/landcover of the study areas.

4. WORK PROGRAMME

4.1 Preparation

The team has prepared the detailed planning for fieldwork and subsequent preliminary data evaluation which has been partly documented in this inception report. See the Time Schedule and attached.

4.2 Outline Planning

During the months of January and February the team concentrated on a review of available information and preparation of fieldwork. The latter comprise the preparation of a detailed work schedule in close co-ordination with the GAA management team. Fieldwork started on 27th February 2005 and is expected to end early May for Phase I and early July for Phase II. Data analysis and reporting shall be done between months of May and July before presentation of the Mid-draft report.

4.3 Organizational Set-Up

The project consists of two major teams which will be working simultaneously (i.e. Water Resources Assessment Team and Landuse, Soil Conservation and Social Political Systems Assessment, Water Supply Planning and Development Team). The first task the (Inception Study) has been carried out by the Senior Rural Water Engineer (Mr. John Fox and two Hydrogeologists, V. Okello and E. Magati. The study took two weeks. The Water Resources Assessment Team shall comprise of Mr. Vincent Okello (Hydrogeologist 1) and Mr. Edwin Magati (Hydrogeologist 2), who will be in the project area for one and half months. They will be closely supervised and supported by the Principal Consultant, Drs. Dirk van Enk. The Landuse systems, Soil Conservation and Socio-political Systems Assessment Team shall comprise of Mr. John Fox (Senior Rural Water Engineer).

Summary of Water Resources Assessment Team and Landuse systems, Soil Conservation and Socio-political Systems Assessment Teams with their Designation is given as follows:

Groundwater Team	**Designation**
Van Enk	Principal Consultant/ Senior Hydrogeologist
John Fox	Snr. Rural Water Engineer (Intermedia)
Vincent Okello	Hydrogeologist 1/GIS Expert (GSK)
Edwin Magati	Hydrogeologist 2/Geophysicist (GSK)

4.4 Time Schedule

The time schedule indicating time allocations and periods of assignment to the project is presented in the Appendix 1.

4.5 Transport

German Agro Action will provide both air and local transport to the Contractor (GSK) during the project period. However, German Agro Action may generally not be able to provide air transport. If ECHO flights resume its activities GAA will facilitate access to this service.

4.6 Equipment

The Consultant will have available the following equipment for the Survey:

Hydro(geo)logical equipment:
- 1 EC meters,
- 2 compasses,
- 1 dippers: 150 m
- 1 Valeport current meter for streamflow measurements

(total value US $ 2,000)

Geophysical Equipment:
- 1 set of Electric Resistivity Equipment ABEM SAS 1000 Terrameter with accessories;
- Geophysical interpretation software;

(total value US $ 15,000)

Field Office Equipment:
- 2 Notebook computers (Toshiba Pentium III and Pentium IV or equivalent),
- 1 HP Deskjet 845C portable colour printer

GIS Equipment
- 2 GPS Germin positioning system.
- 1 A3 Digitizing Table
- 1 A4 Scanner
- Arc View GIS software
- ILWIS 3.2 Academic software
- Map Info 5.5 Professional.

If required, the Consultant can mobilise the following additional equipment:
- 1 ABEM Wadi VLF equipment;
- 1 Geometrics ES 1225 F Seismograph, 12-channel, with spread cables, geophones, seismic sledge-hammer, and all other required accessories.

APPENDIX 1

TIME SCHEDULE & FINANCIAL PROPOSAL FOR IWRMP INVESTIGATIONS

APPENDIX 2

TOPO MAPS FOR THE PROJECT AREA

APPENDIX 3

CURRICULA VITARIUM OF NOMINATED STAFF

APPENDIX 4

TIME SCHEDULE OF SERVICES AND INPUT

APPENDIX 5

CASE STUDIES FOR RAINWATER CATCHMENT TECHNIQUES

Rainwater Harvesting/ Runoff Catchment Technologies

1 Introduction

Throughout the Darfur ecosystem there are increasingly no clear delineations between one category of user livelihoods and another only a "merged" variation of lifestyles over the whole area all of which are being dominated by increasingly harsh environmental conditions. The best way to explain this is to quote from an excellent Baseline Study commissioned by Oxfam In 1997[13]

'The study area falls within the marginal part if the Sahelian zone, being subjected over the last few years to serious changes in the natural environment. This has involved- a decline in tree cover, disappearance of grass species and lack of pasture, shifting wind-blown sands, loss if grazing and a drop in agricultural activity.[14]. This has had the effect of putting tramhumant pastoralists [and dryland farmers] *under increasing pressures, with the northern limits if the grazing zone being pushed southwards. As a consequence, in dry years, herds do not reach the normal rainy season pastures in the north and are being forced to stay well to the south.On the other hand, the sedentary population have expanded their rain fed cultivation; besides increasing their areas under private pasture enclosures (Zaraib EI-Hawal, hence taking up lands that would otherwise been available to transhumant grazing. As the village based production system is taking place in the same area throughout the year, this has added to the pressures if deterioration. Plants are not given sufficient time to regenerate and develop seeds for the following year particularly in the periphery if settlements, completing the disappearing if edible grasses and suppressing the establishment if trees.*))

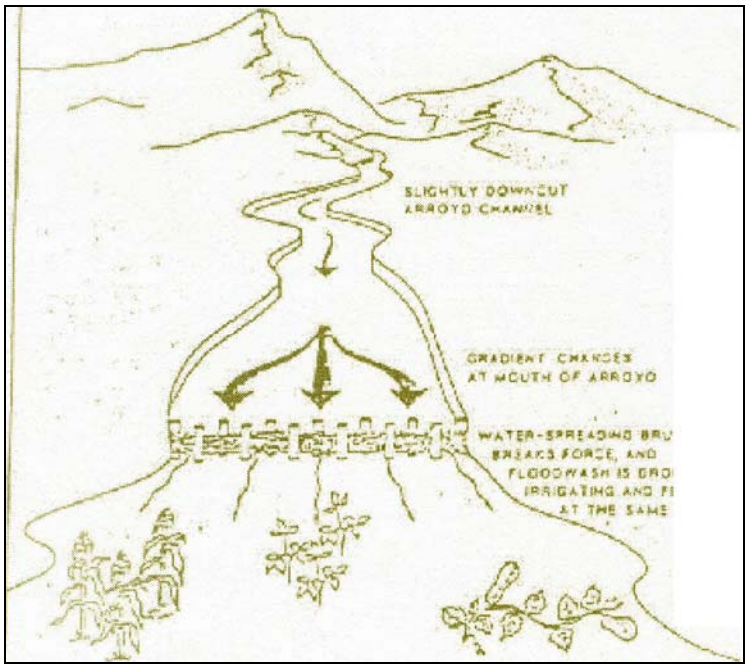
Considering this long term, "natural system-user group" interaction the present CLIP seeks to negotiate with users of competing land use systems and to introduce technologies that they can adopt themselves with a view to adapting to the changed environmental conditions in a way that reduces natural resource based conflict.
This annex illustrates some of the technologies that can be tried and implemented.

2 Alluvial Fan Water Spreading.

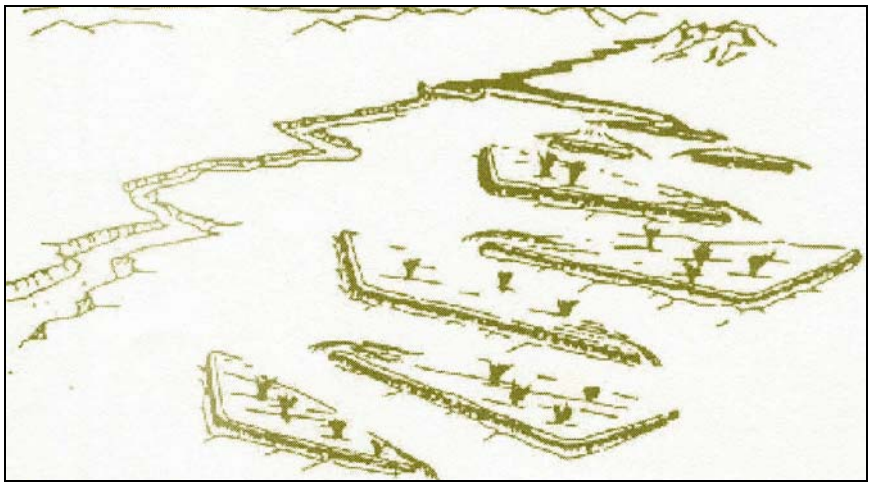
A major characteristic of the Darfur ecosystem is the presence of extensive wadi systems. These systems seasonally flood wide areas and maintain a favourable soil moisture regime for long periods after the floodwater recedes. These areas are unusually fertile as the result of clay and silt deposition by the floodwaters.

There is considerable scope for improving tree, crop and fodder productivity by using a variety of simple water storage techniques that can assist in increasing productivity per unit area and extending the area under production.
Many situations exist where the use of simple barriers can divert water (silt and clay) onto nearby land suitable for vegetative production. The following sketches illustrate the possibilities.

[13] Development Study of the Populations of Kutum (Nomadic) and Malha Local Councils, North Dafur State, M.O. El Sammani, Oxfam Dafur, 1997.
[14] According to the Report there has been a clear downward shift in mean annual rainfall from the early 1970s to present. The long-term average 1915 to 1970 was 298mm. From 1970 on this dropped to 177.1mm a drop of 40% on the previous level.



Alluvial Fan Water Spreading



Flood Water Diversion and micro-catchment basins

Rainwater spreading techniques are based on the collection of flood water from large catchment areas that are channeled and concentrated onto smaller areas to boost the soil moisture storage. The main features of such a system are: a diversion weir and ditch, a conveyance channel, contour bunds and spillway structures.

This technique is valuable for the following conditions:

- soils with a high storage capacity and a slow intake to facilitate even water distribution over the fields or growing areas.
- gentle, broad and smooth slopes free from rills and channels (as they tend to concentrate water and increase the risk of erosion.
- On alluvial or colluvial deposits at the base of ridges or escarpments.
- Alluvial fans where streams leave hilly land and flow into flatter plains.

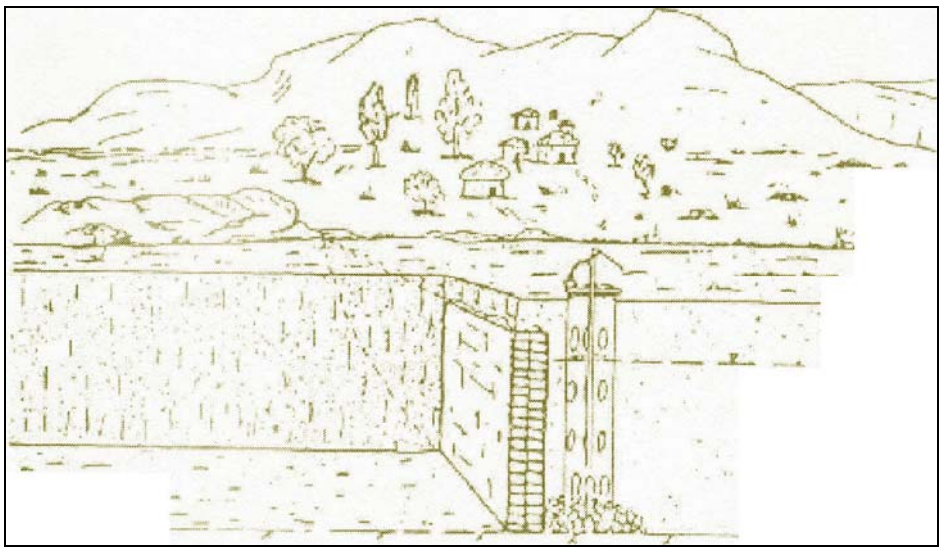
- Stream banks that are intermittently flooded naturally and,
- Where the growing period coincides with the runoff period.

3 Sub-surface Dams

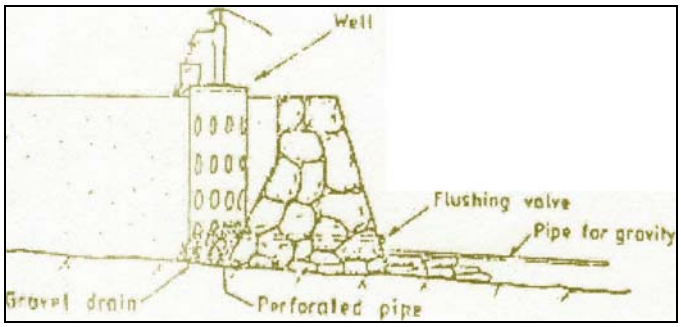
Excavation*:* Sub-surface dams are constructed by building a dam in a trench excavated across the riverbed. The excavation depth ranges from 3-6 metres and therefore human labour can be used. Since the material to be excavated is generally sandy, slope stability can become a problem. The maximum acceptable slope is 30° for sandy material.

Excavation for a sub-surface dam wall is generally done in the dry season to ensure that the water level in the aquifer is at its lowest and so reduces the need for dewatering the construction area.

Dam Construction: The dam wall can be constructed with any material so long as it creates an impermeable screen. Clay is a suitable material in places where clay is easily obtainable and for highly permeable aquifers of limited depths. Use of clay is labour-intensive but has a lower need for skilled labour when compared with stone structures. The clay should be properly compacted. Where there is a high risk of erosion damage to clay surfaces due to groundwater flow, the dam could be covered with plastic sheets.
Water Extraction*:* The sub-surface dam wall is always combined with a drain along the upstream base of the dam. The drain which consists of gravel or slotted pipe surrounded by a gravel filter is to collect and transmit water to a well or through the gravity pipe downstream areas. The well serve as the extraction point for water as shown below.



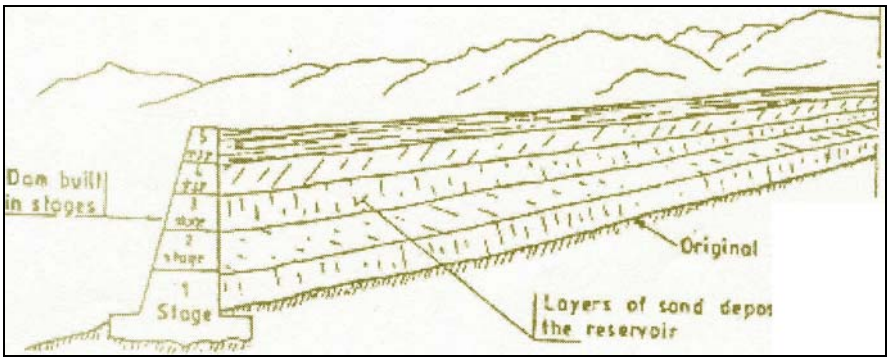
Sub-Surface Dam Construction



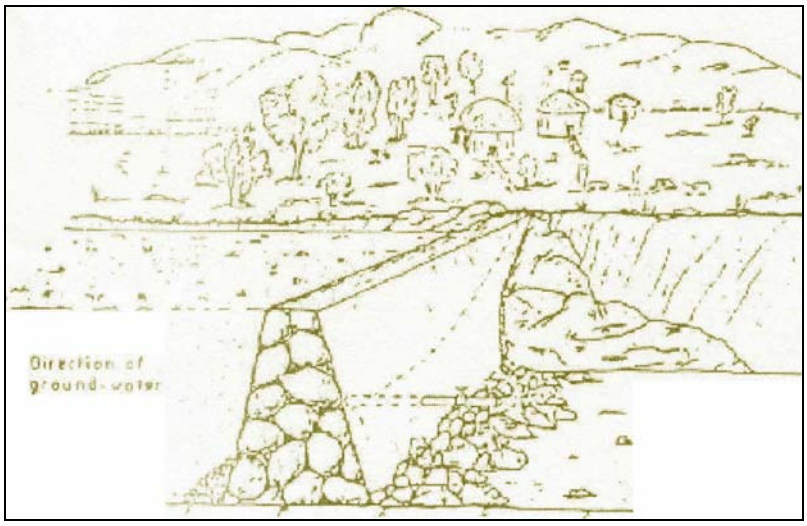
Drainage and abstraction design

4 Sand Dams

A sand dam impounds water in sediments caused to accumulate upstream of the dam wall. This is achieved by constructing a weir of suitable height across the stream or wadi bed. Course particles carried by heavy flows during the rains settle behind the sediments. Eventually the reservoir is filled with sediment. Fine particles flow with the water flowing past the dam wall. The design of a sand dam is complicated by the fact that the material to be used to store water is in the catchment area at the time of construction. The surface flow characteristics will determine the design of the dam in terms of its stability. The dam is constructed in stages; the height of each stage is limited in order to keep sufficient velocity of water so that the particles are washed out from the reservoir while the coarse particles settle. The height of each stage is determined by the expected rate of sedimentation and required flow velocity.



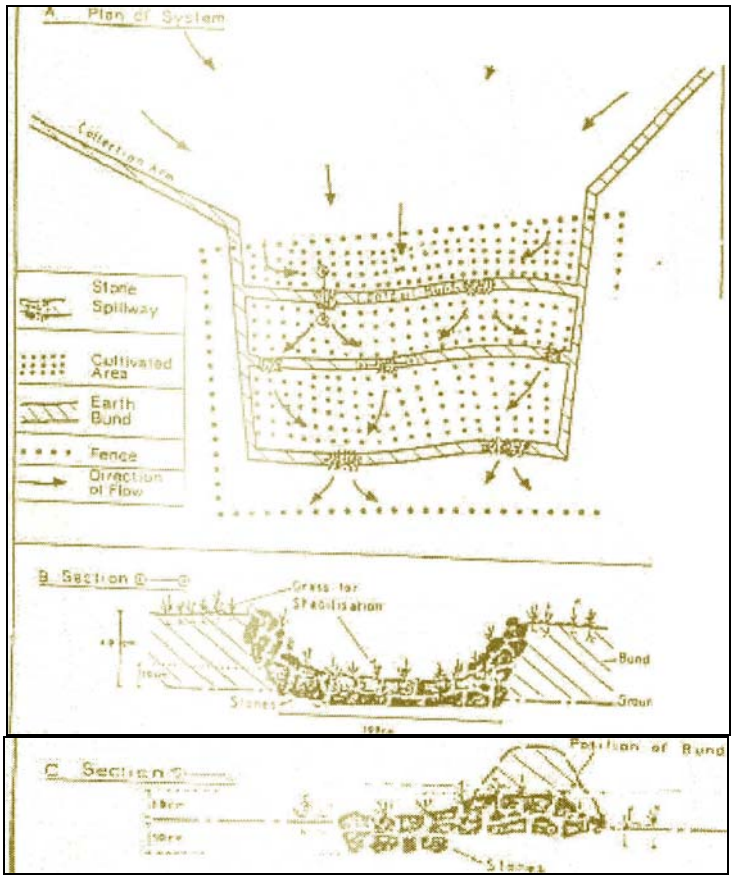
Multi Layer construction of Sand



Completed Sand Dam

5 Macro-Catchment Run off Farming

Macro catchments rely on a large external catchment to generate runoff. They expatriates of runoff and high variation in the quantities received from different rainfall evidence. Heavy rainfall storms the runoff can be turbulent and therefore the potential damage structures and crops is high if the water is not properly controlled. Spillways and water therefore required to allow excess water to be safely discharged in the lower sections causing damage.



***Macro** Catchment System*