Replace by Coverpage

Disclaimer

The designations employed and the presentation of materials in this present document do not imply the expression of any opinion whatsoever on the part of the Nile Basin Initiative nor the Eastern Nile Technical Regional Office concerning the legal or development status of any country, territory, city or area or its authorities, or concerning the delimitation of its frontiers or boundaries.

Table of Contents Field Investigations Study

VOLUME III: MAPS AND DRAWINGS

Maps TM-1to8	Topography of command area, scale 1:10,000 (8 A1 sheets)
Map TM-9	General topography lay-out, scale 1:50,000 (1 A1 sheet)
Map TM-10	Topography of diversion site, scale 1:1,500 (1 A3 sheet)
Map TM-11to12	Topography of the Main Canal alignment and crosssections, scale 1:10,000 and 1:5,000 (2 A1 sheets)
Map TM-13to36	Topography of command area, scale 1:5,000 (24 A1 sheets on soft copy only)
Map TM-37	Detailed topography of pump station site (1 A3 sheet)
Map TM-38to40 sheets)	Detailed topography of sample blocks A and B (3 A1
Map SO-1to8	Soils and profile pits, scale 1:10,000 (8 A1 sheets)
Map SO-2	Location of auger hole points and in-situ physical test results, scale 1:25,000 (1 A1 sheet)
Map LS-1Sto5O	Land suitability, scale 1:25,000 (10 A1 sheets)
Map GE-01	Location of boreholes, testpits and quarry sites, scale 1:50,000

EASTERN NILE IRRIGATION AND DRAINAGE STUDY/FIELD INVESTIGATIONS/FINAL REPORT
DINGER BEREHA PROJECT

Table of contents Volume I: Main Report

List of tables:

List of figures:

List of maps:

List of plates:

ABBREVIATIONS AND ACRONYMS

Fiscal Year:

Egypt: 01 July – 30 June

Ethiopia: 08 July – 07 July

Sudan: calendar year

MEASURES

km	=	kilometre
km^2	=	square kilometre
m	=	metre
m^3	=	cubic metre
mm	=	millimetre
Mm^3	=	million cubic metres
BCM	=	billion cubic metres
1 ha	=	2.38 feddans
1 feddan	=	0.42 ha

ABBREVIATIONS AND ACRONYMS

ADB/F	African Development Bank/Fund
AGS	Addis Geo Systems
ANRS	Amhara National Regional State
API	Aerial Photo Interpretation
ARBID/MPS	Abbay River Basin Integrated Development Master Plan
ASTM	American Society for Testing of Materials
BCM	Billion Cubic Meters = 1 km^3
B/C ratio	Benefit Cost ratio
BH	Borehole
BS	British Standards
CEC	Cation Exchange Capacity

CS	Complementary Surveys
DC	Direct electrical current
DIU	Dams Implementation Unit (Sudan)
DOCS	Date of Commencement of Services
dS/m	deci-Siemens per meter
d/s	downstream
EC	Electrical conductivity
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EMA	Ethiopian Mapping Agency
ENCOM	Eastern Nile Council of Ministers
ENPV	Economic Net Present Value
ENTRO	Eastern Nile Technical Regional Office
ENSAP	Eastern Nile Subsidiary Action Program
ENSAPT	Eastern Nile Subsidiary Action Program Team
ENCOM	Eastern Nile Council of Ministers
EPMS	Environmental Protection Monitoring Strategy
ESP	Exchangeable Sodium percentage
ESCP	Ethiopian Standard Code of Practice
EWA	Ethiopian Water Authority
FAO	Food and Agriculture Organization
FNPV	Financial Net Present Value
FIRR	Financial Economic Rate of Return
G	Gravity
GOE	Government of Egypt
GFDRE	Government of the Federal Democratic Republic of Ethiopia
GOS	Government of Sudan
GPS	Geographical Positioning System
GRP	Glass reinforced polyester
GTZ	German Technical Cooperation Agency

Ha	hectare
HDPE	high density poly ethylene
HP	hydro power
HQ	High Quality (classification for drilling core)
ICCON	International Consortium for Co-operation on the Nile
ICT	International Consultants and Technocrats Pvt LtD
IEE	Initial Environmental Examination
ISL	Isambert Salembier Lino Consultants
LUT	Land Utilisation Type
LUR	Land Use Requirement
masl	Meters above sea level
MC	Main Conveyor
MCA	multi-criteria analysis
mcm	Million Cubic Meters
MoIWR	Ministry of Irrigation and Water Resources (Sudan)
MoWR	Ministry of Water Resources (Ethiopia)
mS	micro Siemens
N1, N2	Land suitability classes
NBI	Nile Basin Initiative
NEDECO	Netherlands Engineering Consultants (Consulting Firm)
NELSAP	Equatorial lakes subsidiary action programme
NELT	North East Lake Tana
NGO	Non-Governmental Organization
Nile-SEC	NBI Secretariat
Nile-COM	Nile Council of Ministers
NQ	Normal Quality (classification of drilling core)
OIDA	Oromiya Irrigation Development Authority
ONRS	Oromya National Regional State
O&M	Operation and Maintenance
P	Pumping

PA	Peasant Association
PF	Pre-feasibility
PFS	Pre-feasibility Study
PMO	Project Management Office
PS	Pump station
RfP	Request for Proposal
RQD	Rock Quality Designation
S1, S2, S3	Land suitability classes
SAP	Subsidiary Action Programmes
SAR	Sodium Adsorption Ration
SEIA	Social and Environmental Impact Assessment
SDS	Small Disturbed Sample
SPT	Standard Penetration Test
SPT-N	Standard Penetration Test-Normal
SVP	the Shared Vision Programme
TAMS	Tippets-Abbett-McCarthy-Stratton Engineers and Architects
tc	ton of cane
T_c	Time of concentration (only used in hydrological calculations)
TCC	Technical Coordinating Committee
TDS	Total Dissolved Solids
TLU	Tropical Livestock Unit (metabolic weight equivalence)
TOR	Terms of Reference
TRBID/MPS	Abbay River Basin Integrated Development Master Plan
TTB2	a set of geological formations
UA	Unit of Account
u/s	upstream
USBR	United States Bureau of Reclamation
UTM	Universal Trans Mercator
VES	Vertical Electric Sounding
WAPCOS	Water and Power Consultancy Services (India) Ltd.

WB	World Bank
WRMP	Water Resources Management Policy
WUA	Water Users Association
WWD&SE	Water Works Design and Supervision Enterprise

CONVERSION FACTORS

0.42 ha = 1.00 feddan

Preface

This report, that comprises three volumes has been prepared in accordance with the requirements of the contract for the Complementary Services, concluded between the Eastern Nile Technical Regional Office (ENTRO), the Client and BRLi, the Consultant who has subcontracted the topographic surveys, soils studies and geotechnical investigations to Metaferia Consultants and Shoraconsult, respectively for the Dinger Bereha project site in Ethiopia and the Wad Meskin project site in Sudan.

The report presents the results of the fully completed soils investigations and the fully completed topographic and geotechnical investigations in the Dinger Bereha Project area. All laboratory analyses for the full soils investigations and for the partly completed geotechnical investigations were finalised by the end of September 2009, whereas the topomap for the command area and for the diversion site were completed by mid October. Reporting on the investigations was completed by the end of October.

The outstanding topographic and geotechnical field investigations, including laboratory analyses were carried out during the period January-March 2010.

EXECUTIVE SUMMARY

TOPOSURVEY

The delineation of the area was made using GIS software and geo-referenced map of EMA, which was digitized by the Consultant for the purpose. On the basis of this delineation, gross command areas under the contours +1240, +1260, and +1280 were determined. A partly forested buffer zone of 200 m wide along Didessa and Dabana Rivers was excluded from the envisaged irrigation command area. Accordingly, considering the exclusion of areas for villages, roads, topographically unsuitable areas, and areas set aside for woodlots and buffer zones along streams, the net command area was assumed to be 70% of the gross delineated area below contour +1240 m and between the contours +1240 and +1260 m, which are bounded by Didessa River from the northeast and Dabana River from southwest. The gross command area below and between these contours was estimated to be over 12,000 ha.

Following the deliniation of the command area, and prior to the start of the field work and mobilization of the topographic survey crews, the teams to undertake the survey works were briefed about the objectives, methodology and planning of the survey work. They were also instructed to perform the assignment conform to the requirements of the TOR and the Inception Report.

The teams were mobilized twice, in 2009 (March to end of June) and 2010 (February to mid March). In Novemember 2009, the topographic survey of the command area and the weir site were completed with the production of topographic maps of the command and the weir site area. In total a gross command area of 10,600 ha was surveyed, as well as the weir site X-sections, while the remaining activities like main canal route survey, survey of details of cross drainage points along the main canal route, pump station, and sample command area blocks were carried out during the second mobilization of the teams.

Generally, the main topographic activities included:

- Topographic survey of total gross command areea of about 10,600 ha was conducted,
- Topographic survey of the weir site and three alternative weir axises across the River Didessa was carried out,
- Installation of six pairs of GPS points, which are tied with the Nation Grid Datum are installed with fairly distribution in the project area,
- Based on these GPS values/points a network of over 140 BMs were established, whereas all other survey work was based on these BMs,
- The main canal route between weirsite and command area route was surveyed over 22 kms,
- Detailed topographic surveys of drainage crossing points along the Main Canal, the pump site, and sample block command areas were undertaken, and
- Topographic maps with various contour intervals of the command and sample block areas, cross sectional profiles of cross drainage spots, longitudanal profiles of the main canal route, and detail topographic and cross sections of the weir site were produced and compiled as a set of maps at different scales.

All these activities, in particular the canal route alignment work, were not easily undertaken due to topographic conditions and lack of access roads and tracks and because the canal route alignment passes through a very dense riverine forest along the Didessa River.

SOIL SURVEY

The soil survey of Eastern Nile Irrigation Project was conducted at a feasibility level in line with FAO guidelines, for crop selection, irrigation designs and agricultural input requirements. It was implemented on grid survey techniques where one observation point represents 8ha. For the depth checking and soil boundary demarcation augur hole descriptions were undertaken at a grid of 400 x 200m interval where, each observation point was described to a maximum depth of 1.25m. Likewise, profile pits were also studied to 2m depth for characterization of chemical and physical properties of the soils. As a result, a total of 1,243 auger holes were described. In addition to that, 103 profile pits were studied and sampled. Taking on an average of four samples from each profile pit a total of 303 samples were collected and analyzed.

In-situ filtration and hydraulic conductivity tests were also studied on 11 representative model profile pits. The data related to the profile pits and auger holes were recorded with the help of GPS. Subsequently, based on significant information soil classification for the project area has been undertaken according to FAO-ISSS, ISRIC 1998 Guidelines. Thus ten sub-soil units and six major soil types have been identified, which include, Nitisols (NT), Acrisols (AC), Vertisols (VR), Cambisols (CM), Gleysols (GL) and Leptosols (LP). The most extensive soils of the project area, which have slope less than 8%, are Nitisols (NT) Vertisols (VR), Acrisols (AC) then followed by Cambisols (CM) and Gleysols (GL). Summarized area coverage of these soil types is presented bellow.

Identified Major Soil Types & Area Coverage

No.	Soil Type	Area	
		ha	%
1	Nitisols (NT)	4,303	40.8
2	Vertisols (VR)	1,053	10.0
3	Acrisols (AC)	1,063	10.1
4	Cambisols (CM)	352	3.3
5	Gleysols (GL)	29	0.3
Total area		6,800	64.5

Nitisols, Acrisols and Cambisols have relatively deep soil depth, well drainage and good workabilit. Likewise, Vertisols have deep soil depth, poor drainage and hard workability. The remaining 3,745ha (35.5%) of the land is occupied by non-potential area.

In general fertility status of the soils of the survey area is found to be low to midium. Based on the laboratory test results fertility status of the soils are medium to low in major nutrients like nitrogen and organic carbon. This may be related to the fact that, the soil is highly weathered and most cations leached down.

Summary of area coverage

No	Area with constraints for irrigation development	Area	
		ha	%
1	Shallow Leptosols and Cambisols < 60cm depth	1,746	16.6
2	Incised stream channels with riverine forest	1,585	15.0
3	Settlements (major villages only, excluding 1,421 Tukul sites)	216	2.1
4	Dense forest	130	1.2
5	Rocky, boulders, stony and shallow areas	67	0.6
6	Total area with constraints for irrigation development	3,745	35.5

The base saturation percentage of the study area is also confirms the same conclusion that the fertility level of the soils is found to be low to midium in most of the soil samples its average value of surface soils is greater than 48%, which indicate that the soils major cations like Calcium, Magnesium, Potassium, and Sodium have been leached down due to high rainfall (1,454mm) and sizable portion of the soil colloid is covered by Aluminum cation.

LAND EVALUATION

Following the TOR, Land evaluation assessment for irrigation development has been conducted based on the methodology outlined in the FAO Soil Bulletin No. 55, Guideline for Land Evaluation for Irrigated Agriculture (FAO, 1985) and Land Evaluation Framework FAO, Soil Bulletin No. 32

As part of land resources study the land evaluation assessment aims to translate land resources data into an expression of suitability of land units (land units map) for a defined use. The soil report and map are the valuable tools and a major land resource database for the anticipated land evaluation assessment. With this regard, the main objective of the land evaluation is to select five land utilization types (LUTs) were identified and defined in terms of their climatic adaptability, economic viability and food preferences. The selected 5 land utilization types are: onion, beans, citrus, maize & sesame. The overall suitability of the land units were then determined on the basis of the suitability ratings, referred to as partial suitability of the individual land use requirements for the LUTs under consideration separately. The evaluation assessments have been carried out assuming moderately to high inputs management levels and high labor intensity. To conduct the l evaluation assessment the land use requirements of these LUTs were determined.

The land use requirements are described by the land characteristics grouped to land qualities needed for the required sustained irrigated agriculture production for the LUTs considered. Based on land characteristics 15 land mapping units have been identified for the study area. After considering various factors namely: agronomic, environmental requirements and conservation, the relevant class determining factors were defined as variables that affect the performance of LUTs on a land unit. Subsequently, individual class determining factors of each land use requirement has been combined (matching) with each land unit and a tentative land suitability classification has been obtained. Thus land suitability maps have been prepared for selected crops separately with surface and overhead irrigation as part of the report. According, a total area of 6,260, 6,231, 6,231, 2,506, and 6,260ha of land is found to be marginally suitable (available) for surface irrigated agriculture development for onion, beans, citrus, maize and sesame respectively. Similarly 6,800, 6,619, 6,619, 2,506 and 6,648ha of lands for overhead irrigation agriculture are also identified for the same LUTs respectively. On the other hand, due to workability and unsuitable for mechanization currently (N1) and permanently (N2) unsuitable areas for all LUTs for both surface and overhead irrigated agriculture were identified. Summary land suitability class of Dinger Bereha study area is presented below. The suitable lands include area of land that will be reduced eventually for infrastructures (for irrigation canals and other infrastructure purposes). Thus, during the designing stage these figures may be lowered by about 5% of the total area anticipated for irrigation development.

In general, most of the soils that have been identified in project area found to be marginally suitable for surface and overhead irrigated agriculture. The limitations are moisture and oxygen unavailability, workability and unsuitability for mechanization. It should also be emphasized that the present land suitability evaluation results are guidelines for future agricultural developments activities.

Summary of land suitability class and area occupation of Dinger Bereha survey area for surface & overhead irrigation development

Land	Onion		Beans		Citrus		Maize		Sesame	
Suitability	Surface	O.head	Surface	O.head	Surface	O.head	Surface	O.head	Surface	O.head
Class	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
S2										
S3	6,260	6,800	6,231	6,619	6,231	6,619	2,506	2,506	6,260	6,648
Sub-Total Suitable	6,260	6,800	6,231	6,619	6,231	6,619	2,506	2,506	6,260	6,648
N1	1,845	2,092	1,874	2,274	1,722	1,334	6,387	6,387	2,632	2,245
N2	2,440	1,653	2,440	1,653	2,593	2,593	1,653	1,653	1,653	1,653
Sub –Total with constraints	4,285	3,745	4,314	3,927	4,315	3,927	8,040	8,040	4,285	3,898
Grand Total	*10,545*	*10,545*	*10,545*	*10,546*	*10,546*	*10,546*	*10,546*	*10,546*	*10,545*	*10,546*

GEOTECHNICAL INVESTIGATIONS

Introduction

The geotechnical investigation conducted includes the following main activities:

- Geophysical investigation at the weir site
- Test pitting and sampling at weir site, canal route and pump stations
- Exploratory core drilling at weir site
- Construction material assessment
- Laboratory testing

The objective of geotechnical investigation conducted was to study the subsurface conditions at major structure sites including the weir site, the canal route and pumping stations, to identify suitable construction materials for the use in the proposed infrastructures, to study the property of construction materials, to assess weir foundation bearing capacity, to identify the geology of the project site at the study level and to give inputs for preparing preliminary design to enable to complete the study of the project. The geophysical survey was undertaken with the aim to get information on the overburden condition of both abutments of the weir axis before concluding the final weir axis for further investigations. A total of eight Vertical electrical soundings (VES) were conducted along the axis options. Exploratory borehole drillings was also used for investigation the weir axis. The drilling points were continuously evaluated with pitting as well.

Geology of the area

Alluvial deposits, sand, silt and clay with a thickness up to five meters have been found following the Didessa river flood plan and along its tributaries. These soil formations were deposited during the rainy seasons, when these areas are flooded. Most part of the project area is covered by residual soil derived from the underlying crystalline basement rocks and the tertiary basalt flows.

Along the canal route almost all of the areas except the creeks and areas characterized by rock exposures are covered by gravelly silty sand, and silty clay. The thicknesses of this residual soil vary from place to place. In the test pits excavated along the route, its thickness ranges from 0 at the creeks to 2.50m in test pit DCTP 52. The bedrock of the area underlie by Precambrian rocks and Tertiary volcanic. The Precambrian rocks cover the largest part of the Dinger irrigation project area. Lithologically, they are represented by high-grade gneiss, migmatites and deformed granitoids. (Tadesse and Yonas, 2005). The Tertiary volcanics is exposed as a cap at high altitude and comprised of volcanic succession of dominantly basaltic composition with minor pyroclastic deposits. They cover few parts of the project area and it is designated as Lower basalt (TV_1).

Exploratory Borehole drilling

Two boreholes with a total length of 22.90m were drilled to investigate the foundation condition of the weir site. The depths and general locations of the boreholes are given in the table below.Depth to bed rock, variation in rock quality, degree of weathering and fracturing of the rock mass and the like are the information collected from the cores of exploratory drillings and the boreholes.

Borehole location and drilling details

BH	Easting (UTM)	Northing (UTM)	Elev. (GPS reading)	Planed Borehole length. (m)	Planed insitu test (SPT) (No.)	Drilled depth	Preformed SPT test no.
DWBH-1	203652	983381	1247m	15	2	12.25	2
DWBH-2	203635	983545	1247m	15	2	10.65	2

Test pitting sampling

A number of test pits were excavated along the main canal route, pump station sites, borrow areas and the weir axis to evaluate the engineering characteristic of the materials in relation to the desired infrastructures as well as to determine depth of suitable material available. The main purpose of excavating test pits at the weir site was to determine the depth to bed rock and to get a better view of the overburden.

Permeability testing

In situ permeability of various soil formations has been determined by the use of falling head method in the test pits. The tests were conducted by using 106mm diameter GI pipe and following the level of water in the pipe with time. This was done after identifying the group of the soil.

Laboratory testing

Soil, rock and water samples have been tested at CDSCo laboratory and Addis Ababa University department of Earth sciences to determine engineering properties and for classifications. The samples are collected from weir axis, canal route, borrow sites, pump station and sand rock quarries.

Construction materials

Assessment of availability of various construction materials suitable for the purpose of constructing the infrastructures such as weir, canal and pump stations at close distances to the proposed site was conducted to determine suitability and available quantity. The materials are:

Borrow clay

Fine clay material suitable for use of fill materials had been identified at three different locations of the Project area. Sources of red clay have been identified at locations close to the beginning, middle way and end point of the canal route. The potential borrow areas are located on high grounds and two of them are currently being used as farm areas. A total of 7 test pits were excavated manually within the identified clay borrow sources. The depths of the tests pits excavated varied from 1.6m to 2.5m. Based on the test pits excavated, the total estimated volume of material available from the three borrows is in excess of 1 million m^3. The clay borrows identified in the project area are similar in origin (mainly residual), are brownish to reddish in colour and also exhibit in general similar properties regarding plasticity. All of them plot above the A line signifying property of low plasticity silt clay.

Rock materials /concrete aggregates

Rock samples have been collected from drilled cores of Gneiss rock as well as blocks of basaltic rock samples from potential quarry sites for testing for evaluation of suitability for the use of as concrete aggregates. The samples were tested on alkali silica reactivity by using OPC type cement, Pakistan, Rock porosity and sodium sulphate soundness. The results of the laboratory tests for both rock types show that there is no alkali silica reactivity sensitivity. Sodium soundness test and porosity of the mentioned rock types in the above paragraph are also in the normal allowable range. These rock materials are found on the hilly areas on the left and right side of the river Didessa. Since the material is available in every hilly area, the volume is in excess and the maximum distance from the weir site isn’t more than 15km.

Sand

Fante River and the river between the villages no 4 and 5 have been identified as sources for sand. The sand is to be used for concrete works of the weir as well as cross drainage structures. Both sites are located along the road from Chewaka town to Village no 5. The approximate maximum distance of both sites from the weir axis is in the range of 22 to 24 km. Representative sand samples have been collected and tested from the sites in laboratory and the test result shows that the sand is suitable for the desired purpose.

1. INTRODUCTION

1.1 BACKGROUND

The Nile Basin Initiative (NBI) was established in 1999 by the ten Nile Riparian States[1] as a co-operative programme to address poverty, environmental degradation and instability in the Nile Basin while promoting socio-economic development. The African Development Bank was represented at the launching of the International Consortium for Co-operation on the Nile (ICCON) which took place in Geneva, 26-28 June 2001, and on that occasion, committed itself to support the Nile countries in their effort "to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the common Nile Basin water resources"[2].

In order to transform their Vision to action, the Nile Riparian countries developed a Strategic Action Programme which is being implemented through two complementary programmes: (i) the Shared Vision Programme (SVP) and (ii) the Subsidiary Action Programme (SAP). The SVP seeks to build trust among the states, improve implementation capacity and lay the foundations for cooperative investment and development. The SAP is oriented towards investment projects at the sub-basin level, involving all potentially affected states.

Two sub-basin Subsidiary Action Programmes (SAP) have been initiated, covering respectively the Eastern Nile and the Nile Equatorial Lakes regions. Egypt, Ethiopia and Sudan form part of the Eastern Nile Subsidiary Action Programme (ENSAP) under the Eastern Nile Council of Ministers of Water Affairs (ENCOM) while Burundi, Democratic Republic of Congo, Egypt, Kenya, Rwanda, Sudan, Tanzania and Uganda form part of the Equatorial Lakes Subsidiary Action Programme (NELSAP). The goal of the ENSAP and the NELSAP are to develop the water resources of the Eastern Nile Basin and of the Equatorial lakes Basin respectively in a sustainable and equitable way to ensure prosperity, security, and peace for the whole Nile basin.

The Eastern Nile Irrigation and Drainage Study Project (ENIDS) aims at contributing to the enhancement of food security, reduction of rural poverty, and reduction of population pressures in the region, with all associated beneficial effects on the environment. The study will contribute to attaining the agricultural sector goals of the participating countries (Egypt, Ethiopia and Sudan), towards an integrated approach to irrigation and drainage development in the Eastern Nile sub-basin as a means for enhancing food security, poverty reduction, improved welfare of the rural population and sustainable natural resource management.

The ongoing study has two components: Engineering Sub-component and the Cooperative Regional Assessment (CRA) sub-component. The engineering sub-component will identify a total of 15,000 ha (net) in Ethiopia and Sudan from among the proposed potential sites and undertake a feasibility study for irrigation development. The CRA sub-component will prepare a guideline for the identification and selection of irrigation and drainage projects presenting regional benefits; undertake assessment of the need for institutional and legislative reforms; and propose a cooperative framework and a common agenda on irrigation development in the Eastern Nile Basin (Egypt, Ethiopia and Sudan) for the medium and long term.

The Inception Phase of the Study described above commenced in September 2007. The findings of this phase indicated that there was a need to undertake detailed field surveys related to soils, topography and geotechnical investigationswhich would be a critical input to the feasibility study under the Engineering sub-component. Therefore, ENTRO made arrangements, intended to prepare soil and topographic maps as well as to undertake geotechnical investigations of the sites selected for feasibility study.

1 The ten Nile countries are Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Eritrea, Kenya, Rwanda, Sudan, Tanzania and Uganda. Eritrea currently holds an observer position.

2 Vision of the NBI

The terms of reference of the complementary surveys were prepared during the beginning of 2008, and after funding was committed by the AfDB, a RFP was issued in March 2008. Proposals were submitted in July 2008 and after evaluation, selection and negotiations a contract was signed in January 2009 by ENTRO, the Client, and the Joint Venture BRLi, Shoraconsult and Metaferia Consulting Engineers (MCE), hereinafter named ‘the Consultant’.

The identification of sites with a total area of 15,000 ha (net) for feasibility study among the proposed potential sites was finalized in September 2008, after the locations of the sites were determined. As per the Phase 1 Engineering Report, the Consultant’s findings indicated that the sites proposed for feasibility study were the Dinger Bereha area, in Ethiopia (see Map 1.1) and the Wad Miskeen project, in Rahad II area in Sudan. The precise boundaries would have to be determined during the Inception Phase of the CS.

Inception Reports were prepared for each project separately. The final version of these reports was approved in May 2009. The surveys, laboratory work, mapping and reporting were carried out between the end of April and the end of October. Part of the toposurvey work and geotechnical investigations could not be completed because fieldwork had to be suspended due to inaccessibility of part of the study area during the rainy season. This could not be avoided, as the start of the fieldwork was delayed due to circumstances beyond the control of the Consultant. Fieldwork was continued as soon as the area became accessible again, which was in January 2010. This report contains all sections that have to be completed according to the TOR.

The Final report contains the following volumes:

- Volume I: Main Report, structured as described below;
- Volumes IIA&B: Annexes, comprising the appendices for each activity separately; and
- Volume III: Maps and Drawings.

This Final Report resembles the structure of the Draft Report:

1) Introduction, which presents the background of the FI and the description of the Project Area;
2) Objective and scope of the FI as defined in the RfP and in the Inception Report;
3) Organisation, management, and overall approach;
4) Topographic surveys, describing the activities and results of the toposurvey team;
5) Soil and land suitability investigations, describing the activities and results of the soil survey team and the laboratories; and
6) Geotechnical investigations, describing the activities and results of the geotechnical investigations team and the laboratories.

Aspects of organization of activities, coordination, schedule and allocated resources are integrated in the respective chapters.

A description of the Project Area is given in the following chapter.

1.2 LOCATION AND DESCRIPTION OF THE PROJECT AREA

1.2.1 General

The Project site is located in the Chewaka Wereda of Illuababora zone in Oromia National Regional State at a distance of about 560 km to West of Addis Ababa (see Map 1.1). The command area under the current topographic survey is extended in 6 Kebeles of the Woreda, and is about 10,000 ha in gross with undulating terrain. It is bounded by Didessa and Dabana rivers, and is located upstream of their confluence. The Project area has been settled by the Government resettlement programme since December 2004. People from the eastern and western Hararge were resettled in the area under the programme. The number of households resettled was estimated at 12,390 when the programme started whereas the house hold number was 14,026 in 2008, with a total population of 78,179 and 92,027 respectively (source: 2008 self-wereda population census for the latest size of the population in the wereda). Farm sizes vary from 1.5-2 ha, depending on the size of the family. Such farm sizes are considered to be small and it is highly likely that in the near future intensification and cultivation of cash crops through irrigation during the dry season is required to prevent poverty. Agriculture is the main stay of the economy of the wereda. The people resettled in the area have started producing different types of agricultural crops under rainfed and traditional irrigation during the rainy and dry seasons respectively. Livestock rearing, particularly fattening of bulls and keeping of goats is also part of the agricultural activities that keeps the resetllers to run a mixed farming system. Irrigation of land would be possible on the left bank bounded by contour +1260 to the west, by Dabana River to the north and by Didessa River to the east. The gross command area was estimated at 6,100 ha between rivers and contour +1240 and 5,500 ha between contours 1240m and contour 1260m. The net irrigable area under command by two stages pumping was estimated at 8,100 or 70% of the total gross area. The pump station would be located at N 990200, E 1098 300. As alternative, the water could be supplied by a weir, located 15 km upstream of the pump station site at N 983500 E 1003 800. Pumping would then be limited to the area of between +1240 and +1260.

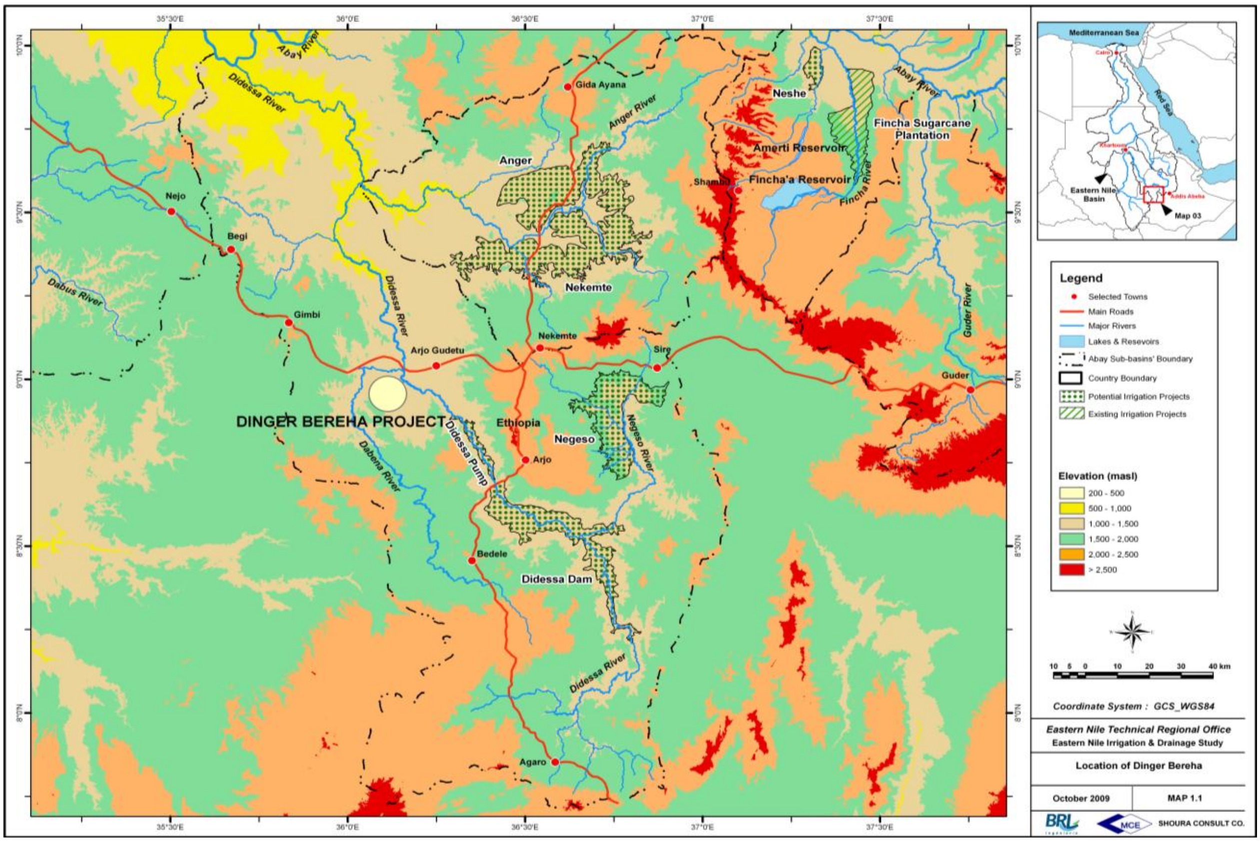
View on Project area (Nov 2008)

Didessa River near Dabana River (Nov 2008)

Because of the different development options (see following section) the command area was divided in two parts:

- the western part, bounded by Didessa River, Dabana River, Chekorsa/Boro River and contour +1260 m; and
- the eastern part, bounded by Chekorsa/Boro River, Didessa River and contour +1260 m.

With GIS software and the Consultant's 1:50,000 georeferenced map database the gross areas between the physical boundaries and contours +1240, +1260, and +1280 were determined. A forested buffer zone of 200 m wide along Didessa and Dabana Rivers was excluded from irrigation development.



Map 1.1: Location of Dinger Bereha Project area

The results of this analysis are presented in Table 1.1. To allow for villages, roads, topographically unsuitable areas, and areas to be set aside for woodlots and bufferzones along streams the net irrigable area was assumed to be 70% of the gross area. In addition, with the Spatial Analist software a slope analysis was prepared of the potential command areas below contour +1260, using a SRTM digital elevation model with 90 m spatial resolution. The results are shown in Table 1.2 and on Map 1.3.

From the tables and the maps it was concluded that:

- 7,852 ha net can be irrigated below contour +1260;
- In the western area, close to the Dabana River there is more than 2,300 ha net available between contours +1260 and +1280. In the eastern zone the area enclosed by these contours is less than 600 ha. The difference is attributed to the fact that the eastern area is smaller and steeper than the western area;
- As in the eastern area the difference between +1260 and +1280 is small, it does not make much sense to lift water higher than an elevation of +1260 m. Therefore the eastern main canal will follow the contour +1260;
- Below contour + 1260, the area with slopes less than 5% is about 5,900 ha net. This is equivalent to about 80% of the 7,500 ha net that would have to be developed. The remaining 20% is situated in the class of 5-8%.

The western area can be commanded by a canal following contour +1260 to be supplied either from the eastern canal and/or by a pumping station at the Dabana River.

Table 1.1: Areas (ha) for different zones, Dinger Bereha

Name	Eastern area		Western area		Total	
	Gross	Net	Gross	Net	Gross	Net
Bufferzone	333	333	328	328	661	661
Below 1240	2,242	1,569	3,846	2,692	6,088	4,261
Below 1260	3,949	2,764	7,268	5,088	11,217	7,852
Below 1280	4,700	3,290	10,584	7,409	15,284	10,699

Note: The 'below' figures do not include the bufferzone areas

Table 1.2: Areas (ha) according to slope class, Dinger Bereha

Slope class (%)	Eastern area below +1260		Western area below +1260		Total below +1260	
	Gross	Net	Gross	Net	Gross	Net
0-2	504	353	996	697	1,500	1,050
2-5	1,940	1,358	4,994	3,496	6,935	4,854
5-8	1,724	1,207	3,179	2,226	3,904	2,433
Over 8	980	686	1,645	1,151	2,625	1,837

Note: The areas do not include the bufferzone area

1.2.2 Previous studies

The command area is part of the previously identified Dabana command area. There were no previous studies for the Dinger Bereha Project, but the irrigable part of the area has been described under the Dabana Project (USBR 1964). Although a site visit to west Wellega zone of Oromia National Regional State was made earlier, and a discussion with the zone's officials was undertaken, no additional documents for review could be made available. Prior to the second site visit (in September 2008), additional documents were searched for review at the Ministry of Water Resources and at the Oromia Regional Water Resources Bureau, but it was not possible to get any additional document that describes the Project area, and/or study on the potential resources of the area.

1.2.3 Development options and Project outline

The cardinal objective of the study is to increase crop yields and improve the living standards of the people in the Project area. This objective can be achieved by diverting water from Didessa River, one of the potential tributaries of Blue Nile, at d/s of the bridge on the road Nekemte via Arjo to Bedele. During the first phase of the ENIDS two alternatives for irrigation were identified:

Option 1: Pumping, without diversion weir: a pump station would be located on the left bank of the Didessa River at N 990 200, E 1098 300, where a suitable site was identified where the north-south ridge, named Lebena is joining Didessa River. The riverbed has an altitude in the order of +1220m. Downstream of this site the riverbed drops 40 m over 4 km, thus increasing the required lift rapidly over a short distance and rendering pump irrigation very costly. Water could be lifted to a canal running at +1240m which would command the area located between contour +1240 and the river. The 31 km long main canal, named MC 1240 would end at the Guracha River, a tributary of the Dabana River and would cross a number of valleys by siphon in order to limit its length. The largest valley, named Hora Chewaka, would be irrigated on the eastern side by a 13.3 km secondary canal running from N 993 500 E 1087 800 in southern direction. The western side would be irrigated by a 14 km long second secondary taking-off at the d/s end of the siphon. At N 991 500, E 1092 500 a booster station would lift water from MC 1240 to a main canal running at +1260 m. Details on capacity, dynamic head, and power requirement are presented in the project cost sheet in Appendix A of the Main Report of the Phase 1 Component 1 study. The station would be supplied by a new 10 km long powerline running from Arjo in southern direction.

Map 1.2. Topography of the Dinger Bereha Project area and surroundings (A3 map)

Map 1.3: Slope Map Dinger Bereha Project (A3 map)

The area located between +1260 and +1240 on the western side of Hora Chewaka valley would be irrigated by a second booster station located at N 994 000, E 1085 000 and a 5 km long main canal, named Ka Kemberi and commanding the Guracha valley.

In addition, water for the western area could be supplied from Dabana River by a pumpstation that would be located at N 993 400 and E 1174 500, on the right bank of Dabana River at an elevation of +1230. Water would be lifted via pipelines over a length of 2,870 m upto an elevation of +1285 m from where it would run through natural streams until it is diverted to the west pump canal or to the higher lying canal that could command the western zone between +1260 and +1280 as well. The headloss will be about 10 m, so the dynamic head would in the order of 65 m.

Option 2: Gravity diversion and boosterpumping: about 15 km upstream of the pumpstation site the riverbed has an altitude of +1240m. At this site (see plates 1.1, 1.2 and 1.3), the river has a bed width in the order of 150 m and water could be diverted by a 3-4 m high concrete weir to a feeder canal running on the left bank that would follow the +1244 contour at a gradient of 0,10 m/km to the foot of the Lebena ridge, at the most eastern tip of the irrigation scheme. The canal would run closely to the river through an area with cross slope between 3 and 10%. The command area between +1240 and +1260 would be irrigated by two boosterstations.

1.2.4 Present situation

People in the Project Area were settled by the Government resettlement program. The resettlement has taken place as of December 2004. Prior to this resettlement program, the area was sparsely inhabited apart by very few Gumuz ethnic people that were residing along the banks of Didessa and Dabana Rivers. The project area is located in Chewaka Wereda of Illuababora zone, in Oromia National Regional State. It is bounded by the Didessa and Dabana Rivers from east and west respectively. It is also bounded by Dabo Wereda in the south and the southwest. Other weredas bounding the Project wereda are Gimbi to north and Leka to the northeast, after the confluence of Dabana River with Didessa River, and to the right bank of Didessa River respectively.

The Project Area is accessible from the Bedele-Nekempte road, which is about 108 km long. The access road departs from this road after 18 km drive from Bedele town and/or after 90 km drive from Nekempte after crossing Arjo town and the Didessa River Bridge. The road that takes to the Wereda capital, Illuharar, passes via Kone town, which is located 17 km away from Illuharar. The road is paved as an all weather road but requires intensive maintenance. The Project area is also accessible from the Nekempte-Assosa road despite that a bridge on the Didessa River has not yet been constructed. A bridge across the Didessa River to join the project area with Nekempte-Gimbi main road would be an important short cut. According to the Chewaka deputy administrator, a bridge will soon be constructed according to a plan of the government, with a full participation of the people.

As the main objective of the Project is to optimise the benefits from the available water resources, the people residing in the area are keen and ready to volunteer to participate and run the irrigation project once developed. The wereda administration head acknowledged that the people have requested pumps to extract irrigation water from deep sources, and the wereda agriculture office has bought some pumps and is ready to distribute these to the farmers on credit basis.

Plate 1.1: Potential site for weir and intake, Didessa River

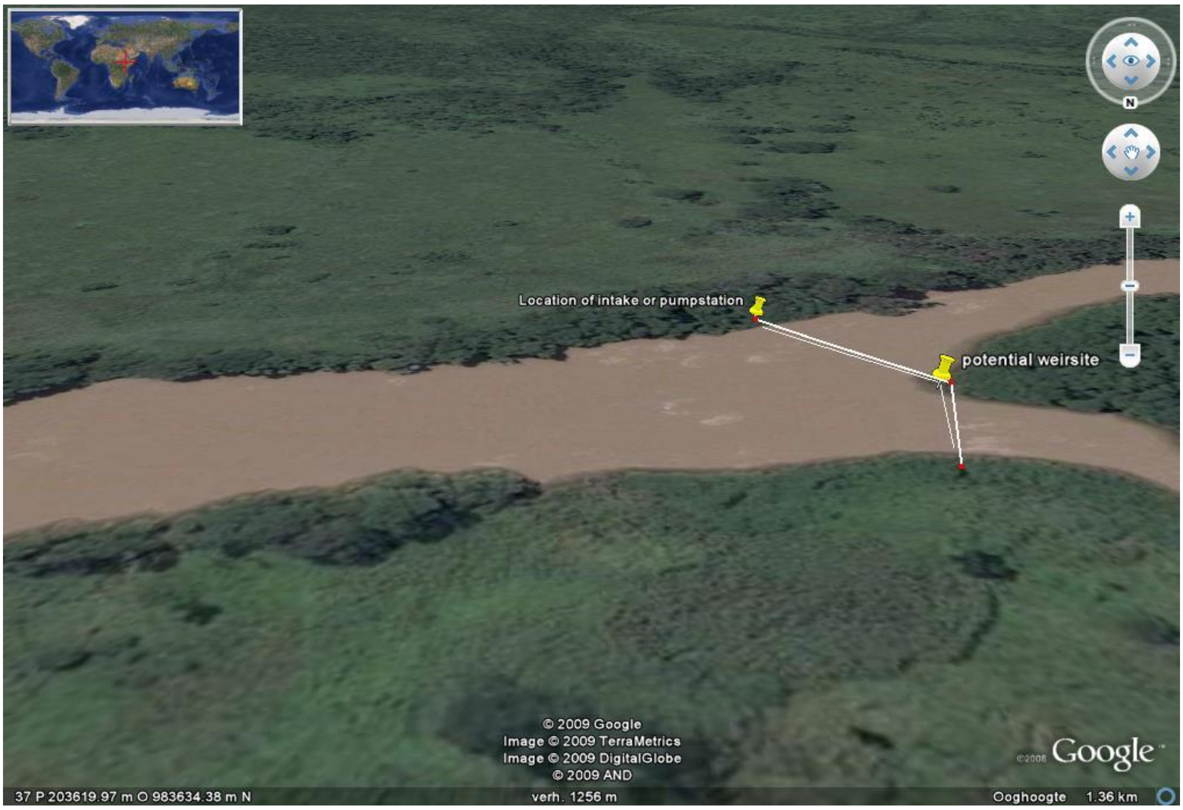


Plate 1.2: Birds eye view of weir and intake in western direction

Plate 1.3: View on bifurcation downstream of diversion site

2. OBJECTIVE AND SCOPE OF THE COMPLEMENTARY SURVEYS

According to the RfP and the Inception Report, the main objective of the FI study is to undertake detailed site investigations on 15,000 hectares (net) in the Dinger Bereha and Wad Miskeen Project areas that would prepare information for feasibility studies of irrigation development. The site investigations were carried out on areas of minimum 7,500 hectares net of land in each country and would include the following:

- Undertaking detail soil survey and land suitability study on 15,000 hectares (net) of irrigable land selected for feasibility study in Sudan and Ethiopia (equally divided between them);
- Conducting detailed topographic surveys and map preparation on the 15,000 hectares of the same selected areas;
- Undertaking detailed geotechnical investigations on diversion sites, pump sites, major structures, and along main canal routes of the selected areas.

While the Engineering component of the ENIDS aims to undertake a feasibility study for irrigation development on 15,000 hectares (net) equally divided between Ethiopia and Sudan, the current task is to provide detailed information on soils and topography as well as on geotechnical conditions at foundations of diversion, pumping sites and in main canal alignments in the selected sites. The site investigation works may need to be conducted on larger areas in order to achieve a net irrigable/suitable area of 15,000 hectares. The Consultant retained for undertaking the feasibility study of the areas, has made a reconnaissance level assessment and delineated the gross areas that needed to be investigated.

3. ORGANISATION AND MANAGEMENT AND OVERALL APPROACH

3.1 RESPONSIBILITIES OF ENTRO AND NATIONAL COORDINATORS

ENTRO is the recipient of the Grant from AfDB and the Executing Agency in charge of direct execution of the Study. ENTRO is located at Addis Ababa, Ethiopia, and is managed by an Executive Director who is Head of the office. The role of ENTRO coordinated the intervention of the Consultant for all matters related to the site investigation activities of component 1 (Engineering sub-study). The line Ministries of the Ethiopian and Sudan Governments will supervise the work of the Consultant concerning the site investigation study, for all aspects related to their national projects. The mandate for provision of information was given to national line ministries; hence the information provision is channelled through national focal persons. The national focal persons of the two countries, Ethiopia and Sudan, will form a Technical Coordinating Committee (TCC) which will liaise, as needed, with ENTRO and ENCOM on all matters related to the site investigation studies.

The specific responsibilities and duties of the national focal persons are, as far as their national sub-component is concerned: to provide all technical information needed by the Consultant to fulfil its assignment at the national level; to follow-up and oversee the day-to-day implementation of the studies; to ensure achievement of study objectives; to manage and oversee, under ultimate responsibility of ENTRO, all activities pertaining to procurement of services; to ensure that reports at all stages of the study are prepared by the Consultant and that the views of the beneficiaries are duly incorporated; to verify the Consultant's claims for payment, to prepare bi-monthly progress reports and the Study Completion Report at the completion of the study for distribution to appropriate bodies.

3.2 RESPONSIBILITIES OF THE CONSULTANT

With regard to the implementation of the FI the Consultant, who is also responsible for the feasibility study cooperated and liaised fully with the ENTRO, which is the executing agency and the Client. He also liaised with all relevant Government's and other agencies on matters pertaining to the proposed study.

The Consultant exercised all due skill, care and diligence in the performance of his services. In that regard the Client recommended strongly the inclusion in the team of local consultants knowledgeable in their field of expertise. The Consultant has taken into account relevant comments from the executing agency, all Government authorities and other agencies and has been responsible for the accuracy of all data collected, his work, conclusions and recommendations. The Consultant carried and is carrying out the study in a professional manner in keeping with internationally accepted standards, using qualified and appropriate staff. The staff implemented the assignment with diligence and within a timeframe agreed upon in the contract.

The Consultant was responsible for providing staff salaries, fees of the experts, benefits, welfare, freight and travel, including visas. The Consultant declared himself prepared to replace any staff member, unable to carry out the work or considered by the Coordinator as unsuitable.

3.3 OVERALL APPROACH

As the Consultant had already established its office in Addis Ababa in order to implement the ENID study, commencement of the assignment could be immediately, with a minimum time for mobilization. This mobilisation started not later than the Date of Commencement of Services (DoCS), which was one week after the date of receipt of the advance payment in the bank account of the Consultant. Because of the serious delay in transfer of the advance payment it was very much likely that the fieldwork could not be completed before the onset of the rain. Therefore, the Consultant decided, after consultation with the Client, to mobilise and start work before the DoCS, using his own financial resources.

Reconnaissance and preparation visits to the Dinger Bereha Project area, the proposed weir&intake sites and the main canal alignment were made between 2nd and 6th February and from 20-22 March 2008. Review of some project relevant documents was made culminating in the preparation and submission of the Inception Report.

Mobilization of topographic survey and soil survey teams was commenced after receipt of the advance payment and before the submission of this Inception Report. The teams would require approximately 1,5-2 months to complete fieldwork, including data collection and sampling. Such fieldwork could only be undertaken during the dry season which ends by the third week of May. Ideally, the soil survey team should have a base topographical plan of the investigation area while they conduct their auger and profile pit surveys. However, in order to compress the field survey period the Consultant did run the two tasks concurrently, with the soils team using handheld GPS instruments to record auger and pit locations for plotting later onto base topographical maps when they are ready. At preliminary stage 1:50,000 maps, satellite images, and Google maps have been used.

4. TOPOGRAPHIC SURVEYS AND MAPPING

4.1 INTRODUCTION

ENTRO has awarded the preparation of Dinger Bereha Field Investigations (FI) to BRLi in January 2009, with Metaferia Consulting Engineers as sub contracted firm. Conducting the topographic survey of the Project was among the principal components of the FI assignments to provide the basic data and working documents for the Feasibility Study (FS) that would be carried out subsequently. This chapter presents the approach and methodologies used to produce topographic maps of the Project command area, the alignment of the feeder canal/Primary canal from the diversion site to pump station 1, details of the diversion/weir/ site, pump and major crossing structures, sample command area and other pertinent survey works.

4.2 TOPOGRAPHIC SURVEY PROGRAM

Initially, the topographic and main canal alignment survey works of the project were planned for execution in three (3) months under the FI contract. It was planned to execute the contract using six survey crews starting in mid-January 2009. However, as the arrangement required some times before the contract preconditions were fulfilled, delay of advance payment as per the schedule, the survey work was rescheduled for completion within four months, starting in late March 2009 to the onset of the rainy season in the Project area, mid June 2009 through increasing the working hours per day and working through the week ends. In line with this, the survey was carried out in four subsequent phases, office preparation and preliminary delineation of the project area boundary, mobilization, and establishment of benchmarks (BMs) and linking of BMs with the national grid points and /or setting of BMs, and level collection and map preparation.

It was intended to continue the survey work of the canal alignment after completing the command area topographic survey followed by survey of detail surveys of the pump stations and major structure sites as found important and on the priority needs for the design of the system for the feasibility study. The plan was interrupted, as the rainy season set in and obstructed the activities of surveying from being executed as planned initially, and this left the activities to be carried over for the next season.

In line with this, the remaining activities like survey of the alignment of the feeder canal/primary canal, detail survey of the major cross drainage structure sites, survey of the pump site and detailed sample command areas was made within the period of February 3rd to March 14th 2010. This indicated that the primary canal alignment survey was very difficult as it is aligned in a very dense forest along the Didessa River and this required quite a long period and more resources than planned initially.

4.3 WEATHER CONDITIONS

In general terms the climate of the area is hot particularly from January to March. The average temperature during the hot season ranges from 35°C to 41°C, and during the rainy season (July-end of August) it varies from 21°C to 27°C. The mean annual rainfall varies from 900 mm to 1,400 mm, and it concentrates during the periods of May to September. The topographic survey was carried out during the dry season including the early part of the Belg Season when the climate was characterized by hot temperatures during the day.

Fieldwork before the rainy season of 2009 was interrupted only for a day because of rain and dense fog. Generally, weather conditions in the Project area did not affect the progress of work significantly in all occasions until it was stopped by the onset of the rainy season at the end of June. As discussed here before, this onset of the rainy season interrupted all activities before completion of the canal alignment survey and other detailed survey works during the last year topographic survey of the Project area. The canal alignment survey and other detailed survey works recommenced after the rainy season, in February 2010 and completed in March 2010 with out any weather causing interruption of work.

4.4 Scope of the Study

Prior to the start of the fieldwork and before mobilization for the topographic survey, the teams to undertake the survey works were briefed about the objectives, methodology and planning of the survey work. The teams include staff experienced in their field in different levels. Camp accommodation within or close to the project area was made available by the Consultant. Senior Surveyors were included in the team to ensure quality. They were responsible for the general supervision and control of this important activity in order to strengthen the day-to-day follow up of the works undertaken. All survey work was carried out conform to the requirements of the TOR and the Inception Report. The topographic survey of the command area was executed so as to prepare for the feasibility design of the irrigation scheme, including selection of irrigation methods, preparation of irrigation layouts, preparation of bill of quantities and cost estimates, design of irrigation infrastructure, etc

Delineation of the command area and the Project area boundaries was made and horizontal and vertical control points were established, with known X-Y-Z co-ordinates. The control points were tied to the national grid of the EMA points, through establishing four sets of benchmarks (BMs), with three in the command area and the other one at the weir/headwork site. The initial BMs were established using differential GPS of dual accuracy under long period observation, which were tied with National Datum. Other benchmarks were extended from these points and levelling of the BMs was carried out. The BMs were established on stable features and clearly marked and painted with visible colours. Furthermore, where there were no permanent features, the BMs were formed by installing 14mm iron bar of about 50 cm long in to the ground so that the top is made above the ground level and the encasing upper part of the bar is prepared in 250x250x250 mm above the top of the concrete, aiming at the use of the BMs for future reference.

The command area survey/ground levels collection/ and benchmarks network establishment covering about a gross area of 10,600 ha was carried out at appropriate grid intervals, and following appropriate methods as stipulated in the ToR and the Inception Report. The topographic maps were prepared with 1m vertical contour interval and at a scale of 1:10,000 for current use. They can be prepared later at larger scales, up to 1:2,500, where and whenever required.

Primary canal alignment survey (from the weir site to the command area), detail survey of the pump site, and the sample command area as well as major structure locations are undertaken in the second round survey work of the overcarried activities due to the onset of the rainy season in the project area. These activities are executed as previously planned in the draft FI report. The maps are prepared at 0.5m vertical interval and at scale of 1:500, 1:200 and 1:100, as required. Finally a base map at a scale of 1:25,000 covering the whole project area, including the primary canal alignment and the weir site topographic maps, is prepared for general use.

The topographic maps produced show every major feature of the areas including, rivers, springs, gullies, hills, settlements, footpaths, cattle crossings, water bodies, etc.

4.5 Study Methodology

4.5.1 Delineation of Irrigable Area for Survey

As was discussed in the FI draft topographic survey report, at the commencement of the study, a review of the 1:50,000 maps obtained from Ethiopian mapping Agency was undertaken as there was no other topographic study of the project area made earlier.

To start with the survey of the command area and in order to delineate the area, the command area was divided in to two parts:

- The western part, bounded by Didessa River, Dabana River, Chekorsa/Boro River and contour +1260 m; and
- The eastern part, bounded by Chekorsa/Boro River, Didessa River and contour +1260m.

The delineation of the area was made using GIS software and geo-referenced map of EMA, which was digitized by the Consultant for the purpose. On the basis of this delineation, gross command areas under the contours +1240, +1260, and +1280 were determined. A partly forested buffer zone of 200 m wide along Didessa and Dabana Rivers was excluded from the envisaged irrigation command area. Accordingly, considering the exclusion of areas for villages, roads, topographically unsuitable areas, and areas set aside for woodlots and buffer zones along streams, the net command area was assumed to be 70% of the gross delineated area below contour +1240 m and between the contours +1240 and +1260 m, which are bounded by Didessa River from the northeast and Dabana River from southwest. The gross command area below and between these contours was estimated to be over 12,000 ha.

Following the demarcation/delineation of the area, the command area boundary and the surrounding areas were identified and coordinates of its boundaries were delivered to the surveyors to carry out the work as planned. Furthermore, a satellite image of January 2008 with high resolution was used and interpretation of the area made at office level. The image was loaded on the computers of the surveyors for use at field level for verification of the survey works. Digitized EMA maps and the satellite image were employed to keep track of the orientation of the survey group and for directing the survey activity. The topographic survey was carried out for the planned study area, excluding the high spots, hills and mountains, buffer zones, villages, and other non-required areas located within the Project area. The work was planned for execution commencing with three survey crews, and increasing as required depending on the rate of progress of the field works. Reference Benchmarks (BMs) were established on the periphery of the Project area as well as within the command area, and located at visible distances depending on the land features. The BM's were connected with GPS points that were established and connected with known references with known levels and coordinates. The levels of the monuments were used for control of the topographic surveys. Traverse survey was carried out for groups of BMs. Ground levels were then collected using Total Stations at maximum grids of 50m x 50m depending on the topography of the land. Using the collected levels, topographic maps were prepared at different scales and contour intervals.

4.5.2 Mobilization

As discussed in the draft FI report, previously the surveying team was mobilized to the site on March 28, 2009 and reached the site on March 29, although it was planned to commence earlier. The survey crew rented a house that accommodated all the survey staffs including the drivers. The Consultant commenced mobilizing three survey teams and equipment to the project site on 28 March 2009. Each crew comprised one chief surveyor, one surveyor, and seven rod-men (the rod-men being trained and recruited from the locality). The survey team stayed on site until the rainy season in the area interrupted activities. The lists of equipment mobilized are shown in Table 4.1 and that of the survey staff are shown on table 4.2. Further to staff mobilized from Addis Ababa, rod-men (labourers) were recruited from the localities and trained for providing assistance for the survey works.

After the staff was mobilized to the project site and settled, the second day in the afternoon, a team of surveyors left for reconnaissance survey of the Project area. The next day the survey crew started to locate spots for the installation of GPS points by digging a hole, filling it with concrete mix and covering it with plastic so as to cure properly.

To locate and establish the six couples of GPS points took almost four days. This happened because every material, water, cement, and crashed aggregates had to be hand-carried using unskilled labour as the sites were inaccessible. Besides, the survey crew spent two more days to establish campsites to facilitate living in these camps.

Table 4.1: Survey equipment used

S. No.	Description	No. available on site
1	Total station, SOKIA 2030 Power set	1
2	Total station, LEICA TC1800	1
3	Total station TOPCON	1
4	Buddy Level SOKIA B20	1
5	Communication radios	7
6	Prisms (Reflectors)	12
7	Lap top computers	2
8	Dual frequency Differential GPS	1 set (3 GPS)
9	Normal GPS	2
11	4WD vehicles	2

Table 4.2: Personnel mobilized to the project site

Sr. No.	List of Manpower	No. on site	Remarks
1	Team leader	1	
2	Chief surveyors	4	
3	Assistant surveyors	2	
4	Level man	2	Two level men were recruited at different times
5	Helpers	30	Recruited locally
6	Drivers	2	
	Total	41	

The surveying crew was remobilized to the project site on fifth of February 2010 to complete the outstanding survey works which were left due to the on set of the rainy season last year. The team included two surveyors and six helpers who coordinated the site clearing activities and helped the surveyors in the execution of the survey works. Feeder canal alignment, details of crossing structures, pump site and sample command areas were some of the major activities undertaken during this mission. The details of the equipments and man-power deployed in the second mobilization of the survey crew are presented on tables 4.3 and 4.4 respectively.

Table 4.3: Survey equipment used

S. No.	Description	No. available on site
1	Total station, SOKIA 2030 Power set	1
2	Buddy Level SOKIA B20	1
3	Communication radios	3
4	Prisms (Reflectors)	4
5	Lap top computers	2
6	Normal GPS	2
7	4WD vehicles	1

Table 4.4: Personnel mobilized to the Project site

Sr. No.	List of Manpower	No. on site	Remarks
1	Team leader	1	
2	Chief surveyors	1	
3	Level man	1	
4	Helpers	6	Recruited locally
5	Daily laborors for site clearing	45	As the site is densely forested it required huge number of D.Ls
6	Drivers	1	
Total		55	

4.5.3 Establishment of benchmarks and connection with the National Grid

As presented in the draft FI report, the establishment of the GPS points was made after the surveying started as problems were experienced in securing differential GPS equipment in time. It was tried to contact the subcontracted GPS crew to come to the project site and to carry out the static differential GPS measurements, but it was not effected at the time the surveyors arrived to site as the equipment had to be secured from another site. In line to this, the surveying crew continued with the topographic survey of the command area from assumed GPS coordinates in order to speed up the assignment and to complete the activities on time as scheduled.

The first GPS crew to install the GPS points arrived to the site after 25 days from the start of the topographic survey and arrival of the survey crews to the site. This first crew failed to install the GPS points as the GPS equipment was not functional. Following this phenomenon, the surveying crew was obliged to change the equipment after their stay on site for four days. The GPS crew came for a second time and established the points after six days. The details of the GPS points installed in the project area are presented in Table 4.5.

All the times waiting for the GPS values, the surveying crew was doing the topo survey based on assumed coordinates. Whereas, after getting UTM GPS coordinates that are connected with the National Grid, as stipulated in the ToR provided by the Client and technical proposal of the Consultant, the surveying crew commenced to survey the command area using these points and at the same time the chief surveyor started to convert the previously surveyed area using assumed coordinates into the new and correct UTM coordinates provided. While the three teams of the surveying crew were doing the topo surveys, the levelling surveyor was doing the installation of benchmarks one day and the reading every other day.

Table 4.5: GPS Points established in the Project area

Descriptions	Easting (UTM)	Northing (UTM)	Elevation (masl)	Site of Installation
GPS001	183609.587	997034.942	1209.404	Daban&Didesaconb1
GPS002	185123.526	992411.970	1246.266	Village 4 area1
GPS003	192140.452	991249.648	1259.141	pump site 2
GPS004	188280.789	987085.297	1220.767	Chewaka town 2
GPS005	189111.294	981232.124	1272.959	Command area boundary 1
GPS006	203610.419	983252.504	1248.268	Weir site1
GPS101	184460.572	996090.143	1245.614	Dab&Dedidessa conful. b2
GPS102	185550.167	993004.519	1238.098	Village4area2
GPS103	191796.762	991359.053	1265.034	Pump site1
GPS104	187815.358	986420.432	1246.491	Chewaka town1
GPS105	189451.702	981924.378	1278.376	Command Ab2
GPS106	203035.333	983071.333	1256.323	Weir site2

The permanent benchmarks (BMs) were established at the appropriate intervals (average 1-2 km) within the Project boundary. These are intervisible. The BMs were established on solid natural or manmade objects such as rock outcrops or the top of pemanent structures, where available. These points are marked in permanent paint and a 200 mm circle diameter drawn around the point and also painted in red.

Where there were no permanent points, the benchmarks were formed by driving a 14 mm diameter steel bar 400 mm long into the ground with the top just above ground level and encasing the upper part of the bar in a 250 x 250 x 250 mm above the top of the concrete.

All benchmarks are clearly marked with an identification number on the site and on the drawings. The benchmark lists, locations, levels and other information are indicated in table 4.6. These BMS are clearly shown on the produced topographic maps. The X, Y, Z coordinates are determined for each benchmark by connecting with the GPS points of which the datum is known and tied with the National datum.

The topographic survey of the command area and production of concrete posts for bench marks started next to establishment of the BMs and identification of the project boundaries for easy and coordinated survey of the command area.

Table 4.6: List of Bench Marks established in the Project area

	Descriptions	Easting (UTM)	Northing (UTM)	Elevation (masl)
1	BM01	184654.173	996260.677	1251.428
2	BM02	184951.169	996579.122	1255.660
3	BM03	185222.346	996777.491	1254.510

4	BM04	186176.427	997365.177	1227.768
5	BM05	184413.533	995168.489	1260.477
6	BM06	183544.090	994586.112	1253.348
7	BM07	184422.494	997105.966	1214.564
8	BM08	184040.526	996480.606	1223.163
9	BM09	185230.033	995948.044	1245.579
10	BM10	186625.005	997514.494	1206.803
11	BM11	186831.737	997881.637	1206.275
12	BM12	185416.928	997763.903	1225.211
13	BM13	183914.662	995556.048	1235.493
14	BM14	183383.607	995662.850	1238.716
15	BM15	183129.194	996122.364	1252.198
16	BM16	183367.906	996924.979	1228.446
17	BM17	183129.453	997702.499	1237.236
18	BM18	182623.172	995740.591	1253.851
19	BM19	182978.345	994853.255	1263.911
20	BM20	183490.780	993898.094	1257.672
21	BM21	184213.836	993191.559	1253.320
22	BM22	184990.474	993428.637	1250.811
23	BM23	185832.029	993907.564	1242.187
24	BM24	185287.120	993988.732	1232.964
25	BM25	186475.851	993492.805	1242.334
26	BM26	186644.745	994210.403	1245.446
27	BM27	184770.354	992126.761	1248.751
28	BM28	184277.277	991754.152	1255.197
29	BM29	183807.515	991502.738	1263.490
30	BM30	183185.736	990981.686	1271.407
31	BM31	182365.809	991092.832	1278.736
32	BM32	182600.157	991592.300	1272.285
33	BM33	182767.125	992276.849	1270.332
34	BM34	184763.224	995179.994	1249.367
35	BM35	184926.125	994688.859	1243.892

36	BM36	184273.057	992367.168	1237.367
37	BM37	182853.122	992540.648	1262.188
38	BM38	182256.990	994721.868	1268.128
39	BM39	181644.028	994449.750	1259.390
40	BM40	181852.066	993786.596	1270.350
41	BM41	182401.437	994253.980	1251.191
42	BM42	184793.960	997996.110	1213.759
43	BM43	185243.988	998476.098	1183.676
44	BM44	182298.157	993006.542	1263.218
45	BM45	181766.644	992156.665	1264.076
46	BM46	181681.890	991224.796	1280.329
47	BM47	188731.873	985545.876	1222.852
48	BM48	189360.541	984284.118	1263.340
49	BM49	189739.980	983988.628	1268.092
50	BM50	190957.876	983898.526	1273.489
51	BM51	189425.853	985893.998	1238.054
52	BM52	190123.540	986288.517	1256.785
53	BM53	189979.010	985139.893	1271.814
54	BM54	189017.374	987892.872	1246.168
55	BM55	187536.319	987998.798	1237.375
56	BM56	186821.629	987139.467	1265.066
57	BM57	186130.121	989541.462	1256.907
58	BM58	186498.102	990138.635	1248.839
59	BM59	185714.613	990380.735	1260.382
60	BM60	187944.285	985019.296	1242.212
61	BM61	187998.070	984086.482	1262.290
62	BM62	188954.881	982533.437	1272.810
63	BM63	188695.058	982099.420	1263.630
64	BM64	188992.013	981666.007	1269.227
65	BM65	189906.749	982102.303	1288.114
66	BM66	190013.142	981660.215	1290.541
67	BM67	190521.275	981281.167	1252.016
68	BM68	190892.639	981783.736	1261.511

69	BM69	189016.990	983466.862	1256.599
70	BM70	186545.736	984793.357	1248.321
71	BM71	186823.484	984159.153	1252.313
72	BM72	187454.184	983461.010	1248.210
73	BM73	185285.769	985559.647	1259.511
74	BM74	185754.264	986458.982	1250.151
75	BM75	185821.679	987329.534	1255.679
76	BM76	186158.790	986544.446	1244.169
77	BM77	185509.874	988071.264	1257.400
78	BM78	185768.542	989174.817	1247.812
79	BM79	184945.390	990295.298	1258.421
80	BM80	184415.362	990349.439	1264.202
81	BM81	184262.414	990304.256	1264.681
82	BM82	183767.702	990020.690	1256.566
83	BM83	183020.489	990152.645	1265.992
84	BM84	182501.803	990497.771	1266.643
85	BM85	182111.106	990524.872	1277.059
86	BM86	186700.070	989489.976	1238.796
87	BM87	188093.261	989583.544	1243.657
88	BM88	188427.338	990207.224	1248.786
89	BM89	189088.184	989381.272	1260.076
90	BM90	188380.282	991072.371	1247.798
91	BM91	187903.277	991916.892	1244.388
92	BM92	190297.205	991752.965	1242.608
93	BM93	190753.537	990971.406	1255.168
94	BM94	190538.697	990797.173	1251.132
95	BM95	190079.301	992397.747	1193.849
96	BM96	189372.997	991924.968	1241.014
97	BM97	189728.092	990261.934	1252.462
98	BM98	188876.016	991048.163	1252.651
99	BM99	188960.252	992521.431	1246.590
100	BM100	188445.812	992397.814	1255.642

101	BM101	188288.227	993076.972	1244.145
102	BM102	188474.024	993810.169	1211.427
103	BM103	191106.370	992224.281	1224.223
104	BM104	190665.869	992153.220	1225.781
105	BM105	191229.715	992664.357	1224.050
106	BM106	190029.499	993021.616	1189.620
107	BM107	189403.460	993122.149	1210.909
108	BM108	187953.671	993339.323	1242.622
109	BM109	187476.001	993399.611	1213.315
110	BM110	192377.052	991260.649	1262.078
111	BM111	193109.911	990936.909	1217.158
112	BM112	193645.500	990964.669	1225.475
113	BM113	194318.405	991556.120	1229.355
114	BM114	194362.939	991626.038	1236.340
115	BM115	194905.177	991441.067	1232.840
116	BM116	183910.311	991046.270	1251.209
117	BM117	184379.035	991618.817	1257.612
118	BM118	184701.755	991014.788	1247.254
119	BM119	185303.238	991580.349	1247.689
120	BM120	185543.495	991709.697	1250.300
121	BM121	186009.516	992038.676	1247.671
122	BM122	186000.636	990867.969	1248.271
123	BM123	186355.399	990931.610	1241.415
124	BM124	186693.223	991773.425	1210.982
125	BM125	187538.272	992242.735	1234.334
126	BM126	186842.849	990949.512	1210.472
127	BM127	186542.263	992725.849	1223.527
128	BM128	186940.882	994910.214	1223.029
129	BM129	186813.192	995416.302	1216.008
130	BM130	186190.414	994782.886	1227.308
131	BM131	185735.242	994399.416	1239.920
132	BM132	185500.002	995468.540	1241.196

133	BM133	185856.155	996184.952	1240.469
134	BM134	181665.703	989283.062	1402.530
135	BM135	181655.552	989249.542	1409.003
136	BM136	182043.528	989130.784	1329.516
137	BM137	187164.023	986231.246	1274.519
138	BM138	187147.178	986211.199	1273.012

During the current survey BMs along the primary canal were established and more BMs on the top of hills or outcrops were established in order to responed the client's comments with regard to the requirement of more permanent BMs out of the cultivated area, and asuming for the of use of these BMs during the subsequent studies and implementation of the project. Additional BMs along the established primary canal route alignment and BMs used to survey the details of the pump site and the sample command areas are presented on table 4.7 hre below. These BMs together with Turning Points (TPs) are used to survey the canal alignment of the primary canal, the detail survey of the pump site and sample command areas. The BMs are tied up with the GPS points formerly stablished and tied up with national grids.

4.5.4 Establishing networks of benchmarks

In order to facilitate the detailed design and the construction of the project works during the implementation phase, adequate numbers of BMs were established for both vertical and horizontal control. Using the five GPS values in the command area and one copule of GPS point at the weir site as a control, the BMs were traversed within the command area as densely as possible. Overall about 138 BMs (posts) were installed at locations where spacing ranged from 500 to 600 meter on average, thus insuring inter-visibility of any two adjacent structures in the command area.

The BMs consisted of one meter concrete posts with steel bar of 1 meter embedded at the centre and extending to the bottom. The posts were installed in the ground at selected locations with the top 200 mm protruding above the ground. After the construction and curing of the BMs, an identification name was written on the top of each in white and red.

Further, to assisting in locating the monuments, and their accessibility for supervision purposes, features like trees, rock outcrops rocks et., which were in the vicinity were also marked in red and white ink such that they could be identified from a distance. The BMs Network was established with in the command area.

In addition to the BMs in the command area, 2 BMs along the canal alignment were installed and numbers of turning points were used to carry out the primary canal route alignment survey.

4.6 FIELD LEVEL TOPOGRAPHIC SURVEY

4.6.1 General

As mentioned here before, as the GPS points were not installed prior to commencement of the detail survey, the elevation of the BMs were also not initially established. The values of the benchmarks have been determined after getting the GPS points installed by running level survey of the monuments.

In addition to this, a close traverse was run on the monuments using Total Stations to establish the positions, coordinates of monuments which were later used as a starting point for all other survey works.

Table 4.7: List of Bench Marks established in the Project area for the survey of canal route alignment and detail surveys

	Descriptions	Easting (UTM)	Northing	Elevation (masl)	Remarks
1	BM54	189017.374	987892.872	1246.168	BM54
2	BM57	186130.121	989541.462	1256.907	BM57
3	BM58	186498.102	990138.635	1248.839	BM58
4	BM59	185714.613	990380.735	1260.382	BM59
5	BM78	185768.542	989174.817	1247.812	BM78
6	BM79	184945.39	990295.298	1258.421	BM79
7	BM80	184415.362	990349.439	1264.202	BM80
8	BM81	184262.414	990304.256	1264.681	BM81
9	BM82	183767.702	990020.69	1256.566	BM82
10	BM86	186700.07	989489.976	1238.796	BM86
11	BM118	184701.755	991014.788	1247.254	BM118
12	BM122	186000.636	990867.969	1248.271	BM122
13	BM123	186355.399	990931.61	1241.415	BM123
14	BM124	186693.223	991773.425	1210.982	BM124
15	BM126	186842.849	990949.512	1210.472	BM126
16	GPS 004	188280.789	987085.297	1220.785	GPS 004
17	GPS 104	187815.358	986420.432	1246.573	GPS 104
18	BM139	201614.27	984873.76	1241.46	Newly established along the MC
19	BM140	201581.00	984863.70	1242.58	Newly established along the MC

4.6.2 Command area survey

The field level survey was carried out in order to collect spot heights in a grid network of 100 × 100 meters. The spacing between points was minimized to show the terrain undulation or specific features when such features occurred. Automatic and digital levels were used to collect the levels. Spot heights are tied and referred to mean sea level after GPS points were fixed by installing and tying the monuments with national grid referenced datum. The three mobilized survey teams commenced topographic survey of the command area demarcated in the Project area prior to the identification of the reference GPS points. The works started at the southern and in the middle of the command area near village number 4 village and Chewaka town respectively.

The surveying activities continued in northerly direction towards the confluence of Dabana and Didessa Rivers where as the other team was assigned to continue the survey work in the north eastern direction, towards Didessa River. In accordance with the TOR, during the topographic survey, every effort had been made to incorporate the main natural and man-made features like ridges, valleys, river courses, etc. At the completion of the survey works the gross area surveyed within the demarcated area and computed using the generated maps was about 10,600 ha. Some of the installed BMs damaged during the farm works were reconstructed and cured. Simultaneously with the topographic survey of the command area, survey of the weir site was carried out in the previous survey era of the project.

In the current survey (February to March, 2010), feeder canal alignment (about 18 km long), and which is aligned along the Didessa course and crossing very densely forested areas covering over half of the total length of the canal is surveyed. In the process of the canal alignment survey, sites with major crossing points are detaily surveyed and maped with a scale of 1:500 or less. Furthermore, BMs along the feeder canal are established where suitable sites for BMs estblisment were identified, and as found necessary. Otherwise, in most cases, turning points, TPs are used to undertake the alignment survey of the Primary canal. The alignment of the primary canal comprises the reach from the southeast tip of the command area to the weir site from where the irrigation water is to be diverted to this Primary canal from the main Didessa River.

Detail survey of sample command areas and the pump site was also one of the activities undertaken during the current survey in order to appropriately complete the FI assignment as per the ToR.

4.6.3 Traversing of benchmarks

The BMs were traversed, using levelling equipment and connected with the GPS points that are tied with the National Grid Datum. A total of 138 plus two BMs which are inter-visible within the command area and along the primary canal respectively are established and traversed all over the command area envisaging that these BMs will be used for the detail design and implementation of the project.

4.6.4 Diversion site survey

In line with the topographic survey of the command area, the weir site area was surveyed and the cross-sections made at three lines of the river Didessa. The survey out puts were plotted and conveyed for use by the geotechnical study sector during the field level investigation as well as for final production of the weir site geotechnical works. To connect these survey works with known BM values, GPS points were established and more than six BMs installed in the vicinity. These sections and topomagraphic map of the weir site are used to prepare the design of the weir and its appurtenant structures. The map of the diversion site is presented in Volume III: Maps and Drawings of the FI study.

4.6.5 Primary canal route survey

The survey of the primary canal alignment was started from its downstream end and continued in upstream direction to the weir site. The area near this site could not be cleared from the savana grasses in time. During this survey period, starting from where the primary (feeder) canal enters the command area to the weir site, a total length of 22 km was surveyed taking over 43 days. Within this reach of the the primary canal about 18 drainage crossing points were found, six to eight of which were found to be big gullies. Crossings at these sites require large box culverts and therefore detailed surveys were undertaken as per the ToR. The cross-sections of the crossing points of the gullies were prepared at various scales as deemed necessary.The survey crew that was mobilized to this site for the second time faced very dense and almost impenetrable jungle and access to undertake the canal route alignment survey.

The team was obiliged to pass all their time in the jungle by residing with the farmers settled at the upper part of the left flank of the Didessa River. They also were facing wild animals and snakes besides the dense forest that was very difficult to clear in order to undertake the alignment survey. As a result, the canal alignment survey had to be carried out with great determination. In line with the canal route survey, details of the crossing points were surveyed and prepared at scale 1:200 or 1:500.

4.6.6 Detail survey of pump and major canal structure sites

In line with the primary canal alignment survey, details of the pump site survey, canal crossing points across the primary canal and sample command area surveys were undertaken and preparation of the topographic maps completed. All necessary maps and sections of the cross drainage sites were prepared at appropriate scales in line with the ToR. This resulted in topographic maps of strip of land with the canal route and the sample command areas and details of the pumpstation surveys.

4.7 GENERATION OF TOPOGRAPHIC MAPS

The survey data collected each day were downloaded after working hours, and checked for consistency and errors. The terrain model was then prepared using the data for further comparing the land features generated with the actual features of the land they represented. For downloading, soft wares COMMSP and TOPCON LINK were used and terrain model generation was conducted using Terramodel software installed on two laptop computers available on site.

The contour maps with contour interval of 0.25 and 1 meter were prepared at office level from the collected field survey data. The digital topographic map with high resolution satellite image (as background) is prepared and printed at scale 1:10,000 (about 8 sheets). The maps show features such as rivers, water bodies, roads and tracks, villages, gullies, hills and footpath, etc. also the areas of dense trees and hills indicated from the satellite image. A map at scale 1:25,000 was also prepared and printed. The maps are presented in Volume III: Maps and Drawings.

4.8 PROBLEMS ENCOUNTERED

The first problem the surveying crew encountered during the topo survey was the inaccessibility of most of the Project area with motorized vehicles. As there were no access roads evenly distributed in the Project area, the survey team was obliged to travel all the time on foot to cover the whole command area, to conduct survey work and to install BMs. Due to this long trip, the team was progressing under capacity followed by less output than usual.

The other problem was that the banks of most of the stream flowing within the command area were densely forested and crossing of these banks and streams was difficulte for the teams, who had to spend additional time to come from one side of the river to the other.

The undulating nature of terrain of the command area coupled with hot temperatures of the area was also some of the constraints that hindered the survey teams' activities. The roughness of the working conditions together with hot temperatures made each surveyor, and even the local helpers recruited as rodmen to be tired easily and become unproductive as expected. Hence all these problems as well as others created a negative impact on the surveying activities, the crew members, the daily labourers and the drivers resulting in less output and in delay in timely completion of the assignment.

Most of the survey team members left their job and returned back to Addis not enduring the hardships faced when the work was going at full capacity and smoothly to complete the assignment as planned. The locally trained rodmen and labourers were quitting the job frequently and/or were not available timely in the mornings. The same was with the drivers, they were not happy to stay at site and preferred to return back to Addis before their contract was terminated.

There were also problems with the Differential GPS Crew. The agreement with the team assigned to install the GPS points was to use three Differential GPS receivers, but they were equipped with only two sets and this resulted in the delay of output.

The farmers' communities residing within the survey area were highly cooperative, and no major problems were encountered by the survey teams in this regard. Most of the communities in the Project area were aware of the planned development program. The major problem faced was the damage caused to few BMs. The team was compelled to reinstall them and resurvey which resulted in lost days.

4.9 CONCLUSIONS

In the draft topographic survey report it was reported that the topographic survey of the command area was completed within the planned period, with minor delays, in accordance with the envisaged program. The activities that remained to be completed after the onset of rainfall during the previous survey period were completed during the second survey time (between Feburuary 3rd to March 15th 2010). During this period, the main activities included the survey of canal alignment, detail survey of sample plots, detail survey of the pump station site which the was determined during the feasibility study (FS), detail survey of major crossing structures, and other uncompleted survey works during the first topographic survey of the command area and the headwork site.

In the previous survey it has been covered a gross area of 10,600 ha out of the planned 11,041 ha demarcated using land characteristics observed from satellite images and digitized 1: 50,000 scale maps of the area. As the gross area surveyed from the demarcated area is more than the amount to be surveyed and agreed with the Client, it is assumed that the command area survey is completed. When the areas occupied by villages, forests, hills, and gullies are excluded, the remaining area will be the area available for development by the Client with regard to topographic survey. The problems faced during the execution of the assignment were insignificant and were related with undulating feature of the command area, dense vegetation along the streams found in the command area and light to medium dense vegetation in some areas. This situation reduced daily output of the surveying team and delayed the progress of the survey work. Mid June 2009 the rainy season started and by the end of June survey activities were suspended, whereas it was recommenced in February 2010 and completed in the second week of March 2010. The weather which was rather hot did not pose major problems as the works were programmed to be carried out in early morning and late afternoon during both survey times.

5. SOIL SURVEY AND LAND EVALUATION

5.1 SOIL SURVEY: EXECUTIVE SUMMARY & REPORT STRUCTURE

5.1.1 Executive Summary

The soil survey of Eastern Nile Irrigation Project was conducted at a feasibility level in line with FAO guidelines, for crop selection, irrigation designs and agricultural input requirements. It was implemented on grid survey techniques where, one observation point represents 8ha. For the depth checking and soil boundary demarcation augur hole descriptions were undertaken at a grid of 400 x 200m interval where, each observation point was described to a maximum depth of 1.25m. Likewise, profile pits were also studied to 2m depth for characterization of chemical and physical properties of the soils. As a result, a total of 1,243 auger holes were described. In addition to that, 103 profile pits were studied and sampled. Taking on an average 4 samples from each profile pit a total of 303 samples were collected and analyzed

In-situ filtration and hydraulic conductivity tests were also studied on 11 representative model profile pits. The data related to the profile pits and auger holes were recorded with the help of GPS. Subsequently, based on significant information soil classification for the project area has been undertaken according to FAO-ISSS, ISRIC 1998 Guidelines. Thus ten sub-soil units and six major soil types have been identified, which include, Nitisols (NT), Acrisols (AC), Vertisols (VR), Cambisols (CM), Gleysols (GL) and Leptosols (LP). The most extensive soils of the project area, which have slope less than 8%, are Nitisols (NT) Vertisols (VR), Acrisols (AC) then followed by Cambisols (CM) and Gleysols (GL). Summarized area coverage of these soil types is presented in table 5.1.

Table 5.1: Identified Major Soil Types & Area Coverage

No.	Soil Type	Area	
		Ha	%
1	Nitisols (NT)	4,303	40.8
2	Vertisols (VR)	1,053	10.0
3	Acrisols (AC)	1,063	10.1
4	Cambisols (CM)	352	3.3
5	Gleysols (GL)	29	0.3
Total area		6,800	64.5

Nitisols, Acrisols and Cambisols have relatively deep soil depth, well drainage and good workabilit. Likewise, Vertisols have deep soil depth, poor drainage and hard workability. The remaining 3,745ha (35.5%) of the land is occupied by area with constraints for irrigation development and land reserved for forest plantations along streambanks (see table 5.2.)

In general fertility status of the soils of the survey area is found to be low to midium. Based on the laboratory test results fertility status of the soils are medium to low in major nutrients like nitrogen and organic carbon. This may be related to the fact that, the soil is highly weathered and most cations leached down.

Table 5.2: Summary of area coverage

No	Area with constraints for irrigation development	Area	
		ha	%
1	Shallow Leptosols and Cambisols < 60cm depth	1,746	16.6
2	Incised stream channels with reverien forest	1,585	15.0
3	Settlements (major villages only, excluding 1421 Tukul sites)	216	2.1
4	Dense forest	130	1.2
5	Rocky, boulders, stony and shallow areas	67	0.6
6	Total area with constraints for irrigation development	3,745	35.5

The base saturation percentage of the study area is also confirms the same conclusion that the fertility level of the soils is found to be low to midium in most of the soil samples its average value of surface soils is greater than 48%, which indicate that the soils major cations like Calcium, Magnesium, Potassium, and Sodium have been leached down due to high rainfall (1454mm) and sizable portion of the soil colloid is covered by Aluminum cation.

5.1.2 Report Structure

The first chapter of the report discusses largely on the background and objectives of the project area. Under general features (Chapter 2) location accessibility, climate topography, present land use and land cover, geology and geo-morphology of the area have been explained briefly. Survey methodology, steps used to accomplish the task was explained under chapter 3. To illustrate the overall situation of the chemical and physical characteristics of soils of the command area, interpretations of analytical data on relevant parameters have been specified for the entire area (Chapter 4). The soil classification was made according to the revised legend of FAO-ISRIC-ISSS,1998, World Reference Base for Soil Resources (Chapter 5). Characterization of each mapping unit is also presented under Chapter 6. For each mapping unit, site information, soil chemical, physical properties and area extent are illustrated. Conclusion and recommendations of the study are also forwarded at the end, Chapter 7. It is deemed that this study presents detail assessment of the soil resource of the project area in a comprehensive way.

5.2 Background

Agricultural production through adopting irrigation for the development of irrigated agriculture and livestock development should be based on physical resources assessment and sustainable resources management. Soil, among others, is an important land resource that influences crop suitability and choice of land utilization types; hence every irrigation project should be pro-accompanied by an intensive soil study to ensure selection of land for irrigation development and other agricultural practices.The assessment of soil suitability for irrigated agriculture usually requires, detailed land resources inventory and its behavior under future system of crop managements. The changes associated with the introduction of irrigation are generally greater than those under rain-fed agricultural practices and accurate prediction requires a thorough knowledge of soils of the command area.

Soils of Irrigation Project Area have been conducted earlier by the USBR in 1964 by Dabana Project. However, taking into account the objective of the present study, the study has been conducted at a larger scale to achieve a density of one auger hole observation per 8ha as required under the Terms of Reference (TOR).

5.3 Study Objectives

The overall objective of the soil survey is to provide detailed information on the soils of the project area and to prepare soil map of the project area at feasibility level for selection of appropriate crops and irrigation design. The study was carried out so as to meet the following specific objectives:

- Investigate and identify different soil types of the project area and describe their physical and chemical properties of the soils and
- Prepare soil map of the study area at 1:10,000.

5.4 Scope of the survey

The TOR calls for soil survey of Dinger Bereha Irrigation Project Area and use the information as a basis for confirming or rejecting the irrigation potentials, for crop selection, irrigation designs, and for identifying agricultural input requirements. Accordingly, the soil survey study was undertaken at an intensive level on 10,545.54ha. Therefore, the study was carried out in compliance with the following standards as specified in the TOR given:

- An overall intensity of one observation per 8ha was adopted. However, in practice this intensity varied from 1 observation per 4ha to 1 observation per 10ha depending on the complexity of mapping units.
- Soil profile pits constitute about 10% of the Auger hole observations and about 10% of the profile pits were considered for deep boring infiltration and hydraulic conductivity measurement. From total profile pits 75% has been described and 3-4 disturbed soil samples were collected for laboratory analysis.
- Soil pits were dug to 2m depths to describe the main soil chemical and physical characteristics. Moreover, mini profile pits of about 1m depth were dug where the soil units have been looked heterogeneous.
- Deep auguring, 3 to 4m depths, was made at representative sites to determine the presence of salinity problem and depth of ground water table. Moreover, in-situ pH tests were conducted.
- A grid auger hole observation points were put in the command area using satellite imagery and aerial photo interpretation units as a basis.
- Detailed soil map of the study area was produced at a scale of 1:10,000.
- Soil and land characteristics description were undertaken according to FAO guidelines (1998).

5.5 General Features of the Area

5.5.1 Location and Accessibility

The proposed Dinger Bereha Irrigation Project site lies in the Nile River Basin, at about 72km north-west of Bedele Town and 555 km south-west of Addis Ababa. It is found in Illubabora Zone, namely Chewaka Wereda in Oromiya Administrative Region. The project area is stretched south to north direction and bounded by Didessa River to the east and Dabana River to the north west direction. It has an elevation range of 1139 to 1260m.a.s.l. Geographically, the Project area is located between UTM 98669m- 998979m north and 19098 195294 east. Map 1.1 shows the location of the Project area.

5.5.2 Physiography and Climate

5.5.2.1 Physiography

The Project area is characterized by pronounced variation in relief. The relief can be identified as to have foure main physiographic features being gently undulating plains with convex interfluves, valley floor, strongly slopping and moderately steep sides of hills & ridges. Detailed descriptions of physiographic features of the area are presented in section 5.10.4.2.

5.5.2.2 Climate

The climate of the study area is hot particularly in the month January to March. The average temperature during the hot season ranges from 35^{0}C to 41^{0}C, and during the rainy season (July to August) varies from 21^{0}C to 27^{0}C. There are three metrological stations for recording climatic data near by the Project area. These metrological stations are located at Bedele, Jimma and Didessa. From these stations Jimma metrological station is the only station, where recorded data for all climatic factors are available for sufficiently long periods. The climatic data measured at this station are rainfall, temperature, relative humidity, sunshine hours and wind speed. The summary of metrological characteristics computed for the Project area is given in Table 5.3. Accrdingly, the study area can be conveniently categorized as moist kola agro-climatic zone. Some of the climatic elements of the study area are discussed briefly in the following sections.

Rainfall

The Project area is situated within the highest rainfall region of the country. The rainfall in the Dinger Bereha project area is characterized by uni-modal type. The rainy months extend from May to October. The rainfall distribution of the area shows that the rainy season varies from 158mm in May to 104mm in October; the maximum peak month is July, which reaches up to 312mm. The dry seasons ranges from December to February. Thus, the average mean annual rainfall of the Project area is 1,454mm.

Temperature

Air temperature regulates the growth and development of plants by regulating the rate of biochemical processes. The growth of many crops ceases below the critical temperatures of 5^{0}C or above 35^{0}C and the crop yields are adversely affected. The average annual maximum and minimum temperature are 25.05^{0}C in April and 19.99^{0}C in December respectively.

Relative Humidity

Relative humidity influences the evaporation, disease prevalence, ripening and maturity of the crops. The average monthly relative humidity of the Project area is 75.51% with minimum value of 56.63% in March. Therefore, relative humidity of the Project area on the average condition can be taken in the range of 56.6% to 88.6%.

Wind Speed

The mean wind speed of the area ranges from 0.48 m/s in September to 1.08 m/s in April. For the computation of evapo-transpiration, wind speed is the relevant variable climatic element.

Sunshine Hours

Data of sunshine hours have been used in estimating evapo-transpiration rates for reference crops. Determined mean sunshine duration for the Project area is above 8.2 hours in the period of November-January and is reduced to 3.7 hours in July. The mean monthly sunshine duration of the command area is given in Table 5.3.

Potential Evapo-transpiration (ETo)

The daily ETo value of the Project area ranges from 3.06mm in July to 4.5mm in April. This parameter would help in selection of rain-fed and irrigated crops in respective production system and aids in the computation of crops water requirements.

Table 5.3: Summary of climatic data for the Project area

	J	F	M	A	M	J	J	A	S	O	N	D	Total
Monthly Mean Temperature in oC													
Ave.	21.9	23.2	25.4	25.1	24	22.1	21.3	21.2	21.8	22.4	22.1	20	
Relative Humidity (%)													
Ave.	65	59	57	68	76	81	87	89	89	85	79	72	
Wind Speed (m/s)													
Ave.	0.6	0.8	1	1.1	1	0.9	0.6	0.5	0.5	0.5	0.5	0.5	
Sunshine Hours (hrs/day)													
Ave.	8.2	7.6	7.5	7.3	7.6	6.1	3.7	4.1	6.2	7.9	8.3	8.3	
Mean Monthly Rainfall													
Ave.	15	18	54	70	181	243	246	239	226	116	31	13	1,454
Monthly ETo (mm/day)													
Ave.	114	114	142	134	133	107	92	96	113	124	114	107	1,390

Source: Hydrology study of the Project area MCE, 2009

5.6 LAND USE /LAND COVER

5.6.1 General

Plants, through their rooting system, and land use types, play vital role in the soil formation, which eventually develop soil types. Accordingly, these factors determine the properties and local variation of soil characteristics. The Dinger Bereha Irrigation Project Area is an elongated gently undulating plain to strongly sloping area mostly occupied by cultivation. According to the interpretation of Satellite Image Spot 5 meter Resolution Ortho Rectified from January 2008, the Project area was dominantly occupied by intensively to moderately cultivated land. As it has been mentioned above, the land use land cover study was undertaken based on satellite imagery in conjunction with other available maps and ground verifications. The maps were used for the interpretation of the land units which was supported by ground checking, sampling and reinterpretation. The land use/cover mapping boundaries delineation were carried out by identifying the variable characteristics of the image elements such as color, tone, pattern and texture. As a result, for the Project area five major land use/cover mapping units were identified and mapped. These units were cultivated land, grass land, natural forest, wooded shrub land and marsh/wet lands.

5.6.2 Cultivated Land Unit

This land unit covers around 4,978ha (47.2%) of the Project area and it is mainly occupied by cereal crops, largely sorghum, maize rice and sesame oil & oil crops. The adaptation and distribution of these crops in the area are highly influenced by rainfall.

5.6.3 Other Land Units

Grass land unit occupies approximately around 1,053ha (9.99%) of the Study area. The remaining land units were occupied by natural forest, 1,716ha (16.2%) which is 130.35ha (1.24%) dense forest mainly along streams and 1,585 (15.03%) riverine fores. Wooded shrub land with sparcelly cultivated land occupy 2,486ha (23.58%) and marsh/wet land occupies around 29ha (0.27%), rocky boulders, rough surface occupies 67.25 (0.64%) and 216ha (2.05%) of the Project area is occupied by settlements including Illuharar Town.

5.7 LIVESTOCK

Livestock keeping is an important component of the production system in the area. It provides almost all the agricultural power which is a vital contribution to the overall economy. Oxen, cow, heifer, sheep, goat, donkey, poultry and bee keeping are the main livestock production system in the study area. In the Project area oxen have been provided to settlers by the administration in order to complement the crop component in the provision of draught power. Most cattle are kept tethered. Other cattle are herded in small units as are sheep and goat although the small ruminant species are often allowed to roam freely. The main cattle breed in the area is the horro type, which is well known as milk producer and is the well-liked type in the west of Oromiya State. Similarly the sheep of the area is also horro type. This type is found in the western and south western parts of the country and is widely distributed from Shoa, to East and West Wollega, Illubabora and Jimma in Oromiya Regional State. With regard to goat the western highland goat is the most common type in the area. It is related to both the central highland and Keffa Type. All poultry in the area are indigenous type. Poultry provides a subsidiary source food and income. Bees are ''farmed" in the traditional way and their honey gathered by the simple expedient of setting fire to the trees in which they have built their nest and then robbing them of their honey.

In relation to current livestock feed there is an abundance of crop residues and by-products. Other crop by-products include the tops of sweet potatoes (and occasionally the tuber), sorghum leaves. (Source: Socio-economic survey of MCE, 2009)

5.8 GEOLOGY AND GEOMORPHOLOGY

The Project area lies on the western edge of the Ethiopian volcanic escarpment. From the plateau at Bedele, the land drops steeply to the Didessa River valley passing through almost 1000m or so of the Tertiary volcanic succession down into the Pre-Cambrian Basement Complex, here comprising gneisses, schists and granites. There is what appears to be a series of erosion surfaces in the landscapes: the high plateau at around 2000 m is one, but this is well oustside the area; a prominent one is at about 1700 masl on the watershed; the DBIP lies mainly on a lower gently dissected surface, at about 1139 - 1260m, herewith termed the 'Chaweka Plains'. The Basement Complex rocks are exposed in the Didessa River, and also as an elevated fault-bounded horst block which forms a massive ridge along the eastern edge of the study area. The Dinger Bereha area, the subject of this soil survey, lies west of this horst block, mostly on gently to moderately undulating landforms with steeper slopes towards the Didessa and Dabana rivers.

The soil-landforms associations are developed over a thin veneer of highly weathered basalt lava and ash on the interfluves. These weathered volcanics, that appear to be either a downfaulted fragment of the Ethiopian volcanic plateau, or the residue of a lava flow that filled this part of the Didessa valley, passes down into the underlying Basement Complex metamorphic rocks that are exposed mostly on middle and basal slopes and in the rivers at the numerous rapid sites. The actual boundary between these geological formations is obscured by thick colluvial and soil mantles. On the undulating lands of the Chaweka Plains, where slopes range up to 15%, the soils vary from shallow to lithic on convex sedentary soil exposures, down to moderately deep and deep on the colluvial slope deposits of the middle and lower slopes and valley floors: this can be considered to be a catenary association of soils.

These valleys, as noted, become much more incised near the Didessa River due to the downcutting of the main rivers in response to deepening of the Abbay gorge, but there has also been isolation and preservation, to a certain extent, of the Chaweka Plains. It is not clear why this has happened, as the landscape of the wetlands is unusual that they remain as 'perched' above the more incised streams. The same type of landscape occurs on the right bank of the Didessa in the 'Didessa State Farm' area, and beyond. It may be that beds of volcano-lacustrine sediments - of unknown age and remnants of an ash fall blanket into wetlands- noticed in sections in a few of the streams that dissect the Chewaka Plains have acted as a knick point control on erosion and downcutting in the area. This has preserved the undulating nature of the Chewaka Plains, but it is considered to be fragile: if gallery forests are removed then there is a great risk that this protection, and other contributory aspects that are undoubtably playing a part also, could be altered and erosion accelerated throughout the Project area.

Much of the soil study area includes the undulating lands with convex interfluves, some granite tors, deep soils on middle and lower slopes, and passing down into flat, poorly drained uncultivated, valley floor, wetlands.

5.9 DRAINAGE

The drainage system of the area is mostly drained towards the Didessa and Dabana Rivers. In spite of that in the Study area there are many intermittent and perennial incised streams like Boro, Mimite and Guracha drained to Dabana and Didessa Rivers.

5.10 METHODOLOGY

5.10.1 General

To provide detailed information on the soil and land data for irrigation development detailed soil survey at feasibility level has been conducted. The survey was undertaken on grid system where, one observation represents 8ha. It is proposed to follow the procedure indicated by FAO guidelines, for soil mapping unit and description of different soil types of the Project area at a scale of 1:10,000. Thus, in order to properly accomplish the soil survey task the survey has been performed in three steps. These steps are:

- Pre-field work
- Field work, and
- Post field work

5.10.2 Pre- field Work

This phase focused mainly on the collection of basic materials like aerial photographs, topographic-maps, satellite imagery and review of previous studies. Previous study documents relevant to the Project area were thoroughly reviewed and survey planning activities have been arranged for subsequent tasks. Field soil survey guidelines, description sheets for auger hole boring, profile pits, hydraulic conductivity and infiltration tests have been prepared during this phase. Besides that, preliminary aerial photography and spot imagery interpretations have been done during this time. The base map, which shows location and numbers of auger hole, profile pits, infiltration and hydraulic conductivity tests also, have been planed during pre-field work time in the office.

5.10.3 Review of Previous Studies

Detailed soil survey investigation for the study area has never been conducted previously. However, some general studies at different levels, such as reconnaissance or semi-detailed level have been undertaken at different times by different agencies. A review of these studies is presented in the following sections.

5.10.3.1 Studies by United States Bureau of Reclamation (USBR, 1964)

In 1964 the United States Bureau of Reclamation (USBR) studied the soils within the Didessa valley region as part of the 'Land and Water Resources Study of the Blue Nile Basin'. This was a reconnaissance study of soils with land classification assessments. The major soils found in the area were Latosols (well drained, deep, reddish brown soils). No data on the soils covered the DBIP area, but in the Arjo-Didessa sub-project 3 profiel pits out of 21 were described.

Even though, this study covered the entire project area, relevance to the present study is insignificant due to the level of the survey and low intensity of survey.

5.10.3.2 Studies by Land Use Planning and Regulatory Department (LUPRD, 1984)

A broad soil survey was carried out by LUPRD for the whole country as part of a resource study for master land use planning. The study provided mapping of soils and their utilization at 1: 1,000,000 scale. The study was based on interpretation of satellite images for the entire country and subsequent field checking. The LUPRD study classified and mapped soils of the entire country mainly based on climate and geo-morphology. Accordingly, for the Project area two soil types, Orthic Acrisols and Dystric Nitisols were identified. Physical descriptions of these soil types are;

Orthic Acrisols: Orthic Acrisols having an ochric A horizon; lacking ferric properties; lacking a high organic matter content in the B horizon and lacking hydromorphic properties within 50 cm of the surface. These soil types cover about 8,909.41ha or 84.78% of the study area.

Dystric Nitosols: Dystric Nitosols have a base saturation of less than 50% in at least a part of the argillic B horizon within 125cm of surface: lacking high organic matter content in the B horizon and lacking an umbric A horizon. These soil types cover around 1,600ha and about 15.22% of the study area.

5.10.3.3 Studies by BCEOM, (1998)

The Abbay Master Plan (BCEOM, 1998) produced soil maps at 1:250,000 scale and established the areas where future development should be planned. The study is most useful as background information on geomorphology, soil classification and chemistry, and land classification. Table 5.4 shows the range of soil conditions found in the Abbay Basin.

5.10.3.4 Concluding Remarks

All the investigations that have been undertaken so far in the Project area could be used as back ground information for the present anticipated survey. Due to their level and intensity of studies the outputs are not of much significance for the present study. Therefore, considering the objective and intensity of the study, the present survey has been conducted as per the required TOR in order to describe the soil suitability for various crops and other managerial input needs.

Table 5.4: Summary of Morphological Characteristics for the Major Soils of Abbay Basin

Soil Group	Depth	Colour	Texture	Structure	Consistence	Drainage
Acrisols	*Deep to very deep*	*Very dark greyish brown*	*C*	*Subangular blocky*	*Friable, sticky and plastic*	*Well*
Alisols	Deep to very deep	Reddish brown	C – CL - SiC	Subangular blocky	Friable to firm, sticky and plastic	Well
Arenosols	Shallow to moderately deep	Dark yellowish brown	LS	Weak, fine sub-angular blocky & single grain	Slightly hard/friable, sticky and non plastic	Well to excessive
Cambisols	*Moderately deep*	*Brown/dark brown*	*SiC*	*Ang/subangular blocky*	*Hard/friable, slightly sticky, slightly plastic*	*Well*
Fluvisols	Deep to very deep	Variable	C-SiC	Weak to massive	No data	Well
Leptosols	*Shallow to very shallow*	*Brown to Yell Br*	*L-CL-C*	*Subangular blocky*	*Firm to slightly hard/ friable; slightly sticky & slightly plastic*	*Well*
Luvisols	Deep to very deep	Brown/Reddish brown	C-SiC	Subangular blocky	Friable to firm, sticky and slightly plastic	Well
Nitisols	*Deep to very deep*	*Reddish brown*	*C-CL-SiCL*	*Subangular blocky*	*Friable to firm, sticky and plastic*	*Well*
Phaeozems	Deep	Dark grey	CL-C	No data	Slightly sticky & slightly plastic, wet	Moderately well to poor
Regosols	Shallow – mod. Deep	Brown	C-Si-LS-SiC- Sl	Angular/Sub-angular blocky	Slightly hard/friable, slightly sticky & plastic	Well
Vertisols	*Deep to very deep*	*Dark grey/black*	*C*	*Subangular - angular blocky*	*Hard/firm, very sticky and very plastic*	*Imperfect to poor*

Source: Abbay Master Plan Project, Phase 2, Reconnaisssance Soil Survey BCEOM, 1998.

5.10.4 Imagery Interpretation and Base Map Production

5.10.4.1 Aerial Photograph and Satellite imagery Interpretation

Two topographic maps at a scale of 1:50,000 (0836A1 Dinger and 0936C3 Didessa Sheets) and 10 approximately 1:50,000 scale black and white aerial photographs were purchased from the Ethiopian Mapping Authority (EMA). Subsequently, by constructing preliminary legends, aerial photo-interpretation was carried out using the geomorphic/physiographic analysis approach. The photo-interpretation approach was mostly based on classification of different landform, slopes and associated soil tones visible on the aerial-photographs. Furthermore Spot Imagery was interpreted and used to establish the location of soil traverse.

The Spot Imagery was also used to provide an up-to-date view of the present land use and other aspects of land cover, including footpaths and roads and settlements. Furthermore Spot Imagery was interpreted to study an up-to-date view of the present land use and land cover, including foot path, roads and settlements. The Spot Imagery has 5m resolution and rectified from January 2008, then it was produced at 1:5,000 scale.

5.10.4.2 Base Map Production

The interpreted preliminary mapping unit along with its legend was transferred to the Spot Image, which was used as base map in the field. On the base map, features, like surface drainage patterns and land use/cover system of the areas are shown. In addition, location and numbers of auger holes, profile pits, infiltration and hydraulic conductivity test sites were marked on the base map. Based on landform, slope breaks and denudation interpretation on aerial photographs land units were constructed and preliminary legend was given for each land units. Accordingly, soil mapping unit legends were constructed at two levels of generalization, namely, geomorphic units (level 1) and slope classes (level 2). As a result of this, four major land units and 12 sub land units were identified and mapped for the Project Area. These land units are:

G - Gently Undulating Plains with Convex Interfluves

This major land unit is characterized by slopes ranger of 0-6%. It is relatively un-dissected up land found between two streams and currently this area is dominantly occupied by intensive cultivation. It is subdivided into three sub-land units namely,

- G1- Upper Part of Gently Undulating Plains
- G2 - Middle & Lower Part of Gently Undulating Plains and
- G3 - Sloping Basement Ridges & Tors

V - Valley Floor

The area is low-lying land bounded by upland usually traversed by a stream or river which receives the drainage of the surrounding heights. It has slopes range of 0-4%. This major land unit is similarly divided into three sub-land units i.e.;

- V1- Seasonally Wet Valley Floor
- V2- Permanently Wet Valley Floor and
- V3- Moderately Dissected Valley Side

U- Strongly Sloping and Moderately Steep Lands

The major land unit is covering the steep and dissected project area and characterized by three sub-land units;

- U1 -Strongly Sloping Upper & Middle Slope of Hills& Ridges
- U2-Strongly Sloping Lower Part of Hills & Ridges
- S- Moderately Steep Side of Hills & Ridges

Miscellaneous Lands

Under this major land unit three sub-land units are categorize, namely;

- R- Incised Stream Channels
- St- Settlements and
- F- Forest area.

The major and sub-land units were delineated on the base map prior to the fieldwork at planning stage (see Figure 5.1). As a result, auger hole transects and profile pits location were marked on 1:20,000 scale topographic maps and 47 routine auger hole observation transects were laid on the base map. Thus, the soil field survey was carried out with transects spaced 200m apart and with routine auger hole observations at spacing of 400m along the transects.

Figure 5.1: Land mapping units of the Project Area (A3 figure)

5.10.5 Field Work Phase

5.10.5.1 General

The fieldwork activity focused mainly on verification of soil mapping units, soil investigation and soil sampling. The investigations were carried out largely on profiles, auger holes, in-situ physical tests (pH, infiltration, hydraulic tests and deep boring). To carry out the soil survey over the study area, firm grid survey technique was applied with an average observation density of one per ha.

5.10.5.2 Auger Holes Studies

Auger hole investigations were conducted mainly to distinguish soil variations within the survey area and map different types of soils in the area. They were carried out at a grid of 200m X 400m which is equivalent to one auger hole observation for every 8ha. Consequently, 1,243 auger holes were described for the Project area. All auger holes observations were described to a maximum depth of 125cm to check and describe surface features, soil depths, and to delineate soil boundaries. All soil descriptions have been recorded on soil description sheets and auger hole observation points were coordinated using GPS.

Accordingly, the external characteristics and soils information were recorded. Slope percentages by using clinometers. Land forms, land use/cover, presence of stoniness, drainage class, and erosion hazards have been also evaluated. Moreover, the internal soil characteristics such as soil depth, texture, soil color, structure, and depth to groundwater were noted for each auger hole description sheets. The descriptions were made with the help of FAO guidelines prepared for facilitating soil description processes. The details of auger holes observations recorded in the field have been encoded and presented in the Appendix 5I.

5.10.5.3 Soil Profile Pit Studies

Soil profile pit descriptions were carried for different soil horizons. The field examinations were recorded on prescribed formats designed for recording profile pit observations along with other site details. The distribution of profile pits was designed fairly over the surveyed area for rendering information on soil properties of the entire area. In order to characterize the soils for irrigation purposes, soil pits were excavated to a depth of 2m and width of 1m. Regardless of the external surface features, information like soil horizons, structure, consistency, porosity, roots calcium carbonate etc were also recorded. The numbers of profile pits were determined based on the number of auger holes planned. Thus the total number of profile pits is equivalent to 10 percent of the overall auger holes observations. Based on this criterion a total of 103 were studied. On the average 4 disturbed soil samples from each profile pit, weighing about 1kg were collected in polythene bags for laboratory test from generic horizons unless it was restricted by lithic contact. Consequently, about 303 soil samples for determination of pH, EC, Texture, Total Nitrogen, Organic Carbon etc,), were collected. Further more 15 samples for deep boring (pH and Ec), were also collected and analyzed in Water Works Design and Supervision Enterprise Laboratory Center and for the determination of soil moisture availability, 68 disturbed samples were collected and analyzed in the National Soil Testing Center of the Ministry of Agriculture and Rural Development.

The main observations recorded for profile pits were layer–wise, color, texture, structure etc. Moreover, other site-specific observations including land use, topography, cropping pattern, parent material, erosion status etc. were also described and recorded according to the FAO guidelines. Soil color description was preformed according to Munsell soil color charts. Profile description and details of soil laboratory results of model profile pits are presented in Appendix 5A. Pictures (1&2) taken during survey time are illustrated below in Plates 5.1 and 5.2.

Plate 5.1: Inspection of profile pit depth #1

Plate 5.2: Inspection of profile pit depth #2

5.10.5.4 Infiltration and Hydraulic Conductivity Tests

In-situ infiltration and hydraulic conductivity measurements were made on representative 11 model profile pits, which is 10% of the Profile pits. The infiltration measurements were determined at three sites, 10m apart from each other, using Double Ring Infiltrometers. Picture taken during the study time is presented below in Plate 5.3.

Hydraulic conductivity tests were also done in triplicate places using the inversed auger hole test method on 11 model profile pits, in places where soil infiltration tests were conducted. The data are illustrated in tables 5.4 and 5.5 respectively. Furthermore, picture taken during study time is also presented in Plate 5.4.

Plate 5.3: Determination of infiltration rates using double ring infiltro-meter

5.10.6 Post fieldwork

5.10.6.1 General

After accomplishment of field data collection, final data compilations and the soil survey report writing were undertaken. Improvements of soil/land units were conducted on the basis of field observation and topographic information. As soon as laboratory results were obtained, final soil legend was developed and the report along with the soil map was prepared.

Plate 5.4: In-situ determination of hydraulic conductivity tests using inverse auger hole method

5.10.6.2 Laboratory Analysis

Analyses were made in Addis Ababa at the laboratories of the National Soil Testing Center, Ministry of Agriculture and Rural Development. All analysis were performed on the air-dried fine earth fraction (<2 mm). The chemical analyses for the profile pits were made on 304 soil samples sent for determination of the following parameters:

- Particle size distribution. Determined by hydrometer method, following pretreatment with H_2O_2 to remove organic matter, and dispersion aided by sodium hexametaphosphate.
- Bulk density. Determined on oven-dry weight basis using core samples.
- Water content at field capacity and permanent wilting point (0.33 and 15 atmospheres respectively) were determined by pressure plate extractor.
- Electrical conductivity (EC). Determined on the soil/water ratio of 1: 2.5.
- Soil pH. Measured in H_2O and 1 M KCl at a soil/solution ratio of 1:2.5.
- Organic carbon. Determined by the wet combustion procedure of Walkley and Black.
- Exchangeable Ca, Mg, K and Na. These were extracted by leaching with 1 M NH4OAc at pH 7, and the cations in the leachate were measured by atomic absorption spectrophotometer.
- Cation Exchange Capacity (CEC). Determined by saturation with NH4OAc at pH 7 and subsequent replacement of NH4 by NaCl extraction.
- Available Phosphorus. Determined by 0.5 M sodium bicarbonate extraction solution (pH 8.5) method of Olsen.
- Free $CaCO_3$ content. Determined by acid neutralization method.

- Exchangeable Acidity was determined using Van Reeuwijk's procedure.
- Available Micronutrients. Determinations used method of Lindsay and Norvell.
- A total of 68 disturbed samples were collected and analyzed for determination of soil moisture availability, at the National Soil Testing Center of the Ministry of Agriculture and Rural Development.

5.10.6.3 Data Encoding

All the field investigation data, collected during the field survey, and laboratory analysis results have been entered into database in Microsoft Excel for storage and processing. The soil database consists of the following five different database recordings on different aspects:

- Location and site description,
- Horizon description,
- Physio-chemical analysis,
- Infiltration tests, and
- Hydraulic conductivity tests

5.10.6.4 Soil Database and GIS

The data collected from the field and laboratory results were encoded and the final soil map was digitized to facilitate the data entry into GIS. The soil database was then linked to the GIS, which contains the map information in a digital form. The profile pit description data have been encoded using MS Word 2007. While preparing thematic maps by GIS, the data entered in MS Excel was transformed in database IV format to use ArcMap GIS. Then, through interconnecting soil database with GIS, statistical and cartographic information have been generated. This was performed by simple extraction and interpretation of one or any combination of attributes using complex models and combining attributes from different sections of the databases.

5.10.6.5 Data Elaboration and Manipulation

In order to characterize properly the final soil mapping unit, the soil database was checked thoroughly. All the field observation points (profile pits and auger holes) have been plotted in the digitized soil map units, and all observations within one soil unit were used to characterize the mapping units.

In this manner a soil description has been made for each soil grouping, using dominant soil characteristics, such as color, drainage, texture, soil depth and slope. In addition soil physico-chemical properties, which are related to one more representative profile, were described.

5.10.6.6 Final Soil Map Production

Once laboratory results were available, all field descriptions were studied and amalgamated. Subsequently, the final map legend was prepared based on field survey and a soil classification has been undertaken according to the World Reference Base for Soil Resources FAO –1998. The soil map unit was constructed on the basis of the land characteristics, which were delineated, on aerial photograph, satellite imagery, topo-map and supported by field observation. As a result the final soil map of the Project area was produced at the scale of 1:10,000.

5.11 INTERPRETATION OF ANALYTICAL DATA OF THE STUDY AREA

5.11.1 General

This chapter presents the approaches and details of the chemical and physical properties of the soil used that were employed in the soil classification attempts. It also presents the overall picture of the soil characteristics of the surveyed area.

5.11.2 Chemical Characteristics

In general, chemical properties of the soil influence the planning of agronomic development activities that are best suited to the proposed irrigation project. As the level of elements measured in soils varies according to laboratory methods and procedures and spectrum of field crops that have different nutrient requirement and toxicity tolerance level, there are no worldwide accepted single criteria used for the interpretation of laboratory results. However, the following summary criterion should be regarded as a general one based on literature in compliance with the applied laboratory methods and procedures. Its main use is to evaluate the natural fertility of soils and to indicate its potentials, abundance or otherwise deficiency in the Project area. For the interpretation of analytical data, summary criteria and recommended range value for the interpretation of soil parameters are given in Appendix 5F.

5.11.2.1 Soil Reaction (pH)

Soil reaction has an important function in the formation and behavior of different types of soils, especially under tropical conditions. It does not have precise significance but some generalizations can nevertheless be made for interpretative purposes. The pH tolerance limits to the growth of different plants, but for most commercial crops a neutral range is most suitable i.e. pH values between 5.5 and 7.5.

The average pH value of the surface soils of the surveyed area is 5.5 and the maximum and minimum pH values as measured in 1:2.5 soil-water suspension ranges from 7.1 to 4.5 which indicate that the soil reaction ranges from neutral to acidic. Similarly the sub-soils have average 5.4, maximum 7.9 and minimum 4.2values. Summarized chemical analysis result is presented in Table 5.7 and in-situ pH results are also presented in appendix 5E. The Δ pH, defined as pH KCl – pH H2O, of all the soil samples have constantly negative values, indicating that the soils have colloidal complexes of net negative charges.

5.11.2.2 Organic Carbon (OC)

Organic carbon is often used as a measure of the quantity of organic matter in the soil, which in turn is taken as a crude measure of fertility status. Likewise, organic matter is the principal storehouse for nutrients influencing soil structure and biological activity. It has been determined by using Walkly and Black method in the laboratory and expressed in percentage. The average, minimum and maximum values of the surface organic carbon content of the soils of the investigation area is 3.6, 1.1 and 7.8% respectively. While, in the sub-surface the average value is 1.4%, maximum 5.2%, and minimum 0.04%. In general, they decrease gradually in depth, which indicates that surface horizons are relatively characterized by accumulation of higher, humidified organic matter content than the sub-surface soils. In soil fertility evaluation values less than 2% of organic carbon as determined by the Walkley - Black method is deemed to be very low. Seeing that soils of the study areas have an average value of greater than 3.6% on surface and 1.4% in sub-surface organic carbon content, hence the response of the soils to organic fertilizer is expected to be high.

5.11.2.3 Total Nitrogen Percentage (TN%)

Nitrogen is an essential nutrient element, which highly influences the plant growth. It is a constituent of chlorophyll and plant proteins. The maximum and minimum values of the total nitrogen percentage of the surface soils range from 0.7% to 0.1% and have an average value of 0.3%. Likewise, the sub-surface soils have average, maximum and minimum values of 0.1%, 0.4% and 0.02% respectively. Therefore, the average values for surface and sub-surfaces soils are found in the range of high (0.3%) to medium (0.1%).

5.11.2.4 Carbon: Nitrogen (C: N) Ratio

The C: N ratios are commonly quoted as indications of organic matter present and, in particular the degree of humification. C: N ratio is an indicator of the process of transformation of organic nitrogen to available nitrogen such as ammonium nitrite and nitrate**.** A minimum acceptable C: N ratio value on surface is 10:1. Accordingly, the average carbon nitrogen ratio value of the soils under study is found within the range of 1: 12. Thus, the organic matter of the soils is found within the range of medium

5.11.2.5 Cation Exchange Capacity (CEC)

Cation Exchange Capacity (CEC) measurements and the derived base saturation percentage are usually used as one of the criteria used for the overall assessments of the potentials fertility status of a soil and possible response to fertilizer application. The FAO (1979) quote CEC values of 8-10 meq/100g of soil as indicative minimum values in the top soil for satisfactory production under irrigation, provided that other factors are favorable. In general, any CEC values of less than 4meq/100gram of soil indicate a degree of infertility or unsuitability of the soils for agricultural development. Accordingly, the maximum and minimum value of cation exchange capacity (CEC) of surface soils of the survey area are 10.2 and 54.1 meq/100g soils respectively, where as the average value is 30.5 meq/100g soils, which is found to be in high range. Similarly, the sub-surface soils have an average, maximum and minimum value of 24.0 meq/100gm soils, 71.6 meq/100gm soils and 6.9 meq/100gm soils respectively.There is a direct correlation between CEC and texture of the soils. The analytical result indicates soils with fine textural classes have higher value of CEC and base saturation percentage for all profile pits.

5.11.2.6 Base Saturation Percentage (BSP)

The proportion of the CEC accounted for by exchangeable bases (Ca, Mg, K & Na) is frequently used as an indication of soil fertility. Unfortunately, base saturation percentage (BSP) does not distinguish between different bases. One should bear in mind that the imbalance in the relative proportion of cations can cause severe plant nutrition problems. BSP values are mostly used as indicators in the process of soil classification. In line with that, BSP > 50% is considered as fertile soil and BSP < 50% is taken as less fertile soil. The calculated BSP values of the surface soils of the study area are found between 15.3 and 95.6 with an average of 48.1. Similarly, the values of the sub-surface soils are found minimum 9, maximum 100 and average of 45.4, indicating that the inherent fertility status of the soils of study area is low to medium. In general soils like Vertisols, Cambisols, Leptosols have average base saturation percentage greater than 50% on surface and sub-surface. To the contrary, Nitisols and Acrisols have less base saturatione percentage value, Table 5.5.

5.11.2.7 Exchangeable Cations (Ca, Mg, K & Na)

The levels of exchangeable cations in a soil are usually of more immediate value in advisory work than the CEC, because they not only indicate existing nutrient status, but can also be used to assess balances amongst cations. This is of great importance because many effects, for example on soil structure and on nutrient uptake by crops, are mostly influenced by the relative concentrations of cations as well as by their absolute levels. Their balances vary in the soil. The ideal cation balance in the soil is calcium occupies 76%, Magnesium 18%, Potassium 6% and Sodium 0%. (Frank Beernaer, Mozambique, 1990).

5.11.2.8 Exchangeable Calcium (Ca)

Normally, Ca deficiency as a plant nutrient occurs only in soils of low CEC at pH values of 5.5 or less. Calcium may also be effectively deficient at high pH levels when there is excessive sodium content. Although it is known that Ca ions have an affinity for phosphate, the effect of the interaction on availability to plants is not well understood. It should be noted, however, that in calcareous soils and soils with high exchangeable Ca phosphorous may be less available to plants. According to the laboratory results the content of exchangeable calcium on surface soils varies from 1.8 to 31.6 with an average value of 10.3meq/100grams of soil. Whereas, in subsurface the value are ranging from 1.8 to 52 with an average value of 7.4meq/100grams of soils. Exchangeable calcium cation greater than 20 meq/100g soil is considered as high level in the soils.

5.11.2.9 Exchangeable Magnesium (Mg)

The presence of Mg deficiency in a crop may not only be associated with low Mg content in the soil, but also with the presence of large amount of other cations, particularly Ca and K. With increasing Ca: Mg ratios above about 5:1, the Mg may become progressively less available to plants. Although soils can remain fertile over a very wide range of Ca: Mg ratios. As it is seen from summerized laboratory result of Table 5.5, the average value of exchangeable magnesium on surface soils is 3.6 meq/100g soils, which is high. Its average value decreases in subsurface to 3.0 meq/100g soils. When Mg is present in very much larger amounts than Ca, Ca will be less available for plants and soil structure becomes weaker due to increased deflocculating of the clay. Its value in surface samples varies from 0.9 to 17 meq/100g soils which is found in high range.

5.11.2.10 Exchangeable Potassium (K)

The overall potassium status of the surfaces soils of the study area varies from 0.1 to 2.0 with an average of 0.5meq/100grams of soil. Similarly, the value of the sub-surface soils varies from 0.1 to 3.3 with an average value of 0.3meq/100grams of soils. And indicate that the average k value of the surface and sub-surface soils are found in the medium range. With high exchangeable potassium percentages (EPP) say above 25% the permeability and structure of the soil may be adversely affected, but not as seriously as with high sodium percentage. In the case of the study area the average value of the surface and subsurface soils are 1.7 and 1.2% respectively.

5.11.2.11 Exchangeable Sodium (Na+)

The overall content of exchangeable sodium of the surface soils of the study area in meq/100g of soil varies from 0.1 to 0.9 with an average of 0.2. And the value for sub-surface are average 0.2meq/100g of soil with minimum and maximum value of 0.1meq/100g and 1.9meq/100grams of soil respectively. In general the average, maximum and minimum content of Na is low, thus it will not imply any adverse effect on soil profile such as increasing dispersion.

5.11.2.12 Calcium (Ca): Magnesium (Mg) ration

In acid soils calcium supplies are smaller than in alkaline soils. Part of the peril of Aluminum toxicity is related to calcium deficiency. Magnesium excess is indicated when exchangeable magnesium represents more than 40-60% of the cation-exchange capacity, or the Ca: Mg ratio is less than 1. With increasing Ca: Mg ratio above about 5:1 the Magnesium may become progressively less available to plants. When Mg is present in very much larger amount the Ca, the latter may become somewhat less available, and soil structure become weaker due to increased deflocculated of the clay. As it is seen, from laboratory result the average Ca:Mg ration of the surface and sub-surface soils of the study area are 3:3 and 2:8 respectively, which is found at optimum range for most of the crops. Ca:Mg approximate rating/interpreting common values are presented in appendix 5F # 11.

5.11.2.13 Ca+Mg/K

Calcium plus Magnesium to Potassium ratio helps for the estimation of the amount of fertilizer needed to manurate the soils. Ca+Mg/K ration greater than 40 indicates relatively overdose of Ca+Mg or lack of potassium in the soils. Likewise, when the value is found between 0 and 15 it shows lack of Ca or Mg in the soils. In the case of the study area the average rate of surface and sub-surface soils are found to be 35 and 47 respectively. The difference of the value shows that accumulation of the cations in sub-surface due to percolation from surface soils. Approximate interpreting value is presented in appendix 5F #11.

5.11.2.14 Exchangeable Sodium Percentage (ESP)

Sodium is not an essentially plant nutrient. Its absence or presence in only very small quantities is therefore not usually detrimental to plant nutrition. However, when sodium is present in significant quantities in soil, particularly in proportion to other cations, it can have an adverse effect, not only on many crops but also on the physical conditions of the soil. A widely used measure of the effects of high sodium level is the exchangeable sodium percentage (ESP). The exchangeable complex of the soils of the study area is largely occupied by calcium and magnesium followed by potassium. Therefore the ES percentage value of surface soils is less than the sub-surface soils with an average value of 1.2 on surface and 1.8 in sub-surface, (Table 5.5). In general, the average value of the exchangeable sodium percentage within 100cm depth is less than 2%, which is very low.

5.11.2.15 Electrical Conductivity (EC)

The electrical conductivity measurements are used as an indicator of total soluble salts in the soil. It is measured in a saturation of extract of the soil water suspension using a conductivity meter. The EC of the surface soil of the study area varies from 0.01 to 0.4 with an average of 0.1dS/m. Likewise, in sub-surface the value relatively decreases in depth and ranges from 0.01 to 0.4 with an average value of 0.04dS/m. In general, the EC values indicate that the soils of the Project area are free of salinity. Hence, salinity should not be a constraint for any crop production in the study area (Table 5.5).

5.11.2.16 Available Phosphorus (Av.P)

Available Phosphorus is the amount of phosphorus readily available for nutrient absorption by plant roots. To determined available phosphorous content of the soils of the study area Olsen's method of bicarbonate extraction method was used. As a result, the average available phosphorus content of the surface soils of the study area is found to be 18.8 ppm which is high (sufficient) and its value decreases gradually to 12.8ppm (medium) in sub- surface. Therefore, the response of soil to phosphorus fertilizer is at the time being is not required but, in the near future application phosphorous fertilizer would be expected.

5.11.2.17 Calcium Carbonate ($CaCO_3$)

The presence of calcium carbonate in the soil indicates that the clay complex is dominated by exchangeable calcium, which typically implies favorable soil physical conditions such as structure. The content of carbonates has been determined at the field level using a 10% HCl solution, and quantitative analyses have been done in the laboratory. Calcium carbonate was observed only on 7 profile pits (DP32, 34, 56, 83, 98 & 105). Thus, on mesotrophic Vertisols and fluvic Cambisols low value of Calcium carbonate were observed. On the other soil types thre is no evidence of $CaCO_3$. In general the value ranges from 0.45 to 6.2 with an average value of 2.65%. As FAO definition, high level of $CaCO_3$ > 15 % affects the physical as well as the chemical properties of the soils.

5.11.2.18 Exchangeable Acidity

Since pH does not precisely identify soils that need lime, determination of acidity and lime required should preferably be measured in terms of exchangeable acidity rather than pH reading. In acid soils the exchange acidity equals the sum of the exchangeable bases plus the exchange acidity. For the determination of exchangeable acidity of soils of the study area 40 soil samples that have < 5.5 pH and falls in strong acid category were selected for analysis. In consequence, when they were tested for exchangeable acidity only 6 samples out of the suspected 40 samples of the soil confirm high exchangeable acidity level. Based on these facts, profile pits DP (52, 79, 80, 86, 90, and 94) have got high exchangeable acidity in the ploughing layer. The maximum acid saturation percentages of profile pits are 46.5, 42.4, 42.5, 38.0, 67.7 and 42.1% respectively. Exchangeable acidity result of selected soil samples is presented in appendix 5C.

5.11.2.19 Micronutrients

Micronutrients are an element that plants must have to complete their life cycles, but only a small amount is required. These elements have often been called trace elements. The amounts of various micronutrients present in soil are extremely variable both among the micronutrients and from one soil to another. Soils properties, especially pH and degree of aeration have a strong influence on the availability of the micronutrients. Since, pH of soils of the study area is low determination of availability of micronutrient of the soils, like Iron (Fe), Manganese (Mn), Copper (Cu) and Zinc (Zn) nutrients were undertaken by using DTPA extracting agent. They are characterized by the following properties.

1. Iron (Fe)
Iron toxicity severely limits on strongly acid soils (with a pH of more than 5), which contain moderate to high amounts of organic matter and reactive iron. Iron toxicity is often associated with a deficiency of phosphate, potassium, zinc, calcium and manganese.

2. Manganese (Mn)
The chemical behavior of Mn in soil is very similar to that of Iron. Its deficiency occurs mainly in poorly drained soils. Total quantities of Mn in soil vary from 100ppm to several thousands of ppm. Manganese availability is closely related to the degree of soil acidity. Nevertheless, when the pH is acidic with pH values of about 5.5 or less it becomes toxic. Values below 20ppm or mg/kg soil are considered as deficient and those over 300ppm are considered toxic. (Department of crop and soil science, Michigan State University, Extension Bulletin, August, 1994).

3. Copper (Cu)
Total Cu in soil falls in the range of 2-100ppm. Its availability is also influenced by soil pH. It decreases slowly with increasing pH. In general, high level of total Cu in soils can be taken as those above about 100ppm and with average value of 30ppm. (E.E. Schulte, University of Wisconsin 1999).

4. Zinc (Zn)
In high rainfall area quantity of Zinc is relatively low. For most crops deficiency system are rarely encountered in the crops in the field. Total Zinc contains in the soil vary from 10-100ppm. In, general its deficiency system occur in acidic soils. Zinc deficiencies are most often seen on sandy soils with high pH levels. Large applications of phosphorus may aggravate zinc deficiencies. Livestock manure is often an excellent source of zinc. (Ontario, 2009).

Based on the laboratory analysis results, the overall average micronutrient value of the Iron, Manganese, Copper and zinc of the ploughed layer of soils of the study area are found to be in adequate category with average values of 67.3, 55.1, 2.1 and 8.5 mg/kg/ppm soil respectively, Table 5.5. Indicative level of micronutrients in the soils and their value ratings are presented in Appendix 5F#13.

5.11.3 Physical Characteristics

5.11.3.1 General

The physical characteristics of soil in the Project area are discussed here under in brief.

5.11.3.2 Texture

Soil texture is a very important physical characteristic of the soils. The soil texture analysis has been carried out in the field by feeling test and laboratory investigation. The texture classes of the investigated soils vary from clay loam to clay for reddish and reddish brown soils and clay to heavy clay for Vertisols. The result of laboratory analysis showed that the content of clay in Vertisols varied from 28.7% to 67.3%, where as in reddish brown soils which are located on gently undulating plain up land areas have on average loam and clay loam texture class. Similarly, soils like fluvic cambisols, with very dark brown soil color have clay loam texture. The soil texture is used to drive hydro-dynamic properties such as water holding capacity (WHC), drain ability of the soil. Workability and the draft requirements of the soil are also determined with soil texture as well as soil structure. In addition, pore-size distribution or pore-geometry of soils is also determined with soil texture. Laboratory results of soil texture class of each land unit are presented in Appendix 5D2.

5.11.3.3 Drainage Classes

The moisture condition of the valley floor area soils was found moist after 30cm soil depth and increases progressively in sub-soils while, other soil types were dry and slightly moist during investigation time. In general, the soils in the valley floor areas have imperfect and poor drainage systems whereas, soils of elevated and hilly areas have somewhat excessively to well drainage. The Vertisols in most parts of the areas have encountered ponds or sink holes up to 1.0m diameter, which holds water during rainy season. As it has been investigated by deep boring most of the soils of survey areas have a deep water table. Depth of ground water table is not a key constraint, which is greater than 5m.

5.11.3.4 Soil Color

Soil color is the most obvious features of the soils that can be easily identified. It has relates to specific chemical, physical and biological properties of the soil. It was measured under dry & moist conditions by determining the Hue, Value and Chroma of the soils using Munsell soil color chart. Soil color of the survey area is mainly related to drainage and to lesser extent, to parent material. Accordingly, the poorly drained valley floor area soils have dark brown (10YR3/1) color on surface and grayish brown (10YR5/2) color in sub-surface, while moderate to well drained soils are characterized by dark reddish (5YR3/4) color on surface to red yellowish color in sub-surface.

Table 5.5: Summarized Average, Maximum & Minimum Analatical Laboratory Results of the Soils

Surface Soils

Value	PH (1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/ Mg	Ca+Mg/ K	Micronutrient mg/kg soil			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.5	4.6	-0.9	0.1	0.3	3.6	12.3	18.8	0.2	0.5	10.3	3.6	14.6	30	48.1	1.2	3.3	35	67.3	55.1	2.1	8.5
Maxi.	7.1	6.5	-0.7	0.4	0.7	7.8	23.3	152.5	0.9	2	31.6	17	36	54.1	95.6	56.2	20	137	408.2	153	11.4	79.2
Min.	4.5	3.7	-0.8	0.01	0.1	1.1	2.7	0.6	0.1	0.1	1.8	0.9	2.9	10.2	15.3	0.2	0.9	9.6	15.1	1.7	0.6	0

Sub-Surface Soils

Aver	5.4	4.5	-0.9	0.04	0.1	1.4	12	12.8	0.2	0.3	7.4	3	10.9	24	45.4	1.8	2.8	46.6				
Max	7.9	7.8	-1.1	0.39	0.4	5.2	60.5	219.5	1.9	3.3	52	14.5	63.5	71.6	122	89.9	27	215.3				
Min	4.2	3.5	-2.9	0.01	0.02	0.04	0.1	0.1	0.1	0.1	1.8	0.9	2.9	6.9	9	0.1	0.9	2.3				

Source : Analytical laboratory result of MCE, 2009

5.11.3.5 Soil Structure

Soil structure refers to the natural organization of soil particles into distinct soil units (aggregates or peds) that result from pedogenic processes. The aggregates are separated from each other by pores or voids. To describe soil structure of the Project area grade, size & type of structure were recognized. Thus, based on field investigation result most of the valley floor area soils, were characterized by strong grade, coarse to medium size on the surface and moderate grade, medium size and platy to prismatic structure in sub-surface. While, the well drained gently undulating plain and hilly area soils have moderate to weak grade, medium size and granular structure in surface. These soils have good workability condition.

5.11.3.6 Deep boring

In order to check the depth of impervious horizon and to monitor fluctuation of water table of the soils of the study area deep borings were conducted at representative 11 sites. The deep boring test auger holes were conducted mostly after 2m and to the maximum depth of 5.8m at place where in situ physical tests have been conducted. Accordingly, in spite of impervious horizon, fluctuation of water table was not observed in all sites even to a maximum depth of 5.8m. The maximum test 5.8m was conducted on profile pit Dp39. On average the tests were investigated largely up to 3m depth. Consequently, 15 deep boring soil samples were collected from 11 sites for determinate of pH and EC of the soils. The deep boring soils have pH reaction of 4.7 to 7.4 and the value for all the tests decrease gradually in depth. The neutral, 7.4 soil reaction was observed on Vertisol soils on profile pit DP 103. The profile pit site is found on seasonally wet valley floor grass land units. The electrical conductivity value of all soils is also very low; maximum value (0.04 dS/m) was recorded similarly on DP 103 in depth 190- 300cm. All the samples indicate free of salinity. The excavations of deep borings were stopped in all sites due to lithic contact of the soils.

5.11.3.7 Effective Soil Depth

As it has been investigated in field, most of the Project area soils in valley floor and gently undulating plain have very deep soil depth. Thus, effective soil depth is not a major limitation for irrigation development in these areas. To the contrary the soils, which are found on the strongly sloping and moderately steep areas, have moderate and shallow soil depth.

5.11.3.8 Infiltration Rate

Infiltration rate refers to the measurement of vertical intake of water into a soil surface and it is important parameter for selection of irrigation systems and management techniques. For the determination of infiltration rate of the soils of survey area, in-situ infiltration tests were carried out. The investigations were undertaken mostly on deep and relatively potential areas which have extensive area occupation. It was studied by using Double Ring Infiltrometer in triplicate which is 10m apart from each other. The basic infiltration rate (IR) of the soils of valley floor area, vertisols ranges from 6.3 to 6.8cm/hr which is found to be marginally suitable level. The reason for higher IR rates measurement of the Vertisols is found due to wide surface and subsurface soil cracks and temperature condition of the area. Soils located on gently undulating areas have basic infiltration ranges of 6.8 to 10.0cm/hr, which is marginally suitable. In general, well drained soils of the study area have relatively higher infiltration rates than the poorly drained soils. Soils with high basic infiltration rates may be unsuitable for flood or furrow irrigation and it may be preferable for overhead irrigation. Determined basic infiltration rates of model profile pits of the study area are shown in Tables 5.6 and complete filed data and recommrnded rating ranges are presented in Appendix 5B and 5F #4 respectively.

Table 5.6: Basic Infiltration Rate of Model Profiles Pits

No	Model Profile	Mapping Unit	Soil type (FAO-1998)	Basic Infiltration Rate (cm/hr)
1	DP2	G1b_2	Rhodic Nitisols (NTro)	6.9
2	DP3	G1b_1	Orthidystric Nitisols (NTdyo)	9.5
3	DP9	V1b_3	Mesotrophic Vertisols VRms)	6.8
4	DP12	G2d_1	Orthidystric Nitisols (NTdyo)	9.7
5	DP18	G2d_1	Orthidystric Nitisols (NTdyo)	9.9
6	DP52	Gb2_4	Hyperferric Acrisols (ACfrh)	10.0
7	DP65	V3c_8	Fluvic Cambisols (CMfv)	9.7
8	DP78	G1b_1	Orthidystric Nitisols (NTdyo)	9.2
9	DP83	V1b_3	Mesotrophic Vertisols VRms)	6.3
10	DP86	Gb2_4	Hyperferric Acrisols (ACfrh)	9.1
11	DP90	G1b_4	Hyperferric Acrisols (ACfrh)	8.6

5.11.3.9 Hydraulic Conductivity Measurements

The hydraulic conductivity (permeability) of the soil is a volume of water, which passes through a unit cross sectional area of the soil unit in a given time. It is expressed in m/day. Its measurements provide information on permeability and drainage characteristics of different soils. The measurements were undertaken in inverse auger hole method in triplicate at each representative model profiles sites. In general, the average hydraulic conductivity (HC) value of the survey area varies from 0.1 to 3.63m/day, which is found in the range of very slow to rapid. The test was under taken at the same place with infiltration measurements. As it is investigated in the field the soils that are located in valley floor areas have lower hydraulic conductivity tests comparing to the gently undulating plain elevated up land areas. Accordingly, on Vertisols, on DP9 and DP83 mapping units very slow hydraulic conductivity tests were recorded, while on well drained Nitsols and Acrisols soils relatively 3.63m/day (very rapid) and 2.4m/day (rapid) Hydraulic conductivity tests were recorded respectively. Summary results of the hydraulic conductivity measurements of model profile pits are shown below in Table 5.7 and complete filed data are presented on Appendix 5B2.

Table 5.7: Summary of Hydraulic Conductivity Test (m/day) of Model Profile Pits

No	Model Profile	Mapping Unit	Replicate Rate K (m/day)	Average Rate K (m/day)	Soil Type (FAO -1998)
1	DP2	G2d-2	6.59		
			2.09	3.63	Rhodic Nitisols (NTro)
			2.2		
2	DP3	G2d_1	0.58		
			1.06	1.3	Orthidystric Nitisols (NTdyo)
			2.27		
3	DP9	V1b_3	0.36		
			0.56	0.04	Mesotrophic Vertisols VRms

			0.28		
4	DP12	G2d_1	4.51		
			4.43	3.6	Orthidystric Nitisols (NTdyo)
			1.87		
5	DP18	G2d_1	0.50		
			0.25	0.38	Orthidystric Nitisols (NTdyo)
			0.39		
6	DP52	G1b_4	1.92		
			2.44	2.4	Hyperferric Acrisols (ACfrh)
			2.85		
7	DP65	V3c-8	0.88		
			1.32	1.40	Fluvic Cambisols (CMfv)
			1.99		
8	DP78	G1b-1	2.10		
			1.00	1.50	Orthidystric Nitisols (NTdyo
			1.38		
9	DP83	V1b_3	0.51		
			0.18	0.10	Mesotrophic Vertisols VRms
			0.21		
10	DP86	Gb1_4	2.22		
			5.83	2.95	Hyperferric Acrisols (ACfrh)
			0.81		
11	DP90	G1b-4	4.10		
			1.50	1.96	Hyperferric Acrisols (ACfrh)
			0.28		

To compare the in-situ physical tests of infiltration rates and hydraulic conductivity tests summary results of the two parameters are presented below in Table 5.8.

Table 5.8: Approxmate Relationship of Texture with Infiltration & Hydraulic Conductivity Tests

No	Mapping Unit	Soil Texture	Basic Infiltration Rate (cm/hr)	Hydraulic Conductivity Test K (m/day)
1	G2d_2	Clay loam	6.9	3.63
2	G2d_1	Clay loam	9.5	1.30
3	V1b_3	Clay loam	6.8	0.40
4	G2d_1	Clay	9.7	3.60
5	G2d_1	Clay	9.9	0.38
6	G1b_4	Sandy Loam	10.0	2.40
7	V3c-8	Sandy Clay L	9.7	1.40
8	G1b_1	Clay	9.2	1.50
9	V1b_3	Clay	6.3	0.10
10	Gb1_4	Clay	9.1	2.95
11	G1b_4	Sandy Clay L	8.6	1.96

5.11.4 Soil Moisture Characteristics

5.11.4.1 General

Soil, water and plant relationship is the fundamental factor for irrigation management. Water retention capacity of a soil in the rooting zone has direct bearing on the required depth and frequency of irrigation. For the determination of bulk density, field capacity, permanent wilting point and soil moisture percentages, 68 undisturbed soil samples were collected from the field and analyzed in the National Soil Testing Laboratory. Consecutively, based on the determined moisture content the available water holding capacity and total readily available (TRA) water holding capacity of the soils were calculated. The calculated water holding capacity of the major soil types are presented blow in Table 5.10.

5.11.4.2 Bulk Density (BD)

Bulk density is determined by the dry weight of 100ml undisturbed core sample taken at field in moist condition. To determine BD of soils of the study area, 68 undisturbed soil samples were collected and analyzed in the National Soil Testing Laboratory Center. The result shows that the BD value of soils of the study ranges from 1.2 to 1.5, Table 5.9.

Thus, the overall BD values indicate that the soils in the study area are not compact and do not restrict root development and water movement.

5.11.4.3 Field Capacity (FC)

If a soil, not under cultivation, is saturated and left to drain, the soil moisture stored in the pore space (after drainage) is known as field capacity. The field capacity of the soil largely depends on the soil texture and structure. Fine textured soils retain more water than coarse textured soils. The field capacity value of soils of the study area varies from 12.6 to 42.3%, with an average value of 27.8%. The fine textured, valley floor area soils retain more water than gently undulating plain area soils. Laboratory results of the FC of soils of the study area are shown below in Table 5.9.

5.11.4.4 Permanent Wilting Point (PWP)

In the field, soil water content gradually decreases from field capacity by continual evapotranspiration process and the soil reaches the wilting point, unless water is replenished before this stage reached and considered as the lower limit of water availability. Plants cannot meet the ETo requirement at wilting point and as a result they run into water stress and this stage is known as Permanent Wilting Point. The Permanent Wilting Point of the study area ranges from 8.2 to 27.7% and have an average value of 20.4%.

5.11.4.5 Available water holding capacity (AWC)

Available water holding capacity (AWC) is the volume of water retained between field capacity and permanent wilting point. Theoretically, all available moisture is not accessible to plants due to imperfect drainage, hydraulic conductivity of the soil and stage of plant growth. Total available water holding capacity value of any soil varies depending upon soil textural classes, organic matter and bulk density. The latter specially varies due to pore geometry of the soil. Soils with coarse texture classes have low AWC and those with fine texture classes have relatively high AWC. For the calculation of AWC of the soils the following formula is used.

$$\mathbf{AWC} = \frac{\mathbf{(FC\text{-}PWP) \times horizon\ depth \times BD}}{\mathbf{100}}$$

The calculated average available water holding capacity (AWC) and readily available water capacity (RAWC) value of the model profile pits are shown in Table 5.9 and in Table 5.10 available waterholding capacities of major soil types are presented.

Table 5.9: Field Capacity, Permanent Welting Point PWP, and Available Water Holding Capacity (AWHC)

Pro. Code	Horizon	Depth (mm)	Texture Class	F.C %	P.W.P %	Bd gm/c	AWC cm/m	Horizon cm/m	AWC mm/m	TRAWC mm/m	FAO Soil Unit -1998
DP2	0-30	300	Cl	32.7	23.8	1.3	11.5	34.6			Rhodic Nitisols (NTro)
	30-70	700	C	33.5	26.3	1.4	10.0	70.1	105	62.9	
DP3	0-50	500	CL	32.8	24.9	1.3	10.4	51.9			Orthidistric Nitisols
	50-100	500	C	34.8	26.4	1.3	10.9	54.6	107	63.9	
DP9	0-30	300	Sacl	22.5	16.4	1.4	8.2	24.7			Mesotrophic Vertisols (VRms)
	30-70	400	CL	23.2	16.4	1.3	8.9	35.5			
	70-100	300	CL	25.1	17.1	1.3	10.4	31.2	91	54.8	
DP11	0-16	160	Clay	21.4	16.1	1.3	6.8	11.0			Orthidistric Nitisols
	16-46	300	Clay	23.9	18.3	1.3	7.1	21.4			(NTdyo)
	46-132	540	Clay	23.9	19.2	1.2	5.8	31.1	63	38.0	
DP12	0-40	400	Clay	29.3	21.8	1.3	9.3	37.1			Orthidistric Nitisols
	40-70	300	Clay	29.8	23.4	1.4	8.6	25.8			(NTdyo)
	70-100	300	Clay	30.1	23.0	1.5	10.3	30.9	94	56.2	
DP18	0-40	400	Clay	31.8	24.7	1.2	8.6	34.6			Orthidistric Nitisols
	40-70	300	Clay	33.2	25.9	1.2	8.9	26.8			(NTdyo)
	70-100	300	Clay	33.4	26.3	1.4	9.8	29.3	91	54.4	
DP20	0-12	120	Sacl	21.0	15.5	1.4	7.3	8.8			Orthidistric Nitisols
	12_32	200	Clay	23.1	18.3	1.3	6.1	12.2			(NTdyo)
	32-115	680	Clay	23.3	19.0	1.3	5.5	37.7	59	35.2	
DP26	0-22	220	Sacl	13.2	9.0	1.3	5.6	12.4			Orthidistric Nitisols
	22-50	280	Sacl	12.6	8.7	1.3	5.2	14.6			(NTdyo)
	50-75	500	Sacl	12.8	8.2	1.3	6.0	30.2	57	34.3	
DP39	0-29	290	CL	34.5	25.7	1.3	11.6	33.6			Rhodic Nitisols (NTro)
	29-47	180	Clay	34.2	26.8	1.2	8.8	15.9			
	47-75	530	Clay	34.7	27.7	1.3	9.3	49.4	99	59.3	
DP41	0-19	190	Silt L	31.7	25.0	1.4	9.1	17.3			Orthidistric Nitisols (NTdyo)
	19-34	150	Clay	32.4	26.0	1.2	7.7	11.6			
	34-62	280	Clay	32.9	26.3	1.4	9.3	26.1			
	62-127	380	Clay	33.5	26.4	1.4	10.1	38.3	93	56.0	
DP47	0-12	120	Clay	26.6	19.5	1.4	9.8	11.8			Orthidistric Nitisols
	12_30	180	Clay	28.5	21.6	1.5	10.1	18.1			
	30-65	700	Clay	30.9	23.1	1.5	11.3	79.4	109	65.6	(NTdyo)
DP65	0-50	500	Sacl	22.1	14.4	1.4	10.6	52.8			Fluvic Cambisols
	50-100	500	Clay	23.4	16.8	1.3	8.6	42.8	96	57.3	(CMfv)
DP52	0-40	400	Sal	28.6	20.1	1.4	11.8	47.3			HyperferricAcrisols (ACfrh)
	40-70	300	Sal	28.4	20.6	1.3	9.8	29.3			
	70-100	300	Clay	27.8	21.1	1.3	8.6	25.7	152	91.4	

DP67	0-14	140	Loam	27.0	19.6	1.4	10.2	14.3			HyperferricAcrisols (ACfrh)
	14-45	310	Sacl	26.9	20.3	1.3	8.9	27.7			
	45-80	550	Clay	29.1	22.4	1.3	8.5	46.6	89	53.1	
DP69	0-20	200	L	32.9	23.5	1.4	13.1	26.1			Hypereutric Cabisols (CMeuh)
	20-.64	440	Clay	28.3	21.4	1.3	8.8	38.8			
	64-160	360	Clay	29.8	23.9	1.4	8.2	29.5	95	56.7	
DP77	0-17	170	Clay	28.3	21	1.3	9.2	15.6			Orthidistric Nitisols NTdyo
	17-57	400	Clay	29.1	22.3	1.3	8.6	34.2			
	57-140	430	Clay	30.9	24.3	1.3	8.5	36.7	87	51.9	
DP78	0-40	400	Clay	27.9	20.3	1.2	9.5	37.9			Orthidistric Nitisols NTdyo
	40-70	300	Clay	28.9	22.0	1.4	9.5	28.5			
	70-100	300	Clay	30.2	22.5	1.4	10.4	31.3	98	58.7	
DP83	0-50	500	Clay	38.2	24.4	1.3	17.4	87			Mesotrophic Vertisols (VRms)
	50-100	500	Clay	42.3	26.3	1.2	19.7	98.3	185	111.2	
DP86	0-50	500	Clay	32.1	22.3	1.3	12.3	61.4			HyperferricAcrisols (ACfrh)
	50-100	500	Clay	31.4	22.6	1.3	11.3	56.6	118	70.8	
DP90	0-40	400	Sacl	32.4	22.2	1.4	14	55.8			HyperferricAcrisols (ACfrh)
	40-70	300	Silt L	33.7	23.3	1.4	14.1	42.3			
	70-100	300	Clay	33.9	24.3	1.2	11.8	35.5	134	80.2	
DP91	0-40	400	Clay	29	18.4	1.3	13.4	53.6			GelivGleysols (GLge)
	40-68	280	Clay	25.1	15.9	1.2	11.3	31.7			
	68-159	320	Clay	30.6	19	1.2	14.1	45.1	130	78.2	
DP93	0-30	300	SaL	24.6	17.3	1.4	10.5	31.4			Hyperferric Acrisols (ACfrh)
	30-54	240	Sacl	28.0	19.9	1.3	10.7	25.7			
	54-102	460	Clay	31.7	20.7	1.2	13.6	62.5	120	71.7	

Source: Laboratory Results of MCE, 2009

As has been recognized by Landon J, R. 1991 the Total Readily Available (TRA) water capacity value is, about 50-70% of the AWC (mm/m).

Table 5.10: Summarized Available Water Holding Capacity (AWHC) of Major Soil Types

No	FAO Soil Type 1998	F.C*	P.W.P**	BD***	AWC	
		%	%	gm/cm-3	mm/m	Rating
1	Nitisols	30.7	24	1.3	98.90	Low
2	Vertisols	30.3	20	1.3	138.35	Medium
3	Acrisols	29.7	21	1.3	122.42	Medium
4	Gleysols	28.2	18	1.2	130.40	Medium
5	Cambisols	26.55	19.3	1.4	95.05	Low

** Field Capacity* *** Permanent Wilting Point* **** Bulk density*

5.12 SOIL CLASSIFICATION

5.12.1 General

This chapter discusses brefiely on soil classification and main soil types of the Project area. The soil classification encompasses the following steps;

By interpreting topographic maps and aerial photographs and spot image of 5m resolution base map for the Project area has been produced, that shows the natural and artificial features of the study area. Following that, by interpreting physio/geomorphic process of the area land form, land use/cover, parent material, major and sub-land units of the area have been identified and soil map for the study area was produced. Selection of sampling sites and intensity of study were planned based on the base maps and field description, sampling and verifications were undertaken subsequently. The field description and interpreted analytical data were used as main input for the classification of soils of the study area.

The soils classifications were undertaken on hierarchical system. It was carried out according to the World Reference Base for Soils Resources (WRB) (ISSS-ISRIC-FAO, 1998 Guidelines. The classification has three levels of generalization and structured in hierarchical order, namely geomorphic units (level 1), soil unit (level 2) and slope class (level 3). The level 1 was recognized and measured from field observation. Likewise, the second level was studied from morphological properties of the soils such as physical and chemical properties of the soils. Finally, by measuring or estimating gradient of the Project areas the third hierarchical level was recognized. As a result, six major soil types and 9 sub-soil types have been identified and mapped for the Project area. List of these major and sub-soil types are illustrated in Table 5.11. Soils of the valley floor area are very deep and have poor drainage, coarse and blocky structure. The organic carbon content of these soils is mostly low. To the contrary the nitrogen content of the soil is relatively high compared to the organic carbon content. The base saturation percentage of both surface and subsurface is high for all areas.

The soils are developed on alluvial parent material and they have relatively high clay contents and imperfect to poor drainage characteristics, and strong hydromorphic properties. Their infiltration rates and hydraulic conductivity testes are found moderate to high. They are characterized by high content of clay that swells when wet and shrink when dry. Soils of the elevated plain lands have deep profiles with predominantly very dark reddish brown (5YR3/2) to dark reddish (2.5YR3/6) soil color on the surface. Although the soils have relatively higher nitrogen content, the surface horizons are recognized as nitic and cambic horizon due to evidence of alteration to the underlying horizon.

Table 5.11: Identified Soil Types as Classified Based on World Reference Base (1998)

Code	Sub- soil Type	Main Soil Type	Sub / Main Soil Type & Code
1	Orthidystric (dyo)	Nitisols (NT)	Orthidystric Nitisols (NTdyo)
2	Rhodic (ro)	Nitisols (NT)	Rhodic Nitisols(NTro)
3	Mesotrophic (ms)	Vertisols (VR)	Mesotrophic Vertisols (VRsm)
4	Hyperferric (frh)	Acrisols (AC)	Hyperferric Acrisols (ACfrh))
5	Orthidystric (dyo)	Cambisols (CM)	Orthidystric Cambisols (CMdyo)
6	Orthieutric (eou)	Leptosols (LP)	Orthieutric (Leptosols (LPeou)
7	Gelic (ge)	Glysols(GL)	Gelic Glysols (GLge)
8	Fluvic (fv)	Cambisols (CM)	Fluvic Cambisols (CMfv)
9	Hypereutric (euh	Cambisols (CM)	Hypereutric Cambisols (CMeuh))

5.12.2 Description of Identified Soil Types

5.12.2.1 General

As it has been discussed in section 5.11, based on field investigations and laboratory results six major soil types namely, Nitisols, Vertisols, Acrisols, Cambisols, Gleysols, and Leptosols have been identified and mapped. Detailed description of physical and chemical properties of these soil types, including their area coverage are presented below.

5.12.2.2 Nitisols (NT)

Nitisols are soils, with shiny pedefaces & B horizon. They have an average clay distribution which does not decrease from its maximum within 150cm of the surface. Nitisols are deep, well-drained, red color with diffuse horizon boundaries and a sub-surface horizon has more than 30% clay and moderate to strong angular blocky structure that easily fall apart into characteristics of shiny elements. These soils have big area coverage when compared to others soil types by area coverage of 4,303ha which is about 40.8% of the study area. The average total nitrogen and organic carbon percentage of the surface soil are 0.3% (high) and 3.5% (low) respectively. Their values decrease in sub-surface to 0.1 and 1.4% respectively. The average available phosphorous content of the surface and sub-surface soils are found to be medium and low with average values of 8.0 and 5.3ppm respectively.

The soils have pH reaction of 5.3 on surface and 5.1 in sub-surface. Similarly, the cation exchangeable capacity and base saturation percentage are characterized by high (30.4meq/100gmsoils) and medium (41.9) on the surface soils. But their values decrease in subsurface to 23.6 meq/100g soil (medium) and 34% (low) respectively. The available micronutrients of the surface soils are found in adequet category with average values of 49.9, 59.7, 1.7 and 3.4mg/kg soil for Iron, Manganus, Copper and Zinc respectively. Summarized analytical laboratory results and physical charactersitcs of the soils are presented in Table 5.12 and 5.12 respectively.

5.12.2.3 Vertisols (VR)

Vertisols are soils developed on valley floor part of the study area and cover around 1,053ha which is 10.0% of the study area. They are characterized by clay to clay loam soil texture. Due to relatively low topographic features (valley floor) of the area and high clay content they have imperfect to poor drainage class. They are characterized by very deep depth & black to very dark gray soil color. They have wide and medium surface crakes in dry seasons and swelling nature during wet season. The soils texture classes vary from clay to clay loam. They have strong and coarse angular block structure on top and moderate to coarse prismatic and angular blocky structure in sub-surface. Their consistencies are also very firm to firm when moist and sticky and very plastic when wet, on top and sub-surface.

As it is seen from Table 5.12 the soil is slightly acidic with an average value of 5.1 on the top and 5.7 in sub-surface. The average content of organic carbons and total nitrogen percentage of the surface soils are 2.9% (low) and 0.2% (medium) respectively. They are none saline and none sodic soils on surface and in sub-surface soils with average value of 0.1dS/m and 0.0.01% respectively. The soils have relatively high average CEC greater than 40.5meg/100g soil on surface and 40.9meg/100g soil in sub-surface. The average base saturation values of surface and subsurface soils are greater than 48 and 68% respectively. Their available water holding capacity (AWC) of the soils is about 138.35mm/m which is medium**.** Likewise, the average available phosphorous content is found to be at high level. The C/N ratio of the surface soils is found within the optimal range of 11:1. Currently, at large they are used for extensive grazing.

Summarized analytical laboratory results and physical charactersitcs of the soils are presented in Table 5.12 and 5.12 respectively**.**

5.12.2.4 Acrisols (AC)

Acrisols are soils that have high clay content in the sub-soil. They have low base saturation percentage and low clays in certain depth. They have deep to very deep depth, red color and sandy clay to silty clay soil texture. These soils are characterized by well drainage. They are found mostly on gentle undulating to slopping physiographic feauture of the study aera. In area wise they occupy around 1,062ha, which is about 10.08% of the study area and equal to vertisols.
The soils have low pH reaction on surface as well as sub-surface with average values of 5.5 and 5.2 respectively. The average organic carbon content of surface soil and sub-surface are 3.6% (low) and 1.6 % (very low) respectively, indicating that the soils need mulching to raise low organic carbon content of the soils. The total nitrogen content of the surface and sub- surface soils are respectively 0.3 % (high) and 0.2 % (medium). Similarly, the average available phosphorus content of the surface and subsurface soils are 25.6ppm and 4.64ppm respectively, which is very low for both layers. The average value of CEC and base saturation percentage of the surface soils are 27.1meq/100g and 48% respectively. Their values decrease in sub-surface to 16.9 meq/100g and 41% respectively showing that the soils fertility is found in medium range. Summarized analytical laboratory results of the soils are presented in Table 5.12.

5.12.2.5 Cambisols (CM)

Cambisols occupy an area of 1,311.4ha, which is about 12.56% of the study area. They are found on strongly sloping land with slope range of 5-8%. Cambisols have very dark brown (10YR3/2) to dark brown (10YR3/4) color on sub-surface. The soils texture is clay loam on surface and clay in sub-surface. They have moderate soil depth. The pH throughout the profile is nearly neutral with an average value of 6.3 on surfaces and 6.1 in sub-surface. The average total nitrogen and organic carbon contents of the surface soils are very high (0.4%) and medium (4.7%) respectively. The average C/N ratio value of the surface and sub-surface are 11:1 and 10:1 which indicate a relatively higher carbon value on both depths. The soils have on average high CEC of 30.7meq/100g of soils and a base saturation of 66% on surface.

As it is seen from laboratory results, despite shallow soil depth, fertility status of the soils is found in the range of medium to high level. Similarly, average available phosphorous content of the surface and sub-surface soils are found to be 60.4ppm and 54.5ppm respectively. The available micronutrients of the surface soils are found in adequet category with average values of 52, 66.5, 3.0, and 19.1mg/kg soil for Iron, Manganus, Copper and Zinc respectively. Currently the soils are used mostly for sorghum cultivation by rain-fed cultivation. Summarized analytical laboratory results and physical charactersitcs of the soils are presented in Table 5.12 and 5.12 respectively.

5.12.2.6 Gleysols (GL)

Gleysols are found on wetland areas, unless they drained, they become saturated with groundwater for long enough periods to develop a characteristic of gleyic color pattern. This pattern is essentially made up of reddish, brownish or yellowish color at ped surface and/or in the upper soil layer or layers, in combination with grayish/bluish colors in the peds and/or deeper in the soil. They have black (10YR 2/1) color on top and dark grayish color in sub-surface. They are characterized by poor drainage class and sticky/plastic consistence. The soil texture is clay throughout the profile depth. These soils occupy insignificant part of the study area, 28.99ha which is about 0.27%.

The pH of the topsoil is 5.2. This value increases in sub-surface to the value of 5.4 and organic carbon and total nitrogen of top soil on average being 4.6% (medium) and 0.3% (very high) respectively. The soils are non-saline and non-sodic with average ECs of < 0.04 dS/m and ESPs of <0.5% on surface. The average cation exchange capacity of topsoil is 35.5 meq/100gm of soil; this value decreases to 25.1 meq/100gm of soils in sub-surface. The base saturation percentages of the top and sub-surface soils are 47% and 55% respectively and the average exchangeable sodium percentage of the same layer is 0.2meq/100gm of soil and 0.22meq/100gm of soil respectively. The Ca: Mg ration of the exchange soil complex on surface is 3:1 and in sub-surface it is 4:1 which are found optimum. Summarized analytical laboratory results and physical characterstics of the soils are presented in Table 5.12 and 5.12 respectively.

5.12.2.7 Leptosols (LP)

Leptosols are shallow soils, over continuous rock and soils that are gravelly and /or stony. They are zonal soils and particularly found on strongly sloping and moderately steep >15% of the study areas. They cover 787.51ha, which is about 7.47% of the study area. Inspite of shallow depth they have moderate fertility status. The soils have dark reddish brown (5YR 3/2) color on surface and reddish brown (5YR 4/3) in sub-surface. The surface soils are gravely and filled with coarse fragments. The soils have strong, medium, coarse and angular blocky structure in sub-surface and strong, coarse and very coarse, platy in sub-surface.

The pH is 5.8 on top and 5.7 in sub-surface. The total nitrogen and organic carbon content of the surface soils are on average 0.4% (very high) and 4.7% (medium), respectively. They have high CEC on average (29.9 meq/100g soils) and base saturation percentage of 56 (medium) on surface. Similarly, the average values of exchangeable calcium and magnesium of the surface soils are 14 and 3.29 meq/100g soils respectively and they are at a high level. The ratio of calcium to magnesium on the surface is 4:1, which is optimum. The average available P content of the same layer is 13.6 ppm, which is very high. The C/N ratio is also found within the optimal range. The only constraints of the soils are depth and steep of the area. Currently the soils are used for sorghum cultivation. Summarized analytical laboratory results and physical characterstics are presented in Table 5.11 and 5.12 respectively.

Table 5.12: Summarized Laboratory Results of Major Soil Types of the study area

1. Nitisols (NT)-Surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.3	4.4	-0.9	0.07	0.3	3.5	12.7	8.0	0.2	0.4	8.5	3.5	12.6	30.4	41.9	0.7	3.0	35.9	49.9	59.7	1.7	3.4
Maxi.	6.4	6.0	-0.4	0.20	0.7	7.3	21.8	85.7	0.3	1.3	26.0	17.0	34.8	54.1	93.8	1.5	8.8	136.5	177.9	139.5	2.9	47.5
Min.	4.5	3.7	-1.3	0.01	0.1	1.5	2.7	0.3	0.1	0.1	1.8	0.9	2.9	10.2	13.2	0.3	1.0	9.6	20.1	11.9	0.6	0.0

Nitisols (NT) - Subsurface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.1	4.4	-0.7	0.02	0.1	1.4	11.5	5.3	0.2	0.2	5.0	2.2	7.6	23.6	34.5	1.0	2.7	40.9				
Maxi.	7.8	8.9	4.1	0.17	0.7	4.6	21.8	100.8	1.9	0.9	29.1	7.2	37.0	66.7	96.1	9.8	9.8	110.5				
Min.	4.3	3.7	-2.9	0.01	0.01	0.02	0.04	0.62	0.1	0.1	1.8	0.9	2.9	6.9	9.0	0.2	0.9	10.8				

2. Vertisols (VR)- Surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.1	4.0	-1.1	0.1	0.2	2.9	11.4	12.8	0.2	0.4	13.5	5.4	19.5	40.5	47.5	0.6	4.0	51.5	241.6	48.9	3.2	6.8
Maxi.	5.5	4.2	-0.8	0.3	0.4	4.6	14.5	43.7	0.3	0.7	21.7	8.1	30.4	52.6	65.5	0.9	20.0	80.4	408.2	101.3	5.6	41.5
Min.	4.6	3.7	-1.4	0.01	0.1	1.1	7.1	1.3	0.2	0.2	6.3	0.9	9.3	26.8	27.4	0.4	1.5	13.7	75.4	12.1	2.1	0.2

Vertisols (VR) - Subsurface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.7	4.4	-1.3	0.1	0.1	1.0	11.6	18.7	0.4	0.3	20.9	6.8	28.4	40.9	68.2	1.1	5.2	100.5				
Maxi.	7.9	7.1	-0.4	0.3	0.2	1.8	17.8	218.5	0.9	0.4	52.0	13.4	63.5	63.8	111.4	2.8	27.0	215.3				
Min.	4.8	3.5	-1.9	0.01	0.02	0.4	7.6	0.3	0.2	0.1	8.9	0.9	13.7	21.7	44.7	0.5	1.3	52.0				

3. Acrisols (AC)-Surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.5	4.8	-0.7	0.1	0.3	3.6	12.5	25.6	0.2	0.5	9.7	3.1	13.5	27.1	48.3	4.6	3.4	26.8	41.9	43.2	1.6	6.7
Maxi.	6.9	6.4	-0.1	0.4	0.6	6.6	17.9	144.4	0.2	1.4	31.6	5.4	35.4	41.8	84.8	56.2	14.0	26.7	79.9	73.4	3.5	58.6
Min.	4.5	3.7	-1.2	0.02	0.1	1.9	7.8	3.1	0.1	0.1	3.2	1.8	5.7	13.3	24.1	0.3	0.9	61.1	26.1	5.6	0.9	0.0

Acrisols (AC)-Subsurface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.2	4.4	-0.7	0.03	0.2	1.6	13.0	4.6	0.2	0.2	4.1	1.8	6.3	16.9	40.5	6.3	2.4	30.5				
Maxi.	7.1	5.8	-0.3	0.07	1.4	3.1	21.2	62.3	0.2	0.9	11.1	4.5	13.9	27.8	89.9	89.9	5.0	17.2				
Min.	4.2	3.9	-1.3	0.01	0.04	0.1	0.1	0.4	0.1	0.1	1.8	0.9	2.9	7.7	10.6	0.4	1.0	39.4				

4. Cambisols (CM)-Surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	6.3	5.5	-0.8	0.1	0.4	4.7	11.4	60.4	0.1	0.9	15.9	4.5	21.5	30.7	66.3	0.6	3.4	21.7	52.0	66.5	3.0	19.1
Maxi.	7.1	6.5	0.1	0.2	0.6	7.8	16.8	152.5	0.3	2.0	27.8	7.2	36.0	47.7	95.6	1.2	5.3	17.8	108.6	152.7	11.4	79.2
Min.	4.6	4.0	-1.8	0.03	0.2	2.0	7.1	3.2	0.1	0.1	1.8	0.9	2.9	14.2	20.7	0.3	1.0	23.4	24.1	21.2	1.5	0.7

Cambisols (CM)-Subsurface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	6.1	5.3	-0.8	0.05	0.2	1.6	10.4	54.5	0.2	0.5	10.0	4.3	15.0	23.7	67.6	0.9	2.7	28.2				
Maxi.	7.1	7.8	1.1	0.14	0.4	3.0	16.2	219.5	0.3	1.0	21.7	14.5	37.2	71.6	122.0	2.3	5.7	37.9				
Min.	4.8	4.0	-1.4	0.01	0.05	0.7	6.9	2.4	0.1	0.1	1.8	0.9	3.0	13.5	21.6	0.1	1.3	23.4				

5. Gleysols (GL)-Surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.2	3.9	-1.3	0.04	0.3	4.6	15.3	3.4	0.2	0.3	11.6	4.5	16.6	35.5	46.6	0.5	2.6	58.5	196.0	16.3	2.3	17.1
Maxi.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Min.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Gleysols (GL)- Sub-surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.4	3.9	-1.5	0.02	0.1	1.2	29.9	8.1	0.2	0.2	10.7	3.0	14.1	25.1	55.0	1.0	3.6	74.7				
Maxi.	5.4	4.0	-1.4	0.02	0.1	1.7	60.5	21.8	0.3	0.2	14.3	3.6	17.6	28.2	62.2	1.2	5.3	82.0				
Min.	5.3	3.8	-1.6	0.02	0.0	0.9	13.4	1.1	0.2	0.1	5.4	2.7	8.4	20.0	42.3	0.6	2.0	58.5				

6. Leptosols (LP)-Surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.8	4.9	-0.9	0.1	0.4	4.7	11.8	13.6	0.4	0.7	13.7	3.3	18.2	29.9	56.4	1.6	4.1	23.4	39.7	53.3	1.0	0.9
Maxi.	6.8	6.0	-0.8	0.2	0.7	6.8	12.8	33.3	0.9	1.3	26.0	4.5	31.1	43.8	70.9	3.6	7.3	22.7	50.8	62.6	1.5	1.7
Min.	4.8	3.9	-1.0	0.01	0.2	2.6	10.2	3.3	0.1	0.1	4.5	1.8	6.6	20.0	33.0	0.3	2.4	45.5	28.7	44.0	0.6	0.1

Leptosols (LP)- Sub-surface

Value	PH(1:2.5)			EC	TN	OC	C/N	Av.P	Cations (meq/100gm soil)					CEC	BSP	ESP	Ca/Mg	Ca+Mg/ K	Micronutrient mg/kg			
	H2O	KCl	ΔPH	dS/m	%	%	N	ppm	Na	K	Ca	Mg	Sum	meq/100g	%	%			Fe	Mn	Cu	Zn
Aver.	5.7	5.0	-0.7	0.04	0.2	1.6	8.5	3.2	0.2	0.3	10.8	3.6	14.8	21.7	64.3	0.8	3.0	43.0				
Maxi.	6.8	6.0	-0.7	0.06	0.2	1.6	9.7	5.6	0.2	0.6	16.1	5.4	22.3	25.8	86.2	1.0	3.0	37.4				
Min.	4.7	4.0	-0.8	0.01	0.2	1.6	7.3	0.8	0.2	0.1	5.4	1.8	7.4	17.5	42.4	0.7	3.0	78.0				

Source: Analytical laboratory Result of MCE, 2009

Table 5.13: Summarized Physical Characterstics of the Major Soil Types.

No	Soil Type	Depth	Texture	Drainage	CaCO3	AWC	Infiltration	H.C	Area	
		cm.	Class	Class	%	mm/m	cm/hr	m/day	ha	%
1	Nitisols (NT)	>180	Clay loam -Clay	WD	6.17	98.9	8.63	2.29	4302.76	41.61
2	Acrisols (AC)	>160	Loam –Sandy clay loam	WD	1.78	122.42	9.23	2.43	1062.72	10.17
3	Leptosols (LP)	>60	Loam –Clay loam	SWED	-	-	-	-	787.51	7.54
4	Cambisols (CM)	>70	Loam –Sandy clay loam	WD	5.33	95.05	-	-	1311.40	12.56
5	Vertisols (VR)	>200	Clay	ID	2.24	138.3 5	6.50	0.1	1053.10	10.08
6	GLeysols (GL)	>184	Clay	PD	-	130.40	-	-	28.99	0.28

Source: Analytical laboratory Result of MCE, 2009

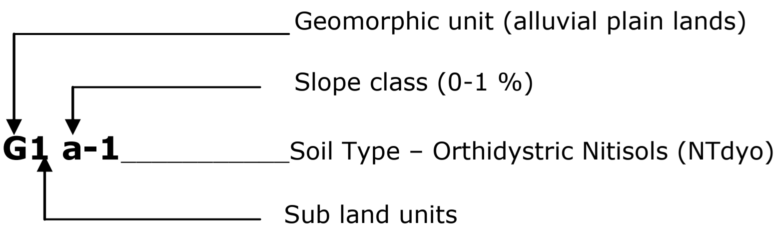
5.13 Description of Soil Mapping Units of the Area

5.13.1 General

The description of the soil-mapping unit follows closely soil/ landform map as described below in the legend. The legend is prepared on the basis of physiographic and other environmental characteristics. It is structured at three level of generalization in hierarchical order, namely geomorphic units (level 1), slope percentage (level 2) and soil type (level 3). Thus, uppercase letters and the next number jointly indicate first level of generalization (geomorphic unit), while the second lower case letters showing the second level of generalization indicates-slope percentage class. Third serial number showing the third level of generalization indicates soil type. The following example shows the structural representation of the soil map legend of study area (Figure 5.2)

Figure 5.2: Structural representation of soil map legend of the study area

Example



Accordingly, for the categorized slope classes the following codes are used.

Code	Slope class (%)
a	0-2
b	2-3
c	3-5
d	5-8
e	8-15
f	>15

The soil formations of the study area are largely influenced by topography and climate. Thus, the gently undulating plain and strongly slopping of the survey area are characterized by well drained, red and red brown soils. Whereas, the flat valley floor area soils have poor drainage, dark grey to black color and swelling fine textured classes.

Similarly, the effect of climate on soil formation is expressed by the influence of precipitation and temperature. Due to the high temperature and high rainfall the weathering process in the elevated parts of the surveyed area (soils development) is relatively rapid and the weathering products vary from clay loam to sandy clay texture. Thus, the landform of the study area could be grouped into four main landforms, 11 sub-land forms and three miscellaneous land units (see Figure 5.3 on following page). Detailed descriptions and area occupation (ha) of each mapping unit is discussed briefly below. The total area coverage of the study area amounts around 10,546ha. Summary of chemical, physical and morphological properties of the soils are shown in Table 5.14 and 5.14 respectively.

5.13.2 Mapping Unit G1b_1

This unit is found on elevated upper part of gently undulating plain mainly in the central part of the study area with slope percent of 0-3. Land that belongs to this unit covers about 1,630.38ha and occupies 15.46% of the surveyed area. For the study of soils of the mapping unit 17 representative profile pits were described. The soils are very deep with this well drained drainage characteristics. The color of the surface soils is dark reddish brown (5YR3/2) and gets dark reddish color (2.5YR3/6) in sub-surface and the texture is clay throughout the soil depth. Consistencies are sticky and plastic when wet, and firm when moist. Surface soils have moderate, medium course and sub angular blocky structure.

The pH of the surface soils (0-18) is about 5.6, which is decreasing gradually to 5.0 in sub surface. The average organic carbon and total nitrogen contents of surface soils are 4.1% (medium) and 0.32% (very high) respectively. The ratio of organic carbon to total nitrogen varies from 13 to 20 with an average value of 14 showing that the value is found in a good range. Throughout the depth the soils are non-saline and non-sodic with average EC of 0.dS/m and ESPs of < 4%. The average value of CEC on surface is less than 28 meq/100g and base saturation is 52.1% while the value in sub-surface is decrease to 19.97 meq/100g and 51.3% respectively, indicating that the soils fertility status is medium. The relative proportion of Mg and Ca in the exchange complex is 3:1 (optimum) on top and decreases in sub-surface to 1.3:1 low, indicating that available P up take may be inhabited. The available P content of the surface soils and sub-surface is 2.68 (pmm) and 0.45ppm which are found in a very low range. The trace elements like Iron, Manganese and Copper are adequate with value of 50, 58 and 1.2 mg/kg soil respectively, whereas Zinc is found in marginal level with an average value of 1.49 mg/kg soil. The average water holding capacity of this unit is 97.86mm/m with infiltration and hydraulic conductivity values of 9.2cm/hr and 1.5m/day respectively. In order to check fluctuation of water table and impervious horizon deep boring was done up to 400cm.Then, after 400cm due to solid contact auguring was not preceded. Following that two samples at the depth of 200-300cm and 300-400cm were taken. They have acid pH reaction, greater than 5.3 and very low EC of 0.01dS/m. Based on the field investigation and laboratory results, the soils are classified as Orthidystric Nitisols (Ndyo). For representative profile and analytical data see Appendix 5A, Profile Pit DP78 and for physical site description and alternative soil/ land management interventions of the mapping units is presented in Table 5.16.

5.13.3 Mapping Unit G1b_4

The unit is mostly located in the western part of the study area. It occupies 675.27ha and forms about 6.46% of the total surveyed area. It is characterized by gently undulating plain land with slope of 0-3%. The soils are developed on colluvial parent material.

The color of the surface soil varies from reddish brown (5YR4/4) to yellowish red (5YR4/6). The soil texture ranges from sandy clay loam to silty loam on surface and throught clay in sub-surface.They have very deep soil profile (> 200 cm), with good drainage. It has a moderate and medium to weak surface structure. The subsoil has medium to coarse angular and sub angular blocky structure and the profiles have a diffused and sometimes wavy boundary. The water holding capacity of this unit is 133.7mm/m with basic infiltration rate and hydraulic conductivity value of 8.6cm/hr and1.96m/day respectively.

Figure 5.3: Soil Mapping Units of the Project area (A3 figure)

The pH of the topsoil is found moderately acidic with value of 5.1. The reaction decreases in sub-surface to 4.5. The organic carbon content on surface soil is 3.9% and decrease in sub-surface to 2.7%, indicating low level of organic carbon and the total nitrogen content of the same layer is high (0.28%) and medium (0.17%) respectively. The C/N ratio of (100cm) top surface soil is 14:1 and the available phosphorus of this unit is low with value of 6.11ppm. They have high CEC, which is greater than 31meq/100g soil and has medium base saturation percentage. The micro nutrient like, Iron, Manganese and Copper are found in adequate level with value of 65.42 and 2.1 while, Zinc is found low with value of 0.41mg/kg soil. Based on the field investigations and laboratory results, the soils are classified as Hyperferric Acrisols (ACfrh). For representative profile and analytical data see Appendix 5A, Profile Pit DP90 and alternative soil/ land management interventions of the land units is presented in Table 5.16.

5.13.4 Mapping Unit G2d_1

This land unit is described as middle & lower slope of gently undulating plains land with slope of 4-6%, found throughout the study area. Its total area extent is about 2,429.96ha, which is about 23.04% of the study area. The soils have deep soil depth, moderately well drained and dark reddish brown (5YR3/4) color on surface and it changes to red (2.5YR4/6) color in sub-surface. The texture is characterized by clay loam in surface and changes to clay in sub-surface. The soils have weak, fine and granular structure. Their consistency is slightly sticky and plastic when wet.

The pH of the top (0-30) soils is 5.33, which is slightly acidic and decreases in subsurface to 4.7. The average organic carbon and total nitrogen values are 2.6 and 0.29% respectively. Both the organic carbon and total nitrogen values are very low and medium respectively and decreases gradually with profile depth. With this level of content, plough back of crop residues and mulching should be encouraged to raise the level of organic carbon and nitrogen to improve the top soils structure and fertility level of the soils.

Salinity and sodicity in the area are negligible with an average ECs <0.07 dS/m and ESPs <0.5% on surface. They have high CEC more than 35meq/100g soils and low base saturation percentage of 40.0%. The average available P content on the first 100cm depth is 1.9ppm which is very low. The water holding capacity, infiltration rates and hydraulic conductivity test results of the soils are 106.5mm/m, 8.6cm/hr and 1.3m/day respectively. The micronutrients like Fe, Mn and Cu have adequate content with value of 26, 74 & 1.8mg/kg soil respectively. Comparing with others Zinc is found in a marginal level with value 1.3mg/kg soil. Based on the field study and laboratory results, the soils are classified as Orthidystric Nitisols (NTdyo). For representative profile and analytical data see Appendix 5A, Profile Pit DP3 and alternative soil /land management options of the land unit is presented in Table, 5.16.

5.13.5 Mapping Unit G2d_2

This unit refers to the middle and lower slope of gently undulating plain elevated lands, with slopes ranging from 4 to 6%. This area is mostly used for sorghum and sesame cultivation. Its total area extent is 242.42ha, which is about 2.57% of the study area. The soils have dark reddish brown (5YR3/4) color on surface and dark red (2.3YR3/6) color in sub-surface layer. The texture is clay loam on surface and increases gradually in sub-surface. They have deep to very deep soil depth and well drainage class. The soils have moderate to coarse sub-angular structure. The water holding capacity of this unit is 104.8mm/m and the basic infiltration and hydraulic conductivity results are marginally suitable (7.9cm/hr) and moderate level (3.6334m/day) respectively.

The soil pH nitrogen of the topsoil is slightly acid and ranges from 5.4 to 5.0, with average value of 5.2. The organic carbon and total nitrogen content of the top soil is 3.2% (low), and 0.0.29% (medium) in the surface. The C/N ratio found in the range of 7:1 to 11:1, which indicates that the total nitrogen content is found in the range of medium to low level. The available phosphorus content of this mapping unit is very low with an average value of 0.5ppm.The exchange complex of the surface soils appears to contain relatively lower exchangeable Ca which is dominated by Mg. There ratio is found in the range of 3:1. When the Ca/Mg ratio is in the range of 3:1 to 4:1 the soil is found on the level of approximately optimum range for most crops. The value of CEC on surface is 40.8meq/100g of soil showing very high level of CEC and to the contrary they have low base saturation percentages. The soils are non-saline and non-sodic with ECs on average < 0.09dS/m and ESPs of 0.5%. As it is seen from laboratory results the soils have low fertility level. The micronutrient values of Fe, Mn and Cu are found on adequate level. But, the value of Zn is found on marginal level with 1.0mg/kg soil. Based on the physical field information and the laboratory result the soils of this unit are classified as Rhodic Nitisols (NTro). For representative profile and analytical data see Appendix 5A Profile Pit DP2

5.13.6 Mapping Unit Sg-6

This land unit is characterized by moderately steep side of hills and ridges developed on basaltic tuffs and has slope percentage of >15. It occupies 787.51ha and forms about 7.46% of the surveyed area. The soils of this land unit have shallow depth less than 60cm and excessive drainage. The soil color is dark reddish brown (5YR3/2) color on surface and reddish brown (5YR4/3) in sub-surface. Consistencies for both layers are friable when dry and slightly sticky and slightly plastic when wet. The soils have weak, fine to medium sub angular blocky structure.

The pH of the soils is throughout the depth is greater than 6.8 which is neutral. The organic carbon and total nitrogen content of the surface soils are 6.8% (medium) and 0.66% (very high), respectively. They decrease in sub-surface with values of organic carbon 1.6% and total nitrogen 0.22%. The soils have high CEC, on average (31.1meq/100g soils) and high base saturation percentage (70.9%). Similarly the exchangeable calcium and magnesium content of the surface soils are 26 and 3.6meq/100g soils respectively. The value is found at very high and high level respectively. The ratio of calcium to magnesium on the surface is 7:1 and decreases in the sub-surface to 3:1. In the exchangeable complex calcium occupies high value than the others cations. On surface soils Mg increasingly unavailable due to high content of Ca and P availability may be reduced. The available P content of the soils is very high (33.3ppm) on top and low (5.6ppm) in sub-surface. Despite, they are shallow and stony, fertility status of the soils is found to be in high level. The Iron, Manganese and Zinc trace elements are adequate in the soils but Cupper is found on marginal level. Indicative level of Micronutrient of the soils and their value rating are present in Appendix 5F #13.
Based on the field investigation and laboratory result the soils are classified as Orthieutric Leptosols (LPeou). For representative profile and analytical data see Appendix 5A Profile Pit DP56.

5.13.7 Mapping Unit U1e_4

This unit refers to the strongly sloping upper and middle part of hills and ridges of study areas, has slope range of 5 to 8%. The land unit occupies around 387.45ha and forms about 3.67% of the study area. The soils are very deep (>160cm), well drained, and have dark reddish brown (5YR3.2) soil color throughout the soils depth. The soil texture is loam on surface and sandy texture in sub-surface. Consistencies are sticky and plastic when wet. The soils have moderate to strong coarse angular structure.

The pH of the surface soils is 5.4 and it decreases to 5.0 in the sub-surface. The average organic carbon and total nitrogen contents of the top soils vary from medium (4.0%) to very low (2.8%) and from very high (0.33%) to medium (0.22%) respectively. The soils have high CEC (34.7meq/100g soil) and medium (41.1%) base saturation percentage on surface layer and decrease for both parameters in depth. The relative proportion of Ca to Mg in the exchange complex of surface soils is low (2:1) which indicates the availability of Ca is low and doesn't hinder the availability of Mg, but available P up take may be inhibited. The available P content in the surface soils is very low (4.61ppm), and decrease gradually in depth to value of 2ppm. The water holding capacity of these soils is 88.5mm/m. The soils micronutrients like, Iron, Manganese and Copper are adequate except Zinc. They have values of 34, 56 and 3.5 mg/kg soil respectively. Similarly zinc has value of 0.45mg/kg which is lowl. Indicative level of micronutrient of the soils and their value rating is present in Appendix 5F #13 .These soils are classified as Hyperferric Acrisols (ACfrh). For representative profile and analytical data see Appendix 5A, Profile Pit DP67.

5.13.8 Mapping Unit Ue1_5

This unit refers to strongly sloping upper and middle part of hills and ridges found largely to the north western of the study area with slope range of 5 to 8%. Total area extent is about 152.51ha and forms about 1.44% of the study area. The soils have moderate depth (0-70cm), well drainage and brown (7.5YR4/4) color on surface and strong brown (2.5YR4/6) in sub surface. The structure of the top soils is weak, fine and granular while, in sub-surface it is characterized by moderate, medium and coarse sub-angular blocky structure. The soil is developed on basaltic tuffs.

The pH of the surface soils (0-38) is 5.3 and it decreases to 4.7in sub-surface**.** The total nitrogen and organic carbon contents of the soils are very high (0.55%) and low (3.9%) on surface layer respectively. whereas in sub-surface they decrease to medium (0.12%) and to very low (1.4%) respectively. With this level of content ploughing back of crop residues and mulching should be encouraged to raise a very low level of organic carbon and total nitrogen content of the soils and to improve the top soils structure. In this mapping unit salinity and sodcity is not a problem; since they have low average values of < 0.05 dS/cm and less than 0.9 ESPs. The soils have on average low cation exchange capacity of 16.7 meq/100g of soil and low (37%) base saturation percentage on top and they decrease in sub-surface to 13.76meq/100gsoil and 22% respectively. The exchange complex of the surface soils appears to contain relatively higher exchangeable Mg than the Ca with an average value of 2.71 and 2.71 meq/100g soils respectively. The Ca/Mg ration is also very low 1:1 on top and and 2:1in sub-surface, which is low. With this range the soil is not favorable for plants growth. Calcium availability slightly reduced. Nevertheless, the average available P content of the top soils is relatively high with an average value of 13.8ppm. The micronutrient value of the four elements Fe, Mn, Cu, and Zn is found in sufficient level. They have value of 35,32,2.1 and 37.4mg/kg soil in that order. Indicative level of micronutrient of the soils and their value rating is present in Appendix 5F #13. Based on the field investigation and laboratory result the soils are classified as Hypereutric Cambisols (CMeuh). For representative profile and analytical data see Appendix 5A, Profile Pit DP94.

5.13.9 Mapping Unit U2f_9

This unit refers to the strongly sloping side of hill and ridge with slope percentage of 8-15. Major part of this land unit is located to the north eastern part of the study area in particular to north and east of village No.7 or Sebategna. It has an area extent of 958.68ha and forms about 9.09% of the study area. The soils are relatively deep and moderately well drained with dark brown (10YR3/3) color on surface and dark yellowish red (10YR34) in sub-surface. The soils have loam soil texture class on top and clay in sub-surface. Their consistency, when wet is slightly sticky and plastic and has fine, medium and granular structure.

The pH of the surface soils is nearly neutral with value of 6.7 and decreases gradually in the sub-surface to the value of 6.5. The organic carbon and total nitrogen percentage of the surface soils are medium and very high with value of 7.8% and 0.6% respectively. In sub-surface they decrease to 1.1% and 0.15% respectively in depth of 52-100cm. The C/N ratio value ranges from 14:1 to 7:1 indicating that the total Nitrogen % is relatively higher than the organic carbon, even though their fertility statue is found in good range. The soils have high CEC greater than 30.46 (meq/100g soil) and high base saturated percentage throughout the soil profile pits depth. The relative proportion of Ca to Mg in the exchange complex of the surface soil is moderately high (4: 1) which is very favorable soil for crop production. In general the average exchangeable value of Mg, Ca, and K are 27.4, 6.84 and 1.7meq/100g soil respectively and they are found in high level. Concerning micronutrients content they found in adequate level, with value of Fe 24, Cu 3.5 and Zinc 8.91mg/kg soil. In general, except the steep slope of the area fertility statue of the soils is found to be in the moderate to high range. Based on the field investigation and laboratory result the soils are classified as Orthidystric Cambisols (CMdyo). For representative profile and analytical data see Appendix 5A, Profile Pit DP15.

5.13.10 Mapping Unit V1b_3

This unit refers to soils developed on seasonally wet valley floor area with slope range of (0-3%). It is wet for some time of the year and currently used for extensive grazing. It has an area extent of 1,053.1ha, and about 10.0% of the study area. The soils are very deep greater than 200 cm, with imperfectly to poor drainage and clay soils texture. They have very dark brown (10YR3/1) color on surface and dark gray (10YR4/1) in the sub surface. Their consistencies are slightly sticky and plastic when wet. The soils have moderate, medium sub angular blocky structure in subsurface and moderate, medium and coarse wedged-shaped in sub-surface.

The pH of the soils is 5.5 on surface and 7.91 in sub-surface, the pH value increases due to $CaCO_3$ accumulation at sub-surface (70-160cm). The total nitrogen and organic carbon content of the surface soils are 0.3% (very high) and 4.6% (low) respectively. The soils are non-sodic and non-saline on surface and sub-surface. The top soils have an average value of ESP < 1.4% and ECs of < 0.03 dS/m and have 2.24% (low) calcium carbonate percentage. The soils have high CEC on average (51.59 meq/100g soils) and high base saturation percentage greater than 60 on surface. The average values of exchangeable calcium and magnesium of the surface soils are 21.7 and 8.1meq/100g soils respectively and they are at a high level. They increase gradually in sub-surface to 52 and 10.41meq/100g respectively. The ratio of calcium to magnesium on the surface is 3:1 which is found optimum for most of the crops.

The vailable P content of the surface soils is 9.22ppm, which is medium and decrease in sub-surface to very low (0.59ppm).The infiltration rate and hydraulic conductivity tests of the soils are 6.3cm/hr (Suitable for surface irrigation) and 0.10m/day(very slow) respectively. Available water holding capacity of the soil is also 185.3 mm/m (high). With regarded to micronutrients content Iron, Manganese and Copper are found at sufficient categories with values of 402, 101 and 5 mg/kg soils respectively. To the contrary Zinc is found on low (0.19 mg/kg soils) category. Indicative level of Micronutrient of the soils and their value rating are presented in Appendix 5F #13. The soils are classified as Mesotrophic Vertisols - (VRms). For representative profile and analytical data see Appendix 5A, Profile Pit DP83.

5.13.11 Mapping Unit V2a_7

This unit occupies insignificant portion of the study with an area extent of 28.99ha, which is about 0.27% of the study area. It is located in the valley bottom with a slope range of 0-2%. The soils are developed on alluvial/fluvial parent material. The unit is currently used for extensive grazing and sugarcane plantations. The soils are very deep and poorly drained. Surface soils have black (10YR2/1) color, and in sub-surface the color is dark grayish brown/red (10YR3/2). The texture of the surface and surface is throughout clay. The surface soils are characterized by moderate to medium sub angular blocky structure. When the soils are wet they have sticky non plastic consistency and when they are moist their consistency is loose to friable.

The pH of the soils is throughout moderately acidic with an average value of 5.2. The organic carbon and total nitrogen values at 0-42cm depth are 4.6% (medium) and 0.3% (high) respectively. The determined values of both elements are very low in subsurface with value of 1.0 and 0.1. The soils are non-saline and non-sodic with average ECs of < 0.04dS/m and ESPs of <0.5%. The soils have high CEC, more than 35.6 meq/100g soils and medium base saturation percentage, which is greater than 47. The average available P content on the first 100cm depth is 1.9 ppm which is very low. The micronutrient content values of Iron, Manganese, Copper and Zinc are found in adequate category with value of 196, 16, 2.3 and 17.1mg/kg soil respectively. Based on the physical field investigations and the laboratory results, the soils are classified as Glic Gleysols (GLge). For representative profile and analytical data see Appendix 5A, Profile Pit DP91

5.13.12 Mapping Unit V3C_8

This unit refers to the moderately dissected valley floor areas, where the soils receive fresh soil materials. It is developed mainly on colluvial parent materials. The effect of erosion seems to have a significant and active role in the soil formation process as well as in the sediment composition. The slope of the land units ranges from 2-4%. It occupies 200.21ha and forms about 1.9% of the study area. The soils are deep (>120cm) with moderately well drained and dark brown (7.5YR32) soil color on surface. They have loam soil texture class on surface and sandy clay loam in surface. Their consistency is sticky and plastic when wet and have moderate, medium and coarse sub-angular block structure

The pH of the surface soils is neutral with an average value of 7.1 and decreases in the sub-surface to the value of 5.85. They are non-saline and non sodic soils with ECs of <0.18dS/m and ESPs of <0.4. The organic carbon and total nitrogen percentage of the surface soils are 1.46 (very low) and 0.18 (medium) respectively. The C/N ratio value ranges from 8:1-11:1 indicating that the organic carbon% is relatively higher than the total nitrogen%, which indicates that the soils are found in good to medium range. The soils have high CEC greater than 56.0 meq/100g soil and high base saturated percentage (83) throughout the soil profile pits. The relative proportion of Ca to Mg in the exchange complex of the surface soil is moderately high, which is very favorable soil for crop productions. The available P content of the surface soil is on the average is 29.73 ppm which is very high but it decreases to low (5.05ppm). They have 152.3mm/m available water holding capacity, which is medium level. The soils infiltration rate and hydraulic conductivity tests are 9.7cm/hr (marginally suitable) and 1.4m/day (slow) respectively. The micronutrients of the soils like Iron, Manganese, Copper and Zinc are found in sufficient categories with value of 30, 89, 1.5 and 3.54mg/kg soil respectively. Based on the field investigation and laboratory result the soils are classified as Fluvic Cambisols – (CMfv). For representative profile and analytical data see Appendix 5A, Profile Pit DP75.

5.13.13 Miscellaneous Land Unit

As miscellaneous land unit, G3d, R, St and F have been identified and mapped. Description of these land units and their area extent are illustrated below.

5.13.14 Mapping Unit G3d

This unit refers to sloping basement ridges & tors which has slope range of 4-6%. The larger part of this land unit is occupied by rock, boulders and rough surface features. The total area coverage is 67.25ha which is about 0.59%. It is found mainly on elevated part of the study area. Due to rocky and stony surface feature profile pit descriptions were not studied, apart auger hole. In general the land unit is not suitable for agricultural developments.

5.13.15 Mapping Unit R

This unit refers to moderately and deeply incised stream channels found throughout the study area. They include the drainage lines of the main river and its tributaries. Currently the area is under risk. Some of the riverien vegetations are already cut down. Unless they are treated with soil conservation measures in the near future, degradation of the areas has negative influence on the anticipated irrigation developments. Therefore, soil conservation is highly recommended to reduce the prevailing erosion of the area. It has an area extent of 219ha and forms about 2.07 % of the survey area.

5.13.16 Mapping Unit ST

This mapping unit occupies the settlement area and towns. The area extent of the land unit is 216.00ha 2.04%).

5.13.17 Mapping Unit F

This land unit is occupied by dense forest vegetable cover. It covers some 130ha, (1.23%) of the study area.

Table 5.14: Summary of Physical and Chemical Properties of Soils of Study Area

Mapping Symbol	pH	EC dS/m	CEC	TN	O.C	C:N	ESP	P2O5	$Caco_3$	B.d	AWC	Infiltration Rates		Hydraulic Conductivity		Area	
	Av.top 25cm	Av.Top. 100cm	AV.Top 25cm	Av.top 25cm	Av.top 25cm	Av.Top 100cm.	Av.Top 100cm	Av.Top. 25cm	Av.Top. 100cm	g/cc^3	mm/m	Measured	FAO Stand.	Measured	FAO Stand.	Ha	%
G1b-1	5.4	0.05	24.8	0.31	3.6	13	1	9.1	-	1.4	98	9.2	1.5	1.5	0.5	1630.38	15.46
G1b-4	5.3	0.06	25.8	0.28	3.2	13	6.7	20.02	1.78	1.3	130.9	9.23	8	2.43	0.5	675.27	6.4
G2d-1	5.2	0.05	31.1	0.26	3.2	13	39.9	9.02	6.17	1.33	80.5	9.8	1.5	1.76	0.5	2429.96	23.04
G2d-2	5.3	0.1	43.2	0.3	4	12	0.5	10.89	-	1.33	101.8	6.9	1.5	3.63	0.5	242.42	2.3
Sg-6	5.8	0.1	29.9	0.4	4.7	12	1.3	13.6	-	1.2	102.8	-	2	-	0.5	787.51	7.47
U1e-4	5.3	0.04	28.5	0.27	3.4	11.2	0.8	3.27	-	1.33	88.5	-	8-	-	1.5	387.45	3.67
U1e-5	5.0	0.06	15.5	0.4	3	9	1	52.75	-	1.3	102.8	-	8	-	0.5	152.51	1.45
U2f-9	6.3	0.09	31.4	0.4	4.4	11	0.6	45.9	-	1.2	94.5	-	2	-	0.5	958.68	9.09
V1b-3	5.1	0.09	39.1	0.2	2.5	10	0.7	12.7	2.24	1.3	138.4	6.5	0.8	0.4	0.3	1053.1	9.99
V2a-7	5.2	0.03	35.6	0.3	4.59	15.6	0.6	3.36	-	1.3	130.3		0.8		0.3	28.99	0.27
V3c-8	6.5	0.2	22.8	0.31	3.1	11.25	0.7	53.125	5.33	1.3	95.6	9.7	2	1.40	0.3	200.21	1.9
G3d	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	67.25	0.64
R	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	1585.46	15.03
St	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	216	2.05
F	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	130.35	1.24
															Total	**10,546**	**100**

Source: Laboratory analyses result, MCE, 2009

Table 5.15: Summary of Morphological Property of the Soils of Study Area

M. Unit Symbol	**Physio/ Geomorphic Land Unit**	Slope %	FAO-1998 Soil	Depth cm.	Drainage Class	Texture Class	Muncull Color	Rock/ Boulders	Flood Class	Erosion hazard		water Table Cm.
										sheet	Gully	
G1b-1	Upper Part of Gently Undulating Plain With Convex Interfluves	0_3	NTdyo	>200	WD	C-Cl	Dark reddish br.-Dark Red	None	Fo	Active	Active	>400
G1b-4	Upper Part of Gently Undulating Plain With Convex Interfluves	0_3	ACfrh	>200	WD	Sacl-SiCl	Dark red-Dar reddish bro.	None	Fo	Active	Active	>400
G2d-1	Middle & Lower Part of Gently Undulating Plains With Convex Interfluves	4_6	NTdyo	>180	WD	Cl-C	Dark reddish brown- Red	None	Fo	Active	Active	>400
G2d-2	Middle & Lower Part of Gently Undulating Plains With Convex Interfluves	4_6	NTro	>200	WD	Cl-C	Dark reddish Brown-Red	None	Fo	Active	Active	>500
Sg-6	Moderately Steep Side of Hill & Ridge	>15	LPeou	>60	SWED	L--Cl	Dark red bro.	>60 Stony, Rocky	F2	High	High	>60
U1e-4	Strongly Sloping Valley & Hill Side	5_8	ACfrh	>160	WD	L-Sacl	Dark red bro.	>160 stony	Fo	High	High	>160
U1e-5	Strongly Sloping Upper part of Hill &Ridge	5_8	CMdyo	>70	WD	Sac-Cl	Brown	> 70 stony	Fo	High	High	>70
U2f-9	Strongly Sloping Hill & Ridge Side	8_15	CMeuh	>100	WD	L-C	Dark brown	>100 stony	Fo	High	High	>100
V1b-3	Seasonally Wet Valley Floor	0_3	VRms	>200	ID	C	Black -Gray	None	F1	No	M	>300
V2a-7	Permanently wet Valley Floor	0_2	GLge	>184	PD	C	Black- Gray	None	F2	No	M	>184
V3d_8	Moderately Dissected Valley Side	4_6	CMfv	>114	WD	L-Sacl	Dark brown	> 114 Gravely	Fo	High	M	>114
G3d	Sloppy Basement Ridges & Tors	-	-	-	-	-	-	-	-	-	-	-
R	Incised Stream Channel	-	-	-	-	-	-	-	-	-	-	-
St	Settlement	-	-	-	-	-	-	-	-	-	-	-
F	Forest	-	-	-	-	-	-	-	-	-	-	-

Source : Laboratory analyses result, MCE, 2009

Table 5.16: Physical Descriptions & Alternative Soil/ Land Management Interventions

M. Unit	FAO- 1998 Soil Type	Land Cover /Use	Major Constraint	Potential	Management Interventions (Major)		
					Fertility Improvement	Soil Erosion Control	Liming
G1b-1	Orthidystric Nitisols	Intensively Cultivated land mainly; ▪ Sorghum ▪ Haricot beans ▪ Sesame & Rice	▪ Moderately acidic soil ▪ Low organic carbon, ▪ Very low available P & (AWC)	▪ High CEC & BSP ▪ High TN % ▪ Deep & Well drained Soil	√	√ Soil & stone bund	√ Dolomitic/ Calictic Lime
G1b-4	Hyperferric Acrisols	Moderately Cultivated land Mainly; ▪ Sorghum & ▪ Rice	▪ Very acidic soil ▪ Low OC, BSP & ▪ Low Available P	▪ Medium AWC, ▪ High CEC & TN% ▪ Deep & Well drained Soil	√	√ Soil & stone bund	√ Dolomitic/ Calictic Lime
G2d-1	Orthidystric Nitisols	Intensively cultivated land Mainly; ▪ Sorghum ▪ Rice &	▪ Moderately acidic soil ▪ Low Organic C, ▪ V. low Available P & ▪ Low-BSP & AWC	▪ High CEC & TN% ▪ Deep & Well drained Soil	√	√	√ Dolomitic lime
G2d-2	Rhodic Nitisols	Intensively cultivated land Mainly; ▪ Sorghum	▪ Moderately Acidic soil ▪ Low OC Very low Av. P & ▪ Low BSP & AWC	▪ High CEC, TN%, ▪ Deep & Well drained soils	√	√	√ Dolomitic/ Calictic Lime
Sg-6	Orthieutric Leptosols	Scattered cultivation/ Shrub & Bushed land Dominant Crops; ▪ Maize & ▪ Sorghum	▪ Moderately steep land >15%, ▪ Stony, Rocky & Shallow soil ▪ Excessive drainage	▪ Very high Av P & TN% ▪ High CEC, BSP & ▪ Moderate Fertility &		√ Terraces Contour ploughing	√ Dolomitic lime
U1e-4	Hyperferric Acrisols	Predominantly cultivated land mainly; ▪ Sorghum	▪ Strongly sloping 5-8% land unit ▪ Moderately acidic soil ▪ Low Av. Phosphorous, ▪ Low BSP, OC & AWC.	▪ High CEC & TN % ▪ Deep & Well drained Soil	√	Contour ploughing, Soil & stone bund	√ Dolomitic/ Calictic Lime

U1e-5	Orthidystric Cambisols	Moderately cultivated land mainly; ▪ Sorghum ▪ Sesame & ▪ Rice	▪ Strongly sloping (5-8%) land unit ▪ Stony and Rocky soil ▪ Moderately acidic soil ▪ Low BSP & OC.	▪ High Ava. P ▪ Medium CEC, ▪ Well drained soils,	√	Contour ploughing, Soil & stone bund & Terraces	√ Dolomitic/ Calictic Lime
U2f-9	Hypereutric Cambisols	Sparsely cultivated, Shrub and Bush land Dominant Crop; ▪ Maize	▪ Strongly sloping 8-15%, ▪ Rock & stony land,	▪ Slightly acidic soil ▪ High Ava. P ▪ CEC & BSP ▪ Medium OC& High N ▪ Well drainage.	√	√ Contour ploughing, Soil & stone bund	√ Dolomitic/ Calictic Lime
V1b-3	Mesotrophic Vertisols	Seasonally wet land ▪ Used for grazing	▪ Poor drainage, ▪ Heavy soil texture, ▪ Moderately acidic soil	▪ Medium Available P. ▪ High CEC, BSP & N, ▪ Medium OC, ▪ Level land	√	√ Gully Control	√ Dolomitic/ Calictic Lime
V2a-7	Glic Gleysols	Seasonally swamp land ▪ Perennial crop, ▪ sugarcane	▪ Poor drainage, ▪ Heavy soil texture, ▪ Moderately Acidic soil ▪ Low BSP, Ava. P	▪ High CEC, Nitrogen, ▪ Level land	Surface Drainage	-	√ Calictic Lime
V3c-8	Fluvic Cambisols	Sparsely cultivated land Dominant Crops; ▪ Sorghum, Maize ▪ Sesame & Rice	▪ Moderately dissected land	▪ Neutral soil reaction, ▪ High CEC, BSP. ▪ Ava. P & Nitrogen, ▪ Well drainage,	√	√ Soil & stone bund -	√ Dolomitic/ Calictic Lime
G3d	Sloppy Basement Ridges	Exposed Rock out crop	▪ Very Shallow, ▪ Rocky and stony land	▪ Settlement	-	-	-
R	Incised Stream Channel	Riverine, disturbed high forest area	-	-	-	Gully Control	-
S	Settlement Area	▪ Settlement	-	-	-	-	-
F	Forest Area	▪ Dense mixed high forest	-	-	-	-	

5.14 SOIL SURVEY: CONCLUSIONS AND RECOMMENDATIONS

5.14.1 Conclusions

The soils study of Eastern Nile, Dinger Bereha Irrigation Development Area was carried out at a feasibility level for 10,546ha of land. According to soil investigation result, from total surveyed area, about 6,260ha (59%) of land is characterized by gently undulating plain and valley floor land form with a slope range of 0-5%, which are expected to be a potential area for irrigation development. Using the methods of topo-graphic maps and aerial photographs interpretation, reviewing previous studies and investigation of field survey, a soil map of 1:10,000 scale and a narrative soil report were produced. In the course of the study soil/land mapping units were verified and representative soil samples have been collected to determine chemical and physical properties of soils. As a result, a total of 1,243 auger holes were described. In addition, 103 profile pits have also been studied and sampled. Taking on an average 4 samples from each profile pit, 303 samples were collected and analyzed at the Water Works Design & Supervision Enterprise Laboratory Serves. Moreover, in-situ infiltration and hydraulic conductivity tests were also studied on 11 representative model profile pits.

The data cites of the study area pertaining to the profiles and auger holes including their location coordinates have been recorded with the help of GPS. Slope percentages were recorded with clinometers. Land form, land use/cover, presence of stoniness, soils drainage, erosion hazards have also been studied in the field. Furthermore, internal soil characteristics such as soil depth, texture, structure, mineral nodules and depth to ground water were noted on each auger hole and profile pits description formats. Thus, based on the investigation results, most of the gently undulating plain with convex interfluve area soils have loam to clay loam on surface and clay texture in subsurface. The Vertisols, which are situated in the valley floor area, have relatively clay to clay-loam soil texture, and the infiltration rate and hydraulic conductivity measurements are found to be at moderate level. Due to relatively low topographic features and high clay contents of the area, the soils have imperfect to poor drainage characteristics.

Cation Exchange Capacity (CEC) and the derived base saturation percentage (BS %) that are important for soil classification, and can be used as indicator for ranking soil fertility assessment are found low to medium. Regarding the total nitrogen percentages the value ranges from medium to very high. On the other hand comparing the organic carbon content with nitrogen content it is found constantly higher for almost all soils.

Subsequently, based on significant information, soils of the Project area are classified based on FAO-ISSS, ISRIC 1998 Guidelines. In due course, four major land units, 12 sub land units and s six major soil types were identified, which include, Nitisols (NT), Acrisols (AC), Vertisols (VR), Cambisols (CM), Gleysols (GL) and Leptosols (LP). The most extensive soils of the Project area are found to be Nitisols which is followed by Acrisols and Cambisols. In area wise Nitisols occupy around 4,303ha, which is about 41% of the study area. Whereas, 1,311ha (12.4%) and 1,063ha (10.1%) are occupied by Acrisols and Cambisols respectively. The remaining area is occupied by Verisols 1,053ha (10.0%), Leptosols 788ha (7.5%) and Gleysols 29ha (0.3%) correspondingly.

With regard to fertility status based on the laboratory test results detailed assessment has been carried out. Accordingly, fertility status of the soils of the study area is found to be low to medium by major nutrients like Phosphorous, Nitrogen and Organic Carbon.

The base saturation percentage of the study area is also confirms the same conclusion that the fertility level of the soils is found to be low to medium. For most of the soils samples its value is observed to be low to medium with an average value of 50 % which indicate that the soils major cations like calcium, magnesium, potassium, and sodium have been leached down and the sizable portion of the soil colloid is covered by Aluminum cation.

As it is observed from laboratory result electrical conductivity (EC) values of all soils of the study area have an average value of 0.1 dS/m, which is very low. It is far below the threshold critical values and therefore, salinity will not be causing any restriction on plant growth of soil of the study area. Similarly, the average value of the exchangeable sodium percentage (ESP) within the 100cm depth of the soils is also low (2). These levels of exchangeable sodium of the soils do not cause any adverse effect for both plant nutrition and physical properties of the soils.

5.14.2 Recommendations

1. As it has been stated, the main constraint for agriculture production in the Project area is believed to be acidity. Yield of any crops are limited mainly as a result of root damage because of Aluminum toxicity. Such damage is readily can be observed on maize. As soon as the plant root is damaged the plant's ability to extract water and nutrients such as phosphorous is severely reduced. As the result plants are very susceptible to drought and are prone to nutrient deficiencies. Based on this fact and others, the sampled area has got acidity potential to hinder crop production unless or else, immediate remedial action is taken to improve the situation. One of the actions to be taken is the use of agricultural lime to neutralize the soil acidity and to suppress the negative effect of aluminum toxicity in the area.

2. The average available phosphorous for most of the soils of the study area is found in the level of medium. The response of soil to phosphorus fertilizer for the time being is not required but, in the near future application of phosphorous fertilizer is indispensable.

3. The valley floor of the study area is covered with Vertisols and they have area coverage of 1,053.1ha. During the wet season the clays of these soils swell and cause pressure in the sub-soil. Therefore, to use these soils properly for future agricultural development, Vertisols management technologies like, broad bed-maker (BBM) should be considered or practiced.

4. During the survey time high deforestation action has been observed in the Project area. This kind of misuse of natural vegetations will have brought high ecological disparity. Therefore, to develop these areas properly and sustainably the prevailing deforestation action has to be stopped and proper management will have to be undertaken especially along the incised stream channels and gully areas.

5. Laboratory results indicated very low of organic carbon having over all an average value of 3.7%. Therefore, to increase the organic matter of the soils of the study area mulching activity has to be done. The positive effect of high organic matter content in the soil is, at the same time, increasing the cation exchange capacity of the soils. Therefore, ploughing back of the crop residues and mulching should be encouraged to raise the very low carbon levels and to improve the structure of the top soils.

6. The amount of lime needed to neutralize soil acidity mostly depends on the crop type, soils, and the effective calcium carbonate equivalent (ECCE) or effective neutralizing value (ENE) of the liming materials. In view of that, when Magnesium deficiencies is occur in the acidic soil dolomitic lime that, containing $MgCO_3$ is particularly advantageous for liming. In the case of soils of the study area as it is learned from laboratory results the Ca: Mg ratio for all identified soil types found to be between 3:1 to 4.1, which is optimum for most of the crops and deficiencies of Mg is not observed. Therefore, with this value ranges to correct soil acidity of the Project area calcitic lime ($CaCO_3$) or dolomitic lime ($MgCO_3$) materials can be used. For that matter both agricultural limes are available from lime crushers at Guder and Degen area.

7. As it is perceived from laboratory result the Ca+Mg/K ratio is high for most of the soils including Cambisols and Leptosols with an average value of greater than 21 and 23 respectively (Table 5.12). Therefore with this value ranges the response of the soils to K fertilizer for the time being is not needed.

8. Standard method for evaluating micronutrients (Fe, Mn, CU and Zn) in soils are not widely agreed. Availability of micronutrients to plants is influenced by crop, soil and environmental factors which must all be taken into consideration when interpreting soil test data. These difficulties have led to an increase in the use of foliar analyses, rather than soil analyses to evaluate micronutrient level in the soil. Hence, the information given in the report helps to show the indicative level of micronutrient in the soils. Therefore, it is recommended that the study of the micronutrients in field trial have to be carried out during the Project operation phase depending on the appearance of the relevant symptom on the plant.

In general, the investigation results of the current study shows that the Project area can be used for irrigation development bearing in mind that application of some of the corrective measures recommended are implemented in order to improve the production of crops sustainably.

References

- Abayneh Esayas with the assistance of Kebede Amede, Soil study of Alewuha Valley Kobo, 1996.
- Gustafson A.f., Soils and Soils management, Agrobios (India)
- BERNSTEIN, L. 1964, Salt Tolerance of Plants, USDA, No. 283.
- Dent, D & Young, A. Soil survey and land evaluation. George Allen and Unwin Ltd.1981, London UK.
- Driessen, P.M and Dudal, R, 1989, Geography, Formations, Properties and Use of Major Soils of the World (eds), Wagnengen, the Netherlands and Leuven, Belgium.
- Dr.Nurhusen Teha & Zeleale S/mariam, 2000 Soil survey Report Afar National Regional state.
- FAO, 1985 Land Evaluation for Irrigated Agriculture Soils Bulletin No. 32, Rome.
- FAO, 1986; Soil Survey Investigation for Irrigation, Soils Bulleting No. 42, Rome.
- FAO, ISSS & ISRIC World Reference Base for Soil Resources, Rome, 1998.
- FAO, Rome, 1979. Soil survey investigation for irrigation development Soil bulletin No.42, Rome.
- Frank Beernaer, Simple and practical methods to evaluate analytical data of soil profiles,INIA, Departement of land & water FAO86/010,Maputo, Mozambique, 1990
- German Agency for technical cooperation LTD, Kobo Alamata agricultural Development Project, Soil study, 1976.
- Landen J.R, 1991, Booker Tropical Soil Manual, a Hand Book for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-Tropics, New York.
- LUPRD, 1984: Geomorphology and soil Map of Ethiopia, Rome.
- Nyle C & Brady, 1990. The Nature and Properties of Soils, Tenth Edition, Macmillan Publishing Company, New York, Collier MaCmillan Puplishers, Londen.
- WWDSE, In Association of MCE and WAPCOS, 2002, "Soil Survey Guideline "Soil Description, Sampling and Coding for Soil Data Base, Addis Ababa.

5.15 LAND EVALUATION : AN INTRODUCTION

5.15.1 Executive Summary

Following the TOR, Land evaluation assessment for irrigation development has been conducted based on the methodology outlined in the FAO Soil Bulletin No. 55, Guideline for Land Evaluation for Irrigated Agriculture (FAO, 1985) and Land Evaluation Framework FAO, Soil Bulletin No. 32.

As part of land resources study the land evaluation assessment aims to translate land resources data into an expression of suitability of land units (land units map) for a defined use. The soil report and map are the valuable tools and a major land resource database for the anticipated land evaluation assessment. With this regard, the main objective of the land evaluation is to select suitable areas for irrigated agriculture development. Thus, five land utilization types (LUTs) were identified and defined in terms of their climatic adaptability, economic viability and food preferences. The selected five land utilization types are: onion, beans, citrus, maize & sesame.

The overall suitability of the land units were then determined on the basis of the suitability ratings, referred to as partial suitability of the individual land use requirements for the LUTs under consideration separately. The evaluation assessments have been carried out assuming moderately to high inputs management levels and high labor intensity. To conduct the land evaluation assessment the land use requirements of these LUTs were determined. The Land use requirements are described by the land characteristics grouped to land qualities needed for the required sustained irrigated agriculture production for the LUTs considered. Based on land characteristics 15 land mapping units have been identified for the study area. After considering various factors namely: agronomic, environmental requirements and conservation, the relevant class determining factors were defined as variables that affect the performance of LUTs on a land unit. Subsequently, individual class determining factors of each land use requirement has been combined (matching) with each land unit and a tentative land suitability classification has been obtained. Thus land suitability maps have been prepared for selected crops separately with surface and overhead irrigation as part of the report. Accordingly, a total area of 6,260, 6,231, 6,231, 2,506, and 6,260ha of land is found to be marginally suitable (available) for surface irrigated agriculture development for onion, beans, citrus, maize and sesame respectively. Similarly 6,800, 6,619, 6,619, 2,506 and 6,648ha of lands for overhead irrigation agriculture are also identified for the same LUTs respectively. On the other hand, due to workability and unsuitable for mechanization currently (N1) and permanently (N2) unsuitable areas for all LUTs for both surface and overhead irrigated agriculture were identified. Summary land suitability class of Diger Bereha study area is presented below. The suitable lands include area of land that will be reduced eventually for infrastructures (for irrigation canals and other infrastructure purposes). Thus, during the designing stage these figures may be lowered by about 5% of the total area anticipated for irrigation development.

In general, most of the soils that have been identified in project area found to be marginally suitable for surface and overhead irrigated agriculture. The limitations are moisture and oxygen unavailability, workability and unsuitability for mechanization. It should also be emphasized that the present land suitability evaluation results are guidelines for future agricultural developments activities.

Table 5.17: Summary of land suitability class of Diger Bereha study area for surface & overhead irrigation

Land	Onion		Beans		Citrus		Maize		Sesame	
Suitability	Surface	O.head	Surface	O.head	Surface	O.head	Surface	O.head	Surface	O.head
Class	Ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
S2										
S3	6,260.3	6,800.3	6,231.31	6,618.8	6,231.3	6,618.8	2,505.9	2,505.9	6,260.3	6,647.8
Sub-Total Suitable	6,260.3	6,800.3	6,231.31	6,618.8	6,231.3	6,618.8	2,505.9	2,505.9	6,260.3	6,647.8
N1	1,845	2,092.5	1,873.99	2,274	1,721.5	1,334	6,387	6,387	2,632.5	2,245.1
N2	2,440.2	1,652.7	2,440.2	1,652.7	2,592.7	2,592.7	1,652.7	1,652.7	1,652.7	1,652.7
Sub -Total Unsuitable	4,285.2	3,745.3	4,314.19	3,926.8	4,314.2	3,926.8	8,039.7	8,039.7	4,285.2	3,897.8
Grand Total	*10,545.5*	*10,545.5*	*10,545.5*	*10,545.5*	*10,545.5*	*10,545.5*	*10,545.5*	*10,545.5*	*10,545.5*	*10,545.5*

5.15.2 Background

The proposed Dinger Bereha Irrigation Project site lies in the Nile River Basin, about 72km North West of Bedele Town and 555km South West of Addis Ababa. It is found in Illuababora Zone, namely in Chewaka Wereda in Oromiya Administrative Region. The Project area is stretched south to north direction and bounded by Didesa River to the east and Dabana River to the North West direction. Geographically, the Project area is located between UTM 98669m-998979m North and 19098m 195294m East. The Project Area is enclosed by ridges to the east and to the west by Torba and Jifara ridges respectively. In general, the steepness of the Project area decreases gradually from two sides (west and east) and forms plain valley in between. The central valley land is characterized by gently undulating plains with convex interfluves, valley floor land and strongly sloping lands. The central part of the Project area has an elevation range of 1139 to 1260 m.a.s.l.

As a result, Eastern Nile Technical Regional Office (ENTRO), requested to survey the Project area at feasibility level to identify the available land to make land suitability assessment for irrigation agricultural development using surface and overhead irrigation system based on climatically adapted, economically viable and socially accepted crops. Thus, five land utilization types (LUTs) are selected, namely onion, beans, citrus, maize, and sesame. Hence, to undertake land evaluation assessment of the study area a comprehensive approach of land resource assessment techniques has been followed in order to identify potential irrigable lands. Therefore, to select suitable land for irrigation development, detailed soil survey at a scale of 1:10,000 has been conducted in the Project area. Following that, the land evaluation assessment for the study area has been undertaken based on FAO guidelines.

The land evaluation assessment, which is part of land resources study, aims to translate land resources data into an expression of suitability of land units (land units map) for a defined use. The soil report and map are the valuable tools and a major land resource database for the anticipated land evaluation assessment. Therefore, in order to carry out land evaluation assessment, it is indispensable to determine potential users and other beneficiaries, for considering whether the benefits will be sustained without irreparable damage to the environment.

With this regard, the main objective of the land evaluation is to select possible relevant land use types for which kind of development land should be classified. The Food and Agricultural Organization (FAO) of the United Nations approach defines that land suitability for irrigation in the manner specified to particular land uses rather than in a general sense, as well as taking into account of non- soil factors like, climate, water resources, social constraints and economic aspects. With this principle, land suitability assessment has been made for five potential land use types (LUTs) based on surface and overhead irrigated agriculture.

5.15.3 Objective

General objectives of the present study:

- To evolve most appropriate and suitable techniques for irrigated agricultural farming with appropriate remedial measurement to improve the deficiencies, if any,
- To avoid the risk of farmers crop failure due to shortage of rainfall, by helping them to develop irrigated agriculture in the area in view of prevailing soil and land characteristics data, and
- To optimize agricultural production from the available land and water resources in a sustainable manner without causing any adverse impact on soil and the overall environment.

Specific objectives of the study:

- To identify suitable areas for irrigated agricultural development, that is simultaneously confirmed to be technically feasible, economically viable, and socially acceptable,
- To compare the major land quality (actual conditions) of the area with land use environmental requirements of land utilization types and classify the soils of the Project area into two land suitability classes for the production of selected land utilization types (LUTs), and
- To illustrate an area of land that possesses specified land qualities and land characteristics (land unit) on a 1:10,000 scale map.

5.15.4 Scope of Work

The scope of the work sited for the land suitability evaluation is summarized as follows:

- Using the results of the soil survey report, prepare a land evaluation report at feasibility level
- Compare major land quality (actual conditions) of the study area with land use environmental requirement of LUTs considered
- Produce land suitability maps at 1:10,000 scale for the LUTs considered

With these objectives in mind a gross area of approximately 10,546ha of land was investigated in the Dinger Bereha valley and by using the soil/land resource data land evaluation assessment was undertaken for irrigated agriculture development.

5.16 METHODOLOGY AND APPROACH

5.17 GENERAL

The land evaluation assessment have been conducted based on the methodology outlined in the FAO Soil Bulletin No. 55, Guideline for Land Evaluation for Irrigated Agriculture (FAO, 1985) and Land Evaluation Framework FAO, Soil Bulletin No. 32,

The FAO framework indicates that it is necessary to evaluate land and not just soils. Thus, the suitability of soils for irrigated crops is useful information but it is inadequate for making decisions about land use development. Therefore, all relevant land characteristics including soils, climate, topography, water resources, etc. and also socio-economic conditions and infrastructure have been considered to undertake suitability assessment of the Project area. Some factors that affect land suitability are permanent and other is changeable at cost. Typical examples for permanent features are temperature, soil texture, depth to bedrock and macro topography. Changeable characteristics which may be altered deliberately or inadvertently, typically may include salinity, depth to groundwater, micro relief, and some social and economic conditions.

Land suitability must therefore be assessed and classified with respect to specified kinds of land use i.e. irrigation and management system. It is obvious that the requirements of crops and irrigation and management methods differ, so the suitability of any land unit may be classed differently for various uses. In the evaluation process, the values of each land quality/characteristic are checked against the class limits of land use requirements for irrigated agricultural development (for each LUT separately). Thus, suitability assessments of the land unit are made for each land use requirements separately. The overall suitability of the land units are then determined on the basis of the suitability ratings, referred to as partial suitability of the individual land use requirements for the LUTs under consideration separately.

The most commonly used method is to assign the suitability class according to the suitability rating of the most limiting condition. For instance, a land unit, which is moderately suitable (S2z) for the production of the LUTs in terms of nutrient availability (z) and marginally suitable (S3m) in terms of moisture availability (m), is classified as marginally suitable (S3m).

Appendix 5G, presents the land use requirements of different land utilization types considered and Appendix 5H, gives the partial suitability ratings of the study area for each LUT separately.

5.17.1 Land Suitability Classes

Land suitability is a measure of how well the qualities and/or characteristics of a land unit match with the requirements of a particular form of LUT. The suitability of the land for specific use has been defined by rating the land qualities of land units, which are relevant to specific land utilization types. The suitability of land for irrigated agriculture has been determined by rating land quality of each soil-mapping unit, which is relevant to the land utilization type. In this way the limitation of each land unit has been identified for the land use under consideration.

Land suitability is defined (FAO, 1976) as the fitness of a specific area of land for specified kind of use a so-called Land Utilization Type (LUT), under a stated system of management. It means to what extent is the land in question able to support the land utilization types under consideration. Each suitability class is divided further into sub-classes to reflect the type of limitations that restrict the suitability of the particular land unit. They can be used to distinguish land with significantly differing managements or production potential. Each class is designated by suffixes (diagnostic factors) or class determining factors that are defined. The first step in classifying suitability is to define each suitability class. The limit for each relevant land characteristics or quality is then set for each class. The FAO Framework encompasses the following three levels of land suitability classes:

- At highest level there are two suitability orders, Suitable *(S)* and Not Suitable *(N).* Suitable land is land on which sustained use of the kind under consideration is expected to yield benefits, which justify the inputs and development costs, without unacceptable risk of damage to land resources. Not Suitable indicates that the land has qualities that appear to preclude sustained use of the kind under consideration

- At second level the suitability orders are divided into five classes, these are: Class *S1,* highly suitable; class *S2,* moderately suitable; class *S3*, marginally suitable; class *N1*, currently not suitable; and class *N2,* permanently not suitable. Fewer or more classes can be designated as appropriate. Only classes with significant economic differences should be distinguished

- At third level there are numbers of classes, which reflect the kind of limitation that restricts the suitability of land for specific land use. Sub-classes, reflecting a requirement or limitation are denoted by a letter suffix, these are d, z, w and d' indicating an oxygen availability, nutrient availability, workability, and soil drainage deficiency respectively.

The structure of the land suitability classification, and land suitability order and class definition are given in this study and an attempt has been made to distinguish between currently and permanently unsuitable (N1 and N2) lands. This distinction is in essence to what extent costs of land improvements are justified. However, in this study, permanently unsuitable refers to severe physical limitations e.g. soil depth, incised stream channels and hilly lands.

The sub-classes reflect the type of limitation. They can be indicated by single character, e.g. m for limited moisture availability. Each suitability class is divided further into sub-classes to reflect the type of limitation that restricts the suitability of the particular land unit. They can be used to distinguish land with significantly differing managements or production potential. The subclass codes are defined specifically for the 5 LUTs under consideration (based on surface and overhead systems of irrigated agricultural development with medium to high input level). The boundaries between suitability classes are subject to revision with time as technologies or socio-economic development occur. Tables 5.18 and 5.19 give application and definition of these classes and sub-classes designations respectively.

Table 5.18: FAO Land suitability classification levels, 1983
(after Ir.c.sys 1991 and H. huizing, ITC 1992)

Order	Class	Name	Definition
S		Suitable	The land can support the land use. Benefits justify inputs without unacceptable risk of damage to land resources.
	S1	Highly Suitable	Land without significant limitations. The potential yield level expected is 85% or more of optimum yield.
	S2	Moderately Suitable	Land having limitations that either reduce productivity or increase the inputs needed to sustain productivity levels compared with those needed on S1 land. The potential yield level expected is 60-85% of the optimum yield.
	S3	Marginally Suitable	Land with limitations so severe that benefits are seriously reduced and/or the inputs required to sustain productivity are such that this cost is only marginally justified. The potential yield level expected is 40-60% of the unsuitable optimum yield.
N		Unsuitable	Land that cannot support the land use sustainable or land on which benefits do not justify inputs.
	N1	Currently Unsuitable	Land with limitations to sustained use that cannot be overcome at currently acceptable cost.
	N2	Permanently Unsuitable	Land with limitations to sustained use that cannot be overcome.

Note: Table 5.18 classification levels represent those used by the FAO but some modifications and updating have been made by different authors based on research results on some definition about yield level, factor ratings, etc based however on FAO system.

5.17.2 Determination Land Utilization Types (LUTs)

Land utilization type is a kind of land use described or defined in a dgree of details greater than that of a major kind of land use. In the context of irrigated agriculture, a land utilization type refers to a crop or crop combination or cropping system.

Land evaluation defines the suitability of a specific area of land (land unit) for specific LUT under stated system of management and input level. The major kind of land use considered for the evaluation is irrigated agricultural development in the command area, using surface and/or overhead irrigation systems.

Thus, to undertake the land evaluation assessement of the study area five land utilization types (LUTs) were identified and defined in terms of their productivity. Primarily, they were selected based on climatic adaptability, economic viability and food preference. As a result, five crop types from vegetable onion, from beans haricot beans/soyaben from cereals maize, from oil crops sesame and citrus were selected.

Table 5.19: Land suitability limitations (Sub-Classes)

Sub- class/ suffixes	Description
c	Climate (Temperature regime): Land units having either very low or very high temperatures below or above the critical temperatures, which may cease the plant growth and may have adverse effect on rate of plant growth, depending on the type of plants and varieties to be grown. Thus, adaptable crops should be carefully selected for evaluation.
m	*Moisture availability:* Land units having soil moisture deficiencies, there is a need for an increased amount and frequency of irrigation and/or selection of draught-resistant crop varieties. Overhead irrigation may be more cost effective.
d	*Oxygen availability:* Land units having soil drainage deficiencies, ascribed to poor soil drainage that may be due to high ground water table, flooding, slow infiltration, slow permeability, slow surface drainage (low physiographic position) or some combination of these. Sub-soiling, diversion ditches and under drainage may be required. Selection of more tolerant crops can be another solution.
n	*Nutrient retention*: Land units having poor capacity of soil to retain added nutrients as against losses caused by leaching, ascribed to low CEC, and these by organic matter. Thus, additional input is required to conserve organic matter and improve soil structure and require fertilizer application.
z	*Nutrient availability*: Land having poor capacity to supply crop with nutrients, ascribed to pH, nutrient availability is lower in pH <6.0 and >7.5 by fixation.
r	Rooting condition: Land units with limited effective soil depth (effective depth is a depth to a limiting horizon having high amount of gravels, hard pan or toxic layers) and restrictive root penetration having massive, columnar or coarse sized structure coupled with very firm consistence and high amount of stones or gravels. Land having restrictive effective soil depth and/or penetrability, which impairs germination and hinders mechanical cultivation.
w	Workability: Land units with poor workability, ascribed to massive clays, poor organic matter content, very firm consistence and occurrence of high amount of stones and gravels in the surface layers.
k	Potential for mechanization: Land units having unfavorable slope steepness, rock hindrances, presence of large amount of surface stones and plastic heavy clays, which affects mechanized agricultural operations by any kind of implements.
t	Land preparation and clearance: Land having topographic limitations ascribed to unfavorable slope angel, micro-relief coupled with excess rock out crops and denser vegetation covers, which needs a higher initial land development cost, requiring land leveling (or short channel lengths and drop structures), grading, terracing, clearances of rock hindrances and vegetation clearances.
e	*Erosion hazard:* Land having an increased water erosion risk under irrigation. Conservation practices and surface drainage control are required.

The evaluation has been carried out assuming moderately to high inputs management levels, moderate to high capital investment and high labor intensity. Thus, the LUTs can be defined, as medium to high input level of fertilizer and herbicide, moderate capital investment, medium to high labour intensity, 100% private property, with moderate and high management level by using surface and overhead irrigation and improved agronomic cultural practices, for local consumption and with international commercial market orientation.

In this evaluation no significant changes are envisaged in the present production pattern system in the way farmers cultivate land. However, required irrigation technology practices will be expected to enhance food security and to reduce rural poverty. Thus, the purpose of the present land evaluation is to assess in qualitative terms, the biophysical suitability of the land for the selected land utilization types.

The results of the physical analysis will be used in the subsequent planning phase to identify opportunities and constraints, to assess the economic viability of changes in management and input levels. The land use reflects the current land use practices that are not expected to change significantly in the foreseeable future without major interventions. The present land evaluation provides a systematic overview of the physical limitations of these land uses. This in turn provides a useful indication on opportunity, and type of improvements required to improve the systems.

5.17.3 Land Use Requirements

5.17.3.1 General

The land use requirements of the LUTs considered are discussed below. Information on land units such as, definitions and descriptions of land units, maps showings the description of different land unit values and characteristics belonging to the land units are obtained from the land resources surveys results.

5.17.3.2 Land Use Requirement or Limitation

Land use requirement is the necessary or desirable condition of land for the successful and sustained practice of a given LUTs. An example of a land use requirement is the moisture availability required by a specific crop to determine an acceptable yield level. Land use requirements may include crop requirements, management requirements and conservation requirements etc. (FAO, 1983). The land use requirements are described by the land characteristics or land qualities needed for sustained production is presented under Appendix 5G. A land characteristic is an attribute of land that can be measured or estimated like, soil drainage, soil pH, soil texture etc. A land quality is a complex attribute of land that has direct effect on land use, but cannot be measured directly. The moisture availability is an example of a land quality. It cannot be measured directly, but it can be calculated from three land characteristics: field capacity, permanent wilting point and bulk density.

Land use requirements also include a set of limiting values. These define the degree of limitation of a specific value of a land quality or characteristic that has adverse effect on the sustainable production. Such sets of limiting values are also referred to as factor ratings. For instance, a deep rooting crop like maize requires an effective soil depth of >100cm or more. An effective soil depth exceeding >100cm, thus will not limit the crop yield and is rated as highly suitable. A soil depth of 75-100cm will have a moderate effect on the yield (rated moderately suitable), a soil depth of 50-75cm will result in a significant yield depression (rated marginally suitable), while soils shallower than 50cm will severely limit the yield potential and are rated as unsuitable.

Some class determining factors that affect land suitability for irrigation are permanent and others are modifiable at cost. *Climate (altitude), soil depth and soil texture* are typical examples of permanent factors. Modifiable or changeable factors, which may be changed, may include: nutrient retention, stoniness, salinity/sodicity, depth of groundwater and socio-economic conditions (e.g. land tenure and accessibility). The costs of necessary land improvements have to be estimated so that the economic and environmental consequences of development can be predicted.

Different (LUTs) irrigation methods and management systems have different ecological requirements. Thus, the agronomic, land development, management; conservation and environmental factors, and the relevant class determining factors are considered and defined as variables that affect the performance of LUTs on a land unit. Then taking each land unit map and rating land qualities or land characteristics relevant to that LUT establish the suitability of land units for a specific use. These requirements are listed in terms of land quality, together with ranges of suitability for the land characteristics, which have been used to assess each land unit.

The Land use requirements are described by the land characteristics grouped to land qualities needed for the required sustained irrigated agriculture production for the LUTs considered as described below. In discussing the land suitability for irrigated agriculture, the quality of irrigation water also needs to be assessed, particularly in respect to its potential effect on soil salinity and sodicity. The result of these analysis show that the water quality is excellent for irrigation purposes. In addition to the physical land qualities, climatic land qualities have to be assessed in land suitability assessment for any LUT.

The study area can be conveniently categorized as moist kola agro-climatic zone. The climate is hot particularly in the month January to March. The average temperature during the hot season ranges from 35^0C to 41^0C, and during the rainy season (July to August) varies from 21^0C to 27^0C. With regard to rainfall, the Project area is situated within the highest rainfall region of the country. The rainfall is characterized by uni-modal type. The rainy months extend from May to October. The rainfall distribution of the area shows that the rainy season varies from 158mm in May to 104mm in October; the maximum peak month is July, which reaches up to 312mm. The dry seasons ranges from December to February. Thus, the mean annual rainfall is 1454mm.

Likewise, the average monthly relative humidity of the Project area is 75.51% with minimum value of 56.63% in March. Therefore, relative humidity of the Project area on the average condition can be taken in the range of 56.6% to 88.6%. Summarized climatic data of the study area have been presented in Table 5.3 and Land Use Requirement for Surface and/or Overhead Irrigation is also presented in Appendix 5G.

Surface irrigation is the most common method of irrigation in the world and now a day's overhead irrigation is also in some countries practiced intensively. Soils with high infiltration rate are commonly not suitable for surface irrigation, because the distribution of irrigation water is difficult to maintain without short furrows. As a result the loamy soils may be considered as marginally suitable, despite the potential optimum nutrient and moisture holding capacity.

However, the range of suitable soils can be considered for overhead irrigation, which involves little land preparation and can provide flexible irrigation interval and water application. Thus coarse and shallower soils may be considered. Loamy and clay soils occurring on slopes up to 6% can be considered for overhead irrigation method. However, overhead irrigation is potentially more efficient and uses less labor than surface irrigation and can be adapted more easily to sand and erodible soils on undulating land. High bulk densities hinder root penetration in fine textured soils, if compacted. In general soils of the area are tillable depending on their textural differences.

5.17.3.3 Land Use Requirement for Selected Land Utilization types

1. Irrigated Vegetables Cultivation, Requirement of Onion (Allium cepa)

Onion is vegetable best suited for small scale irrigation mainly along river terraces, but where cooler temperature prevails. Onion grows on a wide variety of soils, provided they are well aerated and friable as long as sufficient water can be retained. Fertile, loams textured soils are most suitable. The maximum rooting depth of the crop is 50cm. EC values of 1.8 ds/m may cause 10% of yield reduction, and 2.8 ds/m may cause 25% yield reduction. Sodicity affects the productions of onion and 50% yield reduction takes place at exchangeable ESP of 35%. Onion is not grown in the lowland humid tropics. Cool conditions with an adequate moisture supply are most suitable for the early growth of onion, warm and drier conditions are required at maturation and harvesting stages. Optimum pH range is 6.0-7.5, although alkaline soils area also suitable up pH 8.2. Soils with CEC contents of above 16 meq/100g soils, more than 50% base saturation and over 2% organic carbon content are most suited for optimum requirement of onion. Onion requires uniform moisture supply throughout the growing season. The total growing period requirement ranges between 130 and 175 days including nursery management.

Germination takes place in the temperature range of 20-35^0C. Optimum temperatures for the plant growth is between 13 and 24^{0}C. Flowering and consequent low yields are observed at temperatures less than13^{0}C. Early maturity and low yields occur at temperatures greater than 24^{0}C. The optimal precipitation for onion is 350 – 600mm/growing cycle. Low air humidity and low temperatures lead to flowering. Onion is sensitive to day length: 12-13 hours of day length are required in the yield formation period. Land use requirements for surface and overhead irrigated vegetables cultivation is presented in 5G.

2. Requirement of Beans

Climate: Beans are not grown in the low land, humid tropics. Beans can grow in regions that are characterized by air temperature between 18 and 30^{0}C. The optimum temperature range is 15 - 20^{0}C. The crop is sensitive to temperature above 30^{0}C, especially at flowering and seed set. The soil temperature for germination should be more than 15^{0}C. They are sensitive to frost; flowers are damped at 5^{o}C. Moisture stress should be avoided in the flowering and setting periods and dry weather is required at harvest. Excessive rain causes flower drop and diseases. An annual precipitation of 400 - 500mm is adequate for growing beans. Beans prefer a medium to high relative air humidity, especially at flowering. Dry winds affect pollination and therefore, the yield. Strong winds damage the crop.

Soils: The maximum rooting depth of the crop is between 1.0 and 1.5m. The minimum soil depth is about 0.5m and the optimum being 0.75m. However, soils that show surface capping should be avoided. They can be grown on soils with a texture ranging from loamy sand to clay; best are loam to clay loam textures. Soils, with moderately to well drained are most suitable. The crop is sensitive to water logging, surface water standing for only a few hours damages the crop. The pH range is between 5.2 and 8.2 and the optimum is between 6.0 and 7.0. A Land use requirement for surface and overhad irrigated beans cultivation is presented in Appendix 5G.

3. Requirements of Citrus, (Citrus spp.)

Climate: It is mostly grown in sub-tropical countries below 600m.a.s.l. Citrus do not do well on the equator bellow 1800m.a.s.l. It performs well in the temperatures range of 13-39^{0}C, but it prefers air temperatures of 22-30^{0}C. Among citrus spp. grapefruits can withstand long hot periods than other citrus spp.

The required average total rainfall should be >800mm unless irrigated. High wind speed can cause much damage and consideration should be given to the provision of windbreaker. Flowers and young fruits are sensitive to frost. Citrus is intolerant to high humidity, but mandarins can tolerate wetter conditions than other citrus spp.

Soils: Citrus roots have a high oxygen requirement, thus the soil should be well aerated, well drained and not too heavy in textures. The most suited soil textures are light sands to medium loams. It can be grown on poor, sandy soils that are extremely low in natural fertility. An excess of phosphorus can cause micronutrient deficiency and impair nitrogen use. It is also susceptible to magnesium, deficiency caused by excess of calcium and/or potassium. Dolomite and limestone should be used for liming acid soils. The crop is sensitive to water logging and the pH range should be between 5.5 and 7.6.Land use requirements for surface and overhad irrigated citrus cultivation are presented in Appendix 5G.

4. Requirement of Maize (Zea mays)

Maize is a demanding crop, yielding higher than other cereals if climate and soils are favorable.

Climate: Maize has a wide range of tolerance to environmental conditions, but growing season must be frost-free. It grows in temperature that ranges from 14-40^{0}C. The growth of the crop is optimal at temperatures between 18^{0}C and 32^{0}C. The mean maximum temperature should be in the range of 26-29^{0}C, the mean minimum temperature should be in the range of 12-24^0 C, and germination is reduced at 13^{0}C and fails at temperatures below 10^{0}C. It is most sensitive to moisture stress from the beginning of flowering until the end of grain formation.

Soils: Maize can grow on many types of soils. It requires well-drained, well-aerated, deep loam and silt soils, with adequate organic matter. The maximum rooting depth is about 2m, but the majority of the water and nutrient uptake roots are in the top 90cm of the soil. Shallow soils depress yields, both because of increased drought hazard and lower nutrient supplies.

Land units with substantial drainage impediment as shown by mottling within 1m depth from the surface should be avoided, unless installation of artificial drainage is planned. It can't stand water logging in the first 5 weeks after sowing. From the 6th week onwards, water logging for 1 to 2 days may not kill the crop. On soils with low moisture retention capacity, or in areas of low rainfall, a low plant density should be used to avoid competition for water and nutrients. Yield increases with planting density on irrigated plot, but the reverse may occur on rain fed plots. The preferred pH requirement of maize can range from 5.5 to 8.0; however, it can grow in the pH range of 5.2 to 8.2, with proportional yield reduction, but this can be rectified. Strongly acid soils or alkalin soils (PH <5.2 and >8.5), however are unsuitable. It has high nutrient requirement, thus soils having a higher CEC are more suitable. Nitrogen is the most important nutrient. Young maize has difficulty in taking up phosphorous from the less available phosphate forms in the soil. Potassium removal is very high in maize harvested for silage: 200-300kg/ha are removed at harvest time.

To produce some 6ton grain/ha, nutrient removal of 165, 24 and 112 (kg/ha/growing cycle) of N, P_2O_5 and K_2O takes place respectively. The soils of the study area are of moderate to low fertility level, and all have moderate levels of organic matter. Fertilizer application range required to produce about 4ton grains/ha will be 60-100, 50-100, and 30-60 (kg/ha/ growing cycle) for N, P_2O_5 and K_2O respectively. Traditional smallholder yield range is between 0.5 to 1.5ton grain/ha, but good commercial yield under irrigation range between 6 to 9ton grain/ha and 80ton fodder/ha.

Excess of salts: Maize is moderately sensitive to salinity, no yield reduction at an electrical conductivity (EC) of <1.7 dS/m, the yield reduction is 10% at 1.7 to 2.5; 25% at 3.6, 50% at 5.9, and 100% at 10 dS/m. Thus, ECe values requirement for maize ranges from 2.5 to 5.9 with proportional yield reduction. The ESP requirement for maize ranges from 15 to 25, with proportional yield decrease. The optimum ESP levels are below 15; maize can suffer by progressively stunted growth at ESP levels above 15 and about 50% yield reduction is observed at an ESP of 15%. The higher ESP levels can be mitigated by gypsum application to lower at the required level. A land use requirement for surface and overhad irrigated maize cultivation is presented in 5G.

5. Requirement of Sesame (Sesamum Indicum L. Syn.)

Sesame is an adaptable crop to the hotter, less fertile environments of the country, because of its drought resistance, ease of management, adaptability to poor soils and suitability for intercropping. It is therefore, appropriate for cropping in the lowland region, from 0m to 1600m altitude. These areas have a tropical wet and dry or a semiarid climate (Koppen, Aw and Bsh) with a mean annual rainfall of 600-800mm. Although sesame is drought resistant it is very sensitive to excess soil moisture. The best soils are freely drained sandy loams with a pH of 5.5-7.0, but sesame is not exacting in its soil requirements and does reasonably well on poor soils.

Growth habit: An annual erect herb 30-200m tall, with stem longitudinally furrowed and densely hairy. It has a long (90cm) tap root and a dense surface mat of feeding roots. There are a large number of cvs, differing in duration, season of planting, degree of branching, number of flowers per axil, etc. Basically the cvs are classified into two groups, being either shattering or non-shattering according to whether the seed capsules open on drying.

Land preparation: Since sesame seed is small (300 seeds to 1g), it should be planted shallowly on a firm but mellow seedbed. All living weeds should be killed and trash removes or ploughed under since this crop is usually grown in areas of limited rainfall, land preparation should run across the slope to aid in water retention and to minimize run-off.

Planting practices: Seeds are frequently sown broadcast at the rate of 5-8 kg/ha. They are often mixed with sand or with an associated crop such as sorghum before sowing in order to achieve an even spread. If sown mechanically in lines, or if thinning is done, the seed should be sown 2cm deep at an optimum plant population of 200,000ha in rows about 50cm apart, with one seed to 6-12cm of row. Where seedling emergency may be hampered by heavy soil the seedling rate should be increased and the desired stand of plants achieved by thinning after emergence.

Fertilizer application: Sesame is usually not fertilized, but fertilizer experiments have shown good response to N and K; 30-50kg/ha N. 10-20 kg/ha P_2O_5 and 30-40 kg/ha K_2O are generally recommended. A Land use requirement for surface and overhad irrigated sesame cultivation is presented in appendix 5G.

5.17.4 Land Mapping Units

Land mapping units are areas with land qualities that differ sufficiently from those other land units to affect their suitability for different land use. Land units are areas of land with specific characteristics. They are normally represented within a boundary on a map in order to create visually geographical framework. They have been described in terms of their characteristics and qualities. Land characteristic is a simple attribute that can be measured or estimated such as soil texture, effective soil depth, drainage, topography and ability of soil to retain nutrient. Land mapping units are described by their major land characteristics. Land Quality is an attribute of land, which acts in distinct manner and its influence on the suitability of land for irrigated agriculture. In the present study land qualities are water availability, soil depth, hydraulic conductivity, poor drainage, soil workability, susceptibility to erosion and water logging. Based on land characteristics 15 land mapping units have been identified for study area. Summary of these land units characteristics are presented below in Table 5.15. Land and soil characteristics rating are available in Annex B.

Table 5.20: Summary of Physical and Chemical Properties of Soils Study Area

Mapping Unit	pH 1/2.5	EC dS/m 1/2.5	CEC meq/100g	TN (%)	O.C (%)	C:N	ESP %	P2O5 ppm	$Caco_3$ %	B.d	AWC	Infiltration Rates		Hydraulic Conductivity		Area	
												cm/hr	cm/hr	m/day	m/day		
Symbol	Av.top 25cm.	Av.Top. 100cm.	AV.Top 25cm.	Av.top 25cm.	Av.top 25cm.	Av.Top. 100cm.	Av.Top. 100cm.	Av.Top. 25cm.	Av.Top. 100cm	g/cm^3	cm/m	Measured	FAO Meas	Meas.	FAO Stan	ha	%
G1b-1	5.4	0.05	24.8	0.31	3.6	13	1	9.1	-	1.4	98	9.2	1.5	1.5	0.5	1630.38	15.46
G1b-4	5.3	0.06	25.8	0.28	3.2	13	6.7	20.02	1.78	1.3	130.9	9.23	8	2.43	0.5	675.27	6.4
G2d-1	5.2	0.05	31.1	0.26	3.2	13	39.9	9.02	6.17	1.33	80.5	9.8	1.5	1.76	0.5	2429.96	23.04
G2d-2	5.3	0.1	43.2	0.3	4	12	0.5	10.89	-	1.33	101.8	6.9	1.5	3.63	0.5	242.42	2.3
Sg-6	5.8	0.1	29.9	0.4	4.7	12	1.3	13.6	-	1.2	102.8	-	2	-	0.5	787.51	7.47
U1e-4	5.3	0.04	28.5	0.27	3.4	11.2	0.8	3.27	-	1.33	88.5	-	8	-	1.5	387.45	3.67
U1e-5	5.0	0.06	15.5	0.4	3	9	1	52.75	-	1.3	102.8	-	8	-	0.5	152.51	1.45
U2f-9	6.3	0.09	31.4	0.4	4.4	11	0.6	45.9	-	1.2	94.5	-	2	-	0.5	958.68	9.09
V1b-3	5.1	0.09	39.1	0.2	2.5	10	0.7	12.7	2.24	1.3	138.4	6.5	0.8	0.4	0.3	1053.1	9.99
V2a-7	5.2	0.03	35.6	0.3	4.59	15.6	0.6	3.36	-	1.3	130.3	-	0.8	-	0.3	28.99	0.27
V3c-8	6.5	0.2	22.8	0.31	3.1	11.25	0.7	53.125	5.33	1.3	95.6	9.7	2	1.40	0.3	200.21	1.9
G3d	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	67.25	0.64
R	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	1585.46	15.03
St	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	216	2.05
F	-	-	-	-	-	-	-	-	--	-	-	-	-	-	-	130.35	1.24
Total																**10545.5**	**100**

Table 5.21: Summary of Morphological Properties of Land Units of the Project area

Map unit	Land form	Slope %	FAO- 1998	Depth cm	Drainage Class	Texture Class	Soil color	Rock/ Boulders	Flooding	Erosion	Water table
G1b-1	Upper Part of Gently Undulating Plain With Convex Interfluves	0_3	NTdyo	>200	WD	C-Cl	Dark reddish br.-Dark Red	None	Fo	Active	Active
G1b-4	Upper Part of Gently Undulating Plain With Convex Interfluves	0_3	ACfrh	>200	WD	Sacl-SiCl	Dark red-Dar reddish bro.	None	Fo	Active	Active
G2d-1	Middle & Lower Part of Gently Undulating Plains With Convex Interfluves	4_6	NTdyo	>180	WD	Cl-C	Dark reddish brown-Red	None	Fo	Active	Active
G2d-2	Middle & Lower Part of Gently Undulating Plains With Convex Interfluves	4_6	NTro	>200	WD	Cl-C	Dark reddish Brown-Red	None	Fo	Active	Active
Sg-6	Moderately Steep Side of Hill & Ridge	>15	LPeou	>60	SWED	L--Cl	Dark red bro.	>60 Stony, Rocky	F2	High	High
U1e-4	Strongly Sloping Valley & Hill Side	5_8	ACfrh	>160	WD	L-Sacl	Dark red bro.	>160 stony	Fo	High	High
U1e-5	Strongly Sloping Upper part of Hill &Ridge	5_8	CMdyo	>70	WD	Sac-Cl	Brown	> 70 stony	Fo	High	High
U2f-9	Strongly Sloping Hill & Ridge Side	8_15	CMeuh	>100	WD	L-C	Dark brown	>100 stony	Fo	High	High
V1b-3	Seasonally Wet Valley Floor	0_3	VRms	>200	ID	C	Black -Gray	None	F1	No	M
V2a-7	Permanently wet Valley Floor	0_2	GLge	>184	PD	C	Black- Gray	None	F2	No	M
V3c_8	Moderately Dissected Valley Side	4_6	CMfv	>114	WD	L-Sacl	Dark brown	> 114 Gravely	Fo	High	M
G3d	Sloppy Basement Ridges & Tors	-	-	-	-	-	-	-	-	-	-
R	Incised Stream Channel	-	-	-	-	-	-	-	-	-	-
St	Settlement	-	-	-	-	-	-	-	-	-	-
F	Forest	-	-	-	-	-	-	-	-	-	-

5.18 LAND SUITABILITY CLASSIFICATION

5.18.1 General

Land suitability assessment has been made for five selected potential crops. These selected crops are vegetables (Onion), beans, citrus, maize and sesame. The results of matching of land use requirement of each selected crop with the condition of each land mapping unit has been discussed in this section. Summary of the land suitability classes, sub-classes rating of land units by LUTs including area extent are shown in Table 5.18.

5.18.2 Basis for Classification

Land evaluation methodology followed in this report is described in chapter 5.12.2. Table 5.13 shows the structure of FAO Framework for Land Evaluation and Table 5.14 indicates the list of class determining factors or sub-classes (suitability limitations). The major environmental and management requirements of the proposed LUTs for the command area are identified and discussed in section 5.17. Appendix 5G presents the land use requirements for LUTs considered as a guide in assigning land suitability classes and sub-classes to the particular LUT or crop. Each LUT has been assessed separately and land suitability classes, sub-classes and area extent of different land units are presents in Table 5.18

5.18.3 Land Suitability Characterization by Land Units

5.18.3.1 General

Land suitability assessment has been made for five selected potential crops. These selected crops are vegetables (Onion), beans, citrus, maize and sesame. The results of matching of land use requirement of each selected crop with the condition of each land mapping unit has been discussed in this section. The individual class determining factor of each land use requirement has been combined with each land unit and a tentative land suitability classification has been obtained. Summary of the land suitability classes, sub-classes rating of land units by LUTs with their area extent are shown in Table 5.23 and partial suitability classes for Dinger Bereha Irrigation area is also presented in appendix 5H.

5.18.3.2 Land Suitability Classes of Each Land Unit

1. Land Mapping Unit G1b_1

This mapping unit is found largely located in the central part of the study area. It covers around 1,630.38ha and constitutes about 15.46% of the study area. Due to nutrient availability, drainage problem and erosion hazards the land unit is rated as marginally suitable for both surface and overhead irrigated cultivation of onion, beans, citrus, maize and sesame. Land suitability class and sub-class rating of the study area are presented in Table 5.23.

2. Land Mapping Unit G1b_4

The area extent of G1b_4 land unit is around 675.27 ha, which is about 6.4% of the study area. It is rated as marginally suitable due to nutrient availability and drainage limitation for all selected land utilization types both for surface and overhead irrigated agriculture, Table 5.23.

3. Land Mapping Unit G2d_1

This land unit covers around 2,429.96ha or about 23.04% of the study area. It is rated as marginally suitable for onion, beans, citrus and maize both for surface and overhead irrigated cultivation, due to nutrient unavailability, drainage problem, workability and potential for mechanization limitations. But it is rated as currently unsuitable (N1z) cultivation, having nutrent availability limitation for both, surface and overhead irrigated maize cultivation, Table 5.23.

4. Land Mapping Unit G2d_2

This land unit occupies around 242.42ha, which accounts 2.3 % of the study area. It is rated as marginally suitable for onion, beans, citrus, and sesame for surface and overhead irrigated cultivation. Nevertheless, it is down graded to currently unsuitable (N1z) for surface and overhead irrigated maize cultivation due to nutrent availability limitations.

5. Land Mapping Unit Sg_6

This land unit has an area extent of 787.51ha of land and accounts about 7.47% of the study area. The land unit is rated as currently unsuitable (N1wk) for overhead irrigated cultivation of onion and beans, due to workability and rated as unsuitable for both surface and overhead irrigated cultivation of maize and sesame due to unsuitable for mechanization. Further more; it is rated as permanently unsuitable for surface irrigated cultivation of onion, beans and citrus, because of workability and unsuitable for mechanization.

6. Land Mapping Unit U1e_4

It has an area extent of 387.45ha which is about 3.67% of the study area. It is rated as currently unsuitable (N1kw) for surface irrigated cultivation of onion, beans, citrus and sesame. It is also reted as currently unsuitable for both surface and overhead irrigated cultivation of maize. Nevertheless, the land unit is rated as margenaly suitable for overehead irrigated cultivation of onion, beans, citrus and sesame. Land suitability class and sub-class rating of land unit of the study area are presented in Table 5.23.

7. Land Mapping Unit U1e_5

U1e_5, land unit covers an area of 152.51ha, which is about 1.45% of the study area. The unit is rated as permanently unsuitable (N2r) for surface and overhead irrigated cultivation of citrus, because of root condition limitation. It is also rated as currently unsuitable (N1k, N1zwk, N1z and N1zk) for both surface and overhead irrigated cultivation of beans, maize and sesame due to, workability, unsuitable for mechanization and nutrient unavailability limitations. But due to workability limitation it is rated as marginally suitable (S3k,) for overhead irrigated cultivation of onion.

8. Land Mapping Unit U2f_9

The land unit occupies about 958.68 ha (9.09%) of the study area. It is downgraded to currently unsuitable for surface and overhead irrigated cultivation of all land utilization types. A land suitability class and sub-class rating of each land is shown in Table 5.23 and Partial suitability classes for Dinger Bereha Irrigation area is also presented in appendix 5H.

9. Land Mapping Unit V1b_3

This land mapping unit occupies some 1,0531 ha or about 9.99 % of the study area. It is marginally suitable (S3zd[1], S3zrw, S3zr etc.) for surface and overhead irrigated cultivation of onion, beans and citrus, due to nutrient unavailability and drainage limitation it is also rated as currently unsuitable (N1z) for surface and overhead irrigated cultivation of maize.

10. Land Mapping Unit V2a_7

The area extent of this land mapping unit is around 28.99 ha, about 0.27% of the study area. It is rated as currently unsuitable (N1d) for beans, citrus and maize due to drainage problem, but it is classifiedas as margenaly suitable for both surface and overhead irrigated cultivation of onion and sesame due to drainage constraint.

11. Land Mapping Unit V3d_8

This unit covers around 200.21 ha or about 1.9% of the study area. The unit is rated as marginally suitable (S3wk, S3d[1], and S3wkd1 etc) for surface and overhead irrigated cultivation of all land utilization types (LUTs), the major limitation is workability, unsuitable for mechanization and drainage problem.

12. Land Mapping Units (G3d & R)

These land units include slopping basement ridges (with shallow soils and boulders, stony) and incised river channels. In terms of area they have an area extent of 1,652.71 ha which is about 15.67% of the study area. Due to workability and unsuitable for mechanization they are rated as permanently unsuitable (N2/r/t) for all land utilization types.

13. Land Mapping Units St and F

These land units covers around 346.35ha or about 3.29% of the study area. They are described as settlements and forest area, therefore due to their area occupation and unsuitable for mechanization and workability they are rated as currently unsuitable forall land utilization types.

5.18.4 Land Suitability Maps

Following the abovementioned steps land evaluation assessment has been undertaken to select and map suitable lands for irrigation development in the Project. Thus the following land suitability maps have been prepared for selected important crops separately with surface and overhead irrigation, which are availed and presented as part of the report with the maps indicated against them (Table 5.22).

Table 5.22: Type of Land Suitability for LUTs

No.	Type of Land Suitability	Figure
1	Land Suitability for Surface Irrigated Onion Cultivation	(Map LS.1S)
	Land Suitability for Overhead Irrigated Onion Cultivation	(Map LS.1O)
2	Land Suitability for Surface Irrigated Beans Cultivation	(Map LS.2S)
	Land Suitability for Overhead Irrigated Beans Cultivation	(Map LS.2O)
3	Land Suitability for Surface Irrigated Citrus Cultivation	(Map LS.3S)
	Land Suitability for Overhead Irrigated Citrus Cultivation	(Map LS.3O)
4	Land Suitability for Surface Irrigated Mize Cultivation	(Map LS.4S)
	Land Suitability for Overhead Irrigated Mize Cultivation	(Map LS.4O)
5	Land Suitability for Surface Irrigated Sesame Cultivation	(Map LS.5S)
	Land Suitability for Overhead Irrigated Sesame Cultivation	(Map LS.5O)

Table 5.23: Land suitability class and sub-class rating of land units of Dinger Bereha Irrigation Area

No.	Mapping Unit	Area		Onion		Beans		Citrus		Maize		Sesame	
		ha	%	Surface	Over	Surface	Over.	Surface	Over.	Surface	Over.	Surface	Over.
1	G1b-1	1630.38	15.46	S3zd^1	S3zd^1	S3d^{1}e	S3d^1	S3d^{1}e	S3d^{1}e	S3d^1	S3zd^1	S3zd^1	S3zd^1
2	G1b-4	675.27	6.4	S3zd^1	S3zd^1	S3zd^1	S3zd^1	S3d^{1}e	S3d^{1}e	S3zd^1	S3zd^1	S3zd^1	S3zd^1
3	G2d-1	2429.96	23.04	S3zwk	S3zwk	S3zwk	S3zd^1	S3wk	S3wd^1	N1z	N1z	S3zwd^1	S3zd^1
4	G2d-2	242.42	2.3	S3zwk	S3zwk	S3zwk	S3zd^1	S3wk	S3wd^1	N1z	N1z	S3zwk	S3z
5	Sg-6	787.51	7.47	N2wk	N1wk	N2wk	N1wk	N2rwk	N2r	N1wk	N1wk	N1wk	N1wk
6	U1e-4	387.45	3.67	N1kw	S3kw	N1wk	S3zwk	N1kw	S3wk	N1zk	N1zwk	N1wk	S3zwk
7	U1e-5	152.51	1.45	N1k	S3k	N1zwk	N1z	N2r	N2r	N1zk	N1z	N1zwk	N1z
8	U2f-9	958.68	9.09	N1wk	N1wk	N1wk	N1kw	N1wk	N1wk	N1wk	N1wk	N1wk	N1wk
9	V1b-3	1053.1	9.99	S3zd^1	S3zd^1	S3zrw	S3zr	S3zwk	S3dwk	N1z	N1z	S3zd1	S3zd^1
10	V2a-7	28.99	0.27	S3zdd^1	S3zdd^1	N1d	N1d	N1d	N1d	N1z	N1z	S3dd^1	S3zd^1
11	V3c-8	200.21	1.9	S3wk	S3d'	S3wkd^1	S3d^{1}e	S3wk	S3d^1	S3wk	S3d^1	S3wkd^1	Swkd^1
12	G3d	67.25	0.64	N2wk	N2wk	N2wk	N2wk	N2wk	N2wk	N2wk	N2wk	N2wk	N2wk
13	R	1585.46	15.03	N2w	N2w	N2w	N2w	N2w	N2w	N2w	N2w	N2w	N2w
14	St & F	346.35	3.29	N1w	N1w	N1w	N1w	N1w	N1w	N1w	N1w	N1w	N1w

5.19 SOILS AND LAND MANAGEMENT

5.19.1 General

Most of the investigated soils in valley floor area are characterized by clay and clay loam and on gently undulating plain land forms they are characterized mostly by clay loam soil teture. Soil color of the surveyed area is mainly related to drainage and to lesser extent, to parent material. Therefore, the imperfectly drained soils have very dark brown (10YR3/1) color on surface and dark gray (10YR4/1) color in subsurface. The main soil and land management requirements for the study area are briefly described below.

5.19.2 Soil Fertility

Based on the laboratory test results of the soil of the study area, the soils are low to medium in major nutrients like phosphorous, nitrogen and organic carbon. This may be related to the fact that, the soil is highly weathered and most cations leached down. This fact is also due to that the study area receives high rainfall annually, which is more than 1400mm. The base saturation percentage confirms the same conclusion that the fertility level of the soils is low to medium, due to major cations like calcium, magnesium, potassium, and sodium have been leached down and the sizable portion of the soil colloid is covered by Aluminum cation.

5.19.3 Soil Reclamation

The primary yield limiting factor of the area is believed to be acidity. Yield of any crop are limited mainly as a result of root damage because of Aluminum toxicity. Such damage is readily can be observed on cereals crop like maize and finger millet. As soon as, the plant root damaged the plant's ability to extract water and nutrients such as phosphorous is severely reduced. As the result, plants are very susceptible to drought and are prone to nutrient deficiencies. Therefore, all the analyzed soil samples for acidity test which have tested for pH less than 5.5 falls in strong acid category. However, when it was tested for Aluminum toxicity only five samples out of the suspected 40 samples confirm Aluminum toxicity. Most importantly, the effects of acidity on crop yield may be significant. As has already been stated, maize and several other crops would not be expected to produce anything on soils as acid as those collected from the study area and optimally fertilized crops would not be expected to produce more than 50% of their potential. Based on these facts and others, the sampled area has got acidity potential to hinder crop production unless otherwise, immediate remedial action is taken to improve the situations. One of the actions is to be taken is use of agricultural lime to neutralize the soil acidity and to suppress the negative effect of aluminum toxicity in the area. In addition to that, to maintain organic carbon and to increase organic matter of the soils, mulching of crop residues after harvesting should be practiced with application of manure and compost. Planting tree species that are capable of fixing atmospheric nitrogen can improve soil fertility and reduce dependency on chemical fertilizer. In addition, improved agricultural practices such as crop rotation, alley cropping and the use of green manure have to be practiced to provide additional nutrient for plant growth.

5.19.4 Soil Cultivation

Cultivation is done to loosen tight soil to give it a favorable soil structure for seed emergence. At the same time, it eliminates weeds and thus it favors the growth of seedling. Comparing to other soils Vertisols are hard and difficult to cultivate when dry and impossible to break to fine tilt and when wet become very sticky and very plastic. Therefore, these soils should be cultivated when the soil moisture content is not too high or too low.

Furthermore, to use these soils properly for future agricultural development, Vertisols management technologies like, broad bed-maker (BBM) should be considered.

5.19.5 Soil Erosion Control

Most of the study areas soils are under sever sheet, rill and gully erosion. The risk of soil erosion is more considerable mainly on currently cultivated area. During the study time the survey team has observed high deforestation action in the Project area. Pictures taken during the study time are presented in Appendix 5J. This kind of misuse of natural vegetations will have brought high ecological disparity. Therefore, to develop these areas properly and sustainably the prevailing deforestation action has to be stopped and proper management will have to be undertaken especially along the incised stream channels and gully cuts. Adding to that soil erosion control measure should be implemented.

5.19.6 Drainage

Soil drainage is usually reflected by the colors of soil materials. The heavy black clay Vertisols, located in valley floor areas pose a problem of poor drainage and workability. Comparing to other soil types they have relatively low infiltration and hydraulic conductivity rates and thus due to their natural states, they are subject to water logging during most rainy season. The drainage class of these soils falls under imperfect to poor drainage. Therefore, to use this area surface drainage has to be undertaken.

5.20 Conclusions and Recommendations

5.20.1 Conclusions

The Dinger Bereha Project Area has been identified and proposed as one of the potential areas for irrigated agricultural development at feasibility level. The soil survey conducted at this level (feasibility) enabled to identify 16 land units. Following that, physical and chemical characteristics of the soil of the Project area were intensively investigated and classified. As a result, the land evaluation assessment has been undertaken for each land unit, and separate land suitability maps were prepared at 1:10,000 scale for all LUTs. These maps are shown in Table 5.21 (Fig 3.1a-3.5a to 3.1b-3.5b).

As a result, a total area of 6,260.3, 6,231.3, 6,231.3, 2,505.9 and 6,260.3ha of land is found to be marginally suitable (available) for surface irrigated agriculture development for onion, beans, citrus, maize and sesame respectively. Likewise, 6,800.3, 6,618.8, 6,618.8, 2,505.9 and 6,647.8ha of lands are identified for overhead irrigated agriculture development for the same LUTs respectively. On the other hand, due to workability, unsuitable for mechanization rooting conditions and nutrent unavailabilitys and others currently and permanently unsuitable areas for all LUTs for both surface and overhead irrigated agriculture were also identified (Table 5.23).

The suitable lands include area of land that will be reduced eventually for infrastructures (for irrigation canals and other infrastructure purposes). Thus, during the designing stage these figures may be lowered by about 5 of the total area anticipated for irrigation development.

5.20.2 Recommendations

In general, most soils that have been identified in the Dinger Bereha valley area found to be marginally suitable for surface and overhead irrigated agriculture. The limitations are oxygen and nutrent unavailability, workability unsuitability for mechanization and land preparation.

It should also be emphasized that the present land suitability evaluation results are guidelines for future agricultural development activities. Therefore, it is important noting the following remarks/recommendations:

- Some land units can be affected by sheet and gully erosion, and this can be controlled through careful planning and implementation of properly laid-out optimum size of farm units and farming practices
- In the Project area fallowing practices should be discouraged. Instead, application of green manure is strongly recommended. It is generally believed that, fallowing is far less beneficial to the soil than green manuring. Fertilizers are efficient when applied to a soil with abundant organic matter and biologically sound and well structured
- As it is seen from laboratory results, the main constraint for agriculture production in the area is believed to be acidity. Yield of any crops are limited mainly as a result of root damage because of acidity. Such damage is readily can be observed on maize and other crops. As soon as the plant root is damaged the plant's ability to extract water and nutrients such as phosphorous is severely reduced. As the result plants are very susceptible to drought and are prone to nutrient deficiencies. Based on this fact and others, the sampled area has got acidity potential to hinder crop production unless or else, immediate remedial action is taken to improve the situation. One of the actions to be taken is the use of agricultural lime to neutralize the soil acidity and to suppress the negative effect of aluminum toxicity in the area
- The analysed laboratory results indicate overall average low (3.7%) of organic carbon value. Therefore, to increase the organic matter of the soils of the study area mulching activity has to be encouraged. The positive effect of high organic matter content in the soil is at the same time increasing the cation exchange capacity of the soils. Therefore, ploughing back of the crop residues and mulching should be encouraged to raise the very low carbon levels and to improve the structure of the top soils
- The valley floor of the study area is covered with Vertisols and they have area coverage of 1,053ha. During the wet season the clays of these soils swell and cause pressure in the sub-soil. Therefore, to use these soils properly for future agricultural development, Vertisols management technologies like, broad bed-maker (BBM) should be considered or practiced

Therefore, in the long term planning of farming pattern, improved forage crops plantation, mainly legumes should be included in the rotation. Crop rotation is recommended, because it is essential for controlling soil productivity.

Table 5.24: Summary of land suitability class of Dinger Bereha Study Area for surface & overhead irrigation

Land	Onion		Beans		Citrus		Maize		Sesame	
Suitability	Surface	O.head	Surface	O.head	Surface	O.head	Surface	O.head	Surface	O.head
Class	Ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
S2	-	-	-	-	-	-	-	-	-	-
S3	6260.3	6800.3	6231.31	6618.8	6231.3	6618.8	2505.9	2505.9	6260.3	6647.8
Suitable Sub. Total	*6260.3*	*6800.3*	*6231.31*	*6618.8*	*6231.3*	*6618.8*	*2505.9*	*2505.9*	*6260.3*	*6647.8*
N1	1845	2092.5	1873.99	2274	1721.5	1334	6387	6387	2632.5	2245.1
N2	2440.2	1652.7	2440.2	1652.7	2592.7	2592.7	1652.7	1652.7	1652.7	1652.7
Unsuitable Sub. Total	*4285.2*	*3745.3*	*4314.19*	*3926.8*	*4314.2*	*3926.8*	*8039.7*	*8039.7*	*4285.2*	*3897.8*
Grand total	*10545.5*	*10545.5*	*10545.5*	*10545.5*	*10545.5*	*10545.5*	*10545.5*	*10545.5*	*10545.5*	*10545.5*

References

- Driessen, P.M and Dudal, R, 1989, Geography, Formations, Properties and Use of Major Soils of the World (eds), Wagnengen, The Netherlands and Leuven, Belgium
- Frank Beernaert Maputo Simple and Practical Methods to Evaluate Analytical Data of Soil Profiles, Maputo, Mozambique, 1990
- FAO, 1979: Soil Investigation for Irrigation
- FAO, 1976; A Framework for Land Evaluation, Soil Bulletin No. 32, FAO, Rome
- FAO, 1985; Land Evaluation for Irrigated Agriculture Soils Bulletin No. 32, FAO, Rome
- FAO, 1986; Soil Survey Investigation for Irrigation, Soils Bulleting No. 42, FAO, Rome
- Ir. C. sys (etal), 1991 Part I, Principles in Land Evaluation and Crop Production Calculation Brussels
- Ir. C. Sys (etal), 1991, Part II, Methods in Land Evaluation, Brussels
- Ir. C. Sys (etal), 1991, Part III, crop Requirements in Land Evaluation Brussels
- ITC, 1999: Aerial Photo Interpretation for Soil Study
- Landen J.R, 1991, Booker Tropical Soil Manual, a Hand Book for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-Tropics, New York
- UNESCO, 1986: Guidelines for Soil Survey and Land Evaluation in Ecological Research.
- WWD & SE in Association with MCE and WAPCOS, 2005, Pre-feasibility Level Studies, Volume 5A-Irrigation Schemes Erer Irrigation Project, Addis Ababa, Ethiopia
- Land Evaluation Part Three: Crop Environmental Requirement, 1984 Rome

6. GEOTECHNICAL INVESTIGATIONS

6.1 INTRODUCTION

6.1.1 Existing information

The main source for information has been the Abbay River Basin Master Plan report, and the report on geology of Dinger, Dega, and parts of Arjo sub sheets by Tadesse Alemu and Yonas Hageresalam. In addition to the mentioned reports, the following maps and areal photographs were available and used for data processing purposes:

- Topographic map 1:50,000;
- 1:2,000,000 scale geological map of Ethiopia compiled by Kazmin (1973) and Mengesha et al. (1996);
- Geological map of Gore sheet, 1:250,000, 1997;
- Aireal photographs;
- Scope and Objective of the Study.

The aim of the geological and geotechnical study was to obtain sufficient information about the ground conditions for the Project optimization and cost assessment at the current study level. A general geologic map, covering the weir site and canal route provides general geological information, such as location and elevation for boundaries between the main geological formations and soil variation. Detailed geological and geotechnical mapping at the weir site shall give information on ground conditions for project components, including assessment of:

- Soil cover above bed rock;
- Rock quality in regard to foundation;
- Information on possible sources for construction materials for use as concrete aggregate as well as for sand;
- Information on possible sources of clay materials to be used in potential fill materials;
- Information on deposits of alluvial materials with potential of being used as concrete aggregate.

6.1.2 Location and accessibility

The Project area is situated in Western Ethiopia, 250km (air distance) West of Addis Ababa in Oromiya Regional State, Illubabor zone. The Project area can be reached by an all weather asphalt (490km), gravel (70km) and dry weather (14km) road from Addis Ababa. It is 490km to Bedele Town while Village no 1 and Chewaka towns from where Kobo Berha (weir site) is accessed are located at 54km and 60km respectively from Bedele Town. Seasonal track, negotiable 4-WD drive track, 14 km long has been constructed to weir site (Bereha Kobo) from Village no1.

The Dinger Bereha Irrigation Project command area is located along about 18 km long section of the Didessa River between points defined by the co-ordinates UTM (Zone 37) (N 983 437m, E 203 702m) to (N 991 423m, E 19 467). The topography of the area is undulating and incised by gullies, and the right bank was accessed by wooden local boat. The average elevation of the site is about 1248m.The land in the vicinity of river is extensively covered with thick forest and savanna grass.

6.2 Regional and site geology

6.2.1 Regional Geology

The Ethiopian plateau is underlain at depth by Precambrian crystalline basement successions of the Northeast African-Arabian Shield covered in part by Paleozoic and Mesozoic sedimentary sequences and tertiary to quaternary volcanic rocks. The Main Ethiopian Rift valley and the Afar Depression of Ethiopia, divide the Plateau into the Northeastern and Southwestern Plateaux. The Precambrian Basement rocks of the Ethiopian Shield crop out in four areas, that is Northern, Western, Southern and Eastern parts of the country, near the plateau margins. The Western Ethiopia Shield where the Project area is located is one of these exposures.

The western Ethiopia shield is a mosaic of raised metamorphic gneissic domains separated by metamorphic geniuses domains separated by North-South trending belt of low grade metamorphic rocks that contain recognizable volcanic and sedimentary sequences, many of which are highly sheared and intruded by diverse suite of plutonic intrusions. In the Gore Map Sheet Mengesha and Seife (1987) recognized three major domains based on structural style, lithology, and metamorphic grade and referred to the Baro, Birbir, Alghe and Geba Domains. The project is located in the Alghe Group. Early plutonic bodies that are lenticular are recognized and are internally foliated and concordant with their host rocks. There are also late more equi-dimensional and discordant intrusions.

Around the Project area the Precambrian basement terrain is directly overlain above 1,400m meter elevation by flat lying, fine grained, aphanatic, Tertiary Basalt Flows that have a preserved thickness of at least 3 to 4 meters. There is no evidence of Mesozoic Sedimentary rock deposits between the basalts and the underlying Precambrian basement rocks. Thus the marine transgression and regression that led to the deposition of sedimentary rocks elsewhere (mainly in the North and East) of the country presumably did not reach here or were eroded away. Thus the Tertiary basalt lava flows unconformably overlie the Precambrian rocks resting directly on them.

6.2.2 Site geology

6.2.2.1 Soil formation (Quaternary covers)

Alluvial deposits, sand, silt and clay with a thickness up to five meters have been found following the Didessa river flood plan and along its tributaries. These soil formations were deposited during the rainy seasons, when these areas are flooded. Most part of the Project area is covered by residual soil derived from the underlying crystalline basement rocks and the tertiary basalt flows. Along the canal route almost all of the areas except the creaks are covered by gravelly silty sand. The thicknesses of this residual soil vary from place to place. In the test pits excavated along the route, its thickness ranges from 0 at the creeks to 2.50m in test pit DCTP 52.

6.2.2.2 Bed rocks

The bedrock of the area underlie by Precambrian rocks and Tertiary volcanic (Fig. 6.1). The Precambrian rocks cover the largest part of the Dinger irrigation Project area. Lithologically, they are represented by high-grade gneiss and migmatites, deformed granitoids. (Tadesse and Yonas, 2005).

The Tertiary volcanics exposed as a cape at high altitude and comprised of volcanic succession of dominantly basaltic composition with minor pyroclastic deposits. They cover few parts of the Project area and it is designated as Lower basalt (TV_1).

6.2.2.3 Lower basalt (TV_1)

This unit represents the largest part of the Tertiary volcanics and crop out in high elevated parts of Dinger irrigation project area. It is forming gentle slope and steep cliffs and unconformably overlies the Precambrian rocks. The flow is attaining an average thickness of 2 to 4m in the Project area. The rock is grayish black to black and commonly aphanitic to locally porphyritic and amygdaloidal, with amygdules filled by calcite and probably zeolite. The bottom part of the flow is largely porphyritic with phenocrysts of dominant olivine and rarely pyroxene, which lie within aphanitic to fine-grained groundmass. Petrographically, the Lower basalt is composed of 10-30% olivine, and 30-50% plagioclase, and 10-20% opaque minerals, which lie within 30-40% cryptocrystalline to glassy groundmass. Olivine grains are anhedral to subhedral and are fractured and show zoning. They are variably altered to iddingsite and chlorite. The plagioclase grains show zoning and observed as phenocrysts and as laths dominate the groundmass. The texture of the rock is varying from intergranular seriatic to ophitic and subophitic.

6.2.2.4 Precambrian Rocks

This unit generally forms low-lying topography and good exposures are found within stream, riverbeds, and creeks and at the mountain Chuta. This unit occurs surrounded by the granitoid orthogneiss (unit $Pgne_2$), see Fig. 6.1. Quartzo-feldspathic gneiss and banded gneiss are the dominant rock types, which accounts 60 to 70% of the unit. Amphibolite, biotite gneiss and biotite-hornblende represent few parts of the area. Massive to deformed intrusive rocks ranging in composition from gabbro to granite variably intrude the unit. Compared to unit $Pgne_2$ these rocks are less migmatized.

Quartzo-feldspathic gneiss

They are dominantly outcrops within streambeds and creeks but at places they form isolated hills and peaks with blocky and slabby disturbed outcrop. The rock is gray to grayish white and pale pink, fine to medium-grained and shows weakly to strongly developed gneissic banding. The gneissic banding is defined by alternation of quartz and feldspar rich and biotite and/or magnetite rich layers ranging in thickness from 1 to 5 mm. At places the rock is coarse-grained and looks pegmatitic. Along shear zone the rocks are strongly foliated and lineated and crop out as quartzo-feldspathic mylonite.

Banded gneiss

The rock is characteristically banded which consists of alternating felsic and mafic bands/layers ranging in thickness from 0.5 cm to 1 m and dips gently to moderately. The boundaries between the felsic and mafic layers are sharp to gradational. The felsic layers are gray to pinkish gray, medium-grained and are of granitic to granodioritic and rarely tonalitic in composition. In thin sections the felsic layers are composed of quartz, K-feldspar (perthitic microcline), biotite.

Epidote, opaques, represents the accessory minerals. The mafic bands are dark gray, medium-grained and composed of plagioclase, quartz, biotite, hornblende and trace amounts of opaque minerals, epidote, sphene and apatite.

Granitoid orthogneiss ($Pgne_2$)

This unit is characteristically forming domical hills and ridges, and the outstanding Chuta Mountain. It has sub-circular and elliptical shape in area that is widest in the center and narrows at ends. Its contact with unit $Pgne_1$ is tectonic, which is marked by NE-trending ductile D_3 shear zones and by NW-trending Didessa Shear zone.

Lithologically, it is represented by varying proportions of migmatized granite gneiss, granodiorite gneiss, tonalite gneiss and rarely dioritic gneiss with subordinate hypersthene-quartz-feldspar (charnokitic) gneiss, biotite gneiss, hornblende gneiss and quartzo-feldspathic gneiss. Minor screens of metasediments and metavolcanics tectonically interleaved with the granitoid gneiss are common.

6.2.2.5 Tectonic of the area

Geological maping report of the Project area by Tadesse Alemu and Yonas Hageresalam has confirmed that the existence of geological structures such as foliation, lineation, folds and fault/shear zones. On the basis of their geometric characteristics, principles of superposition and crosscutting relationships the structures are belived to be formed in four phases of deformation designated as D_1, D_2, D_3 and D_4. See fig. 6.2.

D_1 deformation are represented by foliation (S_1) and fold (F_1). The S_1 of penetrative planar structure found throughout the high-grade gneissic units (unit $Pgne_1$ and $Pgne_2$), which is represented by amphibolite to locally granulite facies foliation. D_2 is the other phase of the deformation structer which has characterized by folding of gneissic layering (S’) and S_1 foliation into open to tight upright F_2 folds. F_2 folds are N- and NE-trending and plunging at low to moderate angle either to the NE and SW. N- and NNE-trending dominantly ductile shear zones and by brittle to ductile conjugate NW-trending sinistral and ENE- and NE-trending dextral strike-slip faults are another group of geological structures which are resulted in the deformational phase designated as D_3, and the structures this group are recognized in the field as steep to subvertical mylonitic foliation. The final phase (D_4) of the geological structures in the area is represented by folding and shearing events. The structures orginated in this phase are characterized by NW-SE trending ductile to brittle-ductile shear zones and moderately northwest and southeast plunging and stretching lineations. However, no clear geological structures has been observed or noted close to the site where the weir axis, either during the current field obsevation as well as in the report and structural map (fig. 6.2) of the previous geological mapping.

LEGEND

QUATERNARY	Qel	**Elluvium**: red to reddish brown soil.
	Qus	**Undifferentiated covers**: red to reddish brown and gray soil, sandy soil and alluvium with local development of silceret and ferricrete and terrace deposits.
TERTIARY	Tv_3	**Upper Basalt:**aphanitic to locally amygdaloidal and porphyritic. Characteristically forming elongated ridges and domical hills.
	Tv_2	**Middle Basalt:**aphanitic to locally amygdaloidal, and characteristicallyshowing flow banding and lamination. At places they are laterizied and kaoliniti zed. Minor intercalations of tuff, which attains a thickness of 5 to 15 meters are common.
	Tv_1	**LowerBasalt:** commonly aphanitic to phyric and rarely porphyritic. Occassional ly contains xenoliths of mantlerocks and basement rocks.
PRECAMBRIAN	Pgt_2	**Granite:**medium- to coarse-grained, generally massive but marginally foliated.
	Pgt_1	**Deformed granitoid:** they are sub-circular to elliptical, which crop out as blocks and boulders, and characteristically showing exfoliation. Predominantly tonalite/granodiorite and granite withminor amounts of diorite/gabbro. They are varying in texture from medium- to coarse-grained inequigranular to porphyritic and megacry stic.
	$Pgne_1$	**Quartzo-feldspathic gneiss and banded gneiss:** with subordinate amphibolite, garnet-biotite gneiss, sillimanite-quartz gneiss, and calc-silicate gneiss/fels .
	$Pgne_2$	**Granitoid orthogneiss:** characteristically forming outstanding ridges and mountain, and domical hills. They are represented by varying proportion ofmigmatized granite gneiss, granodiorite/tonalite gneiss andrarely dioritic gneiss with subordinate biotite gneiss, hypersthene-quartz-feldspar (charonkitic) gneiss, amphibolite. Minor screens of metasediments and metavolcanics are common.

STRUCTURAL SYMBOLS

- Regional (composite) foliation
- Mylonitic foliation
- Lineation
- Fold axis
- Joint
- Dextral strike-slip shear zone
- Low-angle shear zone (detachment)
- Strike-slip faults (dextral)
- Strike-slip faults (sinistral)
- Lineaments
- Structural trends (aerial photos)

OTHER SYMBOLS

- All-weather road
- Dry-weather road
- Foot trails
- Towns
- Major villages
- Small villages
- Rivers

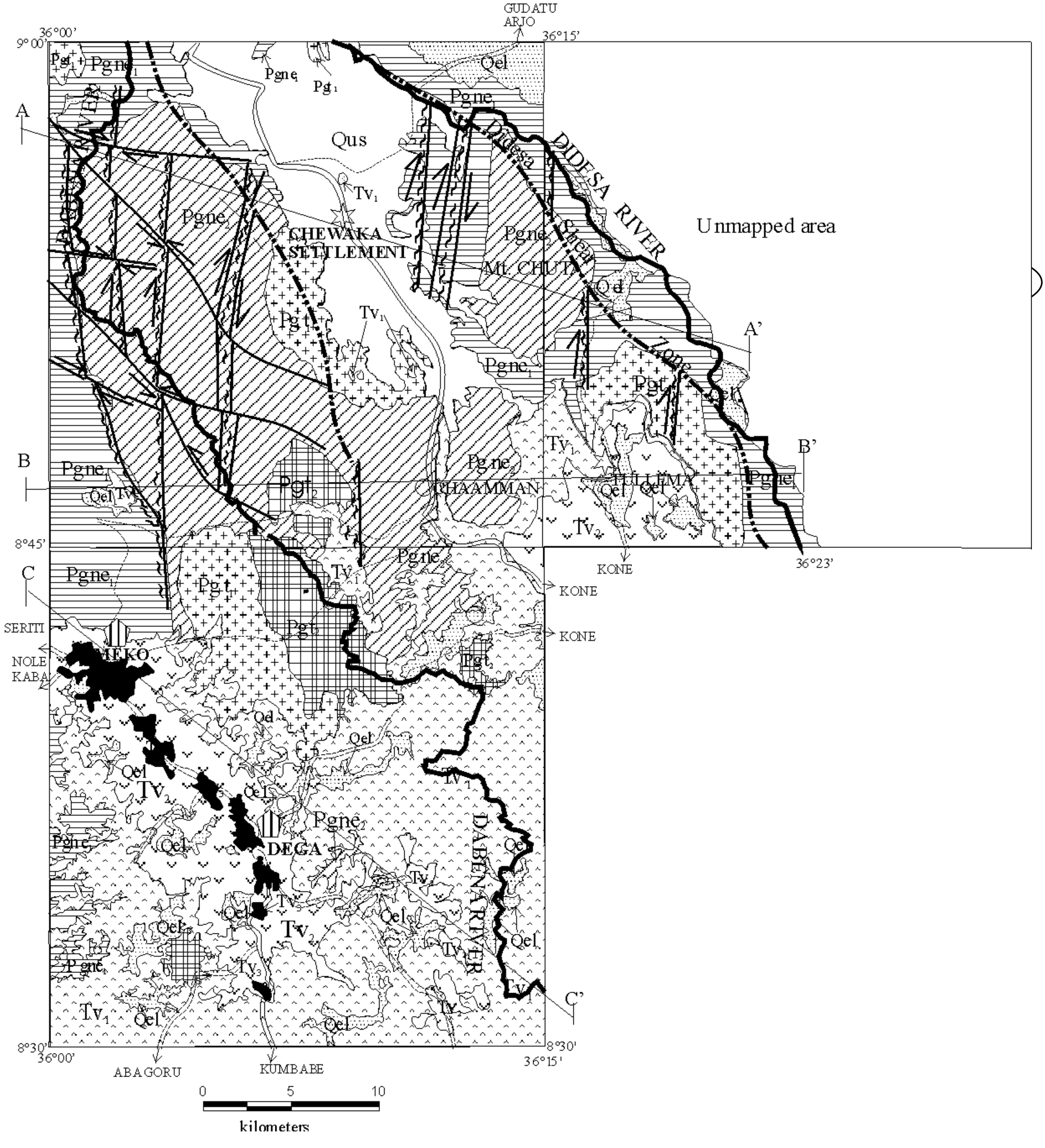


Figure 6.1: Geological map of Dinger Berha Irrigation project area
(Source: Geological Mapping Report by Tadesse Alemu and Yonas Hageresalam)

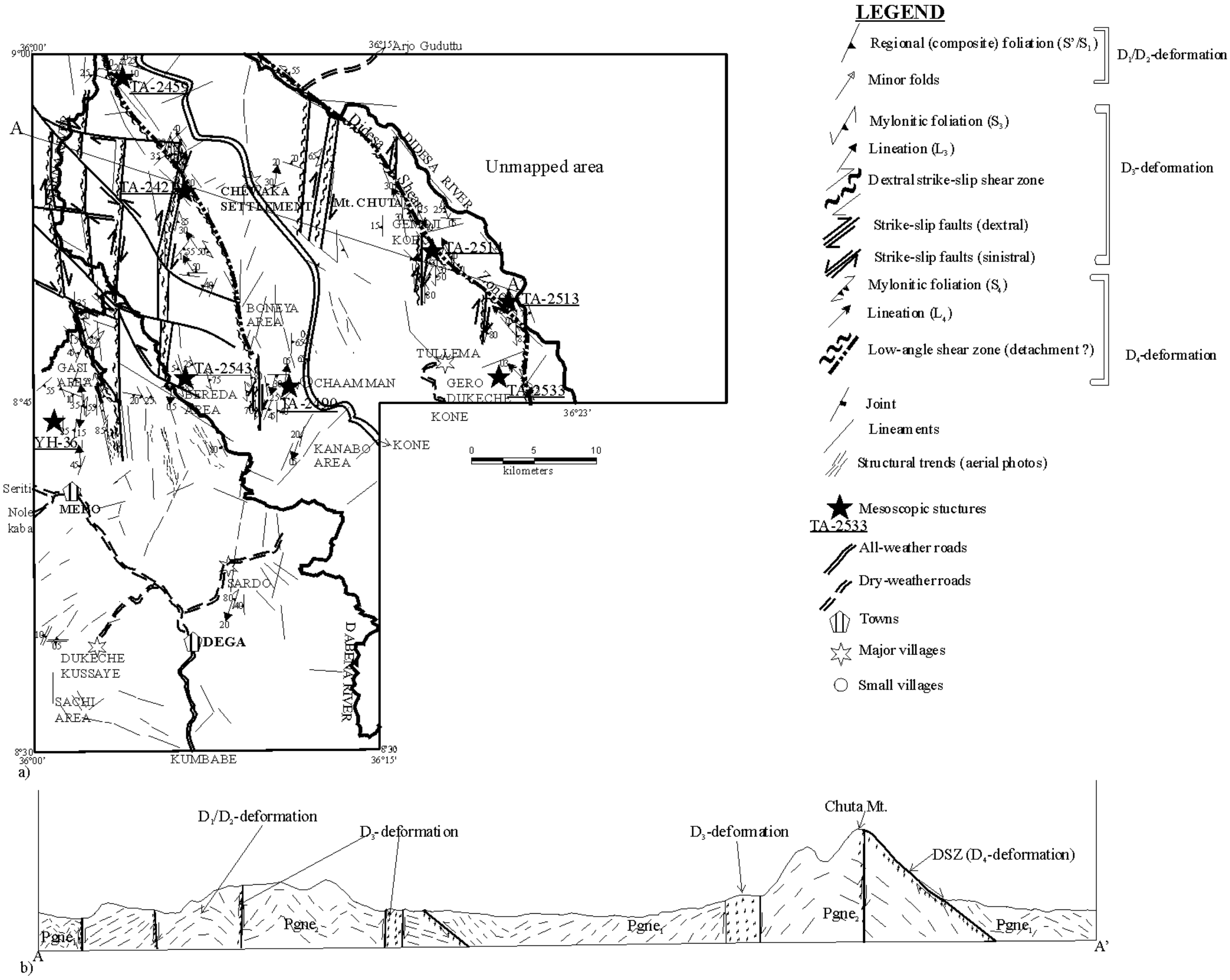


Figure 6.2 : Structural geological map of Dinger Berha Irrigation project area (Source: Geological Mapping Report by Tadesse Alemu and Yonas Hageresalam)

6.3 GEOTECHNICAL INVESTIGATIONS

6.3.1 Planning and procedure used for site investigations

The general initiative is to deal with important geotechnical issues necessary to establish, to a feasibility study level, the technical and economic feasibility of the scheme, with sufficient level of investigations. Relevant information was collected from the previous study and analysis of sufficiency was made related to the actual structures in considerations.

Based on the existing information, an expectation model was developed, taking into account how the planned structures are affected by the actual ground condition. In this development, important site related problems were identified; furthermore gap of information in relation to complementary study evaluations and design of the Project. As result, ground condition parameters considered appropriate for technical optimization are defined.

6.3.2 Site investigation program

Geological and geotechnical site investigation for the weir site and canal route is planned considering obtaining appropriate design parameters for these structures. Following analysis of available data and site assessment, a site investigation was concluded which comprised geophysical investigation, core drillings, test pitting and laboratory testing of rock and soil samples. In the course of implementation of the investigation activities, the conceptual expectation model of the ground is progressively improved and the remaining investigations were adjusted following the results. Results of the site investigations are summarized and interpreted in next sub topic. Reports with detailed investigation results are enclosed as appendices in Volume III, Annex C.

6.3.2.1 Geophysical investigations

Geophysical investigation is intended for verifying the ground conditions of weir site for further investigations and as a supporting information source for the decision of the possible weir axis from different alternatives. This was conducted by senior geophysicist with a close supervision of the Project Geotechnical Engineer. A total of eight Vertical Electrical Soundings (VES) were made, with the aim of determining the thickness of the overburden material, depth of the bed rock and anticipating the quality of the rock (degree of weathering) which of course supplement the geotechnical investigations.

UPSTREAM OF WEIR SITE

At the investigated site (upstream weir axis) the traverse line/weir axis along which the section is constructed is orienting in a N-S direction. Along the profile four VESs namely VES1, VES2 (right bank) and VES3, VES4 (left bank) were carried out. The total length of the surveyed line is 275 m.

The geo-electric section (see Fig. 1, Volume II: Annex B: Appendix Geophysical Investigations) clearly delineates three resistivity layers. The first layer resistivity value is about 11 Ohm-m and the thickness varies between 4m and 1.8m. It is relatively thin (1.8m) at VES4 (left bank), it gets progressively thicker (4m) towards VES1 -VES2. This horizon represents the alluvial soil that covers the river flood area. The low resistivity value of this layer along the whole traverse indicates that it is composed of uniform and fine material, i.e. clay and/ or silty clay.

The second layer has an average thickness of 2m, and the computed true resistivity is almost 90 Ohm-m. This layer may correspond to moderately weathered granitic gneiss which outcrops in the gullies and river bed. The bottom electrical substratum is represented by a high resistivity values ranging between 330 and 380 Ohm-m, it is related to a fresh and massive basement rock/ granitic gneiss.

DOWNSTREAM OF WEIR SITE

The resistivity profile was laid down on the weir axis and its length is 270 meters. Similar to the up stream site, four VESs were conducted, VES5, VES6 (right bank) and VES7, VES8 (left bank). The geo-electric section along VES5-VES8 (see Fig.2, Appendix Geophysical Investigations) is marked by three distinct resistivity layers. The resistivity of the uppermost layer ranges between 5 and 19 ohm-m. The layer has an average thickness of 3m. It possibly represents the top loose sediment along the banks of Didessa River.

The second layer is dominantly marked by moderate resistivities (74-90 Ohm-m), its average thickness is about 2.2 meters. This horizon is related to moderately weathered metamorphic rocks (granitic gneiss). The underlying third layer along the section exhibits high resistivities ranging between 335-424 Ohm-m and lies relatively at shallow depth 4.2m, beneath VES7-VES8 (left bank) while under VES5 and VES6 (right bank) the inferred depth to the top of this resistive layer is about 5.5m. This stratum is interpreted as representing fresh massive basement rock (granitic gneiss). The geophysical investigation report submitted by the geophysicist is enclosed as appendix. Drawings showing the profiles of the weir axes with detail interpretations and conclusions are also presented in the report.

6.3.2.2 Test Pitting

Test pits for characterization of the Project site as well as for collection of samples for laboratory tests have been excavated at the weir axis, canal route, pump stations and borrow sites of Dinger Bereha Irrigation project area. Excavation of test pits at the main canal was conducted from the beginning and end point of the route. The pitting was always accompanied by logging, sampling and conducting in-situ permeability tests of falling head type, when it becomes relevant, see plate 6.1. The interval of pitting was 250m unless it was interrupted by creeks, rock exposures and very dense forest which makes GPS reading impossible.

6.3.2.3 Exploratory core drilling

Because of the necessity for evaluation of ground conditions in line with the infrastructure under consideration, rotary core drillings were carried out at the weir site. The objective of core drillings was to collect samples of the soil and rock materials in a particular continuous profile of under ground formation. Assessment of the core samples and laboratory testing on a selected core samples gave information on the ground condition of a particular location of the borehole. Results of laboratory testing as well as the classification are crucial information for determination the engineering properties of the materials underneath. The planned program for core drillings was totally 30m for both boreholes, which are located on both side of the river. Because of the available ground condition, the drilling program was revised in order to obtain optimum out put from the drillings and avoid unnecessary waste of time and resources. Rotary core drilling was sub contracted to Addis Geosystems Co. Ltd after evaluation of the proposals, which the consultant had requested from local drilling contractors. This rotary core drilling was performed on both sides by using a rotary core drilling rig (see plate 6.2)

6.3.3 Laboratory testing

6.3.3.1 Testing on soil and sand samples

Soil samples collected from the test pits excavated at the canal route, borrow areas and sand quarries of the Project were tested in the soil mechanics laboratory of Construction Design Share Company in Addis Ababa. The soil samples were collected from all parts the canal route and the areas identified as borrow materials for fill of the canal. Moreover, the samples are representative of the materials along the canal route and that of the selected fill materials. The sand samples were also collected from the rivers along the road Chewaka to Village no 5.

Plate 6.1: Conducting in-situ permeability test at test pit DCTP -23

Plate 6.2: Drilling on progress at Borehole no DWBH - 1

The types of laboratory tests include:

- Classification tests
- Analysis of grain size distribution
- Plasticity index
- Determining of shrinkage or swelling properties
- Determination of engineering properties, which comprises
    - Compaction tests
    - Compressive strength tests
    - Triaxial shear strength tests
    - Compressibility tests
    - Organic content
    - Mortar making property

6.3.3.2 Testing on rock samples

Rock samples were also collected from the boreholes and the quarry area; and were tested in the rock mechanical laboratory mentioned for the soil sample test and in Addis Ababa University, Department of Earth Science.

The samples were collected from both boreholes and the quarry sites in order to determine engineering properties of the rock and classify and naming. The laboratory tests comprised:

- Tests for determination of engineering properties
    - Point load
    - Unconfined compression tests
    - Sodium sulphate soundness test
    - Mortar bar method of potential alkali silica reactivity tests
- Tests conducted for classifying and naming is
    - Thin section petrographic analysis

6.4 FINDINGS OF THE INVESTIGATIONS

6.4.1 General

This chapter deals with the results of geophysical investigations, exploratory borehole drillings, test pitting and laboratory testing of the Project which include weir axis, canal route, pump stations and borrow areas as well as the quarry sites. The detailed investigation results are compiled and annexed separately in Volume II, Annex C as:

- Appendix A: Vertical Electrical Sounding (report compiled by Ato Tibeba, Freelance Senior Geophysist)
- Appendix B: Rotary core drilling (from Addis Geosystem P.L.C)
- Appendix C: Test pit logs

- Appendix D: Permeability tests
- Appendix E: Laboratory test results (Construction Design Share Company)

Furthermore, both summaries of the investigation results (factual results) as well as interpretation and discussion of the results from all investigations are included. Discussions and interpretations of the result in terms of the infrastructures under considerations are presented in sub topic 6.5.

6.4.2 Geophysical investigation

6.4.2.1 Vertical Electrical Sounding (VES)

Alluvial deposits, sands and gravels from the weathering of the rock underneath are found on the top of the Precambrian gneiss formation of the weir axis. This has been well thought-out in the interpretation of the electrical soundings conducted in both, the upper weir axis option and the lower as well, see appendix A.

Clear increase in resistivity was observed, from less than 30 ohm-m in the upper 2 - 4 m; then to 90 ohm-m (from the depth 2.7 - 5.6m) and to greater than 300 ohm-m.

The low resistivity, topmost layer is expected to be alluvial sediments and that of the medium resistivity layer is sandy gravel resulting from weathering of bed rock and/or fractured, slightly weathered strong gneiss rock.

The high resistivity values below are believed to represent fresh Precambrian bedrock. The result of resistivity measurement interpretation shows that the top of fractured and weathered rocks bed vary from 4.75 to 6m on the right and 4.2 to 5m on the left side of the river. Interpretation of Vertical Electrical Soundings is an interpretation of indirect measurement based on difference in resistivity conditions of the ground. The precision of the interpretation depends on how well the considered interpretation model fits the actual ground conditions. The interpretation presented on the geophysical investigation is convincing and this has also been checked by drilling two exploratory boreholes on each side of the river.

6.4.3 Exploratory core drilling

Weir site ground condition information from the exploratory boreholes drilling includes depth to bed rock, type of the overburden and the rock type under the overburden, degree of weathering and fracturing of the rock mass. All detail information including core log, core photographs and field in situ testing is enclosed in Appendix E. Core drillings conducted for the weir axis are presented in table 6.1 and their location is shown in Figure 6.2.

Table 6.1: Rotary Core drilling at the Projects weir site

Borehole	Easting (UTM)	Northing (UTM)	Elevation	Drilled Depth (m)	In situ Test (SPT)
DWBH - 1	203652	983381	1247	12.25	2
DWBH - 1	203635	983545	1247	10.65	2
Total				22.9	4

6.4.4 Ground condition

Not much variation of ground condition was observed in the boreholes which were drilled on both sides of the river, see fig 6.4. In table 6.2 the information on overburden thickness, fractured rocks thickness and in situ SPT tests is presented. The first 4.45 – 4.75m is characterized by dark grey reddish brown silty clay, see plate 6.3, and all the materials were found to be well sorted alluvial deposits. Standard penetration tests were conducted in this overburden layer at the depths 2m and 4m in both boreholes and their N-values vary from 23 to 39 showing that the consistency of this alluvial formation is very firm. The core drillings also show that the rock below the overburden is feldspar quartz gneiss. The composition is summarized in the petro-graphic thin section analysis report. Regarding the degree of fracturing some variation is noticed between the two boreholes. In borehole DWBH – 1, in the left side of the river, the RQD value is higher than in borehole DWBH – 2, on the right side of the river, see plate 4. In the borehole DWBH – 2, however, the RQD values increases towards the depth. The dominant area between both boreholes is the riverbed, which is characterised by exposures of massive strong sparsely jointed gneiss. Visual observation of the variation in rock is not possible in this area.

Table 6.2: Summary of information from drilled boreholes

Borehole Name	Overburden Thickness (m)	In-situ test Depth(m)/N-value	Rock Quality Designation	
			RQD (average)	Class
DWBH - 1	4.45	2.0/23 4.0/39	4.45-5.25, 37.5 5.25-12.25, 88	Poor good
DWBH - 2	4.75	2.0/32 4.0/36	4.75-9.05, 37 9.05-10.65, 57	Poor fair

6.4.5 Test pitting

A total of 71 test pits were excavated along the canal route, at the borrow areas and at the two pump station sites for characterization of the foundation of the canal alignment and pump houses, for collection of soil samples for laboratory tests for the determination of engineering properties of the soil with in the canal alignment as well as for determination of engineering properties for use of soil as canal fill materials. Moreover, two test pits were dug on the banks at the diversion site for more visual observations and descriptions of the overburden along the weir axis. The locations of the test pits are shown on Figure 6.3.

All the test pits have been described and logged following the BS soil description and logging procedures. Moreover, permeability conditions of the soil along the canal route have been measured by using the falling head method. A summary of permeability test results is presented in table 6.3 below. The results are presented according to Darcy's law, where coefficient of permeability = k in m/s. Details on each and every test are presented in appendix D in Volume II, Annex C.

<u>Dispersivity</u>

Double hydrometer tests were conducted for evaluation of the dispersivity properties of borrow materials (see table 6.4). In all cases, the specimens behaved as non-dispersive.

Figure 6.3 : Location of boreholes and testpits

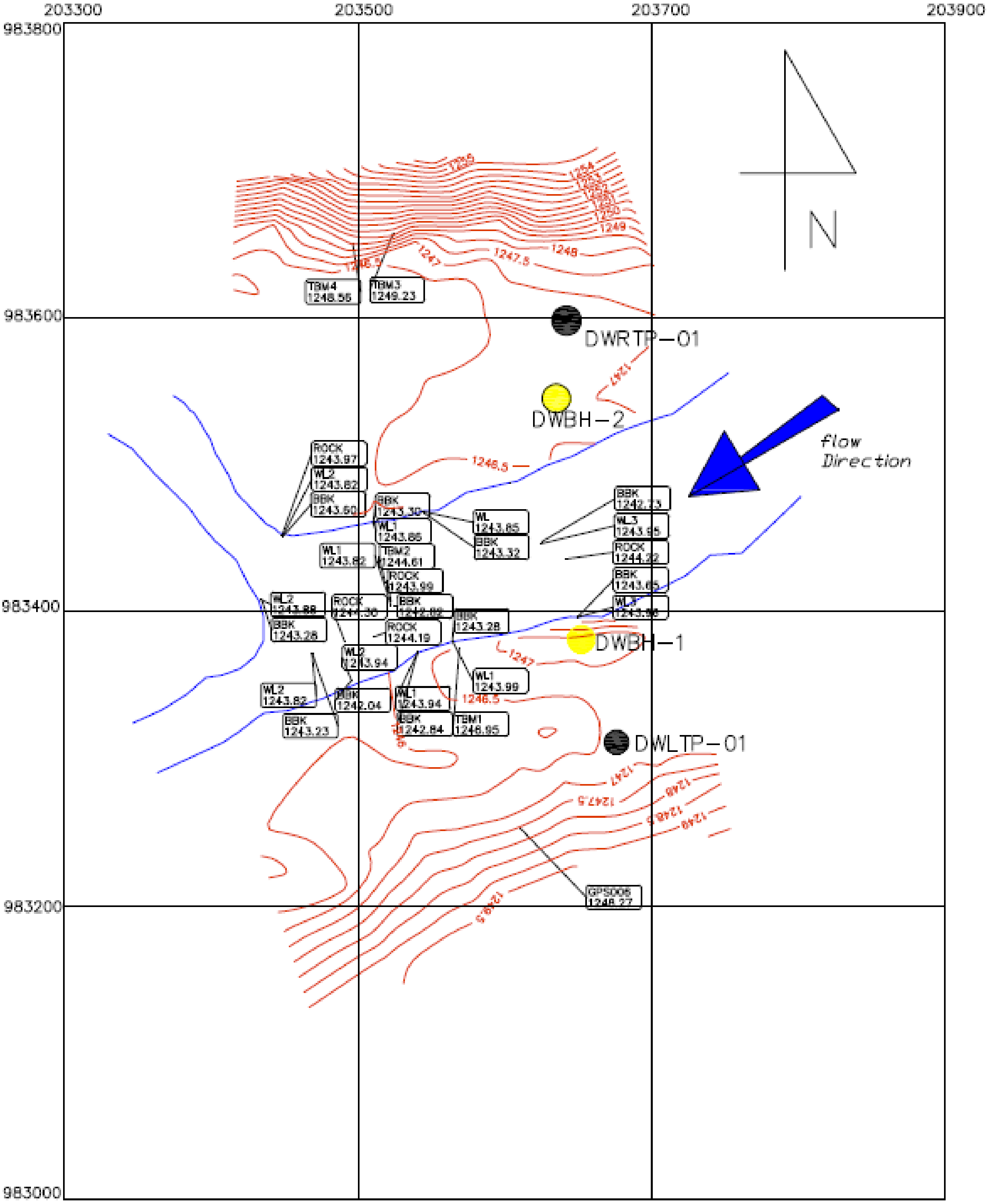


Table 6.3: Summary of field permeability test results

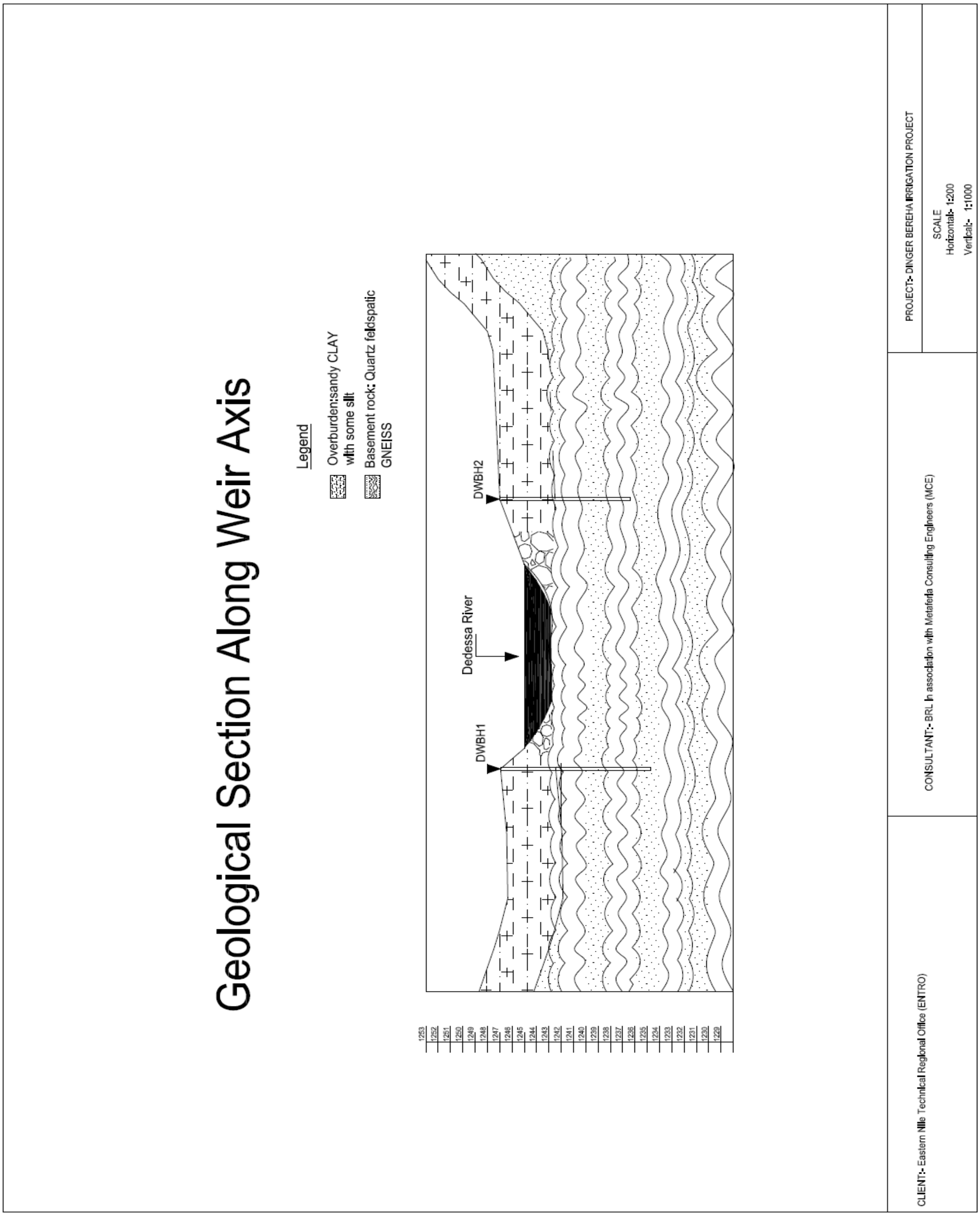
Test pit no	Tested section	Soil type	Coefficient of permeability, K (m/sec)	Comments on permeability condition
DCTP – 1	0.85 -1.15	Gravelly sand with some clay	3.03E-04	Very High
DCTP – 2	0.50 – 0.70	Black cotton soil	6.41E-03	Very High
DCTP – 5	0.95 – 1.25	Black cotton soil	8.50E-04	Very High
DCTP – 8	0.60 – 1.20	Gravelly sandy clay with silt	2.09E-04	Very High
DCTP – 13	0.30 – 1.00	Black cotton soil	4.27E-03	Very High
DCTP – 23	0.50 – 1.80	Sandy silty Clay	4.00E-05	Low to moderate
DCTP – 28	0.85 – 1.15	Gravelly silty Sand	3.38E-04	Very High
DCTP – 45	0.40 – 1.40	Silty Clay	2.96E-05	Low to moderate
DCTP – 48	0.50 – 1.80	Silty Clay	2.62E-05	Low to moderate
DCTP – 52	0.50 – 2.20	Silty Clay	5.30E-05	Low to moderate

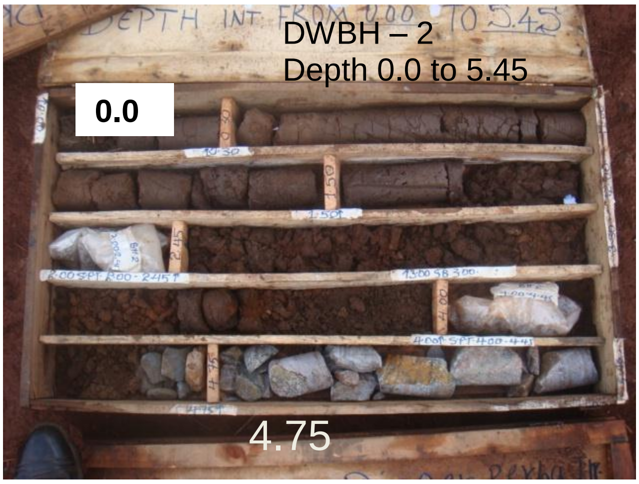
Table 6.4: Summary of dispersion test

Sample no	Dispersiveness (%)	Dispersivity
DCoTP – 1	5.56	ND
DCoTP – 2	6.20	ND
DCTP – 23	6.80	ND
DCTP – 48	5.58	ND
DCTP – 52	6.02	ND
DCTP39	45.14	ND

ND= Not Dispersive D = Dispersive

Figure 6.4: Geological cross section along the weir axis





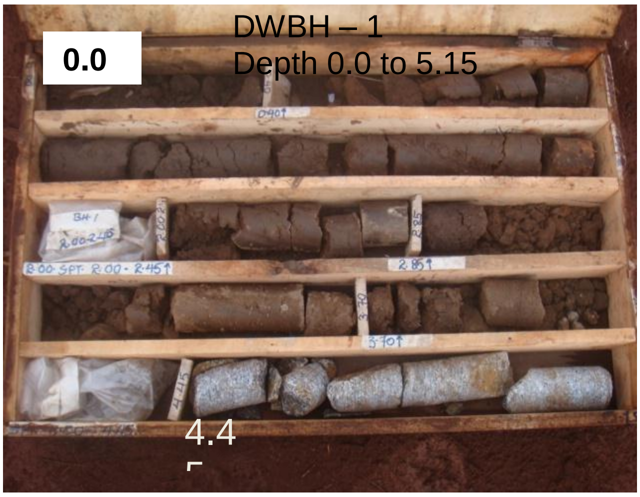


Plate 6.3 : Samples showing depth of overburden in both boreholes

Plate 6.4: Variation of fracturing in both boreholes

6.4.5.1 Variation of materials along the canal route

The length of the conveyor/feeder/main canal is more than 16 km. Due to its long distance coverage and variations in depth, the materials/soil varies considerably and the following four materials types have been identified.

- *Black cotton soil:* this soil type is exposed at the first 6 to 7 km in the areas where the topography is flat and slightly gently sloping. The thickness of this soil group varies from 0.30m to 0.95m. The soil is silty clay material with a high content of clay. Cracking when there is no water is very common for the formation in all locations. Three falling head permeability tests had been conducted in different test pits to characterize the soil conductivity and the soil has been found very permeable (table 6.3).

- *Silty gravelly sand:* this material group was found below the other top soil types and it is the product of weathering and decomposition of the gneiss rocks underneath. The thickness of this material group varies from point to point along the canal alignment. The in-situ falling head tests show that the soil group is very permeable. Detail description of the test pits is presented in Appendix C, Volume II, Annex C.

- *Silty clay*: the soil in this group, in most cases, originates from the decomposition of basalt rocks. The material in this category starts to appear at mid way and the end point of the canal route; however, it is not continuous all the way. The thickness of this soil group along the mentioned canal area is in the range of 1.0 to 1.5m; with interruption to nil at the creeks where weathered gneiss has been exposed in rock exposures. In general the soil is red, moist and firm silty clay. In-situ permeability test results show in general that this soil group exhibits moderate to low permeability.

- *Rock exposures:* the type of rock formation which covers the Project area as a whole is gneiss. Fresh exposures of the formation are common on the elevated areas, in the riverbed and in creeks which are known as temporary and permanent water ways. More over, fresh, strong and massive gneissic rocks exposure, which covers about 1.5km of the canal route is identified between the test pits DCTP31 to DTP 28, see location map of the canal root test pits. This rock is been exposed following the main ridge of the area. In this location, the rock is exposed continuously up to the bed of river Dedessa.
- *Organic humus: t*his soil group are observed in the place where the land is covered by dense forest, covering the top of the surface. It is grey to brown in colour and very loose. The thickness of the soil varies from 0.10 to 0.50m.

6.4.6 Laboratory test results

Soil and rock samples collected from the test pits of the canal route; borrow areas, boreholes and the aggregate quarry sites have been tested in the soil and rock mechanics laboratory of Construction Design Share Company, for determination of engineering properties and for classification. Laboratory test result reports for all of the tests are presented in Appendix E. Most of the test pits are excavated along the canal route for characterization of the canal routes and possible checking for the use as the fill materials. The samples from these test pits are representative of the soil types observed during excavation for investigation of the route.

6.4.7 Soil Samples

Summaries of results from laboratory testing of soil samples are presented in the table 6.7. All soils are collected from the canal route and borrow sites.

6.4.7.1 Samples from black cotton soil

The soil samples from this area are highly plastic, Black to dark grey silty clayey soil with clay content greater than 85%. The liquid limit is varying from 66 – 87%. The plastic index is also increase up to 29.49%; and it swell up to 120% when in contact with water.

6.4.7.2 Samples of borrow areas

The moisture content at an optimum compaction density is in the normal range of 22.6 -22.9%, with an average OMC 22.7%. The results of compaction test show that the materials are suitable to use as a fill material. In addition to this, the shear strength tests conducted by using tri-axial test on the samples shows that the test results of the material is in the normal limit. The detail results from the tri-axial tests for the determination of the shear strength of the material are shown in Appendix E.

6.4.8 Rock samples

All laboratory test results on rock core samples and block rock samples from quarry area for aggregate are summarized and presented in Table 6.5.

6.4.8.1 Rock strength

Uni-axial compressive strength (UCS) and point load testing were conducted on the core samples collected from the bore holes drilled along the weir axis for evaluation of the strength.

a) Point load strength: The point load index is an expression for the induced tensile strength of the rock. Variations in point load indexes indicate the variation in tensile strength.

In the geo-mechanics classification system (Bieniawski system), Point Load Indexes (Is) are classified as shown in the table below:

Point load index, Is(50) in Mpa	Strength class
< 1	Very low
1 – 2	Low
2- 4	Medium
4 – 8	High
> 8	Very High

Point load testing has been conducted on drilled core samples collected from both boreholes. The test results are presented in the table 6.5, and the rocks are generally categorized in the range of medium to high strength class.

b) UCS: International Society for Rock Mechanic (ISRM) classifies Uni-axial Compressive Strength (UCS) strength as:

UCS (Mpa)	Strength class
5 – 25	Low
25 – 50	Medium
50 – 100	High
100 – 250	Very High

Only the basement rock core samples from the boreholes drilled at the weir axis were tested. The results of the testing and their strength class are presented in table 6.5 with those of the point load tests.

Table 6.5: Laboratory testing of core samples strength

BH	Depth	UCS		Point load		Rock porosity (%)	Unit weight	Specific gravity	Sodium sulphate soundness
		Mpa	Class	Mpa	Class				
DWBH -1	5.0- 5.15			5.74	High	0.85			
DWBH -1	5.57- 5.95	51.60	High				2449	2.72	
DWBH -1	7.0-7.5			8.70	V. High		2722		5.25
DWBH -2	5.68- 5.85			4.62	High		2688		
DWBH -2	6.65-6.87	36.37	Medium			0.72	2610		
DWBH -2	9.75-9.96			7.32	High			2.7	

6.4.8.2 *Petro graphic analyses*

Petrographic thin section analyses have been done on two samples, one from each borehole, at Addis Ababa University, Department of Earth Sciences. The results of petrographic thin section analyses are summarized and presented in table 6.6 showing percentage of minerals and the corresponding rock name and types. Details of the test results are attached in Appendix E.

Table 6.6: Petrographic thin section analyses

Borehole / Depth	Minerals present in % by volume							Rock name
	Feldspars	Quartz	Biotite	Epidote	Hornblende	Muscovite	Opaque	
DWBH-1 / 5.57 -5.95	55*	12.5	22	Trace	10	-	-	Biotite feldspar Gneiss
DWBH-2 / 6.65 -6.87	80*	11.5	4	1	-	3**	trace	Feldspar Gneiss
Remarks	*K-feldspar/ perthite			**Alteration product				

Table 6.7: Summary of laboratory test results on collected soil samples , classification tests

No	Code	Depth	Sieve Analysis			Hydrometer Analysis							Atterberg Limits		
			% passing (mm)			Smaller than			Particle size,mm				LL	PI	Soil Class
			2	0.425	0.075	0.02	0.002	0.001	>2mm	Sand (%) 2.0 - 0.075 mm	Silt (%) 0.075-0.002 mm	Clay (%) <0.002 mm			
1	DCoTP-1	0.30-2.50	100	85	75.6	65.86	49	47	0	25.24	71.62	3.14	57.33	23.67	MH
2	DCoTP-2	0.40-2.10	100	87	75.62	64.84	43.8	42.15	0	22.68	74.08	3.24	55.45	25.37	MH
3	DCTP-16	0.30-0.80	100	56.82	47.94	43.33	36.67	36.67	0	52	11	37	66.10	29.49	CL
4	DCTP-20	0.40-1.60	100	74.7	57.46	50.27	40.22	40.22	0	43	17	40	56.25	23.96	CL
5	DCTP-23	0.50-1.80	100	79	69	50.27	36.86	36.86	0	31	33	36	48.25	22.69	CI
6	DCTP-48	0.80-1.80	100	92	79	66.7	53	47.65	0	19.14	77.72	3.18	61.50	25.58	MH
7	DCTP-52	0.50-2.20	100	89	76.6	63.50	52	50.13	0	25.46	71.2	3.34	47.50	22.25	MI
8	DCTP39	0.6 – 3.77	100	75	67	29	8	0	0	33	59	8	38.50	12.98	CI
9	TPRes01	0.50 – 3.00	100	78	65	26	11	0	0	35	54	11	47.80	14.61	ml
10	DCTP37	0.60 – 3.00	-	-	-	-	-	-	-	-	-	-	46.20	17.21	CI
11	DCTP35	0.65 – 3.40	100	82	58	33	13	0	0	42	45	13	-	-	m
12	DTP28	0.70 – 2.20	100	86	63	49	33	0	0	37	30	33	-	-	c

6.4.8.3 Construction materials

Rocks for aggregate

Rock samples have been collected from drilled cores of Gneiss rock as well as blocks of basaltic rock samples from potential quarry sites for testing for evaluation of suitability for the use of as concrete aggregates. The samples were tasted for Alkali silica reactivity by using OPC type cement made of Pakistan, Rock porosity and sodium sulphate soundness. The results of the laboratory test, for both rock types show that there is no alkali silica reactivity sensitivity. Sodium soundness test and porosity of the mentioned rock types are also in the normal allowable range. Detailed results are also presented in Annex C, Appendix E.

Sand

The conducted test results on sand include grain size distribution, shear strength, organic content and mortar making property. The grain size distribution showed that the sand is well graded and; no fine percentage particles which affect the quality of the structure. The organic content observed in the sand quarries is also minimal especially considering that the sampling had been done not prior to the major rainy season. The friction angle found from the test results is quite high. That is not however expected to be a major influence in the design of the structure. Summary of the laboratory tests conducted and interpretative charts are provided in Appendix E.

Soils

The description and notes for borrow materials have been presented in section 6.4.7.2.

Water

Water samples have been collected from Didessa River on June 17, 2009 in order to evaluate the suitability for construction. The tests include sulphate, chloride, total alkali and TDS contents. In addition to this PH value of the water has been tested. The result of all the tests has showed that the content of all elements which are suspected to cause damage on concrete structures are below their maximum allowable limits.

6.5 Anticipated Engineering Conditions, Conclusions and Recommendations

6.5.1 General

Elevation of the riverbed at the weir axis is 1244m. Total length of the canal route is more than 16 km with pump station sites # 1 and 2 (Res01) at E 0192 467m, N 0991 423m and E 188 976, N 0989 689 respectively.

6.5.2 Weir axis

At the weir axis, the river is in an approximately 200m wide flat bottom of a U shaped valley. The bedrock in the weir axis, on both sides, out of the river channel is covered by soil. On the basis of the field investigations, the soil overburden is found to be shallow with a thickness nil at the riverbed to 4.75m for both banks of the river.

The soil at the flat flood plain, along the river consists a layer of alluvial deposited sand silt and clay with a thin layer of organic maters overlaying this alluvial deposit on the parts close to the river. Under a thin layer of top soil the overburden, a bit away from the river bank, consists of light grey silty gravelly sand, which is resulted from the decomposing of basement rock underneath. This sand layer has also contains clay and gravel size particles with gravel is being the dominant particle size next to sand. The thickness of the layer and gravel content of the residual soil seem to increase with the increase of distance from the river.

The river bed at the weir axis consists of massive, very strong and competent Precambrian rock. This formation covers the riverbed through out the Project area. The rock in the boreholes of weir site is found solid and competent, with some jointing near to the surface. The strength test shows that the rock is in the class of high to very high strength. The riverbed through out the Project area is characterized by out crops of apparently best quality Precambrian gneiss formation. Spacing of joint are also in the order of one to two meters indicating the bed rock is massive, solid, fresh and strong. The combination of the basement rock competency and shallow overburden of the weir site leads to the conclusion that the weir structure will be founded on the competent bedrock.

6.5.3 Canal route

The concluded canal alignment is approximately 16 to 17 km in length and its tentative elevation lies between 1248m at the intake and 1237m at the final point where the pump station#1 has to be constructed. Extensive field traversing and excavation of test pits has been undertaken to characterize the ground condition of canal route from the beginning to the end point of the route. Based on the assessment, a considerable variation of soil type, which in turn varies with the properties like permeability, stability and the so on, is identified. According to the available soil type and their engineering properties, the route has been categorized in to three classes.

Canal sections that need replacement by fill material

The soil in this category covers more than 9km. It has estimated to be 90% of the total length. The types of soil in the category are black cotton and residual silty sand resulted from the weathering of bedrock. The engineering properties of both soil types have found not suitable, because of high permeability noticed during the field in situ permeability tests.

Canal sections crossing suitable soils

The soil with good engineering properties is found in the location where test pits no DCTP 23, 52, 48, 44, 39, 38, 37 and Dtp 28 &29 have been excavated. The exact length of the route of the soil in this category will be well estimated after the surveying of the route completed. From the field observation the coverage of this soil group is estimated to be 7 to 8%. The soil in this group is identified by a characteristic of being red to reddish brown, firm, not permeable to slightly permeable silty clay with some sand. The dispersiveness tests also show that the soil in this category is not dispersive.

Canal sections in cut and crossing creeks and the ridge

More than 20 creeks and a ridge with rock exposure have been identified upon the field traversing and visualizing of topographic map of the route. Moreover, there are also some areas with hard, solid and fresh rock exposures. Slightly to moderately weathered basement rocks is exposed in almost all of the creeks which show that the foundation condition for the crossing structures is found excellent. On the other hand, the rocks exposed at the ridge are fresh and very hard; as the result, excavating of this rock locality may need blasting due to its hardness. The estimated coverage of the route by this category is about 1.5 km.

6.5.4 Pump stations

The location of pump station site #1 is at a geographic location E 192 467m, N 991 423m. One test pit has been excavated to a depth of 0.70m to evaluate the ground condition of the site. The soil type is loose soil resulting from the decomposition of the basement rock underneath. It is reddish grey, sandy silty clay. The layer below, up to the depth 0.70m is gravelly sand, being residual soil of the bedrock of the Project area. Below this depth, fresh and solid rock with slightly to moderately weathering has been noted. Moreover the creeks in the near the alignment are characterized by exposures of the same rocks as mentioned. From the general observation of the area and the information from the test pit, it can be concluded that the soil in the area has proved shallow and loose. On the other hand, the bedrock observed in the test pit and the creeks are which favour founding the pump station and its equipment on this rock.

The location of pump station#2 has been investigated by excavating one test pit up to the depth 3m. Its location is at the geographic coordinates E 188 976m, N 989 689 and the symbol of the test pit is TPReso1. The soil is firm to very compact clayey silt with no or low plasticity. The result of strength test also shows that the soil has excellent shear strength which indirectly implies that the bearing capacity is very good.

6.5.5 Construction material assessment/ borrow sites

Rock materials

Rock samples have been collected from drilled cores of Gneiss rock as well as blocks of basaltic rock samples from potential quarry sites for testing for evaluation of suitability for the use of as concrete aggregates. The samples were tested on alkali silica reactivity by using OPC type cement, Pakistan, Rock porosity and sodium sulphate soundness. The results of the laboratory tests for both rock types show that there is no alkali silica reactivity sensitivity. Sodium soundness test and porosity of the mentioned rock types in the above paragraph are also in the normal allowable range. These rock materials are found on the hilly areas on the left and right side of the river. Since the material is available in every hilly area, the volume is in excess and the maximum distance from the weir site not more than 15km. Detailed results are also presented in Appendix E.

Gravel for concrete/coarse aggregates

There are no borrow areas for gravel and coarse aggregates, so this material has to come from crushed rock.

Sand

Fante River and the river between the villages no 4 and 5 have been identified as sources for sand. The sand is to be used for concrete works of the weir as well as cross drainage structures. Both sites are located along the road from Chewaka town to Village no 5. The approximate maximum distance of both sites from the weir axis is in the range of 22 to 24 km. Representative sand samples have been collected and tested from the sites in laboratory and the test result shows that the sand is suitable for the desired propose. The volume of sand observed on the sites during the study is estimated to be more than 30,000m^3. A summary of the laboratory test results conducted and interpretation charts are provided in Volume II, Annex C, Appendix E.

Water

Didessa River would be the main source of water for the construction of the main canal and structures. During the wet season floodwater will carry a lot of silt, but then compaction will be halted anyway because of high rainfall. There are many streams in the Project area that carry relatively clean water of good quality throughout the dry season.

Masonry stone for structures

There are no borrow areas for masonry stone in the Project area or in the near surroundings.

Borrow (Clay) materials for canal fill

Fine clay material suitable for use of fill materials had been identified at three different locations of the Project area. Sources of red clay have been identified at locations close to the beginning, middle way and end point of the canal route. The potential borrow areas are located on high grounds and two of them are currently being used as farm areas. The three borrow areas identified are shown on the location map in Volume 3: Annex Geotechnics. A total of 7 test pits were excavated manually within the identified clay borrow sources. The depths of the tests pits excavated varied from 1.6m to 2.5m. Based on the test pits excavated, the total estimated volume of material available from the three borrows is in excess of 1 million m^3. The clay borrows identified in the Project area are similar in origin (mainly residual), are brownish to reddish in colour and also exhibit in general similar properties regarding plasticity. All of them plot above the A line signifying property of low plasticity silt clay.

The results of the Atterberg limit tests showed that the PI varied between 22 and 29% with the average in the order of 24%. The average LL was in general greater than 56% signifying high plasticity properties. Test results for dispersion property using double hydrometer testing apparatus indicated that the clay material is not dispersive. The coefficient of permeability is quite low (an average of 10^{-6} cm/s) making it quite usable as a fill material. The natural moisture content of the clay sources varied between 11 and 15%. Moisture application will in general be required to get it close to the Optimum moisture content to attain maximum strength. The variations in the optimum moisture content between the various borrow material is insignificant with the average for all the clay borrows being around 22.7%. The tri-axial shear strength tests conducted gave the values reported in Appendix D. The effective cohesion value reported is well higher than could be expected for such material.

6.6 SEISMIC HAZARDS

The geophysical observatory of the Addis Ababa University has specifically assessed the seismic hazard for the Arjo Didessa Irrigation and Hydropower dam site according to the methods advised in the global seismic hazard assessment program (ref: Main Report Feasibility Study Arjo Didessa Irrigation Project, Febr 2007). The proposed weir and other infrastructure sites for the Dinger Irrigation project are very close to the Arjo Didessa Dam site and it has a similar hazard probability zone.

Consequently the analysis and assessment made by the above organization works for the current project. Usually the horizontal acceleration on the seismic hazard map is presented by contouring as a fraction of g. The nearest contour values taken for the Arjo Didessa Dam is 0.05g for the peak horizontal acceleration and 0.025g as a vertical seismic coefficient, which has been also considered for the stability analysis of the structures at Dinger Irrigation project site. According to the ICOLD recommendations, the site with a peak ground acceleration of 0.05g is ranked to hazard class I, which is low hazard. Most structures in this category will not experience damage under maximum design earthquake. Design Earth quake has to be selected at a return period of 300 years, which corresponds to a design peak ground acceleration of 0.05g, i.e., $0.5m/s^2$ for the structures founded on rock. The consequences for the design will be only slightly stronger concrete. All large structures related with Dinger Irrigation project will be founded on hard rock, and no significant deposit of fine sand or silt, which will have a tendency for liquefaction.