Omo Valley Farm Co-operation P.L.C

Addis Ababa

Feasibility Study and Detail Design of Omo Valley Farm Irrigation Project

Section-III: Investigation and Sectoral Studies

Volume-IV: Geotechnical Investigations And Foundation Recommendations

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Geotechnical Investigations and Foundation Recommendations

Final Report

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LIST OF ABBREVIATIONS AND ACRONYMS

BDS	Bulk Disturbed Sample
BS	British Standard
CBR	Californian Bearing Ratio
CH	Chainage
C_U	Undrained shear strength
DBE	Design Base Earthquake
DCP	Dynamic Cone Penetrometer test
E_R	Modulus of deformation
GPS	Global positioning satellite
KPa	Kilopascal
LL	Liquid Limit
MC-CD1	Main canal-Cross Drain
MER	Main Ethiopian Rift
N’	Corrected standard penetration test number
ORN	Overseas road Note
PI	Plasticity Indices
PL	Plastic Limit
PS-1	Main Pump Station
PS-2	Booster Pump Station
SDS	Small Disturbed Sample
SPT	Standard Penetration Test
SNNP	South National Nationality Peoples
SPTN	Standard Penetration Test Number
TP	Test Pit
TRRL	Transport Road Research Laboratory
UCS	Unconfined Compressive Strength
WWDSE	Water Works Design and Supervision

1. INTRODUCTION

1.1 Project Description

This report comprises the result of the Geotechnical Investigation works of Omo Valley Farm irrigation project which has a capacity of cultivating about 5,600 ha of farm land, which is located in Hamer Woreda of South Omo Zone, SNNP Regional State. Water Works Design and Supervision Enterprise have made a contract agreement with the client Omo Valley Farm Corporation P.L.C feasibility and detail to undertake design of farm irrigation system and geotechnical investigation is one of the study components of the project. Accordingly the geotechnical investigation has been made for foundation investigation of canal alignments and drainage structures, farm road sub grade characterization and construction material assessment by means of test pitting and associated in situ infiltrations test, DCP Testing and laboratory testing.

1.2 Scope and Purpose of Investigation

The purposes of this investigation were to investigate engineering performances of the proposed canal route ground materials, available natural construction materials, the sub-surface nature and characterize the area for foundation design of Omo Valley Farm irrigation project and is mainly to provide engineering recommendations regarding the bearing capacities of the formations in terms of shear strength, water tightness and settlement characteristics as outlined here in:.

i. Reviewing available geologic literature and mapping information,

ii. Test pit excavations to explore the sub-surface conditions of the proposed head works, cross drainage, construction material borrow sites and to provide general data regarding the site.

iii. Conducting DCP (Dynamic Cone Penetrometer) testing at intervals of 1000 meters along the farm road to directly measure the field CBR strength of the sub grade and at head work and canal cross drainage sites on surface & within the test pit for foundation investigation via correlating DCP value with SPTN value.

iv. Conducting infiltrations tests using double infiltrometer for evaluating water tightness condition for the canal alignments.

v. Determining the type and extent of sub surface geological layers

vi. performing laboratory tests on selected representative soil and rock samples collected from the test pits and quarry site to evaluate pertinent engineering properties,

vii. analyzing the field and laboratory data to determine the engineering properties of the geotechnical layers and develop appropriate engineering recommendations and to guide design and construction of the project, and

viii. Preparing geotechnical report.

1.3 Location

The project is located in South Nation Nationality and Peoples Regional State (SNNPR), South Omo Zone, Hammer Woreda. The area under investigation is generally characterized by flat topographic feature. The coordinate of Test pits, excavated, are measured using hand held GPS (UTM, Adindan Datum), with +/_ 4m accuracy and are presented under table 1-1:

Table: 1- 1: Coordinates and excavated depth of the Test pits

Nº	TP-ID	Location of test pits		Elevation (Hand GPS)	Depth/mt.
1	MC-CD1-TP-1	190620	573699	424	5.0
2	MC-CD3-TP-1	191414	573920	414	5.0
3	MC-CD4-TP-1	194009	574154	418	5.0
4	MC-CD5-TP-1	194577	574316	413	5.0
5	MC-CD6-TP-1	194763	574310	418	5.0
6	MC-CD7-TP-1	195198	574809	422	3.5
7	MC-TP-1	191580	573646	413	3.0
8	MC-TP-2	192606	574292	410	3.4
9	MC-TP-3	193424	574184	414	3.0
10	(MC)MC-TP-2	195924	576969	470	3.0
12	(MC)MC-TP-3	195057	578340	421	3.0
14	(MC)MC-TP-4	194976	579388	439	3.0
16	(MC)MC-TP-5	194818	579941	467	3.2
17	(MC)MC-TP-6	194030	580678	432	3.0
18	(MC)MC-TP-CD2	195153	579010	422	5.0
19	(MC-1)MC-01-TP-1	197695	577268	461	3.0
20	(MC-1)MC-01-TP-3	197914	578974	477	3.0
21	(MC-1)MC-01-TP-5	198226	581252	456	3.0
22	(MC-1)MC-01-TP-6	197821	582600	459	3.0
23	(MC-1)MC-01-CD-2	197977	578142	464	5.0
24	(MC-1)MC-01-CD-3	198123	578223	468	5.0
25	(MC-1)MC-01-CD-7	198220	581490	463	3.5
26	PL-TP-1	191190	574210	397	3.0
27	PS-1-TP-1	189675	575005	409	5.0
28	PS-1-TP-2	189675	575066	407	5.0
29	PS-1-TP-3	189661	575030	430	1.0

Nº	TP-ID	Location of test pits		Elevation (Hand GPS)	Depth/mt.
30	PS-2	196169	576049	510	5.0
31	G-1	196685	576354	523	5.0
32	G-2	197268	576835	417	5.0
33	S-1-TP-1	195255	574812	462	3.5
34	S-4-TP-1	197687	577120		3.0
35	S-5-TP-1	194031	580749		3.0
36	CB-1-TP-1	193701	573995	409	3.0
37	CB-1-TP-2	193486	573969	428	3.0
38	CB-2-TP-1	191450	582827	429	3.0
39	CB-2-TP-2	191914	582872		3.0
40	GB-TP-1	188690	571428		2.0
41	GB-TP-2	188765	571515		2.0
42	CB-2-AU-1	191679	582967	423	1.0
TOTAL					**139.10**
Remarks: MC-Main canal PC- Primary canal PL- Pipe Line PS-Pump Station G-Gully cross S-Sand CB-Clay Borrow GB-Gravel Borrow AU-Auger					

1.4 Methodology

The methodologies adopted for the geotechnical investigations include trial pitting, lithological description (logging), auguring, conducting double ring infiltration tests, and DCP tests, collecting of representative soil and rock samples and laboratory analysis.

Test pits and auger holes excavation have been carried out along the main canal and main canal-1 covering about 13.140 km and 4.8km starting from the pipe line-1 and pipe line-2 outlet respectively. For both main canal test pits excavation ~~is~~ varies from 3.0 up to 5.0m depth. For head work and canal crossing site test pits excavation 5.0m depth. The materials used during investigation are:

- Double ring infiltrometer,
- DCP with accessories
- Auger,
- GPS, Plastic bags and sacks, cans, rob and ladders, measuring tape, water and others.

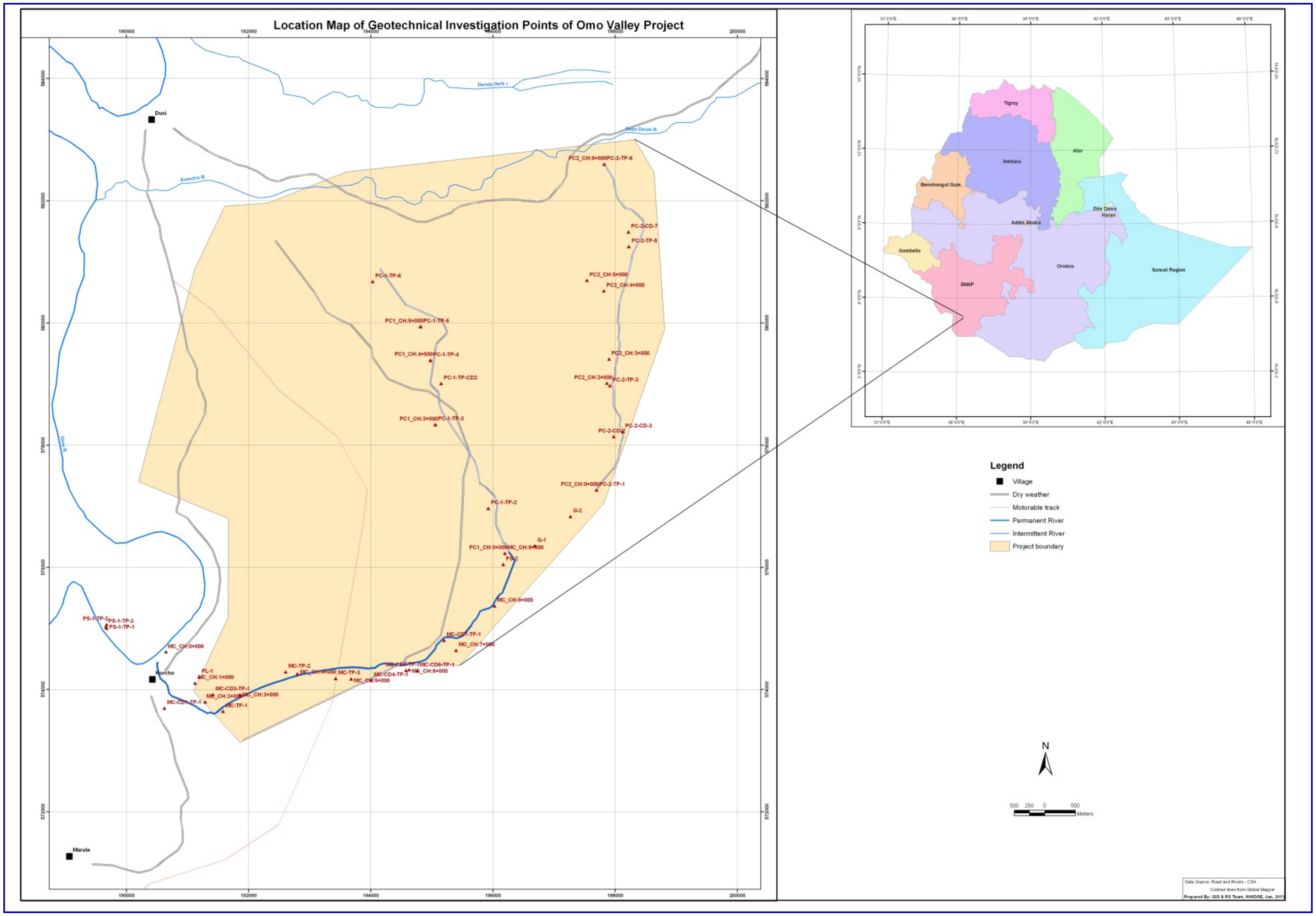

Figure: 1- 1: Location map of project area and investigation points

2. GEOLOGICAL SETTING

2.1 General

According to Davidson, 1983, in the region, the rocks that are regionally widespread are the crystalline basements, the Oligocene flood volcanic, isolated outcrops of post-rift volcanic and Plio-Quaternary formations.

The metamorphic basement rocks in this area are highly deformed and metamorphosed till granulites facies (Davidson, 1983) implying that they belong to the lower complex. The gneiss complex was further subdivided in to different types of gneisses. Based on the review of the map, some of gneiss complex geological units exposed in the project area broadly described as follows.

- Layered mafic gneiss and amphibolites (Peha);
- Meta-sedimentary gneiss, layered biotite-quartzo-feldspathic gneiss, locally with muscovite, garnet, sillimanite, minor interlayered amphibolitic, quartos, pyritic, graphitic and calc-silicate gneisses and marble (Pegb);

Moreover, the other dominant geological unit were exposed in the study is Quaternary deposits. Lacustrine, deltaic, and alluvial deposits of the middle Omo plains, Usno plain, and along the various stream in the region are categorized under this. Hence, the lithological units are mapped and described as;

- Undivided alluvial, fluviatile and lacustrine sediments (Q);
- Fluviatile sand, silt (QL)

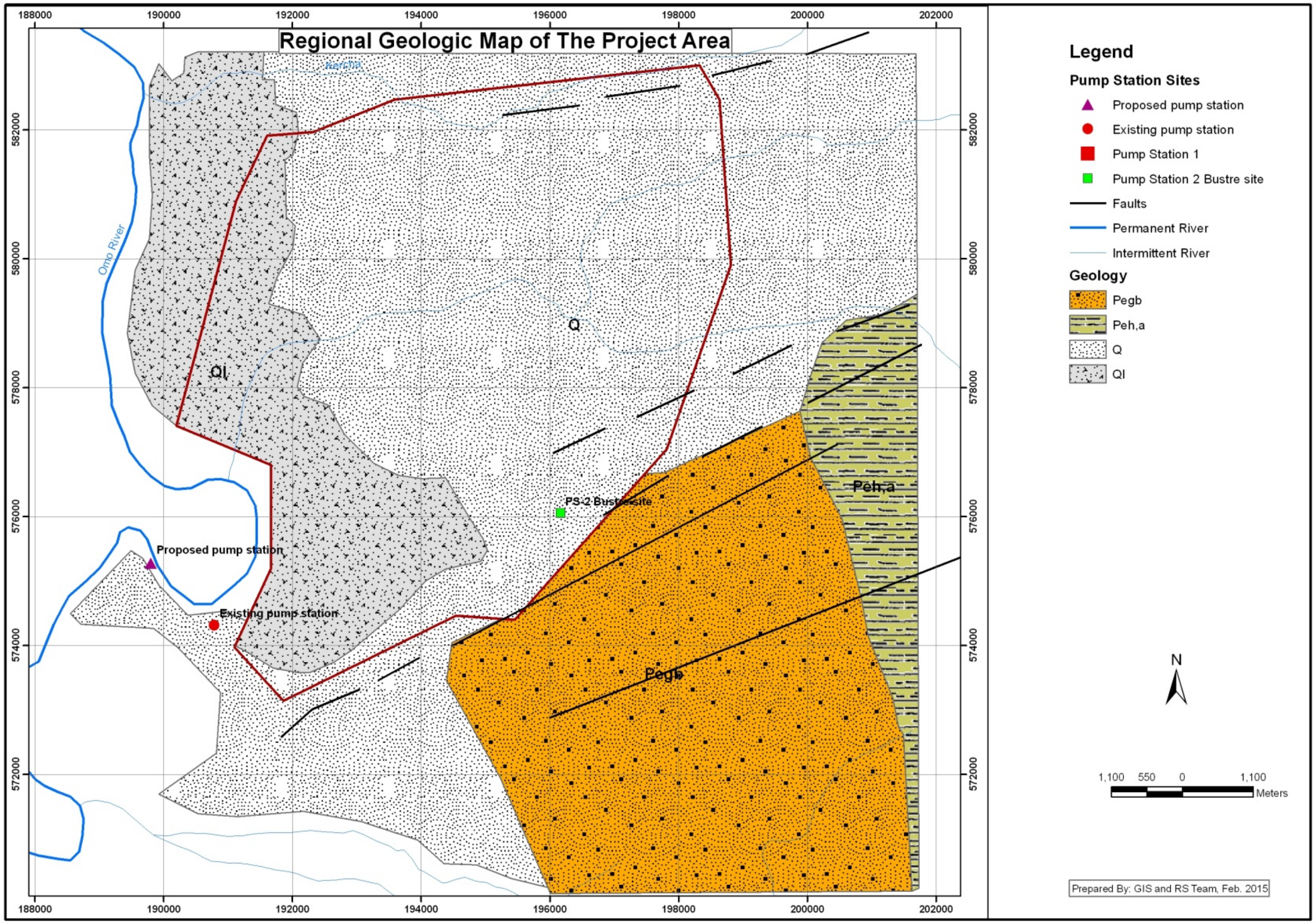

Figure:-2- 1. Regional Geological map of the proposed project sites (compiled from geological maps of Omo area.

Source geological map of Ethiopia (1:500,000)

2.2. Local/Site Geology

The geology of the Project area is metamorphic basement rocks of Precambrian age where exposed in the Eastern boundary of the site ridge of chiefly composed of. These rocks commonly overlain by intercalated sedimentary sequences that outcrop at different locations in the site. The locally the lowland of the farm lands covered by Quaternary Sediments of Plio-Pleistocene Fluvio-Lacustrine deposit. The geological set of the sites are described in detail as follows;

2.2.1 Precambrian basement rocks

The Precambrian crystalline basement rocks of the area occupy much of the geomorphic features in the eastern and north-east sectors of the study area. This includes in the mountains and some of the lowland parts of the near and around the project area. The type of rocks recognized varies as a function of the lithology as inferred from the regional geology of the basin and field observation this are:

2.2.1.1 Meta-sedimentary Gneiss

Meta-sedimentary gneisses are common along the Eastern and North East boundary of the project surrounding where forming elevated plain. Where they exposed, their distinctive layering could be used to identify and map them in the field. This unit is constituted of dark colored hornblende gneiss and amphibolites& biotite gneiss. The field observations of the site in photo 1-1 indicated presence of significant amount of crystalline minerals. It is massive, very hard and tough metamorphic rock.

Photo: 1- 1 photo shows white color crystalline Meta-sedimentary gneiss observed

2.2.1.2 Plio-Pleistocene Fluvio-Lacustrine deposit

This deposit in the study area occurs in the eastern side of Omo River, it covers the lowland of the project area. The deposits lithologically include sand, silt and clay. The sediments in the lowlands are basically sands and silts that are exposed in various parts of the area and along the prominent Rivers of the area like for example, Korcho River and along other have thicker unconsolidated sand with red colored sands was observed in the study area see photo.1-2.

Photo: 1- 2 photo shows Fluvio-Lacustrine deposit on Korcho River

2.3. Seismicity / Design Criteria

Seismic activities in Ethiopia are generally said to be confined to Afar and the Main Ethiopian Rift valley. The Main Ethiopian Rift (MER), which is part of the East African Rift System, and Afar Depression are considered to be locus of volcanic and seismic activities as they represent extensional tectonics in action. The MER meets the two oceanic rifts, namely Red Sea and Gulf Aden in Afar Depression/Triangle forming three-rift (RRR) triple junction.

The Omo Valley Farm project area is located in the Sothern part of the Main Ethiopian Rift Valley, which is seismically active area. According to the seismic Zoning map of Ethiopia (Figure: 2-2), the project site falls under Zone 4 – corresponding to a zone of major damage where the seismic ground shaking would produce intensity VIII and above.

The horizontal and vertical loads under pseudo-static analysis are represented by appropriate seismic coefficient to give the design acceleration as a fraction of the acceleration due to gravity.

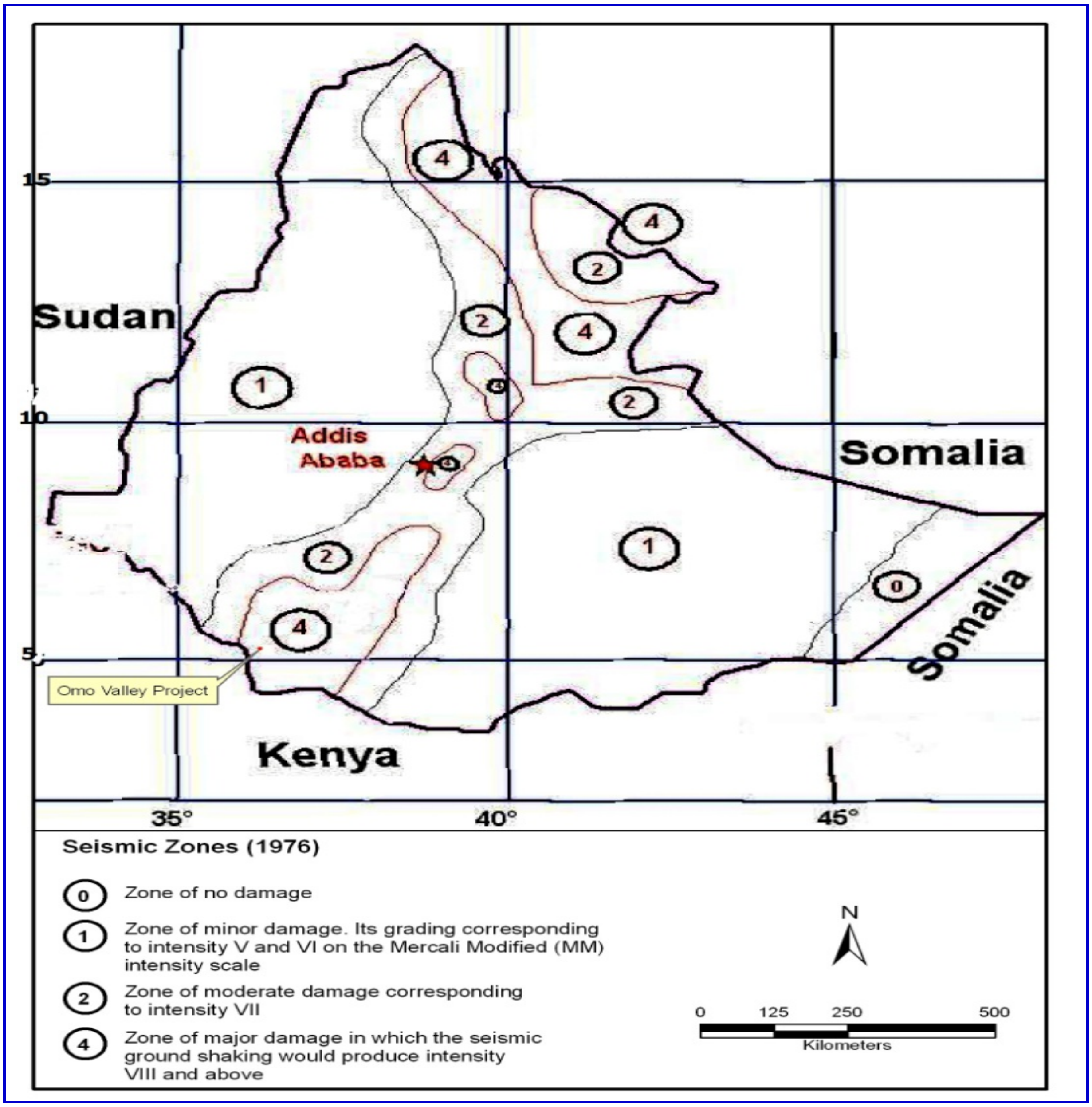

Figure:-2- 2 Seismic Zoning Map of Ethiopia

Remarks: The 'Seismic Risk Map' produced by Laike Mariam Asfaw(1986) for a hundred period and 0.99 probability shows that the study area falls within 8MM scale.

Figure: 2-3 shows seismic hazard map of Ethiopia prepared by the Institute of Geophysical Observatory at Addis Ababa University for a Design Base Earthquake (DBE) with a return period of 300 years (return period for DBE of dams/civil structure is generally taken to be 300 to 400 years). This map shows peak ground acceleration contours as a fraction of acceleration of gravity *g* and has been used as the basis for seismic design of several other dams in Ethiopia. The black star on this map shows the approximate location of the farm site in Omo-Gibe River

Basin with geographic coordinates of 05° 10’ to 05° 16’ Northing and 36° 12’ to 36° 17’ Easting.. Based on this map, the nearest contour to the farm site is with a ground acceleration of 0.15g. Therefore, according to this hazard map, the design horizontal coefficient of acceleration would be 0.15. Based on international practices, the vertical acceleration is considered as 1/2 the horizontal acceleration, which is 0.075g. Hence, the vertical coefficient of acceleration is 0.075.

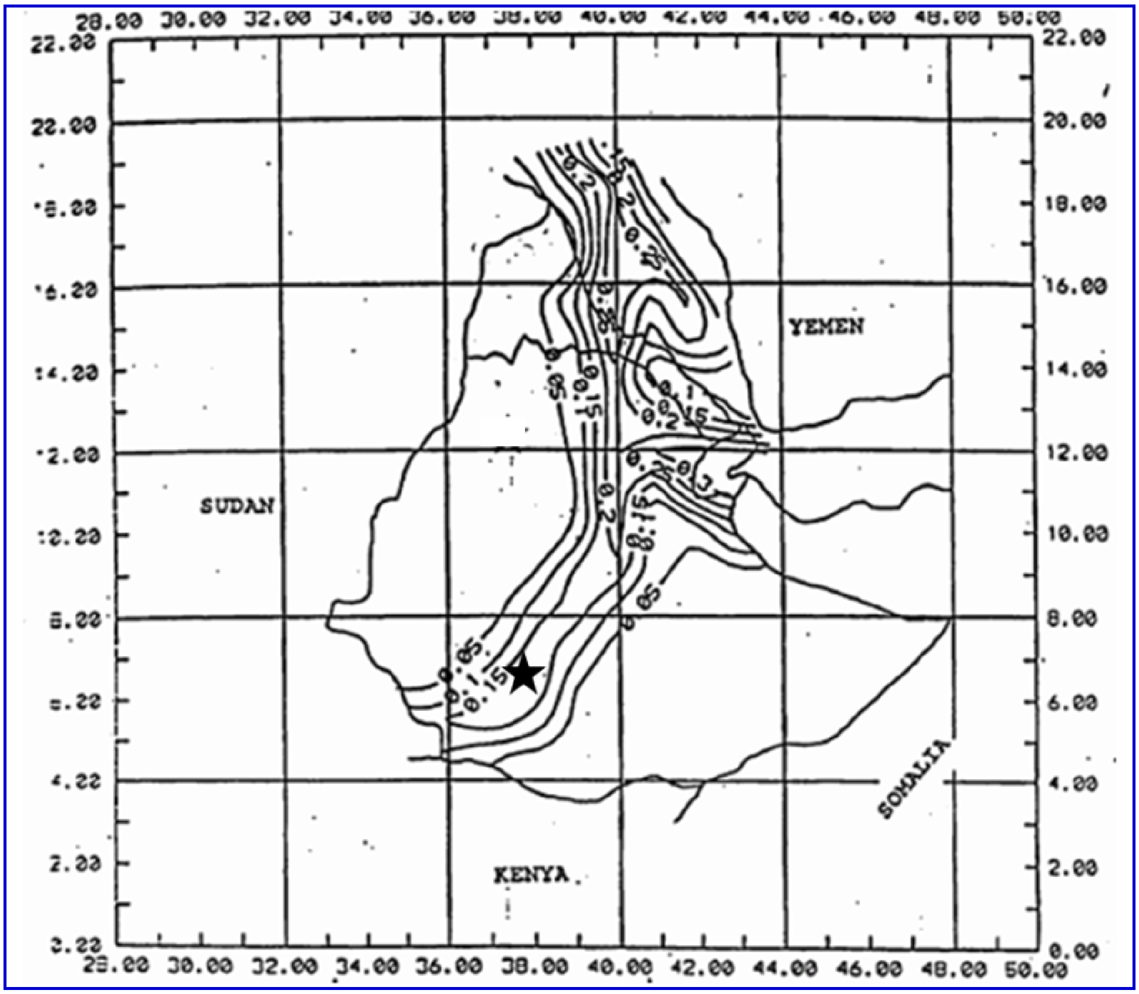

Figure:-2- 3Seismic Hazard Map of Ethiopia and its Northern & Eastern Neighboring Countries, Contours indicate peak ground accelerations as a fraction of g. The Black Star Indicates the Approximate Location of Omo Valley Farm site.

2.4 Groundwater and Cavities

Groundwater was not encountered within the depths of excavated test pits and no groundwater table was observed. No cavities or other kind of weaknesses were noticed within the excavated depths of trial pits.

3. CANAL SYSTEM GEOTECHNICAL INVESTIGATION

3.1 CANAL ROUTE

3.1.1 General

Investigation of the subsurface conditions at a site is prerequisite to the economical design of the irrigation, drainage system works, substructure elements and foundation. It is also necessary to obtain sufficient information for feasibility, detail and economic studies for the Omo-valley farm project.

Comprehensive site investigations have been carried out for the detailed design studies for the irrigation and drainage system works. Under this topic summary of geotechnical investigations undertaken at the Omo-valley project along main canal alignment are presented below and in table 3.1.

a) 17 test pits in the areas of the main canal, of which 6 were to a depth of 5 m and the remainder were between 3.0 m and 3.5 m deep. Nine double ring infiltration tests were carried out in the test pit, one at 0.5m, one at 1.0m, two at 1.5m, two at 2m, one at 3.0m, one at 3.10m and one at the bottom 5m.
b) 7 test pits in the areas of the main canal-1, of which 2 were to a depth of 5 m and the remainder were between 3.0 m and 3.5 m deep. Five double ring infiltration tests were carried out in the test pit, two at 0.5m, one at 1.90m, one at 1.5m, one at 2m and one at 1.5m.

Table: 3- 1Summary of Geotechnical Investigations

Canal name	**Canal Length (km)**	**Number of Test pits**	**Number of Double ring Infiltration Tests**	**Number of Disturbed Samples**
Main canal	13.140	17	9	14
Main canal-1	4.8	7	5	8
Sum	17.94	24	14	22

3.1. 2 Methods of the investigation

3.1.2.1 Engineering Geological Mapping

Engineering geological mapping is a useful tool in making used in civil project (IAEG, 1984). The engineering geological map guides more detailed work of the surface soil and rock properties. Accordingly, in this investigation surface engineering geological mapping is done to classify geological formations in terms of their geotechnical nature (See fig.3-7).

3.1.2.2Test pitting

Test pits with surface area 1.5mx1.5m were manually dug at 17 points in the main canal and 7 points in the main canal-1 of the project area. The test pits were dug by equipment such as, row bar, Hoe, pickaxes, and shovel. A wood ladder is lowered to the bottom of the pit for detailed logging of the various soil horizons and collecting representative samples for visual description. Upon completion of documentation and sampling, the test pit is photographically documented using digital camera followed by backfilling of the pit by the excavated material. A total of 24 test pits were manually dug, relevant information pertinent to the test pits are presented in the following section.

3.1.2.3 In-situ Testing

The following topics are summarizes the field in-situ tests executed for the geotechnical investigation along the canal routs.

3.1.2.3.1 Permeability test

Permeability test is one of the major in situ field tests on geotechnical investigation having significant value in the determination of seepage along the canal alignment, estimation of permeability properties of underlying soil formation can be determined by using either direct method or indirect methods.

Double ring infiltration test, laboratory permeability test and estimation of permeability using grain size are performed on representative soil layers. Choice of test is depending on the prevailing geological material conditions encountered in alignment.

3.1.2.3.1.1 Direct Methods for Determining Permeability

I. Infiltration tests

The results of the infiltration tests are summarized in Table 3-3. They show an enormous range. On the basis of the results, an average infiltration value are presented in the table below can be used as representative of the seepage from infiltration average value. However, some tests are difficult to conduct because of the coarse sand nature of the soil layer; in this case we try to collect water data by simply measuring the amount of water in (lit.) with time taken in (min) see table 3-2 &3-3 and the raw data of infiltration test result in appendix-A-5.

Table: 3- 2: Infiltration test result of main canal

Name	**Main Canal**														
Chainage (m)	**567.0 -1892.8**		**1892.8 -3934.0**		**3934.0 - 4565.9**	**4565.9 - 5045.9**	**5045.8 -6444.5**		**6444.5 -7414.3**		**74414.3 - 10041.2**	**10041.2 - 11038.1**	**11038.1-11587.1**		**11587.6 -13140**
Depth (m)	0.0-2.5	2.5-5.0	0.0-1.8	1.8-3.0	0.0-3.0	0.0-5.0	0.0-2.8	2.8-5.0	0.0-2.0	2.0-5.0	1.5	2.0	0.5	2.0	3.1
	Infiltration rate														
Range	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	**lit./min.**	cm/sec	**lit./min**	cm/sec
Maximum		1.8		8.1		20.7					17.3	10.5	1.8	5.6	8.0
Minimum		1.8		8.1		13.5					17.3	10.5	1.8	5.6	8.0
Average		**1.8**		**8.1**		**17.1**					**17.3**	**10.5**	**1.8**	**5.6**	**8.0**

Table: 3-3: Infiltration test result of main canal-1

Name	**Main Canal_1**				
Chainage (m)	**0+000-0+700**	**0+700 -1+300**	**1+300 -3+000**	**3+000 4+000**	**4+000 -4+800**
Depth (m)	0.5-2.0	1.90	1.50	0.50	0.0-3.0
	Infiltrations rate				
Range	cm/sec	cm/sec	cm/sec	cm/sec	
Maximum	28.4	1.1	0.9	1.4	
Minimum	4.3	1.1	0.9	1.4	
Average	**16.35**	**1.1**	**0.9**	**1.4**	

3.1.2.3.1.2 Indirect Methods for Determining Permeability and laboratory test

Usually, the soil classification is one of the methods in order check on the permeability magnitude. For cohesionless soils, the size and shape of the soil particles influence the permeability. As a result of, the Unified Soil Classification System (U. S. Army Engineer Waterways Experiment Station 1960), Allan Hazen's found Equation, that for uniform loose clean sands the permeability was given by (Taylor 1948)

Equation: 1- 1..$K=100*D_{10}^2$,

Where

k - Coefficient of permeability in cm per second

D_{10} = particle size in cm at which 10 percent of the material is finer by weight (also known as Hazen's effective size). Hazen's experiments were made on sands for which 0.1 mm < D_{10} < 0.3 mm and the uniformity coefficient, C_u < 5, where

$C_u = \frac{d_{60}}{d_{10}}$, where

C_u = uniformity coefficient

D_{60} = particle size at which 60 percent of the material is finer by Weight.

For natural fine to medium, relatively uniform sands, classified SP or SW in the Unified Soil Classification System (U. S. Army Engineer Waterways Experiment Station 1960); generally, d_{10} mm 0.01 to 0.02 implies fine sands and having estimated K value approximately 10^{-4}m/sec.

The results of the classification tests shows that; ML, SC, SM, CL and SP in the Unified Soil Classification System. The result of classification tests with estimated permeability values by Allan Hazen's Equation are summarized in Table 3-4.

Table: 3-4 : Classification tests with estimated permeability values by Allan Hazen's Equation

TP ID	Main Canal				
	Depth (m)	**d_{10} in (cm)**	**d_{10}^2 in (cm)**	**K (cm/sec)**	**Classification test**
MC-TP1	0.0-1.80	0.017	0.000289	$2.9*10^{-2}$	ML
	1.80-3.0	0.0039	1.52E-05	$1.5*10^{-3}$	ML
MC-CD3	0.0-1.5	0.0039	1.52E-05	$1.5*10^{-3}$	ML
	3.20-5.0	0.00031	9.61E-08	$9.61*10^{-6}$	ML
MC-CD4	1.0-2.80	0.00031	9.61E-08	$9.61*10^{-6}$	CL
	2.80-5.0	0.016	0.000256	$2.6*10^{-3}$	ML
MC-CD5	1.10-3.30	0.0021	4.41E-06	$4.4*10^{-4}$	SC
MC-CD6	1.5-2.0	0.0003	9E-08	$9*10^{-6}$	CL
	2.10-5.0	0.016	0.000256	$2.6*10^{-2}$	ML

Table: 3- 5. Indirect method estimation of permeability by grain size and laboratory result of the Main canal.

Name	**Main Canal**																
Chainage (m)	**0+000 -1+677**			**1+677- -4+175**		**4+175-4+775**			**4+776- 4+974**	**4+975 -5+523**		**5+524- 8+094**	**8+095 -10+238**		**10+239- 11+338**		**11+339- 13+140**
Depth (m)	0.0-2.50	1.80-3.0	3.20-5.0	0.0-2.10	2.10-5.0	0.0-1.0	1.0-2.80	2.80-5.0	0.0-5.0	0.0-2.10	2.10-5.0	0.0-5.0	0.0-2.60	2.60-5.0	0.0-1.70	1.70-3.0	0.0-3.0
Soil type	ML	ML	ML	CL	SM to ML	SP	CL	ML	SC	CL	ML	SP	SM	SP	CL	SP	SM
Range	**Permeability**																
	cm/sec			cm/sec		cm/sec			cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec		cm/sec
Maximum	2.9*10-2	1.5*10-3	9.61*10-6			10-4 to 10-2	9.61*10-6	2.6*10-3	4.4*10-4	9*10-6	2.6*10-2	10-4 to 10-2	10-7-10-5	10-4 to 10-2	10-10 to 10-8	10-4 to 10-2	10-7-10-5
Minimum	1.5*10-3																
Average	**3.05*10-2**	**1.5*10-3**	**9.61*10-6**		**1*10-4**	**10-4 to 10-2**	**9.61*10-6**	**2.6*10-3**	**4.4*10-4**	**9*10-6**	**2.6*10-2**	**10-4 to 10-2**	**10-7-10-5**	**10-4 to 10-2**	**10-10 to 10-8**	**10-4 to 10-2**	**10-7-10-5**

Table: 3- 6 laboratory permeability test result of the Main canal-1.

Chainage (m)	**0+000-0+700**	**0+700 -1+300**	**1+300 -3+000**	**3+000 4+000**	**4+000 -4+800**
Depth (m)	0.5-2.0	1.90	1.50	0.50	0.0-3.0
Range	**Permeability**				
	cm/sec	cm/sec	cm/sec	cm/sec	cm/sec
Maximum					8.17*10-4
Minimum					8.17*10-5
Average					**8.17*10-6**

3. 1.2.3.2. In situ DCP test

A total of 14 DCP tests were conducted in the structure sites at the surface and inside test pits in order to determine the resistance of soil horizons. To assess the relative density/consistency of these soils TRRL DCP (Dynamic Cone Penetrometer A2465) with hammer weight of 8kg dropping freely through a height of 575mm and a 60° cone having a diameter of 20mm was used. After assembling the apparatus, the zero reading is recorded followed by raising the hammer and lets it to fall freely. A scale reading is taken after a set number of blows and the number of blows is changed between readings according to the strength of the layer being penetrated. All the DCP test results recorded on a field data sheet are plotted with the depth of penetration against number of blows using a spreadsheet. The slopes of the curves represent the penetration depth per number of blows (Figure 3-1).

The rate of change of the slope of the curves or the penetration depth per number of blows revealed the different soil layers and their relative density or consistency. The DCP values obtained for different soil types then converted to SPT N-values/300mm following the correlation developed by Transport

Road Research Laboratory (TRRL), UK, Overseas road Note (ORN) 9, Design of small bridges (Table 3-8), to compute the bearing capacity using Meyerhof’s equation (cited in Bowels, 1988).

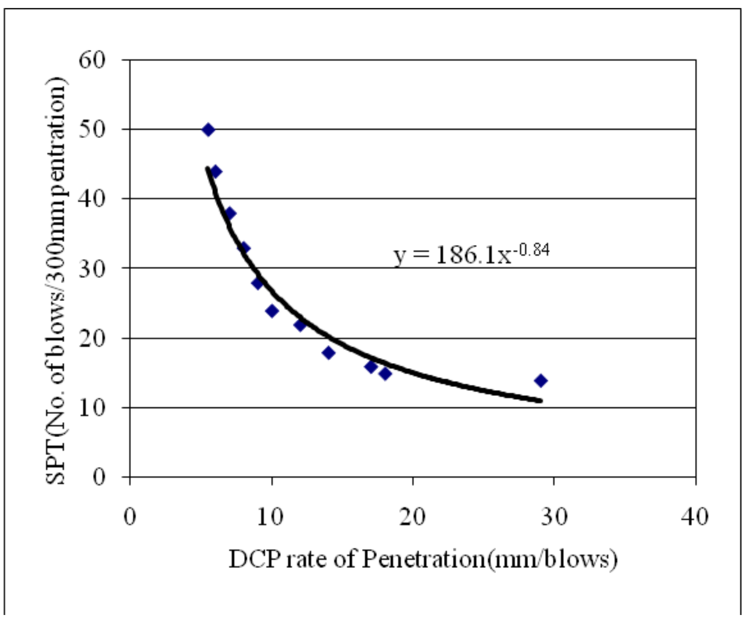

Figure: 3- 1 Typical Dynamic Cone Penetrometer test result

Table: 3- 7: Typical correlation between DCP and SPT values after, TRRL, ORN 9, Design of small bridges

DCP value mm/blow	SPT value blows/300mm
5.5	50
6	44
7	38
8	33
9	28
10	24
12	22
14	18
17	16
18	15
29	14
50	
100	

Dynamic Cone Penetrometer tests were conducted inside/top of test pits at a depth of 0.0m (surface), 1.5m, and 3.0m for the Pump station-2 (Booster) site and for Pump station-1 at a depth of 1.0m and 1.73m to determine the resistance of various soil horizons underlying the pump station Sites. A total of four DCP tests were conducted in both pump station sites at the surface and covered by soils inside test pits in order to determine the resistance these soil horizons.

The statistical average values of the penetration are used for calculating the SPT-Values using the relation in equation (1-2) below. The average DCP value of each layer is converted in to SPT-N values, using the relation suggested by a user guide of Minnesota Department of Transportation (Mn/DOT):

Equation: 1- 2……………………………………………………………SPT= 240.17 DCP$^{-0.967}$

Where SPT= Standard Penetration Test number of blows (N values)

DCP=adjusted dynamic cone penetration result in mm/blow for a given soil layer

Converted SPT N-values are corrected for moisture and considered for computation of the bearing capacity. Design SPT- N values of soils layers below ground obtained from dynamic cone Penetration Data are presented below in table 3-9.

In very fine, or silty, saturated sand Terzaghi and Peck recommended that the penetration number N be corrected to N' if N is greater than 15.

Equation: 1- 3……………………………………………………………N' = 15 + 0.5(N – 15)

The rationale for this correction was that the soil must be dense if the blow count is greater than 15; therefore, the volume displacement at a high penetration rate of SPT would produce high pore pressure which would further increase the blow count.

Table: 3- 8 Dynamic Cone Penetrometer (DCP) test results and converted Standard Penetration (SPT) test results

No.	TP ID.	Depth (m)	DCP Value	SPT N value/300mm	Adjusted SPT N-value
1	MC-CD3-TP1	0.0-0.75	9.95	26	20.5
2	MC-CD4-TP1	0.0-0.62	9.8	26	20.5
3		1.6-2.4	17.7	15	15
4	MC-CD5-TP1	1.5-2.80	60.9	5	10
5		2.80-3.57	20	13	14
6	MC-CD7-TP1	0.0-0.68	12.8	21	18
7	MC-TP-1	0.50-1.29	13.3	20	17.5
8	MC-01-CD-3	0.0-0.73	14.7	18	16.5
9		1.50-2.25	32.7	8	11.5
10	MC-01-CD-7	0.0-0.67	8.8	29	22

In calculating the allowable bearing capacity for designing foundation of the proposed pump station and cross drainage site; the SPT N-values are calculated as the average adjusted N-values found between ½ B above and 2B below the proposed footing depths, with the assumption of B to be the width of the foundation. The adjusted N-value from the measured value presented in Table 3.8.The design SPT N-values are used to determine the bearing capacities, according to Meyerhof's equation (cited in Bowles, 1997) is given as:

Equation: 1- 4………………………………………………………..$q_{all} = N'/F_2(1+F_3/B)K_d$

Where:

q_{all}= Allowable bearing pressure for Settlement limited to 25 mm.
K_d =1+0.33*D/B<1.33
F2 = 0.08
F3 = 0.3
F4 = 1.2
B = Width of foundation
D = Depth of foundation

3.1.2.3.3. Sampling

Representative samples taken from both test pits and subsequent visual description are taken to determine the engineering properties.

3.1.2.3.46 Laboratory Test

Representative soil and rock samples were selected and tested at WWDSE laboratory to check field classification and to determine appropriate engineering properties.

The laboratory testing program for soil samples included moisture content tests, Atterberg Limits tests, sieve analyses, Oedometer consolidation, direct shear, shrinkage limit, free swell, specific gravity; bulk density tests on soil samples. Each soil sample is classified on the basis of texture and plasticity in accordance with the BIRTISH Standard Test and Classification System. Moreover, Compressive strength tests(UCS), specific gravity, water absorption, unit weight, porosity and point load tests have been conducted on rock core samples.

The project site soil and rock are categorized into the major zones on the basis of the field investigation and this has been confirmed by the laboratory test results. The laboratory test results from this exploration are included in the Appendix-B-1 of this report.

The following laboratory tests have been performed on disturbed soil samples and rock collected from excavated test pits: -

Table: 3-9: Laboratory Tests and Standards used

Laboratory testing	Number of Test	Standard
Grain size distribution (sieve analysis)	25	BS Test 7(A) & 7 (B)
Atterberg limits (LL, PL & PI)	25	BS Test 2 (A) & (B)
Natural Moisture Content (NMC)	23	BS Test 1(A)
Specific gravity	2	ASTM, C-128
Bulk unit weight	17	Gibb' & Holtz (1956)s
Free swell	15	Gibb' & Holtz (1956)s
Water absorption	2	ASTM, C-128
Direct shear	12	BS
Oedometer Consolidation	7	BS1377:1975, test17
Standard compaction	2	BS1377:1975, test12 & 13
Permeability	5	ASTM D2434
Sulphate	15	Water Extract
Chloride	15	Water Extract
Double Hydrometer	2	ASTM, D4221
LAA	2	
Point load	1	
CBR	1	AASHTO T 193
Soundness, %	1	
AIV, %	1	
Fineness Modulus	1	

I. Atterberg Limits

The Atterberg limit values of the samples taken from the Main canal& Main canal-1 test pits are given in Table 3-10.

Table: 3-10: Atterberg Limits - Main Canal &Main Canal-1

Test Pit Nr	Location	Depth (m)	Sample Type	Atterberg Limits		
				LL%	PL%	PI%
Main Canal						
MC-CD3-TP-1	Main canal	0.0-1.50	Disturbed	22.50	NP	
		3.20-5.00		32.78	NP	
MC-CD4-TP-1	Main canal	1.00-2.80	Disturbed	22.30	15.56	6.74
		2.80-5.00		24.04	NP	
MC-CD5-TP-1	Main canal	1.10-3.30	Disturbed	17.55	NP	
MC-CD6-TP-1	Main canal	1.50-2.00	Disturbed	42.68	23.85	18.83
		2.10-5.00		23.27	NP	
MC-TP-1	Main canal	0.60-1.80	Disturbed	27.06	NP	
		1.80-3.00		24.00	NP	
(MC)MC-TP-4	Main canal	0.00-1.70	Disturbed	42.42	21.50	20.92
Main Canal-1						
(MC-1)MC-01-CD-2	Main canal -1	1.60-2.0	Disturbed	20.95	NP	
(MC-1)MC-01- CD -3	Main canal -1	1.10-2.0	Disturbed	33.72	27.56	
		2.00-5.00		26.39	19.89	
(MC-1)MC-01-TP-6	Main canal -1	0.00-3.00	Disturbed	25.24	NP	
(MC-1)MC-01-CD-7	Main canal -1	1.00-3.50	Disturbed	25.05	14.60	10.45

According to the standard set by P. Purushothama all the values obtained for the selected samples have plasticity index value of dominantly between 0 &<7; which further implies that the soil material is non to low plastic except two samples have plasticity index value of > 17which implies that the soil material is high plastic.

Table: 3-11 plasticity standard set by P. Purushothama

Plasticity index (%)	Plasticity
0	Non-plastic
<7	Low plastic
7-17	Medium plastic
>17	High plastic

As to the liquid limit value of the samples, one can see that the soil material has low to medium compressibility, since compressibility decreases with decreasing liquid limit. The lower the liquid limit of clay, the lower compressible it will be when compacted.

Table: 3-12 Compressibility guide line table

Liquid limit	compressibility
< 35%	low compressibility
35 - 50 %	medium compressibility
>50%	high compressibility

(Source; P.Purushothama, 2008)

Because of the low plasticity nature of the soil samples, there will be a good workability. Due to low plastic with plasticity index less than 25% it cannot creation foundation problems. Volume changes occur in soil deposits due to changes in water content and in effective stress produced by neutral stress. This further leads to a compression in the soil structure, termed shrinkage.

Table: 3-13 Correlation of Volume change potential plasticity indexes

Volume change potential	**PI (%)**
Low	0 - 30
Moderate	30 - 50
High	>50

Source: Holtz and Gibbs (1956)

Accordingly, the soil samples have plasticity index value range of 0.00-20.9%, which implies low potential volume change of the soil material.

II. Particle Size Analysis

Particle size analysis of soils determines the range of size of particles and the percentage of particles in each of the sizes between the maximum and the minimum. The particle size analyses for the samples from the Main canal are given in Table 3.14.

As can be inferred from Table 3.14, the fine material percentage has a value range of 3.80-54%& 6.3-57.6% for main canal & main canal-1 respectively. Furthermore, from the grain size curve one can see that the soil is well graded; and the workability of a well-graded soil is good.

Table: 3-14 Particle Size Analysis - Main Canal & Main Canal-1

Test Pit Nr	**Location**	**Depth (m)**	**Sample Type**	**Particle size (mm)**					
				Cobble %	**Gravel %**	**Sand %**	**Silt %**	**Clay%**	**Fine %**
Main Canal									
		0.0-1.50	Disturbed	-	-	86.64	9.25	4.11	**13.36**
MC-CD3-TP-1	Main canal	3.20-5.00		-	-	57.12	38.90	9.98	**48.88**
		1.00-2.80	Disturbed	-	-	51.12	38.90	9.98	**48.88**
MC-CD4-TP-1	Main canal	2.80-5.00		-	-	93.23	5.12	1.68	**6.80**
MC-CD5-TP-1	Main canal	1.10-3.30	Disturbed	-	-	62.59	32.91	4.50	**37.41**
		1.50-2.00	Disturbed	-	-	56.55	33.79	9.66	**43.45**
MC-CD6-TP-1	Main canal	2.10-5.00		-	13.94	77.98	7.17	0.91	**8.08**
		0.60-1.80	Disturbed	-	2.23	93.97	3.8	0.00	**3.80**
MC-TP-1	Main canal	1.80-3.00		-	13.24	69.73	13.15	3.88	**17.03**
(MC)MC-TP-4	Main canal	0.00-1.70	Disturbed	-	-	61.00	28.00	11.00	**39.0**
		0.50-1.0		-	-	42.00	42.00	12.00	**54.0**
(MC)MC-CD-4	Main canal	1.8-3.0	Disturbed	-	62.00	38.00	-	-	-
Main Canal-1									
(MC-1)MC-01-CD-2	Main canal -1	1.60-2.0	Disturbed	-	-	93.66	3.08	3.26	**6.3**
		1.10-2.0	Disturbed	-	-	42.41	53.35	4.25	**57.6**
(MC-1)MC-01- CD -3	Main canal -1	2.00-5.00		-	-	59.70	37.80	2.49	**40.3**
		0.00-3.00	Disturbed	-	-	80.00	14.00	6.00	**20.0**
(MC-1)MC-01-TP-6	Main canal -1	0.5-1.0		-	-	80.00	16.00	2.00	**18.0**
(MC-1)MC-01-CD-7	Main canal -1	1.00-3.50	Disturbed	-	7.93	43.25	35.41	13.40	**48.8**

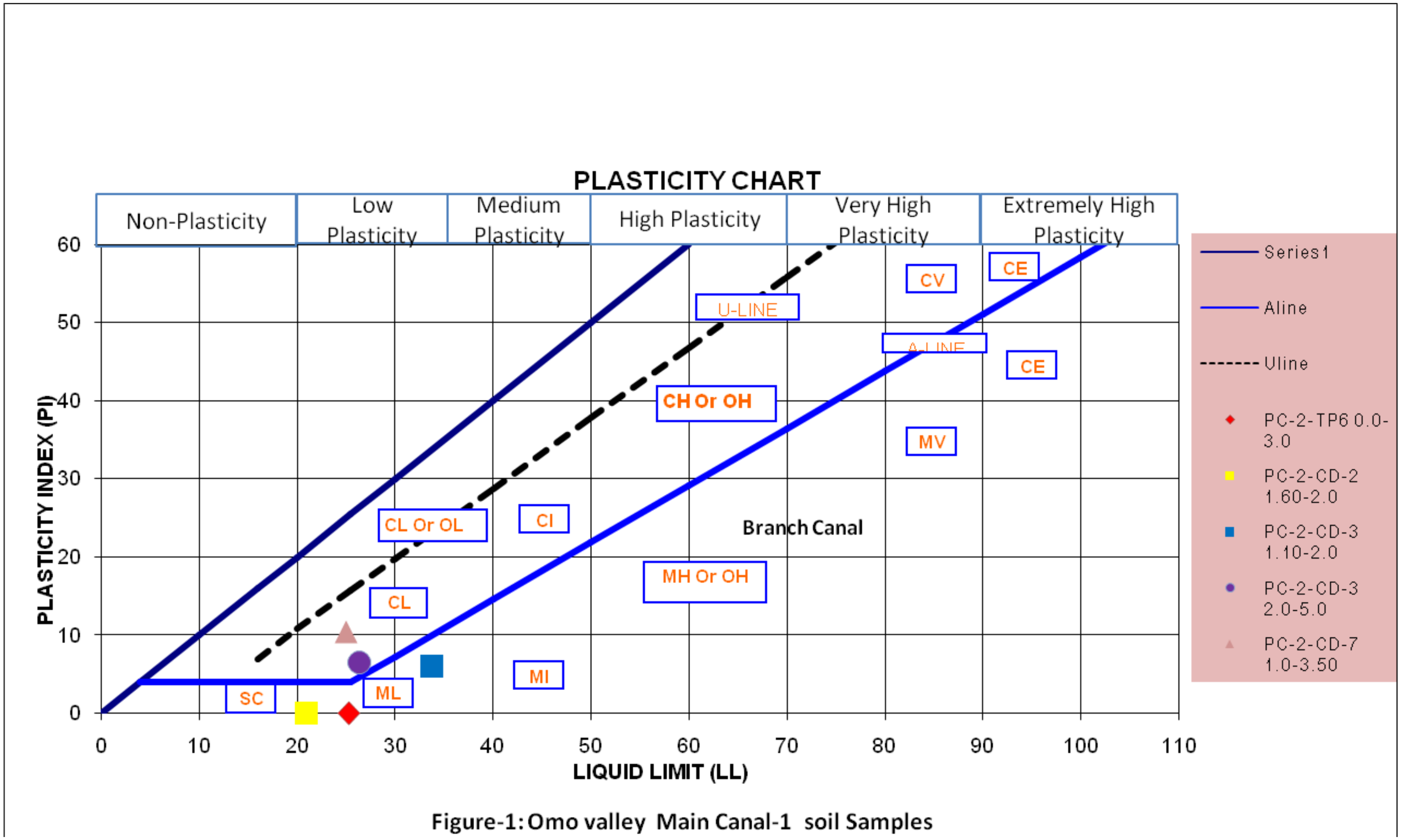

Figure: 3- 2: Omo Valley Main Canal-1 soil Sample classifications by Casagrande Plasticity chart

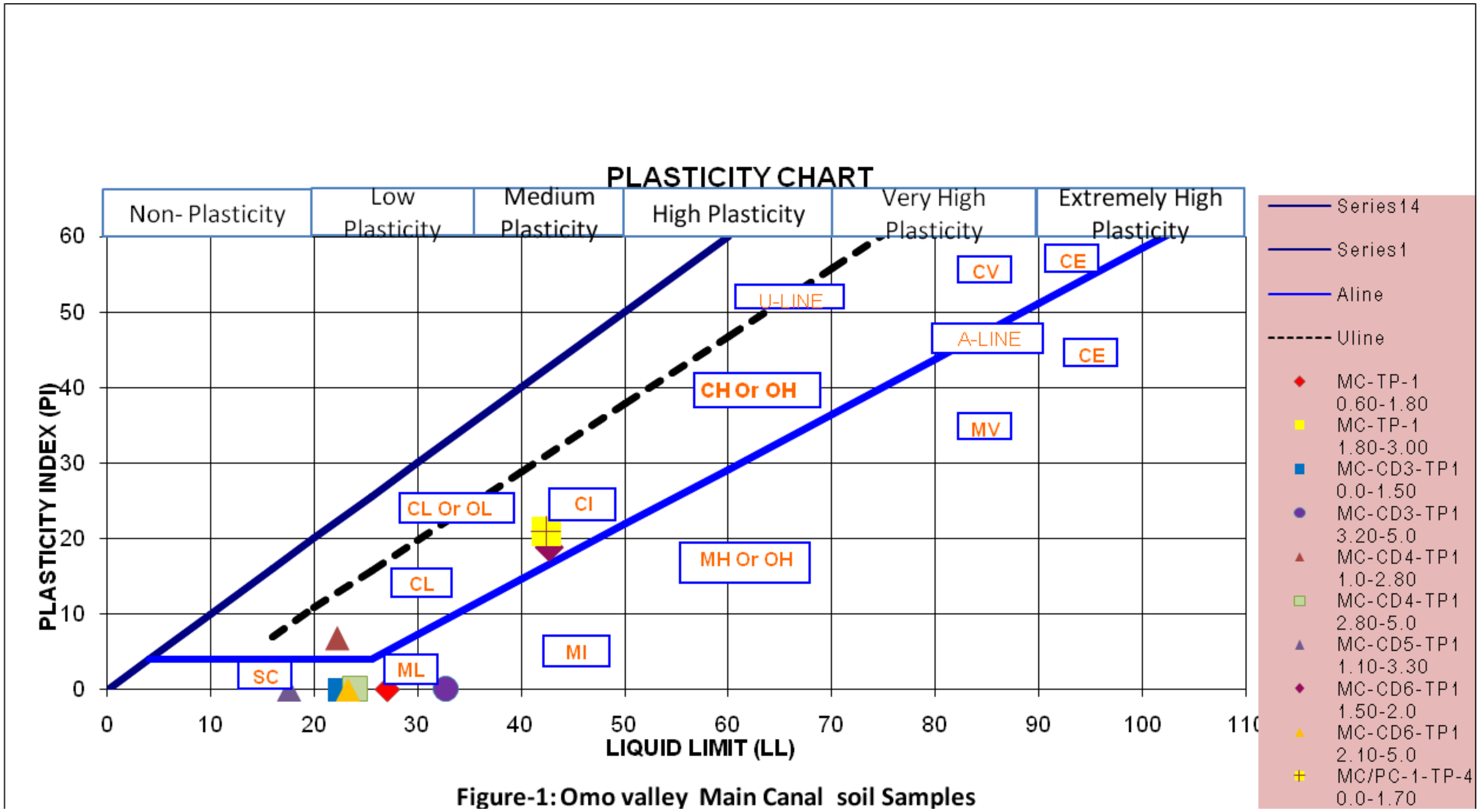

Figure: 3- 3: Omo Valley Main Canal soils Sample classification by Casagrande Plasticity chart

Where

ML - Inorganic silts of low plasticity MH – Inorganic silt of High plasticity

CL – Inorganic clay of low to medium plasticity CH – Inorganic clay of High plasticity

OL – Organic silt of low plasticity OH – Organic clays of High plasticity

III. Moisture Content

The moisture content of soil samples from the Main canal are presented in Table 3.15. Engineering properties change so much with moisture content that it is used primarily to assist in interpreting other index properties.

Table: 3-15. Moisture Content - Main Canal & Main Canal-1

Test Pit No.	Location	Depth (m)	Sample Type	Natural Moisture Content %
Main Canal				
MC-CD3-TP-1	Main canal	0.0-1.50	Disturbed	**0.54**
		3.20-5.00	Disturbed	**1.12**
MC-CD4-TP-1	Main canal	1.00-2.80	Disturbed	**10.8**
MC-CD5-TP-1	Main canal	1.10-3.30	Disturbed	**1.97**
MC-CD6-TP-1	Main canal	1.50-2.00	Disturbed	**2.43**
		2.10-5.00	Disturbed	**0.87**
MC-TP-1	Main canal	0.60-1.80	Disturbed	**5.2**
		1.80-3.00	Disturbed	**7.82**
Main Canal-1				
(MC-1)MC-01-CD-2	Main canal -1	1.60-2.0	Disturbed	**1.39**
(MC-1)MC-01- CD -3	Main canal -1	1.10-2.0	Disturbed	**2.39**
		2.00-5.00	Disturbed	**1.76**
(MC-1)MC-01-CD-7	Main canal -1	1.00-3.50	Disturbed	**0.46**

IV. Specific Gravity

The specific gravity of most soils falls within a narrow range and thus it is not used in the identification or classification of soils as in the identification of minerals. Specific gravity results of the soil are given in Table3.16 from literature review.

As can be inferred from Table 3.16, the specific gravity values have a narrow range of 2.65 to 2.80. This value range is typical for silty sand, sand and inorganic clay.

Table: 3-16: Typical Values of Specific Gravity (Source: Bowles (1978)

Type of soil	Specific gravity , G
Sand	2.65-2.67
Silty sand	2.67-2.70
Inorganic clay	2.70-2.80
Soil with mica or iron	2.75-3.00
Organic soils	Variable but may be under 2.00

V. Dispersion Test

To check the dispersivity of a soil; dispersion tests were conducted on soil samples from Main canals using the double hydrometer method. The results are presented in Table 3.17.

The results obtained indicate that the soil materials in the main canal at ch: 11+038.09-11+587.56 and as well as main canal-1 are non-dispersive; thus erosion would not be a problem.

Table: 3-17.Dispersion Tests

Test Pit Nr	Location	Depth (m)	Sample Type	Double hydrometer
(MC)MC-TP-4	Main canal	0.00-1.70	Disturbed	ND
(MC-1)MC-01-TP-6	Main canal -1	0.00-3.00	Disturbed	ND
		0.5-1.0	Disturbed	ND

Remark: ND = Non dispersive

VI. Free swell

The result of free swell tests on four soil samples from Main canal are given in Table 3.19. Free swell of a soil is the increase in the volume of a soil, without any external constraints, on submergence in water. In general, the free swell ceases when the moisture reaches the plastic limit.

Free swell tests were undertaken in most of the samples and the results are evaluated as per Bureau of Indian Standards and the values and degree of severity are presented in Table: 3-18 and Table: 3-19. The Free Swell results range from 0.00 to 37.5% implying Non-Critical degree of severity.

Table: 3-18.Free Swell Test

Test Pit Nr	Location	Depth (m)	Sample Type	Free Swell (%)
Main canal				
MC-CD3-TP-1	Main canal	0.0-5.00	Disturbed	10.00
MC-CD4-TP-1	Main canal	0.00-5.00	Disturbed	0.00
MC-CD5-TP-1	Main canal	0.00-5.00	Disturbed	0.00
MC-CD6-TP-1	Main canal	1.50-5.00	Disturbed	37.50
(MC)MC-TP-4	Main canal	0.00-1.70	Disturbed	10.00
Main canal-1				
(MC-1)MC-01-TP-6	Main canal -1	0.00-3.00	Disturbed	0.00
(MC-1)MC-01- CD -2	Main canal -1	1.60-4.00	Disturbed	5.00
(MC-1)MC-01- CD -3	Main canal	1.10-5.00	Disturbed	10.00
(MC-1)MC-01-CD-7	Main canal	1.00-3.50	Disturbed	0.00

Table: 3-19: Free Swell Tests and Degree of Severity

S. No	Free Swell (%)	Degree of Severity
1	<50	Non Critical
2	50 – 100	Marginal
3	100 – 200	Critical
4	>200	Severe

VII. Consolidation

The Consolidation test results are given in Table 3.20.

Table: 3-20: Consolidation test

Test Pit Nr	Location	Depth (m)	Sample Type	Conso. Cc
MC-TP1	Main canal	0.00-3.00	Disturbed	0.0341
MC-01-CD-2	Main canal	1.60-4.00	Disturbed	0.057
MC-01-CD-7	Main canal	1.0-3.50	Disturbed	0.046

VIII. Direct Shear

The shear strength depends on clay fraction percentage. Clays with a high clay ø parameters C and fraction percentage exhibit lower shear strengths. Results of Direct Shear Strength test are presented in table 3.21

Table: 3-21: shear strength test

Test Pit Nr	**Location**	**Depth (m)**	**Sample Type**	**Direct Shear**	
				C(KPa)	**ø Deg.**
Main canal					
MC-TP1	Main canal	0.00-3.00	Disturbed	4.33	37.6
MC-CD3-TP-1	Main canal	0.0-5.00	Disturbed	9.93	30.42
MC-CD4-TP-1	Main canal	0.005.00	Disturbed	28.00	27.92
MC-CD5-TP-1	Main canal	1.10-5.00	Disturbed	32.16	27.65
MC-CD6-TP-1	Main canal	1.50-5.00	Disturbed	18.93	28.26
Main canal-1					
(MC-1)MC-01- CD -2	Main canal -1	1.60-4.00	Disturbed	43.66	23.99
(MC-1)MC-01- CD -3	Main canal-1	1.10-5.00	Disturbed	54.39	23.57

IX. Measures against Salt Attack

As stated by California Department of Transportation Materials Engineering and Testing Services Corrosion and Structural Concrete (2012) guidelines for corrosion a site is considered to be corrosive if one or more of the following conditions exist for the representative soil and/or water samples taken at the site: Chloride concentration is 500 ppm or greater, sulfate concentration is 2000 ppm or greater, or the pH is 5.5 or less.

Accordingly, the amount of both Sulphate and chlorides in the subsoil are generally small as observed from the laboratory test results (286.19 ppm & 70 ppm at main pump station and 13.03 ppm & 56.13 ppm at Booster station respectively). Hence, there is no risk of salt attack at both pump station sites.

3.1.2.3.5 Summary

The overall geotechnical investigations and laboratory tests conducted in this investigation are summarized as follows in the following table 3-22.

Table: 3- 22: Summary of the geotechnical investigations carried out along Main Canal & Main Canal-1

Geotechnical investigations carried out	**Quantity**
Test pit excavation	28
DCP in-situ test	10
Infiltrations test	14
Number of disturbed soil sample	27
Laboratory Tests	
Grain size distribution (sieve analysis)	25
Atterberg limits (LL, PL & PI)	25
Natural Moisture Content (NMC)	23
Specific gravity	2

Bulk unit weight	17
Free swell	15
Water absorption	2
Direct shear	12
Oedometer Consolidation	7
Standard compaction	2
Permeability	5
Sulphate	15
Chloride	15
Double Hydrometer	2

3.1.3: Findings from Geotechnical Investigation

3.1.3.1: Geotechnical Characterization of Subsurface Layer of canal routes using laboratory and field description

This chapter deals on comprehensive description and explanation of the outcomes of subsurface investigations by pitting and laboratory testing.

The surrounding area of the canals is covered by various quaternary sedimentary soils mainly alluvial deposits. 5layers are identified across the full length of the profile of Main Canal and for layers in the Main canal-1, having sub parallel and sub horizontal attitude. As depicted in the profile, the thicknesses of the layers vary; some layers are continuous along the canal line. The detailed descriptions soil layers are presented as follows and fig 3-2 -3-4 & Appendix-A-1.The classifications to obtain geotechnical layers have revealed from the qualitative information were obtained in the field by visual inspection. It constitutes the basis for preparing the test pit logs or other records that describe the succession of strata in the underground. The quantitative information was obtained by means of laboratory and field tests and the layers that are constitutes the project area can be summarized as follows;

I. Layer-I Clayey fine Sand unit (ML)

The unit is exposed in the main canal from CH: 0+000 to 1+677km having 0.0-5.0m thickness, from CH:1+677km to 4+175km at depth of 2.10-5.0m, from CH:4+175km to 4+775km at depth of 2.80-5.0m,from CH:4+975km to 5+523km at depth of 2.10-5.0m along the profile section. The geotechnical parameters that are typical of the average behavior of the unit are as follows:

Unit weight (loose) (γ_n) = 10.49-14.21KN/m^3

SPT blow count Nspt= 22-30.5

Effective cohesion c' = 15-48.33kPa

Effective shear strength angle pia'= 18-26 °

Permeability coefficient k = $2.9*10^{-2}$&$9.61*10^{-6}$cm/s for the depth of 0.0 to 3.0m &3.10 – 5.0m of the test pits respectively.

II. Layer-II Dark brown sandy Clay unit (CL)

The unit is exposed in the main canal at CH: 1+677 to 4+174 km at depth range of 0.0-2.10m CH:4+174 - 4+775 km at depth range of 1.0-2.80m, from CH:4+975km to 5+523km at depth of 0.0-2.10m depth and from CH: 10+239 – CH: 11+338km having 0.0-1.70m thickness along the profile section. The geotechnical parameters that are typical of the average behavior of the unit from literature review are as follows:

Unit weight (γ_n) = 12.5-17.5KN/m^3

Permeability coefficient k =10^{-10} -10^{-8}cm/s

III. Layer-III: gravelly Sand unit (SP)

The unit is exposed the main canal at CH: 4+175 to 4+776 km, at depth of 0.0 -1.0m, from CH:5+524 to CH: 8+094 at depth of 0.0-5.0m, CH: 8+095 to 10+238 km having 2.60-5.0m depth and from CH:10+239 to 11+338km with 1.70 to 3.0m thickness along the profile section. The geotechnical parameters that are typical of the average behavior of the unit are as follows:

Unit weight (loose) (γ_n) = 13.13KN/m^3

SPT blow count Nspt= 15-20.5

Effective cohesion c'=28-kPa

Effective shear strength angle pia' 27.9°

Permeability coefficient k =10^{-4} to10^{-2}cm/scm/s

IV. Layer-IV: Silty Sand unit (SM)

The unit is exposed in the top most layers at the main canal at CH: 8+096 to 10+238km at 0.0-2.60m depth and 11+338 to 13+140and main canal-1 from CH: 0+00 – 4+800km average depth of 0.0-1.50m. It is Reddish brown, fine grained, dry, low plasticity. The geotechnical parameters that are typical of the average behavior of the unit are as follows:

Unit weight (γ_n) = 12.5-21KN/m^3

Permeability coefficient k=10^{-7} -10^{-5}cm/s

V. Layer-V: Reddish brown Clayey Sand unit (SC)

The unit is exposed at the main canal at CH: 4+776 to 4+974it is dark brown, fine grained, stiff, and medium plastic, 0.00-5.0m thick and the geotechnical parameters that are typical of the average behavior of the unit are as follows:

Permeability coefficient k=.4.4*10^{-4}

3.2 Pump Station

3.2.1 General

Exploration requirements for the foundations of Pump station depend up on the size and load of the structure; and the character of the ground were the pump station will sit. In the face of the size of the proposed pump station sets with pump house and pipes are relatively massive to require geotechnical considerations a general assessment on the geotechnical conditions of the project proposed pump site is carried out through test pit, sampling and in-situ & laboratory testing.

The objective of the investigation was to identify potential geotechnical conditions in subsurface, which could affect the bearing conditions of the pump site. Accordingly, the site investigation also attempts to foresee and provide against difficulties that may arise during and after construction because of ground and/or other local conditions. The specific objects include:

- Assessing allowable bearing capacity via DCP test and laboratory shear strength parameter

Since soils of different origin and history exhibit different geotechnical natures with respect to the parameters, the general geological-geotechnical condition of the area is believed to govern the parameters used in assessing the potential problems on the site.

3.2.1Methodology

3.2.1.1 Test Pitting

Test pits with surface area 1.5mx1.5m x 5.0m were manually dug at two points in the previous proposed pump station-1 (near Korcho Village) and one in pump station-2 area. The test pits were dug by equipment such as, row bar, Hoe, pickaxes, and shovel. A steel ladder is lowered to the bottom of the pit for detailed logging of the various soil horizons and collecting representative samples for visual description. Upon completion of documentation and sampling, the test pit is photographically documented using digital camera followed by backfilling of the pit by the excavated material. A total of two test pits for pump station-1 were manually dug, relevant information pertinent to the test pits are presented in the profile section.

3.2.1.2 Sampling

During the previous investigation due to the difficulty of access to the foundation level, we were forced to take samples from test pits of the Korcho site soil formation and subsequent visual description are taken to determine the preliminary engineering properties. However, currently excavation works are commenced at the main pump station site which created access to some portion of pump site foundation area. To further characterize the site three soil samples were collected above foundation level and conducted laboratory test.

Table: 3- 23 summary table of investigation

Structure name	**Number of Test pits**	**Number of Disturbed Samples**
Pump station-1 and -2	4	10
Main Pump Station	From excavated face	3

3.2.1.3. In Situ DCP Tests

Dynamic Cone Penetrometer tests were conducted inside test pits at a depth of 0.0m (surface), 1.5m, and 3.0m for the Pump station-2 (Booster) site and for Pump station-1(Korcho Site) at a depth of 1.0m and 1.73m to determine the resistance of various soil horizons underlying the pump station Sites. A total of four DCP tests were conducted in both pump station sites at the surface and covered by soils inside test pits in order to determine the resistance of these soil horizons. For the main pump station site the analysis was undertaken by using shear parameters alone.

The statistical average values of the penetration are used for calculating the SPT-Values using the relation in equation (1-5) below. The average DCP value of each layer is converted in to SPT-N values, using the relation suggested by a user guide of Minnesota Department of Transportation (Mn/DOT):

Equation: 1- 5……………………………………………………………SPT= 240.17 $DCP^{-0.967}$

Where SPT= Standard Penetration Test number of blows (N values)

DCP=adjusted dynamic cone penetration result in mm/blow for a given soil layer

Converted SPT N-values are corrected for moisture and considered for computation of the bearing capacity. Design SPT- N values of soils layers below ground obtained from dynamic cone Penetration Data are presented below in table 3-24.

Table: 3- 24 Summary of DCP result of pump stations

No.	TP ID.	Depth (m)	DCP Value	SPT N value/ 300mm	Adjusted SPT N-value
1	PS-2-TP-1	0.0-1.49	15.7	17	16
2		1.50-2.13	9.8	26	20.5
3	PS-1-TP-1	1.0-1.73	9	29	22
4		1.73-2.62m	5.5	46	30.5

3.2.1.4. Laboratory test results of soil layers

Disturbed soil samples from the depths 0.0 to 5.0 meters of test pits of PS-2 (Booster Site) and 0.0-2.40, 3.4-7.4 & 7.4-10.40 m from main pump station site from surface excavation exposure were taken for laboratory testing. Taking undisturbed samples from the test pits and surface is not possible because of the dense and dry nature of the formation. The laboratory results are summarized in the following table.

Table: 3- 25 Summary of Laboratory Test Results from disturbed Samples

TP ID	Sample type	Sample Depth (m)	Unit weight (gm/cc)	Grain size distribution				Atterberg Limits			Free Swell (%)	NMC (%)	Direct Shear		Conso. Cc	Permeability (cm/sec)	Chemical	
				Sand (%)	Silt (%)	Clay (%)	Fine (%)	LL (%)	PL (%)	PI (%)			C (KPa)	f (Deg.)			Sulphate (meq/l)	Chloride (meq/l)
PS-1-TP1	**BDS**	0.0-5.0	1.12								47.50		48.33	18.00	0.246		8.48	10.36
	SDS	0.0-2.50		65.8	25.9	8.3	**34.18**	22.89	NP			4.89						
	SDS	2.5-5.0		30.4	48.4	21.2	**69.58**	31.86	20.70	11.16								
PS-1-TP2	**BDS**	0.0-5.0	1.07								42.50		15	26	0.19		5.72	8.96
	SDS	0.0-1.30		41.28	43.22	15.50	**58.72**	27.01	17.49	9.52		5.14						
	SDS	1.3-3.0		36.36	48.35	15.29	**63.64**	29.05	24.22	4.83		8.47						
	SDS	3.0-5.0		24.44	47.75	27.81	**75.56**	39.48	22.33	17.15		16.45						
Main Pump stat.	BDS	0.0-2.40	1.172	9.11	35.92	54.97	90.89	49.29	28.86	20.43	57.50	13.9	21.69	19.72				
	BDS	3.4-7.4	1.284	4.45	69.91	25.64	95.55	69.20	30.52	38.68	110	21.03	48.52	11.38		1.89*10-8		
	BDS	7.4-10.4	1.84	70.42	18.20	11.38	29.58	21.03	20.21	0.82	10.00	10.83	49	28.14		2.52*10-6	5.71	1.4

Table: 3- 26: Summary of Laboratory Test Results from disturbed Samples Booster site

No	TP ID	Location of Test pit	Sample type	Sample Depth (m)	Unit weight (gm/cc)	Grain size distribution					Atterberg Limits			Free Swell (%)	NMC (%)	Direct Shear		Conso. Cc	Chemical	
						Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fine (%)	LL (%)	PL (%)	PI (%)			C (KPa)	f (Deg.)		Sulphate (meq/l)	Chloride (meq/l)
1	**PS-2-** TP1	Booster	BDS	0.0-5.0	1.57									0.0		42.33	29.45	0.190	0.26	1.12
2			SDS	1.20-3.0		21.00	73.54	5.46	0.00	5.5	26.10	NP			0.37					
3			SDS	3.0-5.0			94.53	5.47	0.00	5.5	26.40	NP								

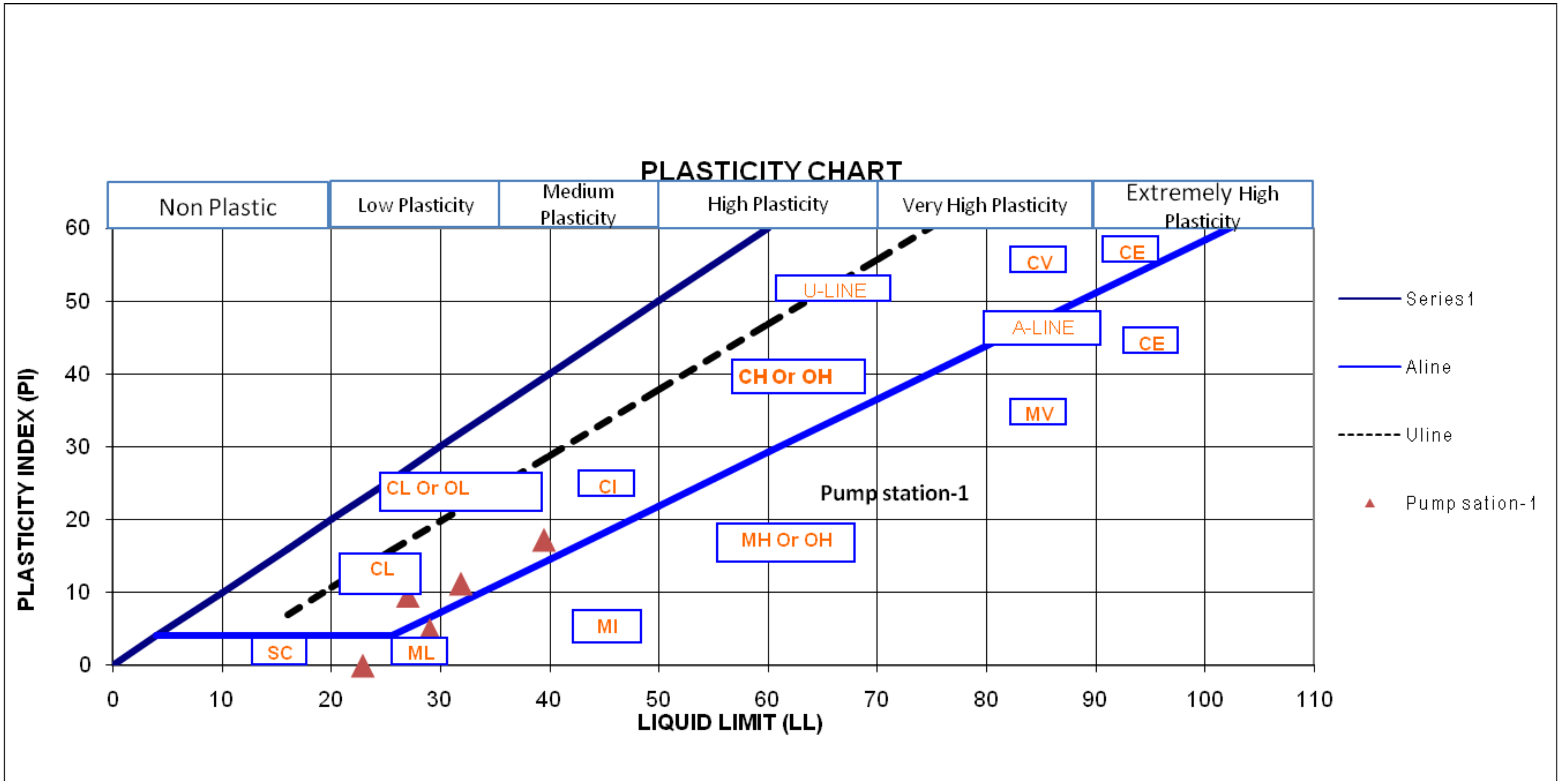

Figure: 3- 4: Omo valley Pump station-1 (Korcho Site) soil Samples

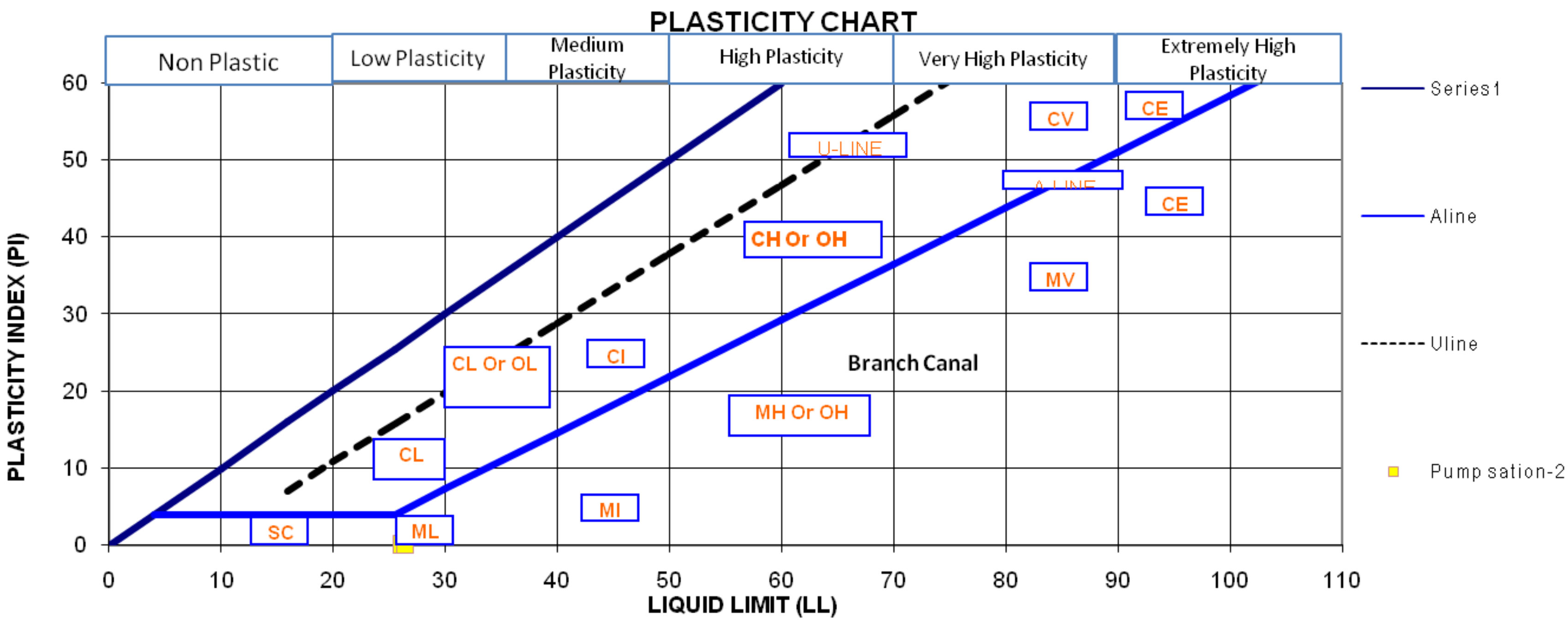

Figure: 3- 5: Omo valley Pump station-2 (Booster Site) soil Samples

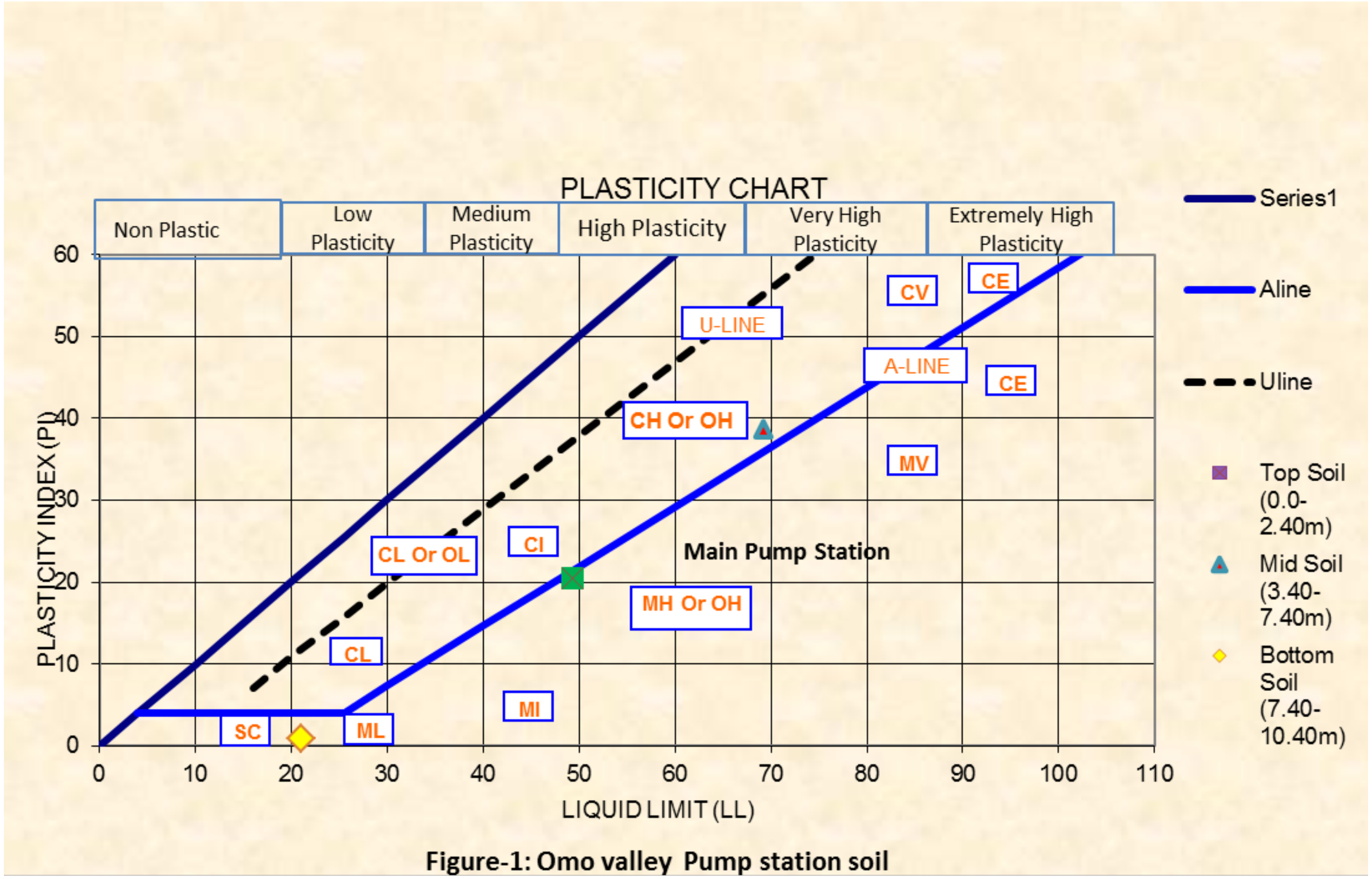

Figure: 3- 6: Main Pump Station Site Soil Sample Plasticity Chart

3.2.2. Geotechnical finding

The subsurface geology is sub-divided into various geotechnical layers based on visual description and in situ (DCP) test results. Based on this geotechnical characteristic the sub-surface geology is sub-divided into the following quasi-homogeneous geotechnical layers.

Main Pump Station Soil Layers
In this station two soil layers are identified and described as follows:

Layer-1 Clayey silt (MH)

The unit is exposed in the main pump station site and can be described as reddish brown, inorganic, highly plasticity, dry, stiff having 0.0 m to 2.40 m thickness at excavation face. The geotechnical parameters that are typical of the average behavior of the unit are as follows:

Unit weight (loose) (γ_n) = 11.5/m^3

Effective cohesion c'- 21.69kPa

Effective shear strength angle ϕ' -19.72 °

Layer-2 Organic Clay (OH)

The unit is exposed in the main pump station site and can be described as dark brown, inorganic, highly plasticity, dry, stiff having 3.4m to 7.40m thickness in the excavated face. The geotechnical parameters that are typical of the average behavior of the unit are as follows:

Unit weight (loose) (γ_n) = 12.6KN/m^3

Effective cohesion c' -48.52 kPa

Effective shear strength angleϕ'-11.38°
Permeability (cm/sec) =1.89*10^{-8}

Layer-3 Clayey Silty Sand (ML)

The unit is exposed in the main pump station site and can be described as Reddish brown, inorganic, low plasticity, dry, stiff having 7.4m to 10.40m thickness in the excavated face. The geotechnical parameters that are typical of the average behavior of the unit are as follows:

Unit weight (loose) (γ_n) = 18KN/m^3

Effective cohesion c' -48.97 kPa

Effective shear strength angleϕ'-28.14°
Permeability (cm/sec) = 2.52*10^{-6}

Photo: 3- 1 View of main pump station site

Pump Station-2 (Booster Site) Soil Layers

<u>Layer-1 silty sand (SM)</u>

The unit is exposed in the pump station-2 site and can be described as light brown-grayish, non-plasticity, dry, loose, with having 5m thickness within the test pit. The geotechnical parameters that are typical of the average behavior of the unit are as follows:

Unit weight (loose) (γ_n) = 15.4 KN/m^3

SPT blow count Nspt= 16-20.5

Effective cohesion c’ = 42.33 kPa

Effective shear strength angle pia’= 29.45°


Photo: 3- 2 View of test pits on proposed pump station-2 (Booster Site).

4 BEARING CAPACITY ANALYSIS

4.1 General

The Selection of a particular type of foundation depends on the magnitude and nature of the subsurface strata, the structural loads, the type of the superstructure and its specific requirements. In terms of their founding depths within subsurface are normally categorized as shallow and deep (pile) foundations. Shallow foundation is the first logical choice of a foundation unless it is considered inadequate for different reasons.

The allowable bearing pressure is the maximum net intensity of loading that can be placed on the soil without any shear failure or the risk of excessive settlement. It is therefore, the smaller of the net safe bearing capacity (shear failure criterion) and the safe bearing pressure (settlement criterion) that has to be considered. Consequently, taking in to account the material properties of the project sites, the foundation ground need to be analyzed taking or considering their strength and engineering characteristics.

A uniform settlement is usually of little consequence in buildings, but a differential settlement can cause severe structural damages.EBCS-7 (1995) recommends permissible total settlements of 50mm and 75mm on sandy and clayey soils, respectively. Differential settlements between adjacent columns up to 20mm are acceptable. In calculation of the allowable bearing capacities of the soils both the total and differential settlement values have estimated to be within tolerable limits (25mm). Therefore, the calculated allowable bearing pressures are including the settlement criteria.

The determination of allowable bearing pressures is discussed based on the strength of the sub-surface formations from in situ test results. Field observation and measurements on different soil layers are the main data used in the analysis of the allowable bearing pressures of the foundations.

After adjusting the N-values based on the above formula, the design N-values are used to determine the allowable bearing capacities of soil layers at each foundation site.

Raft Foundations: According to Meyerhof (1965)], for a raft foundation, when the bearing capacity is based on penetration tests (e.g., SPT, CPT) in cohesionless soils such as sands and sandy gravel, one may use the following equation to calculate the allowable bearing capacity by limiting the tolerable settlement (Bowles, 1996): -

Equation: 1- 6…………………………………………………………………**qall =N(ΔHa/25.0) Kd /0.08**

Where *Kd*= 1 + *0.33D/B* < 1.33
N= SPT blow/300mm
ΔHa = allowable settlement such as 25, 40, 50, 60 mm, etc.
D =depth of foundation
B =width of foundation

Spread Foundations: The design N values are calculated as the average of N values which are found between ½ B above and 2B below the footing depths. The design SPT N values are used to determine the bearing capacities on each site according to Meyerhof's equation (Bowles, 1996):

Equition:1- 7…………………………………………………………..qall = N/F2 [(B+F3)/B)]2kd **B>F4**

Where qall = Allowable bearing pressure for settlement limited to 25 mm.

Kd = 1+0.33D/B < 1.33
F2 = 0.08; F3 = 0.3; F4 = 1.2
B = Width of foundation;
D = Depth of foundation

To be conservative on the results, allowable bearing pressures are calculated for foundation widths equal to assumed foundation depths-geotechnical layer depth- below the ground level for settlement limited to 25mm. Foundation width is, thus can a significantly be selected greater than the given foundation depth but less than the depth is not allowed.

However, the unconfined compressive strength can be estimated from the SPT N' value and the results of the unconfined compressive strength obtained from undisturbed soil samples. Bowles (1997, 5th Edition) gives an empirical correlation between N' value and unconfined compressive strength that can be estimated by the following relation.

Equation: 1- 8…………………………………………..……………………………………qu = **K*N'**
K = 12 for SI unit

And other relation can obtained from Sower's graphs uses Cu =4N for high plasticity clays and increasing to about 15N for low plasticity clays. – Contrast with Stroud and Butler's (1975) graph which shows Cu=4.5N for PI>30%, and increasing to Cu=8N for low plasticity clays (PI=15%).

However on the basis of this, Construction Industry Research Information Association Report No. 143, SPT Methods and Use 1995, Stroud suggested that N value in cohesive soil is not only a function of Undrained shear strength (C_u) but also it has a relationship with Plasticity Index (PI). The plasticity of the foundation soil, anticipated to form the seat of structural footings varies from 12 – 38%. Accordingly for such soils, K value of 4.75 is considered as the most appropriate to correlate the N' values with that of their equivalent un-drained shear strength. Table 3-27 below is the summary of q_u derived from N' VS q_u (= $2C_u$) relationship.

Table: 3- 27: Summary of qu derived from N VS qu relationship for different depth

TP ID.	Depth (m)	PI%	N'	SPT Cu (N' * 4.75)	applied formulas
PS-2-TP-1	0.0-1.49		16		
	1.50-2.13		20.5		
PS-1-TP-1	1.0-1.73	11.16-17.15	22	104.5	Stroud
	1.73-2.62		30.5	144.875	
MC-CD3-TP1	0.0-0.75		20.5	246	
MC-CD4-TP1	0.0-0.62	6.73-18.83	20.5	97.375	Stroud
	1.6-2.4		15	71.25	
MC-CD5-TP1	1.5-2.80		10	47.5	
	2.80-3.57		14	66.5	
MC-CD7-TP1	0.0-0.68		18	85.5	
MC-01-CD-3	0.0-0.73	6.16-10.45	16.5	247.5	Sower's graphs
	1.50-2.25		11.5	172.5	
MC-01-CD-2	0.0-0.73		39	585	
MC-01-CD-7	0.0-0.67		22	330	

In addition to the above analysis, the bearing capacity analysis were done through Terzaghi and Vesic presented the general bearing capacity theory for increasing the computation value more precise, with the ability of the soil to accept this load dependent on:

– The soil properties – cohesion (c), angle of friction (φ) and unit weight (γ).

– The footing geometry – embedment (D_f) and width (B).

– Surcharge (q) resisting movement=γD_f.

– Modifications of the above relationship occur for:

- Water table.
- Shape, depth and inclination factors.
- Soil layering.
- Adjacent to slopes.

Table: 3- 28 Bearing capacity equation.

Consideration	Cohesion	Embedment	Unit weight	Comments
Bearing capacity factors	Nc	Nq	Nγ	These factors are non-dimensional and depend on φ. See next Table
Ultimate bearing capacity (qult)	c Nc+ 1.3 c Nc+ 1.3 c Nc+	q Nq+ qNq+ q Nq+	0.5γ B Nγ 0.4γ B Nγ 0.3γ B Nγ	Strip footing Square footing Circular footing

Finally, the final recommended result of the analyses were done by averaging the result of the following three equations; Terzaghi and Vesic equation and Meyerhof's equation.

Accordingly the allowable bearing capacity shown in Table below is computed as,

Equation: 1- 9……………………………………………………………….qa = qu-net /Sf

Where, Sf is Safety factor = 3

Safe Bearing capacities have been determined for footing widths of 2 – 6.0m with an increment of 0.5m for footing depths of 2 to 4m and the increment become1m that is for the next depths 5, and 6 meters for the Booster site and Canal Cross Drainage Structure sites. However, for Main Pump Station Site allowable bearing capacity have been determined considering footing width of 12m and length of 60m and with increments of 0.5 m for footing depths 1 to 4.0m and by considering the rectangular shape of mat foundation. Consequently, the results for pump station and canal structure sites are presented on Table 3-29 so as to select the appropriate Safe Bearing capacity with different footing width, B and depth, D.

Table: 3- 29: Summary of bearing capacity result of Main Pump Station site

Structure Id.	Depth (m)	Over Burden Υ_{Bulk}, KN/m^3	C, Kpa	Phi (degree)	q_a, Kpa, Vesic
	B = 12m				
Main Pump Station	1	18.032	48.97	28.14	794.1
	1.5	18.032	48.97	28.14	826.0
	2.0	18.032	48.97	28.14	858.5
	2.5	18.032	48.97	28.14	891.5
	3.0	18.032	48.97	28.14	925.2
	3.5	18.032	48.97	28.14	959.3
	4.0	18.032	48.97	28.14	994.1

Table: 3- 30 Summary of bearing capacity result of Pump station_2 (Booster) sites

Structure/ Cross Drain Id.	**Depth (m)**	**Over Burden (Loose) γ_{Bulk}, KN/m^3**	**C, KPa**	**Phi (degree)**	**q_a,KPa, Vesic**	**q_a,KPa, Terzaghi**	**qa, KPa, DCP-SPT Correlation Meyerhof's**	**q_a,KPa, Average**
Pump Station-2	B = 2m							
	2.5	15.4	42.33	29.45	1067.0	777.2	426.1	**756.8**
	3	15.4	42.33	29.45	1125.3	796.9	451.0	**791.1**
	3.5	15.4	42.33	29.45	1179.3	816.5	475.9	**823.9**
	4	15.4	42.33	29.45	1230.0	836.2	500.8	**855.7**
	5	15.4	42.33	29.45	1324.6	875.5	550.6	**916.9**
	6	15.4	42.33	29.45	1413.1	914.8	600.4	**976.1**
	B = 3m							
	2.5	15.4	42.33	29.45	1059.9	791.0	384.7	**745.2**
	3	15.4	42.33	29.45	1142.1	810.6	401.3	**784.7**
	3.5	15.4	42.33	29.45	1131.7	830.3	417.8	**793.3**
	4	15.4	42.33	29.45	1184.1	849.9	434.4	**822.8**
	5	15.4	42.33	29.45	1282.7	889.2	467.6	**879.9**
	6	15.4	42.33	29.45	1375.2	928.5	500.8	**934.9**
	B = 4m							
	2.5	15.4	42.33	29.45	1009.5	804.7	363.9	**726.1**
	3	15.4	42.33	29.45	1077.5	824.4	376.4	**759.4**
	3.5	15.4	42.33	29.45	1147.3	844.0	388.8	**793.4**
	4	15.4	42.33	29.45	1218.9	863.7	401.3	**827.9**
	5	15.4	42.33	29.45	1249.4	903.0	426.1	**859.5**
	6	15.4	42.33	29.45	1343.4	942.3	451.0	**912.2**
	B = 5m							
	2.5	15.4	42.33	29.45	983.9	818.4	351.5	**718.0**
	3	15.4	42.33	29.45	1043.4	838.1	361.4	**747.6**
	3.5	15.4	42.33	29.45	1104.2	857.7	371.4	**777.8**
	4	15.4	42.33	29.45	1166.6	877.4	381.3	**808.4**
	5	15.4	42.33	29.45	1295.7	916.7	401.3	**871.2**
	6	15.4	42.33	29.45	1317.7	956.0	421.2	**898.3**
	B = 6m							
	2.5	15.4	42.33	29.45	970.7	832.2	343.2	**715.4**
	3	15.4	42.33	29.45	1024.5	851.8	351.5	**742.6**
	3.5	15.4	42.33	29.45	1079.4	871.5	359.8	**770.2**
	4	15.4	42.33	29.45	1135.6	891.1	368.1	**798.3**
	5	15.4	42.33	29.45	1251.6	930.4	384.7	**855.6**
	6	15.4	42.33	29.45	1372.5	969.7	401.3	**914.5**

Table: 3- 31 Summary of bearing capacity result of Cross Drain structure sites

Structure/ Cross Drain Id.	**Depth (m)**	**Over Burden (Loose)Υ_{Bulk}, KN/m^3**	**C, KPa**	**Phi (degree)**	**q_a,KPa, Vesic**	**q_a,KPa, Terzaghi**	**qa, KPa, DCP-SPT Correlation Meyerhof's**	**q_a,KPa, Average**
Width, B = 0.5m								
	0.5	12.8	9.93	30.42	257.2	181.7	872.5	**437.1**
	1.0	12.8	9.93	30.42	285.0	193.5	1089.0	**522.5**
	1.5	12.8	9.93	30.42	316.5	205.3	1305.4	**609.1**
MC-CD3-TP1	2.0	12.8	9.93	30.42	343.8	217.1	1521.9	**694.3**
Width, B = 0.5m								
	0.5	13.1	28	28	548.4	396.6	766.08	**570.3**
	1.0	13.1	28	28	581.5	406.4	956.16	**648.0**
	1.5	13.1	28	28	621.0	416.1	1146.24	**727.8**
MC-CD4-TP1	2.0	13.1	28	28	650.8	425.9	1336.32	**804.4**
B = 0.5m								
	0.5	12.5	32.16	27.65	608.0	441.0	532	**527.0**
	1.0	12.5	32.16	27.65	448.8	639.5	664	**584.1**
	1.5	12.5	32.16	27.65	456.5	677.8	796	**643.4**
MC-CD5-TP1	2.0	12.5	32.16	27.65	705.2	464.3	928	**699.1**
B = 0.5m								
	0.5	13.23	18.93	28.26	278.7	386.6		**332.6**
	1.0	13.23	18.93	28.26	289.2	415.9		**352.5**
	1.5	13.23	18.93	28.26	299.7	450.2		**374.9**
MC-CD6-TP1	2.0	13.23	18.93	28.26	310.1	477.7		**393.9**
B = 0.5m								
	0.5						766.08	**766.1**
	1.0						956.16	**956.2**
	1.5						1146.24	**1146.2**
MC-CD7-TP1	2.0						1336.32	**1336.3**
B = 0.5m								
	0.5	13.13	43.66	23.99	600.6	449.7	1659.84	**903.4**
	1.0	13.13	43.66	23.99	629.2	456.1	2071.68	**1052.3**
	1.5	13.13	43.66	23.99	664.5	462.4	2483.52	**1203.5**
MC-01-CD-2	2.0	13.13	43.66	23.99	688.9	468.7	2895.36	**1351.0**
B = 0.5m								
MC-01-CD-3	0.5	11.9	54.39	23.57	716.3	538.6	595.84	**616.9**

Structure/ Cross Drain Id.	Depth (m)	Over Burden (Loose)Υ_{Bulk}, KN/m^3	C, KPa	Phi (degree)	q_a,KPa, Vesic	q_a,KPa, Terzaghi	qa, KPa, DCP-SPT Correlation Meyerhof's	q_a,KPa, Average
	1.0	11.9	54.39	23.57	744.4	542.5	743.68	**676.9**
	1.5	11.9	54.39	23.57	780.0	546.3	891.52	**739.3**
	2.0	11.9	54.39	23.57	802.5	550.1	1039.36	**797.3**
B = 0.5m								
	0.5	13.5	54.39	23.57	721.7	542.3	936.32	**733.4**
	1.0	13.5	54.39	23.57	754.6	549.0	1168.64	**824.1**
	1.5	13.5	54.39	23.57	795.4	555.8	1400.96	**917.4**
MC-01-CD-7	2.0	13.5	54.39	23.57	823.1	562.5	1633.28	**1006.3**

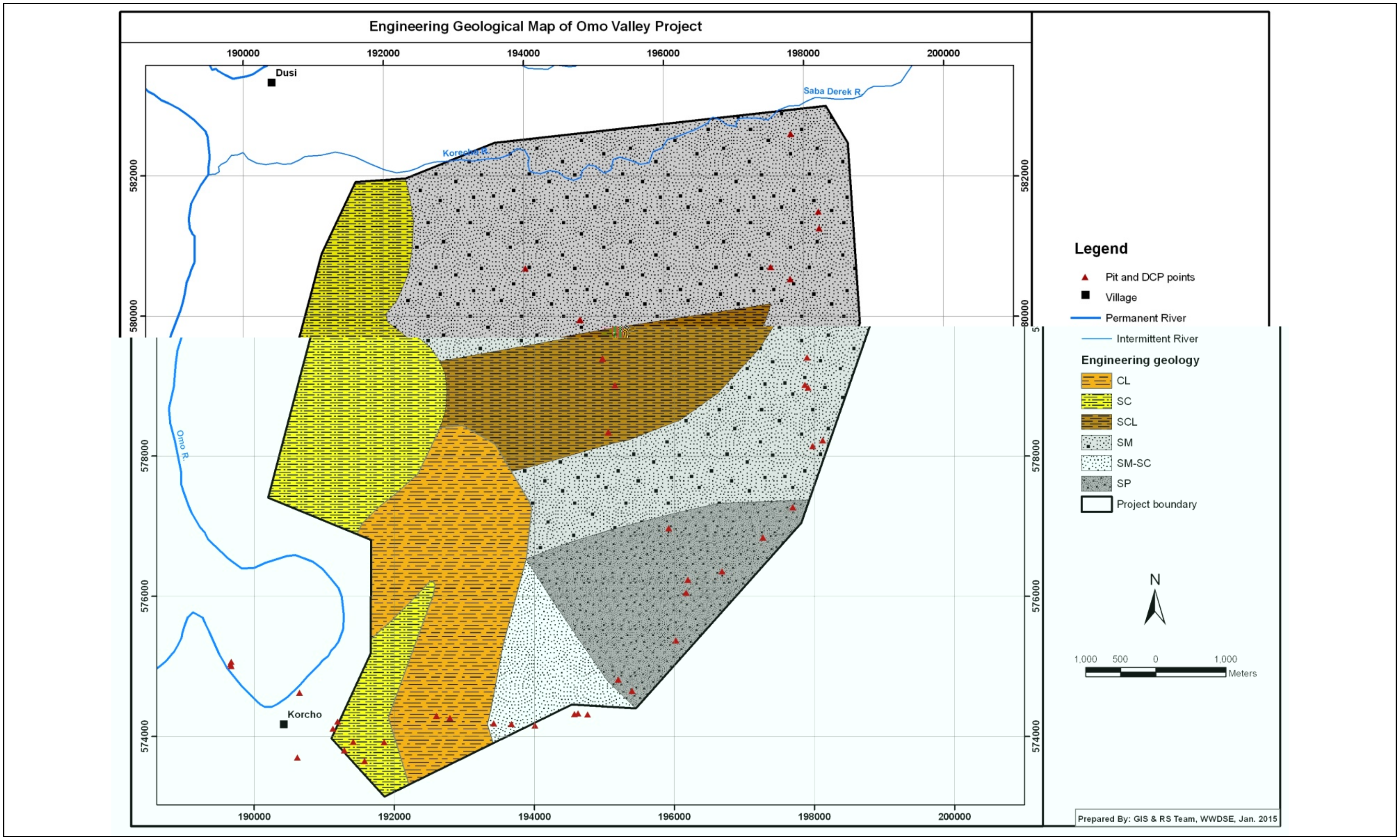

Figure: 3- 7: Engineering Geological map of the site.

Figure: 3- 8: Longitudinal Geological Cross Section (Subsurface Profile) of Main Canal

Figure: 3- 9: Longitudinal Geological Cross Section (Subsurface Profile) of Main Canal-1.

5. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

Geotechnical investigation works have been carried out at Omo Valley Farm Irrigation Project. The project sites included in the investigation are: the proposed canal alignment and pump stations. The investigation was composed of test pitting and visual descriptions, DCP field testing, Infiltration test works and sample collections. Laboratory testing was also conducted to obtain index properties (grain size analysis and Atterberg limits) and engineering properties (compaction (maximum dry density), optimum moisture content, free swell, direct shear and chemical test (i.e. Sulphate and chlorides) of the soil samples collected.

Based on field descriptions and laboratory index test results, the following geotechnical soil units are identified along the main canal; these are: Clayey fine Sand unit (ML) are exposed from CH: 0+000 to 1+677km having 0.0-5.0m thickness, from CH: 1+677km to 4+175km at depth of 2.10-5.0m, from CH: 4+175km to 4+775km at depth of 2.80-5.0m, from CH: 4+975km to 5+523km at depth of 2.10-5.0m; Sandy Clay unit (CL) are exposed at CH: 1+677 to 4+174 km at depth range of 0.0-2.10m CH:4+174 - 4+775 km at depth range of 1.0-2.80m, from CH: 4+975km to 5+523km at depth of 0.0-2.10m depth and from CH: 10+239 – CH: 11+338km having 0.0-1.70m thickness; gravelly Sand unit (SP) are exposed from CH: 4+175 to 4+776 km, at depth of 0.0 -1.0m, from CH:5+524 to CH: 8+094 at depth of 0.0-5.0m, CH: 8+095 to 10+238 km having 2.60-5.0m depth and from CH:10+239 to 11+338km with 1.70 to 3.0m thickness; Silty Sand unit (SM) are exposed from CH: 8+096 to 10+238km at 0.0-2.60m depth and 11+338 to 13+140 at depth of 0.0-3.0m and as well as main canal-1 from CH: 0+00 – 4+800km average depth of 0.0-1.50m and Clayey Sand unit (SC) also exposed from CH: 4+776 to 4+974. It is dark brown, fine grained, stiff, medium plastic, 0.00-5.0m thickness.

At the main pump station site three layers are identified these are: inorganic silt of high plasticity (MH), Organic clay of high plasticity (OH) and inorganic Clayey silty sand with low plasticity (ML) whereas at the Pump Station-2 one geotechnical layer, i.e. silty sand (SM) is identified.

According to the data given in Table 3.15 the dominant grain size of the soil layer along the main canal is fine (ranging from 3.8-48.88% with average of 28.4% silty and clay). The Atterberg limit of this soil indicates LL of 27.8% (on average) and PI (consistency index) of 4% on average which is considered low value. In general, the lower the plasticity index the lower engineering problems associated with the use of the soil as foundation material. This notion has been also reflected on the expansiveness and shrinkage of the layer. The linear shrinkage and Atterberg limits have indicated shrinkage with noncritical degree of severity while swelling potential of the Silty CLAY deposit shows low degree of expansion.

The data obtained from the field and laboratory engineering property test results was processed and accordingly analyses were made on the parameters corresponding to required engineering performance of the investigation sites of the pump stations: having the shear strength parameter of c:48.97, f: 28.14 degree and c:42.33, f: 29.45 degree for main pump station & PS-2 sites respectively. The free swelling condition of both sites is less than 50%.

The first 4.974km of main canal (Chainage: 0+000 to 4+974km), CH:5+524 to 8+094km and the canal route from Chainage:8+095km to 10+238km will be excavated through high to medium pervious soils having hydraulic conductivity values in the range of 10-2 cm/sec to 10-4cm/sec.

The canal alignments from Chainage: 4+975km to 5+523km and 10+239 to 11+338km is characterized by the dark brown silty clay layer and is found to be impervious along the main canal having hydraulic conductivity values in the range of 9*10-6cm/sec to 10-8cm/sec.

However, the free swell result of the canal line range from 0.0 to 48.33% which implies that low expansiveness nature.

Regarding the main pump sites, however, the investigation were extends to the depth of 7-10m 372m elevation from the bank level 382 a.m.s.l by hand held GPS; however, the proposed structure foundation rests below this level. According to the investigation result, from the visual description three soil layers at main pump station site and one soil layer at the booster pump site were found to occur.

Soil Classification, and associated foundation characterizations for the excavated depth 7-10m are considered but the anticipated Engineering conditions for >11meter for the main pump station site, which is still below sampled level, would be estimated using the present investigation.

5.2 Recommendations

5.2.1 Canal Alignment

Based on the climatic, topographic and engineering geological characteristics of the project sites, geotechnical layers conditions which could have potential seepage on the canal line routes are anticipated. The evaluated ground conditions include: permeability, potential desperation, Potential corrosive effects and potential erosions.

Based on the investigation made along the main canal alignment and pump station the following recommendations are given:

- The chainage: 0+000 to 4+974km, 5+524 to 8+094km and 8+095km to 10+238km of the main canal being pervious required to be lined (possibly with the reddish brown silty clay soil found to occur at option- 1 borrow area).
- The dark silty clay at Chainage from: 4+975km to 5+523km and 10+239 to 11+338km is impervious but being medium expansive nature such soil will be problematic as water way, so covering it with compacted gravelly silt material is recommended.

5.2.2 Foundation

Assuming that the soils found to occur in excavated continue up to foundation depth, the following engineering recommendations can be made for pump station site. However, the final recommendation will be considered after direct data at foundation depth of main pump station is obtained from geotechnical core drilling and/or from excavation during construction stage.

Allowable Bearing Capacity

Foundation analyses were made to decide the appropriate foundation type, minimum depth of embedment and to propose the excavation method. Nature of the engineering geological units and the anticipated engineering performances of the ground materials were taken in to consideration together with proposed function of the structure and the maximum load it would carry, to suggest the appropriate foundation type and its depth of embedment.

The maximum allowable bearing pressure was analyzed based for the selected type of foundation for a tolerable settlement of 25mm. The Meyerhof equations for the different foundations, and using SPT-N values, were used for analyses of the maximum bearing pressure.

The field and laboratory data and results are analyzed and evaluations are made on the canal line, the foundation sites and construction material sources.

According to the bearing capacity analysis for foundation of main pump station the third layer would provide at least 794.1 - 994.1Kpa at depth of 1 to 4m and rectangular mat foundation width of 12m and length of 60m; and for PS-2 bearing capacity of 914.5 to 976 kPa at the depth of 6.0m depending on the mat pad width B=6m to B=2 which is considered adequate to accommodate the proposed pump with rather uniform load distribution.

Selection of Foundation

According to the nature and characteristics of the materials encountered in the Test pits, it is recommended to use stiffened mat foundation if the footing is designed on the alluvial clayey sand soil.

It is understood that a mat foundation is commonly used where the base soil has a low bearing capacity and/or the column loads are so large that more than 50 percent of the area is covered by conventional spread footings. Mat foundation is also used for deep basement foundation with both spread the column loads with a more uniform pressure distribution. Mat foundation can also be the floor slab for the basement and used to bridge over horizontal variation of the soil layer on the ground. Accordingly, stiffened /reinforced mat foundation is recommended at a depth of 6.0m below the existing ground level.

The decision whether to use mat foundation on the alluvial soil at a depth of 6m and below or pile foundation depends on the nature of the structure load distribution, subsurface drainage efficiency and obviously based on the cost analysis.

Drainage of Site

It is recommended to design an effective surface water drainage system as well as proper subsurface drainage facility to get rid of the consequences of the surface and infiltrated water into the foundation layers, mainly if the foundation footing is on the alluvial soil and the closeness of the structure to river. The site should be graded so as to direct surface water and lateral water flow if encountered during construction away from all planned structures.

Materials for Replacement, Backfill and Compaction Criteria

Replacing and back filling could be employed to improve the foundation conditions for the foundation footing on the alluvial soil. In general, materials for the backfilling should be granular, not containing rocks or lumps over 15 cm in greatest dimension, free from organic matter, with plasticity index (PI) not more than 10. The backfill material should be laid in lifts not exceeding 25 cm in loose thickness and compacted to at least 95 percent of the maximum dry density at optimum moisture content as determined by modified compaction test (Proctor) (ASTM D-1557).

Seismic Condition

According to seismicity hazard map of Ethiopia the site is located in Zone 4; therefore, being at zone 4 horizontal acceleration of 0.15g can be considered for design.

6.0 FARM ROAD GEOTECHNICAL INVESTIGATIONS

6.1 Introduction

The purpose of the investigation was to identify the geotechnical conditions of Omo valley farm project farm roads. The roads have been designed with irrigation design simultaneously.

In this report we discuss the findings of the geotechnical investigation of irrigation Road on the granular surface alignment extends from the approximate location of the Southern limits of a proposed pump site to Eastern then -northeast –northwest direction, approximately13.140 km of main canal & pipe line road, and also main canal-1 road stretched easterly-northerly approximately 4.8km.

The purpose of these services is to provide information and geotechnical engineering recommendations relative to:

- Pavement sub grade soil conditions
- recommended pavement sections

The recommendations contained in this report are based upon the results of field and laboratory testing, engineering analyses, and experience with similar geotechnical conditions and our understanding of the proposed project.

The project DCP & Test pits for road networks investigation is presented, in figure 6-1 below.

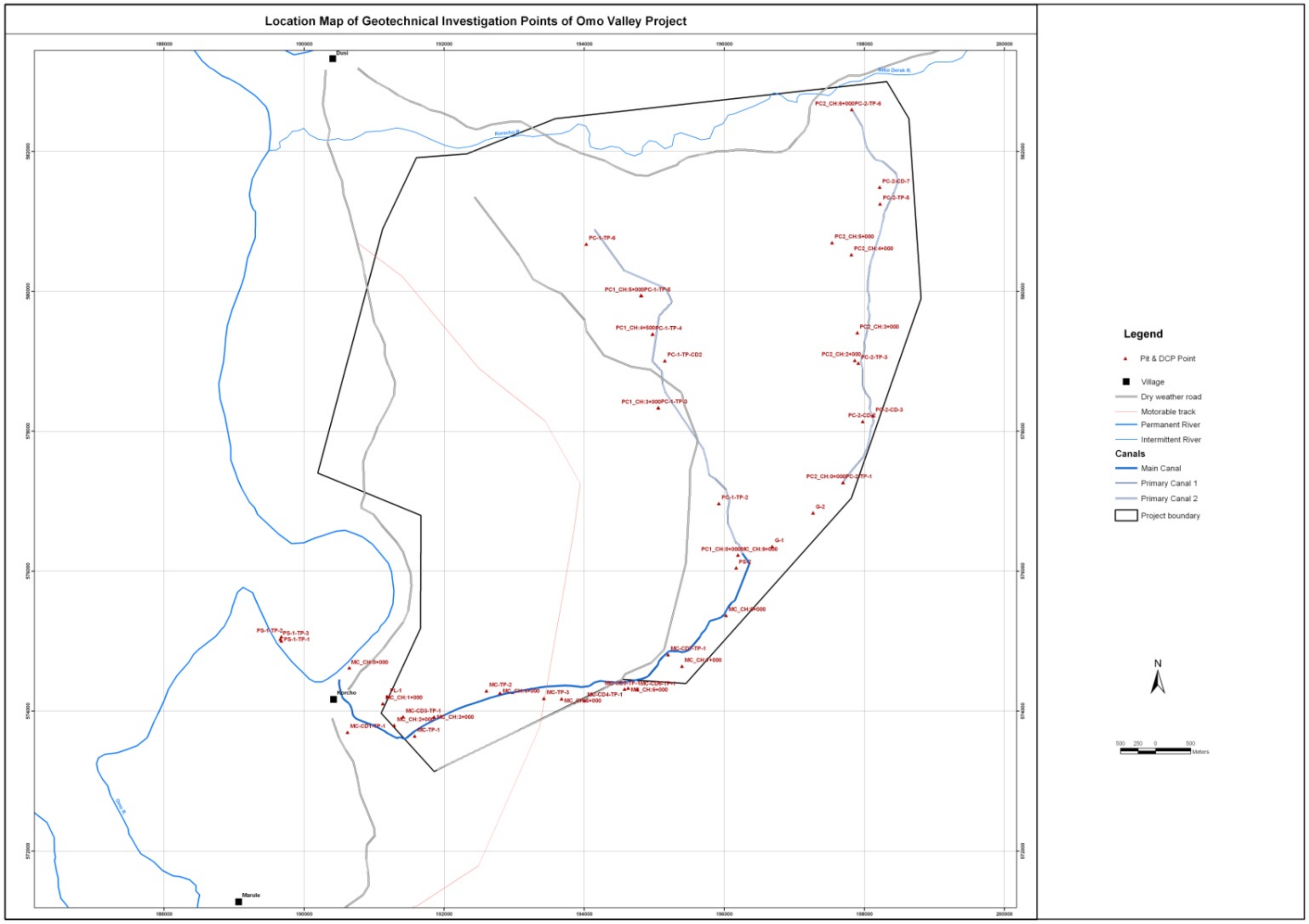

Figure: 6- 1DCP & Test pits. Location map

6.1.1 Scope of Work

The scope of the work includes the preparation of a geotechnical report for the project which involves the following specific tasks

- Geotechnical field soils investigation.
- Material sampling/laboratory testing
- In situ DCP Testing
- Test pits excavation and logging
- Analysis and interpretation of the test results

6.1.2 Existing Site Conditions

6.1.2.1 Native soils

Typically underlying the granular sub base is primarily dry sandy silt with gravel and trace clay. No sign of bedrock was found under the soil material along the canal line.

6.1.2.2 Groundwater Level

No groundwater inflow was encountered in the test pits.

6.1.1.3Terrain

The site is located in flat to rolling desert terrain with sparse vegetation consisting of grasses and shrubs. Numerous rock outcrops and monument features are visible in the eastern surrounding area of the farm land and in the west part of the farm adjacent to the roadway bounded by Omo River.

6.1.1.4 Climate

The project area has a high desert climate typified by low precipitation and great season ranges in temperatures. The average annual precipitation is 300mm, most of which occurs from March to May through June and September in the form of summer thunderstorms. The minimum temperature ranges from 19.7 ^{0}C in February to 21.1 ^{0}C in May with average of 20.4 ^{0}C. The lowest maximum is 38.8 ^{0} C in the month of July with average of 36 ^{0}C. The high temperatures are concurrent with the heaviest seasonal use of the farm Access Road.

6.2 Field Investigation

Techniques that was used for site investigation on the proposed roads are described in here

- Visual inspection and description of test pits along the proposed alignment,
- Use of dynamic cone penetrometer testing to assign uniform sections

- Use of visual inspection to assess the grading and plasticity of in-situ soils and borrow materials
- Sampling and
- Conducting laboratory tests like; Strength, compaction and othertypes of tests

6.2.1 Test pit logging and DCP Testing

There are about 22 tests pits have been excavated depth range of 3 to 5m along the canal alignment were it is used both for canal investigation and sub grade characterization and about 20 DCP test was conducted with 1km interval.

The locations of the test pit and DCP Test point are shown on the drawing titled “Test pit Location map” in fig.6-1. Logs of the test pits are shown in Appendix-A-1, DCP raw data, CBR summary tables, graphs are shown in Appendix-A-1 to A-4.

Table: 6- 1: Coordinates and drilled depth of Test pits

ID No.	Easting	Northing	Depth(m)
MC-CD1-TP-1	190620	573699	5.0
MC-CD3-TP-1	191414	573920	5.0
MC-CD4-TP-1	194009	574154	5.0
MC-CD5-TP-1	194577	574316	5.0
MC-CD6-TP-1	194763	574310	5.0
MC-CD7-TP-1	195198	574809	3.5
MC-TP-1	191580	573646	3.0
MC-TP-2	192606	574292	3.4
MC-TP-3	193424	574184	3.0
MC-TP-2	195924	576969	3.0
MC-TP-3	195057	578340	3.0
MC-TP-4	194976	579388	3.0
MC-TP-5	194818	579941	3.2
MC-TP-6	194030	580678	3.0
MC-TP-CD2	195153	579010	5.0
MC-01-TP-1	197695	577268	3.0
MC-01-TP-3	197914	578974	3.0
MC-01-TP-5	198226	581252	3.0
MC-01-TP-6	197821	582600	3.0
MC-01-CD-2	197977	578142	5.0
MC-01-CD-3	198123	578223	5.0
MC-01-CD-7	198220	581490	3.5

6.2.2 In situ DCP tests

Portable Dynamic Cone Penetration Test (DCP) was conducted inside all test pits. This equipment is composed of a standard hammer, weighing 8kg(17.6 pound) falling freely from a height of 575mm along a frictionless guide rod in accordance with test procedure mentioned in test No. 19 of BS 1377; 1975.

- ✓ A total of 20 tests were performed, in 1000m interval, in soils .The steel rule attached to the guide foot was placed through the slot in the hand guard. The foot was placed on the surface to be tested and the cone tip passed through the guide hole. The entire apparatus was then held by the handle perpendicular to the surface.
- ✓ The drop weight was raised to its maximum height and released. It gained maximum height for each drop but care was taken not to strike the weight against the handle; because doing so would cause the instrument to withdraw and results would be in question.
- ✓ The readings were taken with each blow of the weight. Where the penetration rate was below 20 mm/blow, the frequency of readings may be decreased to:
  - One for every two blows with readings from 10-20 mm
  - One for every five blows with readings from 5-9 mm
  - One for every ten blows with readings from 2-4 mm.
  - Penetration depth less than 1 mm and exceeding 20 blows is considered as refusal.
- ✓ The test depth was determined by to be where test refusal occurs or where the instrument was believed to penetrate a considerable depth through the natural ground below the fill.

Penetration depths for each blow counts are recorded .The records are classified in to zones and averaged to one representative values based on layer identification made on charts. Detail of DCP test records are presented in Appendix-A-2 to A-4.

Table: 6- 2Coordinates of DCP Test

Id. No.	Easting	Northing	Id. No.	Easting	Northing
MC_CH:0+000	190646	574622	PC2_CH:0+000	197695	577268
MC_CH:1+000	191124	574109	PC2_CH:2+000	197865	579015
MC_CH:2+000	191288	573798	PC2_CH:3+000	197900	579410

Id. No.	Easting	Northing	Id. No.	Easting	Northing
MC_CH:3+000	191857	573918	PC2_CH:4+000	197816	580526
MC_CH:4+000	192797	574259	PC2_CH:5+000	197539	580697
MC_CH:5+000	193678	574177	PC2_CH:6+000	197821	582600
MC_CH:6+000	194628	574330	PC1_CH:0+000	196196	576231
MC_CH:7+000	195396	574645	PC1_CH:3+000	195061	578336
MC_CH:8+000	196024	575371	PC1_CH:4+500	194978	579394
MC_CH:9+000	196196	576231	PC1_CH:5+000	194811	579942

6.2.2.1. California Bearing Ratio (CBR)

For pavement design, soil properties at sub grade level are required. It is recommended that DCP test from the designed sub grade level should be conducted for CBR evaluations. This is considered appropriate for design purpose. The number of DCP tests required will very much depend on the uniformity of the sub grade soil. From the logging information, the site engineering geologist decided to do DCP tests for 1000m interval along the canal alignment.

Summary of the CBR strength test results from DCP test along the road network within the command area are presented in Tables 6-4.

For pavement design purposes, road sections must be defined in accordance with sub grade strength class. Accordingly, CBR values are used to classify the road network in to sections and the classification based on sub grade strength is presented in Tables 6-4.

According to the analysis of the sub grade soil classification based on CBR values, 56 % of the sub grade soils belong to the S1soil group and 33% belongs to the S2 soil group; these two soil groups comprise 88% of the sub grade soils within the study area. The remaining 12% of the sub grade soil belongs to S3 and S4 soil groups.

Table: 6- 3Sub grade Strength Classes vs. CBR (ERA Pavement Design Manual-2002)

Sub grade Strength Class	Range CBR (%)
S1	2
S2	3 – 4
S3	5 – 7
S4	8 – 14
S5	15 – 29
S6	30+

According to the ERA standard, almost all types of soil can be used for pavement support, the main limitation being the ease with which the material can be handled and compacted. However, materials with CBR value less than 2 are usually very difficult to work and as sub grade, would lead to uneconomical pavement structures. Such soils are usually considered unsuitable and should be removed; however if these soils must be used they should be covered with a suitable capping layer.

Table: 6- 4 CBR Result Summary

No.	Ch.(Km)	CBR Value	Sub grade class	No.	Ch.(Km)	CBR Value	Sub grade class
Main canal				Branch/Main canal_1			
1	0.0-1.0	6	S3	1	0.0-1.0	32	S6
2	1.0-4.0	22	S5	2	1.0-2.0	8	S3
3	4.0-5.0	50	S6	3	2.0-4.0	18	S5
4	5.0-9.0	23	S5	4	4.0-4.8	45	S6
5	9.0-9,5	13	S4	Tertiary Canal			
6	9.5-10.70	4	S2	1	0.100	8	S3
7	10.7-12.0	26	S5	2	1-6	11-14	S4
8	12.0--12.5	50	S6	3	6-8	15	S5
9	12.5-13.140	12	S4				

Table: 6- 5 Sub grade soil classification based on CBR values with distance coverage

Distance Total (Km)	Subgrade class	% coverage
Main canal		
8.3	S_5	63.20%
1	S_3	0.63%
1.5	S_6	0.95%
0.64	S_4	0.40%
1.2	S_2	0.80%
Branch/Main canal_1		
1.8	S6	37.5%
1	S3	20.8%
2	S5	41.7%
Tertiary Canal		
0.100	S5	12.5%
5	S3	62.5%
2	S4	25%

6.2.3 Laboratory Testing

Samples retrieved during the field exploration were returned to our laboratory for assignment of tests by the project engineering geologist. An applicable program of laboratory testing was developed to determine engineering properties of the subsurface materials. Following the completion of the laboratory testing, the field descriptions were confirmed or modified as necessary and test pit were prepared.

Laboratory tests performed included gradation (BS Test 7(A) & 7 (B)), Atterberg limits (BS Test 2 (A) & (B)), Oedometer Consolidation (BS1377:1975, test17), moisture content (BS Test 1(A)), sulfate content and chloride ion content (water extraction), ASTM D 4327). Gradation and Atterberg limits test results were used to classify the soils in accordance with the AASHTO classification system and the Unified Soil Classification System (USCS). The swell and consolidation tests were used to evaluate potential settlement or expansion of the on-site soils when wetted. Moisture content provides an estimate of the degree of compaction and moisture conditions of the sub grade and underlying materials. Tests for soluble sulfate content, resistivity and soluble chlorides are used to evaluate the potential of the soil to be aggressive to concrete and to corrode buried metal. The laboratory test results are presented in Appendix B-1 to B-2 and on the Test pit logs in Appendix A-1. Photos of the site conditions and Test locations along the project are presented in Appendix-C.

6.3 Subsurface Conditions

6.3.1 Main canal farm road

The sub grade materials in this segment of the road have 3.8 to 13.4 percent fines for main canal Ch.: 0+00 to 3+90, 5+00-10.0 and 11.0-13.140km consisting of Sandy silt mixture trace of clay and Ch.: 3+90 to 5+00km and 10+00-11+00km, plasticity indices that range from non-plastic to 6.74 for Ch.: 0+00-6+444andfor CH:6.444-7.50km & 10-11km PI Value 18.83-20.92 low and high expansion potential when wetted respectively. The natural moisture contents of were relatively low and were 0.54and 5.21 percent, respectively. Sub grade soils from the southern segment have AASHTO classifications of A-1b, A-6, A-2-7, A-2-4 and A-6.

The bulk soil sample from this main canal-1 had a natural moisture content of 0.46-2.39 percent and a loose unit weight of 11.9-13.5KN/m^3. The Clayey sand soil encountered in this root can be classified by AASHTO classification of A-2-6.

Swell/Consolidation tests run on the soils from this project ranged from -0.03 to -0.057% indicating that there are minimal problems from swelling or collapsing soils in the majority of the project.

Table: 6- 6: Laboratory test result summary

Canal Name	unit weight	Finesse (%)	Free Swell (%)	PI	NMC (%)	Cc	Sulphate	Chloride
Main Canal	12.2-14.2				0.54-5.2	0.03	0.26-4.78	0.21-0.7
Main Canal-1	11.9-13.5	18.0-20.0			0.46-2.39	0.046-0.057	0.33-1.72	0.14-0.21
Main Canal (0.0-10km)		3.8-13.4						
Main Canal (10-11.0km)		39-54						
Main Canal (0.0-6.5km)			0.0-10.0					
Main Canal (6.5-7.5km)			37.50					
Main Canal			10.00					

Canal Name	unit weight	Finesse (%)	Free Swell (%)	PI	NMC (%)	Cc	Sulphate	Chloride
(7.5-13.140km)								
Main Canal-1 (0.0-4.8km)			0.0-10.0					
Main Canal (0.0-5km)				NP				
Main Canal (5.0-5.749km)				6.74				
Main Canal (5.749-6.444km)				NP				
Main Canal (6.444-7.50km &10-11km)				18.83-20.92				
Main Canal-1				6.16-10.45				

Remarks: NP-Non plastic

6.3.2 Characteristics of Soil Groups Pertaining To Roads

The properties desired in soils for foundations under roads and for base courses under flexible pavements are adequate strength, good compaction characteristics, adequate drainage, and acceptable compression and expansion characteristics. Some of these properties, if inadequate in the soils available, may be supplied by proper construction methods. For instance, materials having good drainage characteristics are desirable, but if such materials are not available locally, adequate drainage may be obtained by installing a properly designed water-collecting system. Strength requirements for base course materials (to be used immediately under the pavement of a flexible pavement structure) are high and only good-quality materials are acceptable.

However, low strengths in sub grade materials may be compensated for in many cases by increasing the thickness of overlying of base materials in flexible pavement construction.

And the proper design of roads pavements requires the evaluation of soil properties in more detail than is possible by using the general soils classification system. However, the grouping of soils in the classification system is such that a general indication of their behavior in road construction may be obtained. The features Obtained from the Soils-Classification of Laboratory Result are presented in table 6-7 below.

Table: 6- 7: Soil classification (Liu, 1970)

Main canal			
No.	**Ch.(Km)**	**Soil group in USCS**	**Most probable Comparable soil group in AASHTO system**
1	0.0-4.0	SC	A-1b
2	4.0-5.0	CL	A-6
3	5.0-9.0	SM-SC	A-2-7

4	9.0-12.0	SM	A-2-4
5	12.0--12.5	CL	A-6
6	12.5-13.140	SM	A-2-4
Main canal-1			
No.	**Ch.(Km)**	**Soil group in USCS**	**Most probable Comparable soil group in AASHTO system**
1	0.0-1.0	SC	A-2-6
2	1.0-4.8	SM	A-2-4
Tertiary Canal			
No.	**Ch.(Km)**	**Soil group in USCS**	**Most probable Comparable soil group in AASHTO system**
1	0.1-1	SW	A-1b
2	1-8	SM	A-2-4

6.3.2.1Modulus of Deformation

While CBR results are technically an indication of strength, researchers have developed several empirical formulas relating CBR to soil resilient modulus (ER) for roadway sub grade, including:

For fine-grained soils with soaked CBR < 10:

Equation: 1- 10……………………………………………ER(psi)= 1500 ∗ CBR (AASHTO, 1993)

For a wide range of soils:

Equation: 1- 11……………………………………E_R(psi) = 2555 ∗ CBR$^{0.62}$ (AASHTO MEPDG

The relationships are commonly used as estimates, though, because of the complex testing and equipment necessary to directly calculate a soil's resilient modulus.

Table: 6- 8 Summary of a soil's resilient modulus

Main Canal		**Main Canal-1**	
CH: km	E_R(psi)	CH: km	E_R(psi)
0.0-1.0	7759.7	0.1	9274.8
1.0-4.0	17365.7	0.1 to 6	12532.4
4.0-5.0	28890.3	6 to 8	13695.2
5.0-9.0	17851.0	**Tertiary Canal**	
9.0-9,5	12532.4	0.0-1.0	21907.0
9.5-10.70	6034.9	1.0-2.0	9274.8
10.7-12.0	19260.8	2.0-4.0	15334.2
12.0--12.5	28890.3	4.0-4.8	27063.4
12.5-13.140	11925.7		

6.3.2.2 Free Swell

Dry soils with significant proportions of clay swell when they come in contact with water and shrink when dry. Such expansive soils cause considerable damage on structures built on them. Hence swelling characteristics of soils (especially clay soils) should be determined.

The amount of clay content, initial condition of the soil sample and the time allowed for swelling influence the swelling potential. Swelling potential of selected samples is determined at

WWDSE laboratory in Addis. The result of free swell tests on selected soil samples from the road networks are given in Tables 6-6.

Free swell results help to determine the swelling characteristics of soils. In fact, swelling characteristics of soils can also be determined from index properties of soils. Tables 6-9 -6.11 show expansiveness of soils, based on free swell test results and index properties. From the laboratory result except the main canal section 6.5km to 7.5km the P value is <12 and free swell <35%, therefore, the subgrade in the farm site is can be considered as low expansiveness, but at ch:6.5-7,5km of main canal medium expansiveness.

Table: 6- 9: Liquid limit and expansiveness (Burt G. Look, 2007)

Liquid Limit (%) As per Chen	Liquid Limit (%) As per IS 1498	EXPANSIVENESS
<30	20 - 35	Low
30 - 40	35 - 50	Medium
50 - 60	50 - 70	High
>60	70 - 90	Very High

Table: 6- 10: Plasticity index and expansiveness (Burt G. Look, 2007)

Plasticity Index (%) As per Chen	Plasticity Index As per Gibbs and Holtz	Plasticity Index As per IS 1498	EXPANSIVENESS
0 - 15	<20	<12	Low
10.0 - 35	12.0 - 34	12.0 - 23	Medium
20 - 35	34 - 45	23 - 32	High
>35	>45	>32	Very High

Table: 6- 11: Free swell and expansiveness (IS: 2911 Part III-1980)

DIFFERENTIAL FREE SWELL (%)	Free Swell Percent (%)	EXPANSIVENESS
<20	<50	Low
20 - 35	50 - 100	Moderate
35 - 50	100 - 200	High
>50	>200	Very High

7. FARM ROAD GEOTECHNICAL CONCLUSION AND RECOMMENDATIONS

Omo valley Road consists of a network of access roads within the command area of Irrigation Project.

A thorough geotechnical investigation of the sub grade soil was carried out to characterize the sub grade soil and to provide geotechnical information for the pavement design. During the investigation, test pits were dug and logged, representative soil samples were collected and the necessary laboratory tests were carried out followed by analysis and interpretation of the test results.

The results indicated that, soils along the road network basically fall under A-2-4and A-2-7 soil groups. The dominant sub grade class for main canal covers about 63.20% is sub S_5, for main canal-1 about 41.7% also S5-and for tertiary canal S3 about 62.5%.

The CBR values of the S1 and S2 soil groups (especially S1) fall at the lower end indicating that these soils are difficult to work. According to ERA standard, sub grade soils with CBR value less than 2 are usually very difficult to work and as sub grade would lead to uneconomical pavement structures. Such soils are usually considered unsuitable and should be removed; however if these soils must be used they should be covered with a suitable capping layer.

Accordingly, 0.80% main canal road at ch: 9.5 to 10.70km has CBR value 4 of S_2 and it need remedial measures, like replacing with other granular material.

8. CONSTRUCTION MATERIALINVESTIGATION

Various sources have been studied in five phases for the following construction materials to be used on the project:

a) Embankment Materials
b) Sub-base Materials
c) Concrete Aggregates
    i. Fine Aggregates
    ii. Coarse Aggregates
d) Masonry Stones
e) fill material

The location of the sources identified so far for the above listed materials is marked on Figure 9-1. Site photographs for some of the material sources have also been appended to this report as Appendix-C.

8.1 Field and Laboratory Geotechnical Studies

Field and laboratory geotechnical studies have been carried out in WWDSE laboratory services for qualitative and quantitative evaluation of materials listed in Section-2.

While the geotechnical studies carried out construction material assessment are discussed in the following sections.

8.2 Field Geotechnical Studies

During field geotechnical studies carried out, samples were collected for the following materials for subsequent laboratory testing:

- Bulk samples from FRCM location for sub-base material
- Bulk samples from S1 location for concrete fine aggregates
- Bulk samples from CB-1 & CB-2 for the Canal lining or fill.
- Rock samples for masonry

A brief description of field studies carried out has been discussed in the following sections.

8.2.1 Material for General Embankment Fill

Studies carried out in have pump station been utilized for the evaluation of general embankment fill material. No additional geotechnical field studies have been carried out for the general embankment fill therefore; we can use the excavated materials as fill.

8.2.2 Sub-base Material

During this phase of studies FRCM locations could be visited only. The visual inspection revealed that the material at these locations in general comprise 0.50 to 1.5m thick layer of residual soil followed by bed rocks. This layer is mix with rock fragments of gravels size with silty clay and iron minerals as binder in varying proportions. Site photographs for these locations have been appended to this report as Appendix-C.

8.2.3 Concrete Aggregates

8.2.3.1 Fine Aggregate

Four sources i.e. S-1, S-2, S-3, S4, and S-5had recently been identified for concrete fine aggregates. S-1-S-3 source near new camp site all sites was accessible during field studies.

Quartz is the major mineral constituents of the gravels/cobbles. Gravels are rounded to sub-round in varying sizes (fine to coarse gravels/cobbles).

Sand source located near to the command area, at an off-set of approximately range of 0.1km to 2km from New camp site, is a small seasonal nullah/drain conveying the rain water only (FA-4 source is a few km upstream of this location). All layers (0.0-3.0m) of sand are present in the Sewugela & Korcho River as revealed by the excavation of a shallow test pit.

Table: 8- 1Location of sand sources

OPP. ID	Easting	Northing	Depth (m)	River/ site Span	Distance from construction site	Locality name	Geological Description
Opption_1, Sand Boundary points (S-1-TP-1)	195273	574903	3-5m	20 m to 40 m	100 m from New camp site		Alluvial deposit of fine to coarse grained Sand mix with gravel
	195227	574917					
	195210	574901					
	195297	574702					
	195255	574812					
Opption_2 Sand Boundary points	194124	580956	3m	3 m to 7 m	1-2 km far from New camp site		Alluvial deposit of fine to coarse grained Sand mix with gravel

OPP. ID	Easting	Northing	Depth (m)	River/ site Span	Distance from construction site	Locality name	Geological Description
Opption_3 Sand Boundary points	196712	576377	3.5m	3m to 22m	1.5 km far from the new camp site	Near to pipe line_2	Alluvial deposit of fine to coarse grained Sand mix with gravel
	196712	576361					
	197020	576484					
	197024	576482					
Opption_4 Sand Boundary points	194262	574354			100m to 1km, from new camp site	The way to Dus village	Alluvial deposit of fine to coarse grained Sand mix with gravel
	194264	574381					
	194120	574306					
	194129	574298					
	194981	574539	3.5m	8m-13m			
Opption_5 Sand Boundary points (S-4-TP-1)	197687	577120	3m-5m	10m		Sewugela river (NE direction of new camp)	
Opption_6 Sand Boundary points (S-5-TP-1)	194031	580749		3-10m		Tentalo river (Near to Baza Village)	

8.2.3.2 Concrete Coarse Aggregate

Three sources for concrete coarse aggregate i.e. G-1 and G-2 sources were visited during current studies.

Quartz is the major mineral constituents of the gravels/cobbles. Gravels are rounded to sub-round in varying sizes (fine to coarse gravels/cobbles). Natural gravel source is located at an offset of 5km from Omo River around Muruli park. At RS-1 locations rock out crops are exposed in a vast area as shown in the site photographs (Appendix-C). Major rock type is Basement rocks at RS-1 location. FromRS-1 location rocks a crusher is already operational and the aggregate produced. Aggregate produced from RS-1 source had recently been used in the construction of camp building.

Photo: 8- 1: View of Available rock and crusher at site

8.3 Laboratory Geotechnical Studies

The soil/rock samples collected were subjected to some of the below listed laboratory tests as per latest AASHTO/ASTM standards at WWDSE laboratory, for qualitative evaluation of the materials for intended use:

Table: 8- 2 List of Laboratory test

Laboratory testing	**Number of Test**	**Standard**
Grain size distribution (sieve analysis)	3	BS Test 7(A) & 7 (B)
Atterberg limits (LL, PL & PI)	2	BS Test 2 (A) & (B)
Natural Moisture Content (NMC)	2	BS Test 1(A)
Specific gravity	2	ASTM, C-128
Loose unit weight	2	Gibb' & Holtz (1956)s
Free swell	2	Gibb' & Holtz (1956)s
Water absorption	2	ASTM, C-128
Standard compaction	2	BS1377:1975, test12 & 13
Permeability	2	ASTM D2434
Sulphate	2	Water Extract
Chloride	2	Water Extract
LAA	2	
Point load	1	
CBR	1	AASHTO T 193
Soundness, %	1	
AIV, %	1	
Fineness Modulus	1	

The samples collected in the study were subjected to various laboratory tests for qualitative evaluation of the materials for intended use. A comprehensive summary of the laboratory test results obtained for general embankment fill, sub-base material, concrete aggregates, and masonry stone is attached with this report as (Appendix- B-2).

Table: 8- 3 Summary of laboratory test result

II	**Rock Samples**								
No	**Sample ID**	**Location of Quarry Site**	**Sample Depth (m)**	**SG**	**Water Absorption (%)**	**AIV (%)**	**Soundness (SSS) (%)**	**LAA (%)**	**Point Load (Mpa)**
1	**RQ1**	Quarry-1	**Surface**	3.01	0.62	39.92	2.56	49.95	6.62
		LAA-							
REMARK		AIV-Aggregate Impact Value							
		SSS-Soundness by Sodium Sulphate							
		SG- (Specific Gravity)							

III	**Sand/Aggregate & Filter**														
Nº	**TP/ BH ID**	**Location of Borrow/ Quarry**	**Sample Type**	**Depth (m)**	**Specific gravity**	**Grain size distribution**					**LAA (%)**	**Soundness (%)**	**Fineness Modulus**	**Water Absorption (%)**
						Gravel (%)	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Fine (%)**				
1	S1	Sand Sewugela River	SDS	0.0-3.0	2.77	17.71	64.76	14.13	3.40	17.53				
			BDS	0.0-3.0							N/A	12.13	3	2.86

CLAY BORROW SITE																					
						Grain size distribution				**Atterberg Limits**						**Compaction**				**Chemical**	
Nº	**TP ID**	**Location of**	**Sample type**	**Sample Depth**	**Unit weight**	**Sand**	**Silt**	**Clay**	**Fine**	**LL**	**PL**	**PI**	**SL**	**Free Swell**	**Pin**	**NMC**	**OMC**	**MDD**	**Permeab.**	**Sulphate** (meq/l)	**Chloride** (meq/l)
1	**CB-TP-1**	**Clay borrow-2**	**BDS**	0.0-3.0	1.15									57.50			25.20	1.574	1.44*10-2	2.14	2.94
2			**SDS**	0.50-3.0		12.38	58.12	29.50	**87.62**	45.77	23.13	22.64				7.28					
3	**CB-TP-2**	**Clay borrow-1**	**BDS**	0.0-3.0	1.66									42.50			25.40	1.508	2.41*10-5	2.14	2.94
4			**SDS**	0.0-1.60		7.48	83.88	8.64	**92.52**	34.79	27.28	7.51				11.43					

Material studies have been carried out in present studies, as described earlier, to find the suitable sources of construction material for general embankment fill, sub-base construction, concrete fine/coarse aggregate, masonry stone etc., at the locations already identified by the Client in addition to few previously identified locations. Suitability or unsuitability of the aforementioned construction materials and approximate reserve estimation of the suitable sources based on the overall field geotechnical studies and qualitative laboratory testing carried out have been discussed in the following sections.

A figure showing the location of sources identified for construction materials is attached as Figure 8-1.

8.2.4 Material for General Embankment Fill

During pump site foundation investigation the material has been identified plan to use as fill material. The sources were subjected to Gradation Analysis, Atterberg limits, etc for qualitative evaluation. In addition, Clay Borrow opption-1 & Clay Borrow opption-2 site sources can also be proposed to use as fill through blending with sand and silt material.

In engineering practice, generally low plastic or coarser materials are commonly used as backfill. To explore suitable borrow material sources for embankment construction, soil were exposed at the pump station-1 locations to validate their suitability as embankment fill.

Table: 8- 4 Engineering properties of top materials of pump station foundation site.

TP-ID	Depth m	weight (gm/cc)	Grain size distribution				Att. Limit			Free Swell	NMC	C	f	Con so.	Sulp hate	Chlo ride
			Sand	Silt	Clay	Fine	LL	PL	PI			(KPa)	(Deg.)	Cc	(meq/l)	(meq/l)
PS-1-TP 2	0.0-5.0	1.12								47.5		48.33	18.00	0.246	8.48	10.36
	0.00-2.50		65.8	25.9	8.3	34.2	22.89	NP			4.89					
Prop. Pump	1.3-3.0		30.4	48.4	21.2	69.6	31.86	20.70	11.16							

Photo: 8- 2: Clay borrow option-1 site view

Photo: 8- 3: Clay borrow option-2 site view

8.2.4.1 Approximate Quantification of Suitable Material

The material studies reveal that the construction source comprises more than 9.6 &2.7 million cubic meter of CB-1 & CB-2 respectively material will meeting the project requirements.

8.2.5 Sub-base Materials

The shingle / gravel layer to be placed over the compacted embankment is referred to as the sub-base layer in the ERA standard. The prospectively suitable sub-base material sources have been identified in the project area are Gravel at Omo river near to Muruli park and Residual soil rock fragment at the foot of quarry site..

One sources for sub-base material have been identified and evaluated qualitatively.

Materials from these sources were tested for unit weight, gradation, 1-point soaked CBR, The fine fraction at the aforementioned sub-base locations is medium to highly plastic in nature and higher %age of fines may have catastrophic impact on the desired properties.

Therefore, it must be ensured that the maximum fines in material obtained from these sources shall be less than 15%, as the test result of FRCM %age fines-6.37 it implies good.

Visual inspection of material for gravel source reveals that the strong, sub rounded to rounded sandy gravel mix with cobbles and trace of boulder.

Photo: 8- 4: Photo view of FRCM site and Gravel source at Omo River near to Muruli Park

8.2.5.1 Approximate Quantification of Suitable Material

Material sources for the sub-base construction i.e. G1 and FRCM source an area in table 8-1.

8.2.6 Masonry Stone

The qualitative evaluation of the material from RS-1 location (shown in Figure 8-1) that Basement rock available at this location meets the requirements of masonry stone.

The samples from these sources were subjected to water absorption; Quality tests like LAA, Specific Gravity and Soundness have been carried out so as to appropriately evaluate the suitability of these material sources for the subsequent intended use.

On the basis of the studies carried out the test result, the identified sources have good prospects for acceptance.

8.2.6.1 Approximate Quantification of Suitable Material

The quantification of the material available at RS-1 location can be in table 8-5below.

Table: 8- 5 GPS Location of construction material site

OPP. ID	Easting	Northing	elevation(m)	Distance from construction site	Locality name	Geological Description
Rock quarry site	195641	573514	490	823m far from New camp site		
	195610	573626	420			
Clay Borrow Option - 2	191644	582790		about 12 km far from new camp site, 4km from project boundary	Kercha Village	Reddish brown, Clay
	191816	582710				
	191892	582896				
	191942	582898				
	191620	582993				
	191587	583056				
	191332	582976				
	191231	582721				
	192157	582703				
Clay Borrow Option - 1	193486	573969	409	50m from the main canal	In between the two road old and new camp site	Dark brown, Clay
	193701	573995	409			
Gravel Borrow Option - 1	188624	571428		5km far from Main canal	Omo River near to Muruli park, @ the left bank of the river	Dark gray, coarse grained, very strong, sub rounded to rounded, sandy gravel mix with cobbles, pebble and trace of boulders
	188677	571377				
	188658	571393				
	188635	571448				
	188626	571466				
	188624	571499				
	188654	571607				
	188677	571637				
	188663	571698				
	188703	571705				
	188737	571666				
	188776	571581				
	188765	571515				

Table: 8- 6 Anticipated Quantity of construction material sources

No	Site Name	Area	Area_Ha	Meter (m2)	Depth(m)	Volume (m3)
1	Gravel borrow site	28794.4	2.9	28794.4	3.00	**86383.24**
2	Clay borrow opp_1 Site	276870.2	27.7	276870.2	3.5	**969045.5**
3	Sand borrow opp_4 Site	17507.9	1.8	17507.9	4.0	**70031.72**
4	Sand borrow opp_1 Site	16313.8	1.6	16313.8	4.0	**65255.3**
5	Rock Quarry site	92503.3	9.3	92503.3	10.00	**925033.4**
6	Selected material site	34256.6	3.4	34256.6	2.0	**68513.2**
7	Sand borrow opp_3	6778.5	0.7	6778.5	4.0	**27114.07**
8	Sand borrow opp_5	37823.9	3.8	37823.9	4.0	**151295.6**
9	Sand borrow opp_2	42433.8	4.2	42433.8	4.0	**169735.4**
10	Sand borrow opp_6	16285.4	1.6	16285.4	4.0	**65141.8**
11	Clay borrow opp_2 Site	697524.2	69.8	697524.2	4.0	**2790097**

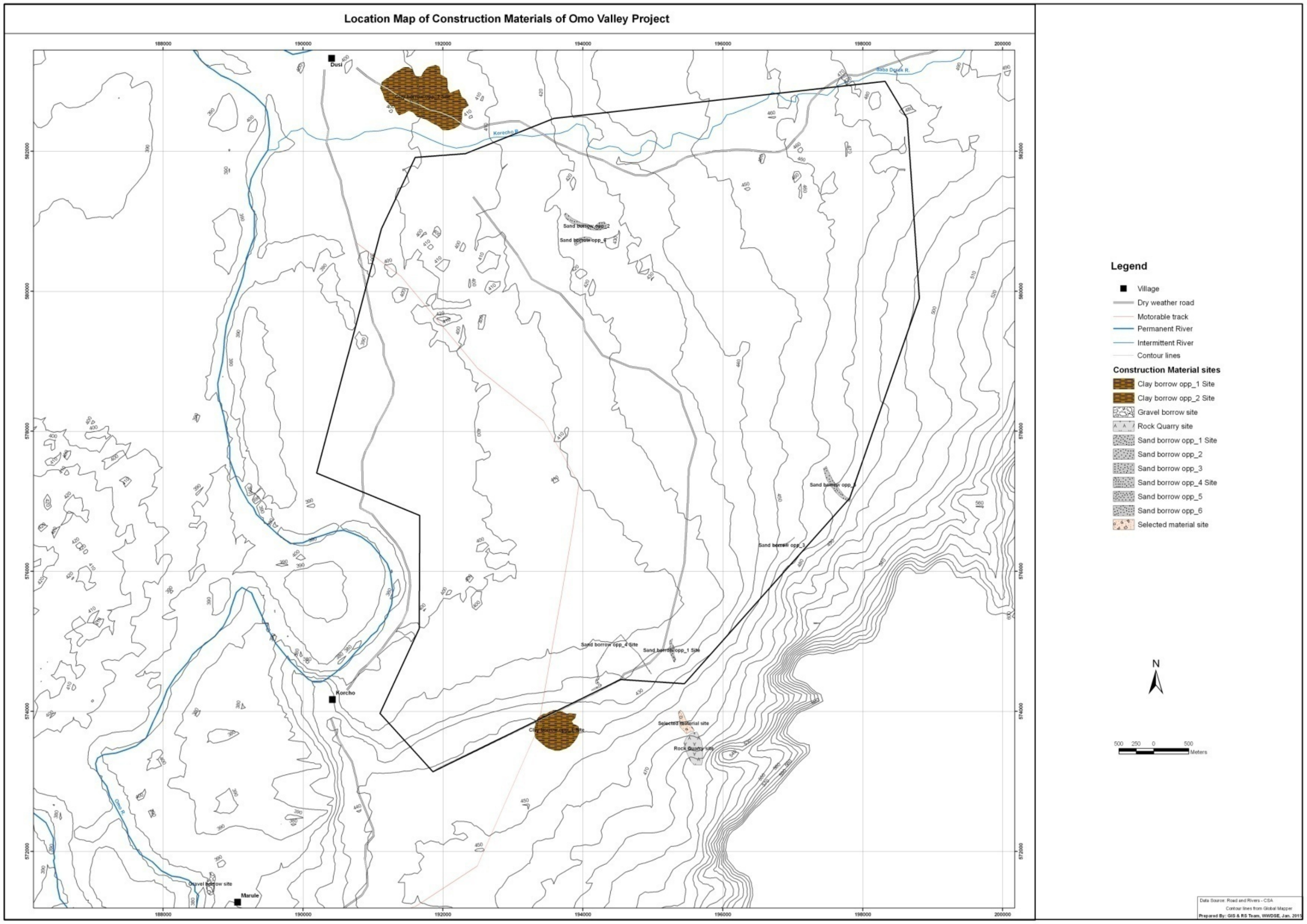

Figure: 8- 1: Construction material source location map

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APPENDICES

APPENDIX-A

APPENDIX A-1: Test Pit Log Descriptions

APPENDIX A-2: DCP Test Raw Data

MAIN CANAL-1 farm road DCP Test Result

Title	**Penetration Data Report**			
Project Name	**Main Canal-1 Farm road**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	223	0
2	1	1	245	22
3	2	3	256	5.5
4	10	13	322	6.6
5	10	23	390	6.8
6	10	33	495	10.5
7	10	43	584	8.9
8	10	53	595	1.1
9	20	73	605	0.5

Chainage (km)	**1**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle(degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	267	0
2	1	1	290	23
3	1	2	300	10
4	1	3	310	10
5	1	4	320	10
6	1	5	325	5
7	1	6	335	10
8	1	7	345	10
9	1	8	357	12
10	1	9	368	11
11	1	10	378	10
12	1	11	388	10
13	1	12	398	10
14	1	13	407	9
15	1	14	418	11
16	1	15	428	10
17	1	16	435	7
18	1	17	467	32
19	1	18	487	20
20	1	19	494	7
21	1	20	508	14
22	1	21	517	9
23	1	22	523	6
24	1	23	534	11
25	1	24	542	8

Chainage (km)	1	Surface Type	Unpaved	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle(degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
26	1	25	552	10
27	1	26	560	8
28	1	27	569	9
29	1	28	579	10
30	1	29	589	10
31	1	30	602	13
32	1	31	614	12
33	1	32	625	11
34	1	33	638	13
35	1	34	653	15
36	1	35	664	11
37	1	36	675	11
38	1	37	700	25
39	1	38	720	20
40	1	39	740	20
41	1	40	767	27
42	1	41	797	30
43	1	42	823	26
44	1	43	854	31
45	1	44	897	43
46	1	45	930	33
47	1	46	965	35
48	1	47	1000	35

Chainage (km)	2	Surface Type	Unpaved	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**CumulativeBlows**	**Penetration Depth**	**Penetration Rate**
1	0	0	235	0
2	1	1	252	17
3	1	2	263	11
4	2	4	287	12
5	2	6	308	10.5
6	2	8	335	13.5
7	2	10	357	11
8	2	12	408	25.5
9	5	17	452	8.8
10	5	22	503	10.2
11	10	32	548	4.5
12	10	42	587	3.9
13	10	52	625	3.8
14	10	62	656	3.1
15	10	72	680	2.4
16	10	82	688	0.8
17	10	92	700	1.2
18	10	102	709	0.9
19	10	112	723	1.4

Chainage (km)	**2**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**CumulativeBlows**	**Penetration Depth**	**Penetration Rate**
20	10	122	742	1.9
21	10	132	760	1.8
22	10	142	770	1
23	10	152	780	1
Remarks:				
Chainage (km)	**3**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	225	0
2	1	1	228	3
3	1	2	300	72
4	1	3	310	10
5	1	4	330	20
6	1	5	345	15
7	1	6	360	15
8	2	8	392	16
9	2	10	416	12
10	2	12	438	11
11	2	14	458	10
12	2	16	477	9.5
13	5	21	516	7.8
14	5	26	548	6.4
15	10	36	595	4.7
16	10	46	620	2.5
17	10	56	654	3.4
18	10	66	680	2.6
19	10	76	720	4
20	10	86	760	4
21	10	96	800	4
Remarks:				

Chainage (km)	**4**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	212	0

Chainage (km)	**4**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
2	10	10	250	3.8
3	10	20	464	21.4
4	10	30	739	27.5
5	10	40	805	6.6
6	10	50	860	5.5
7	10	60	910	5
Remarks:				
Chainage (km)	**5**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	220	0
2	10	10	300	8
3	10	20	360	6
4	10	30	400	4
5	10	40	470	7
6	10	50	530	6
7	10	60	590	6
8	10	70	646	5.6
9	10	80	720	7.4
10	10	90	770	5
Remarks:				

MAIN CANAL-1 STRUCTURE SITE DCP TEST RAW DATA

Chainage (km)	**1.5**	**Surface Type**	**Unpaved**	**TP-I D: PC2-CD2**
Direction	**@1.5m-2.25m**	**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**149**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	149	0
2	1	1	245	96
3	1	2	328	83
4	1	3	405	77
5	1	4	475	70

Chainage (km)	**1.5**	**Surface Type**	**Unpaved**	**TP-I D: PC2-CD2**
Direction	**@1.5m-2.25m**	**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**149**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
6	1	5	533	58
7	1	6	582	49
8	1	7	623	41
9	1	8	660	37
10	1	9	690	30
11	1	10	720	30
12	1	11	740	20
13	1	12	760	20
14	1	13	775	15
15	1	14	795	20
16	1	15	810	15
17	1	16	823	13
18	1	17	837	14
19	1	18	850	13
20	1	19	863	13
21	1	20	876	13
22	1	21	885	9
23	1	22	900	15

Title	**Penetration Data Report**			
Project Name	**Primary Canal-2-CD2-DCP Test Result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**@0.0m-0.73m**	**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**167**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	167	0
2	1	1	190	23
3	1	2	200	10
4	1	3	210	10
5	1	4	220	10
6	1	5	225	5
7	1	6	235	10
8	1	7	245	10
9	1	8	257	12
10	1	9	268	11
11	1	10	278	10
12	1	11	288	10

Title	**Penetration Data Report**			
Project Name	**Primary Canal-2-CD2-DCP Test Result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**@0.0m-0.73m**	**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**167**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
13	1	12	298	10
14	1	13	307	9
15	1	14	318	11
16	1	15	328	10
17	1	16	335	7
18	1	17	357	22
19	1	18	367	10
20	1	19	374	7
21	1	20	387	13
22	1	21	394	7
23	1	22	408	14
24	1	23	417	9
25	1	24	423	6
26	1	25	434	11
27	1	26	442	8
28	1	27	452	10
29	1	28	460	8
30	1	29	469	9
31	1	30	479	10
32	1	31	489	10
33	1	32	502	13
34	1	33	514	12
35	1	34	525	11
36	1	35	538	13
37	1	36	553	15
38	1	37	564	11
39	1	38	575	11
40	1	39	600	25
41	1	40	620	20
42	1	41	640	20
43	1	42	667	27
44	1	43	697	30
45	1	44	723	26
46	1	45	794	71
47	1	46	797	3
48	1	47	830	33
49	1	48	865	35
50	1	49	900	35

Title	**Penetration Data Report**
Project Name	**Primary canal-2_CD3, DCP Test result**

Chainage (km)	**0.0-0.73**	**Surface Type**	**Unpaved**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**21**	**Surface Moisture**	**Very Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	215	0
2	1	1	230	15
3	1	2	235	5
4	1	3	242	7
5	1	4	245	3
6	1	5	248	3
7	1	6	252	4
8	1	7	261	9
9	1	8	264	3
10	1	9	267	3
11	1	10	268	1
12	1	11	272	4
13	1	12	277	5
14	1	13	282	5
15	1	14	287	5
16	1	15	292	5
17	1	16	293	1
18	1	17	294	1
19	1	18	298	4
20	1	19	300	2
21	1	20	305	5
22	1	21	306	1
23	1	22	308	2
24	1	23	313	5
25	1	24	317	4
26	1	25	322	5
27	1	26	323	1
28	1	27	328	5
29	1	28	333	5
30	1	29	336	3
31	1	30	340	4
32	1	31	345	5
33	1	32	350	5
34	1	33	351	1
35	1	34	352	1
36	1	35	353	1
37	1	36	355	2
38	1	37	356	1
39	1	38	362	6
40	1	39	365	3
41	1	40	370	5
42	1	41	371	1
43	1	42	375	4
44	1	43	377	2
45	1	44	382	5
46	1	45	386	4
47	1	46	388	2

Title	**Penetration Data Report**			
Project Name	**Primary canal-2_CD3, DCP Test result**			
Chainage (km)	**0.0-0.73**	**Surface Type**	**Unpaved**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**21**	**Surface Moisture**	**Very Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
48	1	47	392	4
49	1	48	397	5
50	1	49	400	3
51	1	50	403	3
52	1	51	406	3
53	1	52	407	1
54	1	53	408	1
55	1	54	409	1
56	1	55	410	1
57	1	56	420	10
58	1	57	422	2
59	1	58	427	5
60	1	59	428	1
61	1	60	429	1
62	1	61	433	4
63	1	62	436	3
64	1	63	438	2
65	1	64	439	1
66	1	65	447	8
67	2	67	455	4
68	2	69	460	2.5
69	5	74	480	4
70	5	79	510	6
71	5	84	545	7
72	5	89	580	7
73	5	94	614	6.8
74	5	99	655	8.2
75	5	104	670	3
76	5	109	770	20
77	5	114	830	12
78	5	119	900	14
79	5	124	950	10

Title	**Penetration Data Report**			
Project Name	**Primary canal-2_CD7, DCP Test result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**170**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	179	0
2	1	1	197	18
3	1	2	206	9
4	2	4	230	12

Title	**Penetration Data Report**			
Project Name	**Primary canal-2_CD7, DCP Test result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**170**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
5	2	6	253	11.5
6	2	8	273	10
7	2	10	290	8.5
8	2	12	310	10
9	2	14	330	10
10	2	16	350	10
11	2	18	370	10
12	2	20	386	8
13	2	22	402	8
14	2	24	420	9
15	2	26	435	7.5
16	2	28	452	8.5
17	5	33	490	7.6
18	5	38	530	8
19	5	43	572	8.4
20	5	48	620	9.6
21	5	53	663	8.6
22	5	58	705	8.4
23	5	63	745	8
24	5	68	783	7.6
25	5	73	820	7.4
26	5	78	850	6

MAIN CANAL STRUCTURE SITE DCP TEST RAW DATA

Title	**Penetration Data Report**			
Project Name	**MC-TP-2 DCP Test at 0.50m to 1.29m**			
Chainage (km)	**0.5**	**Surface Type**	**Unpaved**	
Direction	**@0.50-1.29**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	120	0
2	1	1	133	13
3	1	2	142	9
4	1	3	150	8
5	1	4	161	11
6	1	5	163	2
7	1	6	173	10
8	1	7	182	9
9	1	8	190	8
10	1	9	200	10
11	1	10	210	10
12	1	11	221	11

Title	**Penetration Data Report**			
Project Name	**MC-TP-2 DCP Test at 0.50m to 1.29m**			
Chainage (km)	**0.5**	**Surface Type**	**Unpaved**	
Direction	**@0.50-1.29**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
13	1	12	233	12
14	1	13	234	1
15	1	14	254	20
16	1	15	264	10
17	1	16	274	10
18	1	17	284	10
19	1	18	295	11
20	1	19	305	10
21	1	20	320	15
22	1	21	329	9
23	1	22	336	7
24	1	23	346	10
25	1	24	355	9
26	1	25	365	10
27	1	26	379	14
28	1	27	390	11
29	1	28	405	15
30	1	29	420	15
31	1	30	430	10
32	1	31	445	15
33	1	32	455	10
34	1	33	470	15
35	1	34	505	35
36	1	35	525	20
37	1	36	540	15
38	1	37	560	20
39	1	38	580	20
40	1	39	600	20
41	1	40	617	17
42	1	41	635	18
43	1	42	652	17
44	1	43	670	18
45	1	44	685	15
46	1	45	702	17
47	1	46	720	18
48	1	47	736	16
49	1	48	755	19
50	1	49	768	13
51	1	50	775	7
52	1	51	785	10
53	1	52	800	15
54	1	53	820	20
55	1	54	840	20
56	1	55	860	20

Title	**Penetration Data Report**			
Project Name	**MC-TP-2 DCP Test at 0.50m to 1.29m**			
Chainage (km)	**0.5**	**Surface Type**	**Unpaved**	
Direction	**@0.50-1.29**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
57	1	56	870	10
58	1	57	890	20
59	1	58	908	18

Title	**Penetration Data Report**			
Project Name	**MC-CD-7-DCP Test Result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**170**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	170	0
2	1	1	190	20
3	1	2	205	15
4	1	3	222	17
5	1	4	225	3
6	1	5	250	25
7	1	6	260	10
8	1	7	270	10
9	1	8	281	11
10	1	9	288	7
11	1	10	300	12
12	1	11	310	10
13	1	12	320	10
14	1	13	335	15
15	1	14	343	8
16	1	15	353	10
17	1	16	355	2
18	1	17	365	10
19	1	18	379	14
20	1	19	392	13
21	1	20	405	13
22	1	21	420	15
23	1	22	430	10
24	1	23	443	13
25	1	24	464	21
26	1	25	477	13
27	1	26	488	11
28	1	27	502	14
29	1	28	512	10
30	1	29	530	18
31	1	30	550	20
32	1	31	573	23

Title	**Penetration Data Report**			
Project Name	**MC-TP-2 DCP Test at 0.50m to 1.29m**			
Chainage (km)	**0.5**	**Surface Type**	**Unpaved**	
Direction	**@0.50-1.29**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
33	1	32	587	14
34	1	33	592	5
35	1	34	617	25
36	1	35	632	15
37	1	36	647	15
38	1	37	663	16
39	1	38	680	17
40	1	39	700	20
41	1	40	712	12
42	1	41	725	13
43	1	42	742	17
44	1	43	757	15
45	1	44	770	13
46	1	45	780	10
47	1	46	790	10
48	1	47	806	16
49	1	48	814	8
50	1	49	823	9
51	1	50	833	10
52	1	51	834	1
53	1	52	850	16

Title	**Penetration Data Report**			
Project Name	**MC-CD-4 DCP Test Result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**@0.0-.62.4**	**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**144**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	144	0
2	2	2	165	10.5
3	2	4	177	6
4	2	6	190	6.5
5	2	8	200	5
6	2	10	210	5
7	2	12	234	12
8	2	14	245	5.5
9	2	16	255	5
10	2	18	265	5
11	2	20	275	5
12	2	22	285	5
13	2	24	295	5

Title	**Penetration Data Report**			
Project Name	**MC-CD-4 DCP Test Result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**@0.0-.62.4**	**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**144**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
14	2	26	315	10
15	2	28	338	11.5
16	2	30	358	10
17	2	32	385	13.5
18	2	34	395	5
19	2	36	409	7
20	2	38	453	22
21	2	40	481	14
22	2	42	513	16
23	2	44	540	13.5
24	2	46	566	13
25	2	48	598	16
26	2	50	614	8
27	2	52	638	12
28	2	54	660	11
29	2	56	685	12.5
30	2	58	718	16.5
31	2	60	737	9.5
32	2	62	768	15.5

Chainage (km)	**1.6**	**Surface Type**	**Unpaved**	**MC-CD-4**
Direction	**@1.60-2.42m**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**145**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	145	0
2	1	1	185	40
3	1	2	220	35
4	1	3	250	30
5	1	4	275	25
6	1	5	295	20
7	1	6	305	10
8	1	7	330	25
9	1	8	350	20
10	1	9	370	20
11	1	10	390	20
12	1	11	410	20
13	1	12	428	18
14	1	13	440	12
15	1	14	460	20
16	1	15	480	20

Chainage (km)	**1.6**	**Surface Type**	**Unpaved**	**MC-CD-4**
Direction	**@1.60-2.42m**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**145**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
17	1	16	515	35
18	1	17	535	20
19	1	18	555	20
20	1	19	570	15
21	2	21	595	12.5
22	2	23	620	12.5
23	2	25	645	12.5
24	2	27	675	15
25	2	29	700	12.5
26	2	31	720	10
27	2	33	755	17.5
28	2	35	785	15
29	2	37	815	15
30	2	39	845	15
31	2	41	865	10
32	2	43	885	10
33	2	45	915	15
34	2	47	935	10
35	2	49	960	12.5

Title	**Penetration Data Report**			
Project Name	**MC-CD5 DCP TEST RESUALT**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**@1.50m to**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**195**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	195	0
2	1	1	257	62
3	1	2	317	60
4	1	3	385	68
5	1	4	480	95
6	1	5	550	70
7	1	6	600	50
8	1	7	645	45
9	1	8	685	40
10	1	9	720	35
11	1	10	760	40
12	1	11	790	30
13	1	12	822	32
14	1	13	860	38
15	1	14	890	30
16	1	15	920	30
17	1	16	973	53

Title	**Penetration Data Report**			
Project Name	**MC-CD5 DCP TEST RESUALT**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**@1.50m to**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**195**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
18	1	17	1055	82
19	1	18	1167	112
20	1	19	1308	141
21	1	20	1473	165
Remarks:				

Chainage (km)	**1**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**165**	**Surface Moisture**	**Dry**	**MC-CD5**
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	165	0
2	1	1	191	26
3	1	2	225	34
4	1	3	253	28
5	1	4	276	23
6	1	5	301	25
7	1	6	323	22
8	1	7	342	19
9	1	8	360	18
10	1	9	380	20
11	1	10	403	23
12	1	11	415	12
13	1	12	433	18
14	1	13	453	20
15	1	14	475	22
16	1	15	500	25
17	1	16	515	15
18	1	17	535	20
19	1	18	560	25
20	1	19	580	20
21	1	20	600	20
22	1	21	620	20
23	1	22	640	20
24	1	23	660	20
25	1	24	670	10
26	1	25	692	22
27	1	26	716	24
28	1	27	735	19
29	1	28	755	20
30	1	29	775	20

Chainage (km)	**1**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**165**	**Surface Moisture**	**Dry**	**MC-CD5**
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
31	1	30	790	15
32	1	31	810	20
33	1	32	825	15
34	1	33	845	20
35	1	34	870	25
36	1	35	890	20
37	1	36	910	20
38	1	37	930	20

Title	**Penetration Data Report**			
Project Name	**MC-CD3**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**1**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	182	0
2	1	1	225	43
3	1	2	249	24
4	1	3	269	20
5	1	4	289	20
6	1	5	305	16
7	1	6	322	17
8	1	7	339	17
9	1	8	354	15
10	1	9	368	14
11	1	10	380	12
12	1	11	392	12
13	1	12	402	10
14	1	13	412	10
15	2	15	432	10
16	2	17	450	9
17	2	19	465	7.5
18	2	21	482	8.5
19	2	23	498	8
20	2	25	514	8
21	2	27	528	7
22	2	29	544	8
23	2	31	559	7.5
24	2	33	578	9.5
25	2	35	590	6

Title	**Penetration Data Report**			
Project Name	**MC-CD3**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**1**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
26	2	37	600	5
27	2	39	622	11
28	2	41	639	8.5
29	2	43	650	5.5
30	2	45	664	7
31	2	47	672	4
32	2	49	690	9
33	2	51	704	7
34	2	53	714	5
35	2	55	734	10
36	2	57	749	7.5
37	2	59	764	7.5
38	2	61	779	7.5
39	2	63	792	6.5
40	2	65	802	5
41	2	67	819	8.5
42	2	69	832	6.5
43	2	71	842	5
44	2	73	854	6
45	2	75	862	4
46	2	77	880	9
47	2	79	900	10
48	2	81	912	6
49	2	83	930	9

MAIN CANAL FARM ROAD DCP TEST DATA

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**0**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	160	0
2	1	1	235	75
3	1	2	275	40
4	1	3	310	35
5	1	4	332	22
6	1	5	348	16
7	1	6	364	16
8	1	7	378	14

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Direction	**0**	**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
9	1	8	395	17
10	1	9	415	20
11	1	10	432	17
12	1	11	450	18
13	1	12	470	20
14	1	13	485	15
15	1	14	500	15
16	1	15	515	15
17	1	16	530	15
18	1	17	540	10
19	1	18	554	14
20	1	19	565	11
21	1	20	577	12
22	1	21	593	16
23	1	22	610	17
24	1	23	625	15
25	1	24	642	17
26	1	25	652	10
27	1	26	662	10
28	1	27	675	13
29	1	28	692	17
30	1	29	704	12
Remarks:				

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**1**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle(degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	112	0
2	1	1	148	36
3	1	2	170	22
4	1	3	185	15
5	1	4	206	21
6	1	5	222	16
7	1	6	248	26
8	1	7	250	2
9	1	8	260	10
10	1	9	270	10
11	2	11	290	10
12	2	13	307	8.5

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**1**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle(degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
13	2	15	324	8.5
14	2	17	342	9
15	2	19	356	7
16	2	21	380	12
17	2	23	394	7
18	2	25	408	7
19	2	27	422	7
20	2	29	435	6.5
21	2	31	445	5
22	2	33	460	7.5
23	2	35	470	5
24	2	37	485	7.5
25	2	39	493	4
26	2	41	510	8.5
27	2	43	522	6
28	2	45	535	6.5
29	2	47	550	7.5
30	2	49	560	5
31	2	51	570	5
32	2	53	580	5
33	2	55	590	5
34	2	57	600	5
35	2	59	610	5
36	2	61	620	5
37	2	63	630	5
38	2	65	640	5
39	2	67	650	5
40	2	69	660	5
41	2	71	670	5
42	2	73	680	5
43	2	75	690	5
44	2	77	700	5
45	2	79	710	5
46	2	81	720	5
47	2	83	730	5
48	2	85	740	5
49	2	87	750	5
50	2	89	760	5
51	2	91	770	5
Remarks:				

Title	**Penetration Data Report**

Project Name	Omo valley project main canal DCP test result			
Chainage (km)	2	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/ Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
1	0	0	102	0
2	1	1	125	23
3	1	2	135	10
4	1	3	142	7
5	1	4	152	10
6	2	6	160	4
7	2	8	170	5
8	2	10	175	2.5
9	2	12	183	4
10	2	14	187	2
11	2	16	190	1.5
12	2	18	198	4
13	2	20	203	2.5
14	2	22	205	1
15	2	24	210	2.5
16	2	26	217	3.5
17	2	28	221	2
18	2	30	224	1.5
19	2	32	232	4
20	2	34	235	1.5
21	2	36	242	3.5
22	2	38	247	2.5
23	2	40	255	4
24	2	42	257	1
25	2	44	260	1.5
26	2	46	265	2.5
27	2	48	270	2.5
28	2	50	275	2.5
29	2	52	280	2.5
30	2	54	284	2
31	2	56	292	4
32	2	58	297	2.5
33	2	60	300	1.5
34	2	62	312	6
35	2	64	317	2.5
36	2	66	322	2.5
37	2	68	328	3
38	2	70	333	2.5
39	2	72	337	2
40	2	74	340	1.5
41	2	76	346	3
42	2	78	350	2
43	2	80	352	1
44	5	85	358	1.2
45	5	90	375	3.4

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**2**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
46	5	95	389	2.8
47	5	100	397	1.6
48	5	105	405	1.6
49	5	110	417	2.4
50	5	115	444	5.4
51	5	120	478	6.8
52	5	125	518	8
53	5	130	577	11.8
54	5	135	625	9.6
55	5	140	670	9
56	5	145	697	5.4
57	5	150	735	7.6
58	5	155	766	6.2
59	5	160	800	6.8
60	5	165	830	6
Remarks:				

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**3**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	110	0
2	1	1	117	7
3	1	2	122	5
4	1	3	127	5
5	2	5	132	2.5
6	2	7	142	5
7	2	9	147	2.5
8	2	11	154	3.5
9	2	13	157	1.5
10	2	15	160	1.5
11	2	17	165	2.5
12	2	19	172	3.5
13	2	21	176	2
14	2	23	182	3
15	2	25	186	2
16	2	27	192	3
17	2	29	196	2

Title	Penetration Data Report			
Project Name	Omo valley project main canal DCP test result			
Chainage (km)	3	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/ Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
18	2	31	200	2
19	2	33	203	1.5
20	5	38	213	2
21	5	43	226	2.6
22	5	48	243	3.4
23	5	53	260	3.4
24	5	58	278	3.6
25	5	63	295	3.4
26	5	68	320	5
27	5	73	345	5
28	5	78	372	5.4
29	5	83	406	6.8
30	5	88	504	19.6
31	5	93	528	4.8
32	5	98	627	19.8
33	5	103	710	16.6
34	5	108	792	16.4
35	5	113	872	16
36	5	118	952	16
Remarks:				

Title	Penetration Data Report			
Project Name	Omo valley project main canal DCP test result			
Chainage (km)	4	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
1	0	0	105	0
2	1	1	115	10
3	1	2	116	1
4	1	3	120	4
5	1	4	125	5
6	1	5	127	2
7	1	6	132	5
8	1	7	133	1
9	1	8	137	4
10	1	9	143	6
11	1	10	144	1
12	2	12	147	1.5
13	2	14	153	3

Title	Penetration Data Report			
Project Name	Omo valley project main canal DCP test result			
Chainage (km)	4	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
14	2	16	161	4
15	2	18	167	3
16	2	20	173	3
17	2	22	181	4
18	2	24	189	4
19	2	26	191	1
20	2	28	200	4.5
21	2	30	210	5
22	2	32	219	4.5
23	2	34	228	4.5
24	2	36	238	5
25	2	38	252	7
26	2	40	263	5.5
27	2	42	272	4.5
28	2	44	282	5
29	2	46	293	5.5
30	2	48	306	6.5
31	2	50	316	5
32	2	52	327	5.5
33	2	54	340	6.5
34	2	56	353	6.5
35	2	58	365	6
36	2	60	379	7
37	2	62	392	6.5
38	2	64	402	5
39	2	66	408	3
40	2	68	418	5
41	2	70	426	4
42	2	72	435	4.5
43	2	74	442	3.5
44	2	76	451	4.5
45	2	78	458	3.5
46	2	80	466	4
47	2	82	478	6
48	2	84	482	2
49	2	86	490	4
50	2	88	497	3.5
51	2	90	509	6
52	2	92	523	7
53	2	94	536	6.5
54	2	96	553	8.5
55	2	98	574	10.5
56	2	100	614	20
57	2	102	660	23

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**4**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
58	2	104	706	23
59	2	106	757	25.5
60	2	108	800	21.5
61	2	110	833	16.5
62	2	112	866	16.5
63	2	114	905	19.5
64	2	116	940	17.5
Remarks:				

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**5**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	180	0
2	1	1	190	10
3	1	2	204	14
4	1	3	205	1
5	1	4	210	5
6	1	5	212	2
7	1	6	216	4
8	1	7	222	6
9	1	8	226	4
10	1	9	230	4
11	1	10	234	4
12	1	11	237	3
13	1	12	240	3
14	1	13	241	1
15	1	14	244	3
16	1	15	247	3
17	1	16	248	1
18	1	17	249	1
19	1	18	250	1
20	1	19	255	5
21	1	20	258	3
22	1	21	260	2
23	1	22	264	4

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**5**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
24	1	23	267	3
25	1	24	270	3
26	1	25	273	3
27	1	26	276	3
28	1	27	278	2
29	1	28	282	4
30	1	29	285	3
31	1	30	288	3
32	1	31	290	2
33	1	32	300	10
34	1	33	303	3
35	1	34	305	2
36	1	35	307	2
37	1	36	308	1
38	1	37	310	2
39	1	38	311	1
40	1	39	313	2
41	1	40	320	7
42	1	41	322	2
43	1	42	324	2
44	1	43	326	2
45	1	44	330	4
46	1	45	332	2
47	1	46	334	2
48	1	47	338	4
49	1	48	340	2
50	1	49	345	5
51	1	50	348	3
52	1	51	350	2
53	1	52	355	5
54	1	53	360	5
55	1	54	365	5
56	1	55	370	5
57	1	56	372	2
58	1	57	375	3
59	1	58	380	5
60	1	59	384	4
61	1	60	388	4
62	1	61	390	2
63	1	62	393	3
64	1	63	404	11
65	1	64	405	1
66	1	65	408	3
67	1	66	413	5

Title	Penetration Data Report			
Project Name	Omo valley project main canal DCP test result			
Chainage (km)	5	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
68	1	67	423	10
69	1	68	425	2
70	1	69	427	2
71	1	70	435	8
72	1	71	440	5
73	1	72	443	3
74	1	73	453	10
75	1	74	460	7
76	1	75	465	5
77	1	76	466	1
Remarks:				

Title	Penetration Data Report			
Project Name	Omo valley project main canal DCP test result			
Chainage (km)	6	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
1	0	0	183	0
2	1	1	186	3
3	1	2	188	2
4	1	3	192	4
5	1	4	195	3
6	1	5	196	1
7	1	6	197	1
8	1	7	200	3
9	1	8	202	2
10	1	9	204	2
11	2	11	205	0.5
12	2	13	208	1.5
13	2	15	210	1
14	2	17	212	1
15	5	22	215	0.6
16	5	27	220	1
17	5	32	222	0.4
18	5	37	223	0.2
19	5	42	224	0.2
20	5	47	227	0.6
21	5	52	232	1
22	5	57	237	1
23	5	62	240	0.6

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**6**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
24	5	67	241	0.2
25	5	72	243	0.4
26	5	77	244	0.2
27	5	82	246	0.4
28	10	92	250	0.4
29	10	102	255	0.5
30	10	112	257	0.2
31	10	122	266	0.9
32	10	132	278	1.2
33	10	142	322	4.4
34	10	152	404	8.2
35	10	162	550	14.6
36	10	172	803	25.3
37	10	182	910	10.7
Remarks:				

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**7**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	185	0
2	1	1	192	7
3	1	2	200	8
4	1	3	206	6
5	1	4	212	6
6	1	5	215	3
7	1	6	218	3
8	1	7	223	5
9	1	8	226	3
10	1	9	230	4
11	1	10	232	2
12	1	11	234	2
13	1	12	236	2
14	1	13	239	3
15	1	14	245	6
16	1	15	248	3
17	1	16	252	4
18	1	17	253	1
19	1	18	256	3

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**7**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
20	1	19	262	6
21	1	20	265	3
22	1	21	268	3
23	1	22	273	5
24	1	23	278	5
25	1	24	282	4
26	1	25	287	5
27	1	26	292	5
28	1	27	302	10
29	1	28	306	4
30	1	29	307	1
31	1	30	314	7
32	1	31	322	8
33	1	32	327	5
34	1	33	336	9
35	1	34	343	7
36	1	35	348	5
37	1	36	356	8
38	1	37	365	9
39	1	38	373	8
40	1	39	380	7
41	1	40	390	10
42	1	41	400	10
43	1	42	410	10
44	1	43	423	13
45	1	44	434	11
46	1	45	447	13
47	1	46	462	15
48	1	47	476	14
49	1	48	492	16
50	1	49	506	14
51	1	50	520	14
52	1	51	536	16
53	1	52	545	9
54	1	53	562	17
55	1	54	574	12
56	1	55	588	14
57	1	56	602	14
58	1	57	613	11
59	1	58	635	22
60	1	59	640	5
61	1	60	653	13
62	1	61	666	13
63	1	62	676	10

Title	Penetration Data Report			
Project Name	Omo valley project main canal DCP test result			
Chainage (km)	7	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
64	1	63	682	6
65	1	64	692	10
66	1	65	702	10
67	1	66	712	10
68	1	67	723	11
69	1	68	734	11
70	1	69	742	8
71	1	70	753	11
72	1	71	764	11
73	1	72	774	10
74	1	73	780	6
75	1	74	790	10
76	1	75	800	10
77	1	76	810	10
78	1	77	820	10
79	1	78	824	4
80	1	79	830	6
81	1	80	840	10
82	1	81	850	10
83	1	82	855	5
84	1	83	860	5
85	1	84	870	10
86	1	85	876	6
87	1	86	880	4
88	1	87	890	10
89	1	88	900	10
Remarks:				

Title	Penetration Data Report			
Project Name	Omo valley project main canal DCP test result			
Chainage (km)	8	Surface Type	Unpaved	
Direction		Thickness (mm)	0	
Location/ Offset	Carriageway	Base Type		
Cone Angle (degrees)	60	Thickness (mm)		
No.	Blows	Cumulative Blows	Penetration Depth	Penetration Rate
1	0	0	190	0
2	1	1	195	5
3	1	2	200	5
4	1	3	208	8
5	1	4	210	2
6	1	5	215	5
7	1	6	218	3
8	1	7	222	4

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**7**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
9	1	8	225	3
10	1	9	228	3
11	1	10	230	2
12	1	11	231	1
13	1	12	235	4
14	1	13	236	1
15	2	15	238	1
16	2	17	240	1
17	2	19	244	2
18	2	21	245	0.5
19	2	23	248	1.5
20	2	25	250	1
21	2	27	251	0.5
22	2	29	253	1
23	2	31	254	0.5
24	2	33	256	1
25	2	35	258	1
26	2	37	263	2.5
27	2	39	265	1
28	2	41	267	1
29	2	43	268	0.5
30	2	45	273	2.5
31	2	47	274	0.5
32	5	52	280	1.2
33	5	57	284	0.8
34	5	62	290	1.2
35	5	67	303	2.6
36	5	72	308	1
37	5	77	328	4
38	5	82	359	6.2
39	5	87	400	8.2
40	5	92	500	20
41	5	97	517	3.4
42	5	102	573	11.2
43	5	107	620	9.4
44	5	112	655	7
45	5	117	696	8.2
46	5	122	740	8.8
47	5	127	782	8.4
48	5	132	826	8.8
49	5	137	870	8.8
Remarks:				

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**9**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	200	0
2	1	1	206	6
3	1	2	210	4
4	1	3	213	3
5	1	4	215	2
6	1	5	220	5
7	1	6	225	5
8	1	7	230	5
9	1	8	235	5
10	1	9	240	5
11	1	10	242	2
12	1	11	245	3
13	1	12	250	5
14	1	13	255	5
15	1	14	258	3
16	1	15	260	2
17	1	16	263	3
18	1	17	266	3
19	1	18	270	4
20	1	19	275	5
21	1	20	277	2
22	1	21	280	3
23	1	22	282	2
24	1	23	284	2
25	1	24	286	2
26	1	25	291	5
27	1	26	295	4
28	1	27	300	5
29	1	28	305	5
30	1	29	307	2
31	1	30	313	6
32	1	31	317	4
33	1	32	320	3
34	1	33	323	3
35	1	34	326	3
36	1	35	330	4
37	1	36	335	5
38	1	37	340	5
39	1	38	343	3
40	1	39	348	5
41	1	40	352	4
42	1	41	357	5
43	1	42	360	3
44	1	43	363	3

Title	**Penetration Data Report**			
Project Name	**Omo valley project main canal DCP test result**			
Chainage (km)	**9**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/ Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
45	1	44	367	4
46	1	45	372	5
47	1	46	377	5
48	1	47	383	6
49	1	48	391	8
50	1	49	397	6
51	1	50	402	5
52	1	51	407	5
53	1	52	412	5
54	1	53	418	6
55	1	54	423	5
56	1	55	430	7
57	1	56	438	8
58	1	57	447	9
59	1	58	456	9
60	1	59	467	11
61	1	60	477	10
62	1	61	485	8
63	1	62	498	13
64	1	63	508	10
65	1	64	521	13
66	1	65	534	13
67	1	66	547	13
68	1	67	562	15
69	1	68	575	13
70	1	69	588	13
71	1	70	607	19
72	1	71	628	21
73	1	72	646	18
74	1	73	668	22
75	1	74	687	19
76	1	75	708	21
77	1	76	734	26
78	1	77	762	28
79	1	78	796	34
80	1	79	824	28
81	1	80	854	30
82	1	81	874	20
83	1	82	900	26
84	1	83	923	23
85	1	84	940	17
Remarks:				

Title	**Penetration Data Report**

Project Name	**DCP test along primary canal-1**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	220	0
2	1	1	240	20
3	1	2	260	20
4	1	3	280	20
5	1	4	292	12
6	1	5	306	14
7	1	6	318	12
8	1	7	332	14
9	1	8	344	12
10	1	9	353	9
11	1	10	373	20
12	1	11	383	10
13	1	12	397	14
14	1	13	407	10
15	1	14	423	16
16	1	15	433	10
17	1	16	446	13
18	1	17	456	10
19	1	18	470	14
20	1	19	482	12
21	1	20	492	10
22	1	21	508	16
23	1	22	515	7
24	1	23	533	18
25	1	24	548	15
26	1	25	568	20
27	1	26	580	12
28	1	27	600	20
29	1	28	615	15
30	1	29	630	15
31	1	30	643	13
32	1	31	657	14
33	1	32	668	11
34	1	33	685	17
35	1	34	700	15
36	1	35	722	22
37	1	36	732	10
38	1	37	750	18
39	1	38	766	16
40	1	39	785	19
41	1	40	800	15
42	1	41	820	20
43	1	42	840	20
44	1	43	860	20
45	1	44	890	30
46	1	45	910	20

Title	**Penetration Data Report**			
Project Name	**DCP test along primary canal-1**			
Chainage (km)	**0**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
47	1	46	940	30
48	1	47	960	20
Remarks:				

Chainage (km)	**1.7**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**0**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	240	0
2	1	1	341	101
3	1	2	423	82
4	1	3	500	77
5	1	4	560	60
6	1	5	623	63
7	1	6	673	50
8	1	7	725	52
9	1	8	760	35
10	1	9	782	22
11	1	10	810	28
12	1	11	833	23
13	1	12	850	17
14	1	13	864	14
15	1	14	892	28
16	1	15	912	20
17	1	16	934	22
18	1	17	938	4
19	1	18	950	12
20	1	19	964	14
21	1	20	978	14
22	1	21	984	6
23	1	22	1000	16
Remarks:				
Chainage (km)	**3**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**0**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	245	0

Chainage (km)	**1.7**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**0**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
2	2	2	277	16
3	10	12	395	11.8
4	10	22	508	11.3
5	10	32	570	6.2
Remarks:				

Chainage (km)	**4.5**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**0**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	223	0
2	5	5	270	9.4
3	10	15	315	4.5
4	10	25	370	5.5
5	10	35	415	4.5
6	10	45	470	5.5
Remarks:				

Chainage (km)	**5**	**Surface Type**	**Unpaved**	
Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**0**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	210	0
2	1	1	257	47
3	5	6	340	16.6
4	5	11	425	17
5	5	16	565	28
6	5	21	670	21
7	5	26	750	16
8	5	31	810	12
9	5	36	880	14
10	5	41	900	4
Remarks:				

PUMP STATION SITE DCP RESULT

Penetration Data Report				
Project	**Omo Valley Farm**			
Site	**Pump station-1 DCP test -1**			
Test Depth (m)	**1.0-1.73**			
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	200	0

Penetration Data Report				
Project	**Omo Valley Farm**			
Site	**Pump station-1 DCP test -1**			
Test Depth (m)	**1.0-1.73**			
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
2	1	1	220	20
3	1	2	230	10
4	1	3	242	12
5	1	4	253	11
6	1	5	265	12
7	1	6	276	11
8	1	7	286	10
9	1	8	295	9
10	1	9	305	10
11	1	10	311	6
12	1	11	318	7
13	1	12	326	8
14	1	13	333	7
15	1	14	341	8
16	1	15	346	5
17	1	16	350	4
18	1	17	358	8
19	1	18	365	7
20	1	19	370	5
21	1	20	380	10
22	1	21	390	10
23	2	23	400	5
24	2	25	425	12.5
25	2	27	442	8.5
26	2	29	454	6
27	2	31	465	5.5
28	2	33	476	5.5
29	2	35	490	7
30	2	37	496	3
31	2	39	510	7
32	2	41	522	6
33	2	43	535	6.5
34	2	45	550	7.5
35	2	47	562	6
36	2	49	580	9
37	2	51	595	7.5
38	2	53	610	7.5
39	2	55	623	6.5
40	2	57	635	6
41	2	59	650	7.5
42	2	61	710	30
43	2	63	720	5
44	2	65	732	6
45	2	67	743	5.5
46	2	69	760	8.5
47	2	71	780	10
48	2	73	805	12.5
49	2	75	835	15

Penetration Data Report				
Project	**Omo Valley Farm**			
Site	**Pump station-1 DCP test -1**			
Test Depth (m)	**1.0-1.73**			
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
50	2	77	860	12.5
51	2	79	880	10
52	2	81	910	15
53	2	83	930	10
Remarks:	Ave. penetration= 9 mm/blow			

Penetration Data Report				
Project	**Omo Valley Farm**			
Site	**Pump station-1 DCP test -2**			
Test Depth (m)	**1.73-2.51**			
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	13	0
2	5	5	16	0.6
3	5	10	18	0.4
4	5	15	100	16.4
5	5	20	125	5
6	5	25	152	5.4
7	5	30	182	6
8	5	35	210	5.6
9	5	40	240	6
10	5	45	262	4.4
11	5	50	280	3.6
12	5	55	305	5
13	5	60	335	6
14	5	65	360	5
15	5	70	385	5
16	5	75	420	7
17	5	80	450	6
18	5	85	480	6
19	5	90	510	6
20	5	95	536	5.2
21	5	100	567	6.2
22	5	105	600	6.6
23	5	110	630	6
24	5	115	660	6
25	5	120	700	8
26	5	125	730	6
27	5	130	760	6
28	5	135	790	6
29	5	140	820	6
30	5	145	850	6
31	5	150	875	5
32	5	155	900	5
Remarks:	Ave. penetration= 6 mm/blow			

Title	**Penetration Data Report**			
Project Name	**Pump Station-2 (Booster Site)**			
Depth (m)	**0.0**	**Surface Type**	**Unpaved**	
Direction		**Thickness (mm)**	**0**	

Location/Offset	**Carriageway**	**Base Type**		
Cone Angle (degrees)	**60**	**Thickness (mm)**		
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	220	0
2	1	1	240	20
3	1	2	260	20
4	1	3	280	20
5	1	4	292	12
6	1	5	306	14
7	1	6	332	26
8	1	7	344	12
9	1	8	353	9
10	1	9	373	20
11	1	10	383	10
12	1	11	397	14
13	1	12	407	10
14	1	13	423	16
15	1	14	433	10
16	1	15	446	13
17	1	16	456	10
18	1	17	470	14
19	1	18	482	12
20	1	19	492	10
21	1	20	508	16
22	1	21	515	7
23	1	22	533	18
24	1	23	548	15
25	1	24	568	20
26	1	25	580	12
27	1	26	600	20
28	1	27	615	15
29	1	28	630	15
30	1	29	643	13
31	1	30	657	14
32	1	31	668	11
33	1	32	685	17
34	1	33	700	15
35	1	34	722	22
36	1	35	732	10
37	1	36	750	18
38	1	37	766	16
39	1	38	785	19
40	1	39	800	15
41	1	40	820	20
42	1	41	840	20
43	1	42	860	20
44	1	43	890	30
45	1	44	910	20
46	1	45	940	30
47	1	46	960	20
48	1	47	970	10

Penetration Data Report				
Project	**Omo Valley Farm**			
Site	**Pump station-1 DCP test -2**			
Test Depth (m)	**1.73-2.51**			
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
49	1	48	990	20
50	1	49	1010	20
51	1	50	1031	21
52	1	51	1055	24
53	1	52	1079	24
54	1	53	1103	24
55	1	54	1125	22
56	1	55	1161	36
57	1	56	1199	38
58	1	57	1215	16
59	1	58	1229	14
60	1	59	1243	14
61	1	60	1260	17
62	1	61	1275	15
63	1	62	1289	14
64	1	63	1303	14
65	1	64	1318	15
66	1	65	1340	22
67	1	66	1345	5
68	1	67	1358	13
69	1	68	1368	10
70	1	69	1378	10
71	1	70	1390	12
72	1	71	1403	13
73	1	72	1418	15
74	1	73	1423	5
75	1	74	1435	12
76	1	75	1449	14
77	1	76	1456	7
78	1	77	1463	7
79	1	78	1471	8
80	1	79	1481	10
81	1	80	1491	10
Remarks:	avg. penetration rate = 15.7			

Depth (m)	**1.5**	**Surface Type**	**Unpaved**	**PS-2-Test-2**
Direction		**Thickness (mm)**	**0**	
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**2**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
1	0	0	220	0
2	1	1	231	11
3	1	2	242	11
4	1	3	250	8
5	1	4	260	10
6	1	5	269	9

Depth (m)	**1.5**	**Surface Type**	**Unpaved**	**PS-2-Test-2**
Direction		**Thickness (mm)**	**0**	
Cone Angle (degrees)	**60**	**Thickness (mm)**		
Zero Error (mm)	**2**	**Surface Moisture**	**Dry**	
No.	**Blows**	**Cumulative Blows**	**Penetration Depth**	**Penetration Rate**
7	1	6	275	6
8	1	7	282	7
9	1	8	292	10
10	1	9	297	5
11	1	10	307	10
12	1	11	315	8
13	1	12	327	12
14	1	13	332	5
15	1	14	342	10
16	1	15	349	7
17	1	16	352	3
18	1	17	356	4
19	1	18	362	6
20	1	19	366	4
21	1	20	374	8
22	1	21	379	5
23	1	22	387	8
24	1	23	390	3
25	1	24	397	7
26	1	25	405	8
27	1	26	410	5
28	1	27	416	6
29	1	28	420	4
30	1	29	426	6
31	1	30	430	4
32	1	31	436	6
33	1	32	442	6
34	1	33	448	6
35	1	34	469	21
36	1	35	490	21
37	1	36	518	28
38	1	37	548	30
39	1	38	569	21
40	1	39	592	23
41	1	40	611	19
42	1	41	630	19
Remarks:	avg. penetration rate = 9.8			

APPENDIX A-3: DCP Test summary

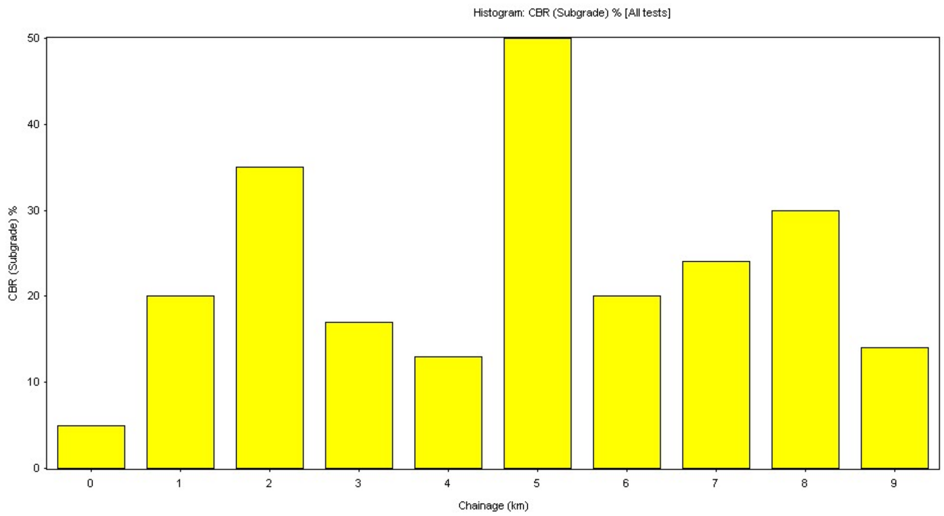
Title	**Tests Summary Report**						
Project Name	**Tertiary canal DCP Test**						
Test No.	**Chainage (km)**	**Location**	**Offset (m)**	**Surface Type**	**Surface Moisture**	**Subgrade CBR**	**SNP**
1	0.1	Carriageway		Unpaved	0.51 (Dry)	8	1.08
2	1	Carriageway		Unpaved	0.51 (Dry)	11	1.3
3	6	Carriageway		Unpaved	0.51 (Dry)	14	1.49
4	8	Carriageway		Unpaved	0.51 (Dry)	15	1.54

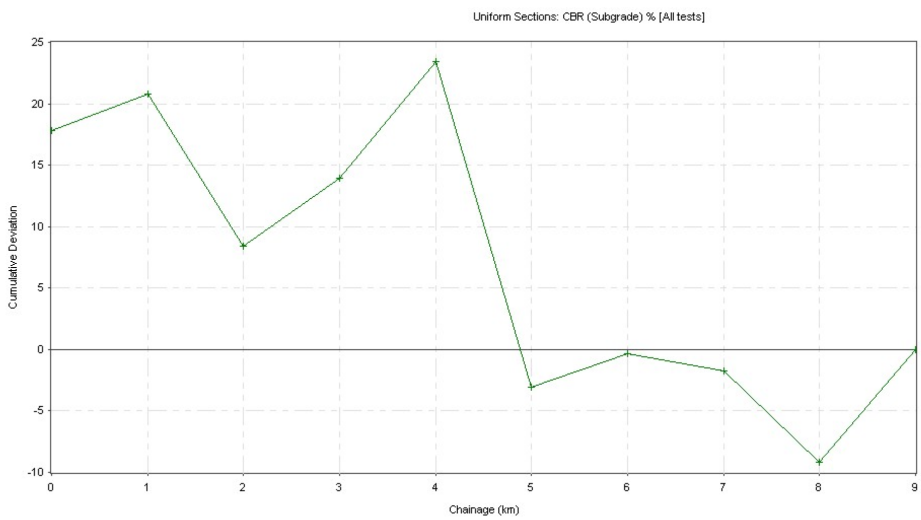
Title	**Tests Summary Report**					
Project Name	**DCP test along primary canal-2 farm road**					
			Upper Layers			
Test No.	**Chainage (km)**	**Location**	**Surface Type**	**Surface Moisture**	**Subgrade CBR**	**SNP**
1	0	Carriageway	Unpaved	0.51 (Dry)	32	1.93
2	1	Carriageway	Unpaved	0.51 (Dry)	8	1.09
3	2	Carriageway	Unpaved	0.51 (Dry)	21	1.74
4	3	Carriageway	Unpaved	0.51 (Dry)	13	1.44
5	4	Carriageway	Unpaved	0.51 (Dry)	20	1.69
6	5	Carriageway	Unpaved	0.51 (Dry)	45	2.05

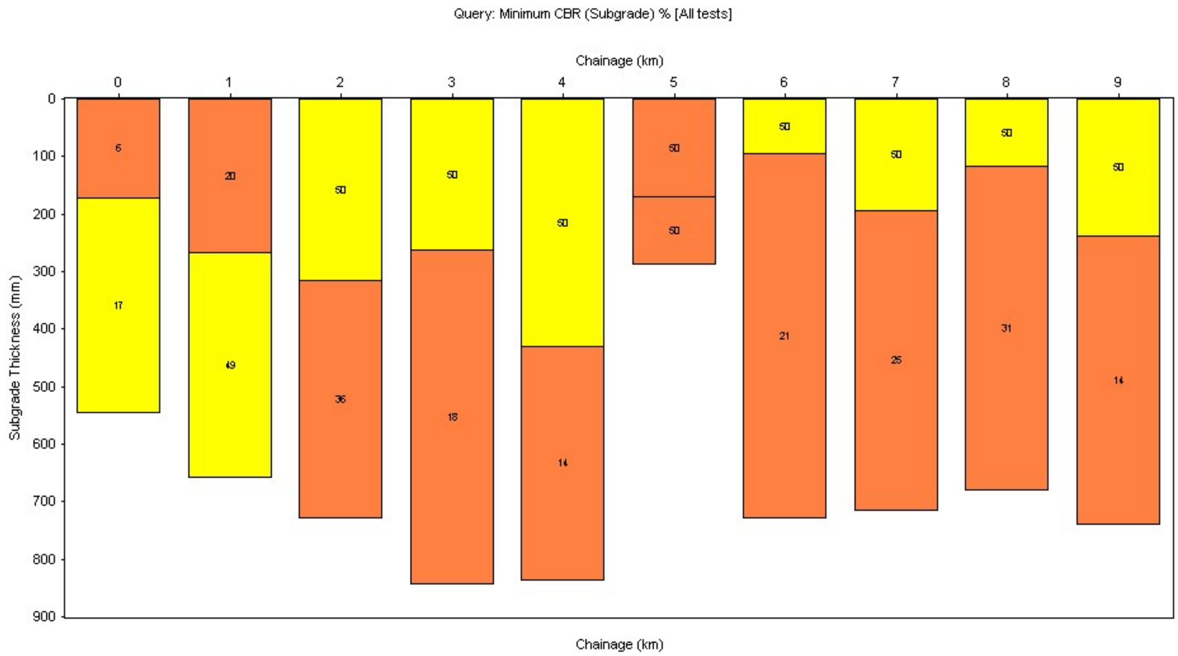
Title	Tests Summary Report					
Project Name	DCP test along primary canal-1					
Test No.	**Chainage (km)**	**Location**	**Surface Type**	**Surface Moisture**	**Subgrade CBR**	**SNP**
1	0	Carriageway	Unpaved	0.51 (Dry)	13	1.43
2	1.7	Carriageway	Unpaved	0.51 (Dry)	4	0.28
3	3	Carriageway	Unpaved	0.51 (Dry)	26	1.84
4	4.5	Carriageway	Unpaved	0.51 (Dry)	50	2.08
5	5	Carriageway	Unpaved	0.51 (Dry)	12	1.34

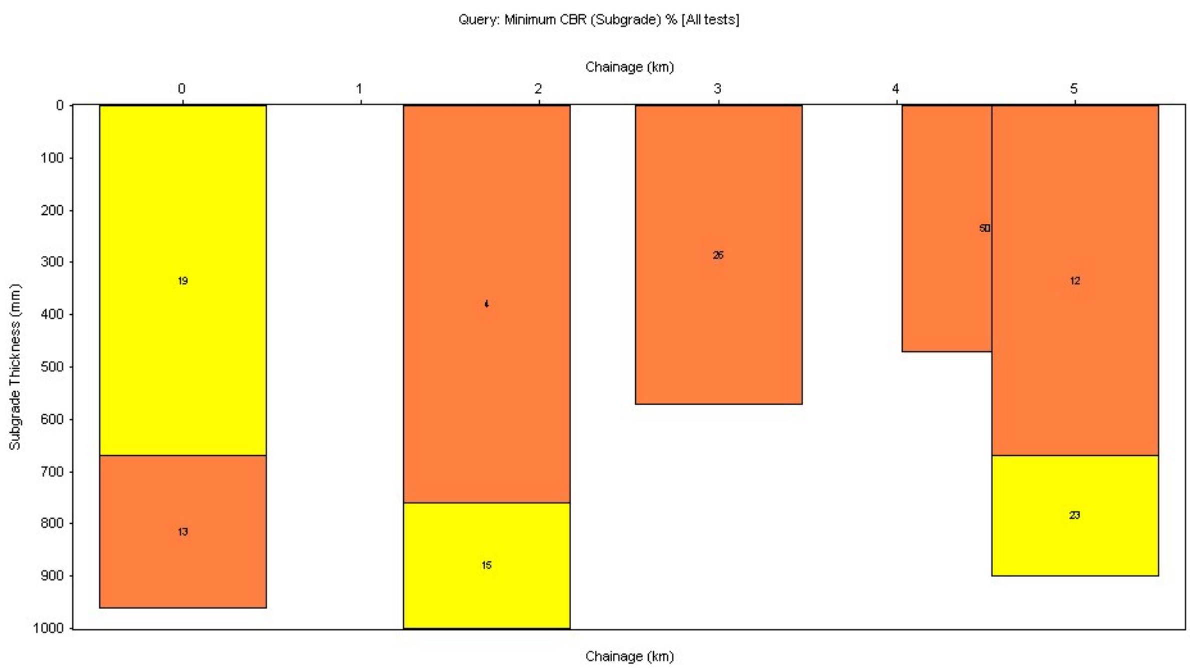
APPENDIX A-4: DCP Test CBR Graphs

MAIN CANAL FARMROAD

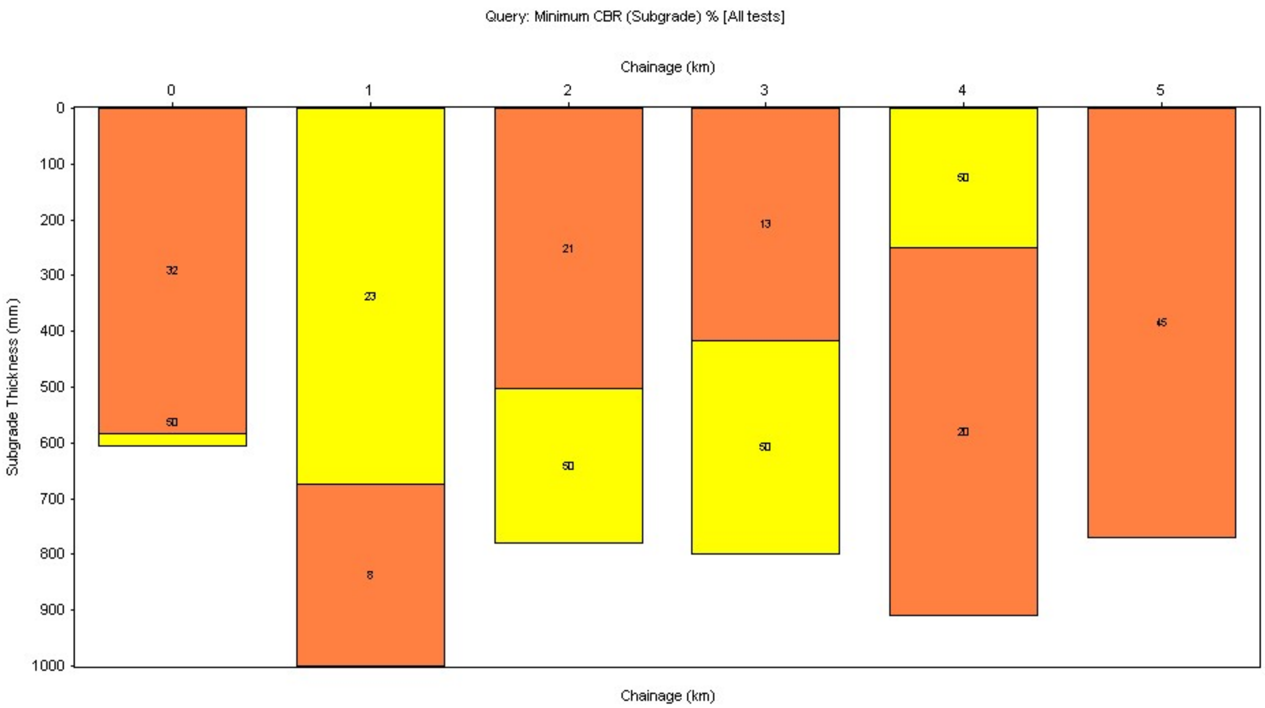


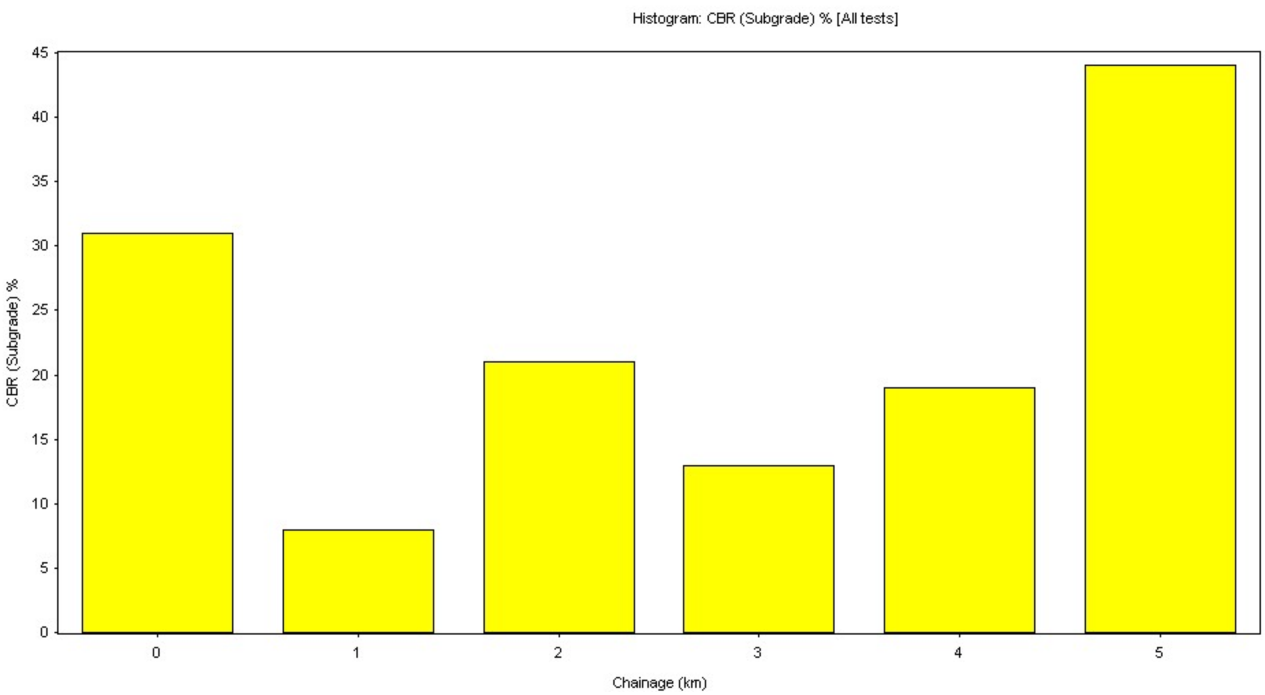



Query: Minimum CBR (Subgrade) % [All tests]
Chainage (km)
Subgrade Thickness (mm)
6
17
20
49
50
36
50
18
50
14
50
50
50
21
50
25
50
31
50
14
Chainage (km)


Query: Minimum CBR (Subgrade) % [All tests]
Chainage (km)
Subgrade Thickness (mm)
19
13
4
15
26
50
12
23
Chainage (km)

MAIN CANAL-1 FARM ROAD GRAPHS





APPENDIX A-5: Infiltration test Raw Data

	Document No.	Issue No.	Page No.	
	OF/WWDSE/338 /	1	1 of 1	

Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. MC-TP-1-IN1	Date: 23/04/07	Replication 1	Author:- A.T
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 3.0			N:191576
			E:573650
			Datum: ADINDAN

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
1:40	0	0	7.0	7.0	0.0	0.0	0	0
	2	2		7.2	0.2	0.2	6.0	6.0
	2	4		7.5	0.3	0.5	9.0	7.5
	2	6		7.6	0.1	0.6	3.0	6.0
	2	8		7.7	0.1	0.7	3.0	5.3
	5	13		7.8	0.1	0.8	1.2	3.7
	5	18		7.9	0.1	0.9	1.2	3.0
	5	23		8.0	0.1	1.0	1.2	2.6
	10	33		8.1	0.1	1.1	0.6	2.0
	10	43		8.2	0.1	1.2	0.6	1.7
	10	53		8.3	0.1	1.3	0.6	1.5
	10	63		8.5	0.2	1.5	1.2	1.4
	15	78		8.6	0.1	1.6	0.4	1.2
	15	93		8.7	0.1	1.7	0.4	1.1
	15	108		9.1	0.4	2.1	1.6	1.2
	15	123		9.9	0.8	2.9	3.2	1.4
	20	143		10.2	0.3	3.2	0.9	1.3

Remarks:

	Document No.	Issue No.	Page No.	
	OF/WWDSE/338 /	1	1 of 1	

Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. MC-TP-2-IN1	Date: 12/05/07	Replication 1	Author:- A.T
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 1.0			N:192606
			E:574292
			Datum: ADINDAN

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
23:00	0	0	186.5	186.5	0.0	0.0	0	0
	2	2		187.5	1.0	1.0	30	30.0
	2	4		188.5	1.0	2.0	30	30.0
	2	6		188.8	0.3	1.3	9	13.0
	2	8		189.1	0.3	0.6	9	4.5
	5	13		190.0	0.9	1.2	10.8	5.5
	5	18		190.5	0.5	1.4	6	4.7
	10	28		191.1	0.6	1.1	3.6	2.4
	10	38		192.8	1.7	2.3	10.2	3.6
	10	48		193.7	0.9	2.6	5.4	3.2
	10	58		194.8	1.1	2.0	6.6	2.1
	15	73	71.2	72.0	0.8	1.9	3.2	1.6
	15	88		72.3	0.3	1.1	1.2	0.7
	15	103		72.8	0.5	0.8	2	0.5
	15	118		78.0	5.2	5.7	20.8	2.9
	15	133		89.0	11.0	16.2	44	7.3
	15	148		98.0	9.0	20.0	36	8.1

Remarks: 54 lts of water used for test, the test conducted at depth of 1.00m, 25cm moisture penetration, source of water is Omo river and dia. If the inner ring =33cm & outer dia.= 57cm 50lts was used for pre-wetting before the test.

	Document No.	Issue No.	Page No.	
	OF/WWDSE/338 /	1	1 of 1	

Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. MC-CD-6-TP-1-IN1	Date: 09/05/07	Replication 1	Author:- A.T
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 1.5			N:574292
			E:194762
			Datum: Adindan

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
23:00	0	0	60.9	60.9	0.0	0.0	0	0
	2	2		70.0	9.1	9.1	273.0	273.0
	2	4		70.1	0.1	9.2	3.0	138.0
	5	9		70.2	0.1	9.3	1.2	62.0
	5	14		70.3	0.1	9.4	1.2	40.3
	5	19		70.4	0.1	9.5	1.2	30.0
	5	24		70.5	0.1	9.6	1.2	24.0
	10	34		70.8	0.3	9.9	1.8	17.5
	10	44		80.5	9.7	19.6	58.2	26.7
	10	54		80.8	0.3	19.9	1.8	22.1
	10	64		80.9	0.1	20.0	0.6	18.8
	15	79		90.4	9.5	29.5	38.0	22.4
	15	94		90.8	0.4	29.9	1.6	19.1
	15	109		100.0	9.2	39.1	36.8	21.5
	15	124		100.6	0.6	39.7	2.4	19.2
	20	144		101.0	0.4	40.1	1.2	16.7
	20	164		101.7	0.7	40.8	2.1	14.9
	20	184		102.4	0.7	41.5	2.1	13.5

Remarks: 27 lts of water used for test, the test conducted at depth of 1.50m, 60cm moisture penetration, source of water is Omo river and dia. If the inner ring =28cm & outer dia.= 56cm 54lts was used for pre wetting before the test.

	Document No.	Issue No.	Page No.	
	OF/WWDSE/338 /	1	1 of 1	

Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. MC-TP-2-IN1	Date: 13/05/07	Replication 1	Author:- A.T
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 1.5			N: 195924
			E: 576969
			Datum: Adindan

Local	Interval (min)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
23:00	0	0	70.2	70.2	0.0	0.0	0	0
	2	2		70.5	0.3	0.3	9.0	9.0
	2	4		80.2	9.7	10.0	291.0	150.0
	2	6		80.7	0.5	10.5	15.0	105.0
	2	8		90.0	9.3	19.8	279.0	148.5
	5	13		100.0	10.0	29.8	120.0	137.5
	5	18		101.0	1.0	30.8	12.0	102.7
	10	28		102.5	1.5	32.3	9.0	69.2
	10	38		103.2	0.7	33.0	4.2	52.1
	10	48		104.5	1.3	34.3	7.8	42.9
	10	58		104.8	0.3	34.6	1.8	35.8
	10	68		105.7	0.9	35.5	5.4	31.3
	15	83	70.0	74.6	4.6	40.1	18.4	29.0
	15	98		75.2	0.6	40.7	2.4	24.9
	15	113		76.4	1.2	41.9	4.8	22.2
	15	128		83.4	7.0	48.9	28.0	22.9
	20	148		90.4	7.0	55.9	21.0	22.7
	20	168		92.3	1.9	57.8	5.7	20.6
;	20	188		93.4	1.1	58.9	3.3	18.8
	20	208		94.5	1.1	60.0	3.3	17.3

Remarks: 54 lts of water used for test, the test conducted at depth of 1.00m, 25cm moisture penetration, source of water is Omo river and dia. If the inner ring =33cm & outer dia.= 57cm
50lts was used for pre wetting before the test.

<table>
<tr><td rowspan="2"></td><td>Document No.</td><td>Issue No.</td><td>Page No.</td><td rowspan="2"></td></tr>
<tr><td>OF/WWDSE/338 /</td><td>1</td><td>1 of 1</td></tr>
<tr><td colspan="5">Project: Omo Valley Farm project</td></tr>
<tr><td colspan="5">Title: Infiltration Rate Measurement Form</td></tr>
<tr><td colspan="2">Test Pit no. MC-TP-3-IN1</td><td>Date: 14/05/07</td><td>Replication 1</td><td>Author:- A.T</td></tr>
<tr><td colspan="4">Surface Features: - Flat surface feature</td><td>UTM Reading</td></tr>
<tr><td colspan="4">Test Depth (m); 2.0</td><td>N:578338</td></tr>
<tr><td colspan="4"></td><td>E:195057</td></tr>
<tr><td colspan="4"></td><td>Datum: Adindan</td></tr>
</table>

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
1:30								

Remarks: due the coarse SAND formation, 150lsts water consume with in 14.25 min.

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	OF/WWDSE/338 /		1		1 of 1			
Project: Omo Valley Farm project								
Title: Infiltration Rate Measurement Form								
Test Pit no. MC-TP-4-IN2			Date: 16/05/07		Replication 1		Author:- A.T	
Surface Features: - Flat surface feature							UTM Reading	
Test Depth (m); 2.0							N:579388	
							E:194976	
							Datum: ADINDAN	
Local	Interval (mm)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
1:30								
Remarks: due the coarse SAND formation, 225lsts water consume with in 40 min.								

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	OF/WWDSE/338 /	1	1 of 1	

Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. MC-TP-4-IN1	Date: 18/05/07	Replication 1	Author:- A.T
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 0.5			N:579388
			E:194976
			Datum: ADINDAN

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
1:30	0	0	7.5	7.5	0.0	0.0	0	0
	2	2		7.7	0.2	0.2	6.0	6.0
	2	4		7.9	0.2	0.4	3.0	6.0
	2	6		8.2	0.3	0.7	3.0	7.0
	5	11		8.9	0.7	1.4	3.8	7.6
	5	16		9.2	0.3	1.7	1.1	6.4
	5	21		9.5	0.3	2.0	0.9	5.7
	10	31		9.8	0.3	2.3	0.6	4.5
	10	41		10.2	0.4	2.7	0.6	4.0
	10	51		10.5	0.3	3.0	0.4	3.5
	15	66		11.0	0.5	3.5	0.5	3.2
	15	81		11.5	0.5	4.0	0.4	3.0
	15	96		12.1	0.6	4.6	0.4	2.9
	20	116	7.5	7.9	0.4	5.0	0.2	2.6
	20	136		8.2	0.3	5.3	0.1	2.3
	20	156		8.5	0.3	5.6	0.1	2.2
	25	181		8.9	0.4	6.0	0.1	2.0
	25	206		9.2	0.3	6.3	0.1	1.8
;								

Remarks: 54 lts of water used for test, the test conducted at depth of 0.50m, 50cm moisture penetration, source of water is Omo river and dia. If the inner ring =28cm & outer dia.= 56cm

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	OF/WWDSE/338 /		1		1 of 1			
Project: Omo Valley Farm project								
Title: Infiltration Rate Measurement Form								
Test Pit no. MC-TP-5-IN1			Date: 23/01/15		Replication 1		Author:- A.T	
Surface Features: - Flat surface feature							UTM Reading	
Test Depth (m); 3.10							N:194814	
							E:579940	
							Datum: ADINDAN	
Local	Interval (mm)	Cumulative time (min)	Depth of water (cm) Initial	Final	Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr) Immediate	Mean
1:28	0	0	7.5	7.5	0.0	0.0	0	0
	2	2		7.9	0.4	0.4	12.0	12.0
	2	4		8.4	0.5	0.9	7.5	13.5
	2	6		9.3	0.9	1.8	9.0	18.0
	5	11		10.0	0.7	2.5	3.8	13.6
	5	16		10.9	0.9	3.4	3.4	12.8
	5	21		11.8	0.9	4.3	2.6	12.3
	10	31		13.2	1.4	5.7	2.7	11.0
3:10	10	41		14.7	1.5	7.2	2.2	10.5
	10	51	7.5	8.9	1.4	8.6	1.6	10.1
	15	66		11.6	2.7	11.3	2.5	10.3
4:00	15	81		13.8	2.2	13.5	1.6	10.0
	15	96	7.5	9.5	2.0	15.5	1.3	9.7
	20	116		12.0	2.5	18.0	1.3	9.3
	20	136	7.5	9.9	2.4	20.4	1.1	9.0
	20	156		12.0	2.1	22.5	0.8	8.7
	20	176	7.5	9.4	1.9	24.4	0.6	8.3
	20	196		11.1	1.7	26.1	0.5	8.0
;								
Remarks: 125 lts of water used for test, the test conducted at depth of 3.10m, 50cm moisture penetration, source of water is Omo river and dia. If the inner ring =18.2cm & outer dia.= 57cm 100lts was used for pre-wetting for two days before the test.								

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Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. MC-01-TP-5-IN1	Date: 23/05/07	Replication 1	Author:- Eyoual
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 0.5			N:581252
			E:198226
			Datum: ADINDAN

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm) Initial	Final	Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr) Immediate	Mean
1:23	0	0	7.5	7.5	0.0	0.0	0	0
	2	2		7.7	0.2	0.2	6.0	6.0
	2	4		7.8	0.1	0.3	1.5	4.5
	2	6		7.9	0.1	0.4	1.0	4.0
	5	11		8.0	0.1	0.5	0.5	2.7
	5	16		8.1	0.1	0.6	0.4	2.3
	5	21		8.3	0.2	0.8	0.6	2.3
	10	31		8.5	0.2	1.0	0.4	1.9
	10	41		8.7	0.2	1.2	0.3	1.8
	10	51		8.9	0.2	1.4	0.2	1.6
	10	61		9.1	0.2	1.6	0.2	1.6
	15	76		9.5	0.4	2.0	0.3	1.6
	15	91		9.8	0.3	2.3	0.2	1.5
	15	106		10.1	0.3	2.6	0.2	1.5
	15	121		10.3	0.2	2.8	0.1	1.4
	20	141		10.8	0.5	3.3	0.2	1.4
	20	161		11.3	0.5	3.8	0.2	1.4
	20	181		11.6	0.3	4.1	0.1	1.4
;								

Remarks: 40 lts of water used for test, the test conducted at depth of 0.50m, source of water is Omo river and dia. 50 lts was used for pre-wetting before the test.

Document No.	Issue No.	Page No.
OF/WWDSE/338 /	1	1 of 1

Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. MC-01-CD-3-IN1	Date: 19/05/07	Replication 1	Author:- Eyoual
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 1.90			N:578435
			E:198217
			Datum: ADINDAN

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
1:23	0	0	7.5	7.5	0.0	0.0	0	0
	2	2		7.7	0.2	0.2	6.0	6.0
	2	4		7.8	0.1	0.3	1.5	4.5
	2	6		7.9	0.1	0.4	1.0	4.0
	5	11		8.1	0.2	0.6	1.1	3.3
	5	16		8.2	0.1	0.7	0.4	2.6
	5	21		8.3	0.1	0.8	0.3	2.3
	10	31		8.5	0.2	1.0	0.4	1.9
	10	41		8.6	0.1	1.1	0.1	1.6
	10	51		8.8	0.2	1.3	0.2	1.5
	10	61		9.0	0.2	1.5	0.2	1.5
	15	76		9.2	0.2	1.7	0.2	1.3
	15	91		9.4	0.2	1.9	0.1	1.3
	15	106		9.7	0.3	2.2	0.2	1.2
	15	121		10.0	0.3	2.5	0.1	1.2
	20	141		10.3	0.3	2.8	0.1	1.2
	20	161		10.6	0.3	3.1	0.1	1.2
	20	181		10.8	0.2	3.3	0.1	1.1
;								

Remarks: 50 lts of water used for test, the test conducted at depth of 1.90m, source of water is Omo river and dia. 50 lts was used for pre-wetting before the test.

	Document No.	Issue No.	Page No.	
	OF/WWDSE/338 /	1	1 of 1	

Project: Omo Valley Farm project

Title: Infiltration Rate Measurement Form

Test Pit no. PC-CD-2-TP-1-IN1	Date: 22/05/07	Replication 1	Author:- A.T
Surface Features: - Flat surface feature			UTM Reading
Test Depth (m); 2.0			N:577935
			E:197977
			Datum: ADINDAN

Local	Interval (min)	Cumulative time (min)	Depth of water (cm)		Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr)	
			Initial	Final			Immediate	Mean
2:30AM	0	0	157.0	157	0.0	0.0	0	0
	2	2		161.2	4.2	4.2	126.0	126.0
	2	4		163.0	1.8	6.0	54.0	90.0
	2	6		165.0	2.0	8.0	60.0	80.0
	5	11		168.0	3.0	11.0	36.0	60.0
	5	16		170.0	2.0	13.0	24.0	48.8
	5	21		173.0	3.0	16.0	36.0	45.7
	10	31	157.0	164.0	7.0	23.0	42.0	44.5
	10	41		170.0	6.0	29.0	36.0	42.4
	10	51		173.0	3.0	32.0	18.0	37.6
	15	66	157.5	166.0	8.5	40.5	34.0	36.8
	15	81		170.0	4.0	44.5	16.0	33.0
	15	96		174.0	4.0	48.5	16.0	30.3
	15	111		178.0	4.0	52.5	16.0	28.4

Remarks: 125 lts of water used for test, the test conducted at depth of 2.0m, 90cm moisture penetration, source of water is Omo river and dia. If the inner ring =33cm & outer dia.= 53cm
54lts was used for pre-wetting before the test.

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	OF/WWDSE/338 /		1	1 of 1				
Project: Omo Valley Farm project								
Title: Infiltration Rate Measurement Form								
Test Pit no. MC-01-TP-1-IN1			Date: 22/05/07	Replication 1			Author:- A.T	
Surface Features: - Flat surface feature							UTM Reading	
Test Depth (m); 0.50							N:577269	
							E:197695	
							Datum: ADINDAN	
Local	Interval (mm)	Cumulative time (min)	Depth of water (cm) Initial	Depth of water (cm) Final	Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr) Immediate	Infiltration rate (cm/hr) Mean
1:40	0	0	7.5	7.5	0.0	0.0	0	0
	2	2		7.6	0.1	0.1	3.0	3.0
	2	4		7.8	0.2	0.3	6.0	4.5
	2	6		8.0	0.2	0.5	6.0	5.0
	5	11		8.4	0.4	0.9	4.8	4.9
	5	16		8.9	0.5	1.4	6.0	5.3
	5	21		9.3	0.4	1.8	4.8	5.1
	10	31		9.9	0.6	2.4	3.6	4.6
	10	41		10.7	0.8	3.2	4.8	4.7
	10	51		11.4	0.7	3.9	4.2	4.6
	10	61		12.3	0.9	4.8	5.4	4.7
	15	76		13.5	1.2	6.0	4.8	4.7
	15	91	7.5	8.5	1.0	7.0	4.0	4.6
	15	106		9.5	1.0	8.0	4.0	4.5
	15	121		10.4	0.9	8.9	3.6	4.4
	20	141		11.8	1.4	10.3	4.2	4.4
	20	161		13.2	1.4	11.7	4.2	4.4
	20	181		14.6	1.4	13.1	4.2	4.3

Remarks: 75lts of water used for test, the test conducted at depth of 5.0m, 50cm moisture penetration, source of water is Omo river and dia. If the inner ring =28cm & outer dia.= 56cm
50lts was used for pre-wetting befor the test.

	Document No.		Issue No.		Page No.		
	OF/WWDSE/338 /		1		1 of 1		
Project: Omo Valley Farm project							
Title: Infiltration Rate Measurement Form							
Test Pit no. MC-01-TP-3-IN1			Date: 27/01/15		Replication 1	Author:- A.T	
Surface Features: - Flat surface feature						UTM Reading	
Test Depth (m); 1.50						N:	
						E:	
						Datum: ADINDAN	

Local	Interval (mm)	Cumulative time (min)	Depth of water (cm) Initial	Depth of water (cm) Final	Intake (cm)	Cumulative intake (cm)	Infiltration rate (cm/hr) Immediate	Infiltration rate (cm/hr) Mean
1:40	0	0	7.5	7.5	0.0	0.0	0	0
	2	2		7.6	0.1	0.1	3.0	3.0
	2	4		7.8	0.2	0.3	6.0	4.5
	2	6		7.9	0.1	0.4	3.0	4.0
	5	11		8.0	0.1	0.5	1.2	2.7
	5	16		8.1	0.1	0.6	1.2	2.3
	5	21		8.1	0.0	0.6	0.0	1.7
	10	31		8.2	0.1	0.7	0.6	1.4
	10	41		8.4	0.2	0.9	1.2	1.3
	10	51		8.5	0.1	1.0	0.6	1.2
	15	66		8.9	0.4	1.4	1.6	1.3
	15	81		9.1	0.2	1.6	0.8	1.2
	15	96		9.3	0.2	1.8	0.8	1.1
	15	111		9.5	0.2	2.0	0.8	1.1
	20	131		9.7	0.2	2.2	0.6	1.0
	20	151		9.9	0.2	2.4	0.6	1.0
	20	171		10.2	0.3	2.7	0.9	0.9
	20	191		10.4	0.2	2.9	0.6	0.9
	20	211		10.6	0.2	3.1	0.6	0.9

Remarks: 50lts of water used for test, the test conducted at depth of 5.0m, 50cm moisture penetration, source of water is Omo river and dia. If the inner ring =28cm & outer dia.= 56cm
50lts was used for pre-wetting befor the test.

APPENDIX-B

APPENDIX B-1: Summary of Laboratory Test Results

OMO VALLEY FARM PROJECT
SUMMARY OF LABORATORY RESULTS
PUMP STATION & GULLY CROSS SITE

						Grain size distribution					Atterberg Limits						Direct Shear			Chemical	
Nº	TP ID	Location of Test pit	Sample type	Sample Depth (m)	Unit weight (gm/cc)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fine (%)	LL (%)	PL (%)	PI (%)	Free Swell (%)	Hole	NMC (%)	C (KPa)	f (Deg.)	Conso. Cc	Sulphate (meq/l)	Chloride (meq/l)
1			BDS	0.0-5.0	1.12									47.5			48.33	18.00	0.246	8.48	10.36
2			SDS	0.0-2.50			65.8	25.9	8.3	34.2	22.89	NP				4.89					
3	PS-1-TP1	Prop. Pump	SDS	2.5-5.0			30.4	48.4	21.2	69.6	31.86	20.70	11.16								
4			BDS	0.0-5.0	1.07									42.5			15	26	0.19	5.72	8.96
5			SDS	0.0-1.30			41.28	43.22	15.50	58.7	27.01	17.49	9.52			5.14					
6			SDS	1.3-3.0			36.36	48.35	15.29	63.6	29.05	24.22	4.83			8.47					
7	PS-1-TP2	Prop. Pump	SDS	3.0-5.0			24.44	47.75	27.81	75.6	39.48	22.33	17.15			16.45					
8		GULLY	BDS	0.0-5.0	1.69									0.0			38.33	28.15	0.032	0.24	0.7
9	G-2-TP-1	CROSS	SDS	1.0-3.70		28.00	66.59	4.71	0.00	4.7	25.12	NP									
10			BDS	0.0-5.0	1.57									0.0			42.33	29.45	0.190	0.26	1.12
11			SDS	1.20-3.0		21.00	73.54	5.46	0.00	5.5	26.10	NP				0.37					
12	PS-2-TP1	BOOSTER	SDS	3.0-5.0			94.53	5.47	0.00	5.5	26.40	NP									

OMO VALLEY FARM PROJECT
SUMMARY OF LABORATORY RESULTS
MAIN CANAL SITE

Nº	TP ID	Location of Test pit	Sample type	Sample Depth (m)	Unit weight (gm/cc)	Grain size Analysis Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fine (%)	Atterberg Limits LL (%)	PL (%)	PI (%)	Free Swell	NMC (%)	Permeab. (cm/sec)	Direct Shear C (KPa)	f (Deg.)	Cc	Chemical Sulphate (meq/l)	Chloride (meq/l)
1	MC-TP-1	Main canal alignment	BDS	0.0-3.0	1.45											2.29*10-2	4.33	37.6	0.0341	0.35	0.56
2			SDS	0.60-1.80		2.23	93.97	3.8	0.00	4	27.06	NP			5.2						
3			SDS	1.80-3.00		13.24	69.73	13.15	3.88	17	24.00	NP			7.82						
4	MC-CD3-TP1	Main canal Cross Drain	BDS	0.0-5.0	1.31									10.00			9.93	30.42		4.78	0.70
5			SDS	0.0-1.50			86.64	9.25	4.11	13	22.50	NP			0.54						
6			SDS	3.20-5.0			57.12	38.90	9.98	49	32.78	NP			1.12						
7	MC-CD4-TP1	Main canal Cross Drain	BDS	0.0-5.0	1.34									0.00			28.00	27.92		3.99	0.42
8			SDS	1.0-2.80			51.12	38.90	9.98	49	22.30	15.56	6.74		10.78						
9			SDS	2.80-5.0			93.23	5.12	1.68	7	24.04	NP									
10	MC-CD5-TP1	Main canal Cross Drain	BDS	1.10-5.0	1.27									0.00			32.16	27.65		0.26	0.35
11			SDS	1.10-3.30			62.59	32.91	4.50	37	17.55	NP			1.97						
12	MC-CD6-TP1	Main canal Cross Drain	BDS	1.50-5.0	1.35									37.50			18.93	28.26		3.99	0.21
13			SDS	1.50-2.0			56.55	33.79	9.66	43	42.68	23.85	18.83		2.43						
14			SDS	2.10-5.0		13.94	77.98	7.17	0.91	8	23.27	NP			0.87						

OMO VALLEY FARM PROJECT

SUMMARY OF LABORATORY RESULTS

PRIMARY CANAL(Main canal) SITE

Nº	TPID	Location ofTest pit	Sampletype	SampleDepth(m)	Unitweight(gm/cc)	Grain size distribution					Atterberg Limits			FreeSwell(%)	Doub.Hydrometer	NMC(%)	Permeab.(cm/sec)	Direct Shear		Con dn.	Chemical	
						Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Fine (%)	LL (%)	PL (%)	PI (%)					C(KPa)	F(Deg.)	Cc	Sulphate (meq/l)	Chloride (meq/l)
1	MC-TP4	Primary canal-1	BDS	0.0-1.70	1.24		61.00	28.00	11.00	39				10.00	ND		.4.24*10-5				0.8	0.14
2			SDS	0.0-1.70							42.42	21.50	20.92									
3	MC-CD4	Cross drainage	SDS	0.50-1.0			42.00	42.00	12.00	54												
4			SDS	1.8-3.0		62.00	38.00															
5	MC-01-TP6	Pri.canal-2	BDS	0.0-3.0	1.31		80.00	14.00	6.00	20	25.24	NP		0.00	ND		8.17*10-4					
6			SDS	0.5-1.0		2.00	80.00	16.00	2.00	18												
7	MC-01-CD-2	Cross drainage	BDS	1.60-4.0	1.34									5.00				43.66	23.99	0.057	0.64	
8			SDS	1.60-2.0			93.66	3.08	3.26		20.95	NP				1.39						
9	MC-01-CD-3	Cross drainage	BDS	1.10-5.0	1.21									10.0				54.39	23.57		0.33	0.14
10			S	1.10			42.4	53.3	4.25	58	33.7	27.5	6.16			2.39						

			DS	-2.0			1	5			2	6										
11			SDS	2.0-5.0			59.70	37.80	2.49	40	26.39	19.89	6.50			1.76						
12	MC-01-CD-7	Cross drainage	BDS	1.0-3.50	1.38									0.0						0.046	1.72	0.21
13			SDS	1.0-3.50		7.93	43.25	35.41	13.40	49	25.05	14.60	10.45			0.46						

Project :- Omo Valley Farm Project									
Location :- Quarry Site									
II	**Rock Samples**								
No	**Sample ID**	**Location of Quarry Site**	**Sample Depth (m)**	**SG**	**Water Absorption (%)**	**AIV (%)**	**Soundness (SSS) (%)**	**LAA (%)**	**Point Load (Mpa)**
1	**RQ1**	Quarry-1	**Surface**	3.01	0.62	39.92	2.56	49.95	6.62

REMARK
LAA-
AIV-Aggregate Impact Value
SSS-Soundness by Sodium Sulphate
SG- (Specific Gravity)

Project :- Omo Valley Farm Project														
Location :- River deposits														
III	**Sand/Aggregate & Filter**													
Nº	**TP/BH ID**	**Location of Borrow/Quarry**	**Sample Type**	**Depth (m)**	**Specific gravity**	**Grain size distribution**					**LAA (%)**	**Soundness (%)**	**Fineness Modulus**	**Water Absorption (%)**
						Gravel (%)	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Fine (%)**				
1	S1	Sand Sewugela River	SDS	0.0-3.0	2.77	17.71	64.76	14.13	3.40	17.53				
2			BDS	0.0-							N/A	12.13	3	2.86

				3.0										

OMO VALLEY FARM PROJECT																			
SUMMARY OF LABORATORY RESULTS																			
CLAY BORROW SITE																			
						Grain size distribution				**Atterberg Limits**				**Compaction**				**Chemical**	
Nº	**TP ID**	**Location of Test pit**	**Sample type**	**Sample Depth (m)**	**Unit weight (gm/cc)**	**Sand** (%)	**Silt** (%)	**Clay** (%)	**Fine** (%)	**LL** (%)	**PL** (%)	**PI** (%)	**Free Swell** (%)	**NMC** (%)	**OMC** (%)	**MDD** (g/cm 3)	**Permeab.** (cm/sec)	**Sulphate** (meq/l)	**Chloride** (meq/l)
1	**CB-TP-1**	**Clay borrow-2**	**BDS**	0.0-3.0	1.15								57.50		25.20	1.574	1.44*10-2	2.14	2.94
2			**SDS**	0.50-3.0		12.38	58.12	29.50	**87.62**	45.77	23.13	22.64		7.28					
3	**CB-TP-2**	**Clay borrow-1**	**BDS**	0.0-3.0	1.66								42.50		25.40	1.508	2.41*10-5	2.14	2.94
4			**SDS**	0.0-1.60		7.48	83.88	8.64	**92.52**	34.79	27.28	7.51		11.43					

APPENDIX B-2: Tables & Chart Reference Used for Analysis

ตารางที่ 4.7 ตารางเปรียบเทียบดินที่จัดกลุ่มตามระบบ AASHTO กับ USCS (Liu, 1970)

Soil group in USCS	Comparable soil groups in AASHTO system		
	Most probable	Possible	Possible but improbable
A-1a	GW, GP	SW, SP	GM, SM
A-1b	SW, SP, GM, SM	GP	-
A-3	SP	-	SW, GP
A-2-4	GM, SM	GC, SC	GW, GP, SW, SP
A-2-5	GM, SM	-	GW, GP
A-2-6	GC, SC	GM, SM	GW, GP
A-2-7	GM, GC, SM, SC	-	GW, GP, SW, SP
A-4	ML, OL	CL, SM, SC	GM, GC
A-5	OH, MH, ML, OL	-	SM, GM
A-6	CL	ML, OL, SC	GC, GM, SM
A-7-5	OH, MH	ML, OL, CH	GM, SM, GC, SC
A-7-6	CH, CL	ML, OL, SC	OH, MH, GC, GM, SM

Table 5.1. AASHTO Classification System

General Classification	*Granular materials (35% or less passing No. 200 Sieve (0.075 mm))*							*Silt-clay Materials More than 35% passing No. 200 Sieve (0.075 mm)*			
Group Classification	*A—1*		*A—3*	*A—2*				*A—4*	*A—5*	*A—6*	*A—7*
	A—1—a	*A—1—b*		*A—2—4*	*A—2—5*	*A—2—6*	*A—2—7*				*A—7—5* *A—7—6*
(*a*) Sieve Analysis: Percent Passing											
(*i*) 2.00 mm (No. 10)	50 max										
(*ii*) 0.425 mm (No. 40)	30 max	50 max	51 min								
(*iii*) 0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
(*b*) Characteristics of fraction passing 0.425 mm (No. 40)											
(*i*) Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
(*ii*) Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
(*c*) Usual types of significant Constituent materials	Stone Fragments Gravel and sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
(*d*) General rating as subgrade.	Excellent to Good							Fair to Poor			

* If plasticity index is equal to or less than (liquid Limit—30), the soil is A—7—5 (*i.e.* PL > 30%)
If plasticity index is greater than (Liquid Limit—30), the soil is A—7—6 (*i.e.* PL < 30%)

TABLE 15.2 Classification of Soils and Soil-Aggregate Mixtures by the AASHTO System

General Classification	Granular Materials (35% or Less Passing 0.075 mm)			Silt-Clay Materials (More than 35% Passing 0.075 mm)			
Group Classification	A-1	A-3[a]	A-2	A-4	A-5	A-6	A-7
Sieve analysis, percent passing:							
2.00 mm (No. 10)	—	—	—	—	—	—	—
0.425 mm (No. 40)	50 max.	51 min.	—	—	—	—	—
0.075 mm (No. 200)	25 max.	10 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing 0.425 mm (No. 40)							
Liquid limit	—	—		40 max.	41 min.	40 max.	41 min.
Plasticity index	6 max.	N.P.	*b*	10 max.	10 max.	11 min.	11 min.
General rating as subgrade	Excellent to good			Fair to poor			

[a] The placing of A-3 before A-2 is necessary in the "left to right elimination process" and does not indicate superiority of A-3 over A-2.

[b] See Table 15.3 for values.

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Table 5.1. AASHTO Classification System

General Classification	*Granular materials (35% or less passing No. 200 Sieve (0.075 mm)*							*Silt-clay Materials More than 35% passing No. 200 Sieve (0.075 mm)*			
Group Classification	*A—1*		*A—3*	*A—2*				*A—4*	*A—5*	*A—6*	*A—7*
	A—1—a	*A—1—b*		*A—2—4*	*A—2—5*	*A—2—6*	*A—2—7*				*A—7—5* *A—7—6*
(*a*) Sieve Analysis: Percent Passing											
(*i*) 2.00 mm (No. 10)	50 max										
(*ii*) 0.425 mm (No. 40)	30 max	50 max	51 min								
(*iii*) 0.075 mm (No. 200)	15 max	25 max	10 max	35 max	35 max	35 max	35 max	36 min	36 min	36 min	36 min
(*b*) Characteristics of fraction passing 0.425 mm (No. 40)											
(*i*) Liquid limit				40 max	41 min	40 max	41 min	40 max	41 min	40 max	41 min
(*ii*) Plasticity index	6 max		N.P.	10 max	10 max	11 min	11 min	10 max	10 max	11 min	11 min*
(*c*) Usual types of significant Constituent materials	Stone Fragments Gravel and sand		Fine Sand	Silty or Clayey Gravel Sand				Silty Soils		Clayey Soils	
(*d*) General rating as subgrade.	Excellent to Good							Fair to Poor			

* If plasticity index is equal to or less than (liquid Limit—30), the soil is A—7—5 (*i.e.* PL > 30%)
If plasticity index is greater than (Liquid Limit—30), the soil is A—7—6 (*i.e.* PL < 30%)

APPENDIX-C

APPENDIX C-1: Site Photographs






Photo: 8- 5: Photo view of construction material sites

Photo: 8- 6: Photo View of field Investigation methodology