4.6 HYDROMETEOROLOGY

A detailed hydro-meteorological study for the study area has been carried out using data obtained from the National Meteorological Agency (NMA). Data has been collected from seven stations in and around the sub-basin. The Report on Sibilu and Gerbi Dam Project, Engineering Geological Investigations, 1986 has been referred to.

4.6.1 CLIMATIC CONDITIONS

4.6.1.1 Rainfall

The position of Inter-Tropical Convergence Zone (ITCZ) and seasonal variations in pressure systems and air circulation, result in the seasonal distribution of rainfall over the project area. This low-pressure area of convergence between tropical easterlies and equatorial westerlies causes equatorial disturbances to take place.

The distribution of rainfall over the highland areas is modified by orographic effects and is significantly correlated with altitude. The main rainy season often extends from end of June through end of September and the small rainy season from end of March to middle of April, the rest of the months are generally dry. **Table 4.3** gives the mean monthly climatic elements as recorded at Fiche, which is the nearest meteorological observatory located about 40 km from the project site.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	13.54	14.39	15.10	15.24	15.09	15.08	13.70	13.08	13.50	12.74	12.67	13.21
Wind (m/ s)	1.8	1.9	2	2	2.2	2	1.8	1.6	2.2	1.6	1.6	1.8
Sunshine (hrs)	8.8	7.7	7.3	7.2	7.5	7	5	5.4	7	8.2	8.8	8.2
Humidity (%)	55.00	47.43	57.35	54.57	50.45	60.70	82.94	84.39	75.15	63.67	59.16	53.71
Evaporation (mm)	137.4	163.96	134.42	144.88	184.1	120.26	47.66	38.48	66.36	112.98	126.72	147.82

Table 4.3 : Mean Monthly Climatic Parameters at Fiche

Rainfall records of eight stations in the vicinity of the project area have been considered to describe the rainfall regime of the area. The pattern of the seasonality of rainfall in the project area is determined by analyzing mean monthly rainfall ratio with that of rainfall module as rainfall coefficient (Daniel Gemechu, Aspects of Climate and Water Budget, 1977).

Rainfall Coefficient	Designation
<0.6	Dry
=> 0.6	Rainy
0.6 to 0.9	Small Rains
> or = 1	Big Rains
1.0 to1 .9	Moderate
2 to 2.9	High
3.0 and over	Very High

4.6.1.2 Rainfall Analyses

In May, the Egyptian high pressure system continues to weaken and ITCZ moves northwards; and in June & July it reaches partially northern Ethiopia and fully north of Ethiopia. The cyclonic cells along the ITCZ lie over Sudan and Arabia. The weak high pressure system over Ethiopia has southeast to northwest axis. This system depresses the ITCZ southwards in north-eastern Eritrea paralleling the Red Sea coast.

The equatorial Indian Ocean's southerly air currents produce dry conditions in southeastern Ethiopia because the air masses subside and blow dry towards the horn. The rest of the country is under equatorial westerlies ascending over the highlands producing the main rainy season.

4.6.1.3 Monthly and Seasonal Distribution of Rainfall

As discussed previously, the area is characterized by two rainfall regimes having six rainy months with bimodal rainfall pattern. The rainy months extend from March to April and June to September and about 80% of the annual rainfall amount occurs during the latter four months. Mean monthly rainfall plots of representative stations are given in **Table 4.4** and depicted in **Fig. 4.16.** The rainfall details at these stations are enclosed as **Annex 4.1**. Very high concentration of rainfall in the months of July and August is markedly distinguished.

The mean annual rainfall of the area is estimated to be about 1158 mm.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Addis Ababa	15.5	38.7	66.8	89.4	83.0	130.7	259.5	276.5	170.9	36.5	7.9	9.5
Chancho	28.5	24.2	61.6	61.0	59.9	133.2	308.2	321.8	125.3	38.1	13.3	13.5
Derba	14.2	31.1	62.2	64.1	122.8	119.8	307.9	320.1	159.0	27.8	9.5	16.2
Entoto	13.3	47.1	68.7	103.2	79.2	131.2	290.8	342.8	166.5	30.8	8.6	6.5
Muketuri	21.7	17.9	59.6	51.3	50.3	90.6	286.2	277.7	87.2	38.8	3.7	9.9
Sendafa	20.4	28.6	56.7	78.8	55.6	111.9	314.5	326.2	121.8	22.2	6.1	7.7
Sululta	27.5	18.0	62.4	64.3	60.7	152.9	313.7	323.2	117.0	24.1	9.5	4.8
Fiche	21.2	33.2	57.3	65.8	51.0	74.0	231.9	260.1	120.5	31.1	8.1	5.6

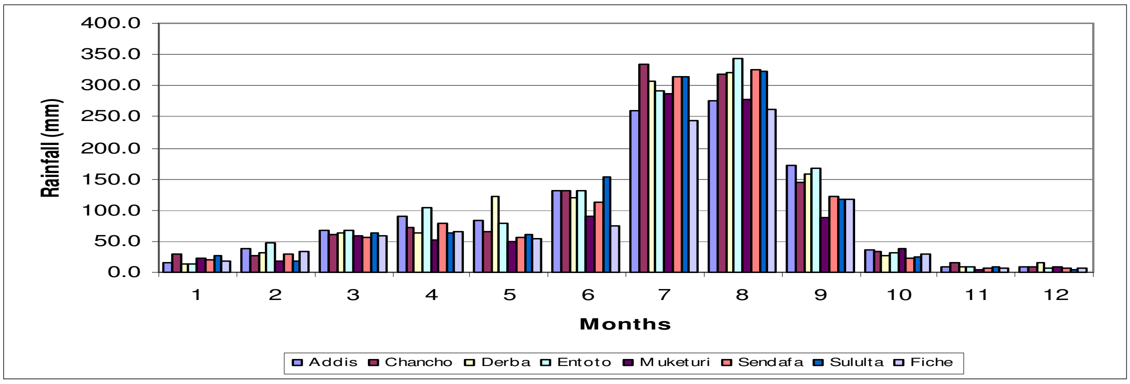

Table 4.4 : Rainfall (mm) at Key Stations

Fig. 4.16 : Mean Monthly Rainfall

Even though data of many stations were collected as above for different parameters, which have been used for regional checks (external consistency), the main data source, representing typically the project area under study, is Addis Ababa.

In view of the overall hydro-meteorological data situation, rainfall data of 15 years is used for the present study.

4.6.1.4 River Flow Analysis

The project area runoff records from Mugher, Deneba and Sibilu rivers were collected for analyzing the statistical descriptors of the catchment yields for the rivers within the project area (Refer **Annex 4.2**).

Such estimates can be relied upon because measurements are taken for sufficient period. In the absence of such records, estimates may be made from records of nearby and similar catchments or generation from rainfall. Only Chancho rainfall and Mugher river flow have good correlation if generation of synthetic flow is required.

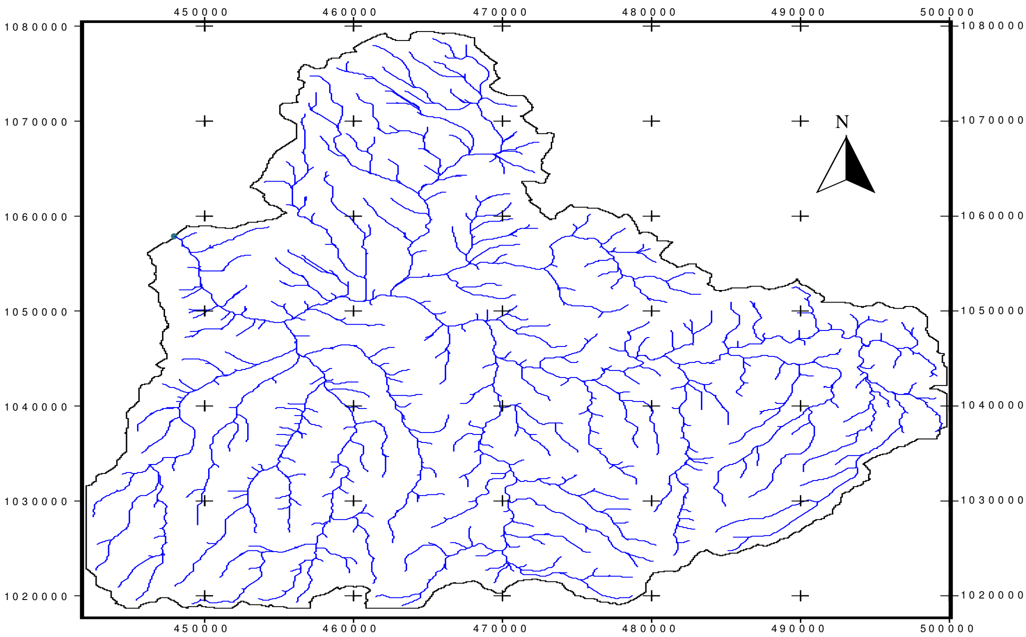

Fig. 4.17 : Derba Drainage Network Map

As seen from the drainage network map in **Fig. 4.17**, the system of rivers is of fifth-order streams as catchments form indicating the amount of branching in the basin where the project site lies. The drainage density is high showing the highly dissected basin that should respond relatively rapidly to rainfall input.

As a result of this phenomenon there are many tributaries of Mugher, namely Aleltu (whose tributary is Gununfela), Kersa, Nara, Guda, Duber, Sibilu, Aleltu (near Derba town), Bole, Kersa Lebu, Duketu and Jema river where the latter 6 confluence with the former ones near Mugher town.

The shape of the catchment is almost circular showing fast response to rainfall input whose surface runoff will be abundant for any conservation scheme. The mean monthly run-off at three stations is given in **Table 4.5**.

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Siblu	*0.53*	*0.35*	*0.41*	*0.52*	*0.59*	*1.61*	*35.54*	*92.02*	*39.27*	*5.10*	*1.39*	*0.80*	***178.15***
Deneba	0.14	0.06	0.05	0.07	0.15	0.41	11.13	32.11	12.52	3.25	1.74	0.24	**62.37**
Mugher	0.65	0.58	0.70	0.85	0.89	2.11	51.81	119.85	53.93	7.67	2.15	1.02	**246.65**

Table 4.5 : Mean Monthly Runoff (Mm^3)

The monthly discharge of Sibilu river ranges from 0.35 million m^3 in February to 92.02 million m^3 in August. The monthly discharge of Deneba river ranges from 0.05 million m^3 in March to 32.11 million m^3 in August and the monthly discharge of Mugher river ranges from 0.58 million m^3 in February to 119.85 million m^3 in August.

4.6.2 FLOOD RISK ASSESSMENT

The following factors are considered in assessing the flood runoff:

- Drainage basin characteristics including size, shape, slope, land use, geology, soil type, surface infiltration, and storage
- Stream channel characteristics including geometry and configuration
- Flood plain characteristics
- Meteorological features such as precipitation amounts and types, storm cell size and distribution characteristics, storm direction, and time rate of precipitation

4.6.2.1 Flood Analysis

The Ethiopian Roads Authority has undertaken a study on the country's rainfall intensity regime and divided it into eight categories for flood analysis for ungauged catchments.

Accordingly the project site falls in rainfall region A2 as shown in **Fig. 4.18.**

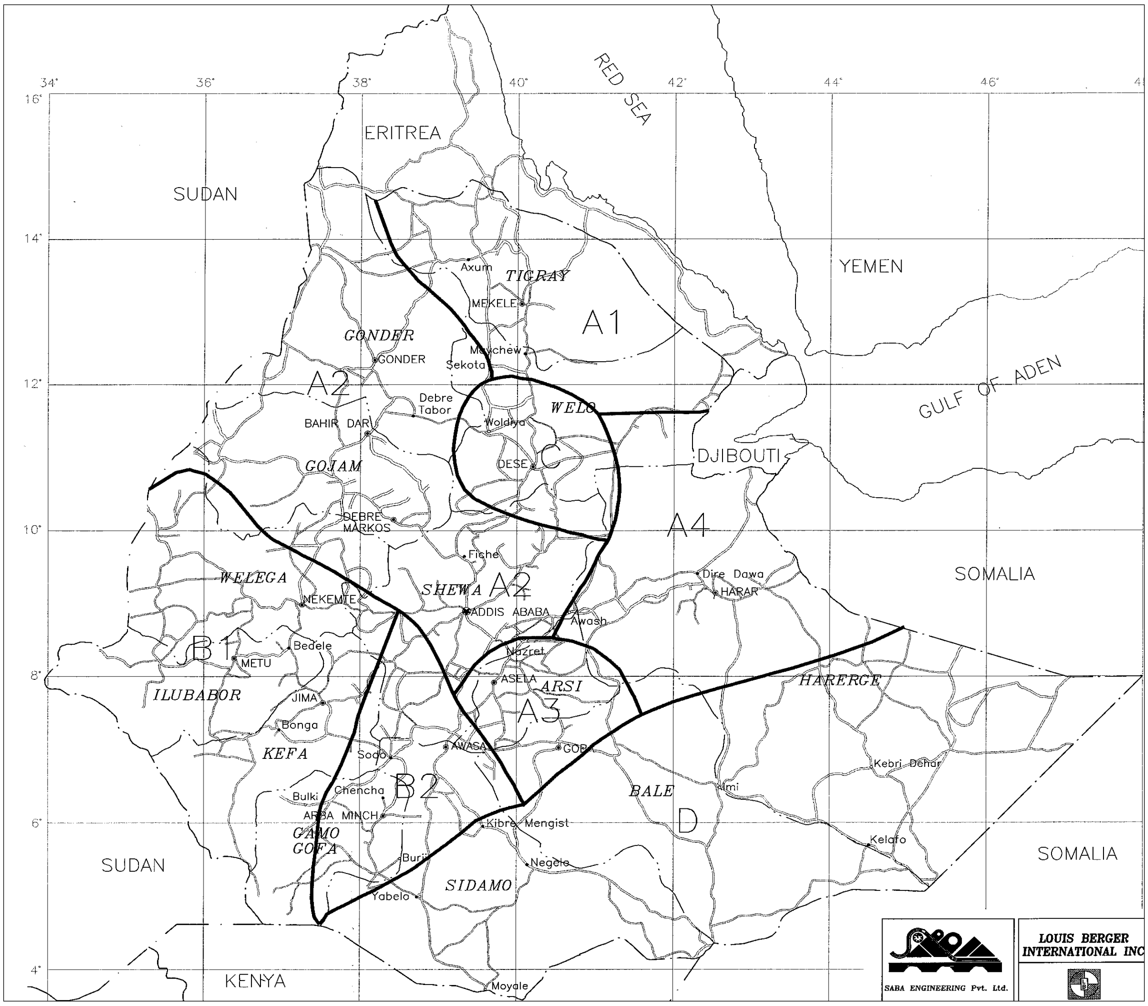

Fig. 4.18 : Rainfall Intensity Regimes

The intensity duration frequency curve as constructed for the region is given in **Fig. 4.19**.

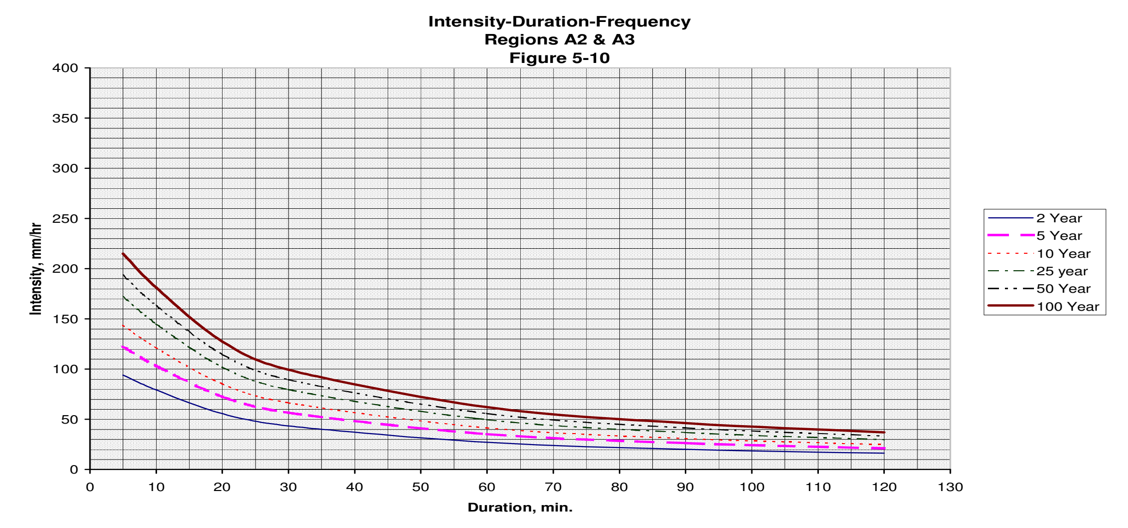

Fig. 4.19 : Intensity Duration frequency Curve for Project Area

The project site is at the upper most part of Abbay River system where well-formed drainage system is not observed for flood to concentrate and endanger the project activity.

The intensity of rainfall for duration of 60 minutes and return period of 25 years is only 50 mm. This amount with a catchment area of 100 km^2 and runoff coefficient of 0.25 has a runoff response of 347.5 m^3/ s. This value can only occur at an outlet of the river system but not anywhere in the catchment. Thus there is no flood risk in the proposed project area.

4.7 HYDROGEOLOGY

The hydrogeology of the project area and its surrounding area has been studied using the following methodology:

- Review of previous works in the area (Abbay River Basin Integrated Master Plan Project, Volume II, Part I - Hydrogeology, 1997.
- Review of Evaluation of Groundwater Potential of Adaa-Becho Plains (Draft Report WWDSE, 2007)
- Study of different scale topographic maps (1:250,000 and 1:50,000) and interpretation of satellite imagery and DEM of the area.
- Water point inventory and reconnaissance geological field survey
- Water quality analysis
- Data integration and analysis to characterize the hydrological condition of the study area|

4.7.1 HYDROGEOLOGICAL SURVEY

Water point inventory was carried out from 25 Aug to 28 Aug 2007. A total of 23 water points were inventoried and data collected from different sources, out of which 13 were boreholes with variable depth and 10 are springs (details are given in **Tables 4.6 and 4.7**). Water samples were collected and analysed from seven representative water points for chemical analysis. Some of the logs of nearby wells in the study area are given below.

Segno Gebeya		
Depth[m]	**Lith. Unit**	**Comment**
6	CLAY	Top soil
28	ROCK5	Moderately weathered scoraceous basalt
34	ROCK5	Highly weathered scoraceous basalt
74	ROCK5	Fractured scoraceous basalt
90	ROCK5	Massive basalt
110	ROCK5	Slightly weathered scoraceous basalt
170	ROCK5	Highly weatherd scoraceous basalt
210	ROCK5	Moderately fractured basalt
250	ROCK5	Highly fractured basalt
273	CLAY	Shale or Mugher mudstone

Chancho		
Depth[m]	**Lith. Unit**	**Comment**
4	CLAY	Top Soil
38	ROCK5	Slightly weathered scoraceous basalt
44	ROCK5	Highly weathered Scoria
146	ROCK5	Moderately weathered scoraceous basalt
164	ROCK5	Highly weathered basalt
176	ROCK5	Massive basalt
186	ROCK5	Fractured basalt
188	ROCK5	Highly weathered scoria
210	ROCK5	Massive basalt
220	ROCK5	Highly weathered scoria
230	ROCK5	Highly weathered basalt
240	ROCK5	Moderatly weathered scoria
264	ROCK5	Massive basalt
268	ROCK5	Highly weathered scoria
280	ROCK5	Massive basalt
290	ROCK5	Highly weathered scoraceous basalt
300	ROCK5	Scoraceous basalt
308	ROCK5	Fractured basalt
312	ROCK5	Massive basalt
320	ROCK5	Moderately weathered scoria
324	ROCK5	Massive basalt

Derba Rob G		
Depth[m]	**Lith. Unit**	**Comment**
4	CLAY	Soil[redacted]
50	ROCK5	Basalt
117	ROCK5	Weathered basalt

Derba Mulo		
Depth[m]	**Lith. Unit**	**Comment**
5	CLAY	Soil
62	ROCK5	Basalt

The well logs show that the main aquifer is scoraceous basalt and fractured basalts. Analysis of the water points inventory data from boreholes in the area showed the following results:

As shown in **Fig. 4.20** the depth of boreholes drilled near the project site varies from 60 m to 324 m. The mean borehole depth near the project area, with similar hydro-geological setup, is 119 m. There is also a general trend that the depth of boreholes is a function of ground surface elevation, i.e., boreholes located at higher altitude areas have deeper depth. However, boreholes, which have depth greater than 200 m are drilled as mapping wells to evaluate the regional aquifer (WWDSE, 2007).

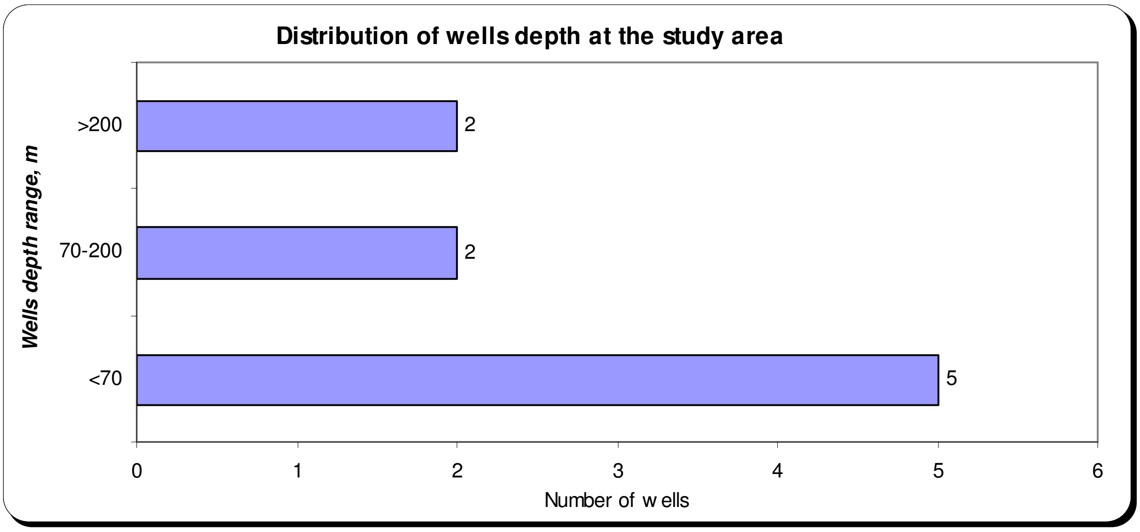

Fig. 4.20 : Wells Depth Distribution in the Study Area

The static water level depth of the boreholes in the area in general increases when the borehole depth increases as shown in **Fig. 4.21**. As can be seen in the figure, deep boreholes have deeper static water level. This indicates that the most permeable zone of the volcanic aquifer is found at depth and the well yield increases as the depth increases.

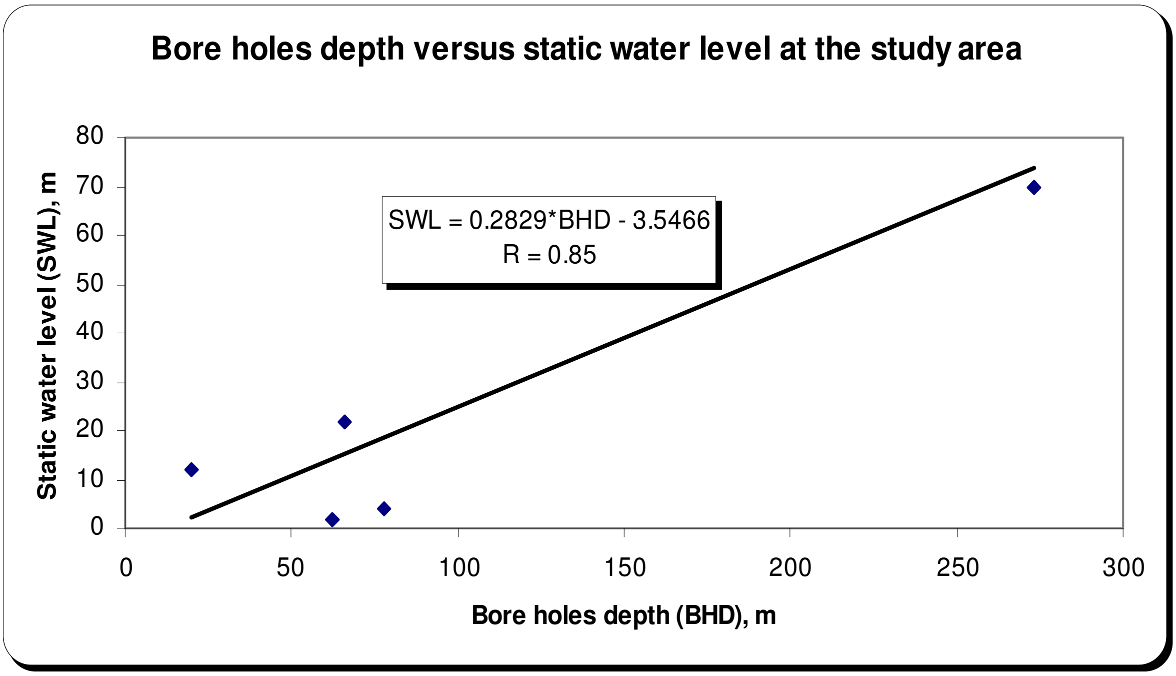

Fig. 4.21 : Boreholes Depth versus Static Water Level

Locality	Water point	UTM Coordinates		Elv (m)	Type of spring	Geology	Geomorphology	Sp eye	Water use	Flow	Yield (l/ s)	Fluctuation	Menzir scale
		E	N										
D/Tsige TWS	Adsp32	482960	1066600	2585	Depression	Basalt	Slope break	Multiple	Domestic	Perennial	20	Low	4
Duber	Adsp37	486182	1045145	2535	Depression	Basalt	Flat area	Single	Domestic	Perennial	15	Low	4
Segno	Adsp40	455664	1027096	2603	Fault	Tuff	Flat area	Single	Domestic	Non Perennial	0.5	High	6
Segno Gebeya	Adsp39	451615	1027364	2673	Depression	Basalt	Hill side	Single	Domestic	Perennial	10	Low	4
Fital	Adsp30	459509	1066272	2627	Depression	Basalt	Hill side	Multiple	Irrigation	Perennial	15	Low	4
Mulo	Adsp38	463227	1037406	2466	Depression	Basalt	Flat area	Single	Domestic	Non Perennial	1	High	5
Bowo	Adsp36	485000	1048933	2617	Fault	Basalt	Flat area	Multiple	Domestic	Perennial	2	Low	5
Sele	Adsp33	484180	1059881	2635	Depression	Basalt	Bank of river	Single	Domestic	Non Perennial	0.5	High	6
Daleti	Adsp31	454415	1063647	2630	Depression	Basalt	Hill side	Multiple	Irrigation	Perennial	10	Low	4
Dire	Adsp29	480642	1069101	2676	Depression	Basalt	Flat area	Single	Domestic	Non Perennial	1	High	5

Table 4.6 : Hydrological Data of Springs

Locality	UTM Coordinates		Elev (m above MSL)	Depth (m)	Static Water Level (m)	Discharge (m^3)	Geology	Aquifer
	E	N						
Derba	463204	1038645	2427	62	2		Basalt	
Derba	463286	1038986	2420	78	4.2	3.2	Basalt	Basalt
Derba	463204	1038645	2416	62	2		Basalt	
Gimbichu	473090	1062210	2654				Basalt	
Segno Gebeya	455620	1026514	2610	273	69.75	2.1	Scoraceous basalt	Scoraceous basalt
Chancho	473911	1031930	2543	324	1	2	Scoraceous basalt	Scoraceous basalt
Midroc well	463700	1035400	2480				Scoraceous basalt	
Abyssinia Cement	469740	1028859	2566				Scoraceous basalt	
Muka Ture	485477	1056545	2635				Basalt	
Solo	489336	1058283	2668	20	12		Basalt	
Gorfo	482263	1038145	2576	66	22	4	Basalt	Scoraceous basalt
Rob Gebeya	466233	1031004	2585	117	55	2	Basalt	Basalt
ChanchoTWS	471304	1027754	2561	65			Scoraceous basalt	

Table 4.7 : Hydrological Data of Boreholes

4.7.2 HYDROGEOLOGY OF THE STUDY AREA

The project site falls in the Abbay River basin. The geomorphology of the study area comprises part of Abbay river plateau composed of Tertiary volcanic unit, dominantly basalt, bounded in the west by deep Mugher River gorges. Mesozoic sedimentary units are exposed in the deep gorges.

The geological formation and hydro-geological conditions of the area are a function of geomorphology. The general hydro-geological set up of the area is governed by the lithological stratigraphy of the area and tectonics.

The recharge condition, groundwater flow and aquifer parameters in the plains of the study area is highly governed by the general bedding of the sedimentary formation underlying the volcanic unit (at reconnaissance level it is confirmed to be in south and southeast direction), the tectonic condition and the hydraulic properties of the different volcanic units that outcrop in the study area.

The study conducted by WWDSE, 2007 has revealed that direction of the regional groundwater flow direction is mainly north-south direction and has identified aquifer configurations of the area, the recharge and discharge mechanism and aquifers properties. Accordingly, the scoraceous basalt formation is a multi-layered aquifer where it is separated by a number of paleosols and massive basalts. The yield of the boreholes and the static water level increases as the well depth increases.

At the western side of the project area, where the Mugher River cuts deep, no spring is observed. The springs inventoried in the area have yields ranging from 0.5 to 20 l/s in the basalt formation but not at the geological contact zone of the Tertiary volcanic and Mesozoic sedimentary formations. Boreholes drilled in the nearby areas at Chancho, Segno Gebeya and Derba area together with the geological mapping have enabled to identify the main aquifers and aquicludes in the study area (**Fig. 4.22).**

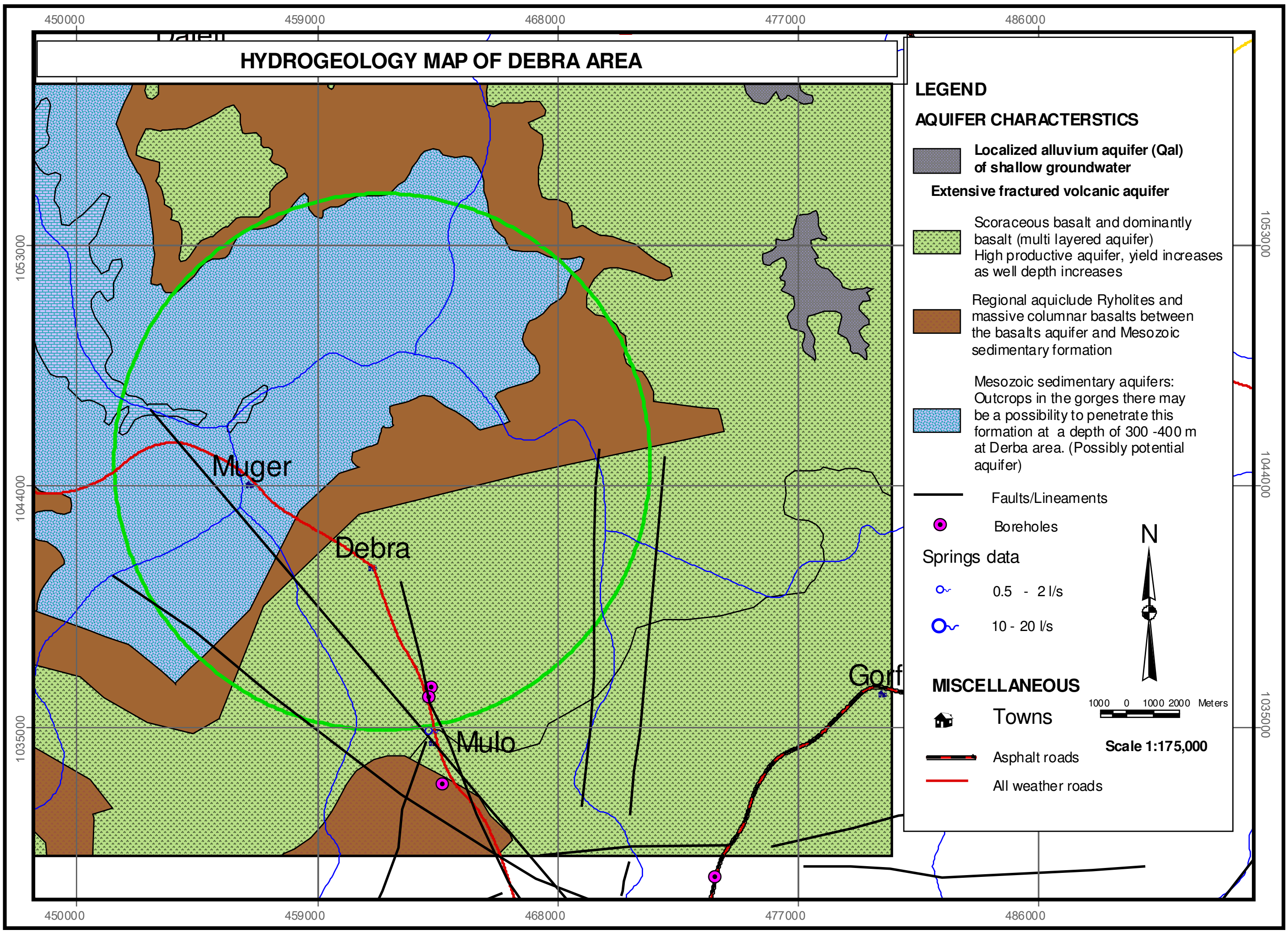

Fig. 4.22 : Hydrogeological Map of the Study Area

4.7.3 HYDRO-LITHOLOGY

4.7.3.1 Scoraceous Basalt and Fractured Basalt Aquifer

This is the major aquifer in the study area, which has a wide distribution and is composed of Tertiary Tarmaber volcanic unit, which is dominantly scoraceous basalt and Amba Aiba basalt. These Tertiary basalt formations occupy a major part of the plains in the study area. Tarmaber and Amba Aiba basalt formations are considered as one hydrogeological unit. The recent mapping wells drilled at Segno Gebeya and Chancho proved this fact. For example, at Segno Gebeya the depth up to 250m was scoraceous basalt intercalated with minor massive basalt and the remaining depth up to 273 m was the sedimentary unit. The complete drilled depth at Chancho site was scoraceous basalt with thin massive basalt intercalations.

The static water level varies from 0 to 70 m. The yield of boreholes is greater than 2 l/s. The water quality is fresh.

The groundwater level elevation contour map is prepared using the springs and shallow wells data to construct the shallowest zone of the major aquifer in the study area (**Fig. 4.23**). The map shows that shallow groundwater flows mainly in the south direction, and this could be the main reason that there are springs emerging from the basalt formation on the plain (Plateau) but not at the contact zones of the sedimentary formation in the Mugher gorges.

The recharge estimation made by different methods by different researchers varies from 100 mm/year to 250 mm/year (WWDSE 2007, Debebe M.2005, Nigussie K. 2005, et. al) in the study area. Accordingly, the total annually recharge of the major aquifer in the study area is estimated from 49 Mm^3/year to 123 Mm^3/year. In order not to overestimate the recharge, the minimum recharge 49 Mm^3/year is considered to be the total recharge in the study area of about 400 km^2. If we consider that 50% of the recharge is discharged as base flow through springs and seepage zone, the minimum net groundwater recharge could be more than 25 Mm^3/year.

Aquicludes: Blue Nile basalt of old basalt and columnar massive basalt is practically impervious except in the local area due to secondary fracturing. Due to its massive and hard condition it is difficult to drill in Blue Nile basalt. This formation acts as an aquiclude between the Mesozoic sedimentary formation and basalt aquifer.

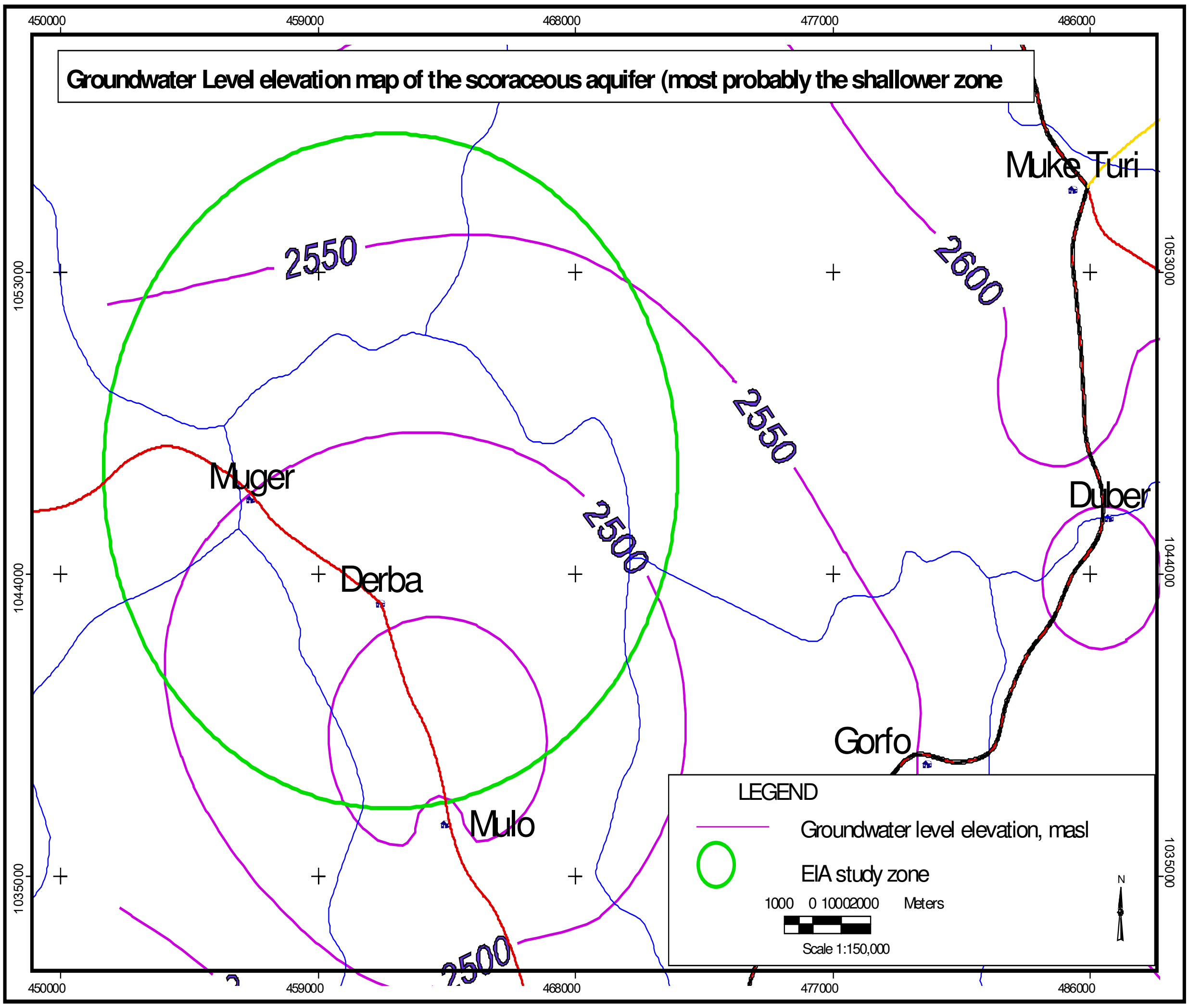

Fig 4.23 : Groundwater level Elevation Contour Map of the Major Aquifer

4.7.3.2 Water Quality

One of the tasks of water point inventory and data collection was to survey the ground water quality of the project area. All water samples collected for laboratory examination were submitted to Water Works Design and Supervision Enterprise (WWDSE) laboratory and analyzed for physical and chemical compositions. During water point inventory seven (7) water samples were collected from the inventoried water points. The water quality parameters considered for analyses are physical and chemical characteristics. The water quality is detailed in **Tables 4.8** and **4.9**. The locations of the water sampling stations are shown in **Fig. 4.24**. The water quality analysis laboratory certificates are enclosed as **Annex 4.3**.

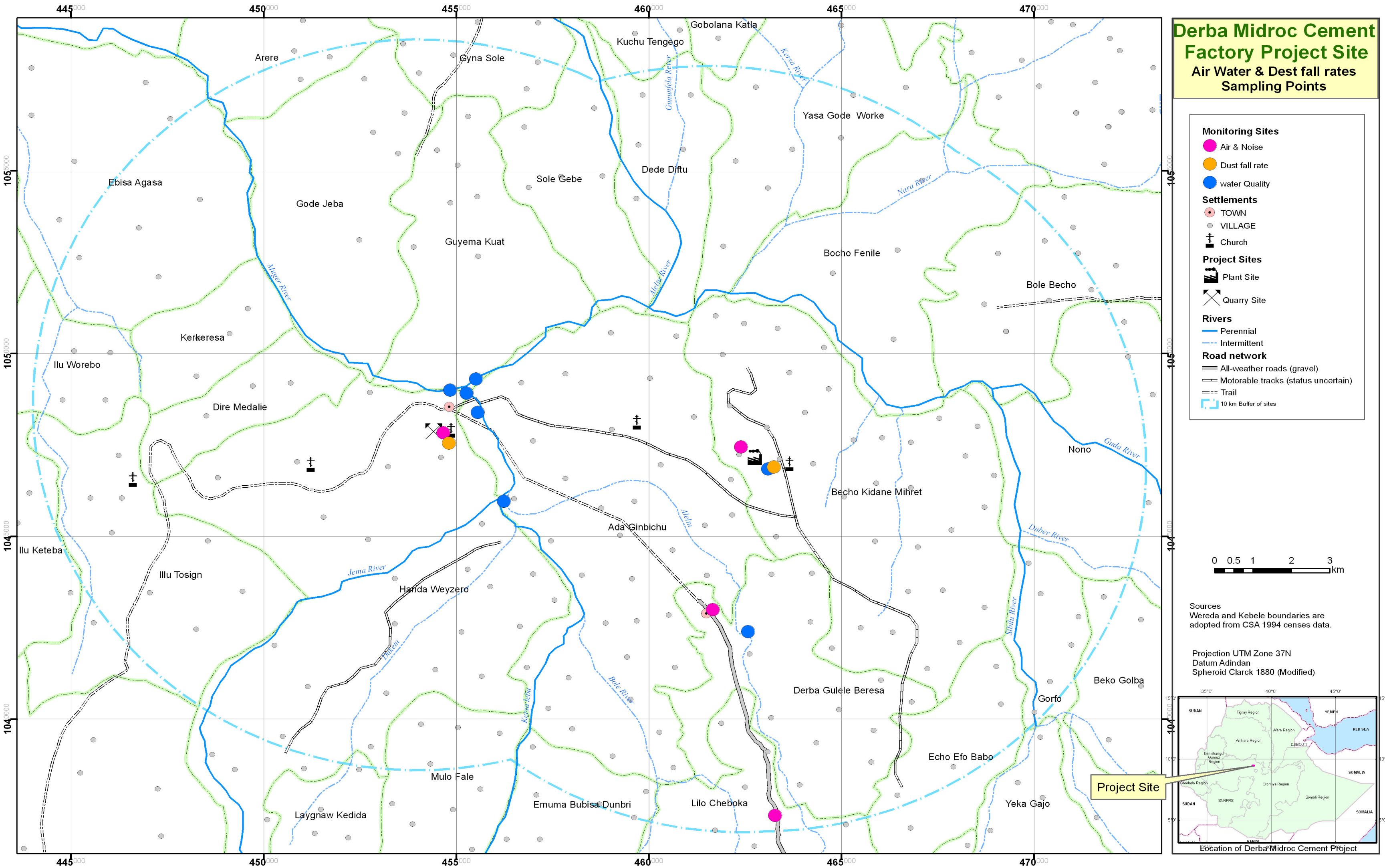

Fig. 4.24 : Water Sampling Locations

The main physical characteristics analysed are: Color, Turbidity, taste, odour and temperature. The following chemical parameters were determined.

- The main cations (NH^+, Na^+, K^+, Ca^{2+}, Mg^{2+}, total Iron and Manganese)
- The main anions (Cl^-, NO_2^-, NO_3^-, F^-, HCO_3^-, SO_4^{2-}, and ortho PO_4^{3-})
- Total alkalinity as mg/l of $CaCO_3$ and
- Total hardness as mg/l of $CaCO_3$
- Electrical Conductivity @25°C
- Total dissolved solids @105°C
- pH @25°C

Parameters	Locality							
	Gimbichu BH **	Segno BH*	Chancho BH	Abys Cement BH **	Solo-BH*	Gorfo - BH **	Duber-SP**	Fital SP**
EC, micro S/cm	315	237	166	117	305	235	238	324
TDS, mg/l	186	152	108	72	176	134	154	192
pH	8	8.16	7.61	6.69	7.29	7	8.06	7.83
NH_4, mg/l	0	0.1	0.26	0.48	0.12	0	0.25	0.16
Na+, mg/l	29	34	30	2.4	5.6	14	19	20
K+, mg/l	2	1.5	0.7	1	1.3	1	1.9	2.7
Ca++, mg/l	84	16	5.34	12.6	48.7	69	94.5	94.5
Mg++, mg/l	21	1.1	0.54	26.55	8.5	2	14.16	38.94
Fe, mg/l	0	0.11	0.12	0.24	0	0	31.1	0.03
Mn++, mg/l		0.02	0.02		0	0		
Cl^-, mg/l	7	6.72	1.92	3.97	8.6	9	3.97	4.96
NO_2^-, mg/l	0			0.02		0	0.01	0
NO_3^-, mg/l		2.46	0.8		14.25	2.93		
F^-, mg/l	1	0.34	0.26	0.48	0.5	1	0.4	0.55
HCO_3^-, mg/l	173	118.9	90.28	63.68	156.8	136	147	202.03
CO_3^{--}, mg/l	0	4.8		0	0	0	0	0
SO_4^{--}, mg/l	9	13.2	7.15	6.96	2.5	2	0.74	1.9
PO_4^{---}, mg/l	0	0.315	0.252	0.07	0.103	0	0.06	0.162
T Hardness, mg/l	109	44	15.4	63	156.2	97	94.5	140
Date of Analysis	28/8/07	28/6/06	28/6/06	28/8/07	24/1/06	28/8/07		

** - Chemical analysis conducted by the DMC project program
*. Chemical analysis results collected from the previous works

Table 4.8 : Water Quality Data of Boreholes and Springs

Comparing the water quality from different sources (boreholes and springs) it was found that the water quality in the study area is almost similar and highly fresh and fulfills the Ethiopian and WHO standard for drinking water, for industrial and irrigation purpose.

Parameters	Min	Max	Avg
EC, micro S/cm	117.0	315.0	229.2
TDS, mg/l	72.0	186.0	138.0
pH	6.7	8.2	7.5
NH_4, mg/l	0.0	0.5	0.2
Na^+, mg/l	2.4	34.0	19.2
K^+, mg/l	0.7	2.0	1.3
Ca^{++}, mg/l	5.3	84.0	39.3
Mg^{++}, mg/l	0.5	26.6	9.9
Fe, mg/l	0.0	0.2	0.1
Mn^{++}, mg/l	0.0	0.0	0.0
Cl^-, mg/l	1.9	9.0	6.2
NO_2^-, mg/l	0.0	0.0	0.0
NO_3^-, mg/l	0.8	14.3	5.1
F^-, mg/l	0.3	1.0	0.6
HCO_3^-, mg/l	63.7	173.0	123.1
CO_3^{--}, mg/l	0.0	4.8	1.0
SO_4^{--}, mg/l	2.0	13.2	6.8
PO_4^{---}, mg/l	0.0	0.3	0.1
T Hardness, mg/l	15.4	156.2	80.8

Table 4.9 : Range of Water Quality in the Study area

4.7.3.3 Conclusions

The detailed hydro-geological study carried out in the area shows that the main aquifer is the scoraceous and fractured basalt distributed at the plains and undulating plains. The basalt aquifer is multi-layered and the static water level and boreholes yield increases as well depth increases indicating that upper part of this aquifer is highly weathered and the transmissivity highly decreases. The groundwater level for shallow wells is very shallow and not greater than 5 m. The groundwater flow is not towards the gorges since there is no spring that emerges at the contact of the sedimentary formation that outcrops in the gorges. On the other hand there are big spring discharges up to 20 l/s on the basalt plain at depressions and slope breaks.

The groundwater recharge is estimated about 25 Mm^3/year for the study area and the water quality is homogenous and acceptable and can be used for any purpose.

The water balance of the study area is summarized in **Table 4.10**.

Net groundwater Available (Mm^3/year)		Abstraction (Mm^3/year)		Balance Available (Mm^3/year)
Net Recharge (available groundwater resource)	25	Water Supply for the community in the area 50 liters per capita (~103,000 people)	3.2	
		Water Supply for Cement factories (Muger and Abysyinia (total ~50l/s)	1.90	
Total	25		5.1	
Net Balance				19.9

Table 4.10 : Groundwater Balance of the Study Area

The cement factories could abstract 7.6% and the community uses about 12.8% of the available groundwater in the study area. The total abstraction together with the cement factories may reach only up to 20% of the available groundwater resources.

Thus it is safe to extract water from the area to meet the water requirement of DMC.

4.8 WATER QUALITY

Water samples were collected and physico-chemical analysis was conducted at the laboratory of the Water Works Design and Construction Authority. Minor constituents and heavy metals were analyzed at the laboratory of the Ethiopian Geological Survey. The maximum permissible level (MPL) of different trace elements and halides allowed in potable water was determined from WHO guidelines for drinking water (WHO, 2005). FAO's guidelines of SAR values for irrigation water were used (FAO, 2005; OECD, 1999). The maximum contaminant level (MCL) for secondary drinking water standards of minor constituents and heavy metals have been considered as per USEPA (2006) standards. The health advisory level (HAL) for Boron is based on USEPA standard. Comparative analysis of the river and spring waters was done using standard limnological methods (Golterman, *et al.*, 1978; Lind, 1979 and others)

The results of the water quality analysis for the three rivers and two springs in the project area is shown in **Table 4.11** and described below.

- Rivers have higher turbidity and total solids but lower total dissolved solids when compared with springs, certainly due to the runoff from the catchment. The rainy period when the sampling took place contributes to the extremely high turbidity values observed in rivers (range 64 - 340 NTU). The high turbidity levels are due to natural reasons and not because of mining activities. Such water is unsuitable for potable purposes, as the MPL in drinking water should not exceed 10 NTU. Even the water in the springs exceeds this value but the villagers of Adero, adjacent to the plant site use this turbid water (19 NTU) for their daily use. The dissolved solids, on the other hand, are higher in the springs, but still lower (234 - 420 mg/l) than the MPL in drinking water (500 mg/l).
- Electrical conductivity is higher for springs than rivers, possibly due to the higher dissolved solids in springs, which contribute to higher ionic composition. The highest conductivity was measured for the Lega Lomi spring (641 μS/cm)
- All the rivers and springs are fresh water with salinity < 1 g/l). This could be inferred from the low conductivity values (115 - 641 μS/cm) and the summation of the cations and anions of the waters. Some discrepancy between the salinity inferred from the two

is high only for the springs, especially, Adero and Lega Lomi spring. It appears that the springs are relatively more saline than the rivers as given below:

Parameter	Lebu	Aleltu	Muger	Teltele	Adero	Lega Lomi
EC (µS/cm)	115	115	253	353	512	641
Salinity from EC (g/l)	0.12	0.12	0.25	0.35	0.51	0.64
Salinity from ∑cations and anions (g/l)	0.12	0.11	0.23	0.30	0.39	0.51

- pH values are more to neutral in general (range 6.69 - 7.35). Bicarbonate alkalinity values are high for all waters, while carbonate exists only in traces. This implies that the waters have high free CO_2 reserve important for photosynthetic organisms. Algal blooms and macrophyte infestations can be expected, especially as the CO_2 is supplemented with high levels of nutrients (N and P). The low pH of the waters implies that they have good buffering capacity against alkali dust particles that would be emitted from the cement plant.
- All waters are high in Calcium, which constitutes 13 to 20% of the total ionic composition and Magnesium is present also. The total hardness of all waters range from 58.8 - 294.0 mg/l and Calcium hardness ranges from 39.9 to 193.2 mg/l. Using both classifications of total and Calcium hardness, the springs would be classified as very hard (Calcium concentration >120 mg/l and Total Hardness >180 mg/l as $CaCO_3$). It is generally assumed that there is no health problem associated with high hardness. Also, the high calcium level and Bicarbonate appear conducive for calcareous invertebrates such as snails whose shell is composed of 99% $CaCO_3$. Snails such as Lymnaea and Bulinus (which are important vectors of Fasciolasis and Schistosomiasis) could develop here even though it was not possible to sample these snails at this time of the year because of the silty and muddy water and the stones and pebbles were fully covered with water.

  Composition of Bicarbonate (%) and Calcium (%) out of Total Ions is as below:

	Lebu	Aleltu	Muger	Teltele	Adero	Lega Lomi
Bicarbonate (%)	55.5	58	65	61	61	50
Calcium (%)	13	14	18	19	20	15

- Nutrients such as Nitrate and Phosphate are high and exceed the minimum required for the establishment of plankton populations (~ 0.01 mg/l) and cause eutrophication tendency. Nitrate values are extremely high in the springs and value as high as 17.2 mg/l and 82.4 mg/l was reported in Adero and Lega Lomi springs, respectively. This could probably be due to waste input from the large livestock, which also water in the springs. Nitrate in excess of 10 mg/l in drinking water can cause disease in children below the age of 6 (methaneglobulinemia). This health problem should be investigated in Adero village and should be avoided in the plant camp in future. The development of mats of green algae in ditches and Derba ropeway station attests to the possibility of eutrophication in impounded waters in the project area.
- Chloride is higher in springs (3.97 - 25.8 mg/l) but far below the concentration recommended in drinking waters (250 mg/l). Fluoride is higher in rivers than springs (range 0.32 - 0.62 mg/l) but much lower that the MCL for drinking waters (4.0 mg/l) or

far below the level that causes dental fluorosis and bone complications (about 2.4 mg/l). Sulphate does not show any general pattern in the rivers and springs. It appears in high concentration in Aleltu river but is nevertheless far below the MPL allowed in drinking waters (250 mg/l).

- The SAR values for the rivers and springs range from 1.72 to 3.59 mg/l and do not show any consistent feature, being highest in Lebu River. In general, SAR values are within FAO's range of 0-9 mg/l conducive for irrigation. Sodium level is low in the waters and ranges from 3-9% of the total ionic composition. The waters of both rivers and springs can be used for irrigation projects.
- Iron level ranges from 0.03 - 0.6 mg/l and is higher in rivers. The MPL of Fe in drinking waters is 0.3 mg/l, which is exceeded in some rivers. The springs, which are presently used by local communities, appear to be safe for drinking from the point of view of iron level.
- Dissolved oxygen levels are high and probably more than 100% saturated. There is enough oxygen to sustain aquatic life such as fish (minimum required 3 mg/l).
- The downstream Mugher River shows the effects of ionic concentration as it collects tributaries from the Lebu, Diketu, Bole and Jemma rivers. It increases in total dissolved solids, total ionic composition, total hardness and total alkalinity. Turbidity decreases probably because of settling out of solids, as the total solid level shows lesser values than the upstream rivers. pH shifts to slightly alkaline condition (pH = 7.35), possible due to higher decomposition rates at downstream site. Phosphate is low and far below the level required to maintain plankton populations. Low phosphate is a reflection of rapid uptake by biota.
- Of the three springs, Lega Lomi has the lowest turbidity and the highest TDS, conductivity, salinity, total hardness and alkalinity and immensely high level of inorganic Nitrate (82.4 mg/l).

Parameter (values in mg/l, unless stated otherwise)	Lebu River	Muger River	Aleltu River	Teltele spring	Adero spring	Lega Lomi spring
Turbidity (NTU)	240.0	64.0	340.0	18.0	19.0	4.0
Total suspended solids 105°C	310.0	74.0	420.0	36.0	44.0	18.0
Total dissolved solids 105°C	88.0	170.0	80.0	234.0	332.0	420.0
Electrical Conductivity (μS/cm)	115.0	253.0	115.0	353.0	512.0	641.0
pH	7.24	7.35	7.19	7.29	6.69	7.3
Na +	11.5	8.4	6.8	9.7	13.7	26.5
K +	2.1	2.2	1.6	1.7	2.1	1.9
Ca ++	15.96	41.16	15.96	56.3	77.3	75.6
Mg ++	4.59	6.63	5.61	7.65	12.2	25.5
Total Fe	0.6	0.3	0.6	0.03	0.04	0.05
Total Hardness (mg/l $CaCO_3$)	58.8	123.9	63.0	172.2	243.6	294.0
Calcium (mg/l Ca)	39.9	102.9	40.0	140.7	193.2	189.0
Magnesium (mg/l Mg)	15.9	23.01	19.5	26.6	42.5	88.5

Parameter (values in mg/l, unless stated otherwise)	Lebu River	Muger River	Aleltu River	Teltele spring	Adero spring	Lega Lomi spring
F^{-1}	0.62	0.7	0.48	0.48	0.32	0.65
Cl^{-1}	5.96	5.96	3.97	6.95	25.8	21.85
NO_3^{-2}	1.77	0.9	0.779	3.9	17.2	82.4
Alkalinity (mg/l $CaCO_3$)	55.8	122.4	54.0	1151.2	192.6	208.8
Carbonate (mg/l CO_3)	Trace	Trace	Trace	Trace	Trace	Trace
Bicarbonate (mg/l HCO_3)	68.07	149.3	65.88	184.46	234.97	254.74
SO_4^{-2}	11.4	15.13	11.53	32.37	12.5	23.69
PO_4^{-3}	0.115	0.057	0.158	0.244	0.854	0.438
SAR (Sodium Adsorption Ratio)	3.59	1.72	2.07	1.72	2.05	3.7
Dissolved Oxygen (mg/l)	6.0	5.0	5.0	6.0	6.0	6.0

Table 4.11 : Surface Water Quality

Table 4.12 gives results of the physico-chemical data for the samples from confluence of Muger and Lebu rivers further at downstream site. No general pattern is obvious, except for the highest pH value recorded (7.59). The chemistry of the confluence site is more similar to the rivers than to the springs.

Parameter (values in mg/l, unless stated otherwise)	Mugher + Lebu confluence
Turbidity (NTU)	280.0
Total solids (105 ^{0} C)	330.0
Total dissolved solids (105°C)	82.0
Conductivity (µS/cm)	109.0
pH	7.58
Na +	7.4
K +	1.8
Ca ++	13.4
Mg ++	3.6
Total Fe	0.44
Total Hardness (mg/l $CaCO_3$)	48.3
Calcium (mg/l Ca)	33.6
Magnesium (mg/l Mg)	12.4
F^-	0.6
Cl^-	3.97
NO_3^{-2}	0.8
Alkalinity (mg/l $CaCO_3$)	57.6
Carbonate (mg/l CO_3)	Trace
Bicarbonate (mg/l HCO_3)	70.77
SO_4^{-2}	6.5
PO_4^{-3}	0.226

Parameter (values in mg/l, unless stated otherwise)	Mugher + Lebu confluence
SAR (Sodium adsorption ratio)	2.55
Dissolved Oxygen (mg/l)	6.0

Table 4.12 :. Water Quality at the Mugher and Lebu Rivers Confluence

The results of the analysis for trace constituents are given in **Table 4.13.**

Sodium levels are low in the samples. Low SAR values were obtained for all water samples, implying that the waters are good for irrigation purposes.

Turbid water of spring near Adero Village

As can be inferred from Table 4.13, Aluminium (Al), Zinc (Zn), Copper (Cu) and total Chromium (Cr) were in lower concentration (< 0.1 mg/l) than the maximum contaminant level (MCL) allowed for secondary drinking water standards and therefore are safe from the health point of view. The MCL of Cadmium (Cd) and Manganese (Mn) are 0.005 and 0.05 mg/l and the measured values of the samples may lie within this limit, as it is reported as < 0.1 mg/l/. Perhaps more sensitive methods to detect the lower limits of these constituents are required in future. The same may hold true for Lead (Pb) where no amount is allowed in drinking water, and the results < 0.1 mg/l do not indicate the lowest range of the measurements. For Boron (as HBO_2), the health advisory level (HAL) of 0.6 mg/l is exceeded by all the water samples, except sample 2 and 4.

It is concluded that the Mugher samples may exceed the maximum permissible level (MPL) for most heavy metals like Cd, Pb, Mn and B, while they meet the drinking water standard for Cr, Al, Zn and Cu.

Sample	Na	Cr	Al	Cd	Zn	Pb	Mn	Cu	HBO_2
1	4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.39
2	9	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	< 0.15
3	6	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	1.47
4	3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.15
5	12	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.59
6	3	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.73
7	19	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.44
EPA MCL*		0.1	0.05-0.2	0.005	5.0	0	0.05	1.3	0.60 HAL**

** Maximum Contaminant Level according to USEPA standards for drinking water*
*** The Health Advisory Level (HAL) for Boron is based on USEPA standard.*

Table 4.13 : Major and Trace Constituents in Derba Water Samples (mg/l)

4.8.1 CONCLUSIONS

- Water samples were collected from 3 rivers, 3 springs and a river confluence, and the physico-chemical analysis was carried in the laboratories of the Water Works Design and Supervision Enterprise and the Ethiopian Geological Survey.

- Rivers had higher turbidities and total solids because of the runoff carried from the catchment. Springs had high total dissolved solids, electrical conductivity and salinity values. All waters are of the freshwater type with salinity < 1 g/l.
- The spring waters had higher total and Calcium hardness and are categorized as very hard. All water had high Bicarbonate but traces of Carbonates. At neutral pH, the waters have high reserves of free CO_2 important for photosynthetic organisms.
- All the waters had high phosphate and nitrate levels, sufficient to cause plankton blooms. The springs had extremely high nitrate values, probably because of livestock waste input.
- All the waters had low Sodium and SAR values, indicating that they are suitable for irrigation purposes. Oxygen levels are ideal for aquatic life forms such as fish.
- Some trace constituents were found in lower amounts than the MCL recommended for drinking waters (Al, Cr, Zn, Cu). Very low values are recommended for Cd, Mn and B, and no amount is tolerated for Pb.
- The river and spring waters of the Mugher valley appear to have good buffering capacity to neutralize alkali dust fallout from the cement project. Because the bypass dust contains alkali particles, dioxins, furans, heavy metals such as Cd, Pb, Se, etc., it is advisable to regularly monitor the level of these minor contaminants in the rivers, springs and in water supply systems in the project area in the future.

4.9 SOIL QUALITY

Soil is the most vital and major part of the land resource. A systematic soil survey has been carried out to assess and pick up the variability of soils that are occurring in the project area. All the important site characteristics such as topography, land use/cover, flooding, erosion risk, mottling, drainage pattern and the other subsurface characteristics of the individual land units have been studied in the field. For further investigation, soil samples were collected and analyzed in the laboratory.

The soil survey was carried out following the general accepted FAO-ISRC standards. The following soil survey methodology and approach was followed:

- Review of all relevant studies and identification of data gaps and short comings
- Conducted field investigation to fill data gaps
- Systematic interpretation of satellite images and 1:50.000 scale topographic maps prepared by the Ethiopian Mapping Authority, and other relevant documents such as the Abbay Master Plan Study were examined to delineate land units
- Auger-hole penetration to the depth of 100 cm unless impervious materials were encountered at shallow depth and described to that depth. A total of 44 auger descriptions were made
- On each description point, important soil and site characteristics such as location from hand-held GPS, slope % clinometer, soil colour Munsell Colour Chart, soil texture, rooting condition, stoniness/ rockiness, $CaCO_3$ content with the reaction of 10% HCl, water table, drainage class, flooding, etc were recorded
- About 15% of auger descriptions were represented by a profile pit, which was excavated to depths of 1m at representative sites were described and sampled;
- An average of two to three soil samples were collected from each profile pit at significant horizons for laboratory analysis. A total of six profile pits were dug and 15 soil samples were collected and analyzed in the Ethiopian Geological Survey's Central Geological Laboratory

- Undisturbed core samples were collected from each profile for the determination of bulk density and soil moisture holding capacity

The derivation of SAR from the exchangeable cations, and the calculation of Nitrogen, Phosphorus, Potassium and Organic Carbon content per hectare were carried out.

On each profile pit description site, in-situ soil physical tests, infiltration rate (Double Ring infiltrometer method) near the profile pit were carried out. Hydraulic conductivity tests were carried out in conjunction with infiltration measurement (Inverse Auger Hole Method).

Soil samples were collected from the project area and analysed at the Water Works Design and Supervision Enterprise (WWDSE) and Ethiopian Institute of Geological Survey (EIGS) laboratories. The results are presented in **Table 4.13.** The details of the soil auger data are enclosed as **Annex 4.4** alongwith the laboratory certificates.

Sn	Parameters	S1	S2	S3	S4	S5	S6
	Location : Northing	1047801	1040750	1047881	1048399	1057999	1040922
	Easting	0464094	0461881	0453697	0459908	0461753	0462995
1	Colour	10YR2/1	10YR2/2	10YR3/6	5YR3/1	10YR3/2	5Y3/1
2	pH	6.91	5.1	8.27	6.87	6.15	7.24
3	EC	0.283	0.407	0.323	0.494	0.362	0.124
4	Avail. Mg %	0.0067	0.004	0.0213	0.009	0.008	0.002
5	Avail. Ca %	0.0466	0.0372	0.1545	0.0389	0.008	0.0179
6	Avail. N %	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016	<0.0016
7	Avail Na %	0.013	0.005	0.004	0.004	0.002	0.004
8	Avail. P %	0.0037	0.005	0.0057	0.0021	0.015	0.0306
9	Avail. K %	0.0067	0.0239	0.0333	0.0679	0.0729	0.011
10	Texture						
	Sand%	16.89	4.48	38.23	38.86	5.82	8.33
	Silt and Clay %	83.11	95.52	61.77	61.14	94.18	91.67
	Texture class	L	C	SC	SC	C	C
11	Cu %	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
12	Pb %	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
13	Cr %	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
14	Zn %	<0.002	0.002	0.002	0.002	0.002	0.002
15	Ni %	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
16	Bulk density g/cm^3	1.84	1.89	1.82	1.73	1.86	1.75
17	SAR	0.084	0.036	0.013	0.026	0.007	0.05
18	Infiltration Rate cm/hr	0.195	0.127	0.67	0.087	0.12	0.433
19	Hydraulic Conductivity M/d	0.37	0.80	0.77	1.27	0.30	0.83
20	Organic carbon %	1.68	1.90	0.51	1.84	1.90	1.0
21	Water Holding Capacity %	43.67	34.99	23.88	27.56	42.09	52.82
22	Nitrogen kg/ha	<32	<32	<32	<32	<32	<32
23	Phosphorus kg/ha	78	158	94	38	320	110

Sn	Parameters	S1	S2	S3	S4	S5	S6
24	Potassium kg/ha	200	520	640	168	144	160
25	O.C. K/ha	336	380	102	368	380	160

Table 4.13 : Soil Quality in the Study Area

4.9.1 SOILS OF THE PROJECT AREA

In this section a brief description of soils of the study area, their origin, morphology and physical properties, which were assessed during field survey are discussed.

Origin

The genesis of all soils is governed by the soil forming factors such as climate, parent materials, living organisms, relief and time. The interaction of these factors on the area can determine the nature of soils.

Morphology

Soils morphology is the external appearance of soils. It examines the details of soils structure which reflects the internal processes that forms as a whole and not as a part of the whole (such as peds, horizons etc.)

The soils morphology is the combination of its depth, colour, tint, texture, structure, consistence, drainage, mottles, nodules etc. and the general build up of soils profile. This together with soils chemistry is used to categorize the soils into soil units.

Soils colour depends on its mineral and organic constituents. The composition of an individual horizon and that of the soils as a whole was assessed by analyzing its colour. The very dark gray to dark brown colour of the soils of the study area indicates the distribution of the organic matter and mineral contents.

The consistence of the soils depends on the overall pattern of individual soil particles and aggregates, on the content and composition of its colloidal particles.

The consistence of the soils of the project area is friable, when moist and very sticky and very plastic when wet, which indicates that the soils have high water holding capacity.

4.9.2 SOIL CLASSIFICATION

According to the FAO World Reference Base on Soil Resources (FAO Report No. 84, 1998) the soil classification is based upon soil properties in the top 1.0 m. Soils are generally classified on a hierarchical system, with increasingly specific criteria used to separate soils down the levels of the system. This approach is adopted here. At the highest level, the units of the FAO-UNESCO legend classify the soils, based on the recognition of diagnostic horizons; viz. soils of similar layers are grouped into one unit.

In the field, the major soil differences observed are soils texture, drainage, colour, slope position, structure, rooting condition, stoniness, and the occurrence of water table. These are fundamental soil characteristic that largely determine many other soil properties such as permeability, potential fertility and mechanical properties. Accordingly the major soil units identified are VERTISOLS, CAMBISOLS, LEPTOSOLS, ALISOLS, REGOSOLS, ACRISOLS, ARENOSOLS and FLUVISOLS. Among these soil units, the dominant soils of the project area are LEPTOSOLS, which are occurring on the steep slopes.

4.9.3 SOIL PHYSICAL PROPERTIES

Proportion of sand, silt and clay particles in a soil is known as soil texture. Their distribution in the field were determined by feeling the soil in between the fingers under moist condition, while in the laboratory, it was determined by the hydrometer or pipette method.

Soil texture could influence nutrient and water holding capacity, aeration, drainage, workability etc. Soils with high clay content having high absorbing capacity and retain nutrients and better moisture holding capacity. In contrast, coarse textured soils have low water holding capacity, high infiltration rate, and very rapid hydraulic conductivity.

Pit No.	Replicate 1	Replicate 2	Replicate 3	Average
1	0.3	0.2	0.09	0.195
2	0.08	0.1	0.2	0.127
3	0.5	0.6	0.4	0.67
4	0.09	0.07	0.1	0.087
5	0.07	0.09	0.2	0.12
6	0.4	0.3	0.6	0.433

Table 4.14 : Infiltration Site Test Results (cm/hr)

Pit No.	Replicate 1	Replicate 2	Replicate 3	Average
1	0.3	0.5	0.6	0.37
2	0.6	1.0	0.8	0.80
3	1.0	0.9	0.7	0.77
4	1.1	1.5	1.2	1.27
5	0.3	0.4	0.2	0.30
6	1.2	0.7	0.6	0.83

Table 4.15 : Hydraulic Conductivity Site Measurement Results (m/d)

Pit No	Depth Cm	Sand %	Silt & Clay %	Texture Class	pH	EC	Available cations %				Sum of	SAR	O.C	Total N %	P	Cr	Zn	Pb	Ni	Cu
					H2O	µS/Cm	Ca	Mg	K	Na	Cations	%	%		%	%	%	%	%	%
P1	0-30	15.2	84.80	L	6.24	461	0.056	0.01	0.01	0.01	0.086	0.055	1.68	<0.0016	0.0039	<0.002	<0.002	<0.002	<0.002	<0.002
	30-60	20.91	79.09	L	7.21	201	0.0299	0.006	0.006	0.014	0.0559	0.104	0.62	<0.0016	0.002	<0.002	<0.002	<0.002	<0.002	<0.002
	60-100	14.55	85.45	L	7.28	186	0.0539	0.004	0.004	0.016	0.0779	0.094	0.28	<0.0016	0.0052	<0.002	<0.002	<0.002	<0.002	<0.002
Aver.		**16.89**	**83.11**	**L**	**6.91**	**283**	**0.0466**	**0.0067**	**0.0067**	**0.013**	**0.0733**	**0.084**	**0.86**	**<0.0016**	**0.0037**	**<0.002**	**<0.002**	**<0.002**	**<0.002**	**<0.002**
P2	0-25	3.12	96.88	C	4.92	482	0.0339	0.004	0.0259	0.006	0.0698	0.041	1.90	<0.0016	0.0079	<0.002	0.002	<0.002	<0.002	<0.002
	25-45	3.75	96.25	C	4.93	483	0.032	0.004	0.024	0.004	0.064	0.030	0.62	<0.0016	<0.0019	<0.002	0.002	<0.002	<0.002	<0.002
	45-100	6.57	93.43	C	5.45	256	0.0458	0.004	0.0219	0.006	0.777	0.038	0.28	<0.0016	0.0054	<0.002	0.002	<0.002	<0.002	<0.002
Aver.		**4.48**	**95.52**	**C**	**5.1**	**407**	**0.0372**	**0.004**	**0.0239**	**0.005**	**0.3036**	**0.036**	**0.93**	**<0.0016**	**0.0050**	**<0.002**	**0.002**	**<0.002**	**<0.002**	**<0.002**
P3	0-25	42.93	57.07	SC	8.32	302	0.1519	0.014	0.032	0.004	0.2019	0.014	0.51	<0.0016	0.0047	<0.002	0.002	<0.002	<0.002	<0.002
	25-60	34.14	65.86	SC	8.07	390	0.1399	0.018	0.034	0.004	0.1959	0.014	0.57	<0.0016	0.007	<0.002	0.002	<0.002	<0.002	<0.002
	60-100	37.62	62.38	SC	8.43	277	0.1716	0.0319	0.0339	0.004	0.2414	0.012	0.32	<0.0016	0.0053	<0.002	0.002	<0.002	<0.002	<0.002
Aver.		**38.23**	**61.77**	**SC**	**8.27**	**323**	**0.1545**	**0.0213**	**0.0333**	**0.004**	**0.2130**	**0.013**	**0.47**	**<0.0016**	**0.0057**	**<0.002**	**0.002**	**<0.002**	**<0.002**	**<0.002**
P4	0-40	35.78	64.22	SC	6.92	563	0.036	0.008	0.0839	0.004	0.1319	0.027	1.84	<0.0016	<0.0019	<0.002	0.002	<0.002	<0.002	<0.002
	40-100	41.95	58.05	SC	6.82	425	0.0419	0.01	0.0519	0.004	0.1017	0.025	1.01	<0.0016	0.0024	<0.002	0.002	<0.002	<0.002	<0.002
Aver.		**38.86**	**61.14**	**SC**	**6.87**	**494**	**0.0389**	**0.009**	**0.0679**	**0.004**	**0.01168**	**0.026**	**1.42**	**<0.0016**	**0.0021**	**<0.002**	**0.002**	**<0.002**	**<0.002**	**<0.002**
P5	0-30	9.14	90.86	C	6.82	476	0.0579	0.008	0.0719	0.002	0.1398	0.011	1.90	<0.0016	0.016	<0.002	0.002	<0.002	<0.002	<0.002
	30-100	2.51	97.49	C	7.48	249	0.5074	0.008	0.0739	0.002	0.5913	0.004	0.67	<0.0016	0.0143	<0.002	0.002	<0.002	<0.002	<0.002
Aver		**5.82**	**94.18**	**C**	**6.15**	**362**	**0.2826**	**0.008**	**0.0729**	**0.002**	**0.3655**	**0.007**	**1.28**	**<0.0016**	**0.015**	**<0.002**	**0.002**	**<0.002**	**<0.002**	**<0.002**
P6	0-30	9.97	90.03	C	7.35	55	0.0279	<0.002	0.008	0.002	0.0379	<0.02	1.00	<0.0016	0.0551	<0.002	0.002	<0.002	<0.002	<0.002
	30-100	6.69	93.31	C	7.13	194	0.008	0.002	0.014	0.006	0.03	0.08	0.93	<0.0016	0.0061	<0.002	0.002	<0.002	<0.002	<0.002
Aver.		**8.33**	**91.67**	**C**	**7.24**	**124**	**0.0179**	**0.002**	**0.011**	**0.004**	**0.0339**	**<0.05**	**0.96**	**<0.0016**	**0.0306**	**<0.002**	**0.002**	**<0.002**	**<0.002**	**<0.002**

SC=Sandy Clay C= Clay L= Loam

Table 4.16 : Soil Analysis Results

The amount of Nutrients available in the ploughing layer in kg/ha, have been calculated as m= V X d, where,

m is the mass of one hectare of soils on the top 20 cm, and calculated 200,000 kg

V is the Volume of soils of the ploughing layer

d is the bulk density of soils

Pit No.	Nitrogen kg/ha	Phosphorus kg/ha	Potassium kg/ha	Organic Carbon kg/ha
1	<32	78	200	336
2	<32	158	520	380
3	<32	94	640	102
4	<32	38	168	368
5	<32	320	144	380
6	<32	110	160	160

Table 4.17 : Nutrients Test Results

4.9.4 SOIL MAPPING UNITS

Soils were categorized according to their similar natures for the mapping purpose and known as SOIL MAPPING UNITS (SMU). Accordingly, seven soil mappings units which have been recognized in the project area are shown in **Fig 4.25** and their brief descriptions are given below.

SMU 1: Deep to very deep, moderately well drained, dark gray to black in colour, clay to silt clay textured, very sticky and plastic when moist, few stones, with localized calcium carbonate concretion, dominated by Eutric Vertisols occupy all directions of the plant area, except the western part and small unit on the northern periphery of the project site and situated on slope 0 to 5%

SMU 2: Deep to very deep, well drained, light red to dark in colour, clay to sandy clay loam in texture, with some dissections of gully on steep slope and dominated by Haplic Alisols, and Cambic Arenosols, situated on slopes 5 to 15% located on the southern and south eastern direction from Derba town.

SMU 3: Very shallow to shallow soils, dark brown in colour, dividing the Mugher valley and the Derba plateau, the upper catchments of the Mugher and the gorges of other rivers and the western periphery of the project area. The unit occupies the escarpment with some rock and stone surfaces, excessively drained soils, slopes within rage of 45 to 60%, in some places the slope exceeds to 90%. The dominant soil unit is Leptosols, rocks and on the bends of the hills covered with residual Cambisols

SMU 4: Shallow to moderately deep, strong brown in colour, mainly occupies the depressions of Mugher valley, some what excessively drained, originated from basalt and lime stone, highly affected by gully, rill and sheet erosion, dominated by Arenosols, Regosols, Cambisols and Leptosols.

SMU 5: Deep to very deep, moderately well drained, dark in colour, volcanic origin, situated on gentle slopes, the dominant soils are Eutric Vertisols and Vertic Cambisols located on the north western and south western periphery of the project site.

SMU 6: Moderately deep to deep, moderately well to imperfectly drained, originated from alluvial, colluvial and residual piedmonts, slopes not more than 5 %

and occupies the small proportion of the eastern periphery. The dominant soil units are Eutric Vertisols, Chromic Luvisols, Eutric Cambisols and Haplic Alisols.

SMU7: River channels and Beds

Table 4.18 shows the major soil classes and the areal distribution of the major soil units in the project area.

Sn	Soil Mapping Units	Area in ha	Percent coverage (%)
1	SMU 1	4,319	8.7
2	SMU 2	3,369	6.8
3	SMU 3	28,600	57.7
4	SMU 4	7,804	15.7
5	SMU 5	2,625	5.3
6	SMU 6	1,171	2.4
7	SMU 7	1, 697	3.4
Total		49,585	100

Table 4.18 : Area Distribution of Soil Groups within the Project Area

4.9.5 Soil Description of the Project Site

4.9.5.1 Soils of the Plant Site

According to the FAO classification, soil of the plant site is classified as Pellic Vertisols. It is moderately deep to deep, moderately well drained, firm when dry, friable when moist, sticky and plastic when wet, has vertic nature, cracking during dry period and swelling during moist season, sub-angular blocky in structure, fertility status is low to moderate, not easily workably due to drainage, slow permeability, cultivated for cereal crops such as wheat, barley and beans. The details of the pit results are enclosed as **Annex 4.3**.

4.9.5.2 Soils of the Quarry Site

According to the FAO classification the soil of the quarry area are classified as Vertic Cambisols. The soils in this site are dark yellowish brown in colour, well drained liable to erosion, weakly developed structure, moderately sticky and moderately plastic, common fine to medium ores, calcareous, very low to low fertility, cultivated for maize, sorghum and teff. They have originated from basalt and limestone. Details of the pit results are given in **Annex 4.4**.

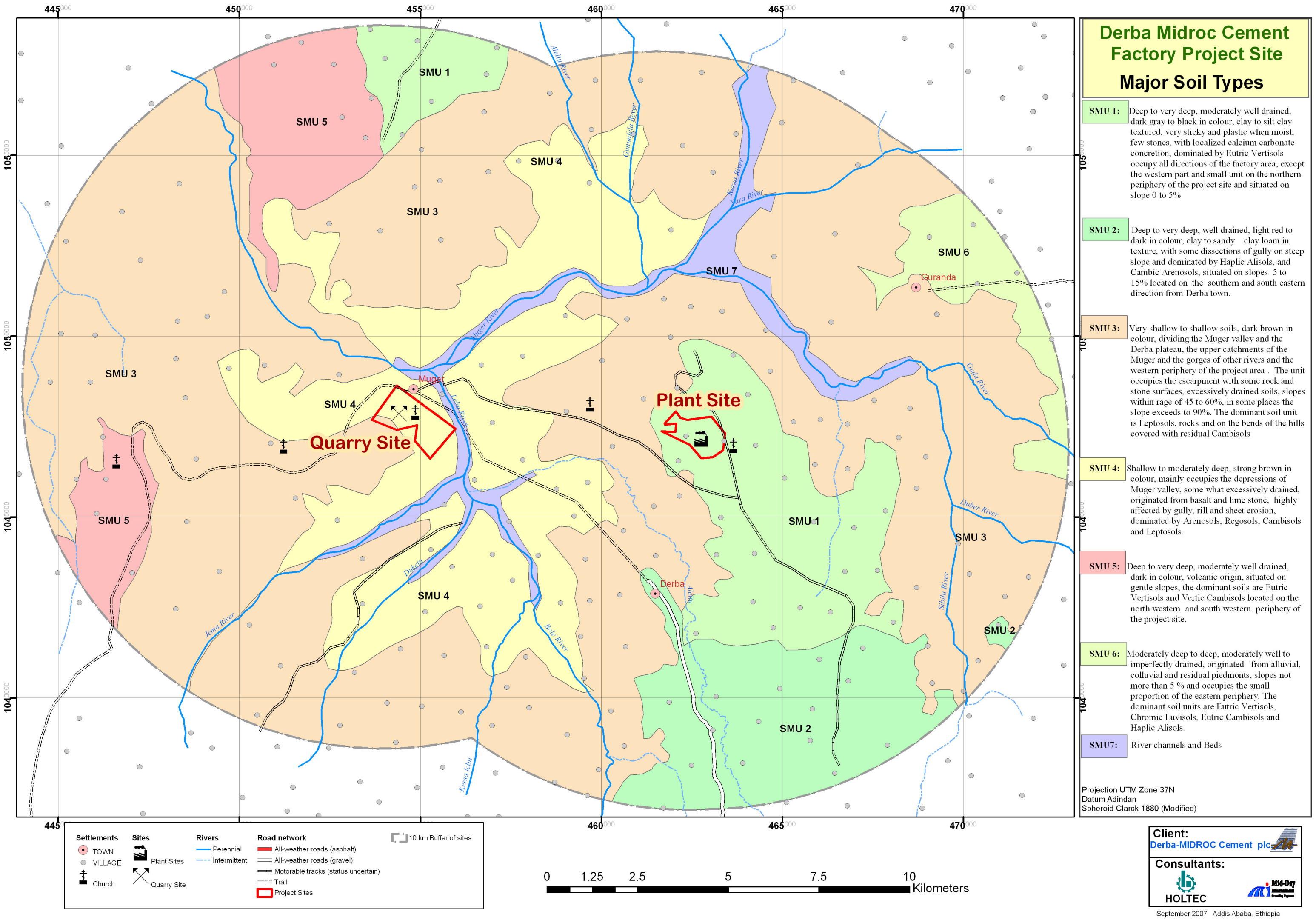

Fig. 4.25 : Soil Types in the Study Area

4.10 AMBIENT AIR QUALITY

The prime objective of the ambient air quality (AAQ) study is to establish the existing ambient air quality within the study area and its conformity to standards specified. The study area represents mostly rural environment with sparse habitation and the ambient air quality levels are expected to be much less than the standards set by EHS guidelines. The sources of air pollution in the region are dust arising from unpaved roads, vehicular movement, construction activities, etc. Other air pollution sources in the area include, cooking using fuel wood, charcoal production, etc.

No previous AAQ data was found for the project area and one month monitoring has been carried out during the study area, which is considered adequate for this EIA. However, it is recommended that full one year monitoring of AAQ be carried out during construction.

The baseline status of the ambient air quality has been established through a scientifically designed ambient air quality monitoring network based on the following considerations:

- Meteorological conditions on synoptic scale
- Topography of the study area
- Representatives of likely impact areas within the study area
- Location of residential areas representing different activities
- Availability of uninterrupted power supply.

The four sampling sites selected are:

- Plant site
- Derba town
- Quarry site
- Lilo Chebeka village

The locations of the sampling stations are shown in **Fig. 4.24.** The photoplate below shows the monitoring in progress at site.

The ambient air quality monitoring has been carried out during the period 31st Aug 07 to 13th Sept 07. The parameters monitored include Total Suspended Particulate Matter (TSPM), Respirable Particulate Matter (PM_{10}), Sulphur Dioxide (SO_2), Oxides of Nitrogen (NOx), and Carbon Monoxide (CO). Due to the limited availability of reliable monitoring equipment in Ethiopia, the following instruments have been used for AAQ monitoring:

Environmental Monitoring Station at Quarry

- Portable air sampling pumps for SPM and PM10
- IOM inhalable dust sampler
- Cyclone/ Spiral sampler for PM10
- Environmental Monitoring Station (EMS) of ELE Interantional for SOx, NOx and CO

4.10.1 Results of the Ambient Air Quality Monitoring

The results of the air quality monitoring at four locations are detailed in **Annex 4.5** and the summarized results are given in **Table 4.19**. Eight hourly sampling for 24 hours continuously has been carried out on 6 days at each location.

Parameters	Concentration (µg/m³)			
	Plant site	Derba	Mining site	Lilo Chebeka village
SPM				
Maximum	81.30	185.20	92.80	61.10
Minimum	69.44	92.60	85.60	33.10
Average	76.0	118.80	88.90	42.50
PM10				
Maximum	57.90	50.50	60.50	18.90
Minimum	45.90	30.04	49.70	10.90
Average	50.30	43.50	54.30	13.30
Draft Ethiopian Standards	150 µg/m³ (24 hours)			
WHO Guidelines (Interim target-1)	150 µg/m³			
SO_x				
Maximum	24.98	35.32	27.95	24.05
Minimum	18.79	18.02	22.63	17.23
Average	21.60	22.70	24.40	19.50
Draft Ethiopian Standards	125 µg/m^3 (24 hours)			
WHO Guidelines (Interim target-1)	125 µg/m^3			
NO_x				
Maximum	7.92	8.46	10.05	7.54
Minimum	5.92	5.98	9.09	5.45
Average	6.90	6.70	9.50	6.30
Draft Ethiopian Standards	200 µg/m^3 (24 hours)			
WHO Guidelines	200 µg/m^3			
CO				
Maximum	1557.80	1546.89	2931.00	1685.00
Minimum	1073.50	1163.40	1932.00	1073.00
Average	1299.00	1268.00	2199.00	1191.00
Draft Ethiopian Standards	10,000 µg/m^3 (8 hours)			

Table 4.19 : Ambient Air Quality in the Study Area

As can be observed for the above table, all parameters monitored are within the WHO guidelines and the draft Ethiopian standards. PM10 concentrations at the sites ranged between 10 and 60.5 µg/ m^3. The highest value was recorded at the quarry site indicating the possible release of particulate from the existing Muger quarry site and the lowest value was recorded at Lilo site, which is a residential area. The SPM concentration at the sites ranged between 33.1 and 185.2 μg/ m^3. The SPM is highest at the Derba town site, which could be attributed to the traffic and vehicular movement and dust from gravel roads.

The concentrations of SO_2, CO, and NO_2 are below the national standard and international guideline values. Slightly high concentration is observed at the quarry site and relatively lower values are observed at Lilo village.

4.10.2 DUST FALL

The plant and mining sites were chosen to study the pre-project dust fall rates and the observations are tabulated below. The dust fall rate is higher at the quarry site than at the plant site.

Sn	Parameters	Plant site	Mining site
1	Dust fall rate (mg/m^2/ day)	209.05	722.34
2	Copper (%)	0.03	<0.03
3	Lead (%)	0.03	0.03
4	Chromium (%)	<0.03	<0.03
5	Cadmium (%)	<0.03	<0.03
6	Aluminium (%)	<0.03	<0.03
7	Zinc (%)	0.05	0.03
8	Silica (%)	13	5

4.11 NOISE LEVELS

The noise levels have been monitored at site and at various locations within the study area during the period August-September 2007. The noise levels have been monitored using a sound level meter with octave filters. Measurements have been made for 24 hours at a frequency of 30 minutes. The photoplate below shows the noise monitoring in progress at the plant site.

Noise Level Monitoring in Progress

The noise levels as recorded at four locations are given in **Table 4.20**.

Sn	Location	Noise level dB(A)					
		Leq Day Time (07.00-22.00 hrs)			Leq Night Time (22.00 - 07.00hrs)		
		I	II	III	I	II	III
1	Plant site	54	42	39	56	44	36
2	Quarry site	37	43	36	44	34	35
3	Derba town	42	41	48	47	38	45
4	Lilo Chebeka village	42	41	-	47	38	-
Average		**42**			**42**		
Draft Ethiopian Norms (Residential areas)		**55**			**45**		

I, II & III represent three sampling dates

Table 4.20 : Noise levels in the Study Area

The noise levels are all within the draft Ethiopian standards as well as EHS guidelines.

4.12 TRAFFIC DENSITY

As a part of the pre-project activities in the area, the following roads are proposed to be constructed/ strengthened. The detailed Road designs have been prepared for these sections and construction is in progress.

- Upgradation of Road from Chancho to Derba
- Construction of road from Derba to Plant site
- Construction of road from Plant site to Quarry

The Derba Junction - Derba road branches off from Chancho at Addis Ababa Gondar Trunk road and leads to Derba. The total length of the road is about 23 km.

A detailed traffic survey has been carried out in the area during the month of August 2007. The main objectives of the traffic survey are the following.

- To obtain data on the volume and composition of motorized traffic particularly the volume of heavy trucks
- To obtain data on the volume of non motorized traffic
- To determine trip pattern and characteristics of motorized traffic
- Traffic Count Period

The traffic count survey on Derba Junction - Derba road was conducted for seven consecutive days between 19 and 26 August 2007, which represents the low business season in Ethiopia in general and the project area in particular. The motorized traffic count was conducted for 12 hours (6:00 am to 6:00 pm) for five days and night count was made for the remaining two days (6:00 pm to 6:00 am), of which one is a market day.

Since the volume and composition of traffic is homogeneous throughout this road, Derba village located along the junction of proposed DMC plant was selected as the monitoring station. Since the station has one leg or direction, two way traffic was counted in single form.

The vehicle classification used in the analysis is consistent with Ethiopian Roads Authority's (ERA's) vehicle classes. The motorized traffic is further analyzed group wise in terms of passenger and freight vehicles categorized based on the kind of service rendered. Passenger vehicles include Car, Land Rover, Small Bus, Medium Bus and Large Bus. Freight vehicles group on the other hand comprises Small Truck, Medium Truck, Heavy Truck and Truck Trailer base on their respective load capacity. The type of vehicles represented by each category is as shown in **Table 4.21.**

Vehicle group	Vehicle category	Type of vehicles
Passenger Vehicles	Cars	Small Cars, Taxis
	Land Rover, 4WD	Land Cruisers, Station Wagons, Double Cabin
	Small bus	Bus with 12-24 seats and includes such vehicles as mini bus
	Medium Bus	Bus with 24-45 seats
	Large Bus	Bus with 45 to 60 seats
Freight Vehicles	Small trucks	Truck with up to 3.5 ton load including pickups, Isuzu
	Medium Trucks	Trucks with 3.6 to 7.6 ton load
	Heavy Trucks	Trucks with 12 to 24 ton load
	Truck Trailers	Trucks with above 24 ton load

Table 4.21 : Vehicle Classification

4.12.1 RESULTS OF THE TRAFFIC SURVEY

The raw traffic count data of the road project were processed in order to estimate the required Average Daily Traffic (ADT) and Average Annual Daily Traffic (AADT), which show the 24 hours and all seasons traffic flows, respectively.

The traffic count results have been converted to Average Daily Traffic (ADT) for the road section and are given below.

Road Section	Car	L/ Rover	S/Bus	L/Bus	S/Trucks	M/Trucks	L/ Trucks	T/T	Total
Derba Junction-Derba	0	27	25	0	27	5	2	0	**86**

Average Daily Traffic of Derba Junction –Derba Road

As can be seen in the above table, the traffic composition of Derba Junction - Derba road is dominated by L/Rover and S/Truck traffic. It accounts for 63% of the total vehicle traffic along the road section of the road followed by S/Buses and Trucks, which account for 29% and 8 %, respectively.

The detailed Average Daily Traffic (ADT) calculation of Derba Junction-Derba is enclosed as **Annex 4.6.**

4.12.2 CONCLUSIONS

The proposed cement plant would produce 5,600 tonnes of cement per day at full capacity upon commencing of production. This would in turn generate substantial demand for trucks. From the point of view of economy of scale the factory would prefer to use heavy trucks including trucks & trailers and articulated trucks. Transportation of cement (around 5,600 tonnes) from the plant to market would require 235 trucks per day assuming a load factor of 240 quintals.

Such trucks would require a strong standard road. The existing Chancho – Derba gravel road clearly cannot accommodate such heavy trucks. Therefore, the existing road will be upgraded to a black topped road.

The 8 km road from Derba to plant is also being upgraded with asphalt. Construction of roads and heavier movement of trucks would also be beneficial in boosting the economy of the area. It is likely that many trucks would travel empty to the plant to transport cement from the plant to the market. These trucks could transport agricultural inputs such as fertilizers and improved seeds to farmers at a lower price than would be possible otherwise. As a result of lower costs of inputs, farmers would be encouraged to use these and the production of crops could be increased raising the living standard of local farmers.

4.13 LAND USE

A major part of the study area comprises of cultivated and grazing land. The study area comprises of core and buffer zones. The core zone comprises of the plant and mining sites and the buffer zones covers an area of 10 km radius around the plant and mining sites.

The land use map of the plant site is enclosed as **Fig. 4.26** and for the quarry site as **Fig. 4.27**. The land use of the total study area is shown in **Fig. 4.28**.

A view of the proposed Project site

The land use pattern of the buffer zone is given below: It can be seen that the major part of the buffer area is farming/grazing land.

Land Use	Total Area (ha)
Farming	2418.7
Grazing	913.8
Residential	337.4
Tree	0.58
Others	11.33

Land Use Pattern in the Buffer Area of 10 km Radius around Mining and Plant Sites

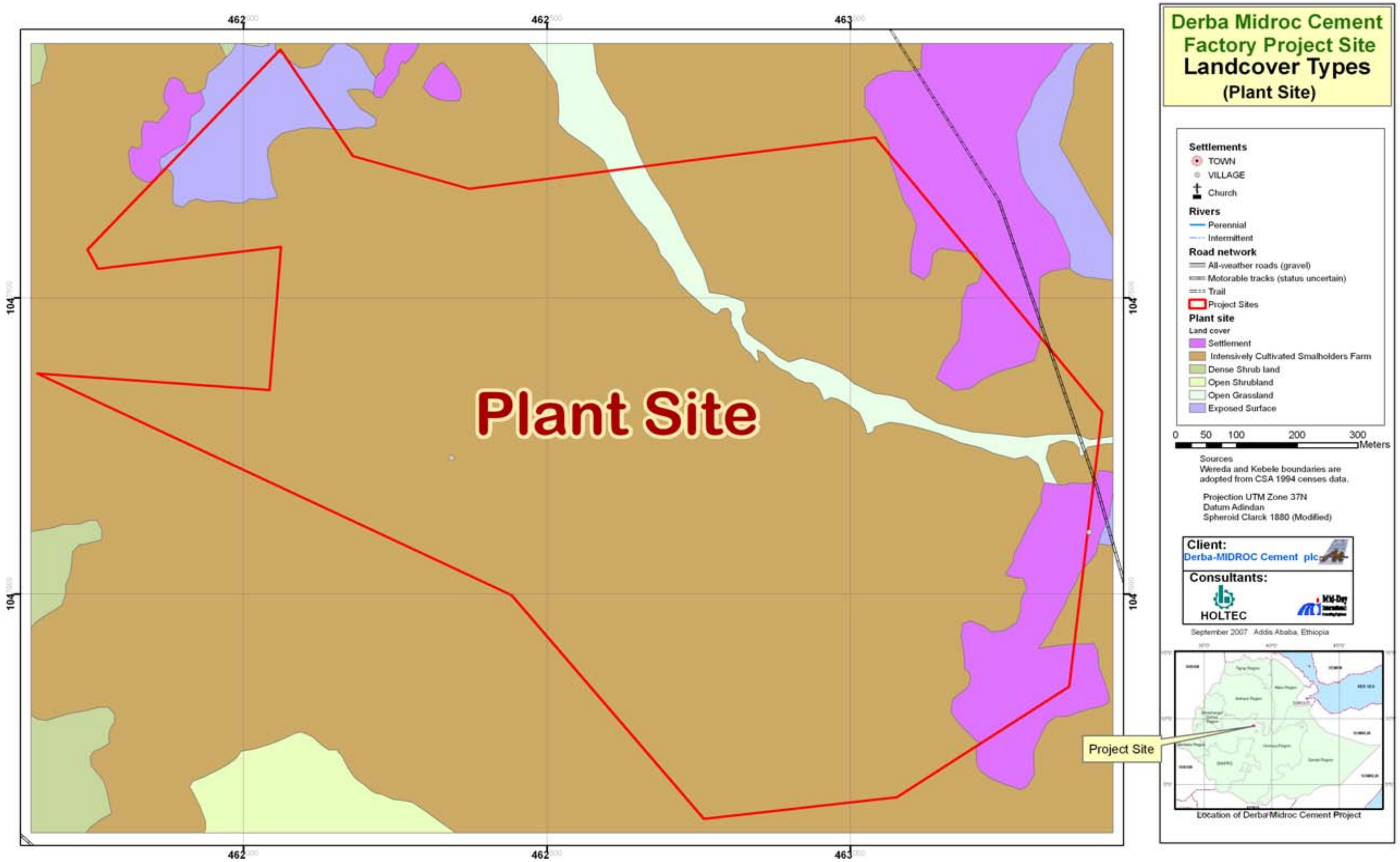

Fig. 4.26 : Land use pattern of the Plant site

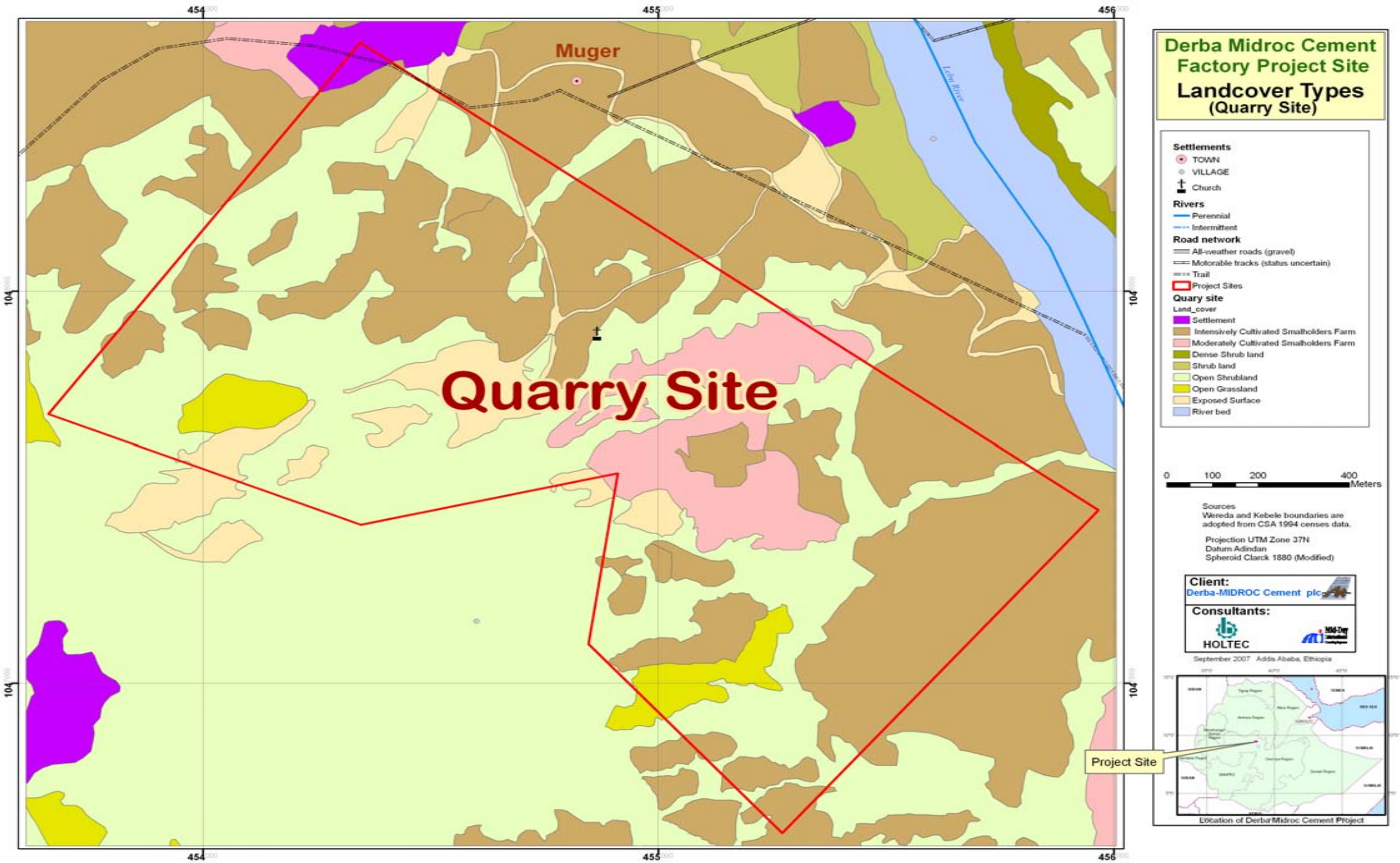

Fig. 4.27 : Land use pattern of the Quarry site

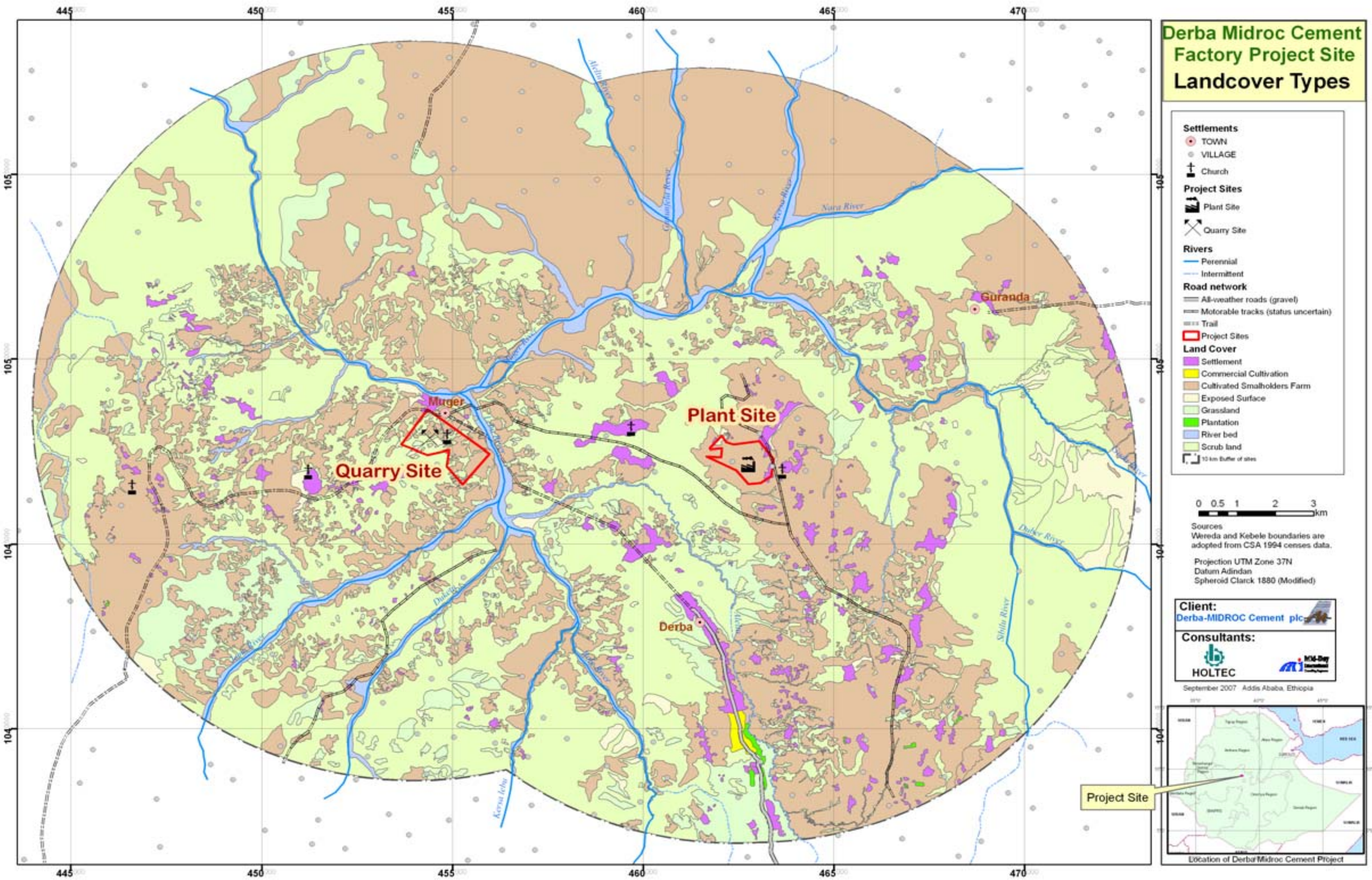

Fig. 4.28 : Land use pattern of the Study Area