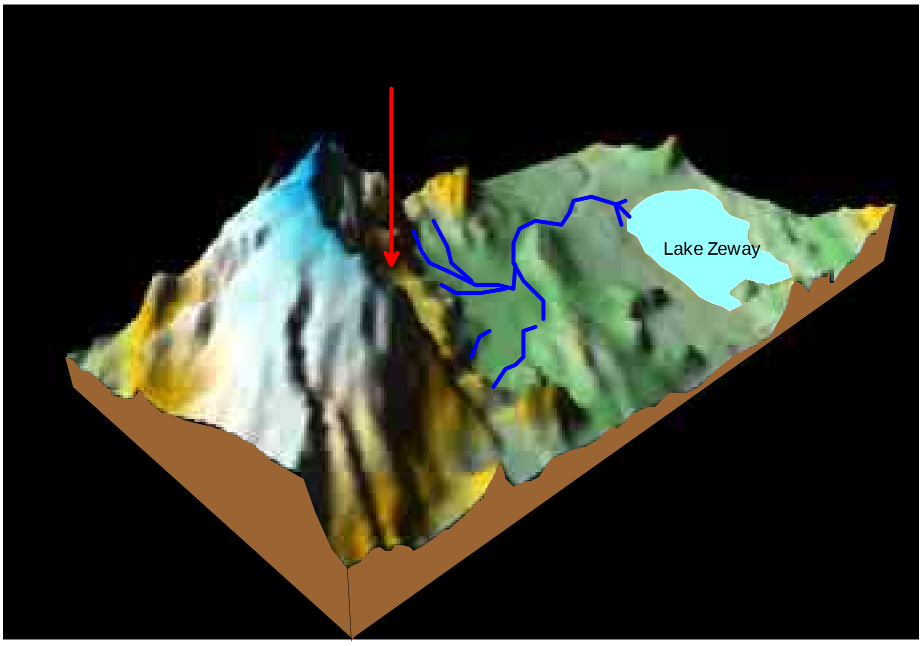
FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

MINNISTRY OF WATER RESOURCES
ETHIOPIAN WATER TECHNOLOGY CENTRE

BUTAJIRA – ZIWAY AREAS DEVELOPMENT STUDY



REPORT

MARCH 2006

AG Consult Consulting Hydrogeologists & Engineers Plc.

P.O.Box. 4661, Tel. 251 01 153397/98 e-mail ag-consult@telecom.net.et

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1 INTRODUCTION

In accordance with the Contract for Consulting Services for Butajira-Ziway Development Project dated May 12, 2005 between the Client:

Ethiopian Water Technology Centre (EWTEC);

And the Consultant:

AG-Consult Consulting Hydrogeologists and Engineers;

The Consultant started the work on May 15, 2005.

In this report only matters that are related to the Actual Study Phase of Butajira-Ziway Development Project are presented.

The history of the project can be summarized as follows:

- APRIL 11, 2005 .... INVITATION TO TENDER
- APRIL 25, 2005 ....SUBMISSION OF TECHNICAL AND FINANCIAL PROPOSALS
- MAY 5, 2005 ....AWARD NOTIFICATION
- MAY 12, 2005 .... SIGNATURE OF CONTRACT FOR CONSULTING SERVICES
- MAY 15, 2005 ....COMMENCEMENT OF SERVICES

1.1 OBJECTIVES OF THE STUDY

1.1.1 Objectives

As it is elaborated in the Terms of Reference (TOR), the general objective of the study is to promote research and development activities of the country for the accelerated development of water sector and for the achievement of the Millennium Development Goal (MDG) in terms of water supply coverage rate.

While the specific objectives of the study are:

- To elucidate groundwater flow mechanism through the type locality of Rift Valley Pediment Slopes.
- To boost groundwater development and management in the study area as well as adjacent areas so as to make ready preparedness against chronic drought.
- To develop and disseminate various types of appropriate technologies to effectively store, lift, utilize and improve the quality of water so as to make the communities resilient against chronic drought.

- o To feed back the outcomes of the study to various training programs of EWTEC, and to utilize the study area as a live experimental field for the training programs.

1.2 THE SCOPE OF THE STUDY

In accordance with the Contract, the scopes of services include three major studies i.e., Preliminary, Actual and Analytical study.

1.2.1 Preliminary Study

The preliminary study covers the period from April 2005 to July 2005 and includes the following major studies:

- Base Line Study
- Groundwater Management Study
- Appropriate Technology Study

At the end of the preliminary study Progress Report has to be submitted.

1.2.2 Actual Study

The Actal study covers the period from August 2005 to March 2006 and includes the following major studies:

- Groundwater Management Study
- Implementation of Appropriate Technology

At the end of the actual study submission of Intrim report.

1.2.3 Analyitical Atudy

The Actal study covers the period from April 2006 to January 2007 and includes the following major studies:

- Groundwater Management
- Formulation of GIS Data base
- Furmulation and dessimination of appropriate technology

At the end of the analytical study submission of final report.

1.3 WORKS UNDERTAKEN DURING THE ACTUAL STUDY

The following works have been undertaken during the Preliminary Study Period:

- ◊ Field hydrogeological and geological investigation
- ◊ Water quality analysis
- ◊ Selection of test drilling sites
- ◊ Preparation of drilling tender
- ◊ Supervision of test drilling
- ◊ Hydrological study
- ◊ Demonstration of appropriate technology
- ◊ Selection and collection of hydro meteorological data

As per the Terms of Reference, this report covers the results of the work undertaken during the actual study period.

2 THE STUDY AREA

2.1 LOCATION

Butajia–Zeway Development Study area is situated in the in the Main Ethiopian Rift Valley in the northern sector of the Lakes Region (See location Maps on next page). Butajira town is situated about 135 km and Zeway is located about 160 km from Addis Ababa. The area stretches from the edges of the western escarpment of the rift valley or the Gurage Chain of Mountain called Zebidar in the west and to the Lake Ziway in the east. The study area covers 30 km by 60 km (1800km^2) within the following coordinates.

Table 1: Study area coordinates

UTM E	UTM N
413000	893000
429000	920000
467000	862500
483000	889000

2.2 AREAS COVERED BY THE STUDY

The whole study area is found within Meki River Catchment and it covers six woredas, namely: Meskan, Mareko, Soddo Siltie, Adamitulu Jido Kombolcha and Dugda Bora.

The first three Woredas are located in Gurage Zone of Southern Nations Nationalities, and Peoples Region (SNNPR). Silte is located in Silti zone of SNNPR. Adamitulu Jido Kombolcha and Dugda Bora are located in East Shewa Zone of Oromia Region.

3. GROUNDWATER MANAGEMENT

2.3 DRILLING AND TESTING RESULTS

One component of the project is the verification of the available groundwater source, which includes test drilling.

The drilling program comprised 6 test boreholes: Drilling of two deep boreholes was outsourced to SABA Engineering PLC and four shallow boreholes are drilled by the drilling team of the Ethiopian Water Technology Centre (EWTEC).

- One deep borehole with 244 m depth (BZDP/TW5) drilled in Tora-Koshe-Dugda ridge at Koshe Town.
- The second deep borehole with 168 m depth (BZDP/TW4) drilled in Inseno Plain at a locality known as Kuno Kertafa.

The shallow boreholes are drilled in the following places

- Butajira pediment/crescent at Kacha Ber 123.8 m deep (BZDP/TW1),
- Scoria cones region at Semen Shershera 86 m deep (BZDP/TW2),
- Kontane-Inseno-Kela plain at Weja Kebele 64 m deep (BZDP/TW3) and
- Gademotta caldera / Ziway plain at Shisho Tora 128 m deep (BZDP/TW6).

Four boreholes drilling and testing ((BZDP/TW1, BZDP/TW2, BZDP/TW3, BZDP/TW4) have been completed until submission of this report. Two boreholes BZDP/TW5 and BZDP/TW6 some works are remaining. At BZDP/TW5 test pumping remains and at BZDP/TW6 development and test pumping is remaining.

2.3.1 Drilling Results

2.3.1.1 BZDP/TW1 Butajira pediment/crescent at Kacha Ber

Location

This test well is situated in Butajira pediment/crescent at Kacha ber Village.

- Geographic coordinates UTM: 424544 E, 894351 N
- Altitude: 2179 m.a.s.l

Purpose

This borehole has been drilled inorder to test the hydrogeological condition underlying the Butajira pediment plain.

Drilling

The total depth of the well below ground surface is 123.83m. After completion of drilling 6 inches PVC casing and screens installed up to 119.38 m. There was no major drilling problem except the collapse encountered in upper unconsolidated sediment. The well was drilled using DTH and mud circulation system.

Well Construction

ND 6 inches PVC casing and screen has been installed down to 120 m depth. The screen casing has been installed between 39.5 - 45.19, 62.38 - 68.06, 73.79 - 79.47, 85.2 - 102.24, and 107.97 - 113.65. The remaining part is blind casing.

Formation Penetrated

The geological formations penetrated are mainly talus and alluvial deposits alternating with some rock layers. These deposits extend down to about 108 m below ground. These rock layers are probably big blocks, which slide down from the escarpment. It is difficult to explain occurrence of layers of basalt and ignimbrite within layers of gravel and clay deposits. The parent rock made up of ignimbrite underlain by basalt started somewhere around 108 m and extended down to 122 m.

It is apparent that the geology penetrated well fits to the geological evolution of the area. The area is a down faulted block receiving flood and sediment deposit from the up thrown block of the escarpment. The variation in the sediment deposit from clay to gravel indicates different stages of faulting or changes in the course of the sediment flux.

The electrical logging result of the borehole shows the alternating sediments up to about 108 m and sharp increase below 108 m depth indicating the bedrock depth.

The gamma log indicates variation in the clay content in the formation penetrated. Higher values are indicated adjacent to weathered rocks and clay deposits. Higher gamma log values correspond with low SP logs indicating clayey layers.

The temperature log indicates the temperature of the water is below 23 ^{o}C, however it has gradually increased from about 20 ^{o}C to 21.5 ^{o}C with depth.

For details see Appendix .

2.3.1.2 BZDP/TW2 Scoria cones region at Semen Shershera

Location

This test well is situated in Scoria cones region at Semen Shershera. It is situated close to the road from Butajira to Ziway .

- Geographic coordinates UTM; 436926 E, 899128N
- Altitude 1981 m.a.s.l .

Purpose

This borehole has been drilled in order to test the hydrogeological condition underlying the Basaltic flow and scoria cone region.

Drilling

The total depth of the well below ground surface is 86m. After completion of drilling 6 inches PVC casing and screens installed up to 86 m. There was no major drilling problem except loss of circulation and sampling difficulties. The well was drilled using mud circulation system.

Well Construction

ND 6 inches PVC casing and screen has been installed down to 86 m depth. The screen casing has been installed between 50 - 56, 61-73, 77-83. The remaining part is blind casing.

Formation Penetrated

The geological formations penetrated are mainly vesicular basalt alternation with scoria. This is quite similar with the geology of the area. It is difficult to explain occurrence of layers of basalt below an ignimbrite layer. Normal succession should be vesicular basalt underlain by ignimbrite or alluvial deposit. The geological log of the old borehole of semen Shershera water supply shows vesicular basalt and scoria underlain by ignimbrite/rhyolite. The geological log of Debub Shershera indicates vesicular basalt underlain by ignimbrite, and the well at Shershera ele shows vesicular basalt underlain by alluvial deposit. The geology indicated as basalt below 56 m depth is probably ignimbrite/rhyolite weathered to different degrees.

It is apparent that the geology penetrated well fits to the geological evolution of the area. The area is a down faulted block which has received flood and sediment deposit from the up thrown block of the escarpment and latter on covered by basic volcanic eruption forming the vesicular lava flows and cinder cones. Absence of the alluvial deposits at some localities and presence at some places indicates that sedimentation took place at some spots where some river or stream channel has developed. Occurrence of sediment deposit within the basaltic flow layers is quite possible, because both the lava flow and sedimentation were possible within the down faulted block.

The electrical logging result of the borehole shows low resistivity layer between 58 m and 72 m depth. Probably this belongs to the weathered ignimbrite/rhyolite layer. The SP log indicates area affected with mud invasion below 57 m. in addition between 57 to 60 and 71 to 70 m depths there is an open area with deep invasion of mud. This could be the reason for non-recovery of samples at some spots. The electrical log indicates that the depth to groundwater level is at about 46 m below ground.

The gamma log is quite uniform and indicates very low clay content in the formation penetrated.

The temperature log indicates the temperature of the water is about 25 ^{o}C, and doesn't show increase or decrease with depth.

For details see Appendix.

2.3.1.3 BZDP/TW3 Kontane-Inseno-Kela plain

Location

This test well is situated at Weja Kebele close to Weja River north of Koshe town.

- Geographic coordinates UTM; 446999 E, 886227 N
- Altitude 1798 m.a.s.l

Purpose

This borehole has been drilled in order to test the aquifer and the water level differences between Tora-Koshe-Dugda ridge and Kontane-Inseno-Kela plain.

Drilling

The total depth of the well below ground surface is 64m. After completion of drilling 6 inches PVC casing and screens installed up to 86 m. There was no major drilling problem. The well was drilled using mud circulation system.

Well Construction

ND 6 inches PVC casing and screen has been installed down to 86 m depth. The screen casing has been installed between 23.40 - 26.25, 37.95 - 43.65, and 55.35 - 63.9. The remaining part is blind casing.

Formation Penetrated

The geological formations penetrated are mainly sand, silt and clay. Mostly sample was not recovered according to the drillers report. It seems that these areas are probably fine silt deposits. Ignimbrite has been drilled 16 m to 20 m, which could be a block of ignimbrite. Below it mainly clay and silt are reported. It seems that the one reported as silt or clay could be sediments deposited or highly weathered rocks in the fault zone; since the site is situated at the main fault zone separating Tora-Koshe-Dugda ridge from Kontane-Inseno-Kela plain.

The electrical logging result of the borehole shows relatively higher resistivity layer between 12 m and 22 m depth. Probably this belongs to the weathered ignimbrite/coarse sand layer. Below 22 m depth the formation has low resistivity, which is quite uniform up to the bottom of the well. The SP log indicates below 10 m depth the formation is more of sandy deposit. This could be the reason for non-recovery of samples at some spots. The electrical log indicates the depth to groundwater level at about 11m.

The gamma log is quite uniform and indicates occurrence of uniformly distributed clay content in the formation penetrated.

The temperature log indicates the temperature of the water doesn't show increase or decrease with depth.

For details see AppendixI.

2.3.1.4 BZDP/TW 4 Kontane-Inseno-Kela plain

Location

This test well is situated at Kuno Kertafa Village west of Inseno town.

- Geographic coordinates UTM; 440020 E, 888300 N
- Altitude 1854 m.a.s.l

Purpose

Many of the wells on the plain are shallow, and mostly the property of the shallow aquifer is partially known. The condition in the deeper part is not well understood. Therefore, the main purpose of this test well is to test the deeper aquifer in Kontane-Inseno-Kela plain.

Drilling

The total depth of the well below ground surface is 168 m. After completion of drilling 6 inches steel casing and screens installed up to 183 m. Due to collapse the casing could not be installed down to 168 m. The well was drilled using DTH system. Drilling problem encountered is caving of the formation. Due to heavy collapse casing was installed using method of simultaneous casing installation along with cleaning of the collapsed material through the casing using smaller diameter bit.

Well Construction

ND 6 inches mild steel casing and screen has been installed down to 163 m depth. 54 m screen casing has been installed between 60-66, 72-78, 84-90, 96-102, 108-114, 120-126, 132-138, 144-150, and 156 -162. The remaining part is plain casing.

Formation Penetrated

The formation is mainly loose pyroclastic deposits mainly fall deposits and reworked water lain pyroclastics. The pyroclstic deposits are composed of pumice, ash, and tuff with pumice and lithic materials.

The aquifer is unconfined and major aquifer occurs below 58 m depth. The aquifer is continuous and the drilling did not penetrate fully the aquifer.

Because of heavy collapse electrical logging was not performed.

2.3.1.5 BZDP/TW5 Tora-Koshe-Dugda ridge

Location

This test well is located at Koshe town, which is situated in the Tora-Koshe-Dugda ridge.

- Geographic coordinates UTM; 448646 E, 885794 N
- Altitude 1864 m.a.s.l

Purpose

The existing data indicates that the aquifer in Tora-Koshe-Dugda ridge has deeper water level as compared to the Kontane-Inseno-Kela plain. This difference requires appropriate explanation. Therefore, the purpose of the drilling at Koshe is to understand the aquifer behaviour with respect to the aquifer at Kontane-Inseno-Kela plain and to understand the water level differences between the two aquifers.

Drilling

The total depth of the well below ground surface is 244 m. After completion of drilling 6 inches steel casing and screens installed up to 242 m. Due to some collapse the casing could not be installed down to 244 m. The well was drilled using DTH system. Drilling problem encountered is circulation loss between 154 m and 196 m. No sample has been recovered from this depth.

Well Construction

ND 6 inches mild steel casing and screen has been installed down to 242 m depth. 42 m screen casing has been installed between 194 and 236 m. The remaining part is plain casing.

Formation Penetrated

The formation is mainly consolidated pyroclastic deposits such as alternating layers of tuff and ignimbrite with layers of ash and weathered tuff/ash. Tuff and ignimbrite deposits are mainly pumaceous and with lithic materials. The lithic materials are mainly derived from basaltic country rocks and some acidic rocks. In some layers the lithic grains are so dominant and in some of existing borehole logs it was described as basaltic layer. Because during drilling the pyroclastic materials get easily crushed and washed away with the drilling fluid and the hard lithic material is recovered. This led to mistakes in logging.

The electrical logging indicates open cavity between 154 m and 159 m depth. This could be the main reason for loss of circulation. The aquifer is encountered below 194 m and main aquifer below 226 m. The drilling did not penetrate fully the aquifer. The electrical logging indicates that the water level in the well is around 132 m depth.

The temperature logging indicates the water temperature increases gradually from about 30 ^{o}C to about 38 ^{o}C.

Gamma logging shows that the aquifer zone has relatively low counts indicating less clay content.

2.3.1.6 BZDP/TW6 Gademotta Caldera / Ziway plain

Location

This test well is located at Shisho Tora village west of adami Tulu village in the Gademotta Caldera.

- Geographic coordinates UTM; 463216 E, 867376 N
- Altitude 1675 m.a.s.l

Purpose

This part of the study area is characterised by a caldera, which is filled with lacustrine sediment filled. The area from the west is bounded by the caldera rim and in the other directions the caldera is downfaulted and covered by lacustrine deposit. The aquifer in this area has limited recharge sources. Therefore, the purpose of this drilling is to study the aquifer condition within the Gademotta caldera.

Drilling

The total depth of the well below ground surface is 128 m. After completion of drilling 6 inches PVC casing and screens installed up to 126 m. Due to some collapse the casing could not be installed down to 128 m. The well was drilled using DTH system up to 100m. Drilling problem encountered is circulation loss between 74 m and 100 m. No sample has been recovered from this depth. Therefore, the drilling changed to mud circulation and additional 28 m was drilled. The aquifer occurs below 100m depths.

Well Construction

ND 6 inches mild steel casing and screen has been installed down to 242 m depth. 42 m screen casing has been installed between 194 and 236 m. The remaining part is plain casing.

Formation Penetrated

The formation is mainly consolidated pyroclastic deposits such as alternating layers of tuff and ignimbrite with layers of ash and weathered tuff/ash. Tuff and ignimbrite deposits are mainly pumaceous and with lithic materials. The lithic materials are mainly derived from basaltic country rocks and some acidic rocks. In some layers the lithic grains are so dominant and in some of existing borehole logs it was described as basaltic layer. Because during drilling the pyroclastic materials get easily crushed and washed away with the drilling fluid and the hard lithic material is recovered. This led to mistakes in logging.

The electrical logging indicates relatively uniform geology. The electrical log indicates the water level I around 74 m depth below ground. Below 94 m depth the resistivity value gradually declines and the SP log gradually increases. This indicates the water-bearing zone occurs below 94 m depth.

The temperature logging indicates the water temperature increases gradually from about 32 ^{o}C to about 35 ^{o}C.

Gamma logging shows that the aquifer zone has relatively low counts indicating less clay content.

2.3.2 Aquifer Testing

2.3.2.1 BZDP/TW1

2.3.2.1.1 Test Pumping

After the well has been developed the well has been test pumped. Step drawdown test was conducted for a total of 3 hours and consisted of three steps, where each steps lated for 1 hour. The well was pumped successively at 1., 1.5, and 2 l/s. The total draw down of the step-wise test was 9.8 m, 55.1 m, and 64 m respectively.

24 hours constant rate test was carried out at the same pumping position at discharge rate of 1.5 lt./sec, The water level at the beginning of the test was at 18 m. During the pumping period the water level did not stabilize and reached 83 m with drawdown of 65 m. The recovery of the well was fast and 100 % recovered within 110 minutes.

2.3.2.1.2 Test Pumping Result

The time-drawdown curve shows that the decline in water level was fast and did nit stablize. The time-drawdown plot has two segments with similar gentle slope. The first segment covers the first 30 minute and the second segment covers the remaining 1410 minutes. No barier boundary effect is shown on the test-pumping curve.

The transmisivity of the aquifer has been calculated from the time-drawdown and recovery data of the constant and step test. The value calculated from the time drawdown of the constant test is 1.02 m^2/day. Summary of the test result is shown in the following table.

Table 3: Summary of test pumping result

BZDP/TW1	
Ground level (m.a.s.l)	2179
Water level below reference point at the beginning of constant discharge test	18 m
Pumping rate (m3/day)	129.6(1.5 l/s)
Pumping test length	24 hours
Stabilized pumping water level (m)	
Drawdown (m)	64.91 m
Specific Capacity (M3/day/m)	1.56
Transmisivity from time drawdown plot (m^2/d)	1.

This transmissivity value characterizes an aquifer with very low potential.

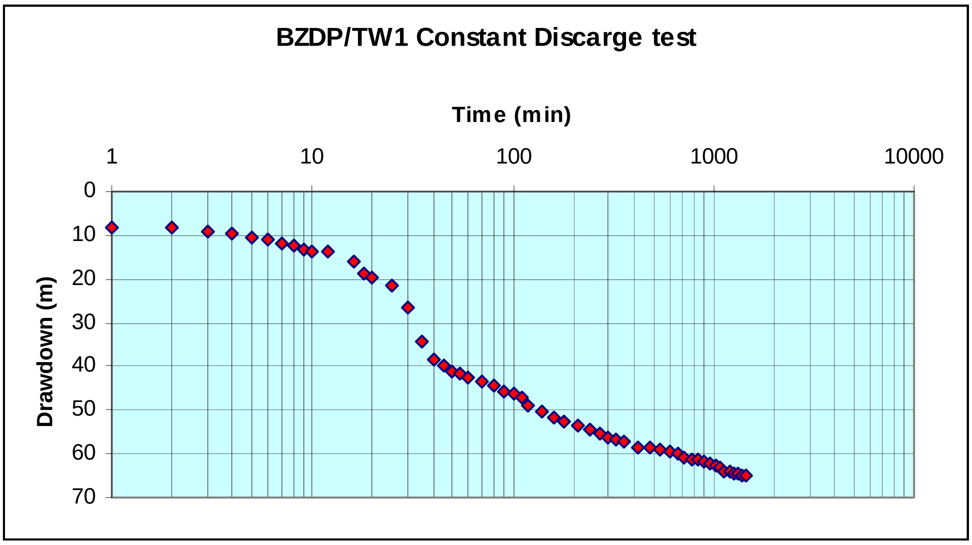

Figure 1 BZDP/TW1 Time Drawdown plot

The step drawdown test result shows that the drawdown in the well is mainly related to well loss.

Table 4: Result of Step Drawdown test

Steps	Sw (m)	Qn (m3/d)	Sw/Qn (d/m2)	B (d/m2)	C (d2/m5)	B*Qn (m)	CQn^2 (m)	Swn (m)
1	9.85	86.4	0.114005	0	0.0028	0.00	20.90	20.90
2	56.8	129.6	0.438272			0.00	47.03	47.03
3	83	172.8	0.480324			0.00	83.61	83.61

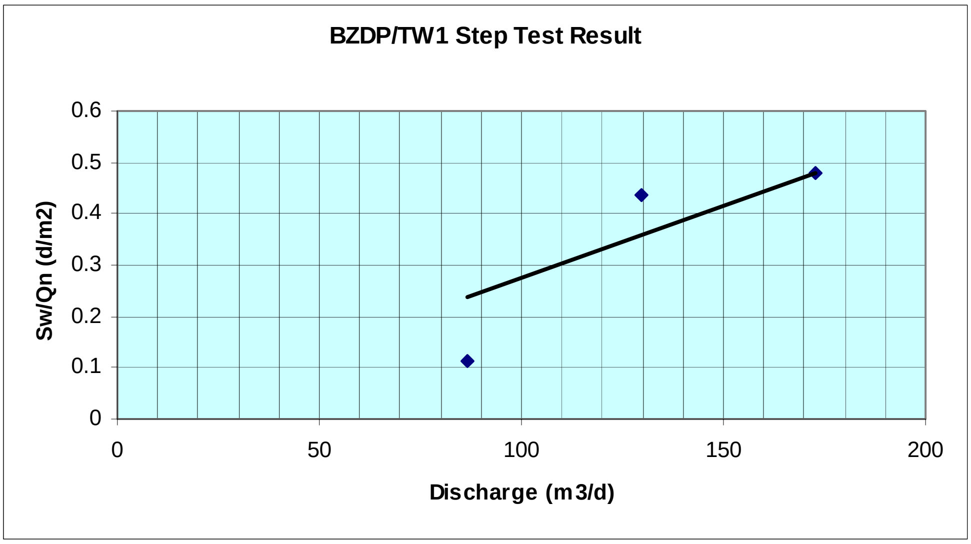

Figure 2 BZDP/TW1 Plot of Specific capacity vs discharge

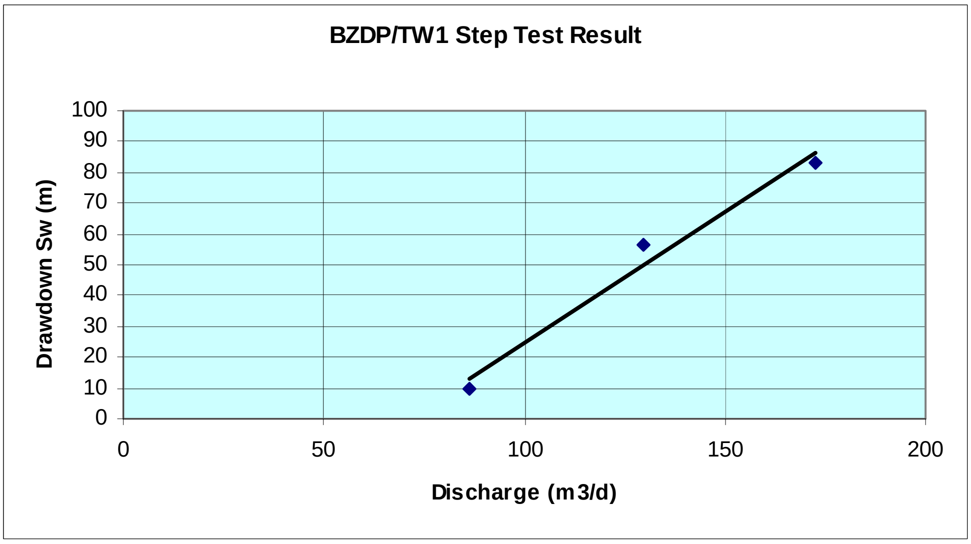

Figure 3 BZDP/TW1 Plot of Drawdown vs discharge

2.3.2.2 BZDP/TW2

2.3.2.2.1 Test Pumping

After the well has been developed it was test pumped. Step drawdown test was conducted for a total of 3 hours and consisted of three steps, where each steps lated for 1 hour. The well was pumped successively at 2, 3, and 4 l/s. The total draw down of the step-wise test was 3.85 m, 6.45 m, and 18.15 m respectively.

28 hours constant rate test was carried out at the same pumping position at discharge rate of 4 lt./sec, The water level at the beginning of the test was at 48.55 m. During the pumping period the water level stabilized around 1000 minute at 70.2 m below ground with a drawdown of 21.6 m. The recovery of the well was fast and 97 % recovered within 60 minutes.

2.3.2.2.2 Test Pumping Result

The transmisivity of the aquifer has been calculated from the time-drawdown data. The value calculated from the time drawdown of the constant test is 11.2 m^2/days. Simi-Logrithmic plot of time drawdown indicates that the aquifer is simi-confined type. Summary of the test result is shown in the following table.

Table 5: BZDP/TW2 Summary of test pumping result

BZDP/TW2	
Ground level (m.a.s.l)	1981 m
Water level below reference point	48.55 m
Pumping rate (m3/day)	345.6 (4 l/s)
Pumping test length	28 hours
Stabilized pumping water level (m)	84.65 m
Drawdown (m)	21.6 m
Specific Capacity (M3/day/m)	16.06
Transmisivity from time drawdown plot (m^2/d)	11.2

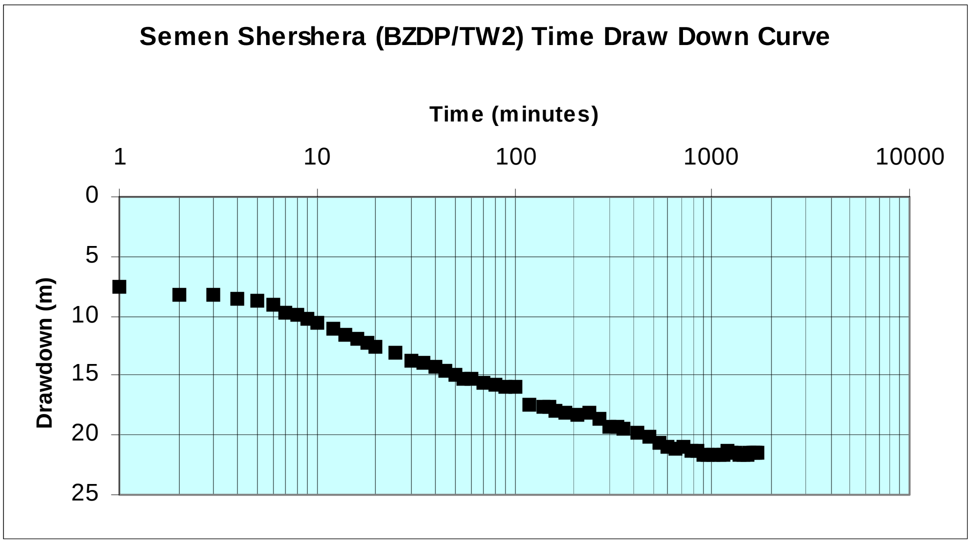

Figure 4 BZDP/TW2 Plot of Time Drawdown curve

The step drawdown test result shows that the drawdown in the well is mainly related to well loss. The optimum prodiction pumping rate from this borehole should not exceed 3.2 l/s.

Table 6: BZDP/TW2 Result of ste drawdown test

Steps	Sw (m)	Qn (m3/d)	Sw/Qn (d/m2)	B (d/m2)	C (d2/m5)	B*Qn (m)	CQn^2 (m)	Swn (m)
1	3.85	172.8	0.02228	0	0.000133	0.00	3.97	3.97
2	6.45	259.2	0.024884			0.00	8.94	8.94
3	18.15	345.6	0.052517			0.00	15.89	15.89

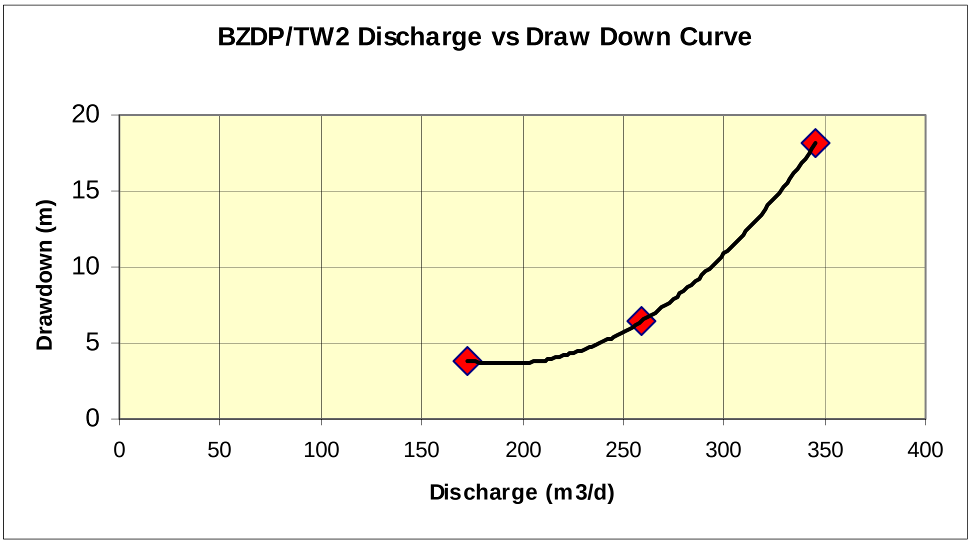

Figure 5 BZDP/TW2 Plot of Drawdown vs discharge

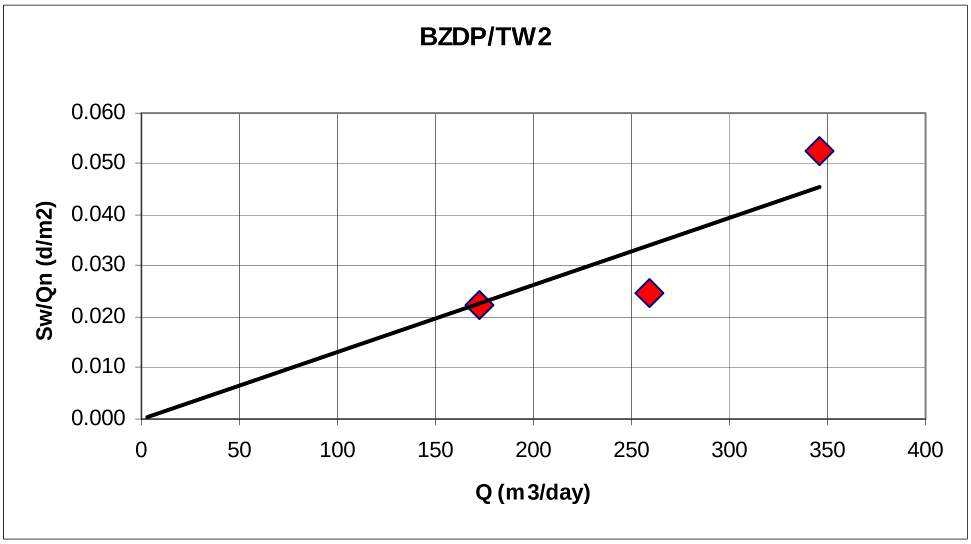

Figure 6 BZDP/TW2 Plot of specific capacity vs discharge

2.3.2.3 BZDP/TW3

2.3.2.3.1 Test Pumping

Because of very low drawdown step test was not conducted. 24 hours constant rate test was carried out at the same pumping position at discharge rate of 8.5 lt./sec, The water level at the beginning of the test was at 9.55 m. During the pumping period the water level stabilized around 1260 minute at 11.4 m below ground with a drawdown of 3.82 m. The recovery of the well was slaw and 88 % recovered within 1640 minutes.

2.3.2.3.2 Test Pumping Result

The transmisivity of the aquifer has been calculated from the time-drawdown data. The value calculated from the time drawdown of the constant test is 232 m^2/days. Summary of the test result is shown in the following table.

Table 7: BZDP/TW3 Summary of test pumping Result

BZDP/TW3	
Ground level (m.a.s.l)	1798 m
Water level below reference point	9.55 m
Pumping rate (m3/day)	731 (8.5 l/s)
Pumping test length	24 hours
Stabilized pumping water level (m)	11.4 m
Drawdown (m)	3.82 m
Specific Capacity (M3/day/m)	193.26
Transmisivity from time drawdown plot (m^2/d)	232

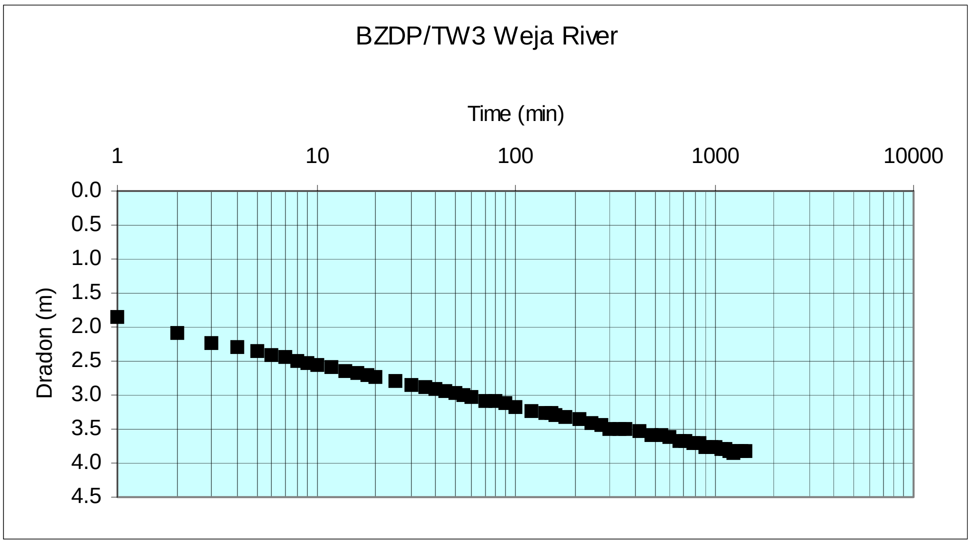

Figure 7 BZDP/TW3 Plot of Time Drawdown curve

2.3.2.4 BZDP/TW4

2.3.2.4.1 Test Pumping

After the well has been developed it was test pumped. Because of low drawdown Step drawdown test was not conducted

8 hours constant rate test was carried out at the same pumping position at discharge rate of 6 lt./sec, The water level at the beginning of the test was at 11.44 m. During the pumping period the water level stabilized around 12.54 m below ground with a drawdown of 1.1 m.

2.3.2.4.2 Test Pumping Result

The transmisivity of the aquifer has been calculated from the time-drawdown data. The value calculated from the time drawdown of the constant test is 505 m^2/day. Summary of the test result is shown in the following table.

Table 8: BZDP/TW4 Summary of test pumping Result

BZDP/TW4	
Ground level (m.a.s.l)	1854 m
Water level below reference point	11.44 m
Pumping rate (m3/day)	518.4 (6 l/s)
Pumping test length	8 hours
Stabilized pumping water level (m)	12.54 m
Drawdown (m)	1.1 m
Specific Capacity (M3/day/m)	471
Transmisivity from time drawdown plot (m^2/d)	505

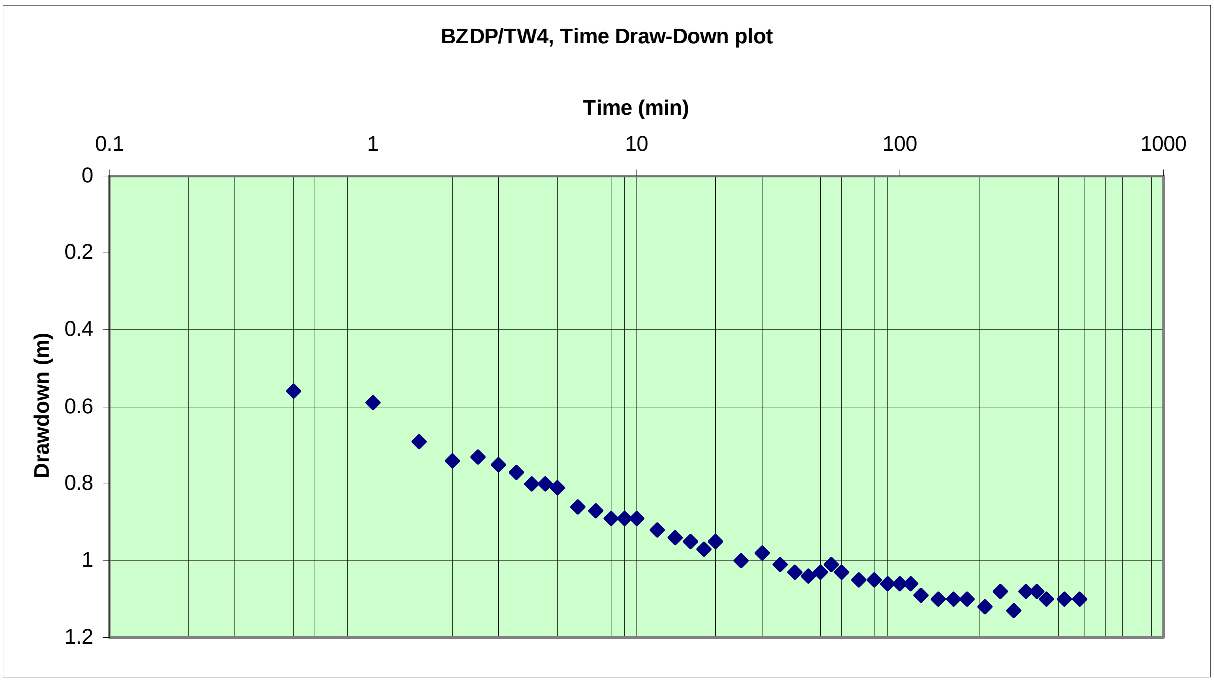

Figure 8 BZDP/TW4 Plot of Time Drawdown curve

2.3.2.4.3 Water Quality Test Result

Water quality test result submitted by SABA Engineering indicated that the water is fresh with TDS 260.8 mg/l. All other major chemical constituents are low except sodium, which is 107.5 mg/l. The fluoride content is reported 1.3 mg/l. This value is high for this area. Therefore, further analysis is recommended.

2.3.2.5 BZDP/TW5

This well was not test pumped until this report is submitted.

Water quality test result submitted by SABA Engineering indicated that the water is fresh with TDS 528 mg/l. All other major chemical constituents are low except sodium, which is 202.25 mg/l and fluoride, which is 5 mg/l. The normal range of values for fluoride in this area is between 3 mg/l and 3.5 mg/l. This value is high for this area. Therefore, further analysis is recommended.

2.3.2.6 BZDP/TW6

This well was not test pumped until this report is submitted.

2.3.3 Summary Of The Test Drilling Results

The new wells recently drilled have provided additional knowledge of the subsurface geology and the hydrogeology of the study area.

2.3.3.1 Butajira Pediment/crescent

The test drilling result close to the escarpment indicated thick unsorted to poorly sorted sediment derived from the escarpment. The alternating gravel and clay deposit has also indicated changes in sedimentation condition or successive faulting conditions.

The sediment deposit changes from poorly sorted deposit to relatively better sorting towards Butajira town or to the southern end of the area. This is shown by the river deposits close to Butajira town and the test drilling results of Butajira Town water supply.

The aquifer is found to be very poor with very low transmissivity. It doesn't have a potential to supply big pumping conditions. However, it can support low pumping condition for household or smaller community demand.

The water level monitoring conducted at this well indicates fast decline in the water level during 2 months period since it's drilling the water level dropped by 3.8 m from 17.6 m t 20.98 m.

In this area the aquifer improves toward it's southern end or close to Butajira area, where well sorted gravel and sand deposits are available. This is indicated from the data of test boreholes, which were drilled for Butajira Town.

The aquifer is in general unconfined at the top part with some semi-confined layers at depth.

2.3.3.2 Scoria cones and basaltic lava flow region

This is the area, which has relatively high relief and separates Butajira pediment/crescent from Kontane-Inseno-Kela plain.

This area is characterised by cinder cones, lava flow and some sedimentation between lava flow layers.

The basaltic deposits sometimes rest on underlying acidic rocks such as ignimbrite or rhyolite and at some places on river sediment deposits. At some places river deposits are found inter-layered between lava flows or scoria deposits.

The test well drilled at Semen Shereshera indicated vesicular and scoria deposits underlain by ignimbrite.

In places such as Shershera Ele, Dirama shershera, Shershera Jole river sediment deposits mainly gavel deposits are encountered.

At place in Butajira Town the Borehole of Girar bet Ledekuman, indicated interlayered gravel deposits within the basaltic lava flows.

Therefore, this region is characterised by basaltic lava flows or scoria/cinder deposits overlaying acidic volcanic rocks or at paces alluvial sediments. This indicates that the basaltic deposits are very young deposits.

The aquifer is found to have variable potential depending up on the amount of scoria deposits. In general it is relatively poor with low transmissivity. The aquifer is in general unconfined at the top part with some semi-confined layers at depth.

2.3.3.3 Kontane-Inseno-Kela plain

The test drilling result in this plain indicated that the major geology comprising this plain is pyroclastic fall deposits and reworked water lain pyroclstics with very little or absent lacustrine deposits. Lacuatrine deposits are limited to some places. Their thickness is over 168 m (which is the depth of the test well). This has also been indicated by the geophysical survey conducted during the preliminary study.

At its western extreme where there are hot springs and lakes and swamps lacustrine deposits as well as calcrete deposits deposited by hot springs is observed.

The aquifer in this plain has high potential to support big pumping schemes. The aquifer is thick with thickness, which can reach to about 200 m. The aquifer is unconfined.

2.3.3.4 Tora-Koshe-Dugda ridge

The test drilling and other existing data indicated that this ridge is mainly made up of tuff deposit with layers of ash. The tuff is composed of mainly pumice and lithic graines mainly derived from basaltic materials.

The aquifer is found at deeper depth deeper than 190 m. The aquifer is confined aquifer, the water level rises above the water strike zone.

2.3.3.5 Gademotta Caldera / Ziway Plain

The test drilling in the Gademotta caldera indicated lacustrine deposit underlain by acidic rock deposit, which is part of the caldera. The aquifer is unconfined aquifer.

2.3.4 Additional Data Collected

Additional data on groundwater level, location of boreholes, water quality, aquifer type and property has been collected.

Out of the collected data 20 boreholes have data on aquifer parameters. These data in addition to newly drilled boreholes are useful to estimate the range aquifer parameters such as, transmissivity and, hydraulic conductivity. These additional data are indicated in the Appendix.

2.4 GEOLOGY

This part of the study comprises all the study results conducted until March, 2006. It includes field investigation as well as test drilling results and thin section study.

2.4.1 Precambrian and Mesozoic Sediments (Pe)

A high grade metamorphic rock biotitle-gnesiss cut by quartzo fieldspathic pegmatic veins and minor migmatites is overlain by 150m – 200m thick typical Adigrat sandstone, cross-bedded quartz sandstone with coarse, medium and fine grained varying in colour form purple, red, pink, yellow and white resting unconformable on the Precambrian, to the west of Kella Town in the western escarpment of the project area.

The thin section study shows that the metamorphic rock has the following composition and property;

- ♦ **Mineralogical Composition**

Orthoclase	50%
Quartz	35%
Plageoclase	13%
Biotite	<1%
Opeque	1%

- ♦ **Description of rock texure**

- A medium to coarse-grained deformed granite
- Deformation is evident by bending of feldspars twin lamelle and undulose extinction or deformation lamellae in quartz,
- Slight sericitization of feldspars and granular texture well preserved.

- ♦ **Rock Name**

- Deformed Granite.

- **Sample Location**

- UTM 442924 E, 912605 N

Figure 9 Photo showing Kella granite

Figure 10 Photo showing Kella granite with pegmatite vein

The thin section study shows that the Sandstone have the following composition and property;

- **Mineralogical Composition**

  Quartz 95%

  Clay matrix 3%

  Opequee 1%

- **Description of rock texure**

- Medium grained well sorted and matured (it contains very little , i.e., <5% clay matrix),
- Very coarse-grained quartz crystals show undulose extinction and deformation lamellae indicating that the quartz crystals are polycrystalline. This is a characteristic of quartz crystals from a metamorphic protolith (sourcerock).

- **Rock Name**

- Sandstone (Quartz Arenite).

- **Sample Location**

- UTM 442724 E, 912605 N

Figure 11. Photo showing Kella sandstone

About 30 m thick reddish grey shale and marls and 20-30 m thick limestone overlie the sandstone. The limestone is dark grey compact and fossiliferous. Compact greenish grey horizontal ignimbrite unit unconformably overlies this limestone.

The thin section study from the sample taken from the limestone has shown the following result.

- **Mineralogical Composition**

Micrite	60%
Fossils	40%

- **Description of rock texure**

- In the micritic matrix or mudstone are floating fossils of bivalves, ooids, peloids, brachiopods
- Recrystallized spary calcite is also present.
- The rock is peloidal-oolitic fossiliferous limestone.

- **Rock Name**

- Fossiliferous limestone

- **Sample Location**

- UTM 442671 E, 913406 N

Figure 12. Photo showing Layer of shale overlaying the limestone to a roadside (UTM 442600 E, 913414 N)

Figure 13. Photo showing Block of shale close to a roadside (UTM 442600 E, 913414 N)

2.4.2 Anchar Basaltsand (N1n)

This is the oldest basaltic rock in the project area, with age ranging 14 to 10 Ma and exposed in the plateau north and northwest of Butajira Town. This formation is composed of alkaline to transitional basalts.

2.4.3 Arba Guracha Silicics (N1ar)

This is the oldest volcanic rock in the project area, with age ranging 14 to 10 Ma and exposed in the plateau northeast of the project area. This formation is composed of rhyolites and ignimbrites.

2.4.4 Nazareth group Dino Formation (NQS)

This is volcanic rock occupies the western escarpment and the plateau. This formation includes what was mapped by Di paola (1972) as basalts and ignimbrites of the plateaux Trap series. The Nazareth group includes ash flow tuffs, pantellritic ignimbrites and un-welded tuffs while the Dino formation is made up of Dino ignimbrites. These rocks outcrop at the NW part of the plateau part in the project area.

2.4.5 Nazareth Group Alkaline and Peralkaline Stratoid Silicics (N1 –2n)

These are alkaline and peralkaline stratoid silicics; Ignimbries, un-welded tuffs, ash flows, rhyolites and trachytes. They range in age between 2-9 million years and are mostly located on the escarpments. This formation ocupies the main part of the escarpment west, northeast and north of Butajira. The ryolitic part of this formation forms domed hills in the escarpment area.

The rocks of this formation are at places highly weathered and some sections show series of weathered layers. It is some times with colunar-joints. In the escarpment exactly west of Butajira block jointing is common feature.

Figure 14. Photo showing Nazreth series volcanics- Rhyolite with columinar joints (UTM 441589 E, 917483 N).

Figure 15. Photo showing highly weathered rhyolite forming part of Nazreth series volcanics

2.4.6 Dino Formation (Qdi)

Dino formation includes peralkaline silicis of ignimrites, tuffs, water lain pyroclasics and occasional lacustrine beds which are overlain by coarse, unwelded pumiceous pyroclastics. The Dino formation of V. Kazmin and Seife Micul Berhe (1980) was previously called as Rift Pyroclastic formation by Di Paola (1972). The rift ignimbrites are highly faulted and outcrop in most parts of the rift.

This formation covers manly the Tora-Dugda Ridge and has over 300m thicknesses. 312m deep borehole drilled at Shirinto Village did not penetrate the formation fully. Geophysical invesigation result has shown over 360 m thickness.

This formation in the Tora – Koshe – Dugda ridge is mainly made up of lithic and pumaceous tuff alternating with highly weathered reddish brown altered / weathered ash affected by some white hydrothermal material.

Figure 16. Photo showing highly weathered Highly weathered ash within the Dino Formation

Figure 17. Photo showing Block Jointing in Dino Formation Tuff

Dino formation also found to occur in the fault Dobo Fault zone a fault zone which separates Kuntane – Inseno-Kella-Plain from the Cinder Cones and Basaltic Flow areas. In this areas it is situated at the fault zone and found overlain by the recent lava flows ans cinder-cones.

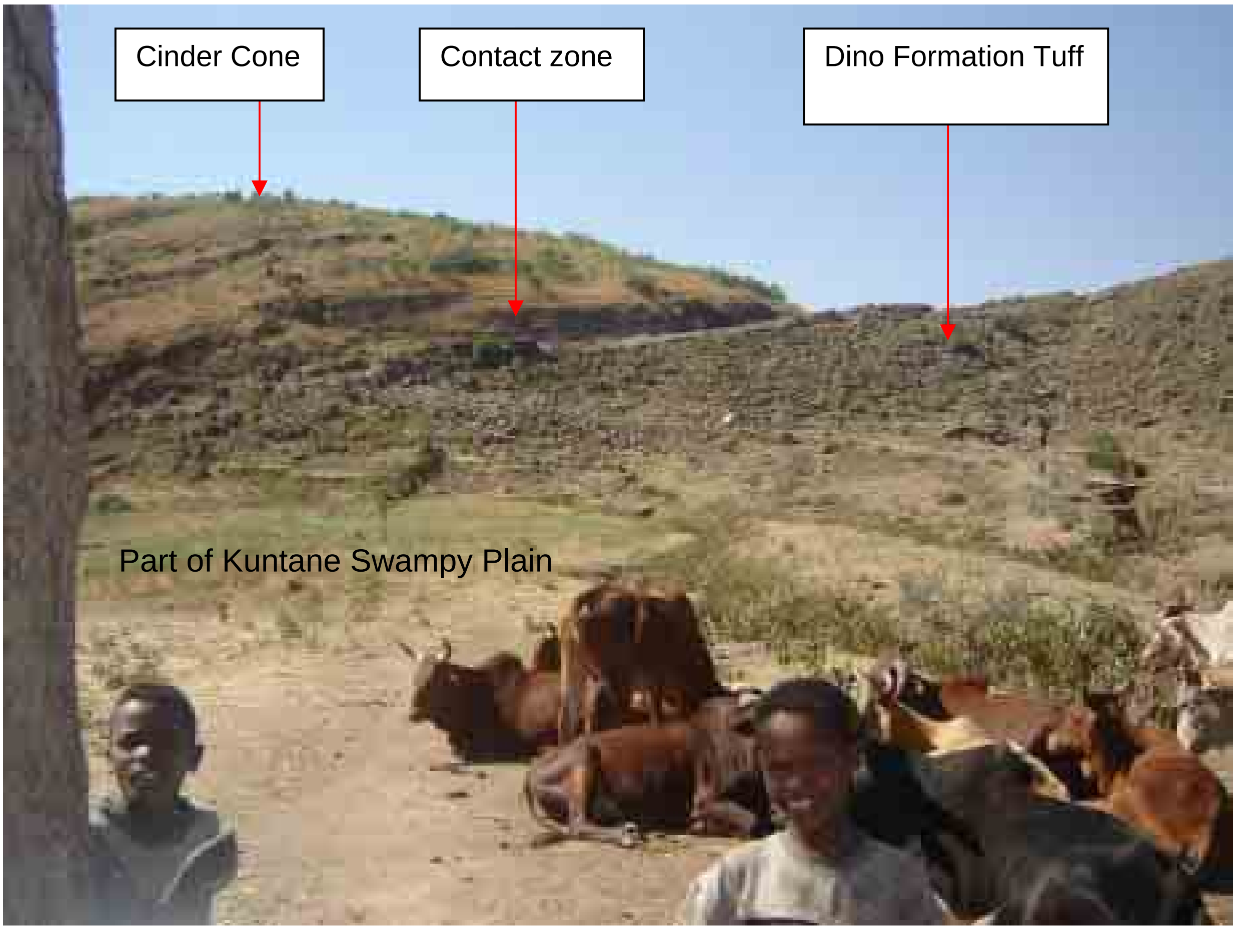

Figure 18. Photo showing Dino Formation overlain by Cinder Cone at Dobo-Sabola fault zone on the road to Kuntane Swamp.

Figure 19. Photo showing Dino Dino Formation overlain by Cinder Cone at Dobo-Sabola fault zone on the road to Kuntane Swamp. Photo from opposite direction of the above photo.

Figure 20 Close View of Pumaceous lithic tuff of Dino Formation shown on the above photographs.

Thin section study of Dino Formation Tuff at three different localities show that this formation is dominantly composed of with over 60% Ash/Dust with varying percentage of glass and minerals of quartz and sanidine. The following is the results of thin section study.

- **Mineralogical Composition**

Ash or Dust	85%
Vesicles	15%

- **Description of rock texure**

- The rock is almost composed of dust or volcanic ash.
- Vesicles are not filled with secondary material.

- **Rock Name**

- Tuff

- **Sample Location**

- UTM 431880 E, 886206 N Road to Kuntane Swamp from Har Shetan direction

- **Mineralogical Composition**

Ash	50%
Quartz	35%
Sanidine	10%
Glass	<3%
Biotite	Trace
Opeque	<1%

- **Description of rock texure**

- Angular and Fractured phynocrysts of quartz and sanidine float in the ash or dust matrix
- Devitrification of minor glass shards present.

- **Rock Name**

- Crystal tuff

- **Sample Location**

- UTM 446691 E, 907681 N, East of Kella Town

♦ **Mineralogical Composition**

Ash	60%
Glass	37%
Sanidine	1%
Quartz	trace
Opeque	1%

- **Description of rock texure**

- Angular phynocrysts of sanidine and quartz float in a matrix of deformed and banded ash or dust and glass shards.
- Almost complete divitrification of glass.
- Discontinuous layering formed by flattening or compaction is evident.

- **Rock Name**

- Welded tuff

- **Sample Location**

- UTM 460782 E, 903642 N

2.4.7 The Gademotta caldera (Qwa)

This caldera forms a half circle starting west of Ziway town where there are two quarry sites and a water reservoir for Ziway Town and ends west of Adamitulu having a diameter of about 30 kilometers.

The rim of the caldera is well preserved with vertical inside walls with 100-200m heights. It is made up of pumice and banded ignimbrite resulting from strong silicic magmatic event about 1.3 to 1.05 million years. This caldera is the oldest collapse structure pre-dating the formation of Ziway Basin, which initiated about 0.3 million years (Caroline, et al, 1999).

To the west of Ziway town the Ethiopian Rural Road Construction and the Dragados (road construction company) have opened two quarries. At the opened quarry, it depicts banding of black and white crystals and is jointed with strike NW-SE dipping 40^0E.

This caldera have been cut by the West Ziway fault and its western rim remains, while the other part is buried under thick lacustrine deposit.

Thin section study of this rock at two different localities has shown that this rock is composed of with over 90% ash and glass. The following is the result of the thin section study.

♦ **Mineralogical Composition**

Ash and Glass	90%
Sanidine	2%
Quartz	1%
Amphibole	<1%
Fragments	<1%
Opeque	4%

- **Description of rock texure**

- Devitrification (almost complete) of the glass matrix
- Angular phenocrysts of sanidine and quartz float in the glass and dust matrix.

- **Rock Name**

- Welded tuff (or ignimbrite)

- **Sample Location**

- UTM 461567 E, 877687 N

Within this caldera west of Adami Tulu town at shisho Tora village exists hills with highly altered rock uplifting the lacostrine deposit. This hill seems as part of late stage activity of the caldera, probably magma eruption fullowing the collapse of the caldera and sedimentation within the caldera. Major part of this rock is altered to a white clay probably kaolinte clay. The sediment deposit overlaying and dipping away from the hills indicate this event. The lacustrine sediment hill at Adami Tulu Town can be attributed to similar activity as of Shisho Tora. Samples have been taken for thin section study from the parent and altered part of the rock. The result shows that the altered rock is completely devirified and become ash, whereas, the parent rock have similar composition as that of the Gademota Calder Rim. The following are results of the thin section study.

♦ **Mineralogical Composition**

Ash	99%
Quartz	1%

- **Description of rock texure**

- Two angular phynocrysts of quartz crystals float in an entirely ash matrix (it may originally have been glass matrix)

- **Rock Name**

- Altered volcanic ash/tuff

- **Sample Location**

- UTM 464287 E, 866458 N Shisho Tora. Sampled from the altered part of the rock

♦ **Mineralogical Composition**

Ash	60%
Glass	39%
Crystals of Quartz, sanidine	1%

- **Description of rock texure**

- The glass shards are flattened and show almost complete devitrification.
- Phenocrysts of quartz and sanidine crystals float in a welded matrix of ash and devitrified glass.
- Discontinous lamination is evident which is caused by compaction and welding of fragments.

- **Rock Name**

- Welded Tuff or ignimbrite

- **Sample Location**

- UTM 464364 E, 866827 N Shisho Tora. Sampled from the parent rock

2.4.8 Central Volcanic complex (Qwpu)

Some rhyolitic lava flows and domes are found associated with the rift ignimbrites with age ranging from 0.24 to 0.02 million years. The alkaline and peralkaline silicis of O-Itu Woshe, Bora, Berecha, Alluto volcanoes, northeast, south and southeast of Lake Ziway. The pyroclastics are unwelded pumice flows and ashes, which are the final products. Qwpu represents pumice and unwelded tuffs, Qwo obsidian and pitchtone and Qwa are rhyalitic lava flows.

Figure 21. Photo showing Unwellded Pumaceous tuff deposit part of Bora Volcanoe northeast of Lake Ziway

2.4.9 Basalts of the rift floor (Qwbp, Qwbh)

Two main fields of recent basalts each having an area of about 800km2 are located close to the western and eastern escarpments. One lava field is in the Butajira-Siltie area while the other is east of lake Ziway. These flows consist of a lot of scoria and their texture varies from aphyric to porphyritic.

Post 0.2 million years fissural basltic eruptions and superimposed scoria cones (Qwbp,) outcrop east of lake Ziway. Outcrop of a flow basaltic hayaloclasites produced by sub-aqueous basaltic volcanism is located south of lake Ziway.

Figure 22. Photo showing Grey Scoria Depost Part Recent basaltic flowa East of Lake Ziway

Figure 23. Photo showing Faulted recent basaltic lava flow deposit east of lake ziway

In the westerl lava field (Qwbh) Cinder cones and lava flows are aligned from Silitie in the south to Shershera in the north of Butajira. They look to have come out along a regional fault. Vesicular basalt with some phenocrysts and red scoria are quarried for road aggregate in the area. Tentatively their thickness based on the borehole data estimated to be about 30 to 100 m.

This eruption has separated Butajira crsent from the Kuntane-Inseno-Kella plain. Within this area there are a number of cinder cones and maars. One eruption centre developed into Crater Lake known as Har Shetal Lake.

Some of the lava filds have AA type flow. This is evident west of Inseno Town between Shereshera Ile and Dobena Irrigation area. This part of the lava flow is underlain by alluvial deposits mainly gravells and boulders as shown by Shershera Ile borehole and the dug wells around Ras Tesssma village.

Drilling results in the area indicate occurrence of coarse alluvial sediment layers below and within the vesicular and scoria flows of the Butajira area. This indicates that these rocks have erupted after the rift system has initiated sediment flux from the western escarpment.

Figure 24. Photo showing Crater Lake Har Shetan

Figure 25. Photo showing Red Scoria/cinder Cone

Figure 26. Photo showing Lava field with AA type flow covered with thin transported soil supprting some vegetation. This flow is underlain by alluvial deposits at some places such as Shershera Ile and Ras Tessem.

2.4.10 Qatwernary Sediments

Lacustrine sediments cover quite a vast area. It consists of layers of alternating silt and clay with volcanoclastic sediments, sands, ashes, transported pumice slit, clay and diatomite. According to Caroline, et al, 1999, sedimentation initiated in the Ziway basin about 0.3 to 0.2 million years which is of the age for the initiation of the Ziway Basin and continued until present. The Lake Ziway lies in an east dipping dawn-faulted basin bounded to the west by about 20 km long NNE trending West Ziway Fault of Holocene Age (Ge'ze, 1974 in Caroline, et al, 1999). This fault forms the Tora-Koshe Dugda ridge Horst, separating the Ziway basin from Inseno - Kella Plain and impeded the drainage from the western escarpment from reaching the Ziway Basin.

Lacustrine deposits in the project area occur in two areas. The major part is the Ziway Plain deposit (Qi) and the second one, which is composed, of lacustrine, alluvial, and pyroclastic deposits, forms the Kuntane-Inseno- Kela Plain (Qa).

2.4.10.1 Lacustrine Sediments (Qi) of Ziway Plain

In the Ziway Plain the thickness is sometimes considerable ranging form few meters to over 100 m. According to Searrle and Gouin (1972) maximum thickness of 380 m estimated from gravity measurement in the south of Lake Ziway and 580 m west of Abijata Lake. The Vertical electrical sounding result conducted during the preliminary study also indicated over 260 m thick lacustrine sediment. A 71 m and 66 m deep borehole at Adami tulu, 100m deep boreholes at Meki, 126m deep borehole of Ziway municipality and 143m deep boreholes at ziway Prison show complex mixture of lacustrine and volcano-clastic deposits such as fall depsits reworked pyroclastics and tuffs.

Pumaceous volcanic fall deposits are evident along Meki river bank and layered lacustrine deposts are exposed around Adami Tulu and south of Lake Ziway.

Thin section study of dark volcanoclastic deposit sampled close to the shore of lake Ziway has shown the following.

♦ **Mineralogical Composition**

Glass	45%
Lithick/rock fragment	40%
Plageoclase	8%
Quartz	4%
Pyroxene	3%
Opeque	trace

- **Description of rock texure**

- No welding or banding of fragments is evident
- This pyroclastic rock consists of crystals of plagioclase, pyroxene and quartz and lithic fragments floating in the glassy matrix

- **Rock Name**

- tuff

- **Sample Location**

- UTM 469999 E, 877201 N . At the shore line of Lake ziway close to Mariam Church

2.4.10.2 Kuntane-Inseno- Kela Plain Fluvio-Lacustrine Deposits (Qa)

Kuntane-Inseno_ Kela Plain (Qa) is a filled graben by pyroclastic, lacustrine and alluvial deposits. Main part of this graben is filled with fall and reworked water lain paroclastic deposits. Close to river courses and old river channels alluvial deposits composed of gravel, boulders and sand are deposited. This sediment has over 300 m thickness.

This plain has two main distinct features. The area between Lake Abaya (Tuffa) and Dobena River area have very flat plain fed by flood and seasonal streams from west of Butajira area. Mostly this part of the plain gets flooded during the summer and devlop temporary lake, which shrinks during the dry season. It is mostly water logged during the rainy season. This is because of the flat topography surface runoff from the west and east and the input of the springs, shallow groundwater and overflow from the lake.

As a result of such complex interaction this palin has both alluvial lacustrine, pyroclasitic and hydrothermal deposits. About 1.5 m high calcrete deposits related to the thermal springs occur close to Kuntane swamp. The hot springs currently along their oulet have also deposited this calcerete.

Both flood water cold spring and hot spring waters mix at the pain and evaporate during the dry season leaving highly mineralised slagish and dark brown color water at Kuntane swamp.

Figure 27. Photo showing Calcerete deposit at Kuntane Plain

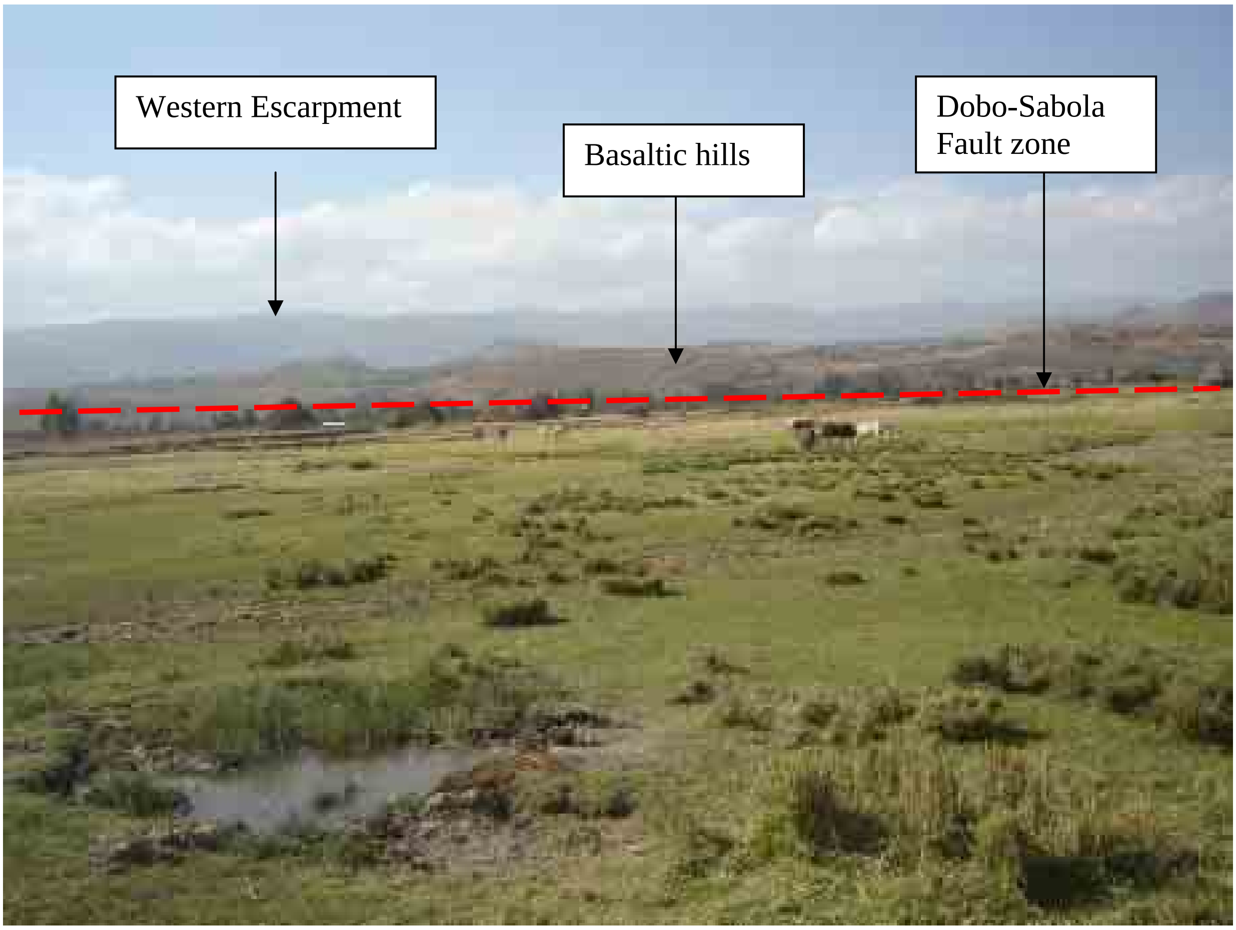

Figure 28. Photo showing Part of Kuntane Plain with Basaltic-Cinder cone areas and western escarpment

Figure 29. Photo showing Eye of Thermal spring with calceret deposit

Figure 30. Photo showing the thermal spring in the dry season flows to the swamp with tall grasses at the back. In summer the whole area gets filled with water.

The area including Dobena River plain up to Kella village are charactersised by perennial rivers such as Dobena River, Akamuja, Lebu and Meki rivers. This part is mainly charctersied by alluvial and pyroclastic deposits and recnt lava flws.

Towards the western escarpment it is mainly characterised by talus deposits, fan deposits and alluvial deposits mixed with some lacustrine deposits.

Figure 31. Photo showing Gravel and boulder deposi along Dobena River Course Inseno-area.

Figure 32. Photo showing Basaltic AA type lava flow at the Dobe River Bed

Figure 33. Photo showing Kella Plain with Tora-Kushe Dugda Ridge further behind

2.4.11 Geological Structures in the project area

The development of tectonic structures as reported in the Progress Report repeated here.

The geological structures relate to the tectonic events that formed the Main Ethiopian Rift, the Wenji Fault Belt, volcanism and collapse structures and Holocene faults.

The present symmetrical rift was fully defined by 3.5 million years when a paroxysm of ignimbrite of the Munisa crystal tuff erupted from large caldera located on the rift floor (WoldeGabriel, 1987 in Caroline, et al, 1999). This is followed by a line of hundreds of young faults and volcanic centres along the rift floor close to the eastern escarpment initiated around 1.6 million years known as the Wenji Fault belt by Mohr (1960). Rhyolitic ridges and domes dated 1.3 – 1.05 million years relate to the activity of a large caldera partly buried beneath the Langano Abijata-Shala basins and known as Gademotta Caldera whose rims are evident west of Lake Ziway.

The further activity in the Wenji Fault Belt and initiation of West Ziway Fault about 0.3 to 0.2 million years cut the Gademotta caldera resulted in the development of Ziway Basin initiating sediment flux from the eastern escarpments. The Western Ziway Fault resulted in the

Development of The Tora-Koshe-Dugda Ridge/Horst, which limited the sediment flux from the western escarpment to Kuntane-Inseno-Kella basin.

Faulting related to the WFB continued into recent associated with fissural basaltic eruptions and superimposed scoria cones especially in east Ziway areas.

These recent eruptions resulted in deposition of pyroclastic sediments associated with lacustrine deposits.

In the western escarpment, fault lines oriented in WNW direction cutting the main NE and N trending fault system of the MER forms semicircular depression. This has resulted in the crescent shaped Butajira plain. The trend of these fault lines is similar to the Munisa transverse faults situated east of Langano. The shape of the faulted basin and the transverse faults cutting the general NE trend of the MER in Butajira area indicates that the Butajira area is a tectonic collapse.

Recent basaltic and cinder cones have erupted following the MER fault trend, which separated the Butajira –Collapse structure from the Inseno - Kella Plain. Therefore, the sediment fluxes from the western escarpment mainly coarse sediments remain in the Butajira-Cresent, while very fine and limited sediment reaches the Kuntane Swamp.

The tectonic development and associated volcanism have resulted in the following morphologically distinct areas.

The western Rift escarpment – The escarment is charcterised by long linear escarpment oriented in the NE directin. It is characterised by steep slope to vertical face with elevation rising from about 2100 m.a.m.s.l around butajira to over 3500 m in the plateaus at the top of the escarpment.

This is characterized by mountain chains and escarpment slopes. The slopes are generally vertical to steep slopes and strongly dissected. Almost all streams crossing the study area originate from this area. Some major springs rise following structural weak zones in this area.

Generally the escarpment is oriented in the NE direction, which changes to semi-circular arc in Butajira area with transverse faults oriented in the WNW directions. These fault orientations are probably related to the formation of Butajira crescent, which seems a caldera/tectonic collapse. These transverse faults do not continue into the Tora-Koshe-Dugda Ridge and the Cinder-cones and basaltic areas indicating older of this collapse. The escarpment comprises the following geologic units.

Butajira Crescent - This comprises the crescent shaped fertile land of the escarpment pediment plain, which includes Butajira town. This is characterised by debris flow from the escarpment area, alluvial deposit and volcanoclastic deposits. Soils in the area are mainly derived from the sediments composed of sandy loams.

Figure 34. Photo showing Butajira Crescent Plain with the Escarpment Mountains at far Behind

Cinder Cones and Basalt Flows – These are recent basaltic volcanic cones erupted following the extensional faults of the MER forming chains of scoria cones and maars both red and black scoria extending between Kibet town in the west and Kella Plain to the east. These basaltic flows and cones separate the Butajira-crescent from the Kuntane-Inseno-Kella plain and block sediment flux from the western escarpment.

This area is characterised by rugged topography as a result of the different shaped cones and hills. Generally this area has thin soil to bare rock surface. The soils are sandy soils mainly derived from the fine-grained scoria fall deposits.

Kuntane – Inseno - Kela Plain - this is flat plain extending between Abaya (Tuffa) Lake in the west and Kella Town in the northeast. Shallow groundwater, sediment deposits and marshes, hot and cold springs characterize this plain. It is characterised by soils derived from weathered volcanic ash and lacustrine sediments.

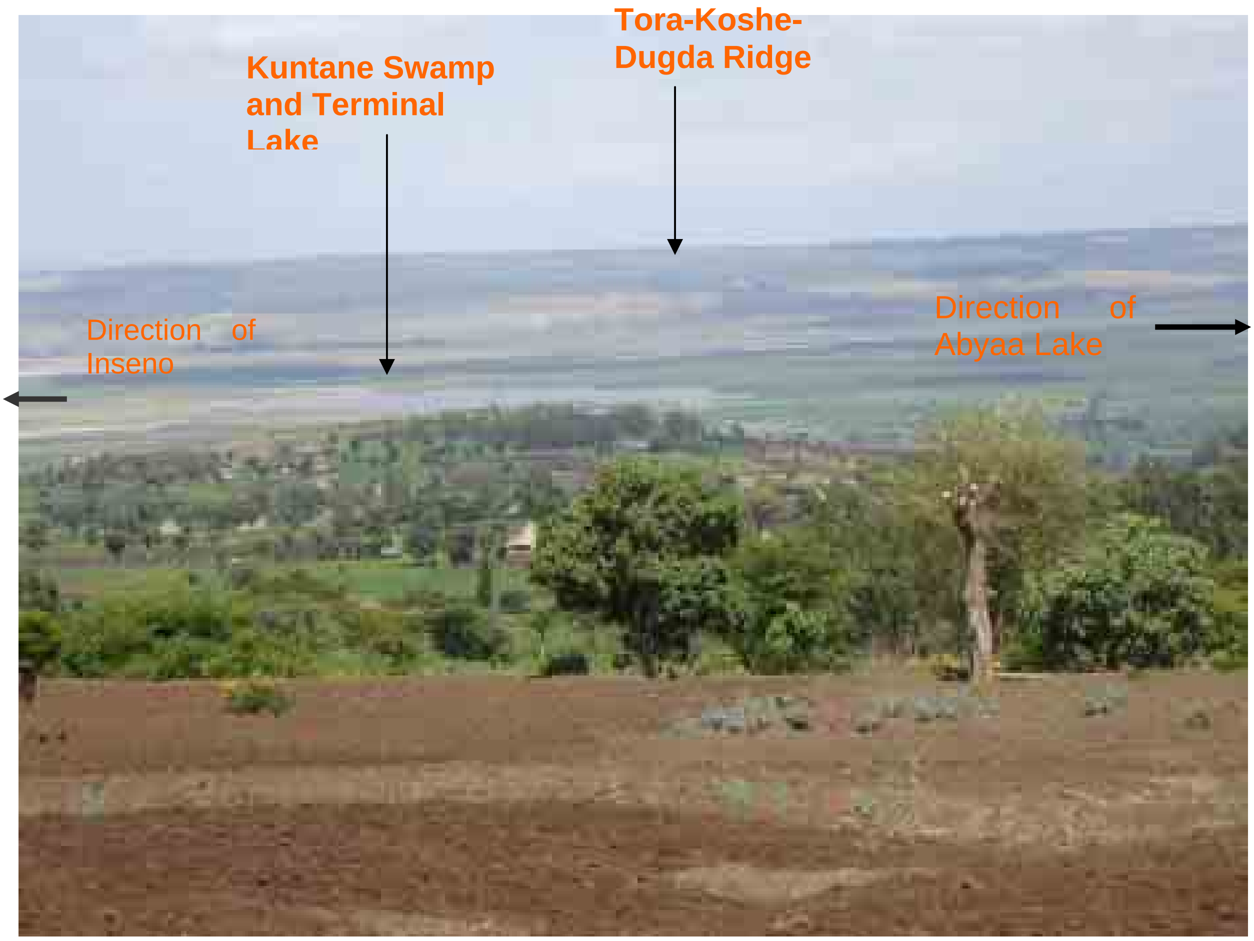

Figure 35. Photo Shwing Kuntane Swampy plain

Figure 36. Photo showing small teminal Lake Abaya/Abijata western end of Kuntane –Inseno Kella Plain

Figure 37. Photo showing Inseno Kella Plain

Tora-Koshe Dugda Ridge - This area is formed of a linear fault horst extending from about Tora village in the west to Dugda Village in the east. The ridge is composed of ignimbrite, tuff and water lain pyroclastics deposits. This area has deep groundwater and has no surface water. This ridge is characterised by an insitu soils derived from weathering of ignimbrite or tuff.

Zeway Plain – this area includes Lake Ziway and is mainly flat plain characterized by shallow to relatively deep groundwater and lacustrine deposits. It is characterised by lacustrine sands, silts and clays interbedded with pumice and other volcanoclastic sediments. Lacustrine clays mainly used for termite hills, which is the main characteristic feature of this zone. The thickness of this sediment is estimated to be over 260 m.

Gademotta Caldera – West of Ziway a crescent shaped about 10 km wide remnant of a caldera rim occurs. It is filled with lacustrine deposit except the remnants of the caldera walls situated to the west attached with the Tora-Koshe-Dugda ridge.

2.4.12 Stratigraphy and Sequence of Events and Evolution of the Geomorphology

- The oldest rocks exposed due to the uplifting and down faulting related to the MER are the Precambrian and Mesozoic sediments situated north of Kella Village. The development of MER attributed to the mantle plume resulting to widespread uplifting and volcanism. In the central MER volcanism started as early as Eocene with mainly basaltic eruptions followed by subsequent rifting which continued Late Miocene.

- Anachar Basalts, Arba Guracha Silicics and Nazareth Group/Trap Series volcanic rocks form the earliest volcanic eruptions and are situated in the western escarpment, where as they are buried deep under the younger deposits in the rift floor. These rocks are dissected both by the NE and WNW fault systems.
- Initiation of sediment flux from the western and eastern escarpment,
- Subsequent faulting and collapse of Butajira Crescent with NE and WNW faults,
- Initiation of Wenji Fault resulted in eruption of voluminous acidic rocks Development of deepening of the MER,
- Gademotta Volcanoe and development of Gademotta collapse/Caldera,
- Initiation of West Ziway Fault, dawn faulting of Gademotta caldera, development of Tora-Koshe Dugda Ridge and deepening of Ziway Basin. Separations of Ziway basin from the Butajira area and sediment flux source to Ziway basin became the eastern Escarpment. The sediment flux from the western escarpment remained west of the Tora – Inseno - Kella Plain. Therefore, sedimentation continued in two separate basins, Ziway basin and Tora – Inseno – Kella basin, and
- Eruption of Silte-Butajira basaltic flows and cones separating Butajira Crescent from Kuntane-Inseno-Kella Plain and giving the present topography of the area. Therefore, coarse sediment fluxes to the Kuntane swamp blocked by these volcanic cones. However, both coarse and fine sedimentation continued in the Kella Plain.

2.4.13 Hydrogeology

2.4.13.1 General

Based on the test drilling results and additional field investigation the hydrogeological charcteristic of each geomorphologial area is summarised as follows.

2.4.13.1.1 The western escarpment

This area receives high rainfall and discharges its surface and subsurface flow to the low-lying areas. Many springs except thermal ones emanate in the escarpment and its foothills. These springs emerge as contact and fracture springs. Contact springs usually yield little water and the discharge significantly goes down during dry season. In contrast fracture springs, which emerge from fractures, faults etc show little seasonal variations and yield more water.

This area is mainly source of water to the riftvalley area.

2.4.13.1.2 Butajira pediment/crescent

This area is situated at the foot (pediment plain) of the western rift escarpment, and shallow groundwater and springs characterize it. The depth to water level varies from surface to about 20 m meters below the ground. Because of this there are a number of family owned dug wells and community wells in the area.

This area is characterized by a complex mixture of sediments composed of unsorted to poorly sorted alluvial, talus or fan deposits, debries flow and volcano-clastic deposits emanating from the volcanic centres in the east and around Koto. The sediment thickness varies from 80 m to about 120m.

This plain receives groundwater recharge mainly from the runoff emanating from the rainfall in the mountains.

Figure 38. Photo showing Sediment type at the foot of the Escarpment

Aquifer

The test drilling results and existing borehole data indicates the aquifer is composed of alluvial and tulus/debries sediment derived from the escarpment. The sediment is mainly made uo of gravells, sands and boulders with interfinguring of some clay deposits. Towards the escarpment the sediment is poorly sorted and dominated by coarse sediments. Further away from the base of the escarpment, the sorting increseas and the sediment size also decrease to sand and gravel size. The aquifer type is unconfined aquifer.

Aquifer Properties

This plain has generally poor aquifer property. The test drilling result and existing data shows it has Transmissivity varying between 1 m2/day to 137 m2/day and hydraulic conductivity 0.02m/day to 3.8 m/day. The transmissivity of aquifer gets poor towards the escarpment base and improves further away from the escarpment. This is directly related to the sorting of the sediment material. The following table summarizes the aquifer property of the area.

Table 9: Summary of aquifer properties

Borehole	Location in UTM		Transmissivity M2/day	Hydraulic conductivity M/day
Kachaber test well BZDP/TW1	424544	894351	1.02	0.02
Butajira Town Test well 1 (TW1)	430838	899162	137	3.8
Butajira Town Test well 1 (TW2)	430990	896373	95.6	2.66
Butajira Hospital	431086	898842	30	0.96

Plot of Transmissivity Vs Specific capacity plot shows that the transmissivity has linear relation with the specific capacity. From the specific capacity value transmissivity can be roughly estimated using the equation shown on the trend line for this area. This equation is only applicable for specific capacity value of over 4 m2/day.

The plot of transmissivity with screen length and depth of borehole shows that the depth of the borehole and screen length has no impact on the transmissivity. This indicates that transmissivity aquifer in this formation doesnot change with depth.

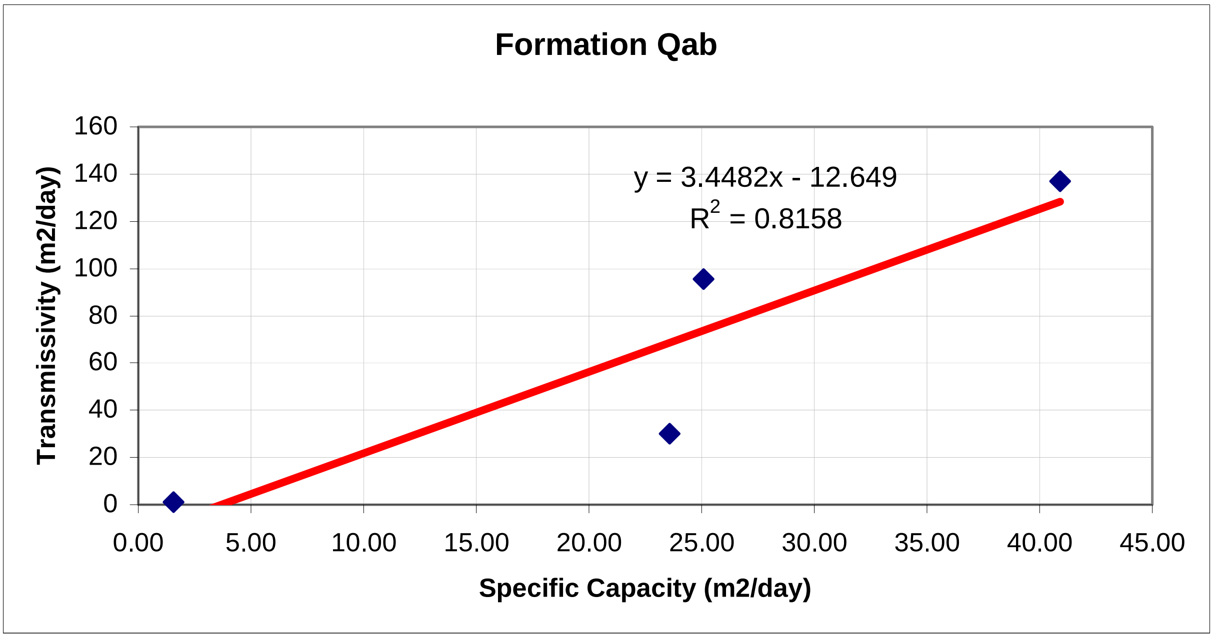

Figure 39. Transmissivity Vs Specific capacity

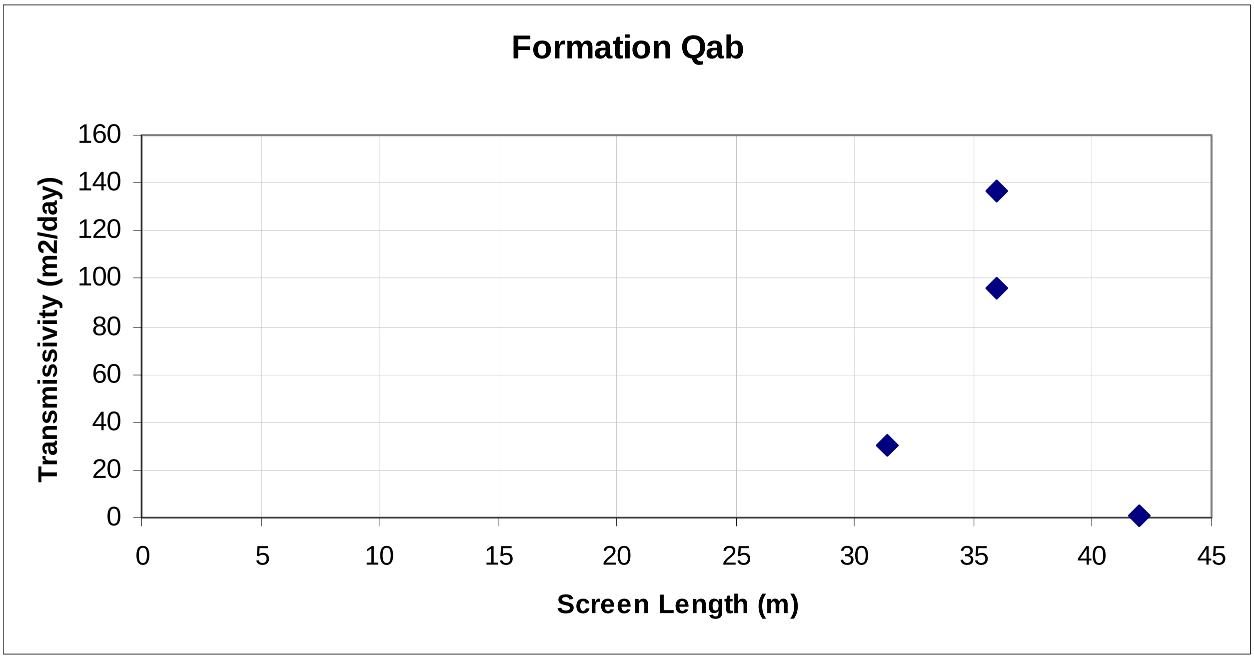

Figure 40. Transmissivity Vs Screen length. The plot shows that transmissivity is not related to depth of aquifer.

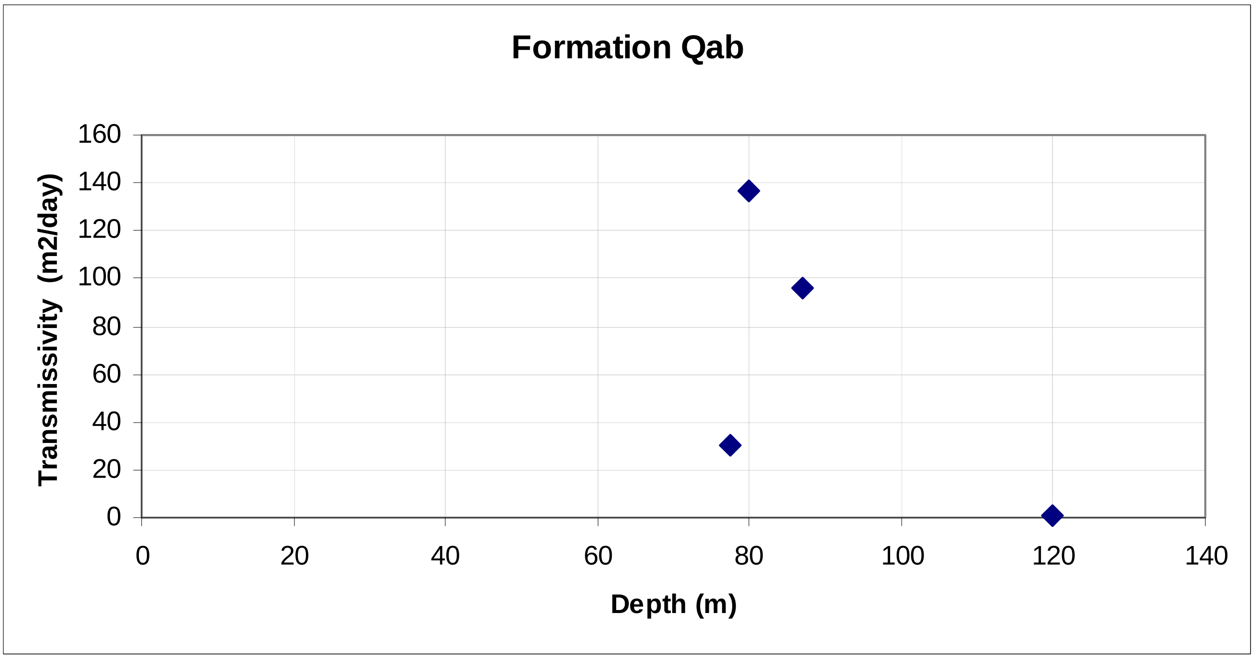

Figure 41. Transmissivity Vs depth of borehole. The plot shows that transmissivity is not related to the screen length in the borehole.

2.4.13.1.3 Scoria cones region

These are situated to the east of Butajira pediment and dominantly composed of scoria cones and associated vesicular basalts. Ground water occurs in these areas at a relatively deeper level with respect to surface topography as compared with Butajira pediment and Kontane-Inseno-kela plain.

Due to the relatively deep water table, most wells constructed in this region use motorized pumps.

Groundwater rechrge is from subsurface growndwater flow from the Butajira Crsent area and direct recharge from rainfall. However the major source is the growndwater inflow.

This area has also Crater Lake known as Har-Shetan. This lake is connected to the groundwater in the area.

Aquifer

The test drilling results and existing borehole data indicates the aquifer is composed of scoria vesicular basalt and at some places sand and gravel deposit underlying thin layer of flows. The thickness of the basaltic flow is highly variable. In the central part of this area where the volcanic centers and vents are located the thickness of the lava flow is high over 100 m thickness. Further away from the volcanic centers, the lava flow is thin and in this areas, such as Shereshera Ile, Dirama Shershera, Shershera Jole areas the underlying sand and gravel deposits contribute to the aquifer.

Aquifer Properties

The available data shows that this region has relatively better transmissivity than Butajira Crscent. The test drilling result and existing data shows it has Transmissivity varying between 16 m2/day to 242 m2/day and hydraulic conductivity 0.9m/day to 20 m/day. This transmissivity data is for the areas away from the volcanic centers. The groundwater gradient in this area (as will be discussed latter) shows that in general the transmissivity of the aquifer in this region is poor. This can also be explained by the existence of a crater lake high above the groundwater elevation of Kuntane-Inseno-Kela Plain and the water level elevation difference between the Btajira Crsent and Kuntane-Inseno-Kela Plain. The aquifer varies from unconfined to semi confined. The aquifer within the basaltic formation is unconfined and the one in the underlying sediment is semiconfined.

Table 10: summary aquifer parameters for scoria cones and basaltic areas

Borehole	Location in UTM		Transmissivity M2/day	Hydraulic conductivity M/day
Butajira Town Netsa Sefer BH1	432756	897440	69.264	
Butajira Town BH2	432084	897957	241.92	
Butajira Town Girar bet Ledikuman	432501	898201	16	0.67
Semen Shershera	436926	899049	187.76	20.86
Kibet town BH2	426927	887719	37.8	0.90

Plot of Transmissivity Vs Specific capacity plot shows that the transmissivity has logarithmic relation with the specific capacity. From the specific capacity value transmissivity can be roughly estimated using the equation shown on the trend line for this area. This equation is only applicable for specific capacity value of over 18m2/day.

The plot of transmissivity with screen length and depth of borehole shows that the depth of the borehole and screen length has no impact on the transmissivity. This indicates that transmissivity aquifer in this formation doesnot change with depth.

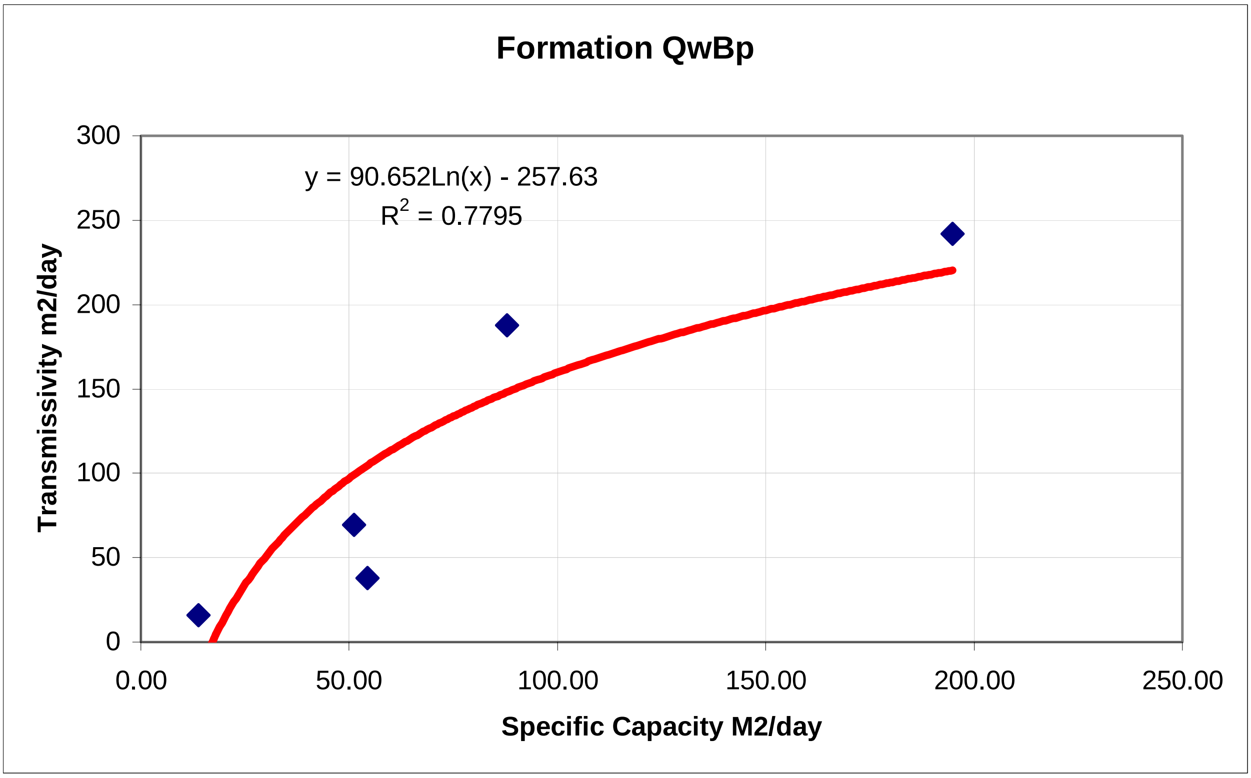

Figure 42. Transmissivity Vs Specific capacity

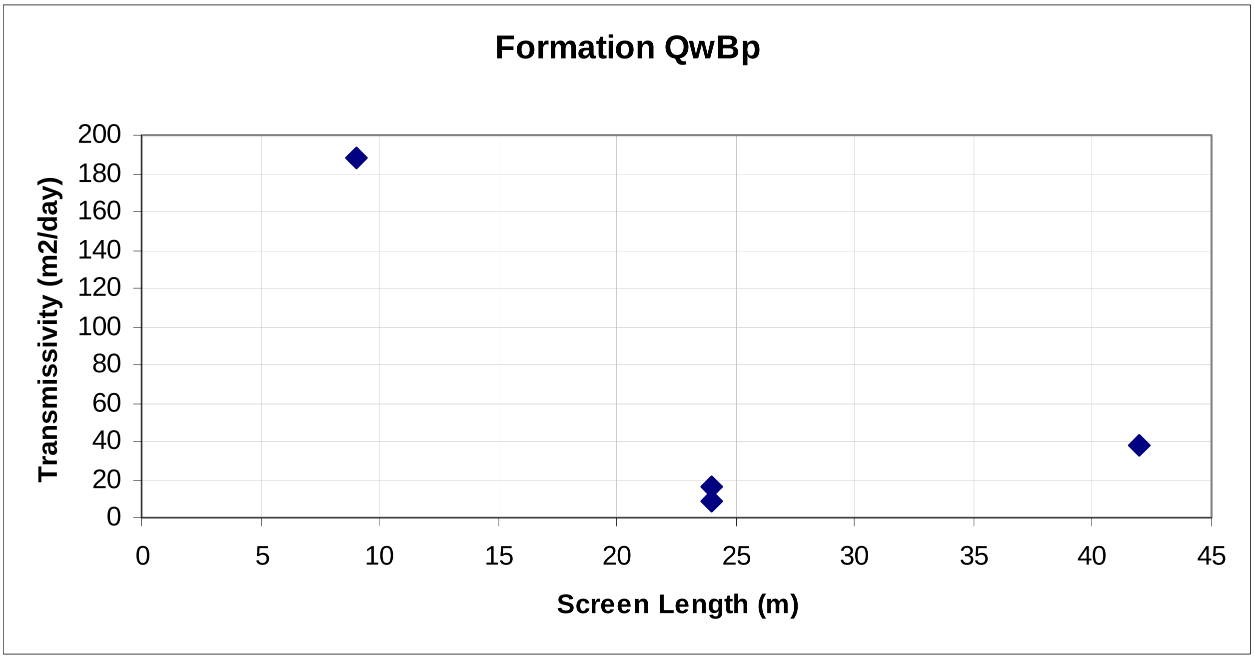

Figure 43. Transmissivity Vs Screen length. The plot shows that transmissivity is not related to depth of aquifer.

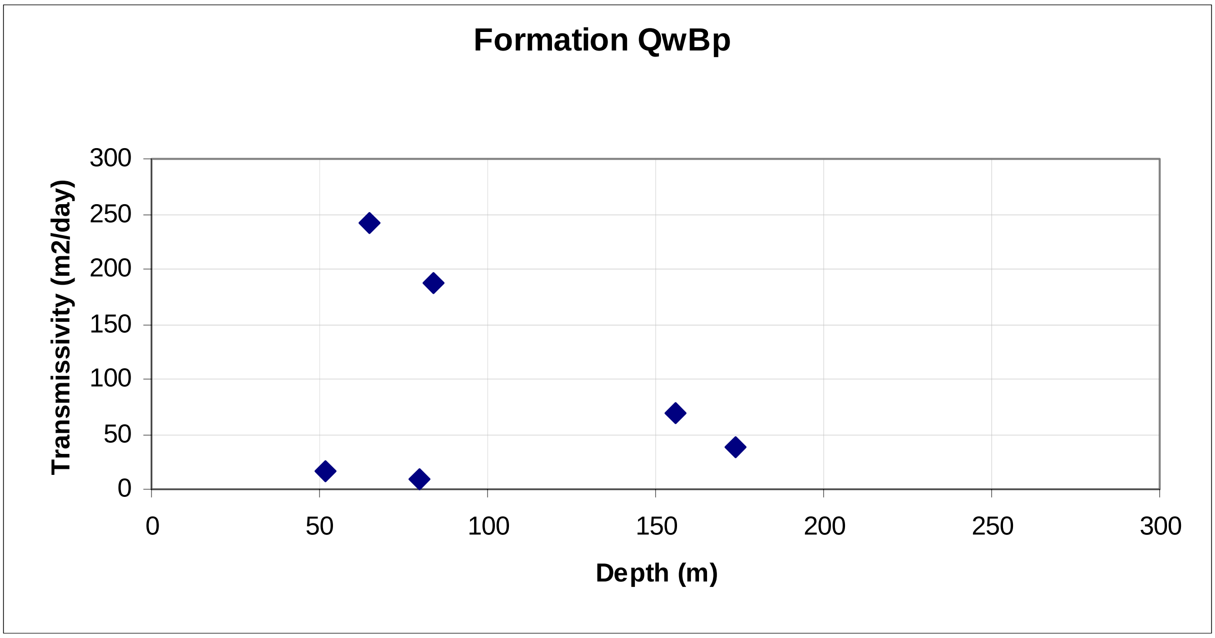

Figure 44. Transmissivity Vs depth of borehole. The plot shows that transmissivity is not related to the screen length in the borehole.

2.4.13.1.4 Kontane-Inseno-Kela plain

This plain is separated from the Butajira Pediment plain by the scoria cones region. This plain receives recharge from several streams from the western escarpment and direct rainfall and growndwater inflow. It is covered by pyroclastic fall and rewarked waterlain pyroclastic deposits, lacustrine, alluvial, debris flow or talus deposits and fan deposits. The lacustrine deposits vary from clayey silt to fine sand deposits and whereas the fluvial deposits vary from silt to cobble size and sometimes up to boulder size. The base of the western escarpment around Kella is mainly characterized talus or debris flow and fan deposits. The thickness of these sediments varies from few meters in the west to several meters (more than 260 meters and more) in the centre and along Woja River; however the thickness of the sediment along Koshe-Dugda ridge shows abrupt pinch out.

This trough is bounded to the west by scoria cones and associated vesicular basalts and to the east by Tora-Koshe Dugda horst (ridge).

The surface water from Butajira and Kibet areas drains to Kontane Marsh and Little Abaya while surface water from Kela and Bui areas drains to the east to this plain and forms Meki River. The overflow from little Abaya (Lake) and Kontane Marsh and Dobena River forms Woja River, which flows towards North east of this plain to join Meki River. Meki River later discharges its water at Ziway Lake.

The groundwater in this zone is generally shallow and abundant; many dug and shallow wells are found in this plain. Thermal springs are also observed in two localities of the plain. Thermal springs have multiple sources (eyes), and both are situated in Kontane marsh indicating that they are probably related to the formation of the young volcanics of the cinder cones and basaltic centres heating up the groundwater.

This area especially between Abijata (Tuffa) Lake and Dobena River is water logged during the rainy season. This is because of the flat topography, surface runoff from the west and east and the input of the springs, shallow groundwater and overflow from the lake Abaya.

Aquifer Properties

Threre is little data of this area. The new 168 m deep test well at Kunu Kertafa has shown very low drawdown, which is about 1.1 m. The, transmissivity computed from this test indicates a value in the order of 500 m2/day. The 60 m deep test borehole drilled close to Weja River has provided transmissivity value of about 219 m2/day. This could be the minimum value of the area because this borehole is situated at the boundary of this aquifer and Tora-koshe- Dugda ridge.

2.4.13.1.5 Tora-Koshe- Dugda ridge

This area serves as the eastern boundary to the Inseno-kela valley and mainly composed of pyroclastic deposits such as tuff and Ignimbrite. It acts as the surface water barrier, i.e., this ridge bound all the surface water from the western. Southeast direction flowing streams while reaching the ridge turn to Northeast direction following the base of the ridge.

The topography gently down slopes towards Lake Ziway and the lithology gradually changes to lake sediment.

The groundwater in this part of the study area is deep. No shallow groundwater is available in this zone. Generally the depth to major groundwater table is over 130 m. The groundwater level in this region suddenly gets deeper probably as a result of the major fault line separating this zone from Kuntane-Inseno-kella Plain.

Aquifer

The test drilling results and existing borehole data indicates the aquifer is composed of ignimbrites and tuffs. The aquifer is a confined aquifer. The test drilling result indicated that the aquifer is below 194 m, however, the water level rose to 132 m.

Aquifer Properties

Existing data shows it has Transmissivity varying between 6 m2/day to 171 m2/day and hydraulic conductivity 0.25m/day to 4.75 m/day.

Table 11: Summary of aqufer properties for Tora-Koshe-Dugda Ridge

Borehole	Location in UTM		Transmissivity M2/day	Hydraulic conductivity M/day
Adele Kobo	453276	901204	12.71	0.71
Tora Town	435852	869258	63.24	2.11
Ilala Jirano	453015	883724	171	4.75
Shirinto	447720	875620	15	0.36
Debub Goto / Yeberasawrhay	435517	877276	6	0.25
Semen Goto	439069	878182	7	0.29
Debub Goto	438154	876204	12.3	0.45
Luke Fake	446742	872640	81.55	2.72

Plot of Transmissivity Vs Specific capacity plot shows that the transmissivity has linear relation with the specific capacity. From the specific capacity value transmissivity can be roughly estimated using the equation shown on the trend line for this area. This equation is only applicable for specific capacity value of over 5.33 m2/day.

The plot of transmissivity with screen length shows that the screen length has no impact on the transmissivity.

The plot of transmissivity vs well depth indicates an exponential relationship. This indicates that deeper drilling increases the transmissivity as well as well yield.

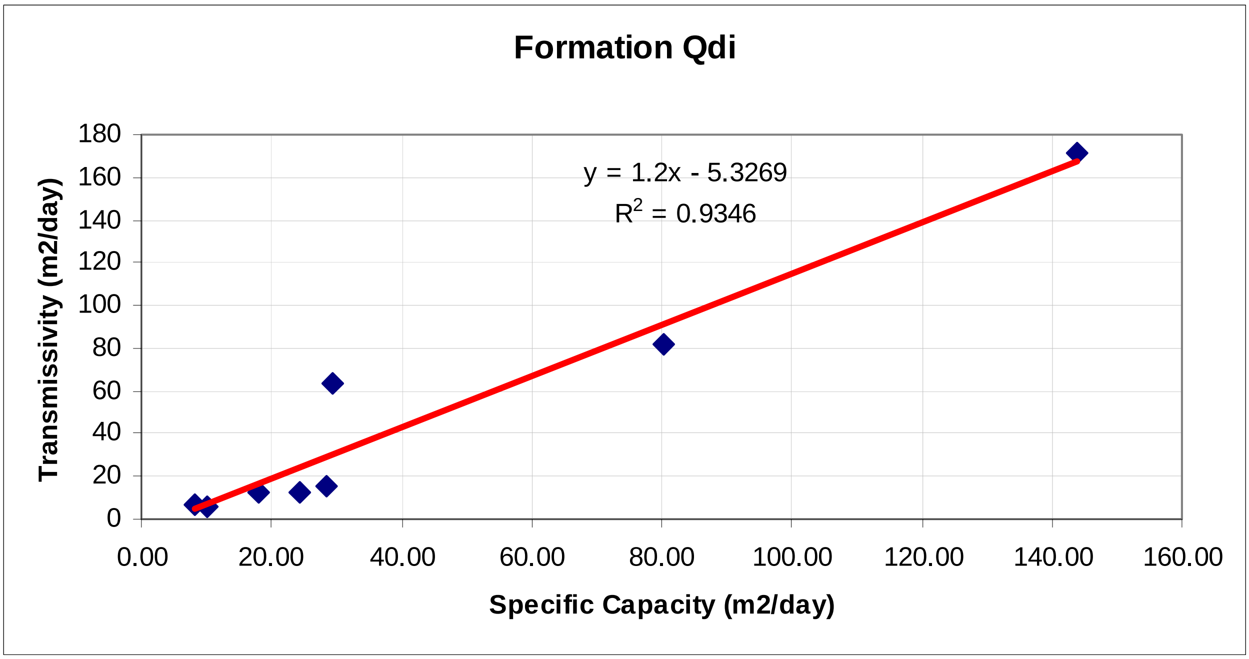

Figure 45. Transmissivity Vs Specific capacity

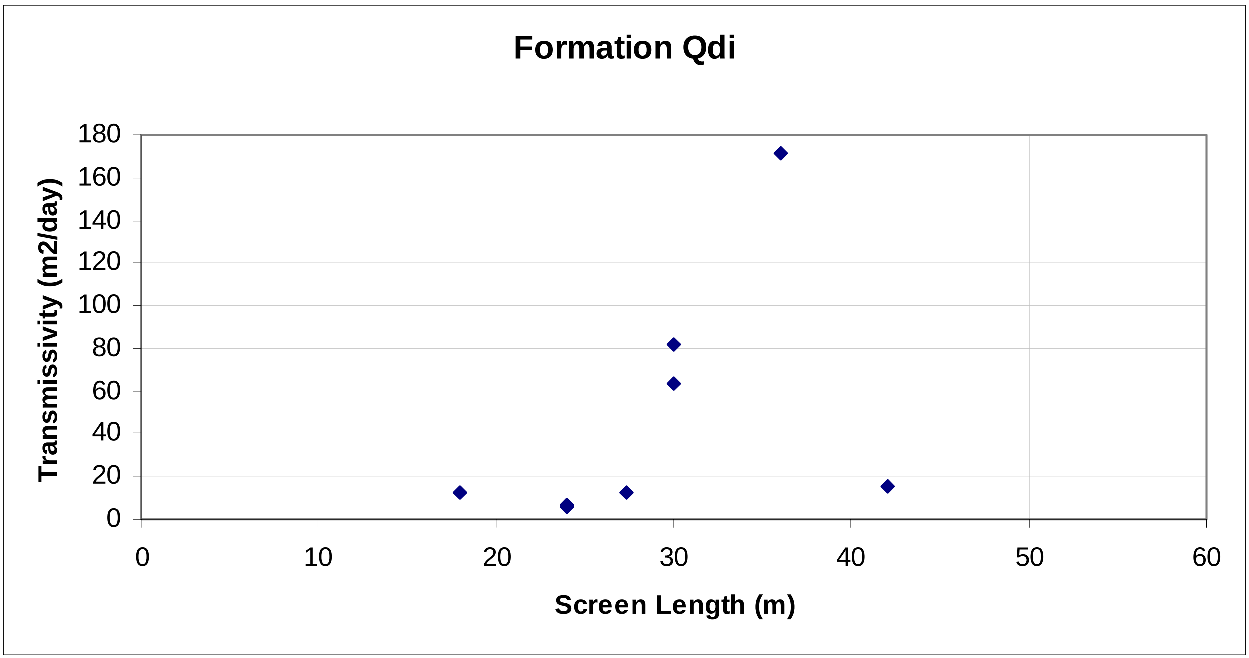

Figure 46. Transmissivity Vs Screen length. The plot shows that transmissivity is not related to depth of aquifer.

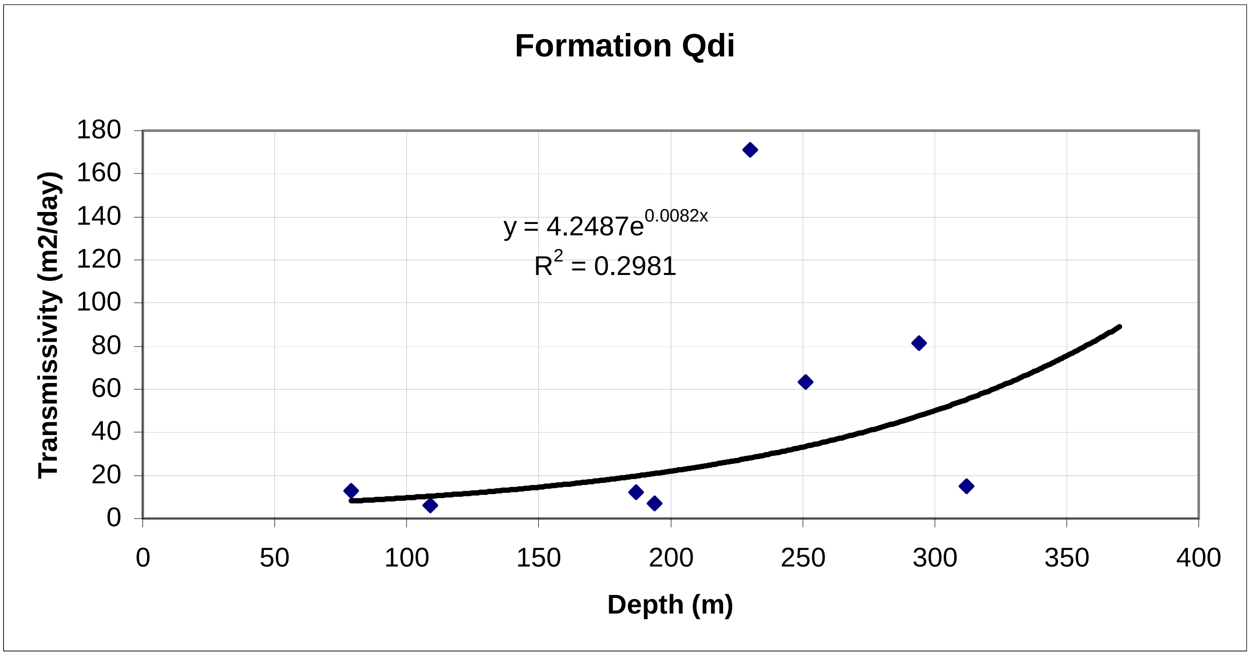

Figure 47. Transmissivity Vs depth of borehole. The plot shows that transmissivity has some relation with depth. Probably indicates that deeper boreholes intersected additional aquifers.

2.4.13.1.6 Gademotta caldera

It is situated to the southwest of Ziway Lake. The rim of the caldera is mainly composed of banded Ignimbrites and rhyolitic Ignimbrites. The floor of the caldera is covered by Lake Sediments. As observed from quarry cuts these sediments are moderately consolidated. At the centre of the caldera it can be expected thick lacustrine deposit

Little is known about its groundwater potential due to the data gaps. There are few boreholes in the area but unfortunately abandoned or non-functioning.

The test drilling result at Shisho Tora indicated SWL of 74 m and lithology a lacustrine deposit underlain by altered acidic volcanic rock similar to the hill close to the drilling site. No test pumping performed at this well until this report is submitted.

2.4.13.1.7 Ziway plain

Lacustrine sediments mixed with pyroclastic fall deposits cover the entire area. Groundwater is fairly shallow. It is close to the surface at the lake's shore area, 20 m in Ziway town and deeper further away from the lake.

Aquifer Properties

Existing data shows it has Transmissivity varying between 95 m2/day to 355 m2/day and hydraulic conductivity 1m/day to 4.4 m/day. The following table provides the observed transmissivity values.

Table 12: Summary of aquifer properties for Ziway plain

Borehole	Location in UTM		Transmissivity M2/day	Hydraulic conductivity M/day
Ziway Prison Borehole	467854	877491	354.24	
Meki Town			100	4.39
Meki Town			100	4.35
Adamitulu			95.28	3.97
Ziway Municipality				1.00

Plot of Transmissivity Vs Specific capacity plot shows that the transmissivity has linear relation with the specific capacity. From the specific capacity value transmissivity can be roughly estimated using the equation shown on the trend line for this area.

The plot of transmissivity with screen length shows that the screen screen length has no impact on the transmissivity.

The plot of transmissivity vs well depth indicates linear relationship. This indicates that deeper drilling increases the transmissivity as well as well yield.

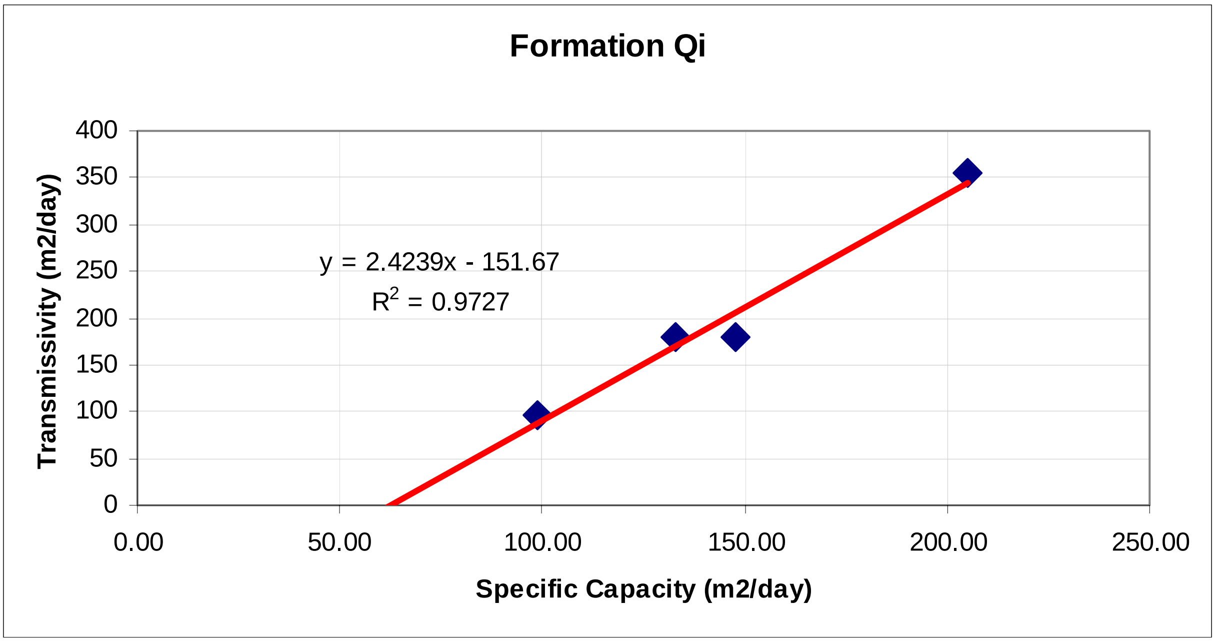

Figure 48. Transmissivity Vs Specific capacity

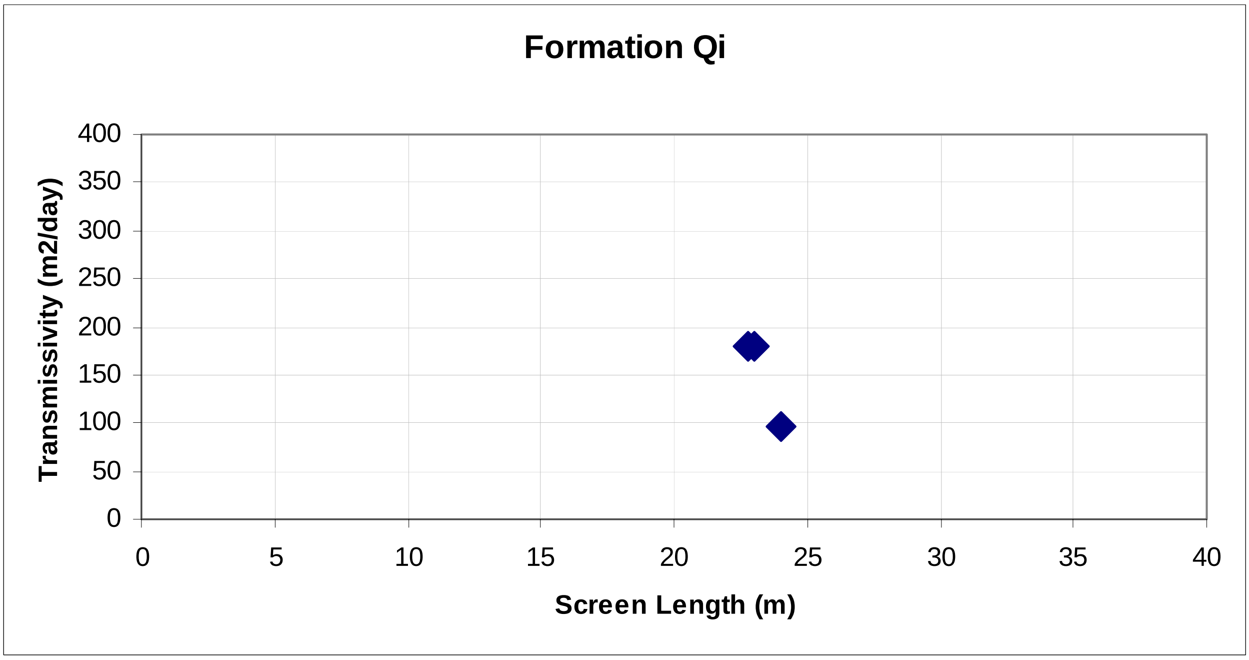

Figure 49. Transmissivity Vs Screen length. The plot shows that transmissivity is not related to depth of aquifer.

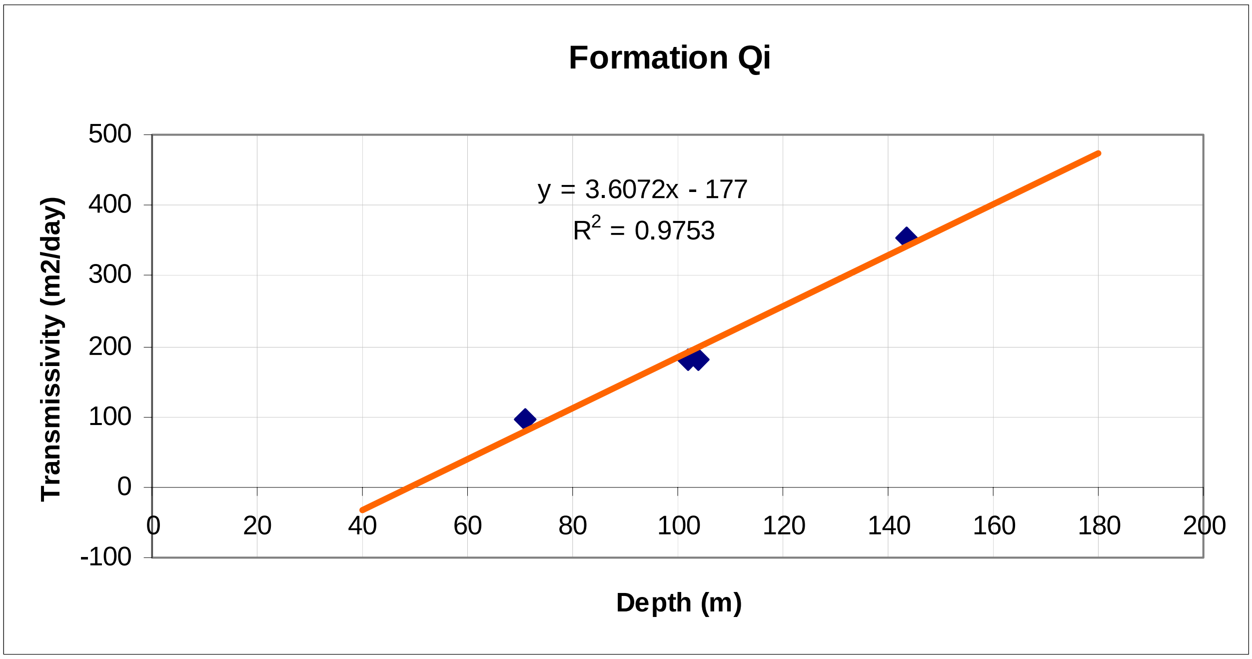

Figure 50. Transmissivity Vs depth of borehole. The plot shows that transmissivity has some relation with depth of boreholes. This means deeper boreholes intersect additional aquifers.

2.4.14 Groundwater Flow

Groundwater contours have been generated based on the available data and field inventory results as shown on the figure of the following page. Groundwater flow is generally towards the east from the western escarpment. The groundwater level is generally flat to gentle slope except at Tora-Koshe-Dugda ridge and the Cinder cone areas. In these areas the groundwater contour shows steep slope showing lower permeability, probably due to the nature of the rocks or the fault systems separating these zones.

The groundwater has a slope of about 0.1 % at Ziway Plain. Tora-Koshe-Dugda ridge has about 1.4%, Kuntane-Inseno-Kela plain 0.3% and Cinder Cone and Basaltic areas about 3.7 %.

The groundwater level drops from about 2000 m in Butajira Crescent to 1800 m amsl in Kuntane Inseno area. The cinder Cone and basaltic flows, which erupted along probably, a regional fault acts as barrier or low permeability zone resulting into steep groundwater slope. This area hosts the Crater Lake Har-Shetan.

The groundwater flows to the lake Ziway, and it can be said that the lake receives groundwater in addition to surface water input. However, the groundwater countour is flat close to the lake and it is not clear whether the groundwater feeds the lake or the lake foods the groundwater. The groundwater observation point at Ziway town would help to identify this by calibrating it with the guage height at the lake.

2.4.15 Storage Parameters

No data is available on the storage properties of the aquifers. This however, has to be estimated taking into account different aquifer types and aquifer materials.

2.5 WATER QUALITY

A number of water samples have been collected from the project area and analyzed for major ionic constituents and for selected minor chemical constituents of natural waters. The total number of the samples is forty seven from which eighteen from borehole, four from shallow wells, two from hand dug wells, five from wells fitted with wind mills, five from springs (one from thermal spring), four from lakes, two rain water samples, one sample from pond and six samples from rivers.

The samples are collected only one time and so that temporal variations cannot be considered. Besides some specific parameters for surface waters such as color and BOD for rivers and transparency for lakes are not measured or analyzed. Regarding the laboratory analyses results of the sampled waters are found to be acceptable by checking the ionic balance calculations of the respective chemical analyses results.

The understanding of the water quality of the project area requires close examinations of physical and chemical factors controlling the source, transport, and fate of natural and anthropogenic contaminants in the overall water resources of the area. Besides, understanding of the natural hydrogeologic and geochemical processes as well as the associated anthropogenic effects on the groundwater and surface water resources is very essential. However, for the sake better understanding and subsequent interpretations of water quality situations of the project area within the overall framework of the project and its specific objectives, the physico-chemical analyses results interpretations are categorized into two major groups, namely: groundwater and surface water.

2.5.1 Groundwater

The chemical compositions of groundwaters of the area show considerable variations, which is related to the extent of mineralization. The extent of mineralization on its turn depends on several factors including the chemical nature of rocks, hydraulic characteristics and residence time. As water moves through the unsaturated zone, physical and chemical processes occur that can affect the chemical composition of water before reaching the saturated groundwater system. Particularly, the concentration of carbon dioxide, which is the by product of biochemical reactions, is an important factor controlling the chemistry of the saturated zone.

Natural or anthropogenic contaminants can be transformed by geochemical, radiological, and microbiological processes as they are transported through various environments within the groundwater system. Some chemical transformations can change harmful contaminants into less harmful chemical species, while other processes can produce compounds that are more harmful to ecosystems or human health than the parent compound.

2.5.2 General Characteristics

Total Dissolved Solids (TDS) is general indicator for the extent of mineralization. Most water samples have appeared fresh; TDS values are less than 1000 mg/l. However, all the groundwater samples do have high mineral content. Groundwater samples from Dudga Bora (Abeno 01), Admi Tulu (Galo Fachasa), Adami Tulu and (Abine Germana, Hand dugwell) are brackish water; TDS Values greater than1000 mg/l.

The TDS values are in generally high in Ziway palin and Tora-Koshe-Dugda Ridge.

The hardness of the groundwater samples are relatively very low. Except two wells (a hand dug well at Mareko Dida Midora ans shallow well at Lamfura Warsha Shanka), the other groundwater samples are very soft.

Table 13: Table – TDS and Fluoride in the project area

Nature of Sample	Location Name	UTME	UTMN	TDS (mg/l)	Fluoride (mg/l)	Remark
Borehole	Meskan Shershera lle	439098	899051	264.00	0.50	Kuntane - Inseno - Kela Plain
Borehole	Silty Dobo Bedeno	432428	886909	272.00	0.80	Kuntane - Inseno - Kela Plain
Borehole	Silty Luke Fake	446742	872640	676.00	3.16	Ziway Plain
Borehole	Adame Tulu Aneno	465724	865471	668.00	3.66	Ziway Plain
Borehole	Adame Tulu Haleku Glenta	465363	869206	560.00	2.50	Ziway Plain
Wind pump	Adame Tulu Galo Fachasa	462137	883385	1066.00	3.66	Ziway Plain
Borehole	Adame Tulu Abosa	469886	886446	732.00	3.30	Ziway Plain
Wind pump	Dgda Bora Laluna Dero	469448	901986	360.00	3.30	Ziway Plain
Wind pump	Dugda Bora Giraba Jarso	477198	901824	972.00	3.70	Ziway Plain
Shallow Well	Tuchi Somya	487538	901548	858.00	3.70	Ziway Plain
Wind pump	Dugda Bora Abeno 01	471764	892451	1090.00	3.66	Ziway Plain
Borehole	BH1(Netsa Sefer)	432792	897549	183.50	nil	Area of Cinder Cones and Basalt Flows
Borehole	BH2(SE Butajira)	432001	897801		0.34	Area of Cinder Cones and Basalt Flows
Borehole	BH4(Gerarbe Ledekuman)	432501	898201		0.50	Area of Cinder Cones and Basalt Flows
Borehole	Mareko Koshe town	448380	884901	494.00	3.16	Tora-Koshe Dugda Ridge
Borehole	Lamfuro Tora town (Amcha)	435852	869258	616.00	3.16	Tora-Koshe Dugda Ridge

PH

The entire boreholes' PH values are in basic regime; between 7.16 and 8.66 values. The range indicates that the carbonate equilibrium conditions of the project area favor the dissociation bicarbonate into carbonate ions.

Major Ionic Composition

The dominant major cataion in the project area is sodium, being balanced by bicarbonate. Eleven groundwater samples do have sodium concentrations greater than 200 mg/l. The other unique feature of the project area in relation to the ionic composition is the relatively high concentration of potassium; in most cases its values are greater than the natural background. For the time being it is not clear the geochemical factor(s) responsible for this unusual phenomenon.

On the Other hand, the concentrations of calcium and magnesium are very law, which was reflected in the low hardness of the respective samples. It requires extensive study to determine the ion exchange mechanisms between the dominant ion (sodium) in the project area and the dominant ion in the natural water environment (calcium).

The chloride concentration of the groundwater is very low indicating the groundwater has little contact to marine rocks at present. In most cases, the presence of chloride in the groundwater sample is practically negligible and appeared minor chemical constituent. The avaerage chloride value is about 17 mg/l with minimum of 1 mg/l and maximum of 109 mg/l..

The other major ion in natural water is sulphate. However, sulphate has appeared one of the minor chemical constituents in the project area withaverage value of 19 mg/l with values ranging from trace to a maximum of 120 mg/l (one sample). 70 % of the samples show value less than 10 mg/l, 9% from 10mg/l to 20 mg/l and 21% over 20 mg/l. It is not clear the cause of such low profile condition of sulphate.

Bicarbonate was the dominant ion in the project area and its proportion to carbonate was being controlled by the PH values of respective groundwater samples. For PH value less than 8.00, the carbonate concentration of the ground water samples aree found to be either negligible or nil.

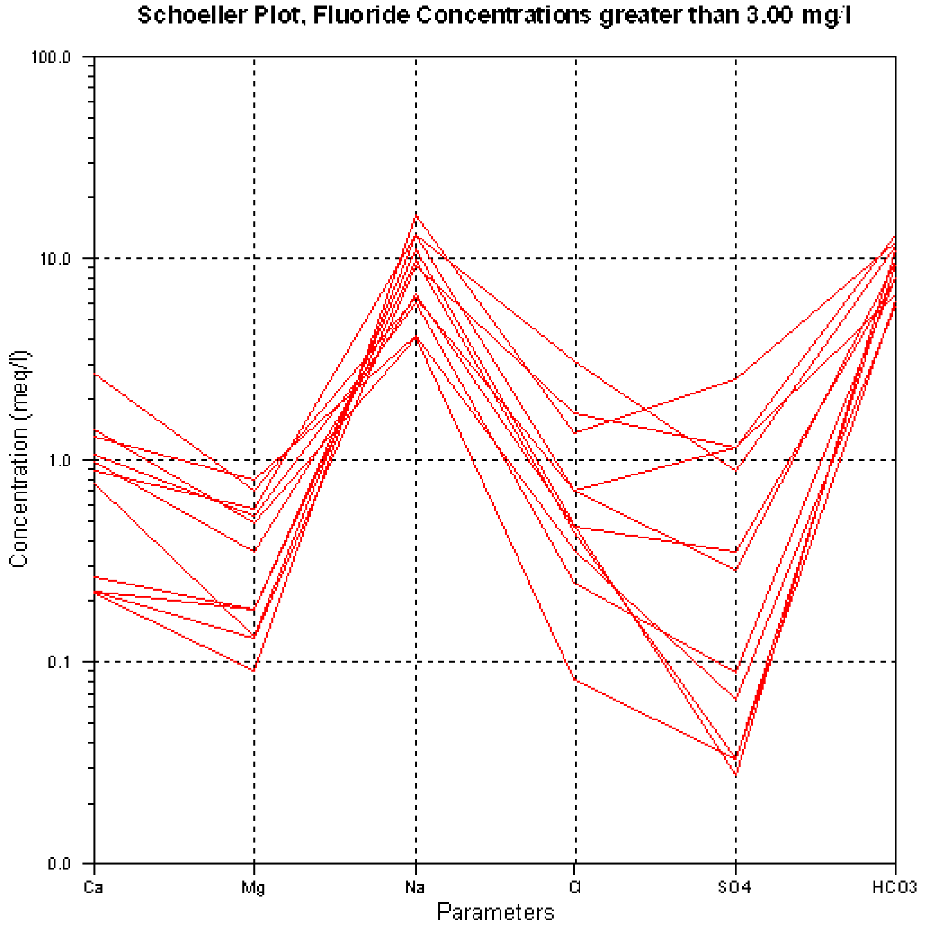

Figure 51.

As can be seen from the Scholler diagram plotted for selected groundwater samples, the sodium ion the major dominant cation counter balanced by bicarbonate anion. On the Other hand, sulphate concentrations in the project area are found to be in trace amounts.

Minor Chemical Constituents

The most important minor chemical constituents for consideration in the project area are Nitrate and Fluoride concentrations as they are causes of anthropogenic pollution and natural contamination respectively. Excessive presences of these ions in drinking water are very serious public health concern.

The fluoride concentrations in the boreholes of the project area ranges from 0.15 to 3.66 mg/l. twelve samples exceed the World Health Organization drinking water quality guidelines and six samples exhibited values above Ethiopian drinking water quality guidelines. The fluoride guideline values for World Health Organization and Ethiopian drinking water quality guidelines are 1.5 and 3.0 mg/l respectively. It has to be noted that fluoride concentrations above 1.5-mg/l causes dental fluorosis and above 3.0 mg/l can cause skeletal fluorosis. Flouride values over 3 mg/l occur in the Ziway Plain and Tora-Koshe-Dugda ridge.

Table 14: Groundwater samples with High Fluoride Concentrations

No	Sampling Points	F Conc. (mg/l)	Remark
1.	Tuchi Somya	3.7	Such level of fluoride concentration in drinking water can cause Dental & Skeletal Fluorosis
2.	Sembero	3.3	"
3.	Dudga Bora (Girano Jarso)	3.7	"
4.	Dudga Bora (Abeno 01)	3.66	"
5	Dudga Bora (Lalano Dero)	3.3	"
6.	Adami Tulu (Galo Fechasa)	3.66	"
7.	Adami Tulu (Abine Germano)	3.96	"
8.	Adami Tulu (Metremoto)	3.16	"
9.	Adami Tulu (Abosa)	3.3	"
10.	Mareko Fako Werabo	3.6	"
11.	Adami Tulu (Aneneo)	3.6	"
12	Amche	3.16	"

Piper Diagram, Fluoride Concentrations greater than 3.00 mg/l

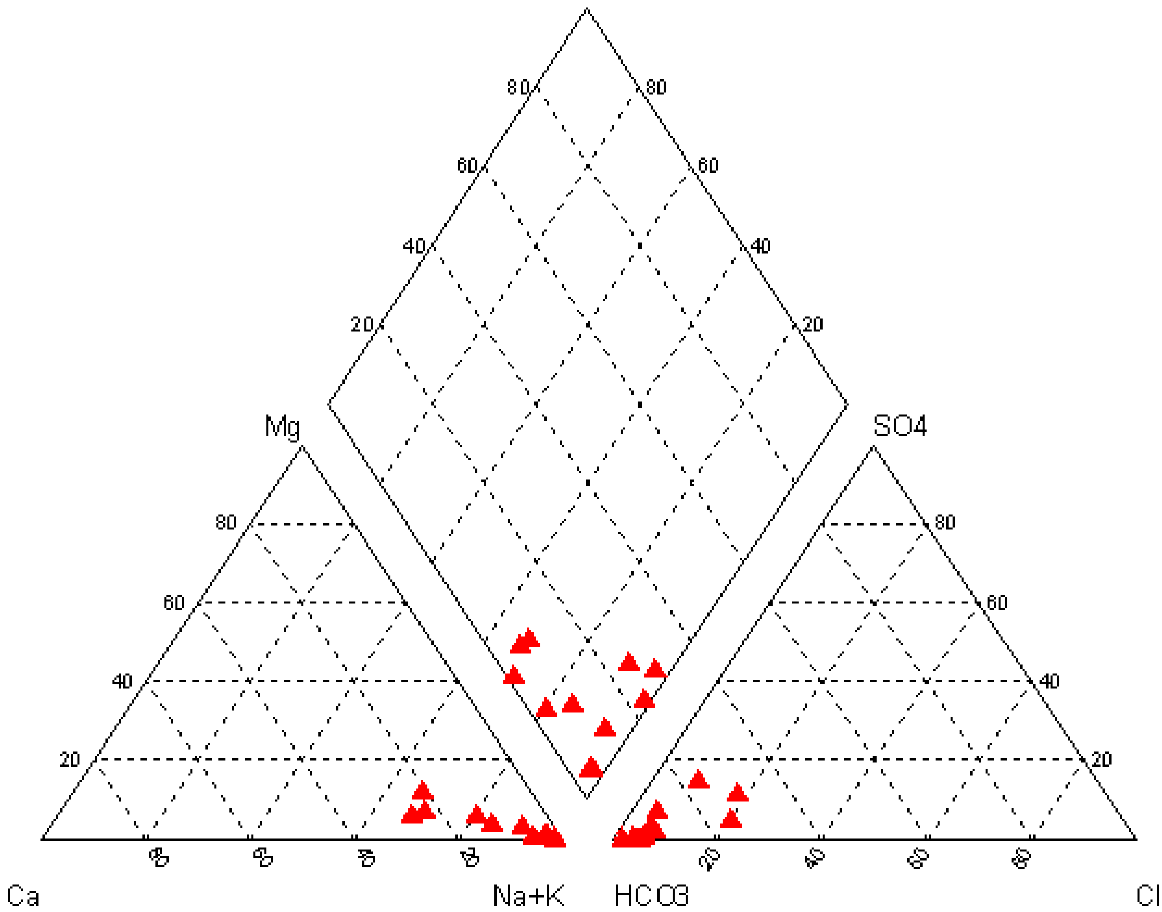

Figure 52

The Nitrate concentrations in the boreholes of the project area ranges from trace amount to 12.5 mg/l. All water samples are well below the Nitrate guideline values of World Health Organization and Ethiopian drinking water quality guidelines. However, six samples have appeared beyond the natural background level groundwater. The nitrate concentrations of these samples are not to the level indicating potential anthropogenic groundwater pollution. The full analyses results of the boreholes are attached as annex of this report.

2.5.3 Springs

Four samples were collected from four springs from the project area. Selected water quality parameters of the springs are presented in the following table. They have shown considerable deviations from the average groundwater (shallow and deep wells) chemical composition of the project area.

Table 15: TDS and Fluoride content of springs

Nature of Sample	Location Name	UTME	UTMN	TDS (mg/l)	Fluoride (mg/l)	Remark
Cold Spring	Meskan Meserete Wogram	429479	909263	40.0	Trace	Butajira Crscent
Thermel spring	Silty Ashute (Kotane Marsh)	432821	884393	1482.0	3.66	Kuntane - Inseno - Kela Plain
Cold Spring	Silty Dobo Sabola (Murtute spring)	436641	889697	278	0.96	Kuntane - Inseno - Kela Plain
Cold Spring	Borkitu Spring Beshila Chefa	485555	872111	190	1.9	Aspring East of Ziway Lake
Cold Spring	Sodo Delamegn	448564	930115	60	Trace	

Table 16: Selected Water Quality Parameters of the spring found in the project area

Name of the Spring	TDS (mg/L)	PH	Na (mg/L)	Ca (mg/L)	NO3 (mg/L)	F (mg/L)	HCO3 (mg/L)
Silty Dobo Sabola	278	7.3	28.5	49.8	12.5	0.96	281.8
Meskan Meseerte Worgam	40	6.76	2.70	5.34	4	Trace	25.62
Silty Ashute (Kontane Marsh)	1482	7.29	450	26.7	7.5	3.66	1175.9
Sodo Delamegn	60	6.57	3.5	8.9	7.5	Trace	40.99
Borkitu Spring Beshila Chefa	190	7.55	42	17.8	10.7	1.9	176.8

As can be seen from the table, except the fluoride concentration of the spring at Silty Ashute (Kontane Marsh) and Burkitu spring (east of lake Ziway), the fluoride concentrations of the springs is very low and practically nil.

Similarly except the thermal spring (Silty Ashute near Kontane Marsh), all springs do have very low sodium content and have appeared fresh water with low mineral content. The mineral content of this spring is associated with its high content of sodium and bicarbonate ions concentrations.

It is also interesting to note that two springs situated close to base of the escarpment (Sodo Delamegn and Meskan Meserete Wegeram) are slightly acidic and have very low mineral content that indicates that their residence in the sub-surface environment relatively short.

2.5.4 Surface Water

The four samples from four rivers were taken during the rainy season. However, the turbidity values of these samples are not very high. It was only Meki River had relatively high turbidity value, which was 550 NTU. It has to be noted that the water quality of rivers will be meaningful while presented with the discharge values of the respective rivers in relation to specific sampling sites.

The mineral content of the sampled rivers were very low. The highest value was observed for Woja River, which has 168 mg/l as TDS value. On the other hand the TDS value of Irisho River at Butajira town was only 64 mg/l.

Regarding the natural chemical constituents of the river, they are in the acceptable range of World Health Organization and Ethiopian drinking water quality guidelines. However, the concentration of nitrate for Woja River is beyond its natural background. This value indicate that the river at the sampling point is somewhat is exposed to contaminations.

Four water samples were collected from four lakes of the Project area for chemical analyses. The water sample from Ziway lake (the biggest among the five) is fresh, very low mineral content. Its fluoride level is 1.6 mg/l and just above the World Health Organization drinking water quality guideline value.

The most important water quality parameters of the lakes are presented in the following table.

Table 17: Selected Water Quality Parameters of the lake found in the project area

Name of the lake	TDS (mg/L)	PH	Na (mg/L)	Ca (mg/L)	NO3 (mg/L)	F (mg/L)	HCO3 (mg/L)
Ziway	332	8.04	78	23.1	8.2	1.6	294.6
Lamfro Archuma	90	7.4	7.5	12.5	16.25	1.68	56.3
Silty Ashute (Kontane Marsh)	6502	9.53	2150	8.9			3135.4
Abaya	296	8.27	58	32.04	18.25	2.2	247.4
Shetan Creater Lake	310	8.59	40	43.6	16.25	0.5	259.1

As can be seen from the above table, except Lake Shetan, all lakes do have fluoride concentration above the World Health Organization drinking water quality guideline value. Although the nitrate concentrations of the lake have appeared below the WHO guideline, except Lake Ziway, all do have nitrate concentrations well above he natural background. These values indicate that there are some activities in the lakes area that leads towards water pollution. Hence, it is strongly recommended to protect the lakes from possible contaminations.

The sample collected from Silty Ashute (Kontane Marsh) is highly mineralized. The TDS value of the sample is 6502 mg/l, which is not normal for inland surface water. The color of the sample was black and has created considerable difficulties during chemical analyses procedures, particularly for parameters their determination were done by colorimetery. Due to this fact, the measurements of fluoride, nitrate and sulphate were not carried out. It must not be noted that it was not possible to filter out the color by filter paper at the laboratory and did not show any changes during the addition of reagents for these measurements.

The high mineral content of the sample is due to the high content of sodium, potassium, bicarbonate, carbonate and chloride, which are 2150 mg/l, 88 mg/l, 3154 mg/l, 600 mg/l and 364.7 mg/l respectively. The PH value of this sample was very high for natural water; it was 9.53. This conecentrain is probably the result of the input from the minralized Ashute thermal spring, surfacewater, and cold springs cyclic evaporation and concentration.

Two samples were collected from the ponds of project area. The chemical content of the ponds is as expected normal; fresh water with very low mineral content. However, the pond at Mareko Ras Migina has got very high turbidity, 1625 NTU.

Two rain samples were collected from Butajira and Ziway towns at June 2005. The samples did have very low mineral content, which were 20 mg/l of TDS values for respective samples. It is clear that such mineral contribution came from dissolved carbon dioxide, which in its turn initiated the carbonate equilibrium of the natural system. However, it is not clear the higher value of nitrate (11mg/l) at Butajira and higher sulphate (4mg/l) content at Ziway. The chloride value is trace at Ziway and 1 mg/l at Butajira.

Five different samples were collected from lake and marsh. One of the lakes, Silty Hare Shetan lake, is crater lake. This lake has the highest PH value among the sampled lakes in the project area, which was 8.6 mg/l. Actually; all lakes are fresh lakes with regard to their chemical composition. Regarding the natural chemical constituents of the lakes, they are in the acceptable range of World Health Organization and Ethiopian drinking water quality guidelines. Except Lake Ziway, the concentrations of nitrate for the lakes are beyond its natural background.

2.5.5 Water Quality and Water Resources Utilization in the Project Area

2.5.5.1 Drinking Water

The major drinking water quality problem in the project area is excessive fluoride. Excessive Fluoride in drinking water poses serious public health concern. Fluoride level greater than 1.5 mg/l causes dental fluorosis, mottling of teeth. Fluoride greater than 3.0 mg/l causes skeletal fluorosis, stiffing of bones including backbone. Fluoride level greater than 9.0 mg/l causes crippling fluorosis with nerve disorder.

A number of groundwater water sources of the project area contain fluoride concentrations greater than 3.0mg/l. Most of surface water sources do have fluoride concentrations less than 1.5 mg/l.

Besides, the sodium concentrations of considerable groundwater samples are greater than 200 mg/l. The World Health Organization drinking water quality guideline value for sodium is 200 mg/l. It is reported that excessive sodium in drinking water causes the increase of blood pressure.

High concentration of these two chemical constituents is mainly occurs in the atora-Koshe-Dugda ridge, Ziway plain and Ashute/Kuntane plain.

Except these two parameters all other water quality parameters are within the acceptable range of both national and WHO drinking water quality guidelines. Of course, the bacteriological quality of the water resources have to be checked before using all sources for drinking purposes and disinfect if it is necessary.

2.5.5.2 Irrigation Water

Water quality requirement for irrigation is related to several factors including salinity (which can be expressed either TDS or Electrical Conductivity), specific toxicity (which can be expressed by sodium, magnesium, chloride and boron) and infiltration (which can be expressed by Electrical conductivity and Sodium Adsorption Ratio).

The following table shows the Sodium Adsorption Ratio (SAR) values and Magnesium Hazard (MH) values for selected and highly mineralized groundwater samples.

Table 18: Sodium Absorption Ratio and Magnesium Hazard Values for selected Groundwater samples

No	Sampling Points	SAR (meq/l)	MH (meq/l)
1.	Tuchi Somya	19.47	14.84
2.	Dugda Bora (Girano Jarso)	4.06	37.87
3.	Dugda Bora (Abeno 01)	15.24	39.41
4	Dugda Bora (Lalano Dero)	4.19	25.45
5.	Adami Tulu (Galo Fechasa)	41.98	29.10
6.	Silty Fako	21.73	37.22
7.	Adami Tulu (Abosa)	23.50	40.63
8.	Mareko Kosho Town	8.21	26.57
9.	Adami Tulu (Aneneo)	21.83	44.63
10	Amche	4.96	21.06
11.	Mareko Fako Worabo	8.21	26.57

As can be seen from the table most of the SAR values lie in the range between 10 and 26, the samples are classified from fair to good for their suitability for irrigation purpose depending the type of to be cultivated. Those water samples whose SAR value less than 10 are classified as excellent for irrigation.

2.3 Industrial Water

It should be noted that the water quality requirements for industries vary with the type of their product and machinery. For instance, high-pressure boilers require high-grade water quality, almost equivalent distilled water. On the other hand, any type of water including highly mineralized water can be applied for cooling condensers.

2.5.6 Conclusion

Except the springs, the groundwater resources of the project area are characterized by high fluoride and sodium contents. At the same time the potassium concentration of the groundwater samples are well above the natural background.

On the other hand, the concentrations of the other major ions such as sulphate, chloride, calcium and magnesium exceptionally are very low. The overall hydrochemistry of the groundwater is controlled by carbonate equilibrium. The PH value has appeared to be a determining factor in the partition processes of carbonates species, particularly between bicarbonate and carbonate ions.

It appeared that the groundwater resources of the project not contaminated. However, the nitrate concentrations of a number wells indicate that the potential of groundwater pollution in the project area.

The chemical compositions of the springs are quite different from those of the wells. Practically, all springs (except Silty Ashute at Kontane Marsh) do have very low mineral content. They are suitable to drinking water purposes with proper capping; their fluoride concentration are within acceptable range of both Ethiopian WHO's drinking water quality guidelines.

Regarding the surface water samples, except Silty Ashute Kontane Marsh all do have normal chemical composition with their respective category. The exceptional very high mineral content of Silty Ashute Kontane Marsh is associated with the spring located its near by accompanied by evaporation.

The fluoride concentration of the groundwater Tora-Koshe-Dugda ridge and Ziway palin is high generally above 3 mg/l.

The lakes sampled in the study area are all fresh with low values of TDS and have also low flouride content.

The area which is highly mineralized is Ashute/Kuntane swamp area. This area has exceptionally high TDS with black color water. The miniralazation is attributed to cyclic evaporation of mineralized water originating from the thermal springs on the plain and additional input from surfacewater and cold springs. In addition this area is characterized by calcrete deposit, indicating deep circulating groendwater heated up and charged with minerals.

2.6 WATER LEVEL MONITORING RESULTS

In February Water Level monitoring commenced on Ziway water supply old borehole and BZSP/TW1 borehole at Kachaber. The monitoring result of one month data indicates that the water level in ziway has not shown any change, however at BZDP/TW1 the water level indicated decline. This is an interesting indication with regards to future study in the groundwater situation. Monitoring will also continue at BZDP/TW2, BZDP/TW3, BZDP/TW4, BZDP/TW5, BZDP/TW6.

The monitoring at BZDP/TW3 and BZDP/TW5 will specially provide information on the response of the deep and shallow aquifer to seasonal variation in recharge and also can give information on the interaction of the two aquifers.

The monitoring at ziway will give information on the interaction of lake and groundwater.

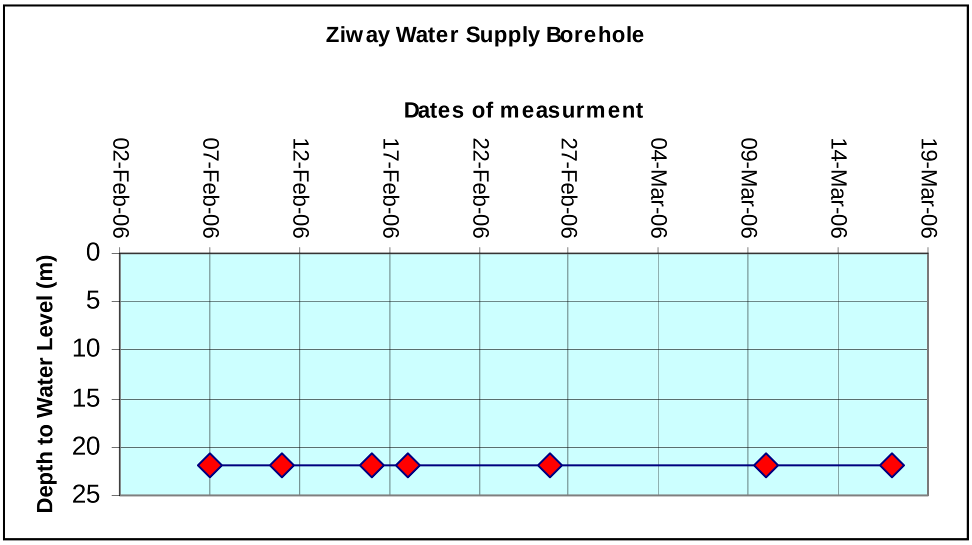

Figure 53. Water level monitoring result at Ziway town

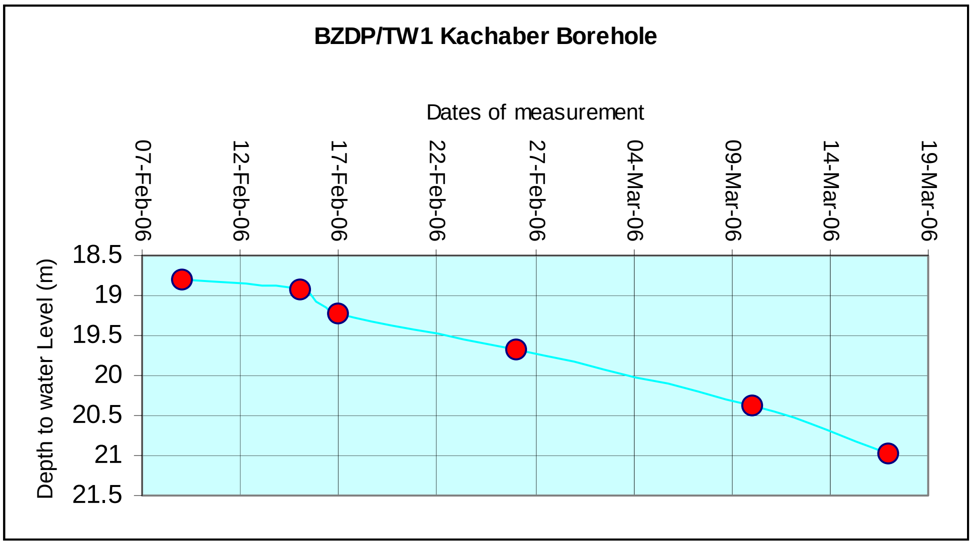

Figure 54. Water level monitoring result atBZDP/TW1 at Kachaber

2.7 HYDROLOGY

2.7.1 Climate

The project area has a wet season from July to September, dry season from October to January, and a season of highly variable rainfall from February to June. The climate of the area around Lake Ziway has arid characteristics for most of the year and monthly average rainfall never exceeds evaporation. However, the climate becomes more humid with increasing altitude on the rift valley flanks constituting the catchments of rivers draining into Lake Zwai.

Whereas over 50% of the annual rainfall is received during the 3-month wet season, rainfall distribution is variable and long dry periods are common. The wet season winds are generally south-easterly or south-westerly, depending on the location of low pressure convergence zone towards the north of the country.

At the beginning of the dry season, the convergence zone moves south across the project area and thereafter a dry northeasterly air-stream is established with very stable conditions. The climate is characterised by low rainfall and humidity, moderate but persistent winds and by a high rate of evaporation, which averages 5.3 mm/day. Night temperatures commonly fall to less than 10°C and frosts can occur on land above 1800 masl.

Between February and June, rain-bearing winds are channelled northwards through Rift Valley with the northward movement of low-pressure convergence zones. Rainfall is sporadic and unpredictable. Sometimes the stable dry season conditions persist until March, though there is great variation from year to year.

Brief account of each climate elements is given below.

2.7.2 Rainfall

The attached map shows the distribution of the mean annual rainfall in the study area. Rainfall is the lowest in the vicinity of the Lakes. On the valley flanks and on hill masses, rainfall rises steadily with elevation to a maximum of 1600 mm around 3000 m.

Makin et al (1976) analysed the reliability of rainfall over consecutive 10-day periods, based on daily records at Adami Tulu and Meki. The 80 and 90 percent dependable rainfall in any consecutive 10-day period, given in Table 1, indicates that, under rain fed conditions, crops are at a considerable risk if planted before the beginning of July. Rainfall is again unreliable by the middle of September.

Table 19: Rainfall (mm) at two levels of probability for consecutive 10-day periods

Probability %	Jan.-Mar.	April I	April II	April III	May I	May II	May III
80	0	0	0	1	0	0	2
90	0	0	0	0	0	0	0
	June I	June II	June III	July I	July II	July III	August I
80	2	3	9	12	18	17	20
90	0	0	2	5	11	9	10
	August II	August III	Sept. I	Sept. II	Sept. III	October - December	
80	23	12	23	12	5	0	
90	16	6	13	2	0	0	

2.7.3 Temperature

The mean daily temperature at Ziway is 19.3°C. The highest temperatures occur between March and June prior to the start of the main rains, though seasonal variation in daily temperature is relatively slight. The attached maps show the spatial variation of maximum, minimum and mean temperature in the study area respectively. Spatial variations in temperature are largely a result of differences in altitude. As can be seen from the map, mean daily temperatures fall with increasing altitude at a rate estimated to be within the range 0.55 – 0.65°C per 100 m, though the lapse rates are not uniform and actual temperature variations depend on exposure and seasonal weather characteristics.

While frost has not been recorded at Ziway, the minimum temperatures in the dry season frequently fall below 10°C and sometimes to 4°C. Temperature at ground level may therefore occasionally fall below freezing point, with implication for crop production.

2.7.4 Relative Humidity

Humidity is the highest in the wet season, and least in February and March, as shown in Figure 53, when there is also marked diurnal variation. The Ziway data seems to overestimate the natural relative humidity due to the fact that the meteorology station is located near the lake.

2.7.5 Wind

Strong and persistent daytime winds are significant feature of the lake Ziway area. During the afternoon in the dry season, the prevailing northeasterly winds are reinforced to the west and south of the lake by local on-shore airflow. Wind speeds are measured in the study area at Bui, Meraro and Ziway. Figure 54 gives the seasonal variation of the mean monthly wind speed at these locations. The mean wind speed is relatively high, averaging 1.19 m/s throughout the year (measures by cup-counter anemometer at 1m above the ground level). The windiest periods are November-January and immediately preceding the main rains in June.

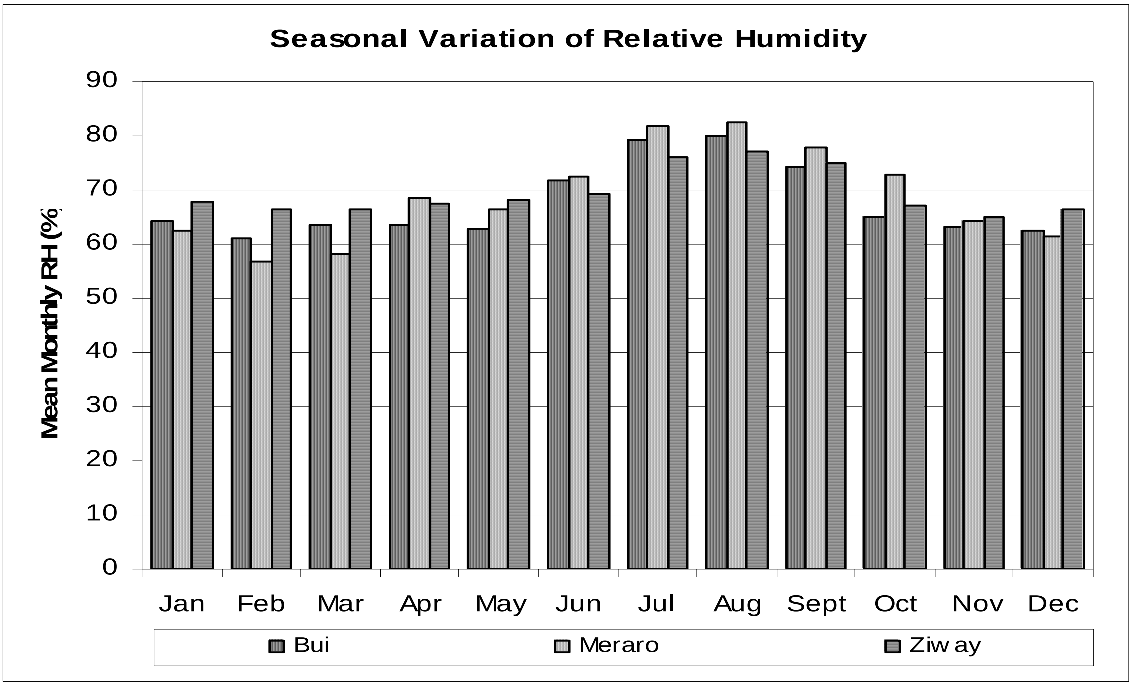

Figure 54: Seasonal variations of mean relative humidity at Bui, Meraro and Ziway

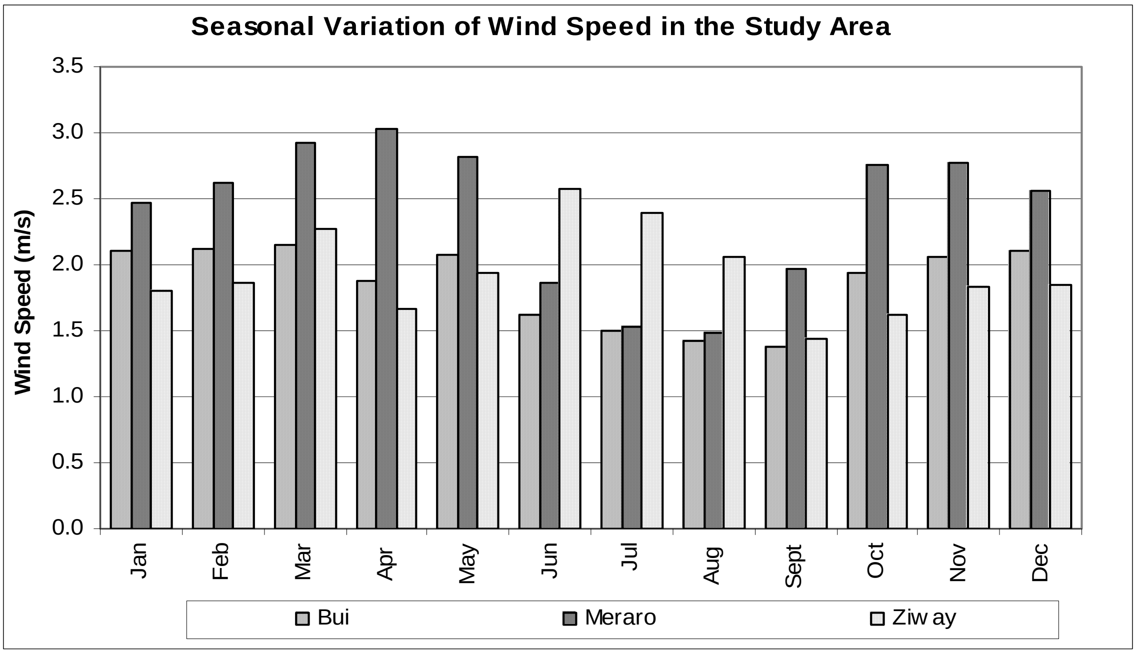

Figure 55: Seasonal variation of wind speed at Bui, Meraro, and Ziway

2.7.6 Sunshine Hours

Figure 55 shows the seasonal variation of actual sunshine hours as recorded at Bui, Meraro and Ziway. The lowest sunshine hours are recorded in the rainy season while the highest values are generally observed in November through February. The high value of sunshine hours recorded at Bui in November appears to be an outlier.

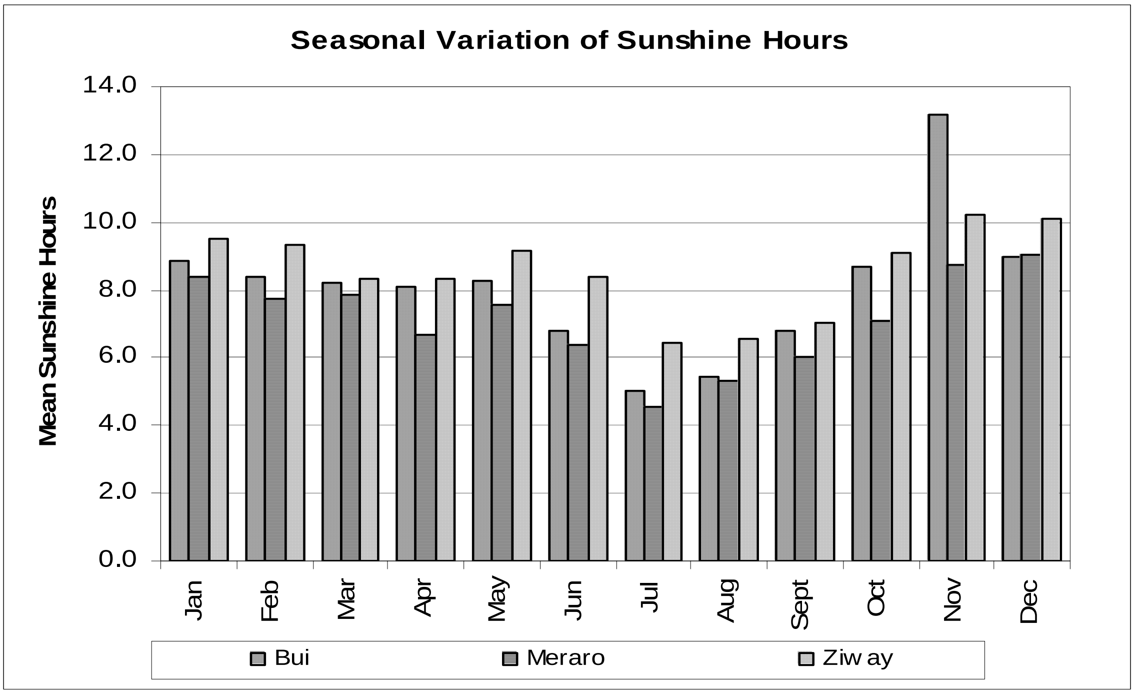

Figure 56: Seasonal variations sunshine hours

2.7.7 Rivers

The major rivers in the study area are Meki and Ketar Rivers. The location of water bodies and stream-flow gauging station is shown in on the map. Meki River and Katar River replenish the Ziway Lake, which in turn give rise to the outflow to Bulbula River that flows south for about 30 km before draining into terminal lake, Lake Abijata. Similarly, Horakelo River flows from Lake Langano to Lake Abijata. Main features of the lakes and rivers in the study area are summarized in Tables 19 and 20 respectively.

Table 20: Main Features of Lakes in the Study Area

Name of the Lake	Lake Area (Km2)	Storage Volume (MCM)	Mean Depth (m)	Altitude (m)	Catchment Area (Km2)	Annual Inflow (MCM)
Ziway	440	1,466	2.5	1,636	7,380	704
Langano	230	3,800	17.0	1,590	2,006	
Abijata	180	954	7.6	1,580	10,740	227

Table 21: Main Features of Rivers in the Study Area

River	Station	Catchment Area (km2)	Annual rainfall (mm)	Annual Runoff (MCM)	Runoff Coefficient	Drain into Lake
Meki	Meki Town	2,433	1,006	291	0.12	Ziway
Katar	Abura	3,350	874	413	0.14	Ziway
Bulbula	Adamitulu	7,488		180		Abijata
Horakelo	Near Bulbula	2,050		47		Abijata

2.7.7.1 Meki River

Meki River originates in the highlands of Gurage and travels a distance of about 100 Km from the highlands at altitude of 3,600 m to 1, 636 m before draining into Lake Ziway. Although the headwaters of the Meki River are at an altitude of about 3000 m, the river rapidly descends the rift valley escarpment to below 2,000 masl before being joined by several major tributaries, including the Lebu, the Akamuja, and the Weja.

The catcment of Meki River includes lakes and swamps (Small terminals Abaya/Abijata Lake and Goletsh Lake and Kuntane Swamp). Some of the runoff enters these water bodies. During the summer season the overflow from these waters enters Weja River, which is tributary of Meki River. The low runoff cooeficient (12%) of Meki River as compared to Keter (14%) can be related to storage of some of the runoff into these places.

Downstream of its confluence with the Weja, the Meki is incised in a steep-sided valley until it reaches Meki Town at the head of its delta. Thereafter, the Meki meanders for 15 km between slightly raised natural levees through deltaic alluvium before entering Lake Ziway at an average elevation of 1,636 masl. During wet season, several shallow overflow channels carry floodwaters causing serious local flooding which raises the water table.

The total catchment area of the river near Meki town is 2, 433 km2. According to the stream-flow data recorded at Meki town (1963 – 2004), average annual runoff volume of the river is 291 MCM. Monthly mean discharge of the river at Meki Town is summarized in Table 21.

Table 22: Mean monthly flow (in m3/s) of Meki River at Meki Town

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
0.94	2.28	5.01	7.01	7.31	6.29	18.75	29.64	19.93	8.77	3.29	0.9	9.18

The high discharge occurs during the months of August and September while minimum flow occurs generally during the dry season from December to February. The river discharge sometimes becomes zero during these months.

Current irrigation practice in the area fully utilaze Dobena river, Akamuja and Lebu streams and some of the springs as a result none of the tributaries contribute to main Meki river during the dry seasons.

The annual flow volume series of Meki River are depicted in Figure 9. Although there is a substantial increase in the exploitation of Meki River tributaries for Irrigation, a trend of decrease in the annual flow volume is not discernible in the time series. This could be due to the fact that irrigations are of very recent time and the major contribution to the annual flow volume comes from the river flow in the rainy season and significant drop of irrigation withdrawal at this time.

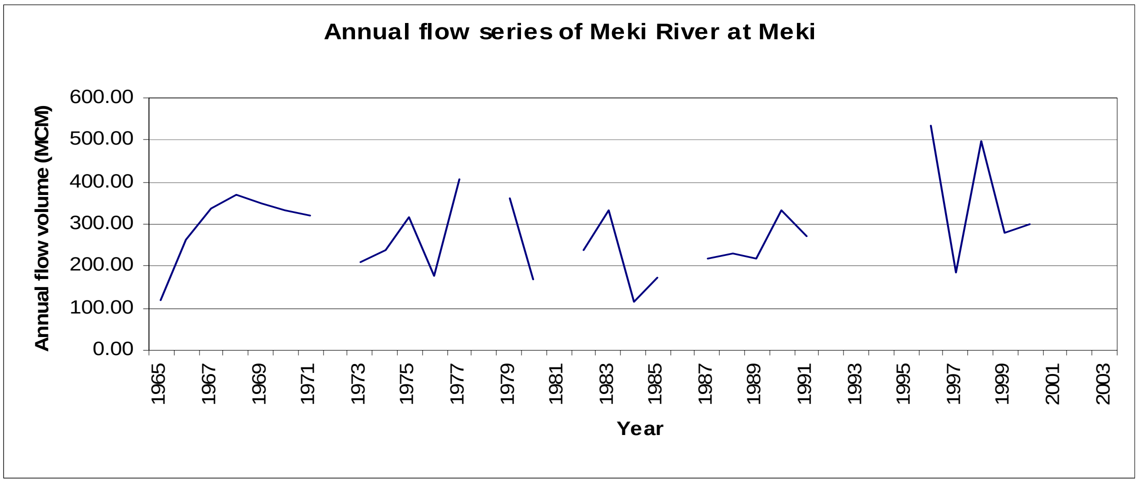

Figure 57: Annual flow volume time series of Meki River

2.7.7.2 Katar River

The catchment of the Katar River ascends to over 4,000 masl on the summits of Mounts Badda and Kaka. Consequently, the gradient of the river is generally steep through its course to Lake Ziway, and it is often deeply incised up to 50 m below the surrounding countryside. Because of the steep configuration of the Katar valley, areas suitable for irrigation are few in number and very limited in extent. Therefore, the prime importance of the Katar River is its contribution to the lake.

Table 23 gives the mean monthly flow volume of Katar River at Abura. Comparison between the average flow values for Meki and Katar Rivers clearly illustrate that Katar river has a higher specific flow. This may be attributed partly to heavier rainfall on the Katar catchment and the steeper slope of the catchment area and partly due to less abstractions of surface flow as noticed in Meki catchment where some surface flows remain in swamps and lake.

Table 23: Mean monthly flow (in m3/s) of Katar River at Abura

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual mean
6.52	6.72	10.25	15.92	15.22	15.73	48.34	139.69	85.72	43.91	12.98	7.11	34.01

The annual flow volume series of the Katar at Ogelcho is shown in Figure 57. The overall pattern of flow is similar to that of the Meki. However, the base flows in the dry season are rather higher.

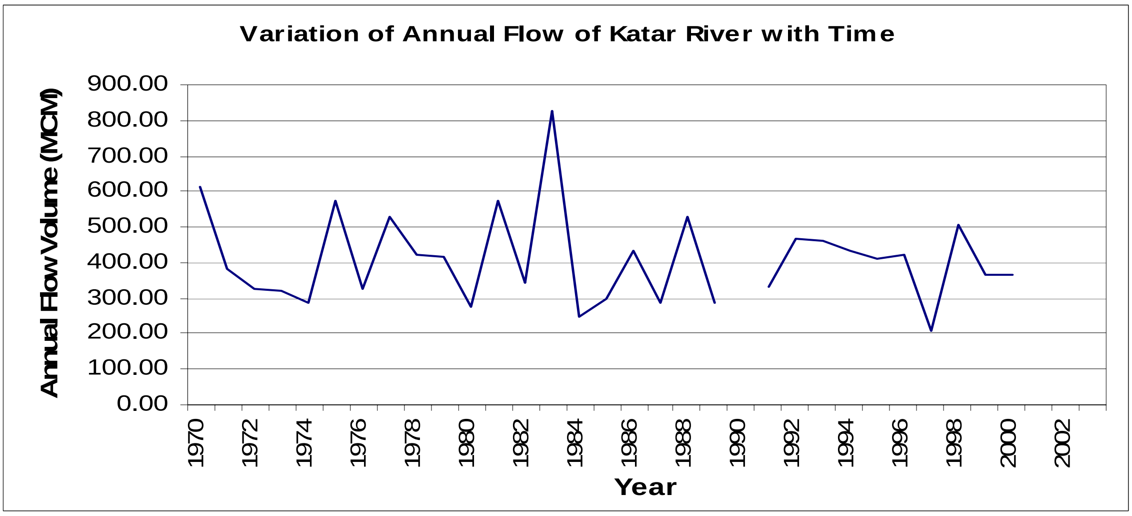

Figure 58: Annual flow volume series of Katar River

2.7.7.3 Bulbula River

The water level of Lake Ziway, which is controlled by the natural basalt bar at some 6 km downstream from the outflow of the lake, influences the Bulbula River flow. The upper part of Bulbula River is also known as Kekeristu River. Bulbula River drains annually about 180 MCM of water on average from Lake Ziway into Lake Abijata. Table 24 relates the average water level of lake Ziway and the monthly discharge of the river recorded at the station near Adami Tulu Town.

Table 24: Relation between water level of Lake Ziway and outflow to Bulbula River

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
L.Ziway water level (m)	1.06	0.95	0.85	0.80	0.76	0.74	0.83	1.19	1.50	1.53	1.34	1.23	1.07
Q (m3/s)	4.07	2.56	1.23	1.34	1.27	1.38	1.98	6.16	13.68	15.09	11.84	7.50	5.70

The Bulbula River descends some 58 m over a distance of 30 km between Lakes Ziway and Abiyata. The level of this river for the first 6 km of its length is virtually the same as that of Lake Ziway due to a lava rock sill that effectively controls the level of the lake. Below the sill, there are a series of minor falls over further banks of lava, before the Bulbula River becomes incised to over 50 m in a steep-sided gorge within poorly consolidated ash deposits. The gorge continues almost to Lake Abiyata, into which the Bulbula flows over a shallow beach. Except periodically during wet season, the flow in the Bulbula usually derives entirely from Lake Ziway. However, the Bulbula does have a significant catchment of its own with ephemeral tributaries from the east occasionally contributing to the flow.

2.7.8 Lakes

2.7.8.1 Lake Ziway

The main water source for the lake is the flows of the Katar and Meki Rivers. The mean annual flows of these rivers are 291 MCM and 413 MCM respectively. The total catchment area of Lake Ziway is 7,380 Km2. The remaining catchment that is surrounding the lake passing through swamps contributes little as the large part of the water evaporating before it contributes to the lake effectively. Therefore, the total annual average inflow in the lake can be safely estimated by the sum of the Katar and Meki river flows, which is about 704 MCM. The mean annual water level time series of Lake Ziway is shown in Figure 58. This data doesnot indicate a declining trend except low water level between 1985 and 1989.

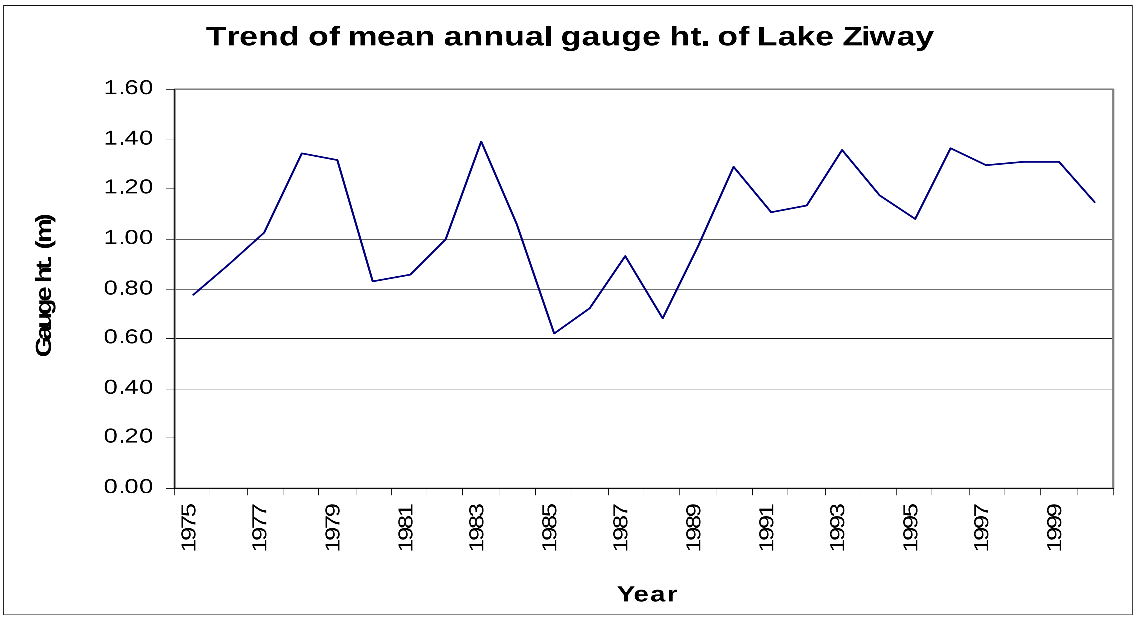

Figure 59: Annual water level series of Lake Ziway

2.7.8.2 Lake Abijata

Lake Abijata is a terminal lake located in the Abijata-Shalla National Park and particularly known for its migratory pelican and flamingo birds. The lake gets its inflow mainly from outflows of Lake Ziway and Lake Langano through Bulbula and Horakelo rivers respectively. Bulbula River contributes an annual flow volume of 125 MCM while Horakelo River contributes about 46 MCM. The remaining part of Lake Abijata catchment contributes relatively little.

Lake Abijata is highly mineralized and thus is not important for use in irrigated agriculture. However, the Abijata Soda Ash Enterprise is extracting about 2 MCM of water annually for soda ash production from lake water since 1990.

3 APPROPRIATE TECHNOLOGY

Out of the proposed appropriate technologies for water lifting, motorised rope pumps both diesel and electrical have been demonstrated by EWTEC and Practika Foundation in Kuntane-Inseno-Kella plain.

Electrical Motor Rope pump was demonstrated at Ras Tessema Village (UTM 440416 E, 896483 N) Existing Hand Dug well. This dug well is 14.5 m deep and has static water level at 14.2 m. However, for longer operation with motorized pump the well needs to be deepened. This site was found sutable to demonstrate this pump, because the aquifer is composed of river gravels, sutable to support motorised pumping from such shallow well. In addition there is an electric power supply for a flourmill. The electric motor can be run with any two-phase power line used for normal lighting of bulbs and flourecents. The following photographs show Motorized Rope pump demonstration at Ras tessema Village.

Figure 60: Motorized (electric motor) rope pump demonstration at Ras Tessema Village

Figure 61: Motorized (electric motor) rope pump demonstration at Ras Tessema Village

Diesel Motor Rope pump was demonstrated at Dobena Bati Village (UTM 440952 E, 894711N) on Existing Hand Dug well. This dug well is 14.6 m deep and has static water level at 13.4m. This site was found suitable to demonstrate this pump, because the dug well is well constructed with concrete rings with good shallow aquifer. The following photographs show diesel motor Rope pump demonstration.

Figure 62: Motorized (diesel motor) rope pump demonstration

Figure 62: Motorized (diesel motor) rope pump demonstration.

4 GENERAL CONCLUSIONS AND RECOMMENADTIONS

4.1 CONCLUSION

The result of the actual study shows that the groundwater flow within the study area is mainly from the western escarpment towards lake ziway, which indicates that it is the main recharge source.

Groundwater potential of the alluvial deposits and debries flow close to the escarpment of Butajira cresent is low with low aquifer parameters and low yield to boreholes. This indicates that for large pumping this aquifer is not sutable. Its shallow water level with low yield is sutable for householed utilization with small pumps. However, further away from the escarpment the sediment and aquifer quality improves and as shown by the test well results of Butajira Town pumping at discharges up to 5 l/s to 10 l/s is possible. The occurrence of deep circulating water is not identified.

The cinder cone and basaltic flows show relatively poor aquifer and this zone acts as a low permeability zone impeding easy growndwater flow to the next Kuntane-Inseno plain. Because of this zone there is steep decline in the water table betwwn Butajira Area and Kuntane-Inseno Plain.

The drilling and testing resulats and avialble data indicated the Kuntane-Inseno-Kella plain has high pothential and thick aquifer. This area can suprt large pumping rates from boreholes as large as over 10's of l/s. The aquifer is thick and unconfined. However, the groundwater quality of this plain deteriorates towards Kuntane Swamp as a result of mineralised hot springs and evaporation and mineral concentration of the swampy plain. This area receives much of its groundwater from growndwater underflow and surface runoff reaching the plain and direct rainfall.

Tora –Koahe-Dugda has relatively less potential with deep groundwater. As a result the low permeability of this zone and major fault zone that creating a low permeability zone the groundwater level between is deep and steep towards the lake Ziway direction. This zone recives its water from lateral groundwater flow from the Kuntane-Inseno-Kella plain area. Since the groundwater is too deep in this area the chance direct rechange from rainfall is vey low.

Ziway plain has shallow groundwater with thick aquifer and relatively good permeability. The growndwater. This zone receives groundwater from the lateral groundwater flow frpm the western areas and partly from the lake. However the influnce of the lake needs further investigation.

Gademota Caldera has relatively deeper groundwater and its main water source is the growndwater flow from the Lake Ziway area and some under flow from the Tora-Koshe Dugda Ridge.

The water quality indicates the major problems for drinking water are fluoride and sodium concentrations. These values get higher in Tora-Koshe-Dugda Ridge and Ziway plain and in addition at Ashute/Kuntane swampy plain as a result of thermal waters impact.

Flouride values over 3 mg/l require deflouridation. Therefore, appropriate technology for deflouridation is vital in the project area. The water quality at Butajira-Crescent, Basaltic areas and Inseno-Kella areas is suitable for drinking purpose.

Based on SAR value the groundwater is generally suitable for irrigation, however, irrigation requirement will also depend on plant type and soil type.

4.2 RECOMMENDATION

The following are recommended for further study during the analytical study.

- Conduct appropriate discharge measurement on the proposed gauging stations of streams,
- Collect data on current utilization of surface water for irrigation schemes, and compare with recommendations of different past studies.
- Identify the impact of current utilization of surface water on the hydrologic system.
- Identify springs with significant discharge, which are currently not properly utilised, and identify methods of utilization.
- Consider waterlogged areas in Kuntane area for reclamation.
- Map different water quality zones based on the water quality analysis and available data.
- Study the impact of thermal springs on the ground and surface water quality.
- Water level observation based on new test wells and on some existing boreholes such as the abandoned boreholes of Ziway town water supply.
- Study lake water balance using different techniques.
- Inventory available groundwater abstraction sources and estimation of actual groundwater utilization
- Study stream water hydrology
- Groundwater modelling
- Establishment of GIS data Base
- Determination of stream-aquifer and lake-aquifer interaction through groundwater monitoring station at Ziway Town and at Weja River.
- Estimation of groundwater recharge using different techniques.
- Estimation of Water Lost in the small Abaya/Abijata Lake and Kntane/Kuna Swamp.
- Water balance study for lake Ziway and estimation of surface water availability.
- Developing empirical relationship between different hydrological parameters.

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