Chapter 3

Hydrology and Hydrogeology Analysis around Lake Beseka

3 Hydrology and Hydrogeology Analysis around Lake Beseka

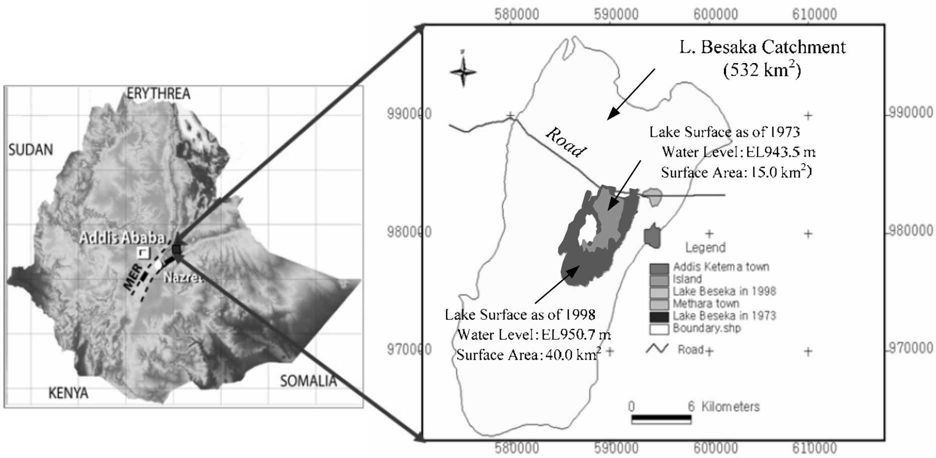
3.1 Introduction

Results of the survey and analysis on topography, geology, geological structures and hydrogeology around Lake Beseka are reported in this chapter. In addition to this, i) analysis on surface temperature of the Lake Beseka, ii) water quality analysis for water samples in and around the Lake Beseka, and iii) water balance analysis with estimated irrigation return flow are undertaken in order to validate the rationality of the widely recognized cause of lake expansion, i.e. excess irrigation water inflow. The results of these analyses are also explained in this chapter.

3.2 The Lake Beseka Issues

3.2.1 Current situation of Lake Beseka

Lake Beseka is located in Fentale District of Oromia Region at about 130 km east from Addis Ababa. The lake has a watershed area of 532 km^2 and is topographically isolated from the Middle Awash River Basin.



Source: Reference ⑩

Figure 3.2.1: Location Map of Lake Beseka

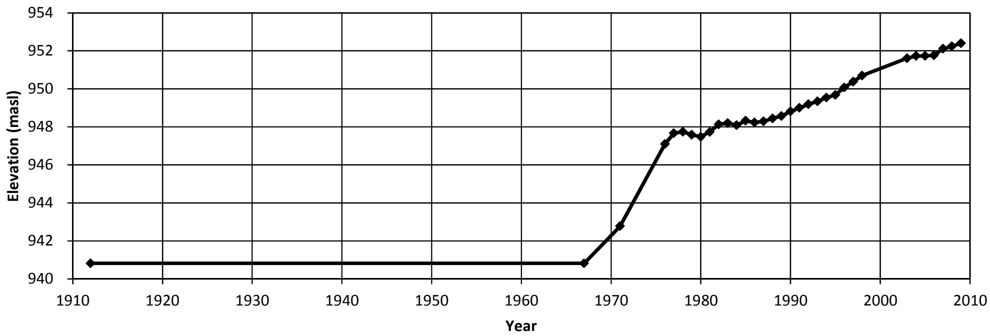
The water surface level of the lake started rising from the 1960s and adverse effects thereby have been reported since 1970s. The national highway, railway, irrigated farms and residential areas around the lake have submerged due to the lake level rise. The lake water level has increased about 12 m and the lake surface area has expanded from 3.6 km^2 to 55 km^2 since late 1960s.

Measures have been implemented to mitigate the effect of the lake level rise, including the heightening and/or shifting existing roads and railways. Measures for lowering the lake levels have also been implemented. In 2004, discharging the lake water to the Awash River was commenced with 8 pump units with total capacity of 1.73 m^3 per second. However, all pumps were submerged by the lake and became dysfunctional in 2009. Also a gravity canal system was installed to discharge the lake water level to the Awash River in 2011. In 2012, the operation of the system ceased by closing outflow regulation gate responding to complaints raised by downstream water users. The lake water now overflows the embankment of the canal system and control gates and is spilling into the Awash River without control.

3.2.2 Water level of Lake Beseka and change in outflow

Water level of Lake Beseka has been recorded since July 1976 since problems on lake expansion was recognized. Previous studies indicate that the lake water level was stable although some seasonal fluctuations were observed. The lake was reported to be about 3 km^2 during dry season and about 5 km^2 during rainy seasons throughout the period from 1912[1] to 1967 at its smallest extent. This is almost equivalent to the surface water level of 941 m above mean sea level. In addition, water level data of the lake in January 1972 are available in the report prepared by the Ministry of Water, Irrigation and Electricity (hereafter referred to as "MoWIE") in 1999.

Figure 3.2.2 provides the historical trend of surface water level in Lake Beseka by incorporating the information above.



Source: the Project Team, Data: Reference ⑤ and ⑥

Figure 3.2.2: Time Series of Water Level of Lake Beseka (1912–2009)

The graph shows sharp increment in the water level for a decade from the late 1960s to late 1970s. The water level increment became smaller after the late 1970s, although continuous increase in the water level is observed.

3.2.3 Irrigation plan and current situation around Lake Beseka

The expansion of Lake Beseka has occurred at a corresponding timing with intensive development of irrigation projects in the lake watershed diverting the Awash River water. Almost all of existing studies and researches conclude that excess water from large-scale irrigation projects have caused this lake expansion to some extent[2].

The state owned farms in Metehara Sugar Estate (hereafter referred to as "MSE") in south of the lake, Nura Hira citrus farm in the south end of the watershed, and Fentale irrigation project are the large-scale irrigation schemes in and around the Lake Beseka watershed (see Table 3.2.1 and Figure 3.2.3).

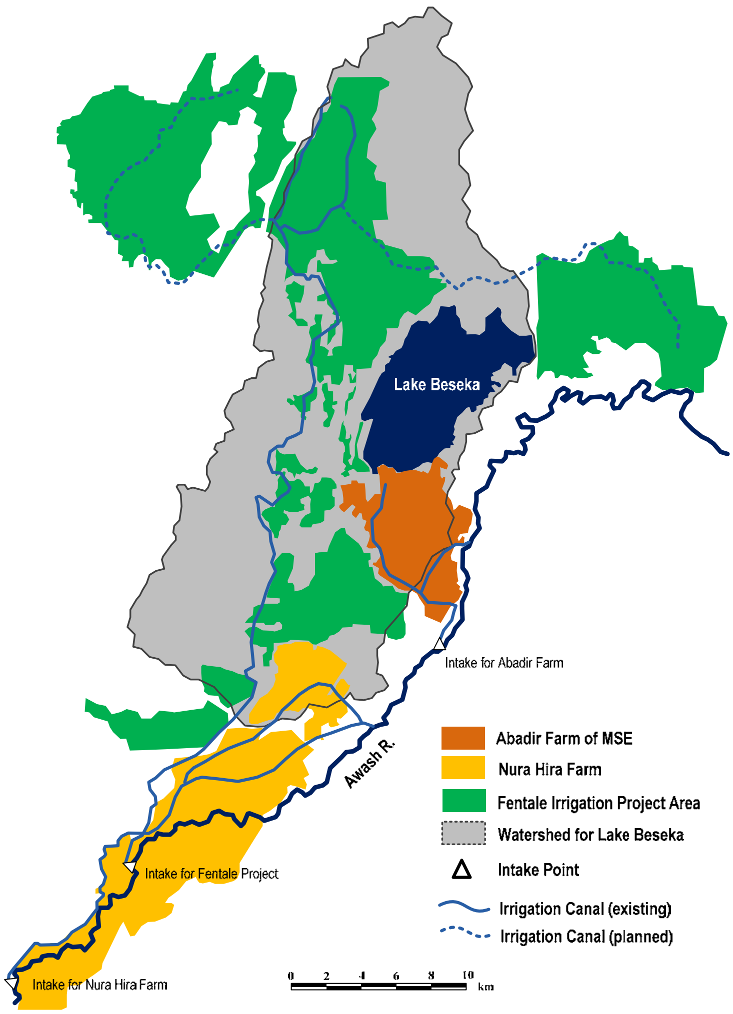
Table 3.2.1: Major Irrigation Schemes in the Lake Beseka Watershed

Scheme	Commencement of Irrigation	Total Area (Gross)	Area drains to Lake Beseka	Crops
Abadir Farm	1968	3,158 ha	2,315 ha	Sugarcane

[1] Water level in 1912 is based on the topographic map prepared by French Engineers for construction of Addis Ababa–Djibouti railway.
[2] Based on the hydrochemical and isotopic analyses undertaken, Ayalew (2009) concluded that the effect of irrigation water release on the lake expansion is negligible. All other available studies regard excess irrigation water as the dominant cause.

Scheme	Commencement of Irrigation	Total Area (Gross)	Area drains to Lake Beseka	Crops
Nura Hira	Late 1960s	6,335 ha	1,529 ha	Orange, Mandarin, Maize, Tomato, Onion, Cotton, etc.
Fentale	2007 (not completed)	18,000 ha	6,000 ha	Maize, Groundnut, Sugarcane, Onion, Forage, etc.

Source: the Project Team, Data: Reference ⑤ and ⑥



Source: the Project Team, Data: Reference ⑥ and existing 1:50,000 topographic maps

Figure 3.2.3: Irrigation Projects in and around the Lake Beseka Watershed

Annual mean water intake was about 102 million m^3 ($3.24\ m^3$/sec) in Abadir and about 105 million m^3 ($3.34\ m^3$/sec) by Nura Hira farm.

3.3 Topography, geology and geological structure

3.3.1 Topography

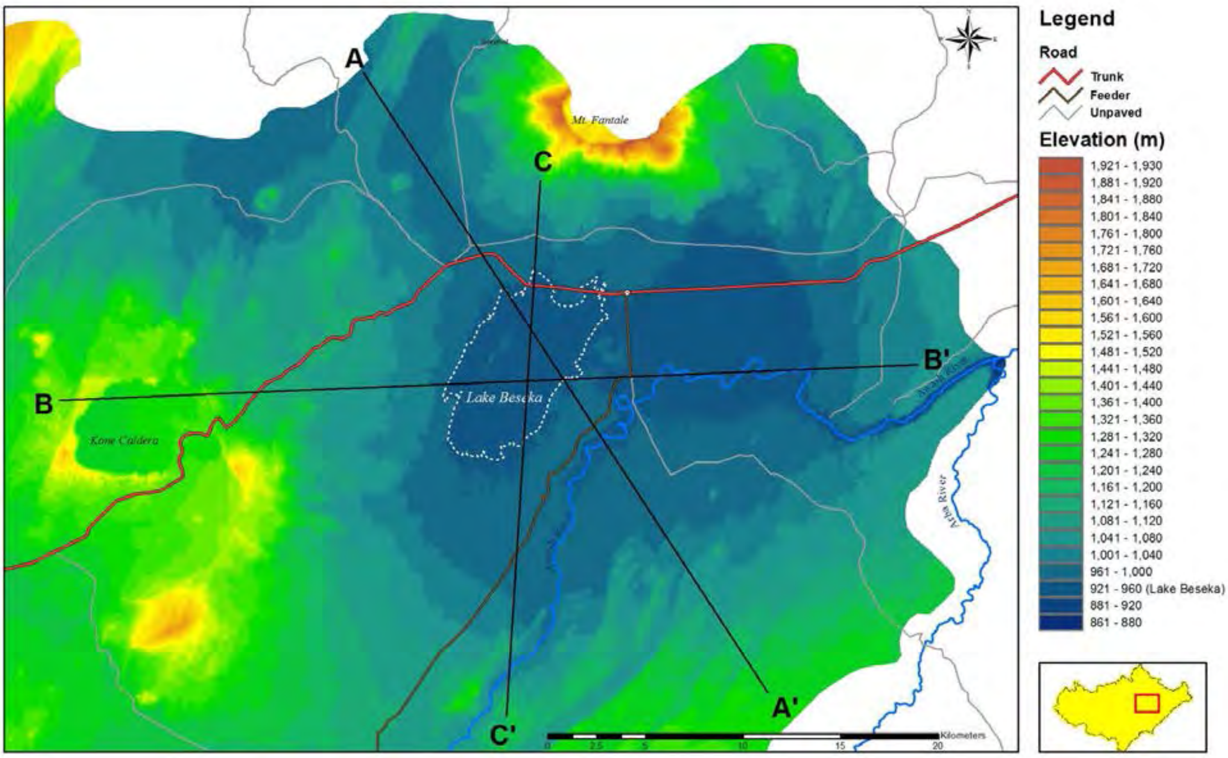
An elevation map around Lake Beseka created with the DEM data of the ALOS satellite image purchased by the project (Resolution 5 m, vertical accuracy 5 m) is shown in Figure 3.3.1. In addition, a topographic classification map around Lake Beseka created through the field work and analysis of the obtained data (ASTER DEM shaded relief map, SPOT satellite image and existing geological map) is shown in Figure 3.3.2.

The topography around Lake Beseka is divided into seven classes, such as alluvial lower plain, Basalt lower plain, middle plain, upper plain, acidic rock dome, gorge and lake taking volcanic ejecta, deposits and geological structure into consideration. Each characteristic is explained in Table 3.3.1.

Table 3.3.1: Classification and Characteristics of Topography around Lake Beseka

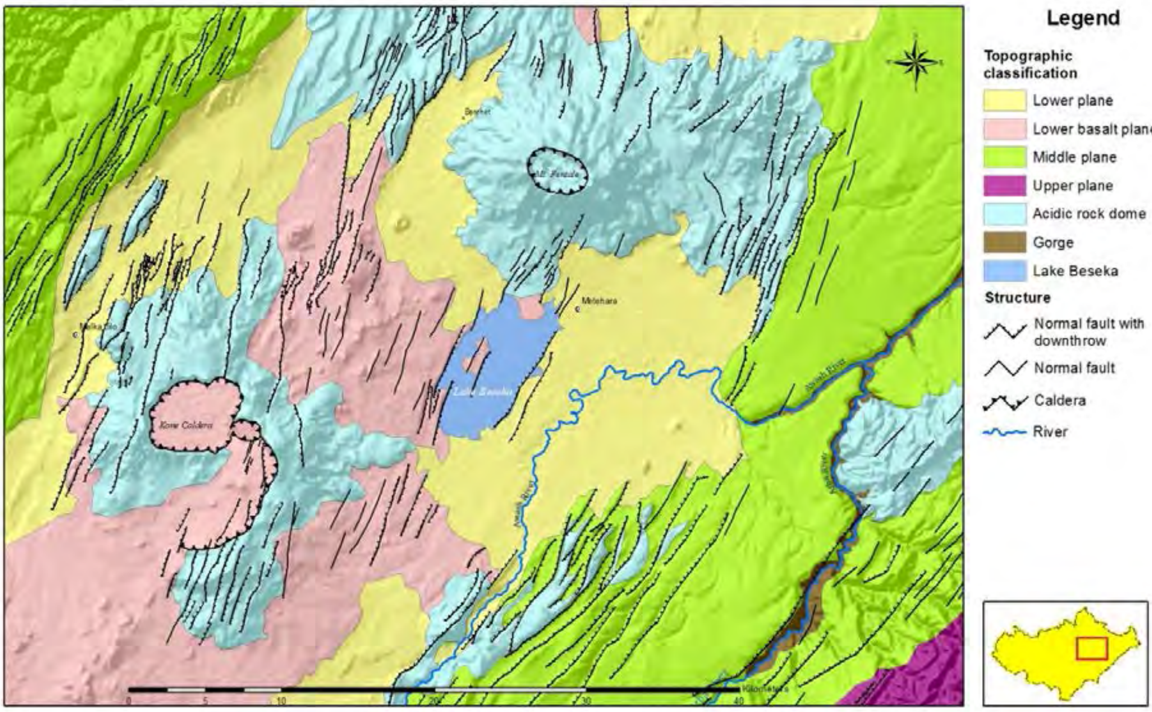
Classification	Characteristics
Alluvial lower plain	This is mainly composed of the flood plain of Awash River and the flat plain formed by young ignimbrite of Mt. Fentale. It is the lowest topographic plain in the area located at the center of the rift.
Pleistocene basalt lower plain	This is mainly formed by the numerous lava flows of Pleistocene basalts and has an undulating land surface. Although this plain is one step higher than the alluvial lower plain, it is also distributed in the central part of the rift.
Middle plain	This plain is one step higher than the alluvial lower plain and the Pleistocene basalt lower plain, and bounded from them by the NE-SW or NNE-SSW faults. It is composed of volcanic ejecta of the Oligocene to the early Pleistocene (Dino ignimbrite and Bofa basalts) and the plain surface which is relatively flat slightly inclines towards the center of the rift.
Upper plain	This plain is mainly composed of older basalts (Miocene) and the major fault escarpments of the MER are developed in this area.
Acidic rock dome	This is dome topography composed of Tertiary to Quaternary rhyolites and trachytes which form the major part of Mt. Fentale, Kone caldera, Mt. Birenti, Mt. Hada etc. or lava plateau of these rocks.
Gorge	This is topography formed in the middle plain through the dissection by the Awash River and the Arba River. The gorge developed along the Arba River is parallel to the NE-SW faults but that along the Awash River has been developed free from any fault trends.
Lake	Lake Beseka

Source: the Project Team



Source; Project Team Data: ALOS, Resolution 5 m, vertical accuracy 5 m

Figure 3.3.1: Elevation Map around Lake Beseka



Source: the Project Team, Data: Result of geological survey in this Project

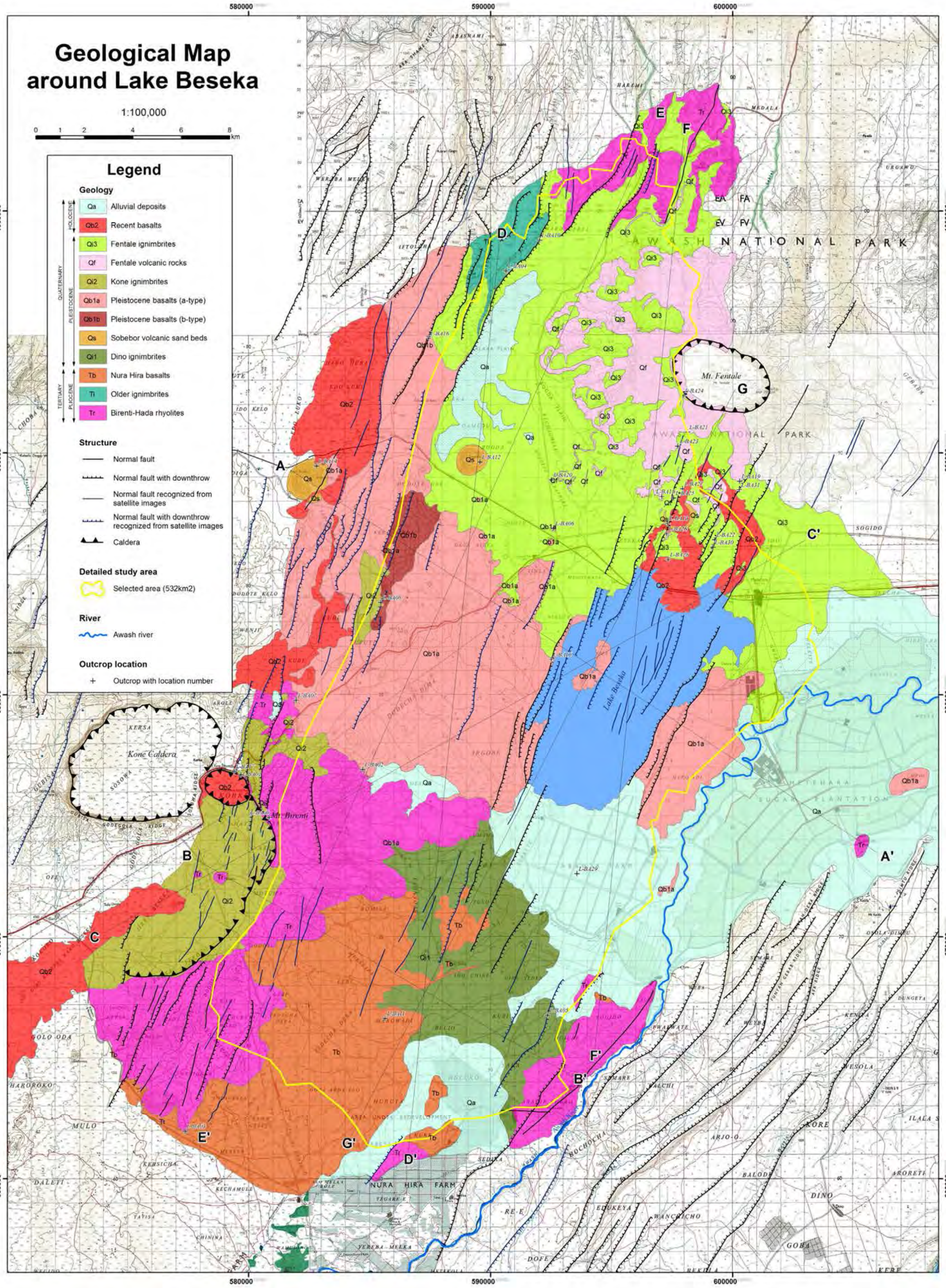
Figure 3.3.2: Topographic Classification Map around Lake Beseka (background: shaded relief map created from ASTER DEM data)

3.3.2 Geology

a. Geological units

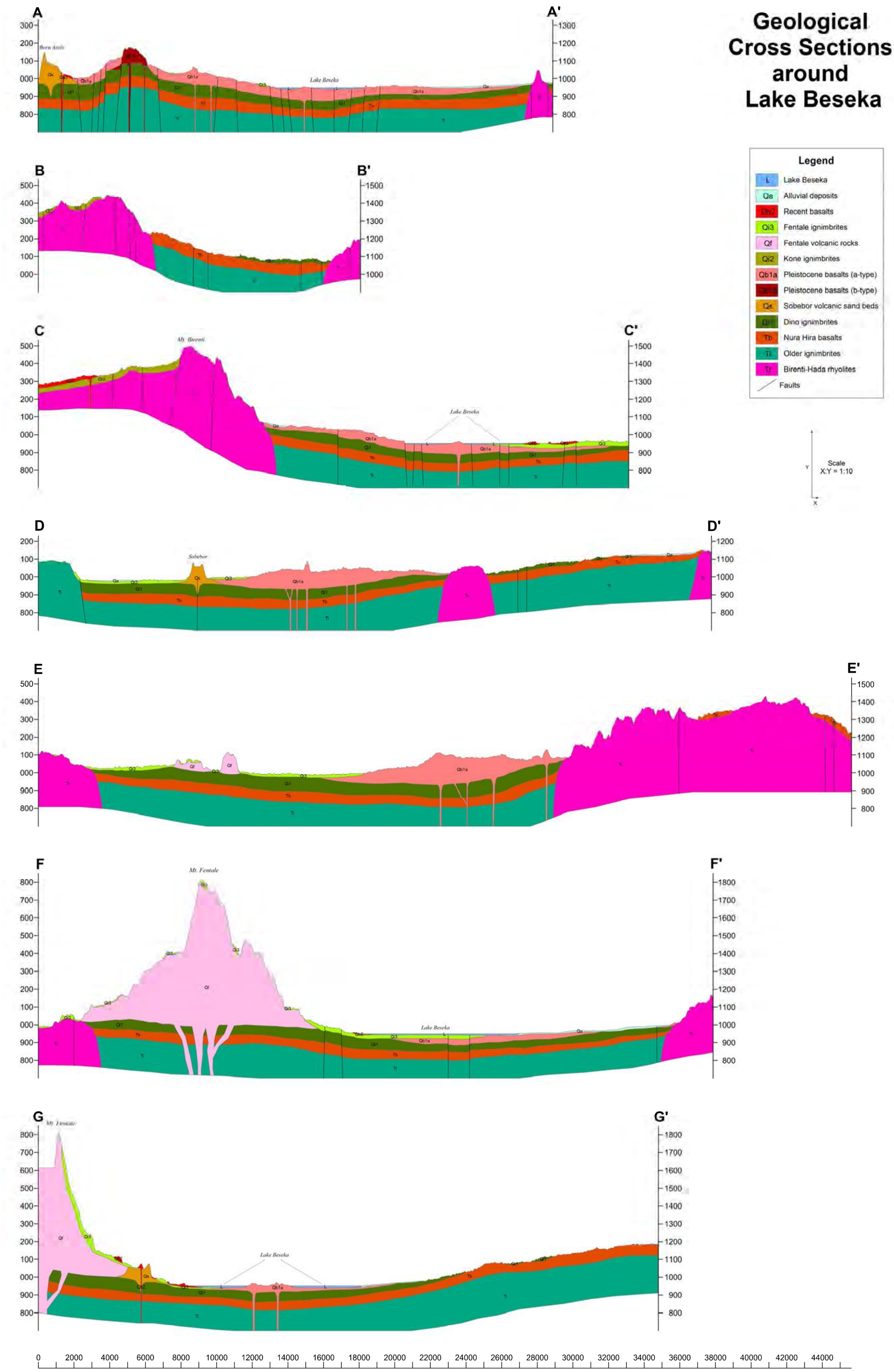
A detailed geological map of an Awash River sub-basin which extends from the northwestern foot of Mt. Fentale to the Nura Hira farm including Lake Beseka (hereinafter referred to as the detailed study area) was prepared at a scale of 1:100,000 (532 km^2). As for existing geological maps of this area, there is a map of 1:250,000 compiled by Kazmin and Berhe (1978) and a map of 1:100,000 by EIGS and ELC (1987). The former includes a larger area from around Nazret to Metehara and the established stratigraphy and the described names of each geological unit are still often quoted in other research papers and reports. The latter is an output of a comprehensive geothermal study including petrological analysis. However, there still needed a further detailed study and discussion for the geological boundaries and stratigraphy of the area around Lake Beseka. Therefore, a detailed geological field survey was conducted and the geological map of the area was revised. A geological map and sections of the detailed study area are shown in Figure 3.3.3 and Figure 3.3.4.

The locations of outcrops expressed by the location numbers (L-BA**) in this chapter are expressed in the geological map around Lake Beseka.



Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.3: Geological Map around Lake Beseka



Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.4: Geological Section around Lake Beseka

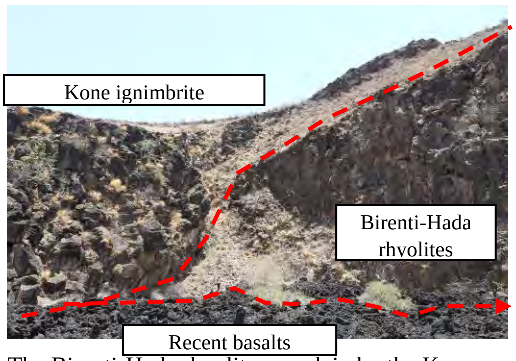
1) Birenti-Hada Rhyolites

This unit is fine to coarse grained rhyolites mainly distributed in Mt. Birenti and Mt. Hada in the west to the southwest of the detailed study area. In addition, the rhyolites distributed around Mt. Abadir and Mt. Dekaki in the south and north of the detailed study area, respectively are also considered as the same horizon due to the characteristics of the rock facies and topography.

The rhyolites are gray to greenish gray in color, and the matrix is fine grained and often glassy with flow structures, and scattered with hornblende and feldspar phenocrysts. Generally platy joints develop around the surface and the inside of the lava body is massive. Obsidian bands develop from around Mt. Bilenti to the southwards. Coarse grained rhyolites with feldspar phenocrysts 1 to 3 mm in size are distributed at Mt. Mekidera exceptionally.

It is observed that these rhyolites are unconformably overlain by the Kone ignimbrite at the east wall of Korke caldera (L-BA01), by the Pleistocene basalts at the northeast foot of Mr. Birenti (L-BA02) and by the Nura Hira basalts at the south foot of Mt. Hada (L-BA03).

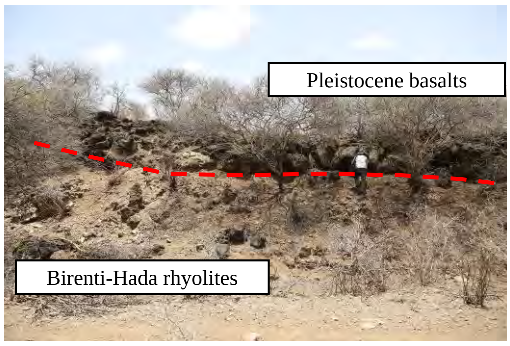
In the existing geological maps, Kazmin and Berhe (1978) and EIGS and ELC (1987) have shown “Unwelded rhyolitic pumice and unwelded tuff” or “Welded tuff” around Mt. Birenti. However, this study revealed that rhyolites are distributed wider and the stratigraphical position is lower than previously considered. Therefore, this unit is newly named as Birenti-Hada rhyolites.



The Birenti-Hada rhyolites overlain by the Kone ignimbrite (north wall of Korke caldera). L-BA01


Obsidian bands developed around the peak of Mt. Belenti. L-BA09


Platy joints of the Birenti-Hada rhyolites.



The Birenti-Hada rhyolites overlain by the Pleistocene basalts. L-BA02

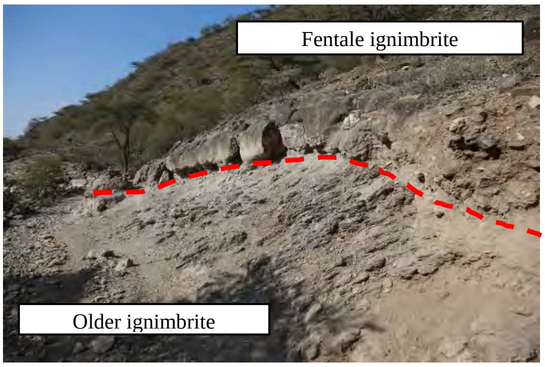
Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.5: Outcrop Photos of Birenti-Hada Rhyolites

2) Older Ignimbrite

This is widespread ignimbrite composed of greenish to greenish gray highly welded tuff to slightly welded tuff and pumice. In the detailed study area this geological unit outcrops in the NNE-SSW trending, east-facing fault escarpment (60 to 100 m in height) located at the northwest area of the detailed study area and is expanding out of the detailed study area further westwards. In the southwest part of the fault escarpment, it is observed that the Fentale ignimbrite overlie unconformably the fault slope formed by the old ignimbrite (L-BA04). The older ignimbrite are composed of several flow units with different welding grades. The characteristics of this welded tuff is similar to those of the Fentale ignimbrite and it is often difficult to distinguish. However, this unconformable contact between the two units allows them to be differentiated (photo).

This unit is correlated with welded tuffs of Nazret Group of Kazmin and Berhe (1978) which is widespread to the west of the detailed study area.



The Fentale ignimbrite unconformably overlie inclined welded tuff of the older ignimbrite (Haro Gersa). L-BA04

A NNE-SSW trending fault escarpment on which the older ignimbrite are exposed (Haro Gersa). L-BA10

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.6: Outcrop Photos of the Older Ignimbrite

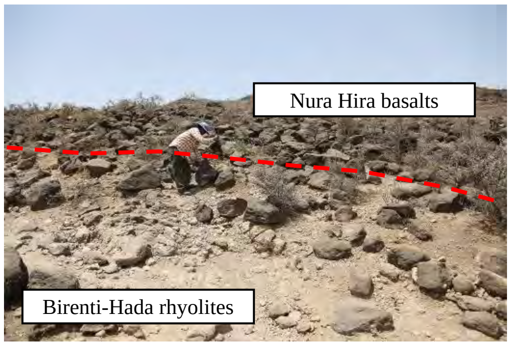
3) Nura Hira Basalts

This unit is composed of black aphyric basalt lavas distributed around the north of Nura Hira farm. Although the area covered by these basalts was an extension of the Pleistocene to sub-recent basalts according to Kazmin and Berhe (1978), considering the characteristics of petrological characteristics, topography and stratigraphy, this unit was distinguished and newly named as Nura Hira basalts.

The topography formed by this unit is relatively flat and continuous and covered by relatively thicker shrubs. Most of the basalts of this unit are aphyric but sometimes pyroxene and plagioclase phenocrysts of about 1mm in size are observed. Olivine and pyroxene phenocrysts (about 0.5 mm in size) are included in the fine grain basalt distributed in some areas such as the north of Kubi Dimtu. The lava is usually vesicular near the surface.

It is observed that this unit overlies the Birenti-Hada rhyolites unconformably at the south foot of Mt. Hada (L-BA03) and is overlain by the Kone ignimbrite unconformably along the road connecting Nura Hira farm and Abadir farm (L-BA05).

Flat plain formed by the Nura Hira basalts (northwest of the Nura Hira farm).



The Birenti-Hada rhyolites unconformably overlain by the Nura Hira basalts (southern foot of Mt. Hada). L-BA03

Source: the Project Team, Data: Result of geological survey in this Project

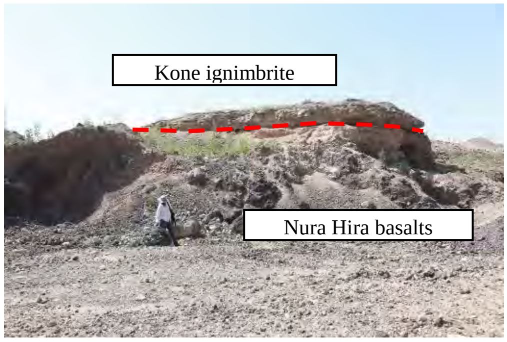
Figure 3.3.7: Outcrop Photos of the Nura Hira Basalts

4) Dino Ignimbrite

This unit is an extension of the widely distributed welded tuff (Dino ignimbrite, Kazmin and Berhe (1978)) mainly distributed southeast out of the detailed study area between the right bank of the Awash River and Arba River. In the detailed study area, it is thinly (maximum about 5 m thick) distributed at the southwest of Lake Beseka in a limited area. It forms relatively flat topography. The tuff is greenish gray colored and weakly welded. It includes hornblende. The rock facies of this unit resembles that of Kone ignimbrite and Fentale ignimbrite, but they are separated due to discontinuity of distribution and topography.

It is observed that this unit overlays the Nura Hira basalts along the road connecting Nura Hira farm and Abadir farm. (L-BA05)

Dino ignimbrite exposed along the irrigation channel at the north of Nura Hira farm. L-BA11



Nura Hira basalts overlain by the Kone ignimbrite. L-BA05

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.8: Outcrop Photos of Dino Ignimbrite

5) Sobebor Volcanic Sand Beds

This unit is represented by the Sobebor hill (L-BA12) located at the southern part of the Alaka plain and observed at only three locations such as Sobebor hill, Dinbiba (L-BA13) on the southern foot of Mt. Fentale and Boru Arole hill (L-BA14) about 6 km westwards from Sobebor. This unit forms an independent hill (tuff ring) at each location and three locations are arranged so as to draw a gentle arc shape. The size of the hills is vast and they have big craters with a diameter of 0.5 to 1 km at the center, which makes the appearance different from other scoria cones.

This unit is composed of thick layers of yellowish brown volcanic sand and silt with lamina with a thickness of 2 to 10 cm. Sometimes lapilli and boulders with a diameter of 1 to 30 cm are also included. The lamina inclines towards the outside from the center 20 to 30 degrees. At Dinbiba, some parts of the crater rim have remained and fresh basalt lavas (recent basalts) spilled out from the center. Fresh basalts came out from a collapsed hillside at Boru Arole.

Previous reports such as Kazmin and Berhe (1978) and EIGS and ELC (1987) mentioned this unit as basaltic hyaloclastites. However, it seems that they were either confused with the cause of hyaloclastite or the definition of the term was different at that time. The term "hyaloclastite" is generally used for the pyroclastic rocks formed when magma gets into water and is crushed due to rapid cooling. There is no evidence of these causes in the sediment of this unit. Moreover, it does not include original magma fragments (direct products of magma) in the sediment unlike scoria and pumice, which indicates that this sediment could be the remnant of a continuous phreatic eruption.

This unit is overlain by the Fentale ignimbrite at Dinbiba (L-BA13).

Sobebor tuff ring from a distance.

Sand beds inclined towards outside of the hill (Sobebor).

Sedimentary structure (parallel lamina) in the sand beds (Sobebor)

Inside the Sobebor crater. L-BA12

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.9: Outcrop Photos of Sobebor Volcanic Sand Beds

6) Pleistocene Basalts

This unit is composed of basalts and scoria distributed mainly in the west and partly in the east of Lake Beseka. Taking the rock type into consideration, it is divided into two parts; olivine-pyroxene basalts (a-type) and alteration between porphyritic pyroxene basalts and aphyric basalts (b-type).

Within the distribution area of this unit, a-type occupies most of the area. The basalts of a-type contain a lot of olivine and pyroxene phenocrysts with a size of 0.5 to 1 mm with black with fine grained matrix. The lava is very vesicular near the surface and often filled with the secondary mineral (zeolite). The lava is aa-type and it remains the original undulated topography of lava flow. Most of the scoria cones distributed in the detailed study area are located within the distribution area of this unit. In addition, with the analysis of topography and satellite images, it is observed that most Pleistocene basalts spouted out from these cones. Generally, a scoria cone was formed first and then, lava erupted from the center or the side of the cone. The scoria cones are aligned in an NNE-SSW direction which is the same as the Wonji fault trend. This indicates that the magma erupted along the weak zones of faults.

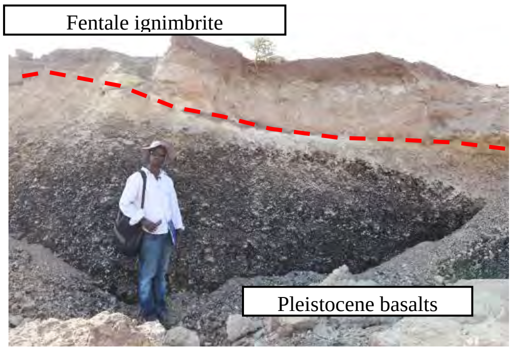
B-type basalts are distributed only in the west part of the detailed study area along the hills extending in a NNE-SSE direction between Dodote and Tututi about 6 km long and 0.5 to 1 km wide, and in the west of Alaka plain along a fault escarpment. The basalts of b-type are composed of porphyritic basalts and aphyric basalts. The former contains plagioclase phenocrysts with pyroxene reaching a prominent size of 5mm and olivine averaging a smaller size of 1 to 3 mm. Porphyritic basalts and aphyric basalts are distributed in the same area but the relationship of these two could not be observed directly.

Because a-type is distributed on a part of the hill formed by b-type, it is considered that a-type is younger than b-type.

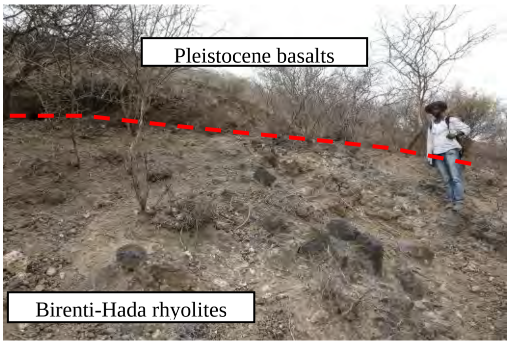
It is observed that this unit overlies Birenti-Hada rhyolites unconformably at the northeast of the Korke caldera (L-BA07) and is overlain by Fentale ignimbrite unconformably at the scoria cone (Ilala) located at the southwest foot of Mt. Fentale (L-BA06). Although a direct relationship between this unit and Kone ignimbrite was observed, this unit is considered younger than Kone ignimbrite from the view point of topography and distributional characteristics.

Olivine-pyroxene basalt exposed on the fault escarpment west of Lake Beseka (a-type). L-BA15

Porphyritic basalt exposed on the fault escarpment in the west of the Alaka plain (b-type). L-BA16



Scoria of the Pleistocene basalts (a-type) overlain by the Fentale ignimbrite (Ilala). L-BA06



The Birenti-Hada rhyolites overlain by scoria of the Pleistocene basatlt (a-type) (northeast of the Korke caldera). L-BA07

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.10: Outcrop Photos of the Pleistocene Basalts

7) Kone Ignimbrite

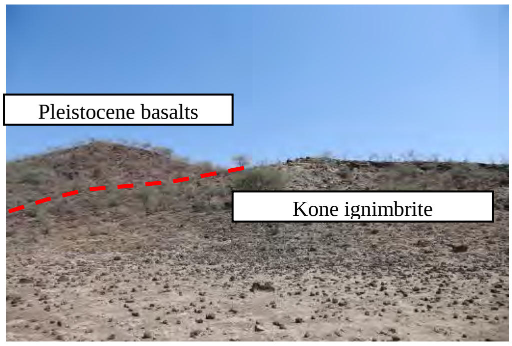
This unit is composed of greenish gray to gray colored highly welded tuff to unwelded tuff and pumice mainly distributed east of Kone caldera. The tuff contains relatively higher numbers of hornblendes 1 to 3 mm in size and foreign lapilli of up to several centimeters in size.

Continuous welded tuff with about 70 m in thickness forms a caldera wall on the south edge of the Korke caldera subordinately situated besides the Kone caldera. EIGS and ELC (1987) described several flow units of welded tuff on the wall of the Korke caldera. On the east wall of the Korke caldera, it is observed that several layers of unwelded pumice including obsidian lapilli 1 to 5 cm in size continue for about 20 m below the welded tuff.

The characteristics of the welded tuff of this unit is similar to the Fentale ignimbrite and Dino ignimbrite, which makes identification through facies difficult. Therefore, these units were distinguished from the view point of distributional continuation.

It is observed that this unit unconformably overlies Birenti-Hada rhyolites at the east wall of Korke caldera (L-BA01) and the Pleistocene basalts at the east of Kube (L-BA08).

The Kone ignimbrite exposed on the west wall of Korke caldera. L-BA17



Kone ignimbrite which overlay the Pleistocene basalts (east of Kube). L-BA08

Source: the Project Team, Data: Result of geological survey in this Project

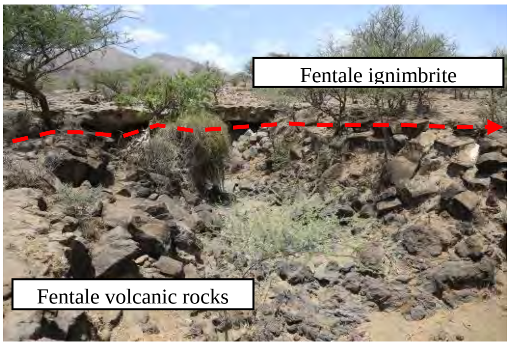
Figure 3.3.11: Outcrop Photos of Kone Ignimbrite

8) Fentale Volcanic Rocks

Mt. Fentale (2,007 m) is located just north of Lake Beseka and has an elevation gap of about 1,050 m between the surface of the lake. It has a caldera with a diameter of about 4 x 2.5 km on the top of the mountain. This unit is composed of acidic rocks which form the main body of Mt. Fentale.

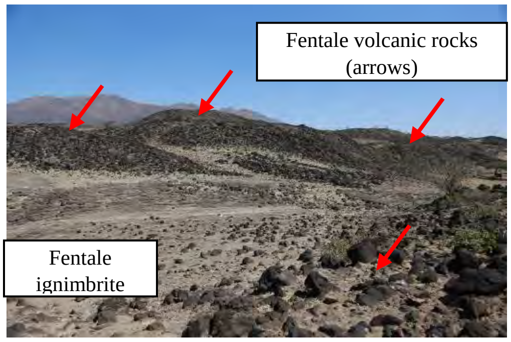
In the detailed study area, the west part of Mt. Fentale is included. Within the detailed study area, the volcano is composed of rhyolite and trachyte lavas in which phenocrysts of alkali feldspar and hornblende are scattered. The lava surface is block type with a diameter from several dozen cm to about 1 m. The lavas are generally very glassy and are black to deep green in color.

The lavas distributed on the foot of the mountain remain in the original topography of the lava flow and each lava flow can be distinguished through the analysis of satellite images and digital elevation model. However, since the characteristics of the lavas distributed in the detailed study area are almost similar to each other, they are grouped as the Fentale volcanic rocks in this report.



Trachyte of the Fentale volcanic rocks overlain by the Fentale ignimbrite (southern foot of Mt. Fentale). L-BA18

Block lava of glassy trachyte (south foot of Mt. Fentale). L-BA19



Glassy trachytes (arrow) exposed after the erosion of the Fentale ignimbrite (southern foot of Mt. Fentale). L-BA20

Glassy rhyolites exposed on the southern slope of Mt. Fentale. L-BA21

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.12: Outcrop Photos of the Fentale Volcanic Rocks

9) Fentale Ignimbrite

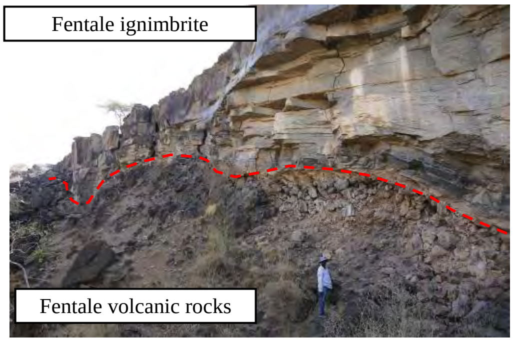
This unit is composed of greenish gray to whitish gray welded to unwelded tuff and pumice which erupted from Mt. Fentale. It is distributed at the slope of Mt. Fentale, foot of the mountain and widely around the surrounding area. It includes a lot of lapilli with a diameter of a few mm to several cm and develops glassy (obsidian) lens structure (fiamme). The size of the fiamme is variable from several mm to more than 50 cm. There is unwelded pumice at the bottom of the welded tuff.

This unit covers 15 to 18 km towards south to west directions from Mt. Fentale and more than 30 km towards east direction according to Kazmin and Berhe (1978). On the slope of Mt. Fentale, welded tuff thinly are deposited in the gentle valleys and plains (about 1m thick). At the southwestern to western side around the mountain peak of Mt. Fentale, it is observed that pumice and welded tuff are deposited from the top of the caldera wall towards the outside overlaying rhyolites of the Fentale volcanic rocks.

At the southern foot of Mt. Fentale, there is a thick deposit of pumice. This is considered the secondary sediment of collapsed pumice which originally was deposited on the mountain slope. This pumice is assumed to be a part of pyroclastic rocks of the Fentale ignimbrite. This pumice is covered by the Holocene basalts.

The maximum observed thickness of this unit is about 10m in the outcrops, but a borehole log record shows about 30 m of welded tuff for the horizon assumed as the Fentale ignimbrite (AW BH-5).

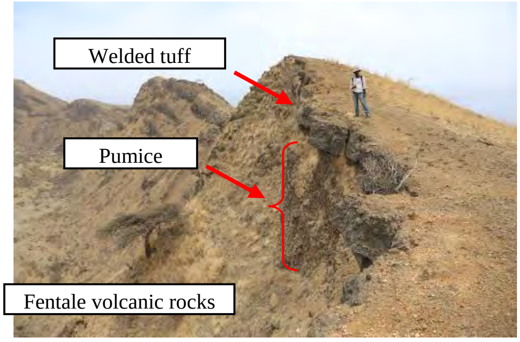
There is a report about the age of this unit as 1.1±0.1 Ma (Gibson (1970)). However, EIGS and ELC (1987) indicated a possibility of a much younger age for the unit due to its topographical characteristics.



The Fentale ignimbrite which overlies the trachyte of the Fentale volcanic rocks. (Southern foot of Mt. Fentale). L-BA22

Glassy lens structure (fiamme) of the Fentale ignimbrite.

Welded tuff of the Fentale ignimbrite which cover the southern slope of Mt. Fentale. Black oval patterns are fiammes seen from above. L-BA23



Pumice and welded tuff deposited out of the caldera rim of Mt. Fentale. L-BA24

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.13: Outcrop Photos of the Fentale Ignimbrite

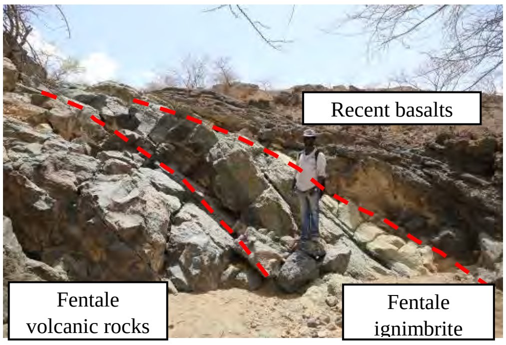
10) Recent Basalts

This unit distributed in the detailed study area is black vesicular aphyric basalt and it is the youngest volcanic ejecta in the area (1810 to 1830, Buxton (1949)). It is located at the southern foot of Mt. Fentale and the southern tip of the lava reaches Lake Beseka. Since it is a very recent basalt, there is little vegetation on the lava and the lava flow maintains its original shape without weathering or erosion. The viscosity of the lava is very low and spatter cones and lava tunnels are developed and a few ropy structures are observed near the eruption center. These characteristics of pahoehoe lava turn into those of aa lava after some distance from the eruption center. There are several eruption centers along the faults (in and out of the tuff ring of the Sobebor sand beds and at the southern foot of Mt. Fentale)

Since there is little vegetation and soil developed on these lavas, their distribution is clearly demarcated from other units. Many other recent basalts are distributed west of the detailed study area at Boru Arole, Kube, Korke and Kokoro, etc. At all these locations, the basalts generally contain olivine and pyroxene. Most of them are aa lava but the basalt distributed at Boru Alole shows pahoehoe characteristics such as lava tunnels and ropy structures. The mineral composition of these basalts are different from that of the detailed study area, they are considered to be the basalts of a similar age due to the freshness of their surface.

Lava tunnel observed near the eruption center of the recent basalt lava (Dinbiba). L-BA26

Spatter cone developed at the spout of the recent basalt lava (Dinbiba). L-BA26



The recent basalts over the Fentale ignimbrite and the Fentale volcanic rocks. L-BA27

The recent basalts reaching Lake Beseka. L-BA28

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.14: Outcrop Photos of the Recent Basalts

11) Alluvial Deposits

This unit is mainly a flood plain deposit of the Awash River and is composed of sand and silt. Most of the area is now utilized for sugar plantations. In addition, alluvial deposits are distributed at the Alaka plain on the west of Mt. Fentale and eastern foot of Mt. Bilenti.

Alluvial plain utilized for a sugar plantation (Abadir farm). L-BA29

Section of alluvial deposits (northeast of Mt. Bilenti)

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.15: Photos of Alluvial Plains and Deposits

3.3.3 Geological structure

The vicinity around Lake Beseka is located at the very center of Main Ethiopian Rift and the geological structure is dominated by the Quaternary still active NNE-SSW trending normal faults (Wonji Fault Belt, Mohr (1960)). The faults distributed in the detailed study area are divided into two segments; one is the area around Kone caldera and the other is around Lake Beseka (EIGS and ELC (1987)). From the view point of topography and geological structure, since the area around Lake Beseka is located in the lower position of the rift, it may indicate that the active center has shifted from the Kone caldera area to the Lake Beseka area. The youngest fault in the detailed study area is observed on the recent basalt (1810 to 1830, Buxton (1949) north of Lake Beseka (L-BA31).

Although the displacement of the normal faults observed in the detailed study area is relatively small, mostly less than 10m, the displacement gap becomes larger when the faults get closer to the main fault escarpment of MER (NE-SW trend). The largest displacement is observed at the Haro Gersa area for about 100 m. The inclination angle of the faults observed in the field is almost vertical.

In addition, some of the normal faults show open cracks within the detailed study area. A relatively long extending normal fault passing through the northeast of Mt. Fentale up to Lake Beseka has an open crack with a width of about 10m in addition to the 10m displacement about 2 km north of the lake (L-BA30).

Open crack with a width of more than 10 m at 2 km north of Lake Beseka. L-BA30

A normal fault extending from Lake Beseka towards Mt. Fentale.

Recent basalt lava section cut by a fault. L-BA31

NNE-SSW trending fault escarpment at the western part of the detailed study area (Haro Gersa)

Source: the Project Team, Data: Result of geological survey in this Project

Figure 3.3.16: Outcrop Photos of Faults distributed in the Detailed Study Area

3.4 Hydrogeology

3.4.1 Aquifer classification and groundwater Flow

As mentioned in Chapter 2, the existing wells data around Lake Beseka was mainly collected from the following reports.

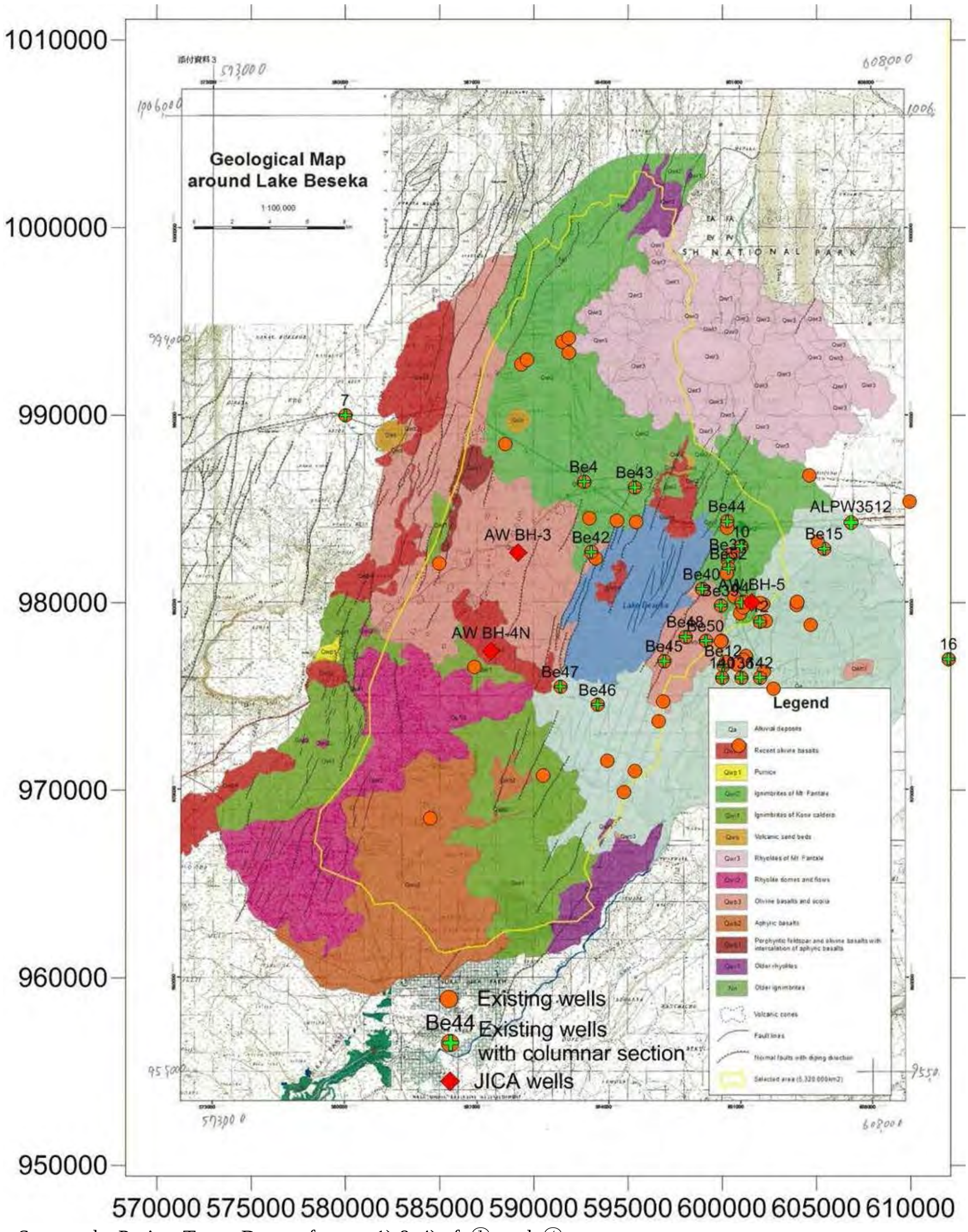
- Hydrogeology (Map) of the Nazret, EIGS, 1985
- Study and design of Lake Beseka level rise project II, WWDSE, planned by MoWE, 2011

All existing wells around Lake Beseka, were plotted on the geological map around Lake Beseka created in this Project (refer to Figure 3.4.1). Lithological conditions of JICA wells were clarified by the chip sampling of drilling, so the columnar sections of JICA wells are able to correlate with the geology around Lake Beseka (refer to Figure 3.4.2 to Figure 3.4.4). Table 3.4.1 shows the results of geological interpretation for each existing well by using the geological map and the columnar section for each of the existing wells.

The depth of almost all existing wells around Lake Beseka was less than 70 m; the geological conditions of these existing wells can be correlated with the geology of JICA wells with depths less than 100 m. The geology of JICA wells more than 100 m deep was correlated with the results of a geological survey and geological map. Transmissivity and Specific capacity are shown in Table 3.4.1. The aquifer of each existing well is estimated in reference to the groundwater level and the depth of screen.

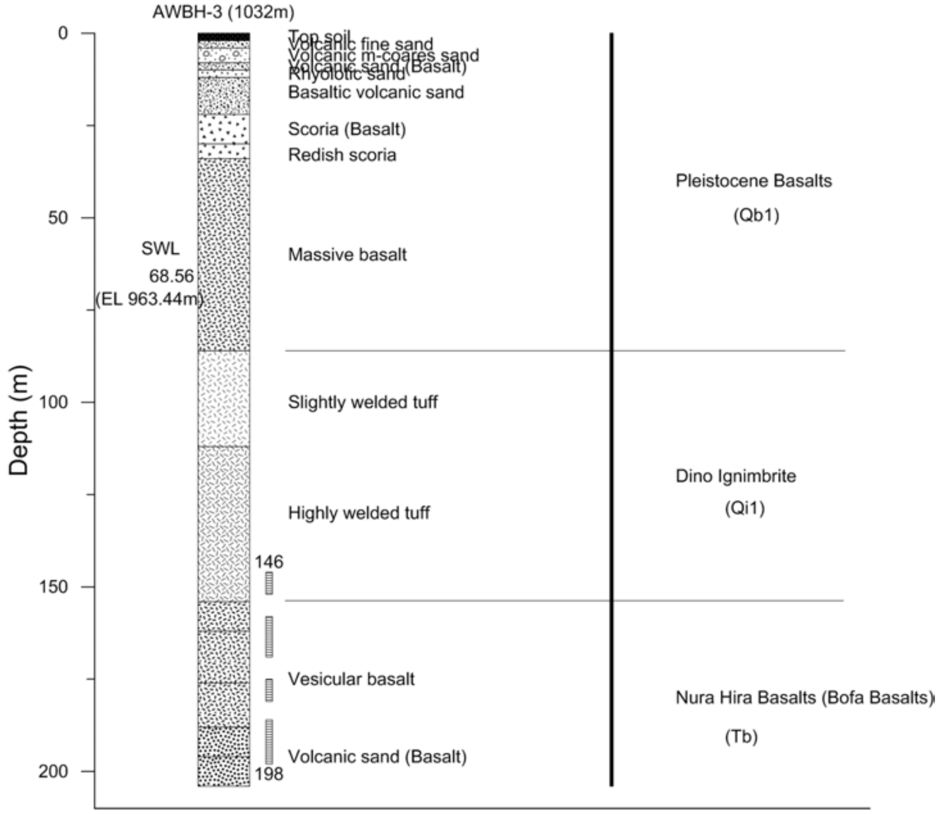
The groundwater flow was discussed around Lake Beseka by the two categories, using the existing wells of less than 100 m deep or more than 100 m deep because of the differences of groundwater level by the geology and depth of aquifer speculated. Figure 3.4.5 shows the groundwater level contour map for existing wells less than 100 m deep, and Figure 3.4.6 shows that of wells more than 100 m deep. The former shows a SW to NE flow direction, and the latter shows a south to north flow direction. There is a difference of groundwater flow by the aquifer depth. The aquifers are classified by the correlation with each geological layer, and the classification of aquifers was conducted and is shown in Table 3.4.2 in accordance with the Table 3.4.1.

As mentioned in Chapter 2, fluoride concentration in the water around Lake Beseka is high and exceeds the Ethiopian standard. There is no correlation between fluoride concentration and depth as Figure 3.4.7 shows.



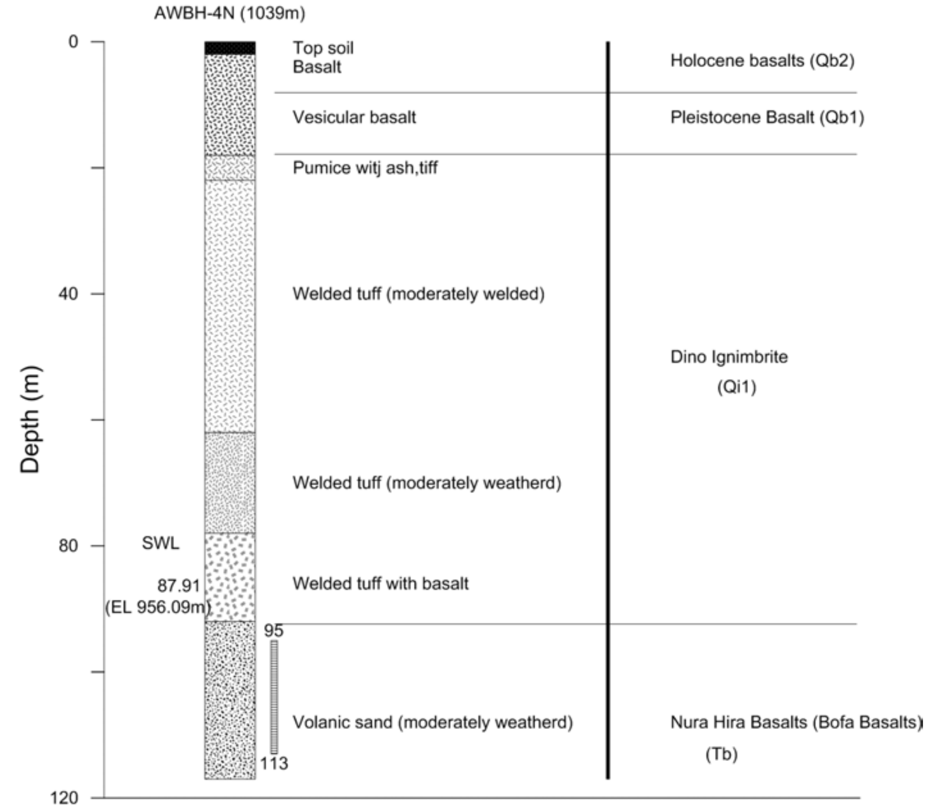
Source: the Project Team, Data: reference 1) & 4) of ① and ④

Figure 3.4.1: Geological Map, Existing Wells and JICA Wells around Lake Beseka



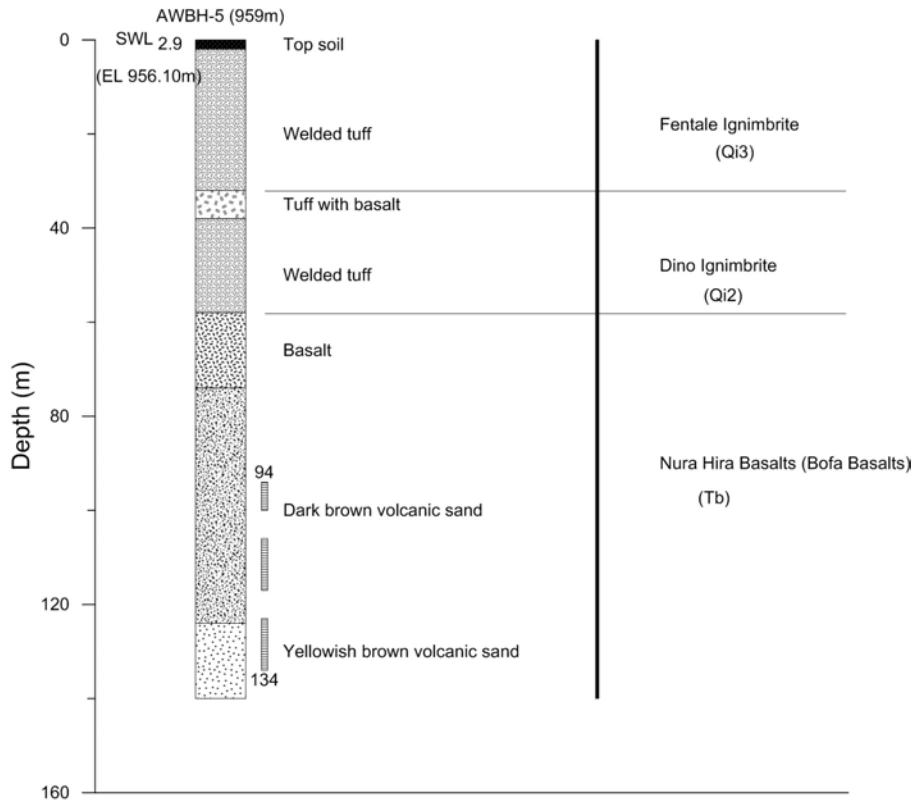
Source: the Project Team, Data: reference ④

Figure 3.4.2: Columnar Section of JICA Well (AW BH-3) and Geological Correlation



Source: the Project Team, Data: reference ④

Figure 3.4.3: Columnar Section of JICA Well (AW BH-4N) and Geological Correlation



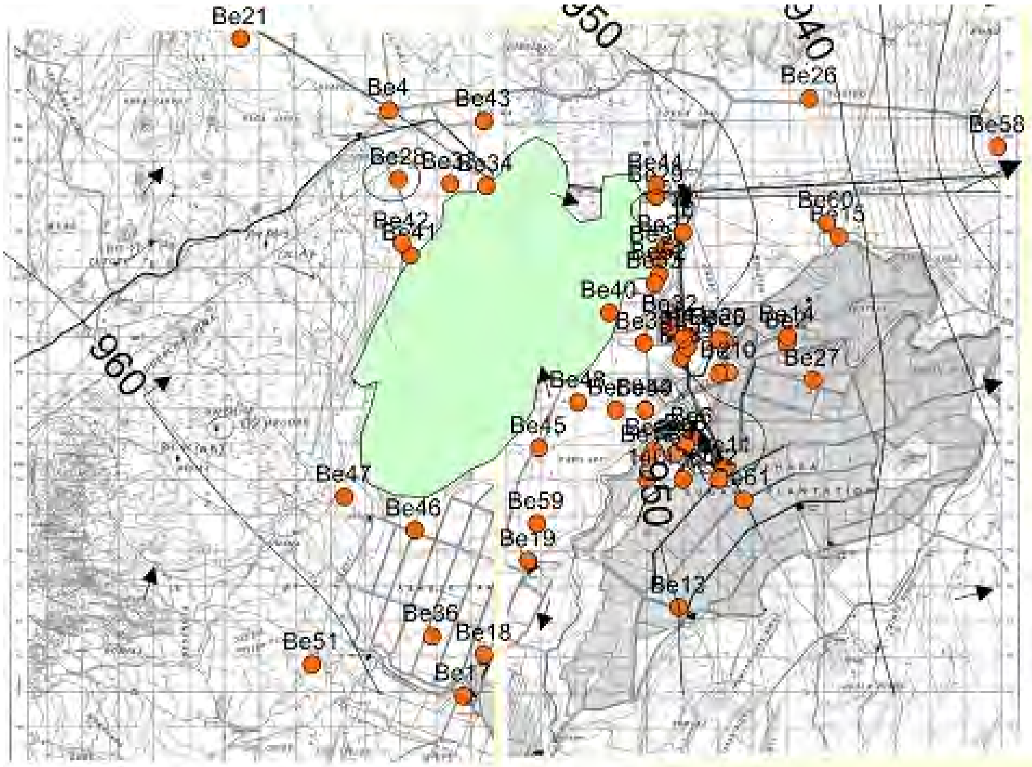
Source: the Project Team, Data: reference ④

Figure 3.4.4: Columnar Section of JICA Well (AW BH-5) and Geological Correlation

Table 3.4.1: Existing Wells and JICA Wells with Columnar Section around Lake Beseka

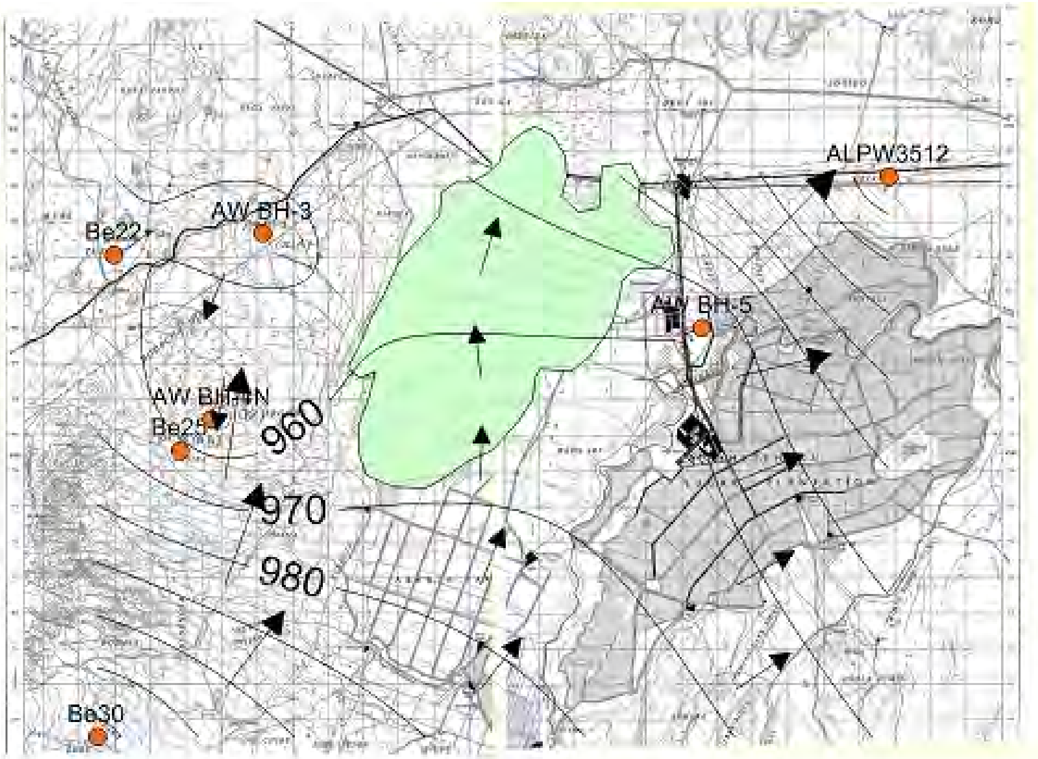
X	Y	No	H	SWL	GWL	GWL2010	Total D (m)	Q(L/sec)	Existing name	Top of Screen(m)	Top of Screen (Elevation)	T (m2/day)	Geology	Aquifer
592664	986463	Be4	981.29	30.94	950.35	953.09	53.3	-	BHI-02	29.3	951.99	8088	Geological map: Fentale Ignimbrite (Qi3), Lower part: Pleistocene basalt(Qb1)	Qb1
600048	976634	Be12	959	15.32	943.68	955.36	48	6.5	BHMR-20	12	947	965	Geological map: Alluvium, Lower part: Fentale Ignimbrite(Qi3)	Alluvium sand
605405	982881	Be15	949.8	6.15	943.65	945	30	4	BHG-32	15	934.8	60.4	Geological map: Alluvium, Lower part: Fentale Ignimbrite(Qi3)	Qi3
600305	982301	Be38	953.21	3.7	949.51	951.31	56	-	BH-59	-	-	-	Geological map: Alluvium, Lower part: Fentale Ignimbrite(Qi3)	Alluvium sand
599903	979853	Be39	953.93	4.43	949.5	951.3	50.65	-	BH-23	18.65	935.28	2681	Geological map: Fentale Ignimbrite(Qi3)	Qi3
598914	980723	Be40	953.02	3.24	949.78	951.58	30.24	-	BH-37	11	942.02	502	Geological map: Between Holocene basalt(Qb2) and Fentale Ignimbrite(Qi3), Columnar section: Fentale(Qi3)+Pleistocene basalt(Qb1)	Qi3
593035	982691	Be42	958.32	8.18	950.14	952.88	73	-	BH-50B	17.25	941.07	-	Geological map: Basalt & Scoria (Qb1), Lower part: Tuff (from 50m deep).Tuff belongs to Dino Ignimbrite(Qi1)	Qb1
595362	986153	Be43	973.83	23.16	950.67	953.42	59	-	BH-57	24	949.83	217.8	Geological map: FentaleIgnimbrite (Qi3). Columnar section is same lithology.	Qi3
600252	984352	Be44	958.93	8.62	950.31	951.91	50.5	-	BH-58	-	-	-	Geological map: Fentale Ignimbrite (Qi3)	Qi3
596921	976889	Be45	955.14	4.2	950.94	953.44	71.45	-	BH-63	-	-	-	Geological map: Basalt & Scoria (Qb1), Lower part: Tuff (from 50m deep).	Qb1
593389	974555	Be46	955.53	4.54	950.99	954.79	46.3	-	BH-62	-	-	-	Geological map: Alluvium (Depth to 17m), Lower part: Scoria, Basalt(Qb1), Tuff (from about 44m deep)	Qb1
591413	975520	Be47	959.35	7.7	951.65	955.35	29.45	-	BH-60	-	-	728	Geological map: Alluvium (Depth to 12m), Lower part: Tuff(Qi2)	Qi2(Fissure)
598043	978183	Be48	965.16	14.25	950.91	953.42	50.45	-	BH-66	28.75	936.41	189	Geological map: Basalt and Scoria (Qb1), to about 40m depth	Qb1
599118	977968	Be50	958.64	8.08	950.56	952.36	42.45	-	BH-64	-	-	-	Geological map: Basalt and Scoria (Qb1), and many tuff layers (Dino ignimbrite (Qi1) from 14m deep)	Qi1
600331	981811	Be52	953.42	3.65	949.77	951.57	44.45	-	BH-05	23	930.42	996	Geological map: Fentale Ignimbrite(Qi3)	Qi3のBreccia
580000	990000	7	1000	25	975	975	50.6	6.7	-	25	975	-	Geolgical map: Kone Ignimbrite (Qi2)	Qi2(Fissure)
601000	983000	10	1000	13.6	986.4	986.4	56	12	-	-	-	-	Geological map: Fentale Ignimbrite (Qi3), Depth to about 10m, Lower part: Basalt(Qb1)	Qb1
602000	979000	12	950	8.8	941.2	941.2	42.6	12	-	-	-	-	Geologicalmap: Alluvium deposit, Basalt(Holocene basalt)(Qb2), Lower part: Fentale Ignimbrite(Qi3)	Breccia (Qi3, fissure)
601000	980000	14	950	11.19	938.81	938.81	49.6	7	-	-	-	Sc: 3.1(l/sec/m)	Fentale Ignimbrite	Qi3
601000	976000	136	960	20.6	939.4	939.4	42	6	-	32	928	Sc: 0.6	Geological map: Alluvium, Lower part: Basalt(Qb1).	Qa
600000	976000	140	960	25.6	934.4	934.4	45	8	-	24.5	935.5	Sc: 2.3	Geological map: Alluvium, Lower part: Basalt(Qb1).	Qa
602000	976000	142	966	42.8	923.2	923.2	52	8	-	30	936	Sc: 4.7	Geological map: Alluvium, Lower part: Basalt(Qb1).	Qa+Qb1
606822	984277	ALPW3512	942	46.65	895.35	895.35	595	100	-	111.41	830.59	703, Sc:6.5	Qi3, Pleistocene basalt(Qb1), Dino Ignimbrite (Qi1), Bofa basalts (Tb3), Nazret G (Ti3), Alaji Basalt (Tb1)	Qi1, Basalt(Tb1)
589168	982673	AW BH-3	1032	68.56	963.44	963.44	204	6.3	-	158	874	-	Qb1(Pleistocene Basalt), Dino Ignimbrite, Bofa besalts	Bofa(Tb3)
587744	977436	AW BH-4N	1044	87.91	956.09	956.09	117	4.43	-	96	948	3.52	Qb2(Recent Basalt), Qb1, Dino Ignimbrite, Bofa basalts	Bofa (Tb3)
601567	980025	AW BH-5	959	2.90	956.10	956.10	140	7.6	-	94	865	-	Fentale Ignimbrite, Dino Ignimbrite, Bofa basalts	Bofa (Tb3)

Source: the Project Team, Data: reference 1), 4) of ①, 5) of ②and ④



Source: the Project Team, Data: reference 1) & 4) of ① and ④

Figure 3.4.5: Groundwater Level Contour Map around Lake Beseka (Less than 100 m depth of Existing Wells)



Source: the Project Team, Data: reference 1), 4) of ①, 5) of ②and ④

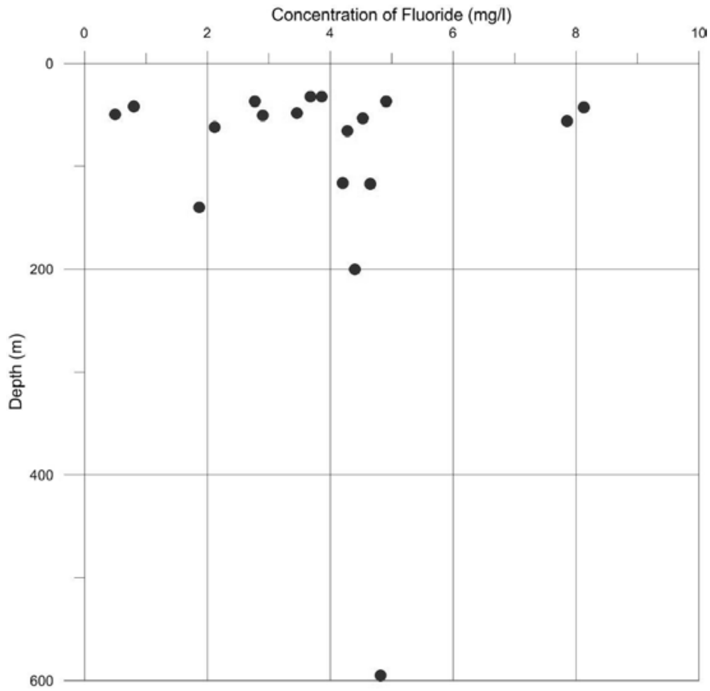
Figure 3.4.6: Groundwater Level Contour Map around Lake Beseka (More than 100 m depth of Existing Wells)

Table 3.4.2: Aquifer Unit Classification and Characteristics around Lake Beseka

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
Quaternary Pleistocene -Holocene	Holocene deposits	Qal (including Lacustrine deposits)	• Along the Awash River, alluvial sediment covers a small area. • The Alluvium around Lake Beseka consists of sand, mud and gravel, and the thickness of alluvium reaches about 11-40 m. Most of the boreholes in these areas have yield from 3 to7 L/sec.
	Recent Basalts	Qb2	• They are products of fissure eruption • They are highly vesicular, and can store an appreciable quantity (amount) of groundwater. • They are considered to have a high permeability. However it is difficult to predict whether or not an impermeable layer exists below.
	Fentale Ignimbrite	Qi3	• “Fentale Group of Ignimbrites (Qwi2)” shows different hydrogeological characteristics in different areas. • To the west and south of the Fentale volcano, this welded tuff is greyish green, fresh, columnar jointed with blisters and crevasses. So these fractures act as groundwater conducts, some existing boreholes have a yield of 7 L/sec. Such layers in this area have high permeability. • Depth of existing boreholes is 30-60 m. Although the yield data are limited, there is a record of 7 L/sec.
	Pleistocen e Basalts	Qb1	• They are vertically and horizontally jointed. • Drawdown is small by the existing borehole and specific capacity is more than 7 L/sec/m in some areas. Other yields are 1.4 and 1.6 L/sec respectively. • The basalt layer occurs at 50 m to 70 m depth of the existing wells around Lake Beseka. The record of yield is sparse, but there are partial records of 8 to 12 L/sec. • Therefore, these groups of basalt are considered to have moderate permeability.
	Dino Ignimbrite	Qi1	• “Dino Ignimbrites (Qwi)” corresponded to this layer are jointed and faulted. • Yield data from existing boreholes are limited around Lake Beseka. • Although there is a layer correlate with Dino in JICA well, the groundwater was taken from the lower layers. • According to the information in other area, the average of specific capacity of the existing well gives 2.2 L/sec/m. It is grouped as moderately permeable formation. The average of the yield indicates more than 6 L/sec.
Tertiary Pliocene	Nura Hira Basalts	Tb (correlate with Bofa baslts)	• Columnar jointing is very well developed with openings of 2-3 cm joints and a distance of 1 m between joints in the outcrop. • There are no outcrops around Lake Beseka, but JICA wells correlated with the Bofa horizon, the yield ranges from 6 to 11 L/sec and specific capacity is 0.15 to 9.3 L/sec/m. • In general Bofa basalts are expected to have high to medium permeability.
	Older Ignimbrite	Ti (correlate with upper Naret Pyroclastic deposits)	• “Nazret Group of Ignimbrites (Nn)” shows variable permeability in different areas. • Geology consists of Ignimbrites, welded tuffs, ash flows, rhyolites and tuffs. • The group to the northeast of Melka Jilo and north of Kone Caldera is jointed and faulted and a borehole drilled in this formation has a yield of 6.7 L/sec. • The average yield is 15 L/sec as a whole, specific capacity is more than 2 L/sec/m. There are highly productive areas in the Study

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
			area. • In the other areas, they predominantly consist of ash flow and tuff, and bore holes drilled in this formation have low yields according to the information.
	Birenti-Hada Rhyolites	Tr (correlate with Pliocene rhyolite)	• Mainly consists of rhyolites with pumice tuff. • They are generally grouped as formations of middle permeability by fractured aspects.

Source: the Project Team, Data: reference 1), 4) of ① and ④



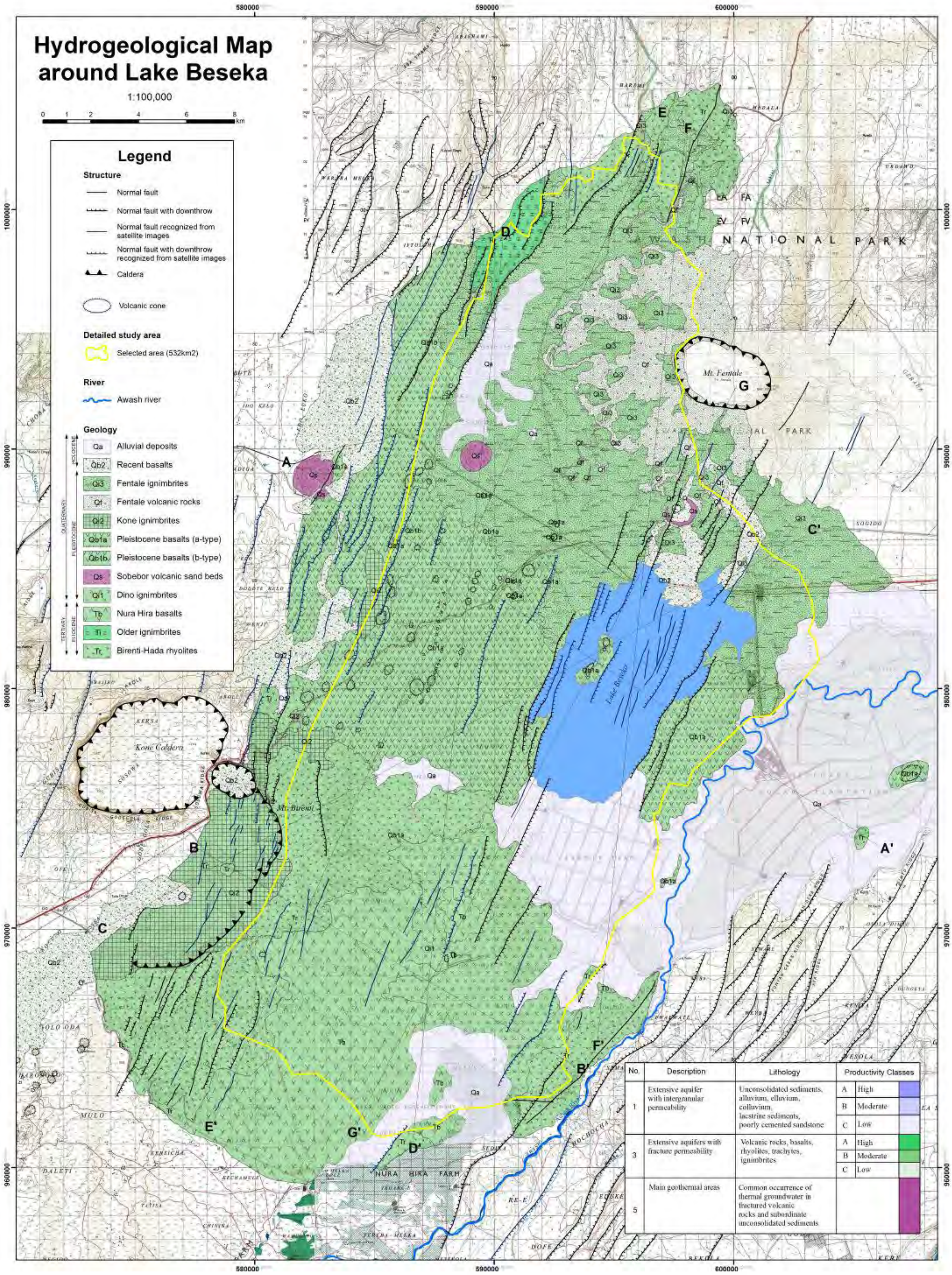
Source: the Project Team, Data: reference 1), 4) of ①, 5) of ②and ④

Figure 3.4.7: Well Depth and Fluoride Concentration around Lake Beseka

3.4.2 Hydrogeological map and cross-sections

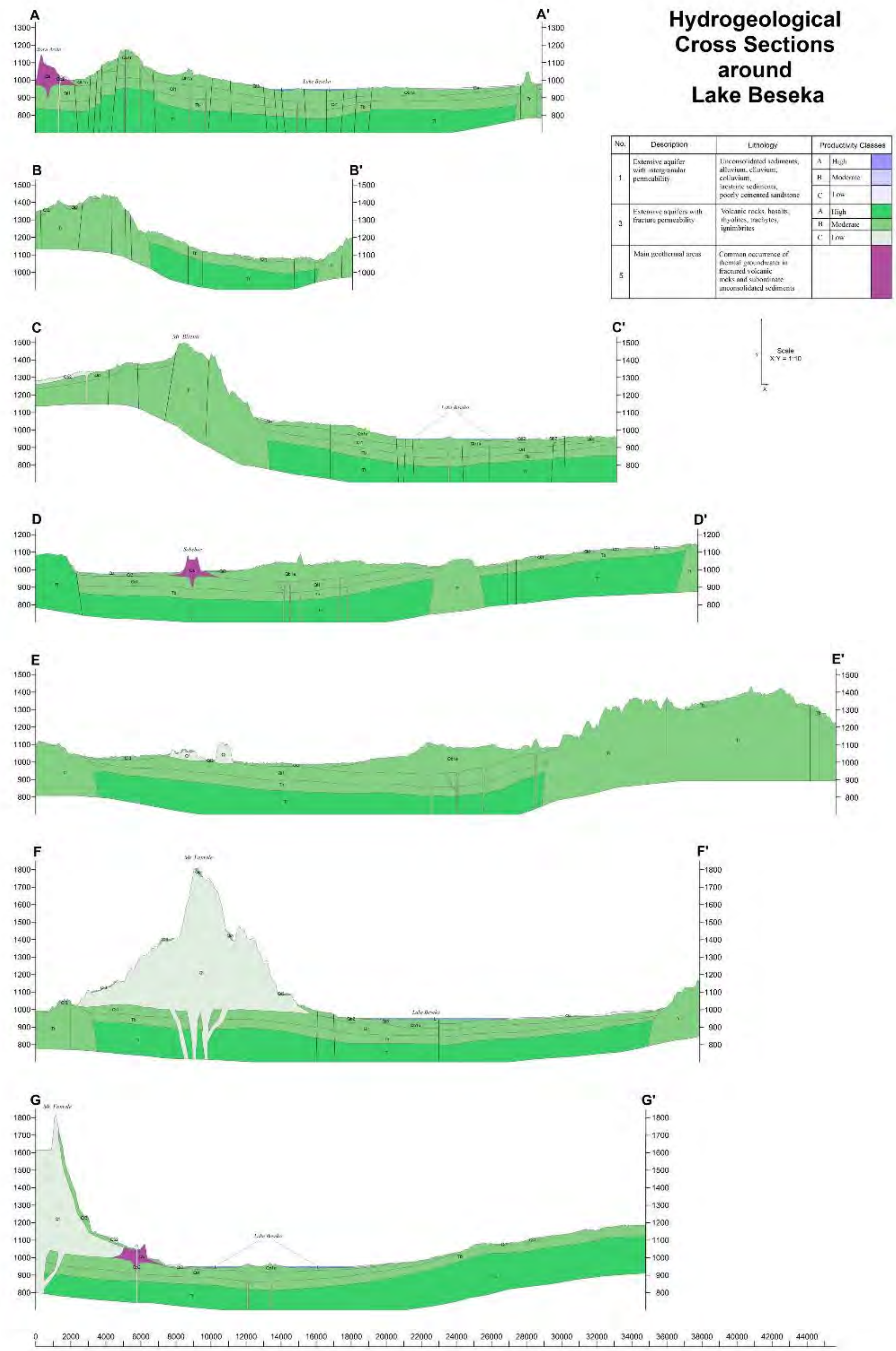
Aquifer units in the Middle Awash river basin were classified based on the existing information in Ethiopia such as a hydrogeological map with scale of 1:2,000,000 prepared by GSE (aquifer unit classification and definitions). The productivity of aquifer units were estimated through the aquifer information obtained on the hydrogeological survey in this Project. Based on these units, a hydrogeological map and cross-sections were prepared for the Middle Awash river basin. The hydrogeological map and cross-sections for the Lake Beseka area were then prepared referring to the geological survey results for the Lake Beseka area as shown below.

Most of the aquifer units distributed in the surface area, except for the surrounding area of the Mt. Fentale, are considered to have medium permeability, and these reach up to around 150 m in depth. In the deeper area than this, pyroclastic deposits of Tertiary Pliocene are distributed and the aquifer unit in this area is considered to have high productivity.



Source: the Project Team, Data: reference 1), 4) of ①, ④and⑬

Figure 3.4.8: Hydrogeological Map around Lake Beseka



Source: the Project Team, Data: reference 1), 4) of ①, ④and⑬

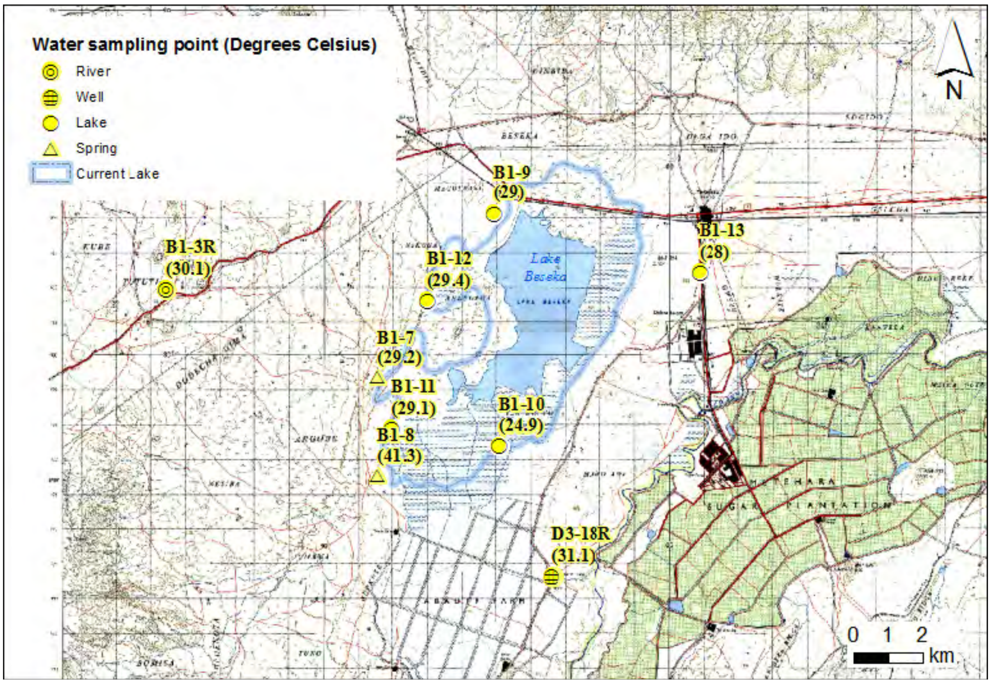
Figure 3.4.9: Hydrogeological Section around Lake Beseka

3.5 Inflow situation of springs and irrigation water

3.5.1 Ageing of spring inflow by satellite image analysis

a. Background and Objective

Figure 3.5.1 shows the current boundary of Lake Beseka and the result of water sampling on a topographic map from 1975. The numbers inside the brackets at each of the sampling points show the temperature of the water samples. From this figure, high temperature springs (hot springs) can be confirmed at the west side of Lake Beseka.



Source: the Project Team, Data: Result of survey in this Project

Figure 3.5.1: Result of Water Temperature Study around Lake Beseka

There are two types of water which are likely to flow into Lake Beseka:

A) High temperature groundwater from the west side of the lake
B) Excess water discharged from Abadir irrigation area etc.

There might be a clue on the cause of surface expansion in Lake Beseka if the changes in the surface temperature of the lake can be traced for the past years. However, there is no past continuous record of surface temperature measurements in Lake Beseka Therefore, satellite images have been utilized to estimate the changes of surface temperatures over the past few years.

The surface temperature of Lake Beseka will be calculated using the Landsat data from various years.

b. Data and method of analysis

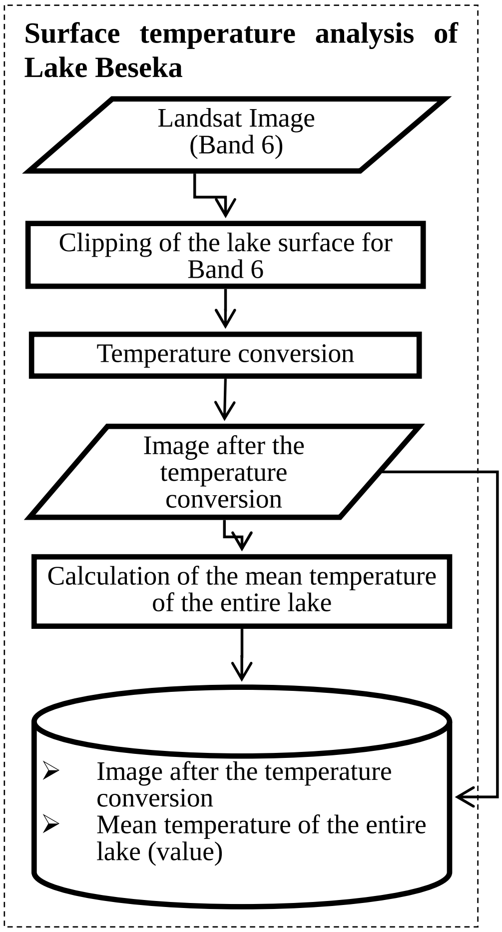
The satellite data used in the analysis are shown in Table 3.5.1. Also, the flow of the analysis is shown in Figure 3.5.2.

Table 3.5.1: Data used for the Analysis

No.	Satellite	Date of acquisition
1	Landsat 5	21st January 1986
2	Landsat 5	13th December 1994
3	Landsat 5	30th January 1995
4	Landsat 5	24th December 1998
5	Landsat 5	25th January 1999
6	Landsat 5	27th December 1999
7	Landsat 5	6th December 2009
8	Landsat 5	9th December 2010

Source: the Project Team

The data above has been selected/acquired from the archive of United States Geological Survey (http://earthexplorer.usgs.gov/).

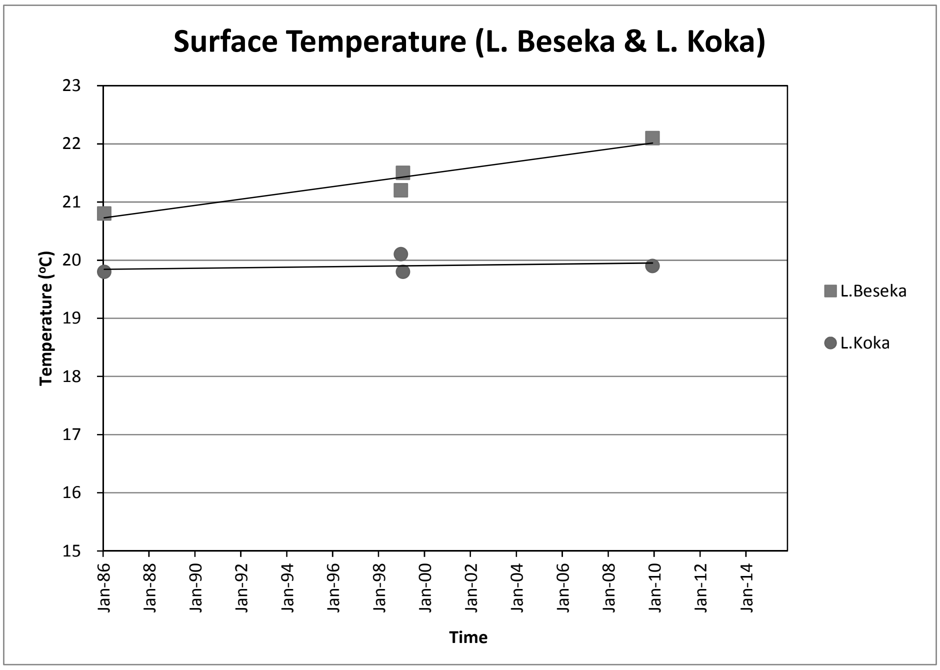


Source: the Project Team

Figure 3.5.2: The Analysis Flow of Surface Temperature using Landsat Data

c. Result of analysis

Four scenes (1986/1/21, 1998/12/24, 1999/1/25, 2009/12/6) of Lake Koka which are relatively stable around 20 °C, were compared with Lake Beseka.

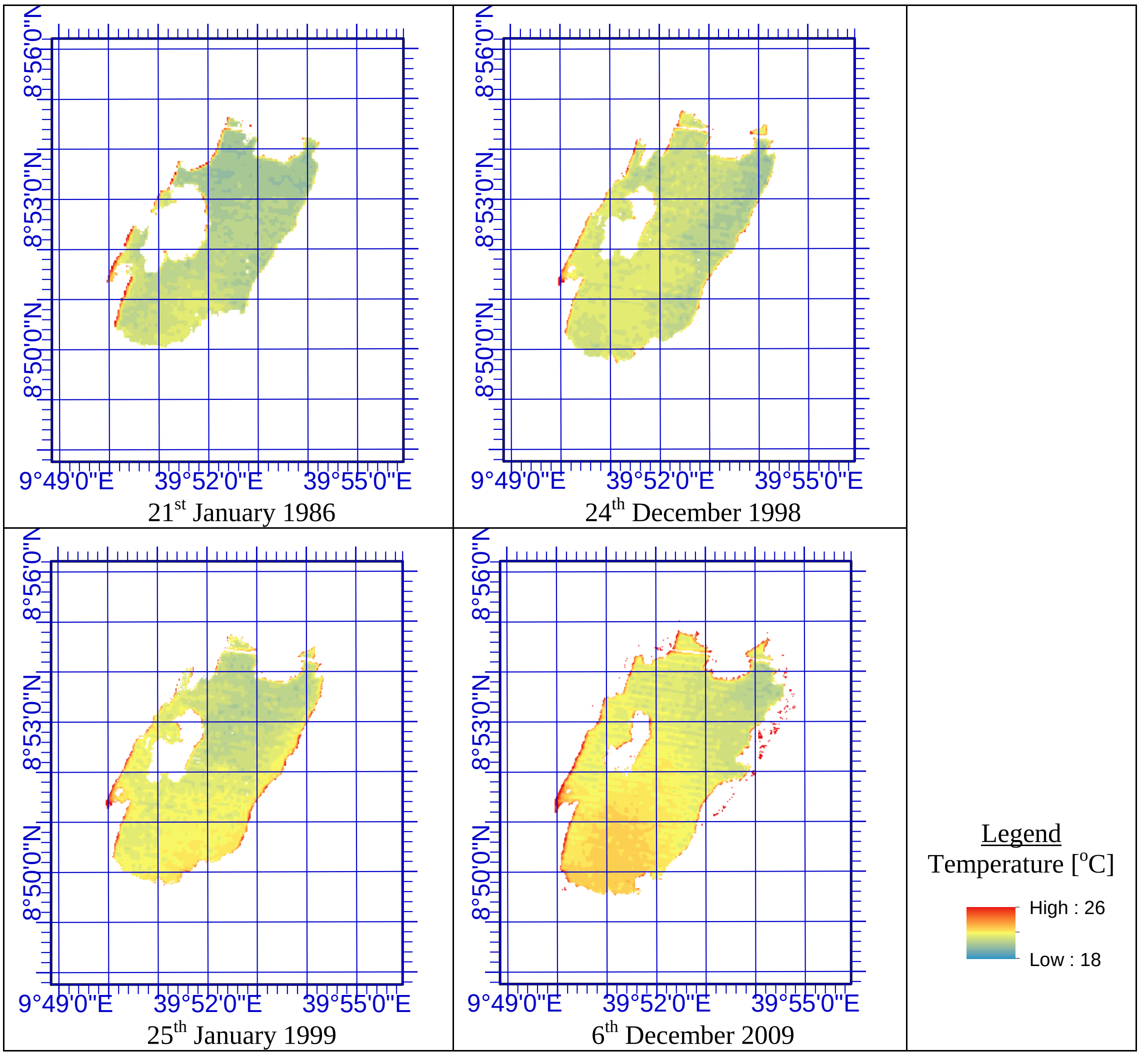


Source: the Project Team, Data: Result of analysis in this Project

Figure 3.5.3: Comparison of Surface Temperatures between Lake Beseka and Lake Koka

The surface temperature of Lake Beseka is higher than Lake Koka as shown in the figure above. In addition, the surface temperature of Lake Beseka seems to be in rising trend. It is conceivable that the inflow of the high temperature spring from the west side of Lake Beseka is causing the increase in the lake's surface temperature.

The figure below shows the surface temperature distribution of the four scenes in Lake Beseka. It is clear that the surface temperature at the west side of the lake is higher than the other areas.



Source: the Project Team, Data: Result of analysis in this Project

Figure 3.5.4: Surface Temperature Distribution of Lake Beseka

Although only a limited number of scenes were used for the analysis, it is conceivable that the surface temperature of Lake Beseka has been increasing over the previous years as the surface temperature of Lake Koka was stable in the same scenes. This means, there is no contradiction in the theory of the increase in the surface temperature caused by the inflow of the hot spring from the west side of the lake since the lake volume was also expanding during this period.

However, there are limits in this analysis and the result cannot be directly linked to a specific cause.

- The number of scenes used for the analysis was small and it does not absolutely prove the increasing trend of the surface temperature of Lake Beseka.

- Even if the increasing trend of the lake is proven, there is still a possibility of inflow caused by the water from the river (irrigation water) if the temperature of Lake Beseka was somehow lower than the river when the lake and the river were not connected by the irrigation farm.

Actual temperature measurements were taken during the water quality survey for this Project.

The thermometer measurement results of Lake Beseka, Lake Koka and the Awash River are shown in Table 3.5.2.

Table 3.5.2: Temperature Result during the Water Quality Survey (9th March 2014)

Point	Temperature	Remarks
Lake Beseka	28.3 °C	Arithmetical average of six points at the lake
Tone spring	41.3 °C	Spring at the west bank of Lake Beseka
Awash River (East side of Metehara Plantation)	25.1 °C	
Lake Koka	21.3 °C	Data of a point at the lake

Source: the Project Team, Data: Result of survey in this Project

The table above shows that the temperature of Lake Beseka is higher than the Awash River, which means the theory that Lake Beseka's increase in surface temperature is caused by the inflow of hot springs is more rational.

3.5.2 Results of water quality testing

The water quality testing around Lake Beseka was carried out for the purpose of understanding the recent inflow conditions from the surrounding area to Lake Beseka. The testing involved comparing the water quality of Lake Beseka with that of wells, springs, and river & irrigation water. As mentioned in the second phase, the water quality of water resources around Lake Beseka have specific properties compared to the other areas in terms of the main seven ions and fluoride concentration. The sampling points around Lake Beseka conducted by the Study team are shown in Table 3.5.3. Moreover, the existing water quality data around Lake Beseka is utilized as the reference data (refer to Table 3.5.4).

Table 3.5.3: List of Sampling Points around Lake Beseka

Zone or Region	Detailed Place	Type of Water Sources	Number of Sampling Points		SL. No.	Location ID (Sample ID)	Reference Coordinate		Remarks
			For Physio-chemical Analysis	For Isotope Analysis			Easting	Northing	
East Shewa	Around Lake Besaka	Awash River Water	1	0		B1-2R	587,951	968,181	From BH-53 to River/Canal
		Existing Well	1	0		B1-4	604,677	978,810	From BHM-12 to R28
		Existing Well	1	0		B1-5	604,309	975,247	From BH-41to M21
		Existing Well	1	0		B1-6	601,234	972,270	From BH-64 to L11
	Near the Tone spring	Spring	1	0		B1-7	591,607	979,363	Lake water?
	Spring of Southwest Side of Lake Besaka	Spring	1	0		B1-8	591,608	976,552	
	North-western part of the Lake Besaka	Lake Besaka Water	1	0		B1-9	594,960	984,098	
	South-eastern part of the Lake Besaka	Lake Besaka Water	1	0		B1-10	595,100	977,400	Same point with suggestion
	South-western part of the Lake Besaka	Lake Besaka Water	1	0		B1-11	592,000	977,900	Same point with suggestion
	Central-western part of the Lake Besaka	Lake Besaka Water	1	0		B1-12	593,000	981,600	Same point with suggestion
	Drainage Channel of Lake Besaka	Lake Besaka Water	1	0		B1-13	600,905	982,406	Lake outlet
	Along Wast of Lake Beseka	Spring	1	1		B1-14	592,612	981,509	
	In Metehara Plantation	Awash River Water	1	1		B1-15	598,077	972,974	
	From Nura Hera Farm	Awash River Water	1	1		B1-16	592,729	967,092	Irrigation water
	Middle Awash River	Awash River Water	1	1		B1-17	596,078	965,762	River intake point
	Metehara SP	Awash River Water	1	1		B1-18	601,502	978,505	
	South of Lake Besaka	Lake Besaka Water	1	1		B1-19	595,246	975,723	
	Tone Spring	Spring	1	1		B1-20	591,674	978,734	
	Around Lake Besaka (AW BH-3)	New Well	1	1		E1-1	589,167	982,682	
	Around Lake Besaka (AW BH-4N)	New Well	1	1		E1-2	587,754	977,437	
	Around Lake Besaka (AW BH-5)	New Well	1	1		E1-3	601,565	980,024	
	West of Lake Beseka	Lake Water	1	1		B1-21	592,146	980,409	
	West of Lake Beseka	Spring	1	1		B1-22	591,536	979,199	
	West of Lake Beseka	Lake Water	1	1		B1-23	591,532	979,193	
	South of Lake Beseka	Lake Water	1	1		B1-24	593,045	975,249	
	South of Lake Beseka	Lake Water+Irrigation	1	1		B1-25	593,044	975,228	
	South of Lake Beseka	Lake Water	1	1		B1-26	594,247	974,998	
	South of Lake Beseka	Irrigation Water	1	1		B1-27	593,243	972,517	
	East of Lake Beseka	Lake Water	1	1		B1-28	598,897	980,437	
	East of Lake Beseka	Lake Water	1	1		B1-29	596,741	978,173	
	East of Lake Beseka	Lake Water	1	1		B1-30	598,698	984,130	
			31	**20**					

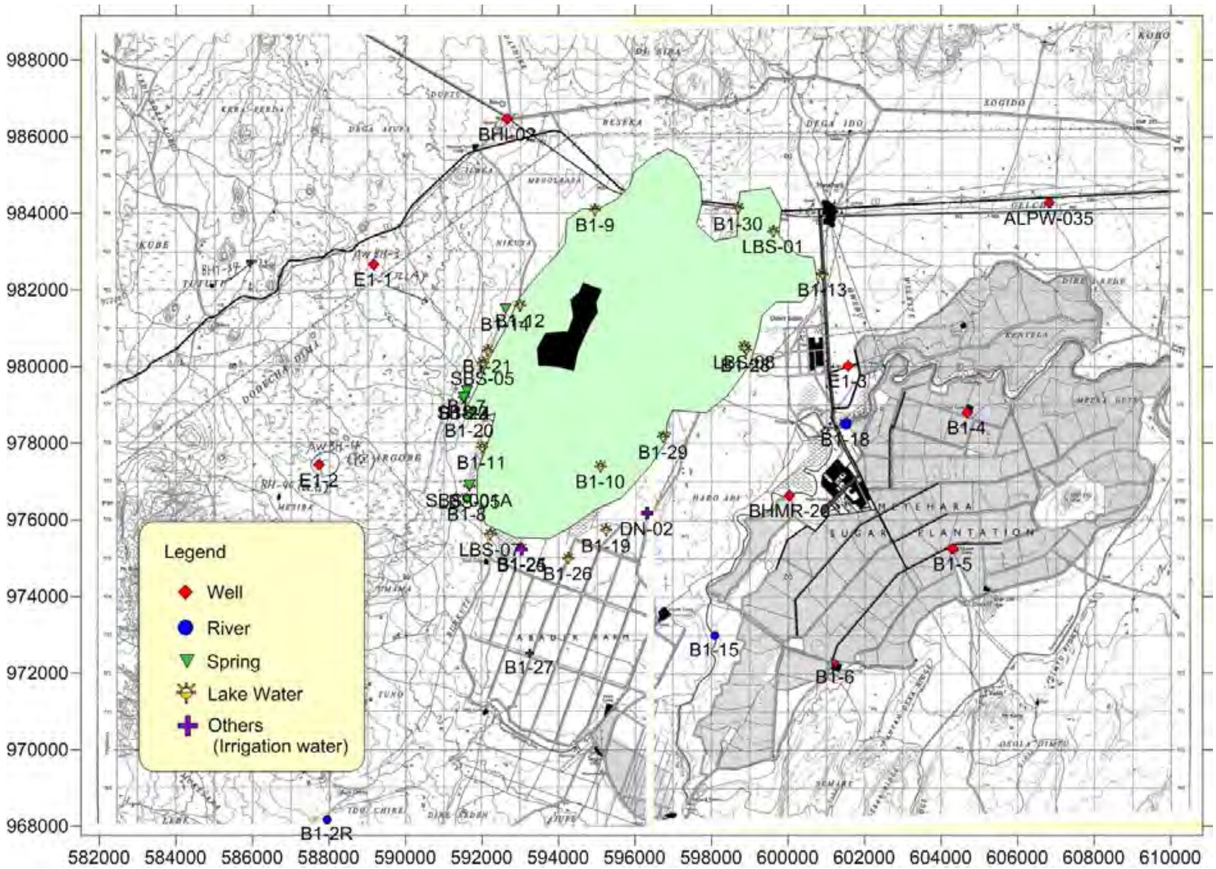
Source: the Project Team, Data: reference ④

Table 3.5.4: List of Existing Water Quality Data (around Lake Beseka)

Code	Easting	Northing	Resource	Remarks
LBS-01	599,618	983,534	Lake water	North East of Lake Beseka
LBS-08	598,860	980,515	Lake water	East of Lake Beseka
DN-02	596,308	976,168	Irrigation	South East of Lake Beseka
LBS-07	592,218	975,624	Lake water	South of Lake Beseka
LBS-05	591,670	976,881	Lake water	South West of Lake Beseka
SBS-4	591,533	979,204	Hot spring	West of Lake Beseka
SBS-05	592,019	980,096	Lake water	West of Lake Beseka
SBS-001A	591,669	976,913	Hot spring	South West of Lake Beseka
ALPW-035	606,822	984,277	Existing well	Depth; 595m (WWDSE,2015)
BHMR-20	600,048	976,634	Existing well	Same to Be12, Depth;48m
BHI-02	592,664	986,463	Existing well	Same to Be4, Depth; 53m

Source: the Project Team, Data: reference 4) of ①, 5) of ②

The sampling points and existing water quality testing points are shown in Figure 3.5.5.



Source: the Project Team, Data: reference ④

Figure 3.5.5: Location Map of Water Quality Testing Points around Lake Beseka

a. Characteristic of water quality by Trilinear Diagram

The results of the water quality testing around Lake Beseka are seen in the annex of this chapter. The Trilinear Diagram is shown in Figure 3.5.6 using the main ions. Figure 3.5.6 shows the following results and interpretations.

- The river and irrigation water (this canal water is classed as “others”) belong to the

$CaHCO_3$ type of water quality, and shows the same behaviour as surface water. Irrigation water sampled near Lake Beseka indicates a $NaHCO_3$ type due to the effects of Lake water.

- Both existing and JICA wells around Lake Beseka have been located in the west and east of Lake Beseka, and the depth of each well is different. However, with the exception of a few wells, those wells belong to the $NaHCO_3$ type of retarded deep groundwater. In the Trilinear Diagram, one well is plotted at a range of shallow groundwater by the effect of the shallow well, and a well belong to the Na_2SO_4 type containing the SO_4 and Cl ions. The water quality of the groundwater of each well is not affected by Lake Beseka's water because the water quality of both existing and JICA wells do not change as a whole even if the location of each well is different.

- The (hot) springs are located in the west and south west of Lake Beseka. It is difficult to find out the accurate points of the springs in the current situation because the springs have been submerged under the Lake. However it can be assumed to spring the groundwater along the flow line from the west and south west of Lake Beseka based on the groundwater level contour map as mentioned above. The characteristic of the springs belongs to the same type of both existing and JICA wells plotted in the $NaHCO_3$ type.

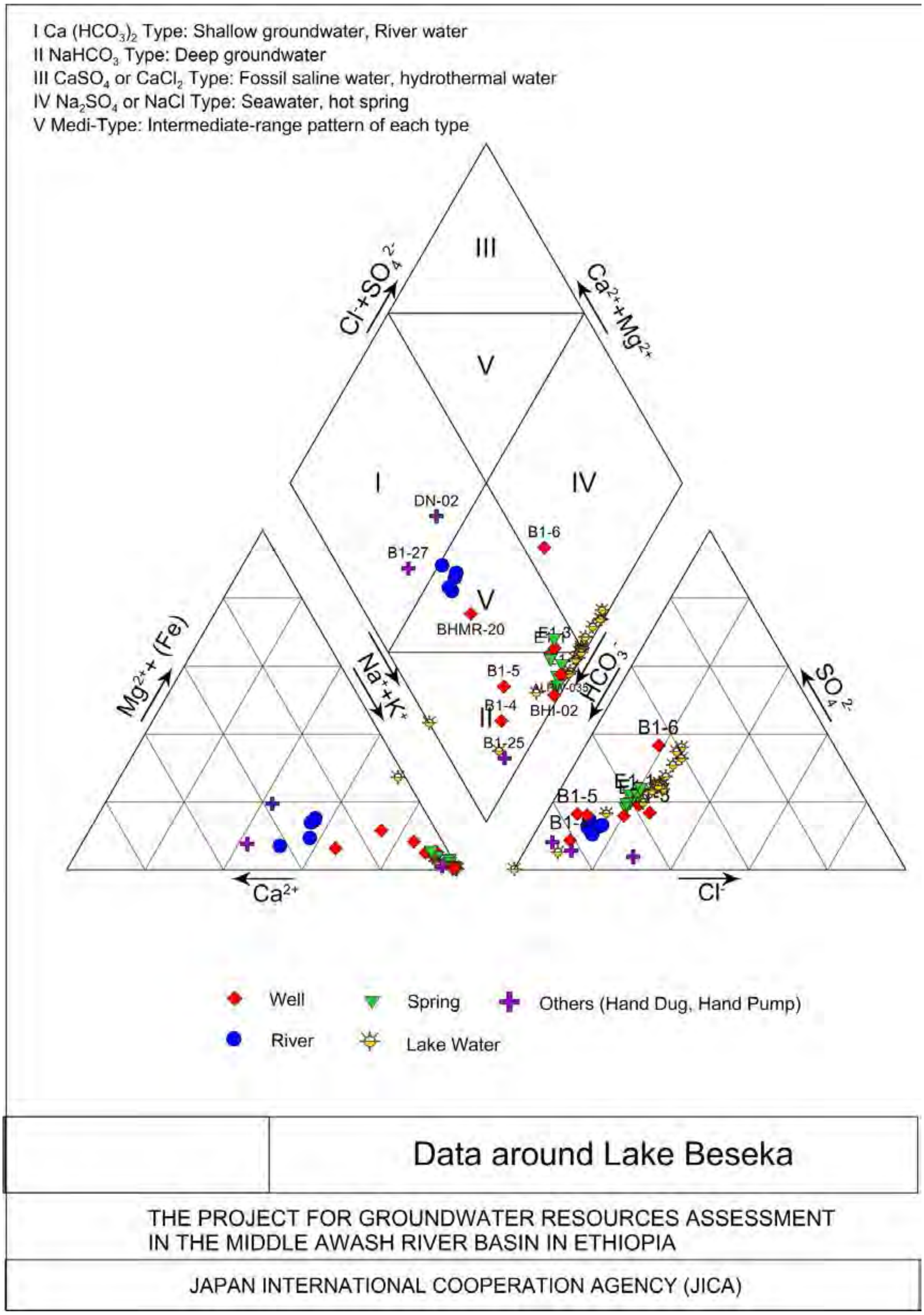
- The lake water shows the $NaHCO_3$ and Na_2SO_4 or NaCl types in the Trilinear Diagram, and the water quality of the lake water has the retarded deep groundwater characteristics as well as hot spring characteristics (near the component of the sea water). The lake water is affected by the spring, clearly having the same component. In other words, according to the assortment of the main ions, the water quality of the lake water is directly affected by the groundwater and spring.

- The change of anion and cation appears like the trace below in response to the retarded time and flow distance of the groundwater. This is generally called "the water quality evolution of the groundwater".

  Anion: $HCO_3^- \rightarrow HCO_3^- + SO_4^{2-} \rightarrow SO_4^{2-} + HCO_3^- \rightarrow SO_4^{2-} + Cl^- \rightarrow Cl^- + SO_4^{2-} \rightarrow Cl^-$

  Cation: $Ca^{2+} \rightarrow Ca^{2+} + Na^+ \rightarrow Na^+$

  In the Trilinear Diagram, the type of the water quality is changed from I to II and IV. This is the change of the water quality of the groundwater in accordance with the retarded time, and Figure 3.5.6 shows the change of ion from river water to spring and lake water. The river water is plotted near I type, the groundwater and spring is plotted in II type and almost all of the lake water belongs to the IV type. In other words, the lake water is strongly affected by the water quality of the groundwater and spring compared to that of river and irrigation water.

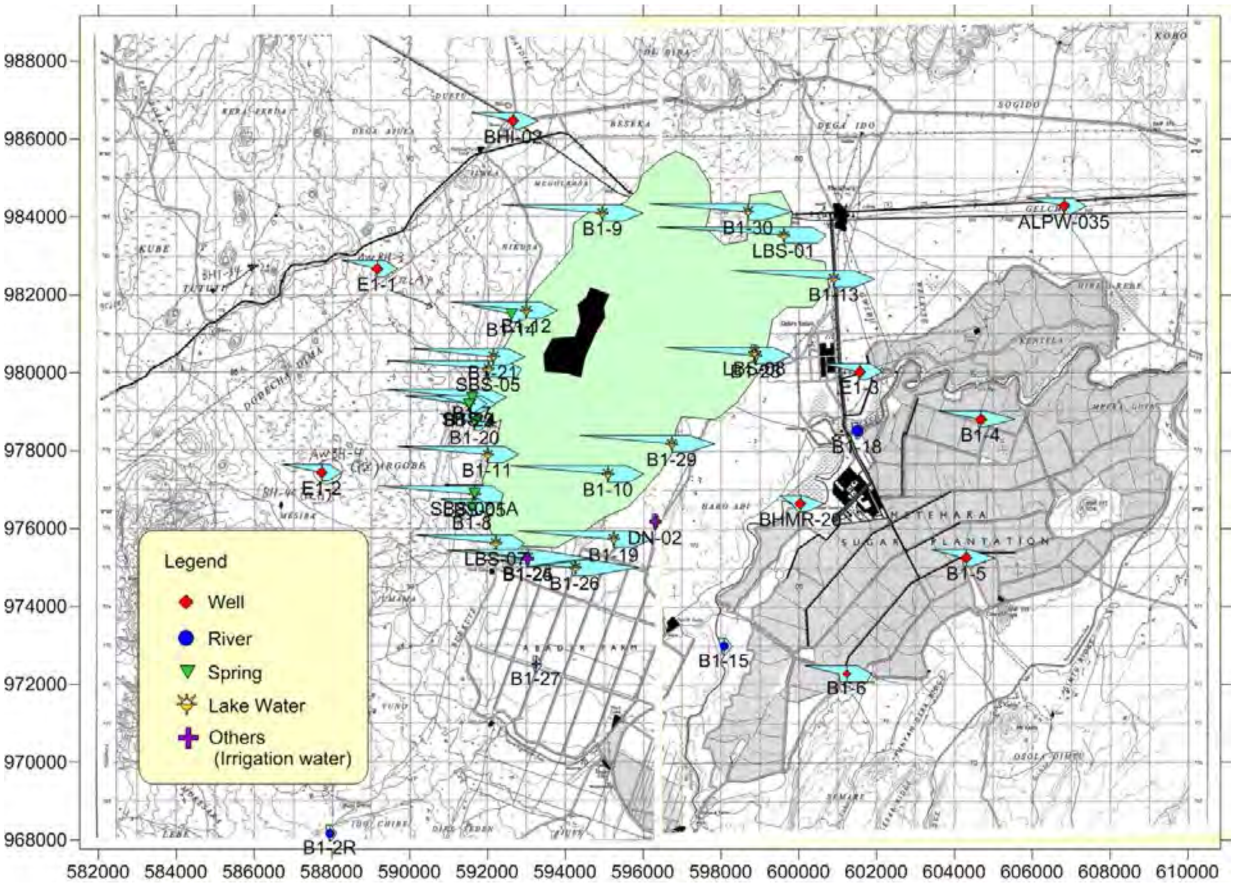


Source: the Project Team, Data: reference ④

Figure 3.5.6: Trilinear Diagram around Lake Beseka

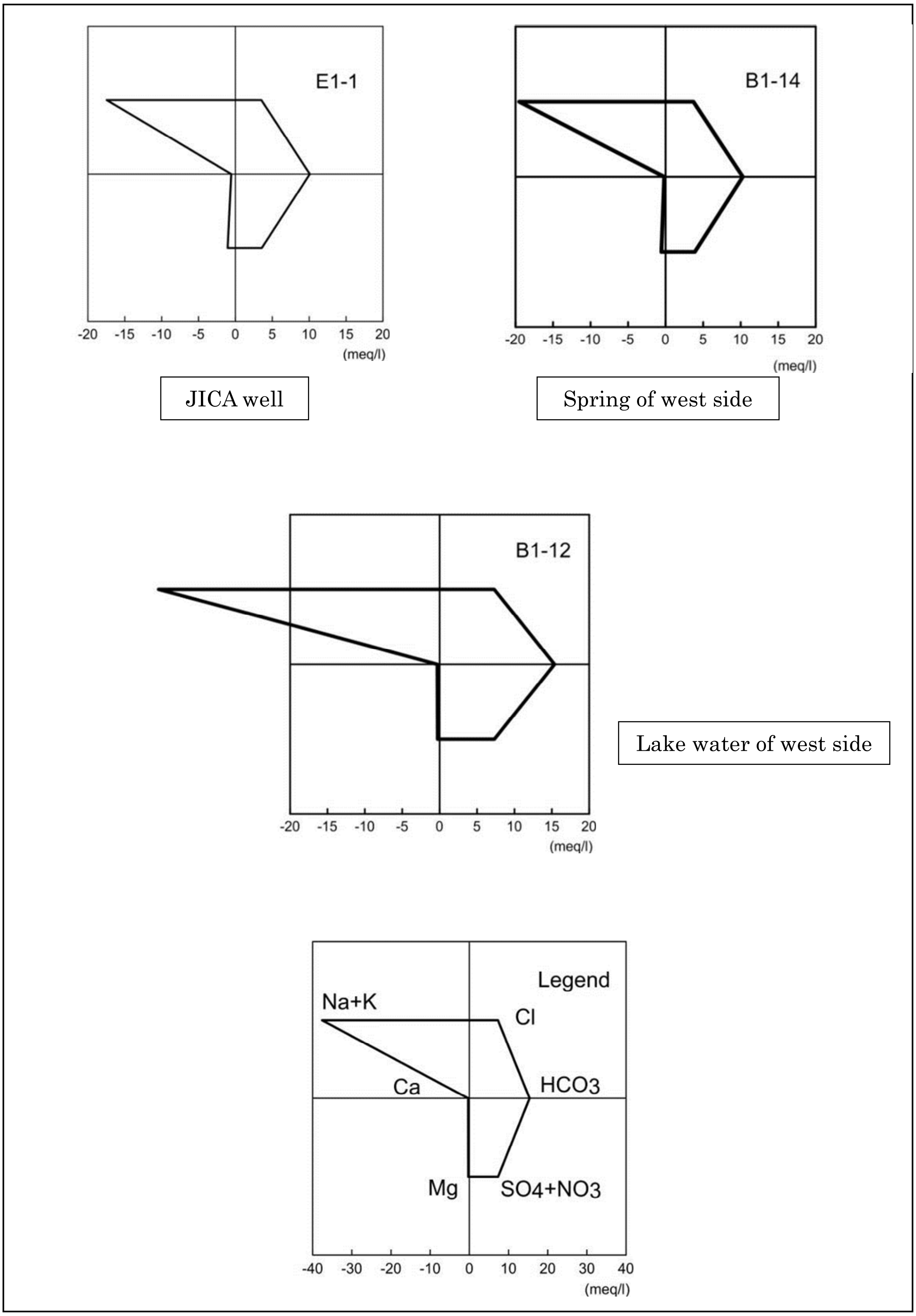
b. Characteristic of water quality by hexadiagram

The hexadiagram contains concentration information and total salinity weight, and can be used to represent water quality visually as mentioned in Chapter 2. The sampling points and existing data points with the hexadiagram are shown in Figure 3.5.7. The hexadiagrams at points of west to south west and south of Lake Beseka having possibilities for inflow into Lake Beseka from its surrounding area are shown in Figure 3.5.8, Figure 3.5.9 and Figure 3.5.10, respectively.



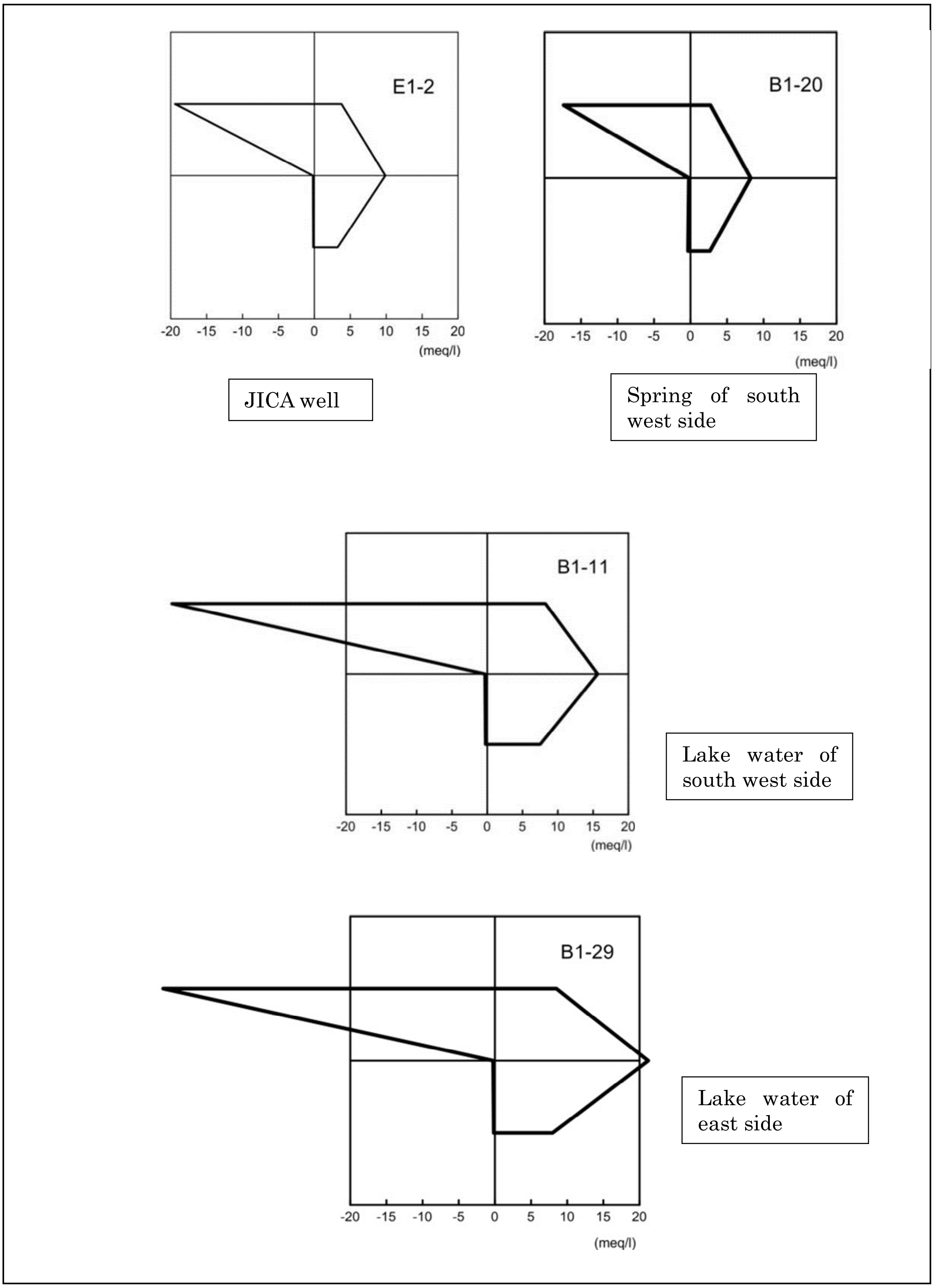
Source: the Project Team, Data: reference ④

Figure 3.5.7: Hexadiagram at Sampling Points around Lake Beseka



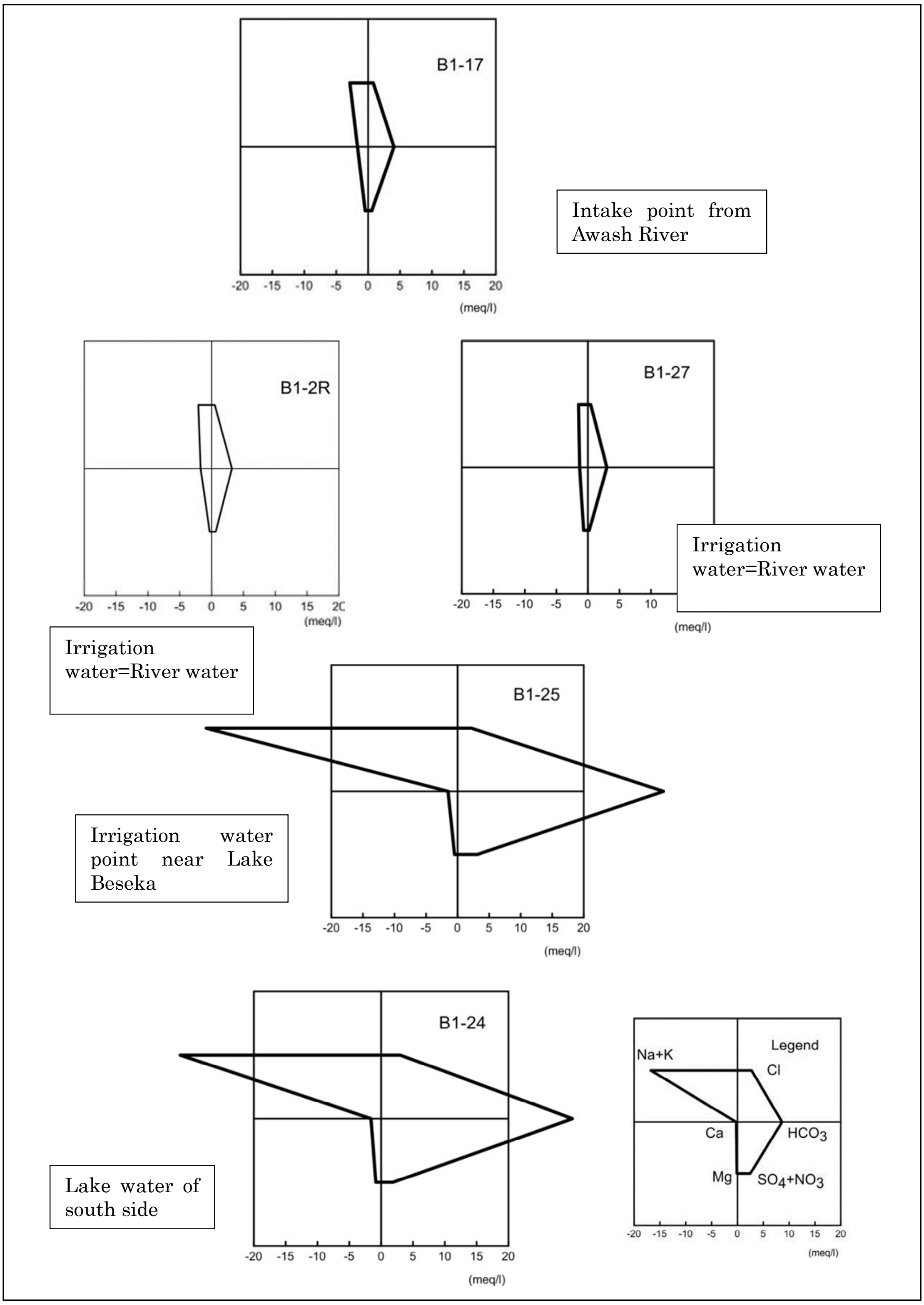
Source: the Project Team, Data: reference ④

Figure 3.5.8: Hexadiagram of Main Sampling Points at West of Lake Beseka



Source: the Project Team, Data: reference ④

Figure 3.5.9: Hexadiagram of Main Sampling Points at South West of Lake Beseka



Source: the Project Team, Data: reference ④

Figure 3.5.10: Hexadiagram of Main Sampling Points at South of Lake Beseka

These figures show the following results and hypotheses:

- The results of the hexadiagram for the groundwater from nine wells around Lake Beseka are shown in Figure 3.5.7. The water quality of these nine points belong to the $NAHCO_3$

type. One point (B1-6) out of nine contains a high concentration of $Cl^-$and SO_4^{2-} ions compared to the that of other points. This point is plotted in the area of IV in the Trilinear Diagram and this is indicated by the effect deep groundwater. The depth of each well is 50m to 595m deep and there is considerable width. The main aquifer consists of basalt, and the groundwater of the each well indicates the retarded deep groundwater type. The river and irrigation water (this canal water is classed as “others”), belong to the $CaHCO_3$ type of water quality like the Trilinear Diagram, and the concentration is also thin compared to the other resource. The concentration and visual type of the spring are similar to that of the groundwater from wells. The type of the springs belongs to the retarded deep groundwater type, and the springs are affected by the groundwater from the west and south west of Lake Beseka. Figure 3.5.7 shows the lake water belongs to the $Na\text{-}HCO_3$ type and has a high concentration including high amounts of SO_4^{2-} and Cl^- ions,. As just described, the water quality of the lake water is affected by the inflow of the springs (groundwater), according to the hexadiagram. Generally, in the deep groundwater, the oxygen is consumed when the decay of organic matter and NO_3 and SO_4 disappear in the reductive environment. However, in the groundwater of wells around Lake Beseka, the NO_3 and SO_4 do not disappear. So the oxygenation may be slow (the retarded time is not so long).

- Figure 3.5.8 shows the hexadiagram of the groundwater of wells and springs around Lake Beseka as well as lake water. The hexadiagrams of the springs resemble the groundwater of wells in shape and concentration. The Na of springs increases a little bit because the springs retain the Na during the inflow of groundwater to springs because Na has a soluble aspect in water. The Na, SO_4, Cl and HCO_3 ions increase in the Lake water keeping the characteristic of the springs. In particular, the concentration of the HCO_3 ion increases in the Lake water due to carbon dioxide existing as the atmosphere in the air reacts with the water. Figure 3.5.9 also shows the same situation like Figure 3.5.8. In the east of Lake Beseka, HCO_3 and other anions also tend to increase because of the long retarded time in Lake Beseka.

- The change of the water quality in the lake water at the south area of Lake Beseka is shown in Figure 3.5.10. In this figure, the water quality among the river water, irrigation water, and lake water is compared. The water quality of the river water and irrigation water include the Ca ion compared to that of the groundwater, springs and lake water at the west and south-west of the Lake Beseka. Therefore, Ca is found in the Lake water and the water between the lake and the irrigation area (refer to the points of B1-24 and B1-25 belonged to the $NaHCO_3$ type). B1-25 was collected between the lake and the irrigation area, but the water quality of B1-25 is affected by that of the lake water. The HCO_3 has high values while SO_4 & Cl have low values at the south area of Lake Beseka. It is highly probable that it is affected by the vegetation of the sugar cane at the irrigation area of southern Lake Beseka.

- The lake water is affected in totality by the groundwater and springs according to the hexadiagram. On the other hand, lake water at the south area is affected by the river and irrigation water due to the existence of Ca ion. However, according to the hexadiagram, aside from the south area of Lake Beseka, the entire lake water is not affected by the river water because there is no Ca ion in the water throughout the whole of Lake Beseka.

- The component and visual type of the lake water is very similar to that of springs even if there is a difference of the concentration according to the hexadiagram. It is hypothesized that the springs are concentrated from evaporation and the concentration of the lake water is made in these environments. As mentioned above, the analysis results indicate the present lake water is not influenced by the river water regardless of the existence of Ca ion.

- Although this conclusion mentioned above cannot directly account for Lake Beseka's dramatic water rise, the water quality of almost all the lake water suggests the effect of the groundwater (springs) from the characteristic of the hexadiagram.

c. Isotope analysis

Isotope analysis was conducted by the IAEA in regard to the groundwater of JICA wells. On the contrary, isotope analysis of the river waters (including irrigation water), springs and lake waters around Lake Beseka were carried out in AAU and the analysis results were utilized for useful information for tracing the source of waters. The sampling points analysed and the results of the isotope analysis are shown in the Table 3.5.5.

Table 3.5.5: Results and List of Isotope Analysis

Detailed Place	Type of Water Sources	Location ID (Sample ID)	Reference Coordinate		Date of Sampling	δ ^{2}H (‰)	δ ^{18}O (‰)
			Easting	Northing			
Around Ombole (Hombole)	Awash River Water	A1-1(D)	475,873	925,842	2015/1/16	-2.69	-1.31
Around North of Gefersa	Awash River Water	A1-2(D)	525,365	937,096	2015/1/10	5.81	-0.16
Around Awash Melkasa	Awash River Water	A1-3(D)	536,207	927,203	2015/1/10	9.11	0.35
Around Doni	Awash River Water	A1-4(D)	562,223	940,652	2015/1/15	8.43	-0.07
East of Metehara Sugar Plantation	Awash River Water	A1-5(D)	611,191	977,348	2015/1/15	15.39	1.89
Lake Koka	Mojo River Water	A1-7(D)	506,888	929,588	2015/1/16	6.08	0.36
Along Wast of Lake Beseka	Spring	B1-14	592,612	981,509	2014/7/7	-14.38	-2.76
In Metehara Plantation	Awash River Water	B1-15	598,077	972,974	2014/7/8	-12.78	-1.42
From Nura Hera Farm	Awash River Water	B1-16	592,729	967,092	2014/7/8	-11.22	-0.86
Middle Awash River	Awash River Water	B1-17	596,078	965,762	2014/7/8	-3.88	-1.06
Metehara SP	Awash River Water	B1-18	601,502	978,505	2014/7/9	-12.58	-1.02
South of Lake Besaka	Lake Besaka Water	B1-19	595,246	975,723	2014/7/9	31.64	3.29
Tone Spring	Spring	B1-20	591,674	978,734	2014/7/9	2.55	-1.74
West of Lake Beseka	Lake Water	B1-21(D)	592,146	980,409	2015/1/8	16.41	2.69
West of Lake Beseka	Spring	B1-22(D)	591,536	979,199	2015/1/8	-9.56	-2.68
West of Lake Beseka	Lake Water	B1-23(D)	591,532	979,193	2015/1/8	9.79	1.04
South of Lake Beseka	Lake Water	B1-24(D)	593,045	975,249	2015/1/9	25.55	2.97
South of Lake Beseka	Lake Water+Irrigation	B1-25(D)	593,044	975,228	2015/1/9	34.28	4.81
South of Lake Beseka	Lake Water	B1-26(D)	594,247	974,998	2015/1/9	21.64	2.94
South of Lake Beseka	Irrigation Water	B1-27(D)	593,243	972,517	2015/1/9	6.45	0.19
East of Lake Beseka	Lake Water	B1-28(D)	598,897	980,437	2015/1/9	25.77	4.55
East of Lake Beseka	Lake Water	B1-29(D)	596,741	978,173	2015/1/9	25.41	4.49
East of Lake Beseka	Lake Water	B1-30(D)	598,698	984,130	2015/1/9	26.26	4.44
Around Lake Besaka (AW BH-3)	New Well	E1-1	589,167	982,682	2014/8/9	-9.79	-2.65
Around Lake Besaka (AW BH-4N)	New Well	E1-2	587,754	977,437	2014/11/12	-9.75	-2.72
Around Lake Besaka (AW BH-5)	New Well	E1-3	601,565	980,024	2014/4/2	1.65	-1.08
Around Feto (AW BH-6)	New Well	E1-4	552,789	958,778	2015/8/11	-33.1	-6.24
Between Doni and Bofo (AW BH-9)	New Well	E1-6	555,025	936,983	2014/9/22	-12.87	-3.55
Around Sire (AW BH-11)	New Well	E3-2	553,313	916,009	2015/4/3	-12.2	-3.03
Around Balchi (AW BH-1)	New Well	E4-1	542,642	985,361	2015/4/8	-11.78	-3.11
Around Melka Jiro (AW BH-2)	New Well	E4-2	567,414	980,822	2015/7/21	-27.3	-6.10
Around Dehaye (AW BH-12)	New Well	E4-3	550,405	1,027,427	2014/10/20	-30.59	-5.41

Source: the Project Team, Data: reference ④, analyzed by AAU and IAEA

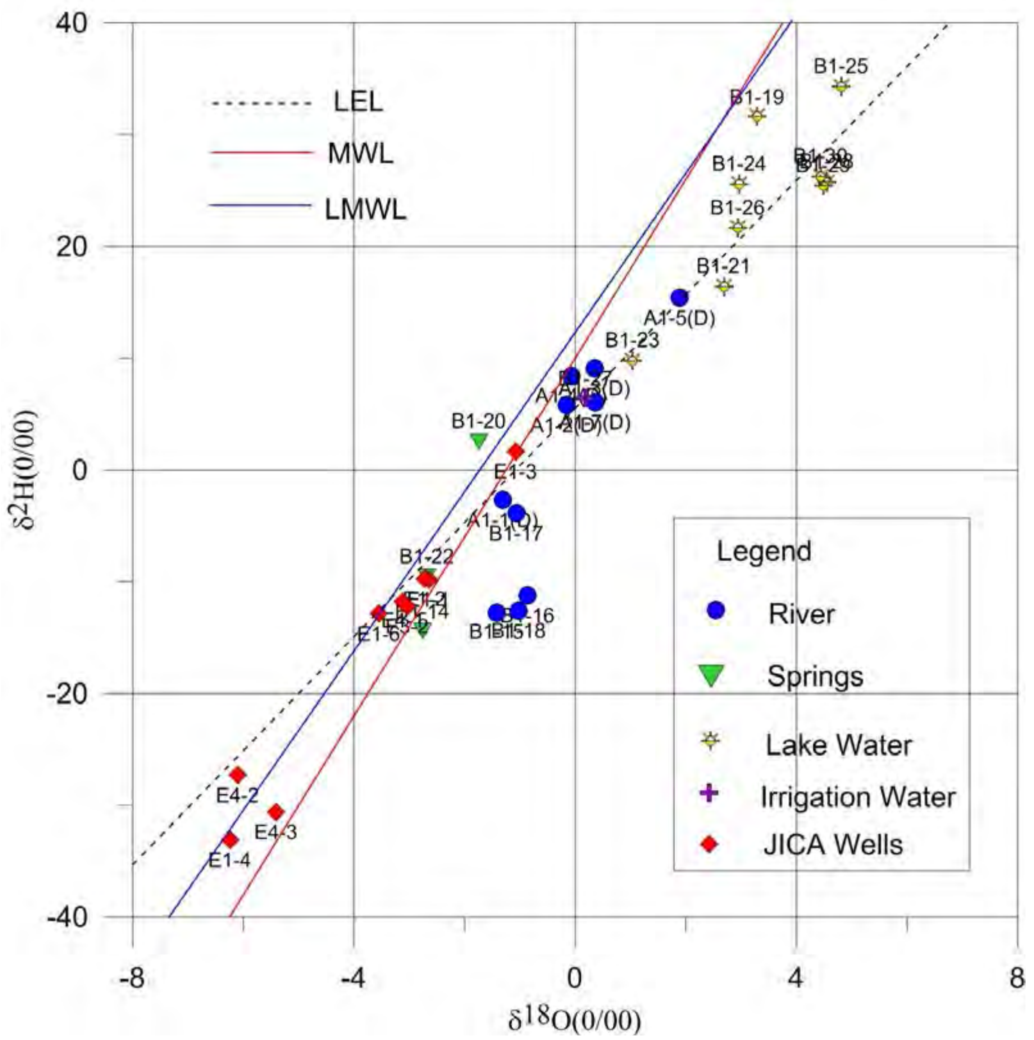
In stable isotopes in water, ^{2}H (D) of mass number 2, and ^{18}O of mass number 18 were used for the analysis. A water molecule consists of these atoms, and these are contained in the river and groundwater in high concentration (high compared to the other concentrated components). These isotope molecules are ideal tracers for the comprehension of groundwater flow in the hydrologic cycle because they do not have a chemical reaction with other matter like dissolved matter.

The results of the analysis for the stable isotopes are shown in Figure 3.5.11 as delta (δ) diagram. Generally, the straight line for precipitation and surface water is made using plotted points of precipitation around the world. This line is called the Meteoric Water Line (hereafter refer to as "MWL") as $\delta D = 8\delta^{18}O+10$.

As the formation temperature decreases and the latitude increases, the isotopic ratio of precipitation decreases along the MWL. This is called the temperature effect or latitude effect. Moreover, when the precipitation increases, the isotopic ratio decreases in what is called the precipitation effect. Isotopic ratio at higher elevations decreases or when the precipitation moves toward continental regions, isotopic ratio has a tendency to decrease. The former is called the altitude effect, and the latter is called the continental region effect.

Meteoric waters do not always plot on MWL, as they are affected by various local and regional factors such as source of moisture, extent of evaporation during rainfall, altitude, and so on. For instance, the line that is formed by plotting δ^2H and $\delta^{18}O$ for specific regions is called the Local Meteoric Water Line (hereafter referred to as "LMWL"). Records from 1964 to 2004 were used to establish the LMWL, and the line defined by the relation $\delta D = 7.12\delta^{18}O+12.3$ with a regression coefficient (r^2) of 0.93. Figure 3.5.11 includes MWL and LMWL.

The isotopic ratio of the precipitation or groundwater and river water derived from rainfall is plotted near the MWL. The δ value of the groundwater is similar to that of precipitation as the weighted mean near the point of groundwater. For the isotopic ratio of springs, one outcrop of groundwater was plotted near the LMWL. It is possible it was derived from the Addis Ababa rainfall in Figure 3.5.11. The isotopic ratio of river water can be plotted with three groups as a whole in Figure 3.5.11. The river waters marked by (D) including A1-5 (D) sample are plotted at a relatively high isotopic ratio. As these samples were collected in the dry season, it is possible to recognize the precipitation effect. Also, sample A1-5 (D) is influenced by the lake water because the sampling point of is located downstream of Lake Beseka. The low isotopic ratio group of the river waters is located below MWL. This group reflects the precipitation effect because of the sampling was done in the rainy season. The lake waters are plotted in the lower right below the MWL. The lake is characterized by an enriched composition compared to their inflows due to the isotopic fractionation during the evaporation process. Consequently, the isotopic ratio of evaporating lake plots below the MWL, along a line called Local Evaporation Line (hereafter referred to as "LEL"). The slope of LEL is found mainly from 3.5 to 6, and depends on local climate factors. The lake waters with some river waters plot along the LEL are defined by the relation $\delta D = 5.1\delta^{18}O+5.5$ in reference to Eleni, 2009. The LEL intersects the LMWL at the isotopic value of -3.40‰ in $\delta^{18}O$ and -11.84‰ in δ^2H (refer to Figure 3.5.11). As this isotopic value is comparable to the isotopic ratio of the groundwater in the up watershed, it was discussed in the flow system of the western part of the watershed. The average δ values of the groundwater in JICA wells (AW BH-1, 3, 4N, 9, and 11) taken in the western part of the watershed is characterized by an isotopic ratio of -3.01‰ in $\delta^{18}O$ and -11.28‰ in δ^2H (refer to Figure 3.5.11).This value is similar to that of the intersected point of LEL. This suggests that the inflow to Lake Beseka comes from the groundwater at the western and northwest part of the watershed. For example, Eleni, 2009 described the isotopic value of -2.8‰ in $\delta^{18}O$ and -10.7‰ in δ^2H as the average of the groundwater system in the western part of the lake watershed.



Source: the Project Team, Data: reference 5) of ①, and ④

Figure 3.5.11: Delta Diagram of Stable Isotope around Lake Beseka

d. Tritium Analysis

The results of the tritium analysis and sampling points are shown in Table 3.5.6 below. The sampling of groundwater with JICA wells will be carried out from now. A1-1 (D) to A1-7 (D) are samples from the Awash River, B1-21 to B1-30 are almost all lake waters and B1-22 and B1-27 are sampled from spring and irrigation water respectively.

Table 3.5.6: List of Points for Tritium Analysis

Detailed Place	Type of Water Sources	SL. No.	Location ID (Sample ID)	Reference Coordinate		Final Result TU±0.5σ
				Easting	Northing	
Around Ombole (Hombole)	Awash River Water	1	A1-1(D)	475,873	925,842	**2.33**
Around North of Gefersa	Awash River Water	2	A1-2(D)	525,365	937,096	**2.25**
Around Awash Melkasa	Awash River Water	3	A1-3(D)	536,207	927,203	**2.23**
Around Doni	Awash River Water	4	A1-4(D)	562,223	940,652	**2.17**
East of Metehara Sugar Plantation	Awash River Water	5	A1-5(D)	611,191	977,348	**2.19**
Lake Koka	Mojo River Water	6	A1-7(D)	506,888	929,588	**2.32**
West of Lake Beseka	Lake Water	7	B1-21	592,146	980,409	**2.21**
West of Lake Beseka	Spring	8	B1-22	591,536	979,199	**2.35**
West of Lake Beseka	Lake Water	9	B1-23	591,532	979,193	**2.30**
South of Lake Beseka	Lake Water	10	B1-24	593,045	975,249	**2.26**
South of Lake Beseka	Lake Water+Irrigation	11	B1-25	593,044	975,228	**2.14**
South of Lake Beseka	Lake Water	12	B1-26	594,247	974,998	**2.27**
South of Lake Beseka	Irrigation Water	13	B1-27	593,243	972,517	**2.25**
East of Lake Besek	Lake Water	14	B1-28	598,897	980,437	**2.13**
East of Lake Besek	Lake Water	15	B1-29	596,741	978,173	**2.36**
East of Lake Besek	Lake Water	16	B1-30	598,698	984,130	**2.29**
Around Lake Besaka (AW BH-3)	New Well	17	E1-1	589,167	982,682	-
Around Lake Besaka (AW BH-4N)	New Well	18	E1-2	587,754	977,437	-
Around Lake Besaka (AW BH-5)	New Well	19	E1-3	601,565	980,024	-
Around Feto (AW BH-6)	New Well	20	E1-4	552,789	958,778	**2.43**
Between Doni and Bofo (AW BH-9)	New Well	21	E1-6	555,025	936,983	-
Around Sire (AW BH-11)	New Well	22	E3-2	553,313	916,009	-
Around Balchi (AW BH-1)	New Well	23	E4-1	542,642	985,361	-
Around Melka Jiro (AW BH-2)	New Well	24	E4-2	567,414	980,822	**3.01**
Around Dehaye (AW BH-12)	New Well	25	E4-3	550,405	1,027,427	-

Source: the Project Team, Data: reference ④, analyzed by AAU and IAEA

Tritium (^3H) is a radioactive hydrogen isotope with a half-life of 12.43 years and changes to ^3He by beta-decay. The tritium concentrations are almost parallel in the vapor of the troposphere. The usual concentration in the mid-latitude rainfall was 10 tritium units (hereafter refer to as “TU”). However, following atmospheric detonation of thermonuclear bombs after 1952, a large amount of tritium, in particular, 1000 TU was released into the atmosphere in the peak period between 1963 to 1964,. After that, the tritium concentration was back to a natural level of 5 to 10 TU in 1990 due to decreasing tritium concentrations year on year after the experiments were finished. The tritium content of lake waters is 2.245 TU on average, that of river waters indicates 2.248 TU on average and that of springs is 2.35 TU for one point. Seifu Kebede, et al, 2008 says the tritium concentration of the groundwater around Lake Beseka is 1.5 and 5.8 TU, and that of a hot spring in the Fentale volcano is 0.7 TU. Eleni Ayalew Belay, 2009 shows the tritium content of the rainfall in Addis Ababa is transitional from 5 to 15 TU from1984 to 1997. The value of tritium contents in this Study indicates a mixture of recharge from sub-modern (prior to 1953) and modern (after 1953) meteoric waters.

3.5.3 Estimation of irrigation return flow

a. General

The purpose of the analysis here is to assess the extent of the irrigation return flow’s contribution to the expansion of the Lake Beseka which started in the late 1960s. Currently, the developed irrigation projects in and around the Lake Beseka catchment are the Abadir farm, Nura Hira farm and Fentale project (see Figure 3.2.3).

Irrigation efficiency as well as the possible irrigation return flow amount from the Abadir farm are tried to be estimated in this analysis based on the available data. The relevancy of widely recognized cause of the lake expansion, that is irrigation return flow, is reviewed from the following viewpoints:

- Evaluation of the irrigation efficiency in Abadir farm and estimation of possible return flow amount into the Lake Beseka

- Review of consistency of water balance of the Lake Beseka under the scenario with possible return flow

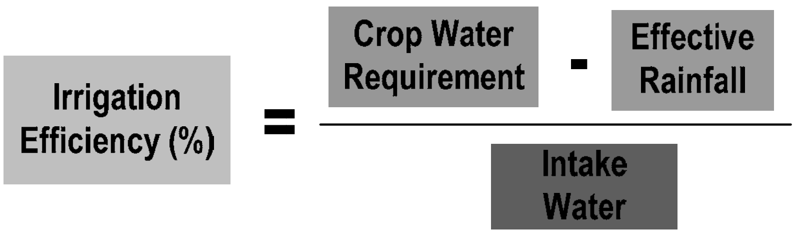
b. Irrigation efficiency in Abadir farm

b.1 Irrigation water losses and standard for efficiency evaluation

Irrigation efficiency is generally estimated by multiplying the conveyance efficiency and application efficiency. According to the Food and Agriculture Organization of the United Nations (FAO, 1989), the irrigation efficiency is evaluated as ‘Good’ for 50-60%, ‘Reasonable’ for the 40% level and ‘Poor’ for 20-30%.

b.2 Estimation of irrigation efficiency

The water requirement for cultivation (crop water requirement) in the farm is estimated first and then the irrigation efficiency is estimated comparing the water requirement that is actually taken from the Awash River with the amount of effective rainfall over the farm fields. Namely, the crop water requirement minus the effective rainfall is divided by the water intake from Awash River to obtain the irrigation efficiency.



Source: the Project Team

Figure 3.5.12: Irrigation Efficiency Calculation Used in this Project

b.2.1 Volume of water intake by Abadir farm

According to the water intake record by Abadir farm from 1977 to 2009, the intake amount varies between 80 and 130 million m^3 and annual mean water intake is approx. 102 million m^3 (3.24 m^3/sec). The total area of Abadir is 3,158 ha and cultivation area reaches 2,842 ha if 90% of the total area is for cultivation. The annual mean water intake is therefore converted in the height of 3,589 mm (= 102 / 2,842 x 10^5).

b.2.2 Estimation of crop water requirement

Crop water requirement for cultivation of sugarcane, which has been cultivated in Abadir farm since 1978, is estimated by the following formula:

$ET_{sugarcane} = ETo \times Kc$

where, $ET_{sugarcane}$: Water requirement for sugarcane (mm/year)
ETo: Reference evapotranspiration (mm/year)
Kc: Crop coefficient

ETo is calculated as 2,224 mm/year based on the meteorological data at Metehara station employing Penman-Monteith method[3].

Based on the typical growth stages of sugarcane and associated duration and Kc values proposed by FAO, the annual mean Kc value is estimated at 0.965.

The crop water requirement for sugarcane is then estimated at 2,146 mm/year (= 2,224 x 0.965).

b.2.3 Estimation of effective rainfall

The effective rainfall is defined as the rainfall which contributes to the crop growth. This is estimated based on the total rainfall amount applying the empirical formula proposed by the FAO-AGLW (FAO Water Resource, Development and Management Services).

The estimated mean annual effective rainfall is 220 mm

b.2.4 Estimation and evaluation of irrigation efficiency

The above calculation results are summarized below:

Mean annual water intake by Abadir farm:	3,589 mm
Mean annual crop water requirement in Abadir farm:	2,146 mm
Mean annual effective rainfall in Abadir farm:	220 mm

The irrigation efficiency in Abadir farm is estimated at about 54% (= (2,146 – 220) / 3,589). It is evaluated as ‘Good’ irrigation practices according to the FAO’s criteria.

b.2.5 Estimation of return flow to the Lake Beseka

When the irrigation efficiency in Abadir farm is 54%, the remaining 46% of intake water disappears without contributing to the crop growth. Since the annual water intake by Abadir farm is approx. 102 million m^3, the annual irrigation water loss is approx. 47 million m^3.

Out of the total area of Abadir farm of 3,158 ha, 2,315 ha (73.3%) is within the lake catchment. Therefore, the irrigation water losses occur in the lake catchment and it can be estimated at approx. 35 million m^3 (= 47 million m^3 x 73.3%), and it is considered as the possible maximum return flow to the Lake Beseka.

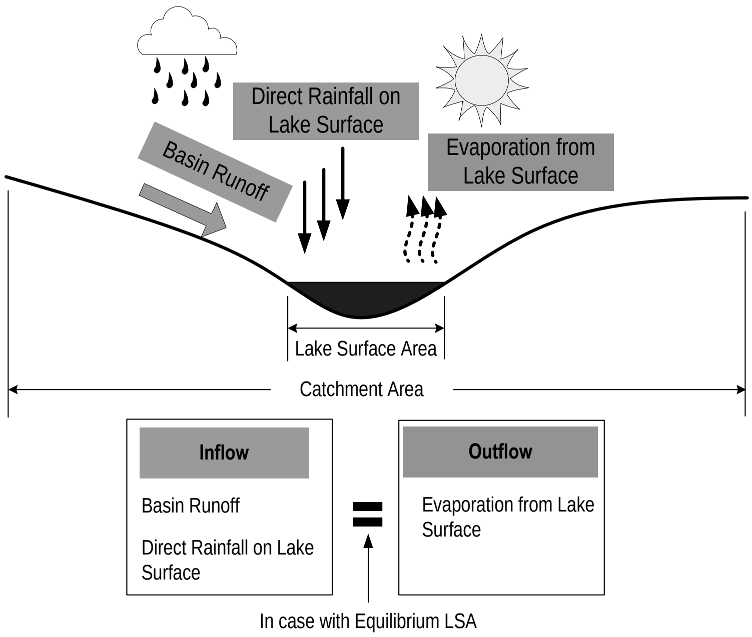
c. Effects of irrigation return flow on the lake water balance

The effects of the possible maximum return flow from the irrigation area elaborated above on the annual water balance in the lake are assessed here. The annual water balance in the lake without return flow is estimated first, and then the water balance is analyzed adding the return flow in order to check whether or not this will sufficiently explain the sudden expansion of the lake.

[3] http://www.fao.org/docrep/x0490e/x0490e00.htm#Contents

c.1 Definition of equilibrium lake surface area and conditions for the analysis

The lake catchment is reported to be isolated from the Awash River Basin before the construction of drainage facilities in 2004. Water balance situation in the lake catchment is schematically shown in Figure 3.5.13 below:



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.13: Water Balance in Isolated Lake Catchment

The inflow to the Lake Beseka consists of the direct rainfall on the lake surface and the runoff from the lake catchment. The lake outflow consists only of evaporation from the lake surface. The volume of the surface evaporation increases in proportion to the lake surface area. So, in the long term, if the hydrometeorological conditions remain unchanged, the lake surface area shall converge at a size in which the surface evaporation amount is balanced with the inflow components, namely direct rainfall plus basin runoff. This converged lake surface area is defined as the equilibrium lake surface area (ELSA) in this analysis.

The following relationship is realized if the surface area of the Lake Beseka is ELSA:

$$E \cdot ELSA = R \cdot ELSA + Q$$

where,
ELSA: Equilibrium lake surface area
E: Mean annual evaporation (height)
R: Mean annual rainfall (height)
Q: Mean annual runoff from the catchment (volume)

Although there shall be minor fluctuations of the lake surface area due to the occurrence of floods/draughts, seasonal variation of rainfall or other reasons, the surface area may not deviate from ELSA in the long term.

Hydrometeorological analysis in this Project figured out the mean annual rainfall and evaporation at Metehara observatory station of 508 mm and 3,023 mm, respectively. The data at this observatory station is applied to the lake catchment. Applying the pan coefficient of 0.8 which was used in the past similar studies, the annual evaporation from the lake surface is 2,418 mm (= 3,023 x 0.8)

Runoff from the lake catchment (Q) is calculated by multiplying the mean annual rainfall (R) with runoff coefficient (C). Following formula proposed in the hydrological analysis is used for estimation of C:

$$C = 1.090(A - ELSA)^{-0.236}$$

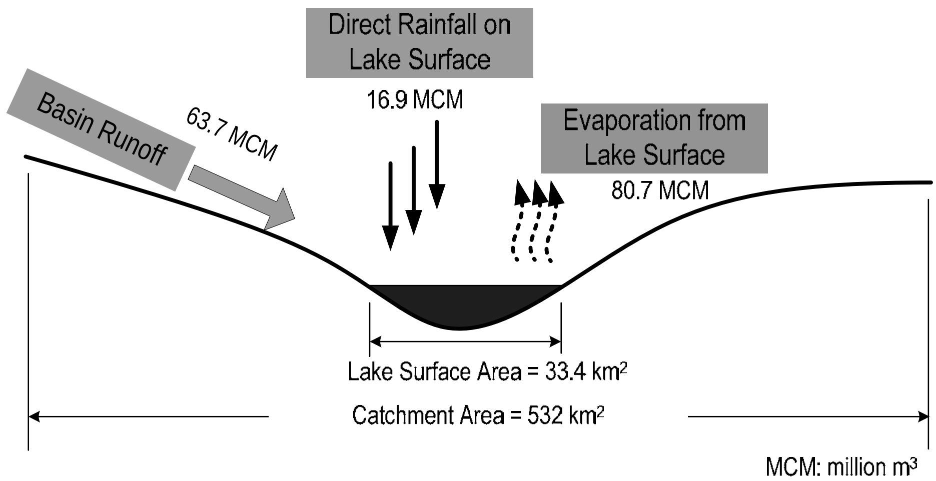
where, ELSA: Equilibrium lake surface area (km^2)
A: The lake catchment area (= 532 km^2)

The calculated ELSA in the above condition is 33.4 km^2.

Table 3.5.7: Mean Annual Water Balance in the Lake Beseka (ELSA＝33.4 km^2)

Items	Volume	Calculation / Remarks
Inflow		
Direct Rainfall on the Lake Surface	16.9 (10^{6}m^3)	508 mm x 33.4 km^2
Runoff from the Lake Catchment	63.7 (10^{6}m^3)	508 mm x 1.090 (532 km^2 – 33.4 km^2)$^{-0.236}$ x (532 km^2 – 33.4 km^2)
Total Inflow	**80.7 (10^{6}m^3)**	
Outflow		
Evaporation from the Lake Surface	80.7 (10^{6}m^3)	3,023 mm x 0.8 x 33.4 km^2
Total Outflow	**80.7 (10^{6}m^3)**	
Balance	**0.0 (10^{6}m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.14: Mean Annual Water Balance in the Lake Beseka (ELSA＝33.4 km^2)

On the other hand, the existing information says that the Lake Beseka kept its surface area in the range of 3 – 5 km^2 before 1970. In other words, it means that the ELSA was 3 – 5 km^2 before and that the water amount cannot be balanced only with the outflow by surface evaporation. Table 3.5.8 shows the water balance calculation with 4 km^2 of ELSA.

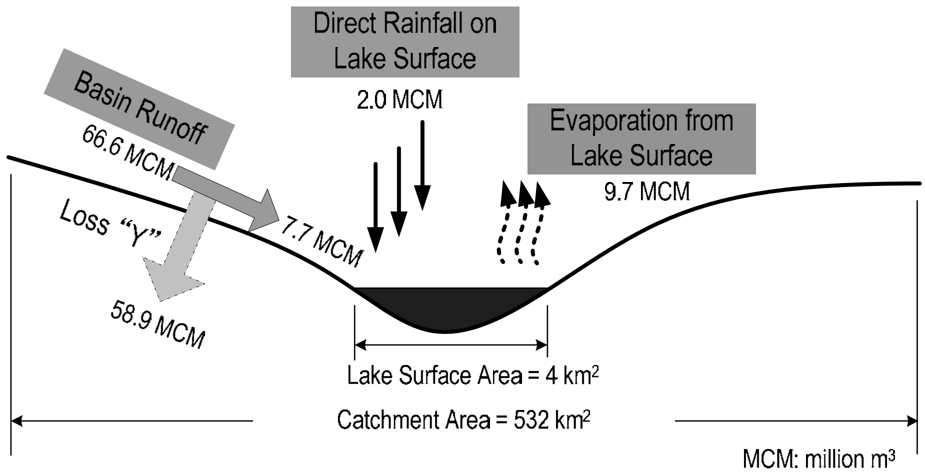
Table 3.5.8: Mean Annual Water Balance in the Lake Beseka (ELSA＝4 km^2)

Items	Volume	Calculation / Remarks
Inflow		
Direct Rainfall on the Lake Surface	2.0 (10^6m^3)	508 mm x 4 km^2
Runoff from the Lake Catchment	66.6 (10^6m^3)	508 mm x 1.090 (532 km^2 – 4 $km^2)^{-0.236}$ x (532 km^2 – 4 km^2)
Total Inflow	**68.6 (10^6m^3)**	
Outflow		
Evaporation from the Lake Surface	9.7 (10^6m^3)	3,023 mm x 0.8 x 4 km^2
Total Outflow	**9.7 (10^6m^3)**	
Balance	**58.9 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project

The total outflow is only 9.7 million m^3, while the total inflow amounts to 68.6 million m^3. It is an inflow excess of 58.9 million m^3 on terms of water balance. This suggests the necessity of the introduction of an assumption in order to stabilize the water in the lake area of 4 km^2.

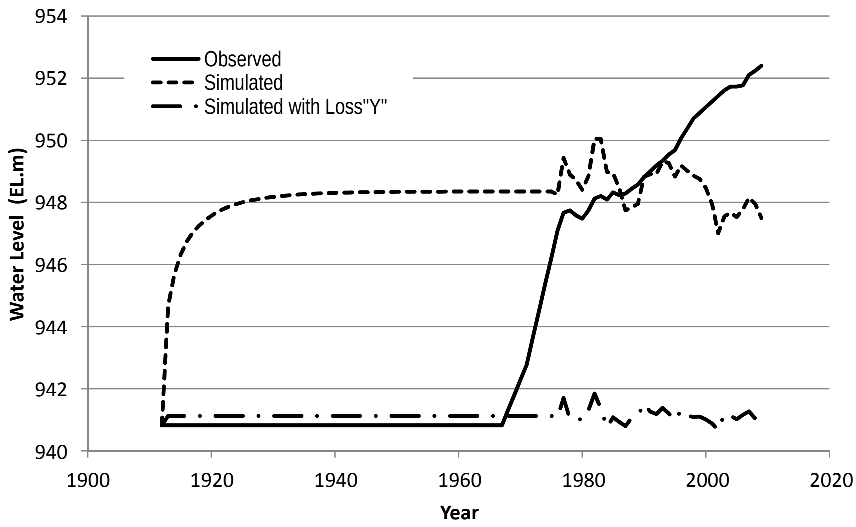
[Assumption]
The amount of 58.9 MCM out of the basin runoff (66.6 MCM) is lost due to deep percolation, etc. before reaching the Lake. This is called loss “Y”.



Source: the Project Team, Data: Result of hydrology survey in this Project

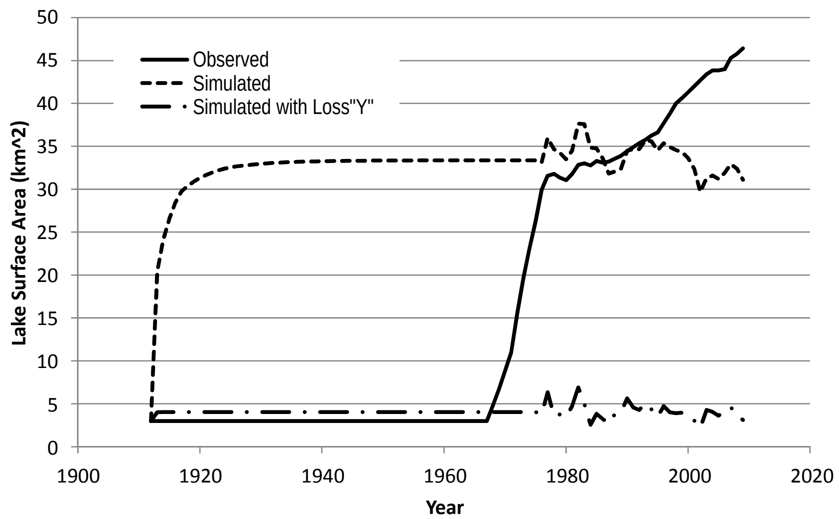
Figure 3.5.15: Mean Annual Water Balance in the Lake Beseka with Loss “Y” (ELSA ＝4 km^2)

Historical changes of the lake water level and surface area are calculated using the annual rainfall data in the basin. Time series of the lake water level and surface area are presented in Figure 3.5.16 and Figure 3.5.17, respectively.



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.16: Observed and Simulated Historical Changes of the Lake Water Level



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.17: Observed and Simulated Historical Changes of the Lake Surface Area

As seen in the figures above, without loss “Y”, the lake water level rapidly rises at the beginning (Year 1912) and reaches up to around EL. 948 m. The Lake Beseka surface area becomes approx. 33 km^2. This does not explain the lake size as of the late 1960s.

When the loss “Y” is considered, the Lake surface area is in a stable condition with an approximate size of about 4 km^2, though minor variation of area due to the rainfall amount is found. This adequately explains the situation before the expansion of the Lake Beseka.

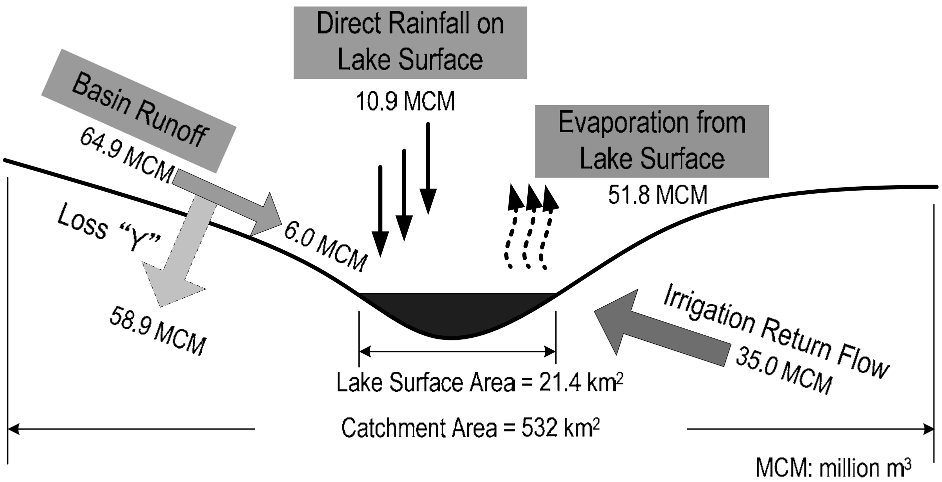
c.2 Water balance calculation with return flow (with loss “Y”)

The possible maximum return flow from Abadir farm is estimated at approx. 35 million m^3 per annum as explained in b.2.5 above. The ELSA is 21.4 km^2 if this return flow is taken into account for the water balance calculation (see Table 3.5.9 and Figure 3.5.18).

Table 3.5.9: Mean Annual Water Balance in the Lake Beseka with 35 MCM Return Flow

Items	Area/Volume	Calculation / Remarks
ELSA	21.4 km^2	
Inflow		
Direct Rainfall on the Lake Surface	10.9 ($10^6 m^3$)	508 mm x 21.4 km^2
Runoff from the Lake Catchment	64.9 ($10^6 m^3$)	508 mm x 1.090 (532 km^2 – 21.4 km^2)$^{-0.236}$ x (532 km^2 – 21.4 km^2)
Loss "Y"	-58.9 ($10^6 m^3$)	
Irrigation Return Flow	35.0 ($10^6 m^3$)	
Total Inflow	**51.8 ($10^6 m^3$)**	
Outflow		
Evaporation from the Lake Surface	51.8 ($10^6 m^3$)	3,023 mm x 0.8 x 21.4 km^2
Total Outflow	**51.8 ($10^6 m^3$)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.18: Mean Annual Water Balance in the Lake Beseka with 35 MCM Return Flow

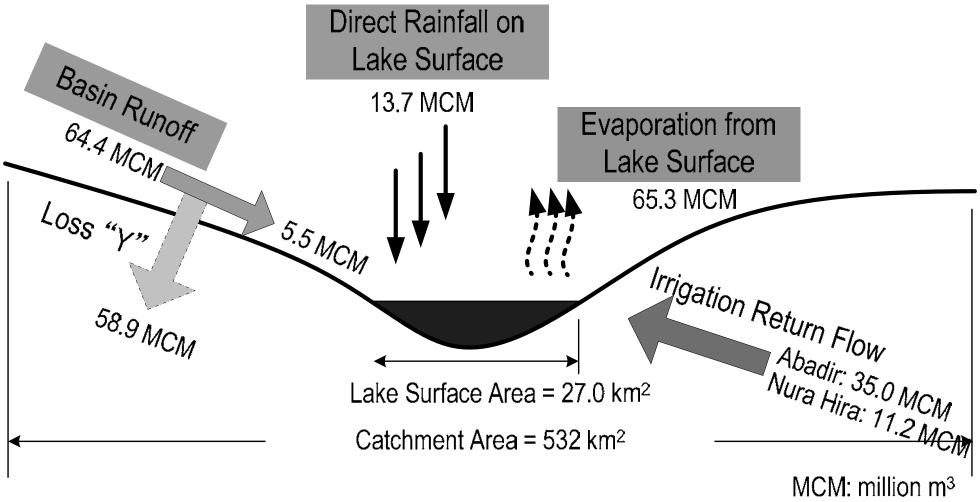
Previous surveys state that 11.2 million m^3 of return flow reached the Lake Beseka annually from Nura Hira farm during the period from 1977 to 1983. The calculated ELSA is 27.0 km^2 if the return flows from both Abadir and Nura Hira farms (46.2 million m^3 per annum in total) are taken into account.

Table 3.5.10: Mean Annual Water Balance in the Lake Beseka with 46.2 MCM Return Flow

Items	Area/Volume	Calculation / Remarks
ELSA	27.0 km^2	
Inflow		
Direct Rainfall on the Lake Surface	13.7 ($10^6 m^3$)	508 mm x 27.0 km^2
Runoff from the Lake Catchment	64.4 ($10^6 m^3$)	508 mm x 1.090 (532 km^2 – 27.0 km^2)$^{-0.236}$ x (532 km^2 – 27.0 km^2)
Loss "Y"	-58.9 ($10^6 m^3$)	
Irrigation Return Flow (Abadir)	35.0 ($10^6 m^3$)	

Items	Area/Volume	Calculation / Remarks
Irrigation Return Flow (Nura Hira)	11.2 (10^6m^3)	
Total Inflow	**65.3 (10^6m^3)**	
Outflow		
Evaporation from the Lake Surface	65.3 (10^6m^3)	3,023 mm x 0.8 x 27.0 km^2
Total Outflow	**65.3 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project



Source: the Project Team, Data: Result of hydrology survey in this Project

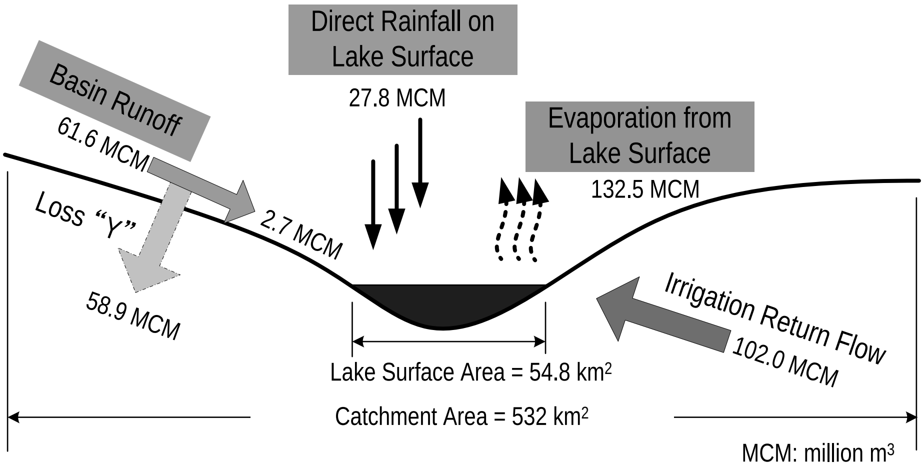
Figure 3.5.19: Mean Annual Water Balance in the Lake Beseka with 46.2 MCM Return Flow

Another extreme case is considered. In this case, all intake water of Abadir farm (102 million m^3 per annum, see b.2.1 above) is supposed to discharge into the Lake Beseka without any uses or losses. The result is provided in Table 3.5.11 and Figure 3.5.20 below:

Table 3.5.11: Mean Annual Water Balance in the Lake Beseka with 102 MCM Return Flow

Items	Area/Volume	Calculation / Remarks
ELSA	54.8 km^2	
Inflow		
Direct Rainfall on the Lake Surface	27.8 (10^6m^3)	508 mm x 54.8 km^2
Runoff from the Lake Catchment	61.6 (10^6m^3)	508 mm x 1.090 (532 km^2 – 54.8 km^2)$^{-0.236}$ x (532 km^2 – 54.8 km^2)
Loss "Y"	-58.9 (10^6m^3)	
Irrigation Return Flow	102.0 (10^6m^3)	
Total Inflow	**132.5 (10^6m^3)**	
Outflow		
Evaporation from the Lake Surface	132.5 (10^6m^3)	3,023 mm x 0.8 x 54.8 km^2
Total Outflow	**132.5 (10^6m^3)**	

Source: the Project Team, Data: Result of hydrology survey in this Project

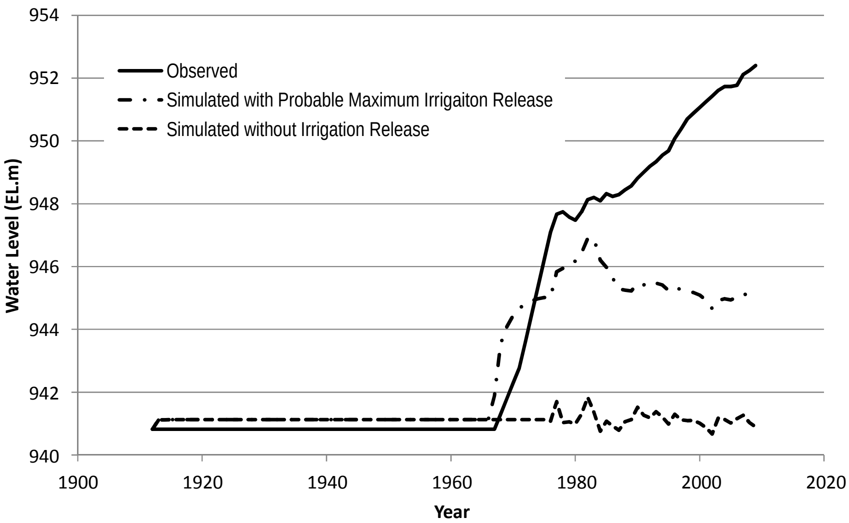


Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.20: Mean Annual Water Balance in the Lake Beseka with 102 MCM Return Flow

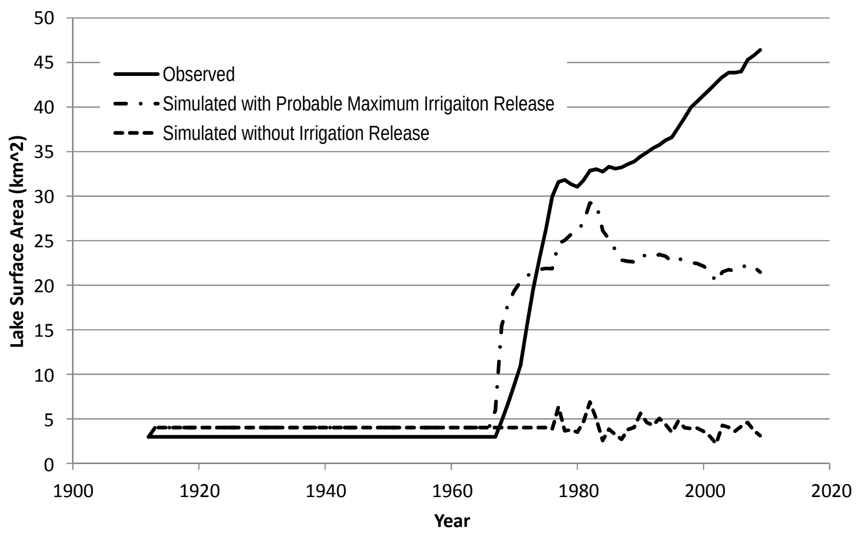
According to the above, possible maximum lake surface area would be around 20 km^2 in case with the return flow from Abadir farm. It would be around 27 km^2 even if the return flow from Nura Hira farm, which is actually no longer reaching the lake (as a result of the countermeasure works), is added. If the lake size of 50 km^2 is kept by the irrigation return flow, the required scale of the return flow is some 100 million m^3 per annum.

The following graphs show the historical changes of the water level and surface area of Lake Beseka assuming that all return flow from Abadir and Nura Hira farms discharge into the lake.



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.21: Simulated Time Series of the Lake Water Level with Irrigation Return Flow



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.22: Simulated Time Series of the Lake Surface Area with Irrigation Return Flow

The lake water level rose sharply after the start of the Abadir farm operation. The water level reached up to EL. 947 m (surface area: 30 km^2) in 1983 due to additional return flow from Nura Hira farm. The water level finally converged at around EL. 945 m (surface area: 23 km^2).

d. Discussions

The analyses made in this subsection 3.5.3 are summarized below:

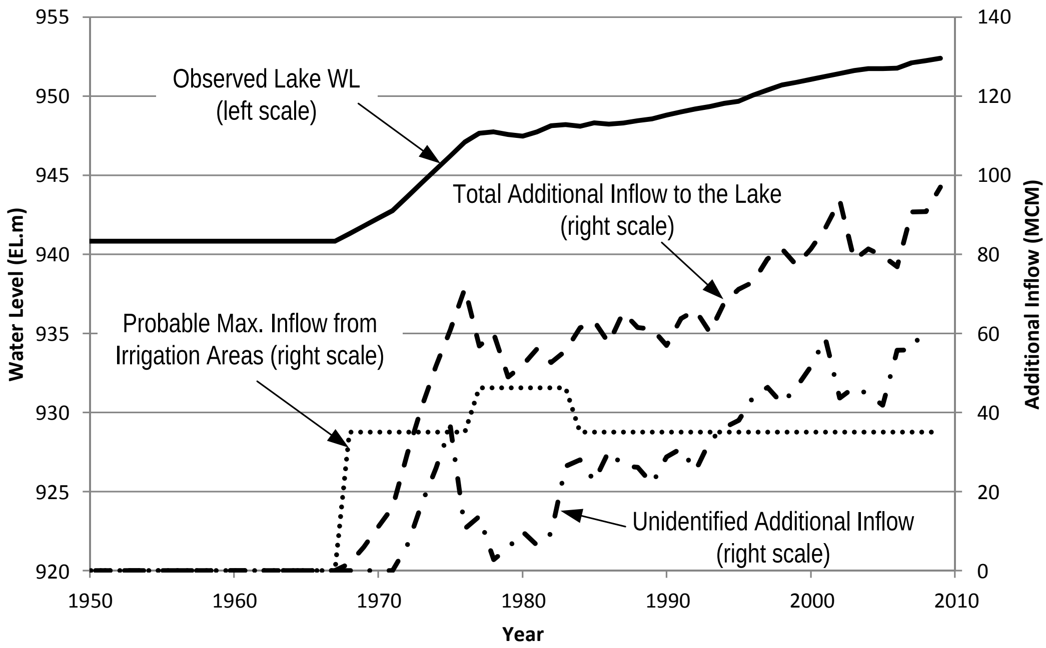
- The irrigation efficiency in Abadir farm is estimated based on 1) water intake record, 2) crop water requirement for sugarcane and 3) effective rainfall. The estimated efficiency is about 54% and this is high enough.
- The possible maximum return flow from Abadir farm is 35 million m^3 per annum. However, since this includes water losses which should actually occur before arriving to the Lake Beseka in the form of evaporation and so on, the actual annual return flow must be much smaller than 35 million m^3.
- The hydrological equilibrium state before 1960s, in which the Lake Beseka surface area was approx. 4 km^2, cannot be explained without considering 58.9 million m^3/year of loss “Y” from the basin in addition to the evaporation from the lake surface.
- Under the condition with loss “Y”, the possible maximum Lake Beseka surface area is around 20 km^2 with Abadir farm’s return flow. The area reaches up to 27 km^2 considering the Nura Hira farm’s return flow additionally. Regardless, these areas are far below the actually observed lake surface area of 50 km^2.

The following can be said from the above findings:

- Considering the fact that the timing of the Lake Beseka level rise coincides with that of commencements of large irrigation projects and water balance calculation results, we cannot conclude that there are definitely no effects by irrigation return flow on the Lake Beseka expansion.

- However, the expandable area due to return flow is limited far below the actual area, even if we introduce the extreme assumption in which all irrigation losses reach the lake and form the lake water.
- Other key factors besides irrigation return flow such as sudden decrease or disappearance of loss “Y”, sudden emergence of trans-basin flow from adjacent catchment, etc. shall be considered for explaining the expansion of Lake Beseka.

Figure 3.5.23 estimates the required additional inflow to the lake to explain the actual observed lake level rise after late 1960s. This strongly implies the existence of some kind of additional inflow (or decrease in loss “Y”) in an upward trend other than uniform irrigation return flow.



Source: the Project Team, Data: Result of hydrology survey in this Project

Figure 3.5.23: Annual Additional Inflow to the Lake required for Explanation of Actual Lake Rise

In terms of the countermeasures against irrigation return flow, the following points shall be kept in mind:

- It is not realistic to force Abadir farm to improve irrigation efficiency because the farm already has high efficiency.
- Countermeasures in Nura Hira farm have already been taken.
- It is not realistic to abandon the existing Abadir and Fentale irrigation projects.
- It is almost impossible to trap irrigation return flow before reaching the Lake Beseka because the flow shall pass through broad areas such as soil layers and shallow groundwater domains.

The most practical way to mitigate the influence of irrigation return flow is to install drainage facilities (eg. drainage pump, channel, etc.) in the Lake Beseka and strive, as far as possible, to release the same amount as there is incoming in the return flow. Possible maximum annual return flow is estimated as follows:

Abadir farm: 35 million m^3/year

All irrigation losses are assumed to become the lake water from the conservative view.

Fentale project: 91 million m^3/year

The return flow is estimated at a rate proportion to the area of Abadir farm in the Lake Beseka catchment (2,315 ha). The irrigation area of Fentale project in the Lake Beseka catchment is about 6,000 ha. So, the possible maximum annual return flow from Fentale project is 91 million m^3 (= 35 million m^3 x 6,000 ha / 2,315 ha)

The required drainage capacity is therefore 126 million m^3 per annum (4 m^3/sec). Drainage facilities from the Lake Beseka have been installed since 2004. According to the reconnaissance by the Project Team, the capacity of the existing drainage channel is at least 4.20 m^3/sec (= 7 m (width) x 1.2 m (depth) x 0.5 m/sec (velocity)). The existing drainage facilities therefore have sufficient capacity as the countermeasure against irrigation return flow.

3.6 Analyses on Groundwater Recharge and Movement for Lake Beseka Area

3.6.1 Return flow from the irrigation area

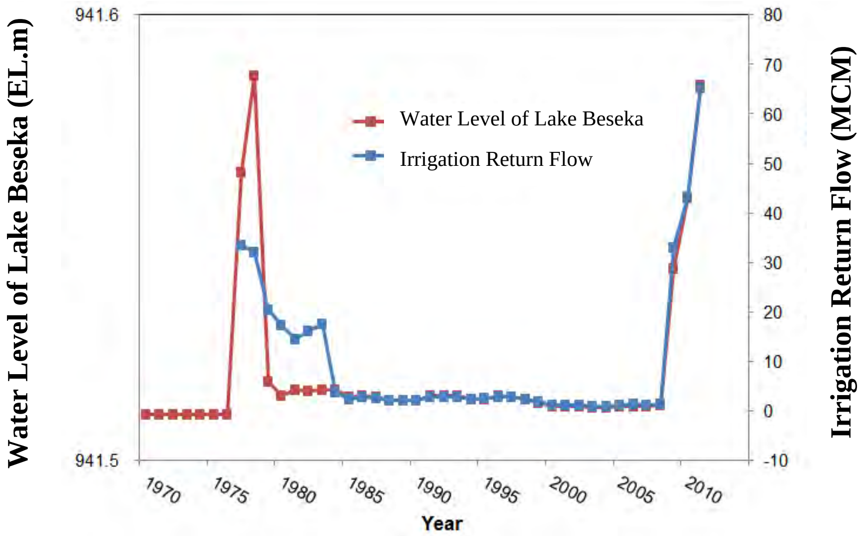
There are several factors which are believed to be the cause of water level rise of Lake Beseka including the inflow of the irrigation water from the sugarcane plantation farms which started from 1960’s. The possibility of the water level rise by the irrigation water has been considered using the model.

A data of return flow from the irrigation farms (excess water) into Lake Beseka from 1977 to 2011 prepared by MoWIE was applied for this model calculation.

After the calculation of the recharge amount in each farm, the groundwater model was calculated with the three criteria listed below.

3.6.2 The result of 1st analysis (criteria)

Figure 3.6.1 shows the analysis results of the first criteria. The fluctuation of the water level in Lake Beseka seems to match the fluctuation in the irrigation farms.



Source: the Project Team

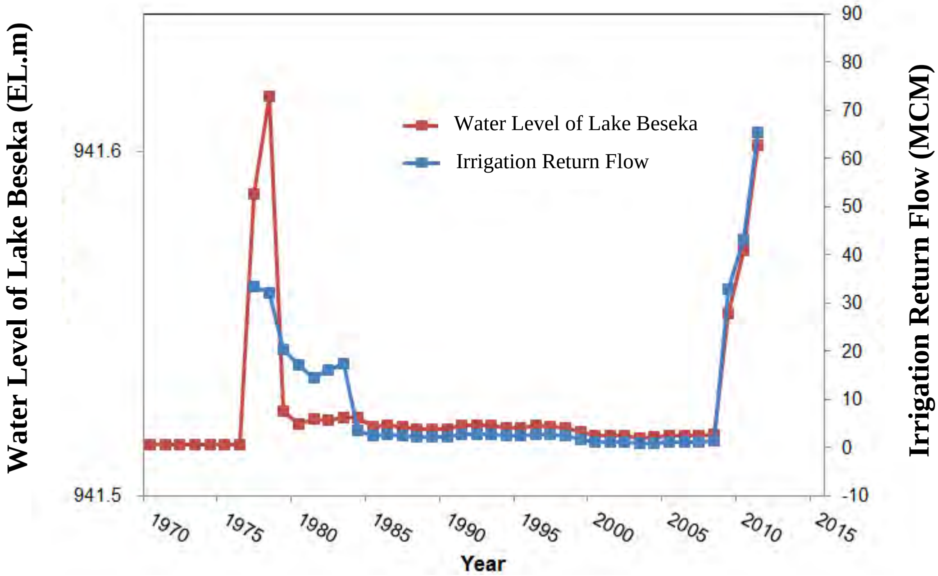
Figure 3.6.1: Results of Irrigation Return Flow and Water Level (50% of Irrigation Return Flow)

The largest increase in water level was seen in 1978 which matches the maximum return flow period of Abadir farm (0.026 m higher than the initial water level). On the other hand, the minimum increase in water level was seen in 2003 which assumed to be caused by return flow from the Abadir farm only (0.005 m higher than the initial water level).

3.6.3 The result of 2nd analysis (criteria)

The analysis results of the second criteria (same recharge amount with the estimated irrigation return flow) is shown in Figure 3.6.2.

The trend of the water level seems to be the same as the result of the first analysis where the fluctuation is dominated by the return flow of irrigation farms. The largest increase in water level was seen in 1978 where the water level was 0.05 m higher than the initial water level. This is two times of the result calculated in the first analysis (the return flow amount was 50% in the first analysis). The minimum increase in water level was seen in 2003 (same as the first analysis) where the water level is 0.0009 m higher than the initial water level.



Source: the Project Team

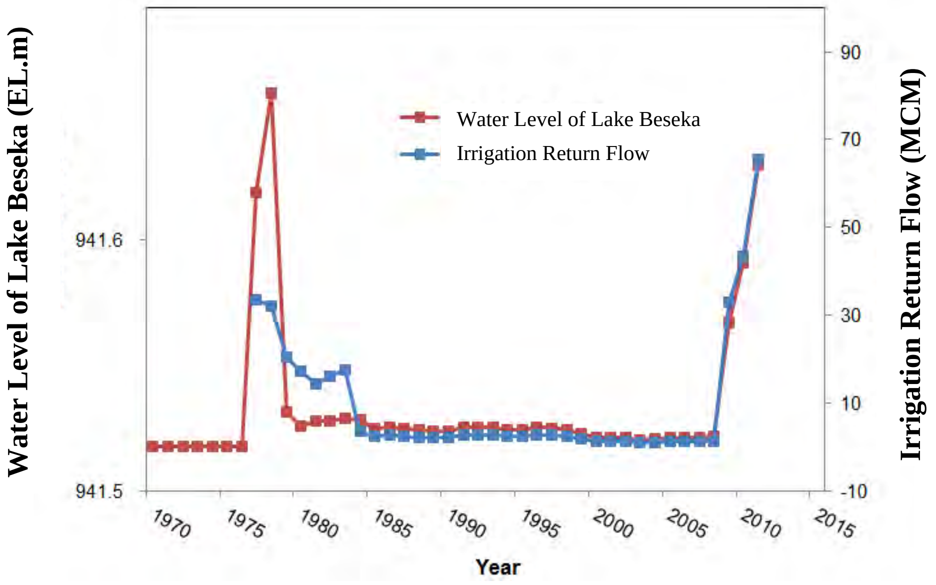
Figure 3.6.2: Result of Irrigation Return Flow and Water Level (Equal to the Irrigation Return Flow)

3.6.4 The result of 3rd analysis (Criteria)

The analysis result of the third criteria (estimated irrigation return flow is set as double that of the 2nd analysis) is shown in Figure 3.6.3.

The trend of the water level seems to be the same as the result of the first and second analysis where the fluctuation is dominated by the return flow of irrigation farms. The largest increase in water level was seen in 1978 where the water level was 0.1 m higher than the initial water level. The minimum increase in water level was seen in 2003 where the water level 0.0018 m higher than the initial water level. These values are double the results of the second analysis and four times higher than the first analysis.

Judging from the results of the abovementioned groundwater model analysis, it seems the return flow of the irrigation water is hardly affecting the rise of the water level in Lake Beseka. The water level could rise only 0.1 m even though the return flow of the irrigation water is set to be twice as high as that of the groundwater model. This means that the irrigation water can hardly be considered as the main reason for the rise in water level at Lake Beseka.

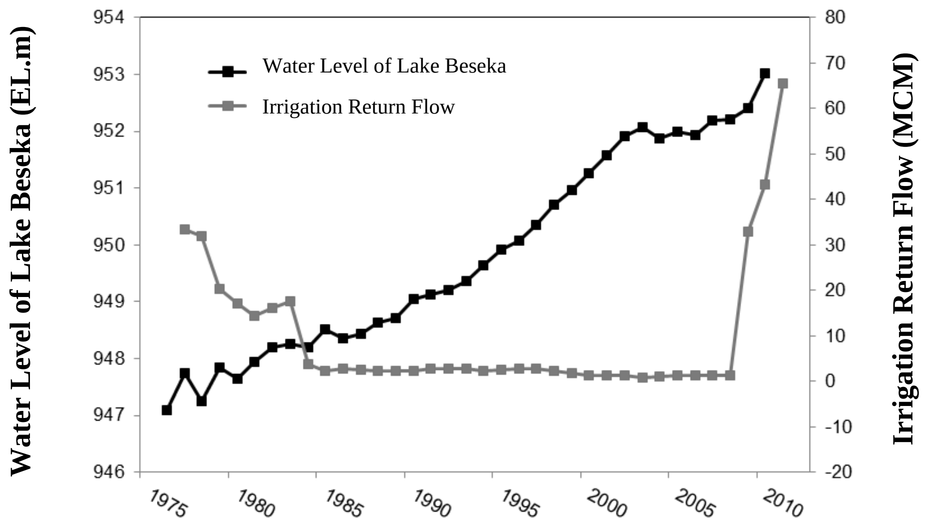


Source: the Project Team

Figure 3.6.3: Result of Irrigation Return Flow and Water Level (Double of Irrigation Return Flow)

3.6.5 Comparison between the irrigation return flow and water level rise in Lake Beseka

Figure 3.6.4 shows the comparison of the water level at Lake Beseka and irrigation return flow.



Source: the Project Team

Figure 3.6.4: Comparison of the Water Level at Lake Beseka and Irrigation Return Flow

As shown in the analysis results by the groundwater model, the water level of Lake Beseka is dominated by the irrigation return flow, which means the irrigation return flow does somehow affect the fluctuation of water level in Lake Beseka.

However, as shown in Figure 3.6.4, no matter how much the irrigation return flow is reduced or maintained, the water level of the lake will keep increasing. From 1984 to 2008, the irrigation return flow was only confirmed only at the Abadir farm which is located at the south of the Lake Beseka. The maximum return flow was 2.8 MCM, the minimum return flow was 0.9 MCM and the average was 2.0 MCM. The analysis result by the groundwater model shows that the water level has decreased.

On the other hand, the data of MoWIE shows the increase of the water level where the water level was increase at least 4.98 m in 2003. From the groundwater model, there is no increase of the water level of Lake Beseka even though there is a return flow from the irrigation. The results of three criterions shows that the water level is 0.0018 m (maximum), 0.00009 m (intermediate) and 0.0005 m (minimum) higher than the initial water level. This shows that there is not much difference from the initial water level. Based on the groundwater model analysis, the return flow from the irrigation does not much affect the rise in the water level of Lake Beseka, which means there is a possibility of other factors causing the water level rise monitored by MoWIE.

3.7 Discussions

Results of the surveys and analyses on topography, geology, geological structures and hydrogeology are reported in this chapter. In addition to these, i) analysis on surface temperature of the Lake Beseka, ii) water quality analysis for water samples in and around the Lake Beseka, and iii) water balance analysis with estimated irrigation return flow are undertaken in order to validate the rationality of widely recognized cause of the Lake Beseka expansion, i.e. excess irrigation water.

Temperature analyses based on the infrared data of Landsat images suggest the continuous rise of the lake surface temperature. This strongly implies the continuous inflow of high-temperature spring water from western or southwestern side of the Lake Beseka Basin as the cause of Lake Beseka expansion rather than intrusion of excess irrigation water.

Water quality analysis in and around the Lake Beseka revealed that the current water quality of the lake, classified into $NaHCO_3$ or Na_2SO_4/NaCl type, is very similar to those of surrounding groundwater and springs, mainly classified into $NaHCO_3$ type. In view of chemical evolution, the lake water has clearly evolved from spring water and no effects of river water (irrigation water) are found. The trace of intrusion of irrigation water (or Awash River water) can be found from the slightly detected calcium ion only in the southern shore where the Lake Beseka faces the Abadir farm. This result also suggests the importance of other factors for explanation of the lake expansion than irrigation return flow.

The irrigation efficiency in Abadir farm is high enough in accordance with the FAO’s standard, and the farm has practiced effective irrigation. On the other hand, as long as the irrigation projects in the Lake Beseka Basin involve water transmission from outside of the basin, the return flow theoretically contributes to the lake expansion. The water balance analysis is undertaken to see whether or not the return flow from the irrigation projects developed in late 1960s can explain the lake expansion without contradiction. The result shows that the lake surface area cannot reach up to currently observed level even if the possible maximum return flow is applied with extreme assumptions.

Based on the above results, the Project Team considers the process of expansion of Lake Beseka as follows:

- The scale of Lake Beseka has remained stable with a surface area of around 4 km^2 until the 1960s.
- The groundwater inflow to the lake began to increase after the late 1960s.
- The lake water level sharply rose due to groundwater inflow promoted by the return flow from the irrigation projects which were developed around the same time.
- The amount of groundwater inflow to the lake has been in upward trend year after year making the lake the current size.
- The source of the groundwater inflow is the same as that of hot springs in the western and southwestern shores of the lake because the lake surface temperature is in upward trend.

Since the following points are difficult to evaluate, further scientific investigations are expected.

- What triggered the increase in groundwater inflow since the late 1960s?
- To what extent the groundwater inflow will eventually increase? Will it be in static condition or it will turn into a downward trend?

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3) Allaidege plain groundwater resources assessment project, WWDSE planned by MoWR, 2009
4) Study and design of Lake Besaka level rise project II, WWDSE, planned by MoWE, 2011
5) Growing lake with growing problems: integrated hydrogeological investigation on Lake Beseka, Ethiopia, ELENI AYALEW BELAY, 2009
6) Assessment and evaluation of causes for Beseka Lake level rise and design mitigation measures Part II: Study for medium and long term solutions (Main report final), MoWIE and OWWDSE, 2014

② Well development records, borehole logs and pumping test results

1) Existing well data (incl. borehole logs and pumping test results) from West Hararge Zone Water Office
2) Existing well data (incl. borehole logs and pumping test results) from Arsi Zone Water Office
3) Existing well data (incl. borehole logs and pumping test results) from East Shewa Zone Water Office
4) Well development records and individual well data in Arerti Woreda (Amhara Region) and Lomme Woreda (Oromia Region)
5) Data from irrigation well by WWDSE, 2014 (depth: 595 m)

③ Others

1) Hydrogeological map of Ethiopia (1:2,000,000) compiled by Tesfaye Chernet and the Regional Geology Department, EIGS, 1988

④ Data including photographs taken by the Project Team though field survey, analysis and interviews etc.

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⑦ Irrigation Water Management: Irrigation Scheduling, 1989 (http://www.fao.org/docrep/t7202e/t7202e00.htm#Contents)

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⑨ Manual for CROPWAT version 5.2. FAO, Rome. 45pp.

⑩ Growing Lake with Growing Problems: Integrated Hydrogeological Investigation on Lake Beseka, Ethiopia, Eleni Ayalew Belay, 2009

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Chapter 4

Groundwater Potential

4 Groundwater Potential

4.1 Introduction

Groundwater recharge in the middle Awash River basin was calculated using the amount of rainfall, runoff coefficient of river and basic flow index. The groundwater recharge is a basic and useful value for groundwater usage. The groundwater potential of the middle Awash River Basin is high. It is possible to use groundwater from now due to the high amount of the groundwater recharge compared with the current groundwater usage. However, even if there is a sufficient supply of groundwater in the middle Awash River basin, it is necessary to evaluate aquifer potential to know how much groundwater can be used. Therefore the productivity of the groundwater in each aquifer was evaluated using the yield and specific capacity worked out by the pumping tests. And the water quality of groundwater was evaluated for not only quantity, but also quality.

4.2 Groundwater potential

4.2.1 Aquifer classification and characteristics

Table 4.2.1 shows the hydrogeological aspects of the aquifer and the basic quantitative values. The volcanic deposits consisting of tuff rings including scoria cones, marl and volcanic bodies in the small area were excluded.

Table 4.2.1: Aquifer Unit Classification and Characteristics

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
Quaternary Pleistocene -Holocene	Holocene deposits	Qal (including Lacustrine deposits)	• Along the Awash River, alluvial sediment covers a small area. • The Alluvium around Lake Beseka consists of sand, mud and gravel, and the thickness of alluvium reaches about 11-40m. Most of the boreholes in these areas have yield from 3 to 7L/sec. • The lacustrine sediment distributes widely in the Wonji, Debre Zeit, Mojo, Koka and Nazret areas. This sediment is about 50m thick in the Wonji area, and mainly consists of gravel and sand. • In the Wonji area, the yield of the borehole ranges from 1 to 7L/sec. • In northeast of Debre Zeit, the lacustrine sediment which has a thickness of more than 60m (maximum), is composed of coarse sand with pebbles. The average value of specific capacity is 0.4 to 1.1L/sec/m.
	Recent Basalts	Qb2	• They are products of fissure eruption and are highly vesicular, and can store an appreciable quantity (amount) of groundwater. • They are considered to have a high permeability. • However it is difficult to predict whether or not an impermeable layer exists below.

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
	Fentale Ignimbrite/Kone Ignimbrite	Qi3/Qi2	• “Fentale Group of Ignimbrites (Qwi2)” shows different hydrogeological characteristics in different areas. • To the west and south of the Fentale volcano, this welded tuff is greyish green, fresh, columnar jointed with blisters and crevasses. So these fractures act as groundwater conducts, some existing boreholes have a yield of 7L/sec. Such layers in this area have high permeability. • On the other hand, east and northeast (behind Awash town) of the Fentale volcano, the same group is highly weathered and joints are filled with clay materials. An existing well drilled up to 200m in a valley was found to be dry. In this area, these layers are considered to have low permeability. • On the whole, the average of the yield is 6L/sec, and of the specific capacity is 3L/sec/m, the results indicates the middle permeability.
	Pleistocene Basalts	Qb1	• They are vertically and horizontally jointed. • Drawdown is small by the existing borehole and specific capacity is more than 7L/sec/m in some areas. Other yields are 1.4 and 1.6L/sec respectively. • The basalt layer occurs at 50m to 70m depth of the existing wells around Lake Beseka. The record of yield is sparse, but there are partial records of 8 to 12L/sec. • Therefore, these groups of basalt are considered to have moderate permeability.
	Chefe Donsa pyroclastic deposits	Qp1	• “Unwelded Rhyolitic Pumice and Unwelded Tiffs (Qwpu)” corresponding to W shows rhyolitic pumice and un-welded tuffs interbedded with clay. • The clay beds have reduced its permeability, so it is considered to have low permeability. • The yield is 1 to 5L/sec, and the average of the specific capacity is 4 L/sec/m.
	Dino Ignimbrite	Qi1	• “Dino Ignimbrites (Qwi)”corresponded to this layer are jointed and faulted. • The average of specific capacity of the existing well gives 2.2L/sec/m. It is grouped as moderately permeable formation. The average of the yield indicates more than 6L/sec. • The JICA well correlates to this horizon, but the screen position is below this horizon.
Tertiary Pliocene	Bofa basalts	Tb3	• Columnar jointing is very well developed with openings of 2-3cm joints and a distance of 1m between joints in the outcrop.

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
			• In the Bofa area, the depth to groundwater is more than 100m due to the deep nature of the vertical joints. And most of the precipitation infiltrates into the groundwater. • About eight kilometers southeast of Bishoftu, a borehole drilled on the Bofa basalt gives an appreciable quantity of water at a depth of 36m. • The JICA well correlates to this horizon, and yield is 4.4 to 11L/sec and the specific capacity is 0.15 to 9L/sec/m. • In general Bofa basalts are expected to have high to medium permeability.
	Lower and upper Nazret Pyroclastic deposits	Ti3/Ti2	• "Nazret Group of Ignimbrites (Nn)" shows variable permeability in different areas. • Geology consists of Ignimbrites, welded tuffs, ash flows, rhyolites and tuffs. • The group to the northeast of Melka Jilo and north of Kone Caldera is jointed and faulted and a borehole drilled in this formation has a yield of 6.7L/sec. In this area, these groups have high permeability. • In the Koka area, the strata are composed of pyroclastics containing tuffs with silt and silty sands and is jointed and faulted. However, there is no information on the yield of borehole(s). Thermal springs near points have a discharge of 38 - 798L/sec. • The average yield is 15L/sec as a whole, specific capacity is more than 2L/sec/m. There are highly productive areas in the Study area. • In the other areas, they predominantly consist of ash flow and tuff, and bore holes drilled in this formation have low yields according to the information.
	Pliocene rhyolite	Tr2	• Tr2 consists of older alkaline and peralkaline rhyolite domes and flows • They are generally grouped as formations of middle permeability by fractured aspects.
Tertiary Miocene	Anchar Basalt	Tb2	• It consists of basalts interbedded with tuff • Basalt layers occur without tuff interbeds (in the valley of Cherora), Nine can have high permeability. • Yield is 6 to 8L/sec in the West Hararge area. • However, in most places, as it occurs interbedded with tuff which lowers its permeability, it is grouped as a moderately permeable formation, but high permeability is shown in the fracture zone. • The average of the yield is 9L/sec and of the specific capacity is 3.8L/sec/m
	Alaji Basalt	Tb1	• It is vesicular at the top, flow banded in the middle and massive at the bottom.

Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
			• It is faulted, however in some places, it is found interbedded with red paleosoil beds which reduce its permeability. Some springs with discharge of up to 2.7L/sec emerge from the contact of the basalt and the red beds. • So this basalt is grouped as a moderate aquifer, but high permeability is shown in the fracture zone. The average yield is 16L/sec as a whole, specific capacity is 2.7L/sec/m. There are highly productive areas in Study area. • The existing wells in the northwest area of Mojo obtain the yield of 37 to 60L/sec in the wells of the 300m to 380m in depth.

Source: the Project Team, Data: reference 1) of ①, ②

4.2.2 Evaluation of aquifer potential

Three (3) types of aquifers were identified by the study of the existing well inventory, new borehole data and the geological survey.

1) Alluvium and lacustrine deposits

2) Quaternary Pleistocene tuff, and welded tuff and basalt

3) Tertiary Pliocene, Miocene tuff, and welded tuff and basalt

Aquifer and productivity classifications are carried out and shown in Table 4.2.2 below by the geological classification in the project area in consideration with the aquifer classification using the geological divisions for the whole area of Ethiopia.

Table 4.2.2: Modified Hydrogeological Map - Aquifer Classifications and Definitions

No.	Description	Lithology	Productivity Classes	
1	Extensive aquifers with intergranular permeability	Unconsolidated sediments, alluvium, elluvium, colluvium, lacustrine sediments, poorly cemented sandstone	A	High
			B	Moderate
			C	Low
3	Extensive aquifers with fracture permeability	Volcanic rocks, basalts, rhyolites, trachyte, ignimbrites	A	High
			B	Moderate
			C	Low
5	Main geothermal areas	Common occurrence of thermal groundwater in fractured volcanic rocks and subordinate unconsolidated sediments	No classes	

Source: GSE, 1988 (reference 2) of ③), modified partly

Each aquifer and strata are classified by Table 4.2.2 based on the geological stratigraphy in the project area. The productivity is also classified by the yield and specific capacity calculated by the pumping test. The yield in the project area can be divided into the values below on the whole.

A: High yield (equal to or more than 10 L/sec)

B: Middle yield (5 L/sec to less than 10 L/sec)

C: Low yield (less than 5 L/sec)

The specific capacity related to the pump capacities in the project area can be divided into the values below.

A: High specific capacity (equal to or more than 4 L/sec/m)

B: Middle specific capacity (2 L/sec/m to less than 4 L/sec)

C: Low specific capacity (less than 2 L/sec/m)

The evaluation of productivity is carried out by a combination of both of the above (specific capacity and yield). In addition, the transmissibility is treated as a reference because of the lack of data. Table 4.2.3 below shows the aquifer classification and information of the existing wells and JICA wells.

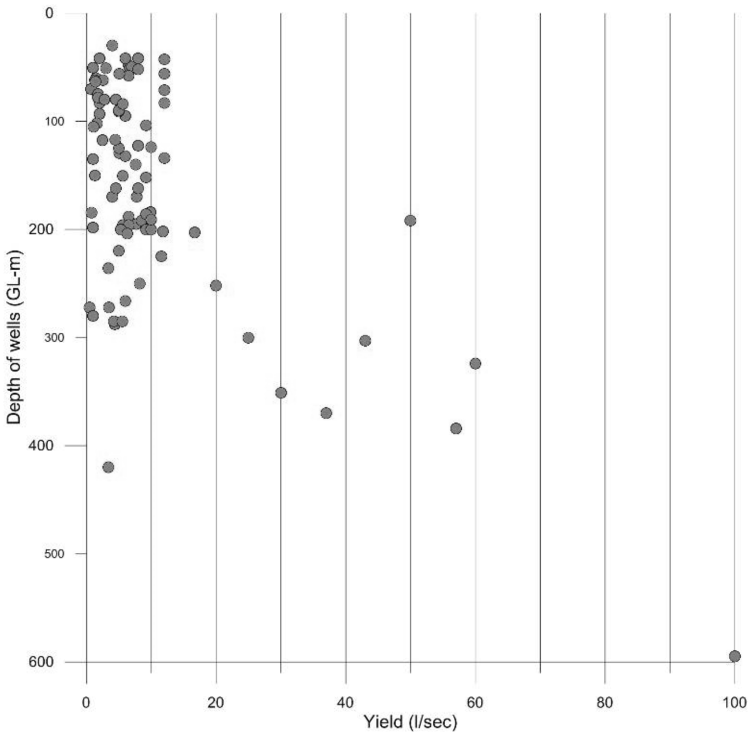
Table 4.2.3: Aquifer Parameters and Units of Existing Wells and JICA Wells

	Aquifer	Symbol	Main lithology	Q(l/sec)			Specific Capacity (l/sec/m)			Transmissivity (m^2/day)		
				AVE	MAX	MIN	AVE	MAX	MIN	AVE	MAX	MIN
1	Alluvium and Lacustrine deposits	Qal (including Lc)	fine sand, clay	5.2	6.5	3.0	1.1	1.1	1.1	966.0	966.0	966.0
			gravel, mud	3.3	6.5	0.8	0.4	0.8	0.1	-	-	-
2	Quaternary Pleistocene Tuff, Welded tuff and Basalt	Qi3/Qi2	Strongly and consolidated welded tuff,	5.7	7.0	4.7	3.1	3.1	3.1	501.0	996.2	60.4
		Qb1	Aphyric basalt	7.4	12.0	1.4	3.2	8.7	1.2	189.2	189.2	189.2
		Qp1	Pumice & tuff intercalated with poorly welded tuff	2.2	5.0	1.0	4.4	7.1	1.6	-	-	-
		Qr1	Rhyolite	5.3	9.2	1.8	1.9	2.2	1.9	102.7	171.0	34.4
		Qi1	Greenish grey welded tuff	6.2	16.7	1.3	2.2	9.4	0.1	284.8	1044.0	0.1
3	Tertiary Pliocene, Miocene Tuff, Welded Tuff and Basalt	Tb3	Aphyric basalt	7.0	11.1	4.4	3.3	9.3	0.2	33.7	107.0	0.0
		Ti3/Ti2	Welded tuff, pumice and tuff	15.4	57.0	0.5	2.3	6.8	0.0	337.9	1230.0	0.5
		Tb2	Aphyric basalt	9.0	20.0	4.5	3.8	7.1	0.5	102.4	102.4	102.4
		Tb1	Porous plagioclase aphyric basalt	13.2	60.0	3.5	5.9	8.1	0.1	287.4	1150.0	0.0

Source: the Project Team, Data: reference ①, ② The aquifer units are classified in accordance with the geological stratigraphy in the project area and each aquifer can be divided into the Ethiopian aquifer units modified as shown in Table 4.2.2. Table 4.2.4 includes the evaluation of aquifer potential in reference to the aquifer information of Table 4.2.3. The hydrogeological map is created based on these evaluations.

The concrete samples of the aquifer potential in the project area are mainly described as follows:

- The relationship between the yield and the drilling depth in the Project area is shown in Figure 4.2.1. Figure 4.2.1 shows that many of the wells in the Project area have a drilling depth between 250 and 300m, and many yields are less than 10L/sec (including JICA wells) regardless of the drilling depth. It is possible to obtain a yield of more than 20L/sec when the wells reach 300m or deeper in Tertiary Pliocene welded tuff and Miocene basalt. These areas are located in and around the ArertI area of the Amhara Region, and in the area from the northwest Mojo to Debre Zeit.



Source: the Project Team, Data: reference ①, ②

Figure 4.2.1: Relationship between Well Depth and Yield in Project Area

- Well depth can be correlated with the groundwater table (hydraulic head) in the basalt and acidic volcanic rock called ignimbrite. These strata appear frequently in the aquifers in which the wells of the project area are located. In cases where the drilling depth reaches more than 400m and the groundwater level is deeper than 200m, the yield is 3.4L/sec, similar to the wells of the small watershed at Dera area. JICA well was drilled up to 270m deep in the Tertiary basalt in the lowland of the Rift Valley along the Awash River. The hydraulic head is 140m deep as a confined aquifer, and yield was 3.5L/sec. On the other hand, the wells that are deeper than 300 m and have a yield of more than 40 L/sec indicate a hydraulic head of from 7 to 50m (refer to Figure 4.2.1).

- Stepped structure affected by the faults in the tectonic activities is formed in fractured and cracked basalts along the escarpment of Rift Valley ridge. In that case, the fractures and cracks play an important role in obtaining yield. One of the JICA wells was located in the midway area into the discharge area from the Rift Valley ridge. This well was drilled up to 250m deep and reached the lowest horizon of basalt, but the result of the drilling was dry due to the non-fractured basalt. Despite drilling to 250m, the low hydraulic head meant it would be too difficult to obtain water from this well.

- On the other hand, in the West Hararge zone, located in the Rift Valley ridge, the Tertiary basalt occurs at a relatively shallow depth, therefore for example, the groundwater of 5L/sec yield by drilling about 150m deep can be secured.

- It is difficult to utilize the groundwater with water quality issues even if the groundwater has high potential. As mentioned in Chapter 2, high concentration areas of fluoride can be seen in the direction from ENE to WSW in the central watershed of the project area. In particular, there were many wells with fluoride concentrations of more than 10mg/l around Lake Beseka and Lake Koka. As before, the deeper the depth of drilling, the lower concentration of fluoride in general. However, no matter the depth of wells drilled around Lake Beseka the fluoride concentration exceeded the Ethiopian standard.

Table 4.2.4: Aquifer Classification and Productivity

Age			Area: Nazret-Mt.Boseti	Area: Kone-Mt.Fantale	Area: Mojo-Arerti-Debre Birhan	Area: Awash-Asebe Teferi	Area: Lake Besaka (1:100,000)	This study	Aquifer Units of Ethiopia	Productivity Level
Cainozoic	Quarternary	Holocene	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium (Qa)	Alluvium (Qal)	1	C
			Recent rhyolitic domes & lava flows	Recent rhyolitic domes & lava flows				Recent rhyolitic domes & lava flows (Qr2)	5	–
			Holocene basalts	Holocene basalts			Holocene basalts (Qb2)	Holocene basalts (Qb2)	3	C
		Pleistocene basalt	Fantale ignimbrites	Fantale ignimbrites	Fantale ignimbrites	Fantale ignimbrites	Fentale ignimbrites (Qi3)	Fentale ignimbrites (Qi3)	3	B
				Fantale volcanic rocks			Fentale volcanic rocks (Qf)	Fentale volcanic rocks (Qf)	3	C
			Boseti pumice falls	Kone pumice falls	Boseti pumice falls			Boseti & Kone pumice falls (Qp2)	1	C
				Kone ignimbrites		Asebot welded tuffs	Kone ignimbrites (Qi2)	Kone ignimbrites (Qi2)	3	B
			Pleistocene basalts	Pleistocene basalts	Pleistocene basalt	Dofan basalt	Pleistocene basalts (Qb1)	Pleistocene basalts (Qb1)	3	B
				Tuff ring deposits	Maar deposits		Sobebor volcanic sand beds (Qs)	Sobebor volcanic sand beds (Qs)	5	–
					Zikwala Trachytes			Zikwala Trachytes (Qt)	3	C
			Chefe Donsa pyroclastic deposits		Chefe Donsa pyroclastic deposits	Awash Arba Volcano-sedimentary rocks		Chefe Donsa pyroclastic deposits (Qp1)	1	B
			Pleistocene rhyolites					Pleistocene rhyolites (Qr1)	3	C
			Dino ignimbrites	Dino ignimbrites	Dino ignimbrites	Dino ignimbrites	Dino ignimbrites (Qi1)	Dino ignimbrites (Qi1)	3	B
	Tertiary	Pliocene	Bofa basalt	Bofa basalts	Tulu Rie basalts	Bofa basalt	Nuea Hira basalts (Tb)	Bofa basalts (Tb3)	3	B
			Chilalo Trachybasalts					Chilalo Trachybasalts (Tt)	3	B
			Nazret pyroclastic deposits: Upper		Nazret pyroclastic deposits: Upper		Old ignimbrites (Ti)	Upper Nazret pyroclastic deposit (Ti3)	3	A
			Nazret pyroclastic deposits: Lower		Nazret pyroclastic deposits: Lower	Adele rhyolitic tuffs		Lower Nazret pyroclastic deposits (Ti2)	3	A
			Chefeko rhyolites	Birenti-Hada rhyolites	Mt. Bokan rhyolites	Gara Gumbi rhyolites	Birenti-Hada rhyolites (Tr)	Pliocene rhyolites (Tr2)	3	B
		Miocene			Tarmaber-Megezeze basalts	Anchar basalts		Anchar basalts (Tb2)	3	B
					Debre Birhan ignimbrites			Debre Birhan ignimbrites (Ti1)	3	C
						Huse Ridge rhyolites		Huse Ridge rhyolites (Tr1)	3	C
			Alaji basalts		Kesem basalts	Alaji basalts		Alaji basalts (Tb1)	3	A

Source: the Project Team, Data: reference ④

4.2.3 Groundwater recharge and yield

The middle Awash river basin is divided into thirteen sub-basins, and the basic flow (groundwater recharge) was estimated using the annual rainfall, run-off coefficient of river and basic flow index in the sub-basins (refer to Table 4.2.5). Figure 4.2.2 includes sub-basins with the annual mean groundwater recharge (x $10^6 m^3$/year), target small towns and model existing well points.

Table 4.2.5: Result of Groundwater Recharge Estimation by Sub-basins

SL No.	Sub-basin	Area (A) [km^2]	Annual Rainfall (R) [mm/yr]	Runoff Coefficient (C) [-]	Base Flow Index (BFI) [-]	Annual Groundwater Recharge (GWR) [mm/yr]	Annual Groundwater Recharge (GWR) [$10^6 m^3$/yr]	GWR/R [%]
1	SB1-L	2,068	1,097	0.18	0.44	87.2	180.3	7.9%
2	SB1-R	2,508	1,075	0.17	0.46	84.4	211.6	7.8%
3	SB2-L	4,860	982	0.15	0.51	73.7	358.4	7.5%
4	SB2-R	1,859	867	0.18	0.43	69.4	129.0	8.0%
5	SB3-L	508	853	0.25	0.35	74.4	37.8	8.7%
6	SB3-R	2,743	832	0.17	0.46	64.9	178.1	7.8%
7	SB4-L-U	435	824	0.26	0.34	72.5	31.6	8.8%
8	SB4-L-D	312	548	0.28	0.32	49.3	15.4	9.0%
9	SB4-R	3,367	806	0.16	0.48	62.0	208.8	7.7%
10	SB5-L	5,710	779	0.14	0.53	57.9	330.8	7.4%
11	SB5-R	2,347	870	0.17	0.45	68.6	161.0	7.9%
12	SB-BSK-W	2,041	740	0.18	0.44	58.9	120.2	8.0%
13	SB-BSK	532	548	0.25	0.35	47.6	25.3	8.7%
All Basin		29,290	876	-	-	67.9	1,988.3	7.7%

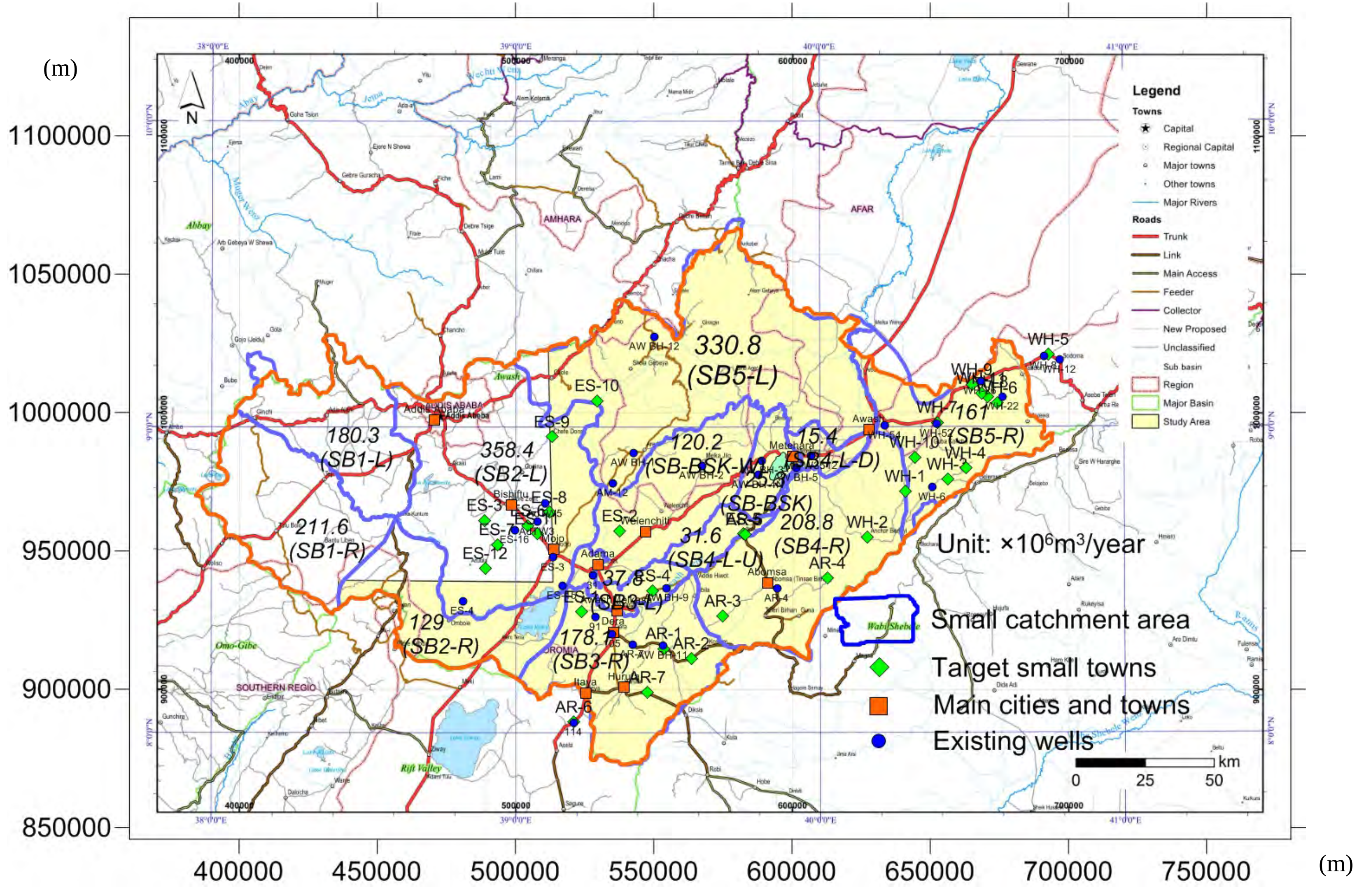
Source: the Project Team, Data: Result of hydrology survey in this Project

A comparison was made between the groundwater recharge value in the each sub-basin and the estimated groundwater usage as of 2035 calculated by adding estimated groundwater pumping volumes for 2035 for estimates (by estimating water usage demand using 2035 population projections based on current pumping volume data) for the main medium to large cities and planned pumping volumes (based on an assumption of maximum water usage of the estimated water demand in 2035 using a maximum daily per capita water demand unit of 50L/c/day) in the small towns in the target area. The main medium to large cities are Addis Ababa, Bishoftu (old name: Debre Zeit), Mojo, Adama (old name: Nazret), Huruta, Itaya, Welenchiti, Dera, Awash Melkasa, Abomsa, Metehara and Awash. However, as Adama, Metehara and Awash are using surface water and Hurta, Itaya, Welenchiti, Dera and Awash Melkasa are using the spring water, therefore the values from such towns and cities were excluded from the abovementioned calculation of estimated groundwater pumping volumes for 2035.

Further, the water usage volume as of 2035 is calculated (based on the assumption that representative existing wells are continuously used until 2035) by multiplying the current pumping volume by the estimated population growth rate (approx. 2.23 times that of 2015) of neighboring target small towns.

The ratio between the groundwater recharge and yield (well pumping capacity) is shown in Table 4.2.6 as approximately 1 to 5% in the major sub-basins for which data was obtained. Therefore, it is considered that groundwater wells drilled in these sub-basins will produce a sufficient pumping yield, as shown in the results of Table 4.2.6.

The ratio between the groundwater recharge and yield in the SB2-L sub-basin shows more than 35%, because a large city, Addis Ababa, and medium-sized towns, Bishoftu and Moji which have large yields are included in this sub-basin, as shown in Figure 4.2.2. Although the yield of the existing well in SB4-L-D is very large (yield: 100L/sec), the area of the sub-basin is narrow and has low recharge of groundwater. So the ratio is about 45% in the SB4-L-D.



Source: the Project Team, Data: reference ④

Figure 4.2.2: Location Map of Sub-Basin, Small Towns and Model Existing Wells

Table 4.2.6: Ratio between Groundwater Recharge and Yield

Sub-Basin	Yield in big and middle towns (Estimation as of 2035) (Y1) [$10^6 m^3$/year]	Yield in target small towns (Estimation as of 2035) (Y2) [$10^6 m^3$/year]	Yield in model existing wells (Estimation as of 2035) (Y3) [$10^6 m^3$/year]	Amount of total yield [$10^6 m^3$/year] (Y=Y1+Y2+Y3)	Groundwater recharge(GWR) [10^6 m^3/year]	Y/GWR [%]
SB2-L	120.90	2.25	11.0	134.15	358.4	37.4
SB3-L	-	0.25	0.42	0.67	37.8	1.8
SB3-R	-	1.65	1.49	3.14	178.1	1.8
SB4-L-U	-	0.32	-	0.32	31.6	1.0
SB4-R	0.36	1.46	0.30	2.12	208.8	1.0
SB5-R	-	2.06	3.36	5.42	161.0	3.3
SB-BSK-W	0.59	0.14	0.49	1.22	120.2	1.0
SB5-L	-	-	1.59	1.59	330.8	0.5
SB-BSK	-	-	1.29	1.29	25.3	5.0
SB4-L-D	-	-	7.03	7.03	15.4	45.6

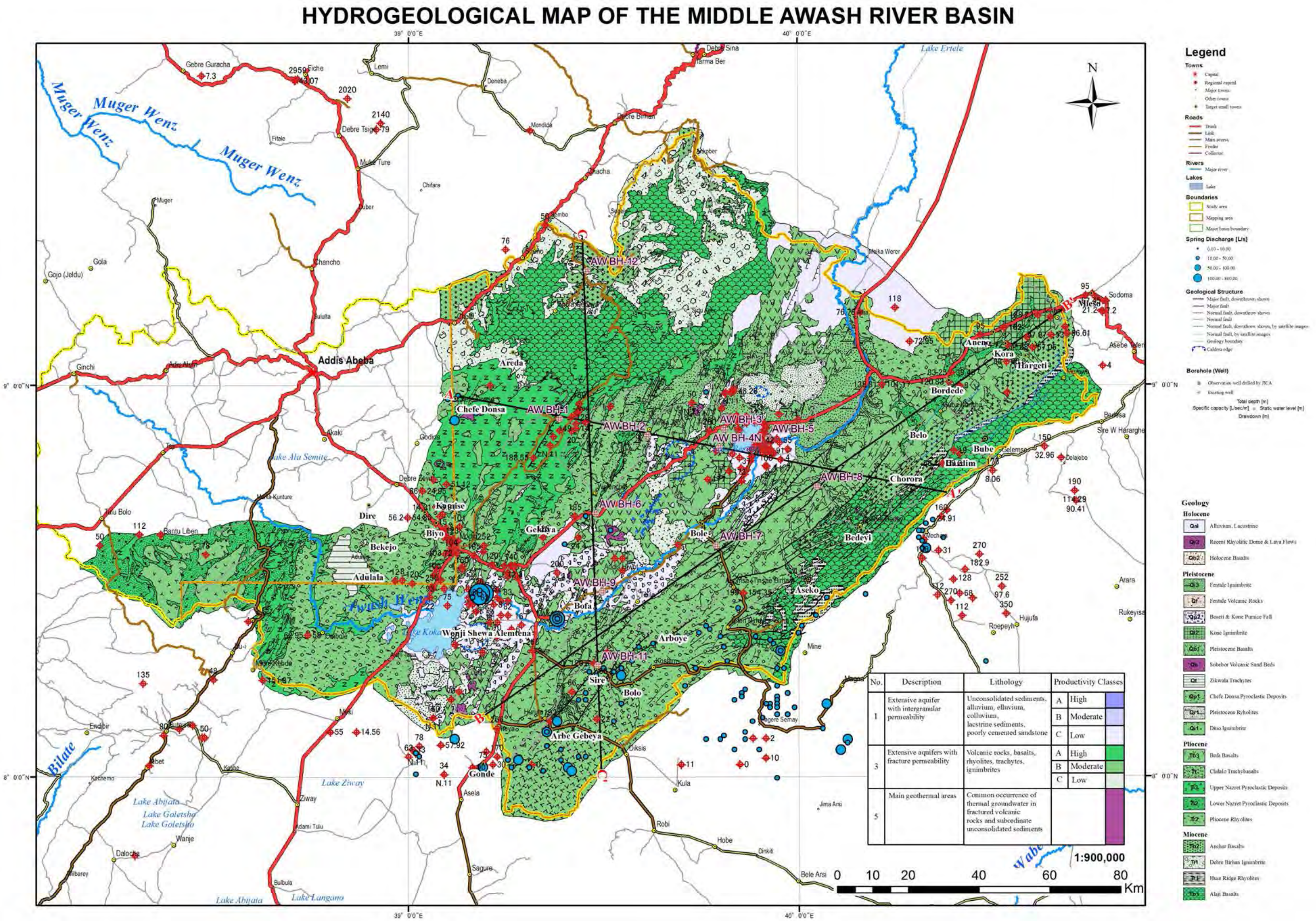
Source: the Project Team, Data: Calculation by project member

4.3 Hydrogeological map and groundwater flow

The hydrogeological map was created in accordance with the evaluation of productivity based on the relationship between the geology and aquifer units and aquifer information. It is possible to use the hydrogeological map to make a judgement about the actual capacity (groundwater potential) of aquifers in the project area. Judging from the map it is considered that each sub-basin will be able to supply a sufficient amount of groundwater to meet water usage demand based on the fact the ratio between groundwater recharge and estimated yield is low.

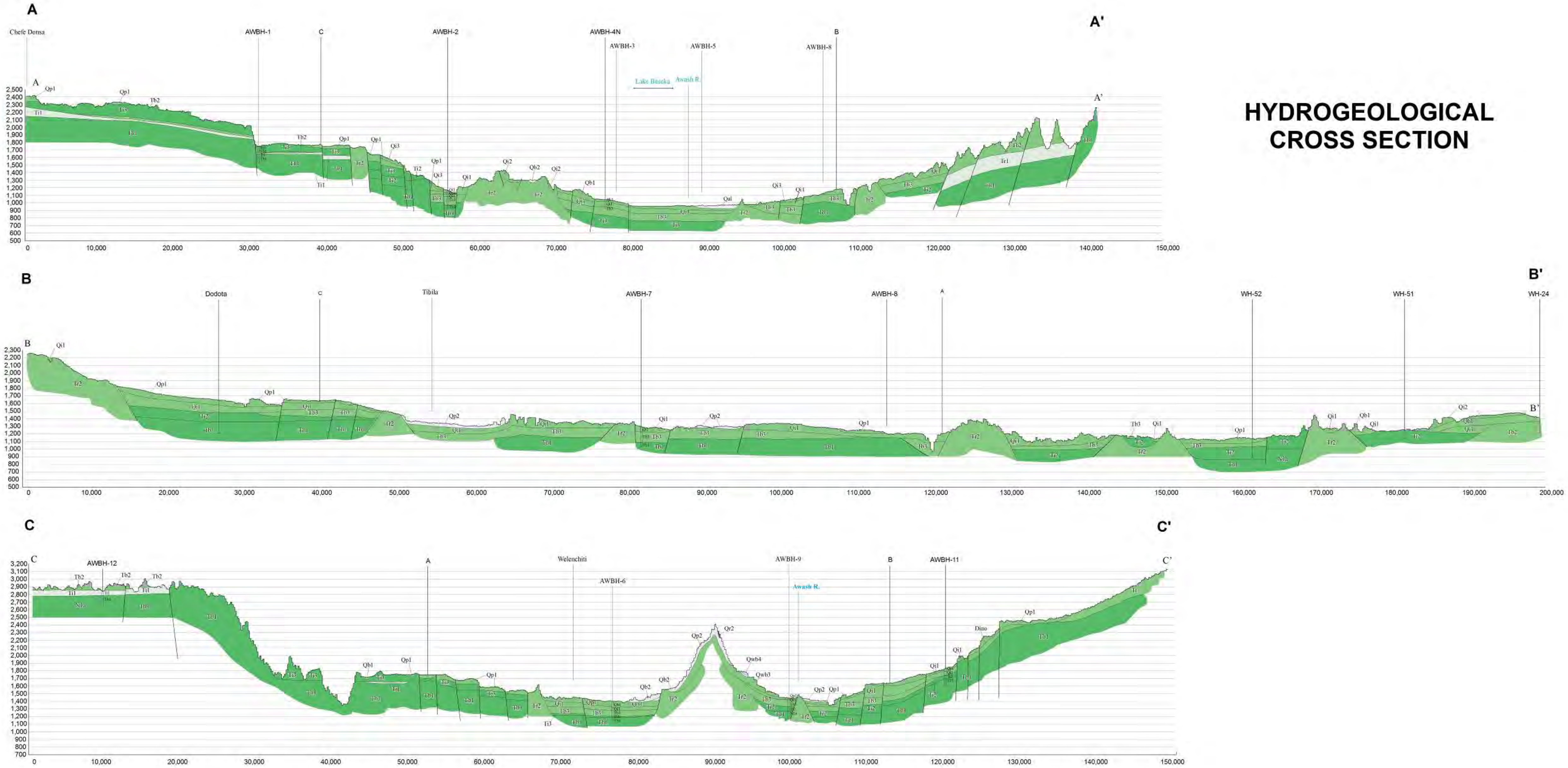
The hydrogeological map and cross-sections are shown in Figure 4.3.1 and Figure 4.3.2.

Figure 4.3.3 shows the groundwater table contour map based on the static water level showing the confined aquifer, except the unconfined aquifer, partly using the information of JICA wells and existing wells. The direction of flow line is assumed to be from the south east and the north west of the Rift Valley highland to the rift floor of the north east to the south west along the Awash River. It is considered the groundwater flows along the geography. In Dera area located in the Arsi Zone, the flow line is in the direction of a small watershed.



Source: the Project Team, Data: reference ①, ②, ③, ④

Figure 4.3.1: Hydrogeological Map in the Middle Awash River Basin

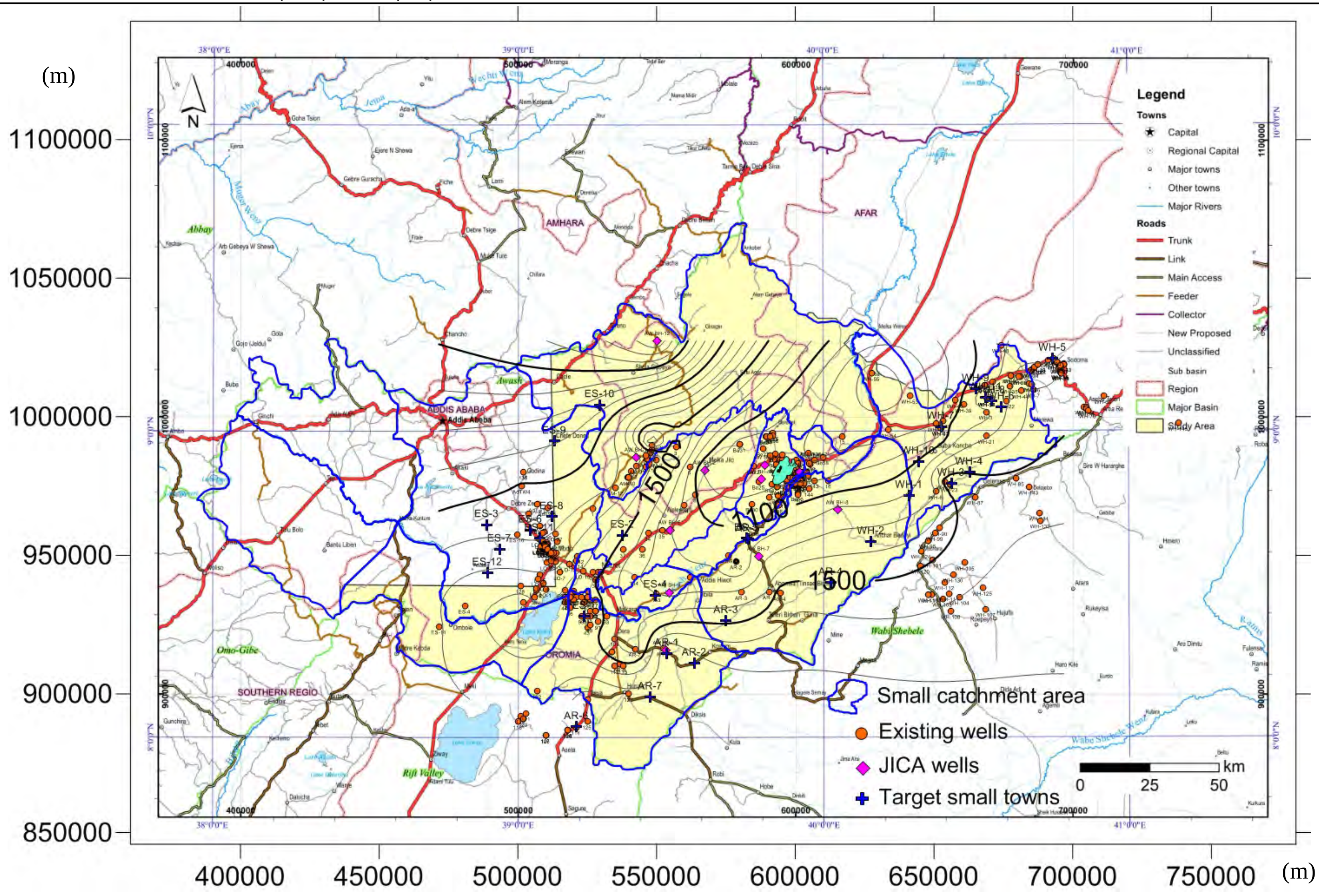


No.	Description	Lithology	Productivity Classes		
1	Extensive aquifer with intergranular permeability	Unconsolidated sediments, alluvium, elluvium, colluvium, lacstrine sediments, poorly cemented sandstone	A	High	
			B	Moderate	
			C	Low	
3	Extensive aquifers with fracture permeability	Volcanic rocks, basalts, rhyolites, trachytes, ignimbrites	A	High	
			B	Moderate	
			C	Low	
5	Main geothermal areas	Common occurrence of thermal groundwater in fractured volcanic rocks and subordinate unconsolidated sediments			

Hydrogeological Cross Section	December 2015
THE PROJECT FOR GROUNDWATER RESOURCES ASSESSMENT IN THE MIDDLE AWASH RIVER BASIN IN THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

Source: the Project Team, Data: reference ①, ②, ③, ④

Figure 4.3.2: Hydrogeological Cross Sections



Source: the Project Team, Data: reference ①, ②, ④

Figure 4.3.3: Groundwater Table Contour Map

4.4 Water quality testing

4.4.1 Analysis items, methodology and analysis results

In the first and second phases a total of 104 samples were taken. The samples were taken from existing wells (38 points), springs (25 points), river (21 points) and lake water (7 points) JICA wells (9 points) and others (4 points). The samples are to be collected and analyzed by outsourcing to local companies (sampling: AWE CONSULTANTS PLC; Analysis: Water Works Design & Supervision Enterprise). The results of water sampling and analysis around Lake Beseka will be shown in Chapter 3 for the analysis of Lake Beseka.

The sampling point map is presented in Figure 4.4.1.

The water quality testing consists of the general testing and isotope analysis.

a. General water quality testing

General water quality tests are analysed on site and in laboratory.

a.1 Site analysis

The 12 parameters for on-site water quality measurements are as follows:

Water temperature, electric conductivity (EC), pH, oxidation-reduction potential (ORP), Fe, Mn, F, NO_3, As, NH_4, Escherichia coli and Viable bacteria

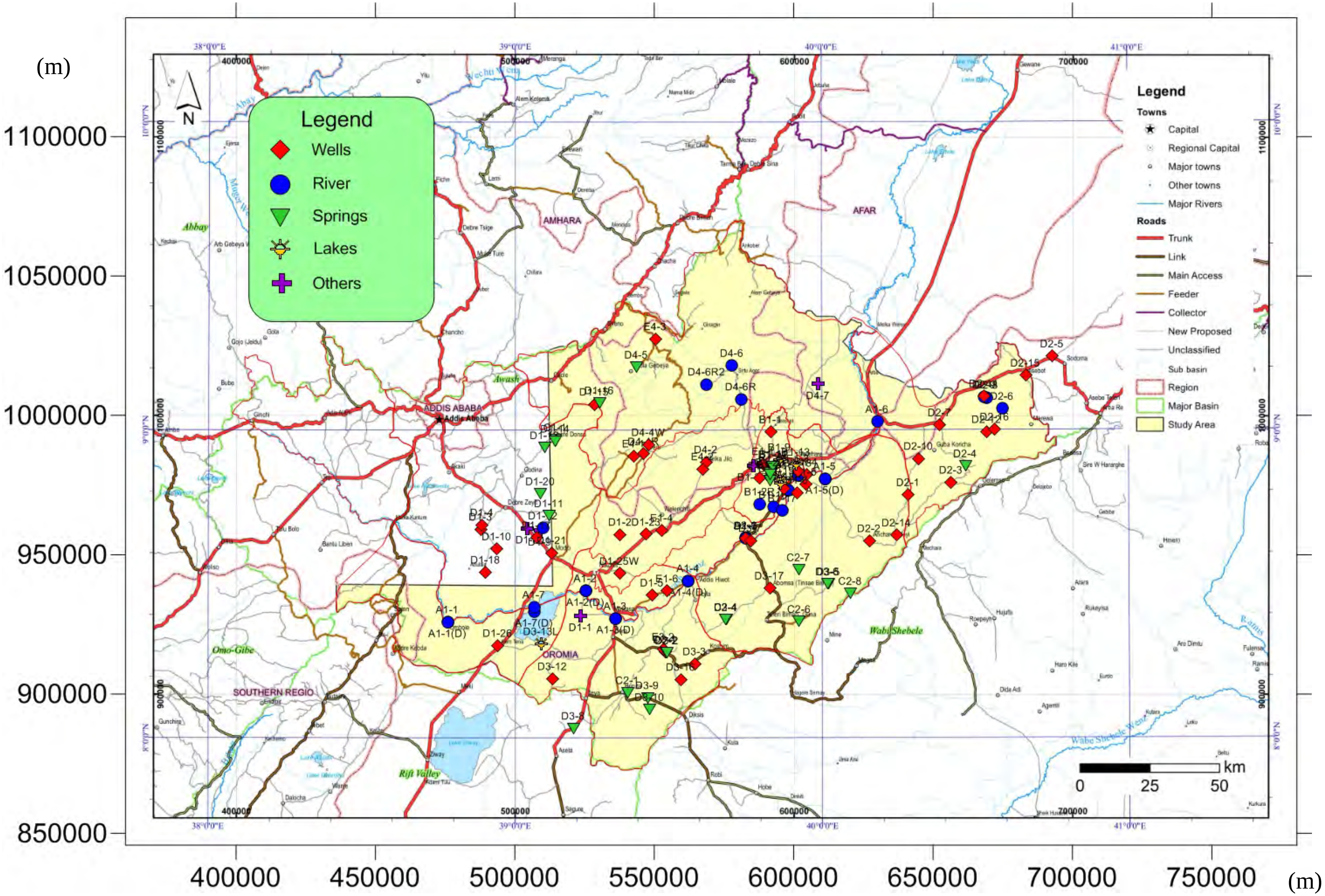
The results of site analysis are shown in the data book.

a.2 Laboratory analysis

In the laboratory, the following 22 parameters were analysed for each sample:

Taste, odor, turbidity, total dissolved solids (TDS), suspended solids (SS), pH, electric conductivity (EC), total hardness ($CaCO_3$), Calcium (Ca), Magnesium (Mg), Potassium ((K), Sodium (Na), Iron (Fe), Manganese (Mn), Chloride (Cl) Sulfate (SO_4), Nitrate (NO_3), Nitrite (NO_2), Alkalinity (CO_3^{2-}, HCO_3^-) Fluoride (F), Total Phosphorus (TP) and ammonia (NH_3+NH_4)

The new Ethiopian standard of water quality for drinking water was prepared under the direction of the Technical Committee for Water Quality and published by the Ethiopian Standards Agency from 2013, as Table 4.4.1 shows. Our project also adopts the new Ethiopian standard.



Source: the Project Team, Data: reference ④

Figure 4.4.1: Location Map of Sampling Points for Water Quality Testing

Table 4.4.1: New Water Quality Standard of Ethiopia and WHO

Analysis items	Ethiopian (mg/L)	WHO (mg/L)	Method	Remark
Escherichia Coli	0	0	Pack test	On site
Viable Bacteria	0	0	Pack test	On site
Arsenic	0.01	0.01*	Pack test	On site
Fluoride	1.5	1.5*	ES ISO 10359-1	On site & in lab.
Nitrate	50	50*	ES ISO 7890-3	On site & in lab.
Color	15	15	ES ISO 7887	
Turbidity	5	5	ES ISO 7027	
Taste	n.o	n.o	ES605	
Odor	n.o	n.o	ES605	
pH	6.5 - 8.5	6.5 - 8.5	ES ISO 10523	On site & in lab.
TDS	1000	600	ES 609	
TS	-	-		
Total Hardness	300	300	ES 607	
Calcium	75	-	ES ISO 7980	
Magnesium	50	-	ES ISO 7980	
Sulfate	250	250	ES ISO 9280	
Chloride	250	250	ES ISO 9297	
Iron	0.3	0.3	ES ISO 6332	On site & in lab.
Manganese	0.5	0.1	ES ISO 6333	On site & in lab.
Ammonium (NH3+NH4)	1.5	1.5	ES ISO 7150-2	On site & in lab.
Total Nitrogen (Excluding NO3)	-	-	-	
Nitrite	3	3*	ES ISO 6777	
Alminium	0.2	0.2	ES ISO 12020	
Sodium	200	200	ES ISO 9964-1	
Temperature	n.o.	-	-	
Electrical Conductivity	-	-	-	On site & in lab.
Potassium	1.5	-	ES ISO 9964-2	
Bicarbonate	-	-	-	

Compulsory Ethiopian Standard: Drinking water-Specifications, 2013
WHO guideline: * : Health guideline value

b. Isotope analysis

The main items of isotope analysis are heavy hydrogen, Oxygen-18, Noble gases (i.e. He gas), tritium, and Carbon-14. The isotope analysis was carried out on JICA test wells. The analysis of isotopes has been entrusted to the International Atomic Energy Agency. The samples were sent to IAEA after completion of well drilling. Moreover, isotope analysis was executed by Addis Ababa University for isotopic ratios of δ^{18}O and δD for 17 samples collected around Lake Beseka in the second phase. The results of Isotope Analysis are shown in Chapter 3. Moreover, the sending of samples to IAEA from AW BH-2 and AW BH-6 (JICA wells) was delayed because of delays in drilling, so the stable isotope analysis was carried out in AAU in parallel.

c. Results of analysis

The results of each analysis and the original data of sampling is attached in the data book. By comparing these results with the Ethiopian standards and WHO guidelines, it is found that there are few analysis items, besides fluoride, that exceed either standard in most of the wells. The total hardness and calcium of existing wells and springs mainly in 10 points exceed the Ethiopian standard along the Rift Valley ridge in the south of the Study area (including three target small towns). The results of fluoride concentrations in the wells are as follows;

[Fluoride]

- Groundwater was sampled from 38 existing wells and nine JICA wells. Nineteen out of 38 existing wells are used as boreholes in target small towns for making provisional water supply planning. Well information was obtained from 14 out of 19 existing wells. Twenty wells of 38 show high concentrations of fluoride exceeding the new Ethiopian standard (1.5mg/L, the same guideline value as WHO).

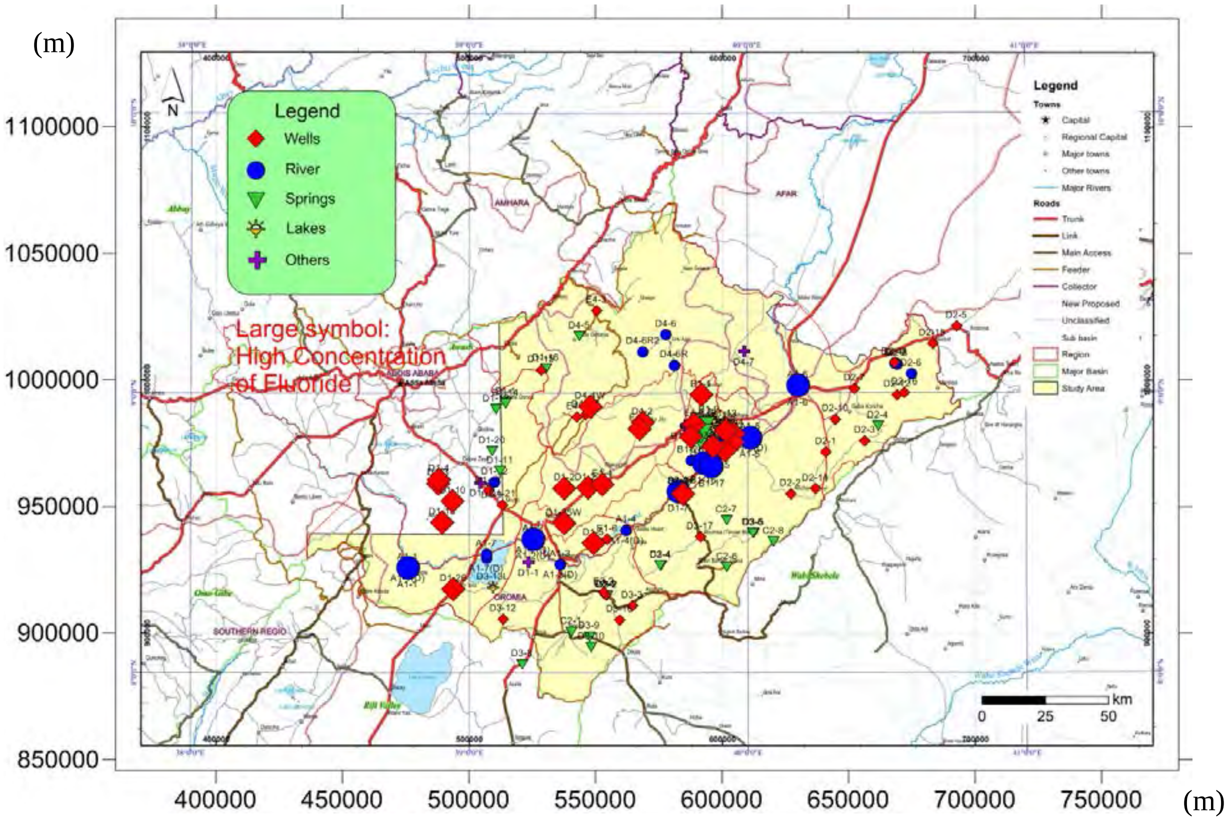
- In the Study area, the high concentration zone of fluoride has been seen along the low-lying areas of the Rift Valley basin in an ENE to WSW direction. Fluoride concentration is high of 3 to 4 mg/L and low of less than 3mg/L, which exceeds the WHO and Ethiopian standards, in a 50-km area concentrically centered on Adama including Lake Koka area. The fluoride concentration in other areas is less than or equal to 3mg/L and also exceeds the Ethiopian standard. The depth of wells in this area is 48 m to 180m. The well depth in the area which alluvium is distributed is less than 50m.

- Fluoride concentrations are less than or equal to 0.5 mg/L in almost all existing wells around the West Hararge area. The depth of sampled existing wells is 78 to 130m and less than 50m in some cases. In the south side of the Study area, in the Rift Valley ridge, the fluoride concentrations are also less than or equal to 1mg/L and do not exceed the WHO guidelines.

- Fluoride concentrations of existing wells, springs and lake water exceed the Ethiopian standard around Lake Beseka and the Melka Jilo area at the north west of the Study area. The maximum concentration of fluoride exceeds 23mg/l in the lake water. The Awash River also exceeds the Ethiopian standard for fluoride, in particular, the points downstream in the river from Lake Beseka indicate a 3mg/l concentration of fluoride. Almost all the depths of existing wells are less than 60 m.

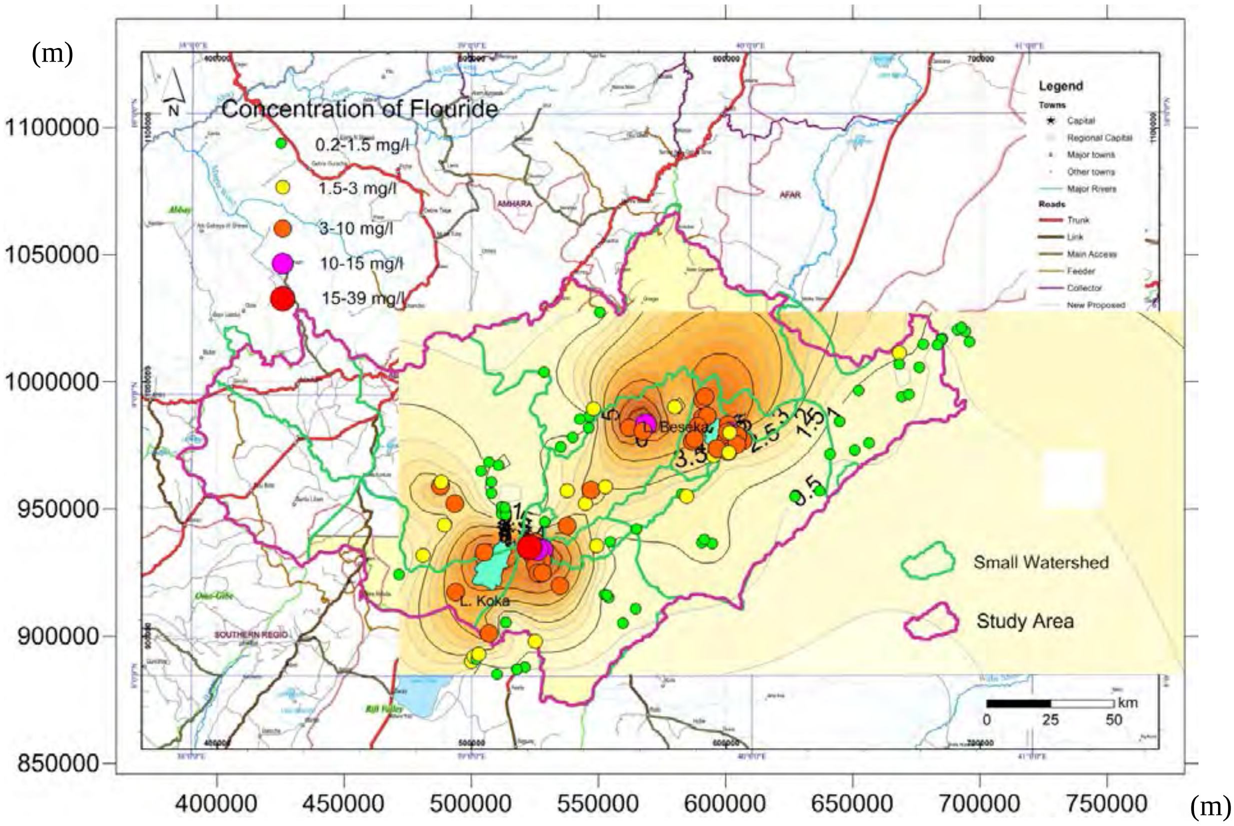
- Figure 4.4.2 shows the points of every type that exceeded the Ethiopian standard (1.5mg/L), and the distribution map of fluoride concentration in the Study area by only using the results of existing wells including JICA wells is shown in Figure 4.4.3. Judging from a geological perspective the fluoride concentration is not considered to exceed the WHO standard in the area of Miocene and Plio-Pleistocene basalt (located in the north and south ridge of the Rift Valley, respectively), but the fluoride concentration tends to take high value in almost all areas of Plio-Pleistocene welded tuff and in the distributed area of Pleistocene and Holocene acidic volcanic rocks (low-lying areas of the Rift Valley basin, Lake Beseka and Koka area).

- Figure 4.4.4 shows the relationship between well depth and the concentration of fluoride. For example, in the Lake Beseka area, the concentration of fluoride is high, exceeding the Ethiopian standard with no correlation to the well depth (comparing wells less than 100m deep with a well that is 595m deep). On the other hand, the concentration of fluoride in the wells of the West Hararge Zone does not exceed the Ethiopian standard, with no correlation to the well depth on the whole. However, the whole Study area, as shown in Figure 4.4.4, exhibits a declining trend of the concentration of fluoride when the wells become deeper.



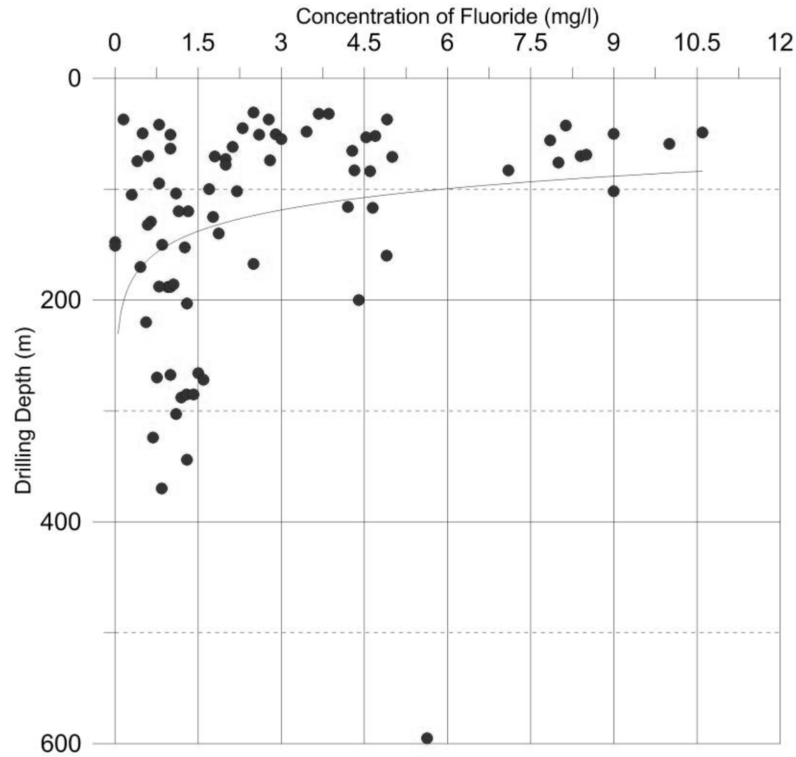
Source: the Project Team, Data: reference ①,②and ④

Figure 4.4.2: Point Map of High Concentration of Fluoride in Study Area (All Types)



Source: the Project Team, Data: reference ①,②and ④

Figure 4.4.3: Distribution Map of Concentration of Fluoride in Study Area



Source: the Project Team, Data: reference ①,②and ④

Figure 4.4.4: Relationship between Well Depth and Concentration of Fluoride

4.4.2 Characteristics of the water quality

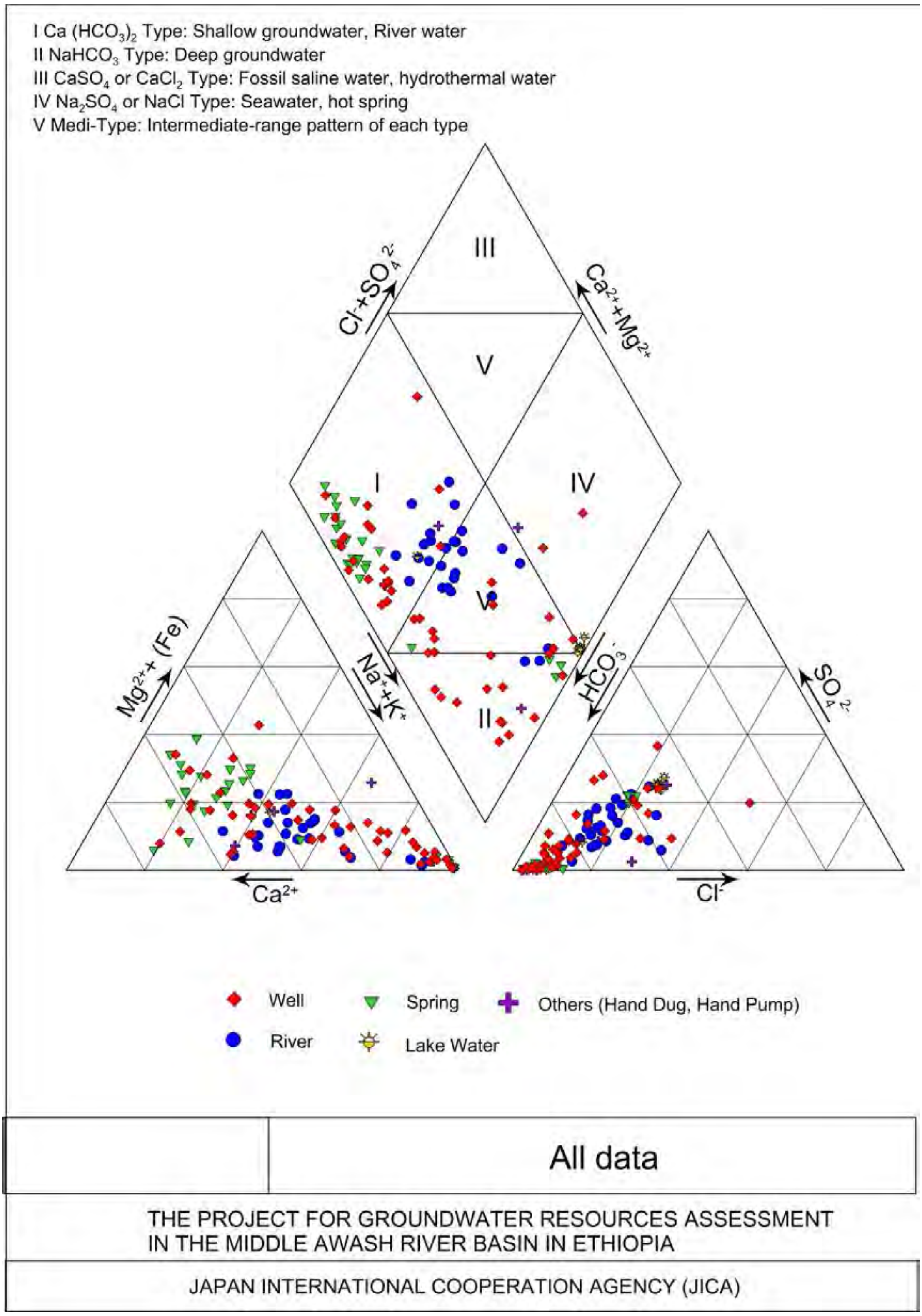
All samples were plotted in a trilinear diagram and a hexadiagram to evaluate and classify the characteristics of the water quality into certain water quality classifications.

a. Characteristics of the water quality in the trilinear diagram

Trilinear diagrams do not display the concentration, but display the percent of composition against the total equivalent weight respectively for main cations and anions. The information on concentration in trilinear diagrams is poor, but many data can be expressed in one area. The classification of water in the key diagram is generally as follow:

Ⅰ $Ca(HCO_3)_2$ Type (Carbonate hardness) : Shallow groundwater, river water
Ⅱ $NaHCO_3$ Type (Carbonate alkali) : Deep groundwater
Ⅲ $CaSO_4$ $CaCl_2$ Type (Noncarbonate hardness) : Hot spring, fossilized salt water
Ⅳ Na_2SO_4 NaCl Type (Noncarbonate alkali) : Seawater, groundwater with component of seawater
Ⅴ Intermediate range type : Intermediate-range pattern of each type

Trilinear diagram of all points analysed in the Study area is shown in Figure 4.4.5.



Source: the Project Team, Data: reference ④

Figure 4.4.5: Trilinear Diagram (All Data)

Characteristic of water quality in trilinear diagram of all samples is as follows;

- After analysis of samples in the second phase, the water quality of samples of river water increased in intermediate positions in comparison to shallow groundwater and deep groundwater samples. A sample of Awash River flowing into Lake Koka is plotted in the same type of intermediate position as hot spring water and retention type groundwater. Another sample taken downstream of Lake Beseka on the Awash River indicates water of deep groundwater type. It is assumed that this water is affected by the water flowing from Lake Beseka. The water quality type of the Awash River belongs to the shallow groundwater and river types located downstream of Lake Koka to upstream of Lake Beseka.

- All samples of existing wells except one sample is plotted in the type of shallow groundwater, deep groundwater (retention type), and intermediate type of each type mentioned above. The plotted points are dispersed in the key diagram. Two samples are plotted in the IV type. The deep groundwater type is located in the Rift valley floor around Lake Koka and around Lake Beseka (existing wells in east Lake Beseka and JICA wells) The depth of sampling existing wells is 100 to 200m. The sample points of shallow groundwater type are distributed in the direction of northeast – southwest around the Rift Valley ridge.

- Almost all samples of springs belong to the circular shallow water type. Four springs (including the additional two samples after P/R2) flowing in Lake Beseka are located in the deep groundwater type in the key diagram. Characteristics of groundwater flowing in Lake Beseka are expressed.

- In lake water, the difference of water quality between Lake Koka and Lake Beseka appears clearly. Lake Koka water belongs to the shallow circular water type, and Lake Beseka water belongs to the intermediate type of water with the component of seawater and deep retention groundwater. This pattern is similar with the spring flowing into Lake Beseka. According to the Trilinear Diagram, Lake Beseka water belongs to the types of $Na\text{-}HCO_3$ or $Na_2SO_4\text{-}NaCl$ and it is considered that the Lake water is affected by the springs of the west side of Lake Beseka.

b. Characteristics of the water quality by hexa diagram

The hexadiagram contains information on concentration and total salinity weight, and can be used to represent water quality visually. The figure which the type of key diagram in the trilinear diagram is expressed in the hexadiagram. This figure has the advantage that a water quality pattern is clear visually.

The characteristic of water resources such as existing well, river and so on is combined with the results of the trilinear diagram. As mentioned above, in the hexadiagram, the difference of concentration is clear from the figuration of diagram. The results of the hexadiagram of all water resources plotted in the Study area map are shown in Figure 4.4.6.

The main characteristic of the hexadiagram is as follows;

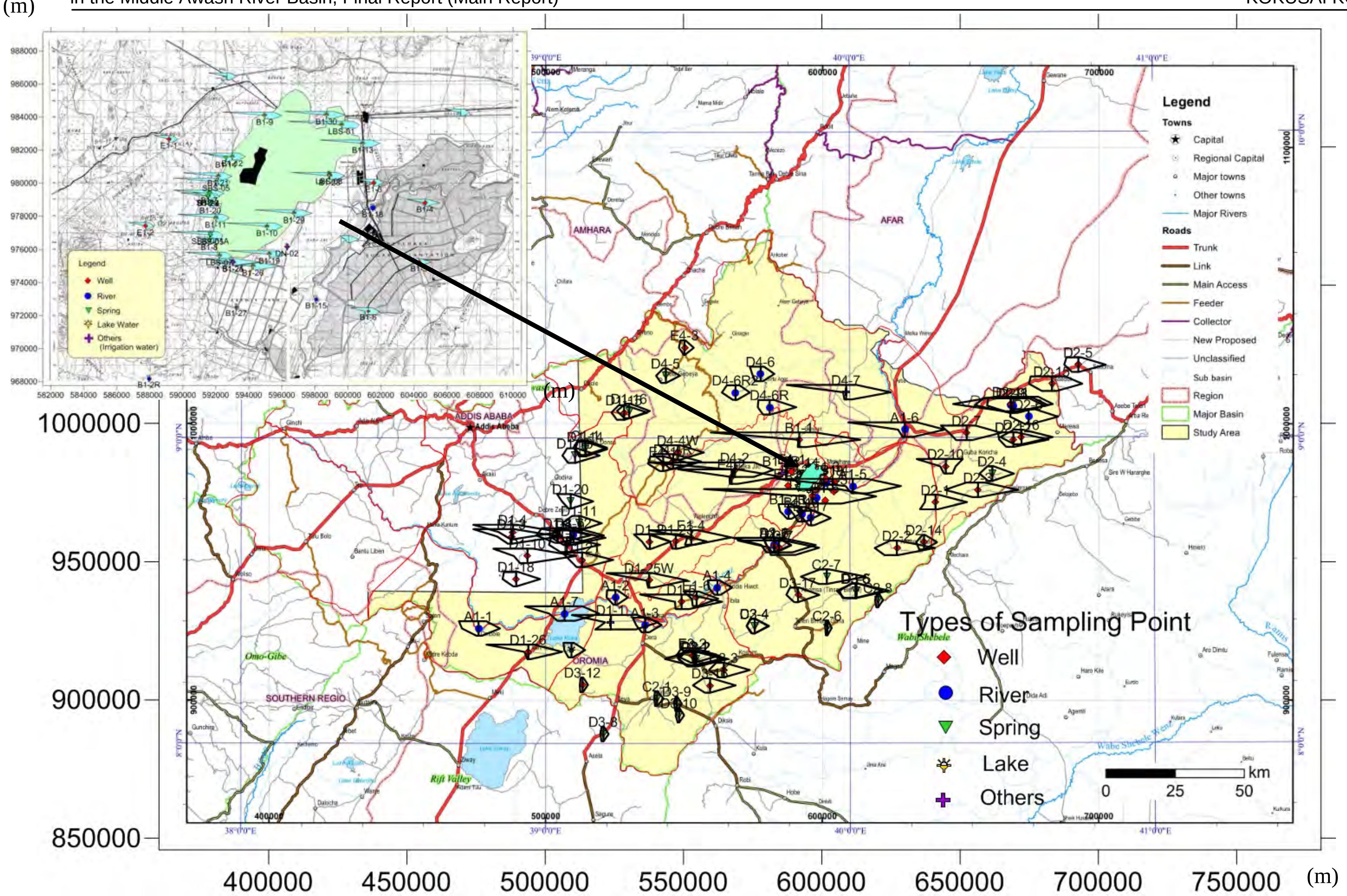
- The concentration of river water is high at the point flowing into Lake Koka and at the sampling points downstream of Lake Beseka from the Awash River. In particular, the latter indicates the type of $NaHCO_3$, and it is assumed that this water is affected by deep and retention groundwater.

- In existing wells, the groundwater of shallow type, deep and retention type and intermediate type of each type above are represented in hexadiagrams. The sampling points around Lake Koka indicate the $NaHCO_3$ type, and the concentration is high and the type is $NaHCO_3$ (not $CaHCO_3$ type) around Lake Beseka. One point in West Hararge indicates the NaCl type by the figuration.

- The samples of spring belong to the $CaHCO_3$ type in the hexadiagram, but there is a difference of concentration in each sample. Two springs of Lake Beseka have a high concentration and belong to the $NaHCO_3$ type by figuration. These springs are deep and retention-type groundwater.

- The hexadiagram type and concentration of Lake Koka and Lake Beseka is clearly different. This difference can be attributed to the formation process of each lake. The water quality pattern in Lake Beseka is the type of water with a component of seawater. It is deep- and retention-type groundwater and the entire concentration is also very high.

- Figure 4.4.6 shows the different types of water quality in the west side, and east side of Lake Beseka and around the lake. There is $CaHCO_3$ types in the springs and existing wells of the Rift Valley ridge in the Study area, and $NaHCO_3$ types in the existing wells and river water from the Rift Valley floor.



Source: the Project Team, Data: reference ④

Figure 4.4.6: Distribution Map of the Hexadiagram (All Data)

4.5 Summary

The summary of the groundwater potential is as follows;

- The classification and characteristic of aquifer were categorized in accordance with the geological stratigraphy and the description of lithology based on the geological survey in the field. The main aquifer is as follows; 1) Alluvium and lacustrine deposits, 2) Quaternary Pleistocene tuff, and welded tuff and basalt, 3) Tertiary Pliocene, Miocene tuff, and welded tuff and basalt.
- The classification and information of aquifer in the middle Awash River basin were categorized in reference to the entire Ethiopian aquifer classification and definition. And the productivity of each aquifer unit was estimated in A (high) to C (Low). The stratigraphy was divided in the 22 strata, and the results of the aquifer classification and the productivity estimation on each strata were reflected in the hydrological map.
- The ratio between the groundwater recharge and yield (estimated yield as of 2035) is shown as approximately 1 to 5 % in the major sub-basin. Such sub-basins will produce a sufficient yield of groundwater. The ratio between the groundwater recharge and yield in the sub-basins that include large cities such as Addis Ababa or sub-basins of low groundwater recharge is about 35% to 45%.
- According to the hydrogeological map and cross-sections, the geology indicated the high productivity of groundwater is the Tertiary Miocene basalts and Pliocene pyroclastic deposits. These strata are mainly distributed on the surface in the north west and south east area along the rift valley ridge, and these strata were also found in the floor of the middle Awash River basin in subsurface.
- The general water quality testing were carried out on a total of 104 samples. The samples were taken from existing wells (38 points), springs (25 points), rivers (21 points), lake water (7 points), JICA wells (9 points) and others (4 points). The isotope analysis for the nine samples of JICA wells are mainly conducted in IAEA.
- Fluoride concentrations is the main health related parameter to exceed the WHO guideline (1.5mg/L) in the water quality testing. From the results of water quality testing on wells, geological judgment says that the fluoride concentration tends be high in almost all areas of Plio-Pleistocene welded tuff and in the distributed area of Pleistocene and Holocene acidic volcanic rocks (low-lying areas of the Rift Valley basin, Lake Beseka and Koka area). The relationship between well depth and the concentration of fluoride shows that the whole Study area exhibits a declining trend of the concentration of fluoride when the wells become deeper. However, such analysis also needs to take into consideration the above geological findings.
- Characteristic of the water quality by trilinear diagram and hexadiagram were surveyed and discussed. Trilinear diagram says all samples of existing wells except one sample is plotted in the type of shallow groundwater, deep groundwater (retention type), and intermediate type of each type mentioned above. The plotted points are dispersed in the key diagram. Lake Beseka water and the springs of the west side of Lake Beseka belong to the types of deep groundwater (Na-HCO_3 or Na_2SO_4-$NaCl$ types) and it is considered that the lake water is affected by those springs.
- Hexa diagram shows that there is $CaHCO_3$ types in the springs and existing wells of the Rift Valley ridge in the Study area, and $NaHCO_3$ types in the existing wells and river water from the Rift Valley floor.

Reference materials

① Main well records mentioned in existing reports:

1) Hydrogeology (map) of the Nazret, EIGS, 1985
2) Evaluation of water resources of the Ada'a and Becho plans groundwater basin for irrigation development project, WWDSE, planned by MoWR, 2009
3) Allaidege plain groundwater resources assessment project, WWDSE planned by MoWR, 2009
4) Study and design of Lake Besaka level rise project Ⅱ, WWDSE, planned by MoWE, 2011
5) Growing lake with growing problems: integrated hydrogeological investigation on Lake Beseka, Ethiopia, ELENI AYALEW BELAY, 2009
6) Assessment and evaluation of causes for Beseka Lake level rise and design mitigation measures PartⅡ: Study for medium and long term solutions (Main report final), MoWIE and OWWDSE, 2014
7) Groundwater origin and flow along selected transects in Ethiopian rift volcanic aquifers, Seifu Kebede et all, 2008

② Well drilling records including well columnar section and pumping test record:

1) Existing well data including columnar section and pumping test record in West Hararge Zone
2) Existing well data including columnar section and pumping test record in Arsi Zone.
3) Existing well data including columnar section and pumping test record in East Shewa Zone
4) Well completion reports and well data in Arerti（Amhara Region）woreda, Lomme（Oromia Region）woreda
5) WWDSE, 2014 Irrigation data（Well depth 595m）

③ Others references

1) Editing: Japanese Association of Groundwater Hydrology, Science for brand-name spring water, 1994
2) Hydrogeological map of Ethiopia (1:2,000,000) compiled by Tesfaye Chernet and the Regional Geology Department, EIGS, 1988

④ Data (including photo on site) from field survey and interview, etc by the Project Team

Chapter 5

Groundwater Modelling to Simulate Future Water Use and Evaluate Potential for Groundwater Development

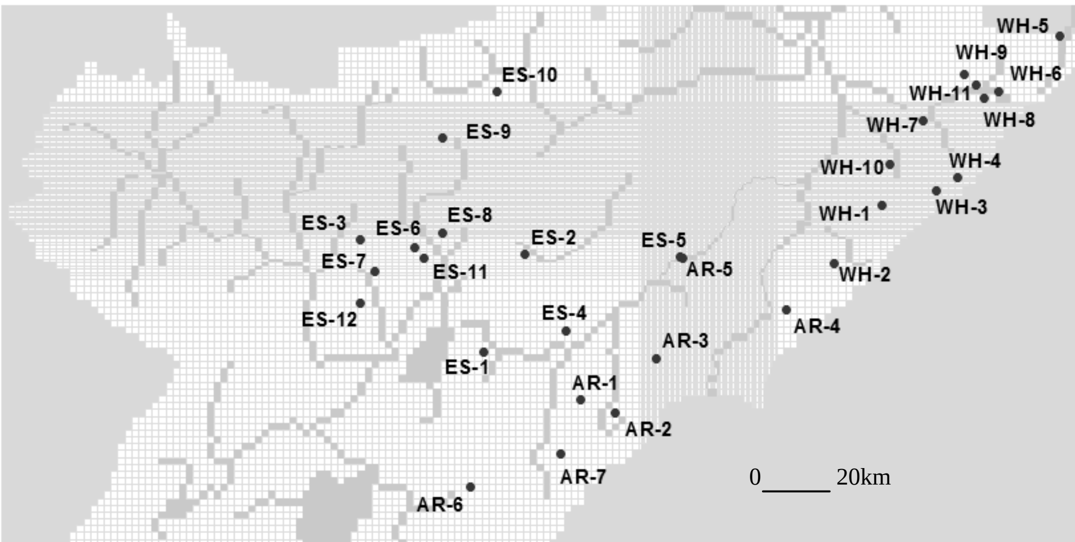
5 Groundwater Modeling to Simulate Future Water Use and Evaluate Potential for Groundwater Development

5.1 Introduction

The groundwater models were created to be used as the basic data to assess the feasibility of the developed water supply plans. The model parameters and packages were set up by employing useful groundwater parameters so that the groundwater model corresponds to the actual groundwater environment. The groundwater models were calibrated (explained in the Interim Report) which were then used to calculate the impact of well construction and usage for water supply on groundwater levels (depletion and replenishment relationship) and also on the groundwater environment.

5.2 Specifications of planned wells

The groundwater modelling simulations covered all of the original 30 target small towns. Eleven of the thirty target towns were excluded from the water supply plans because other projects will (or were to) be carried out in those towns, or the water quality there showed high concentrations of fluoride (exceeding the old Ethiopian standard of 3.0mg/L) and so on. However those 11 small towns were included in the groundwater simulations so as to secure sufficient data to establish the relationship between drawdown of groundwater and water demand (estimated yield) in the entire project area. From now, sufficient number of wells will need to be constructed in the target towns to meet the estimated water demand (2020). The location map of the planned wells in the target small towns is shown in Figure 5.2.1.



Source: the Project Team, Data: Production by Project member

Figure 5.2.1: Location Map of the Target Small Towns (with Wells)

The town number, coordinates, line-column, planned well depth and layer (Five layers are divided for the modelling and the number indicates the layer which the planned depth of each well reaches) in the target small towns of Figure 5.2.1 are as follows:

Table 5.2.1: Well Information in the Model

Town number	Easting	Northing	Row	Colum	Estimated depth (m)	Layer
AR-1	553789	914629	124	85	250	2
AR-2	563663	911085	126	90	250	2
AR-3	575105	926450	118	104	250	3
AR-4	612898	940113	111	175	250	2
AR-5	582942	955787	100	119	250	3
AR-6	521176	888123	137	69	150	3
AR-7	547813	898826	132	82	250	3
ES-1	523983	927885	117	71	200	3
ES-2	537805	957201	99	77	200	3
ES-3	488864	961034	95	53	250	3
ES-4	549706	935610	114	83	250	3
ES-5	582430	956118	100	118	250	3
ES-6	504593	959074	97	61	300	3
ES-7	493382	952238	104	55	200	3
ES-8	512241	963884	91	65	350	3
ES-9	513210	991145	36	65	200	3
ES-10	529573	1004272	13	73	250	3
ES-11	507829	956072	100	62	300	3
ES-12	489099	943666	110	53	200	3
WH-1	641097	971517	75	189	150	3
WH-2	627376	954910	102	182	250	3
WH-3	656277	975905	67	197	150	3
WH-4	662813	979936	59	200	200	3
WH-5	692799	1021080	5	215	150	2
WH-6	674221	1003489	13	206	250	3
WH-7	652603	996461	26	195	250	3
WH-8	670893	1005689	14	204	200	3
WH-9	665114	1010056	10	201	300	3
WH-10	644399	983865	51	190	200	3
WH-11	668599	1006889	12	203	200	3

Source: the Project Team, Data: Calculation by Project member

5.3 Future pumping scenarios

The estimated years of the analysis of the groundwater fluctuation was set from 2020 to 2035 in the target small towns. The target year of the new water supply plan was set as 2020, and the water demand (estimated necessary yield of wells to meet such demand) will increase from the target year. After that, the next target year is set as 2030 in consideration of the depreciation costs (for pumps, etc.) over ten years. Moreover, five years were added and the final year was set as 2035; namely: 2020 + 10 years + 5 years. Taking this matter into consideration, not only one plan for water supply in the future, but another two plans have been formulated to correspond to relatively small and large population increase conditions, respectively. The final three scenarios for the analysis of increasing water demand (yield) are as follows: (The number: daily unit water demand (yield) (m^3/day) of 2035)

- Scenario_1 15,226 m^3/day (planned daily water supply of the target small towns (total))
- Scenario_2 18,279 m^3/day (maximum planned daily water supply of the target small towns (total); unit water demand of 40 L/c/day)
- Scenario_3 22,224 m^3/day (minimum planned daily water supply of the target small towns (total); unit water demand of 50 L/c/day)

The break-down of the three scenarios from 2019 to 2035 is as follows: Scenario_1 the water demand increases by 1.22 times, Scenario_2 increases by 1.47 times and Scenario_3 increases by 1.8 times. Unit water demand changed in the urban area from 40L/c/day to 50L/c/day, but the unit water demand did not change in the rural areas (25L/c/day) in Scenario 3. The estimated water demand (yield) of 2019, 2020 and 2035 in Scenario_1 is as follows:

Table 5.3.1: Water Demand (Yield) in the Small Towns of Scenario 1 (m^3/day)

ID	Small towns	Urban and Rural	2019	2020	2035
AR-1	Sire	Urban	549.2	671.4	1,226.7
AR-2	Bolo	Urban	78.2	95.5	174.5
AR-3	Arboye	Urban	375.1	458.5	837.8
AR-4	Aseko	Urban	263.7	322.3	588.7
AR-5	Golegota	Urban	361.0	441.1	806.2
AR-6	Gonde	Urban	169.0	206.6	377.6
AR-7	Arbe Gebeya	Urban	137.8	168.4	307.6
ES-1	Wonji Shewa Alemtena	Urban	425.7	520.5	950.8
ES-2	Geldiya	Urban	111.0	135.7	248.0
ES-3	Dire	Urban	330.5	404.0	738.2
ES-4	Bofa	Urban	204.0	249.3	455.5
ES-5	Bole	Urban	263.3	321.8	588.2
ES-6	Ude Dhankaka	Urban	281.6	344.3	628.9
ES-7	Bekejo	Rural	200.8	228.3	335.5
ES-8	Kamise	Urban	234.1	286.2	523.0
ES-9	Chefe Donsa	Urban	420.8	514.5	940.0
ES-10	Areda	Urban	134.5	164.3	300.1
ES-11	Biyo	Urban	133.6	163.1	298.3
ES-12	Adulala	Urban	194.4	237.7	434.3
WH-1	Chorora	Rural	86.0	97.7	143.7
WH-2	Bedeyi	Urban	149.1	182.3	333.0
WH-3	Hardim	Urban	291.7	356.6	651.5
WH-4	Bube	Rural	189.8	215.7	317.1
WH-5	Mieso	Urban	870.3	1,064.1	1,944.3
WH-6	Hargeti	Rural	101.3	115.2	169.4
WH-7	Bordede	Urban	143.9	175.9	321.5
WH-8	Kenteri	Rural	53.8	61.0	89.7
WH-9	Aneno	Rural	85.3	97.1	142.6
WH-10	Belo	Rural	139.0	158.2	232.3
WH-11	Kora	Rural	72.5	82.5	121.3

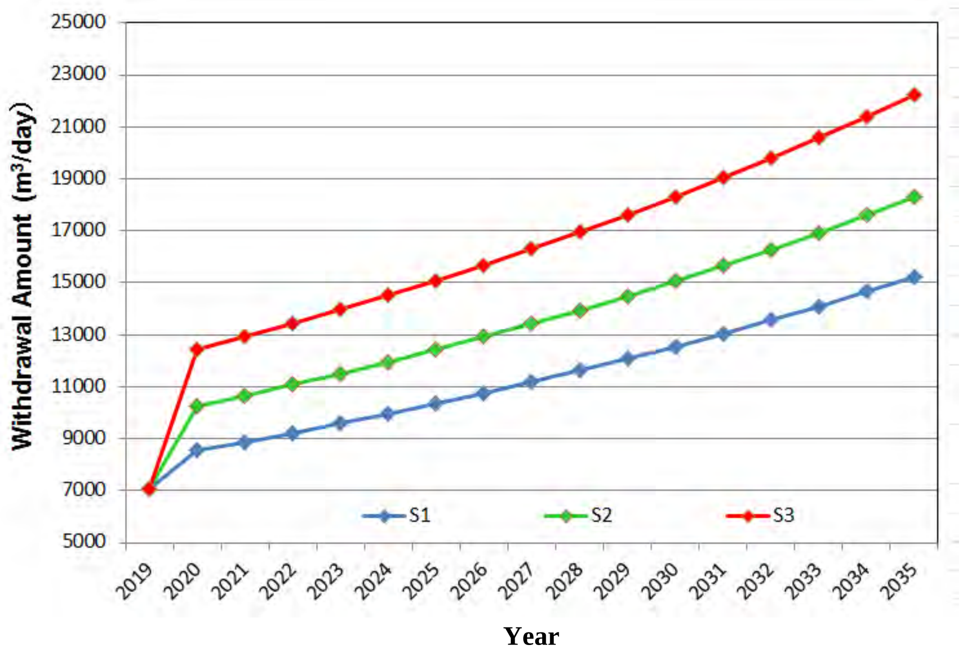
Source: the Project Team, Data: Calculation by Project member

Total amount of changes in Scenario 1 to 3 from 2019 to 2035 are shown in the following Table 5.3.2) and figure 5.3.1.

Table 5.3.2: Ageing of the Estimated Water Demand (Yield) of Each Scenario (m^3/day)

Year	Scenario1	Scenario2	Scenario3
2019	7051.0	7051.0	7051.0
2020	8,539.8	10,251.6	12,422.5
2021	8,874.3	10,653.4	12,912.8
2022	9,221.9	11,070.8	13,423.5
2023	9,583.2	11,504.4	13,953.8
2024	9,959.0	11,955.7	14,504.8
2025	10,350.0	12,425.2	15,078.4
2026	10,755.9	12,912.4	15,674.4
2027	11,178.5	13,419.4	16,295.5
2028	11,617.5	13,946.4	16,940.8
2029	12,074.6	14,495.6	17,612.4
2030	12,550.1	15,066.1	18,310.3
2031	13,044.4	15,659.5	19,037.3
2032	13,558.3	16,276.7	19,791.6
2033	14,091.8	16,916.8	20,576.1
2034	14,647.9	17,584.4	21,394.9
2035	15,226.3	18,279.2	22,244.7

Source: the Project Team, Data: Calculation by Project member



S1: Scenario1, S2: Scenario 2 and S3: Scenario 3

Source: the Project Team, Data: Calculation by Project member

Figure 5.3.1: Aging Figure of Estimated Water Demand (Yield) of Each Scenario

5.4 Specification in analysis of transient flow

5.4.1 Parameter

The parameters are specified in general (tentative values) as follows:

- Storage Coefficient : 0.0001 (uniformity)
- Specific Yield : 0.15 (uniformity)

5.4.2 Period specification

A year will be separated into two periods corresponding to the dry season from November of the previous year to March, and the rainy season from April to October. The total number of periods in the 16 calculation years (2020-2035) should be calculated as follows:

Total Periods ＝ 16 × 2 = 32 Periods

To get relatively detailed water level fluctuation information, not only period's specification based of seasons but also time steps are specified in monthly units. Therefore, in the 16 calculation years, the total time steps are:

Total Steps ＝ 16 × 2 = 32 Steps

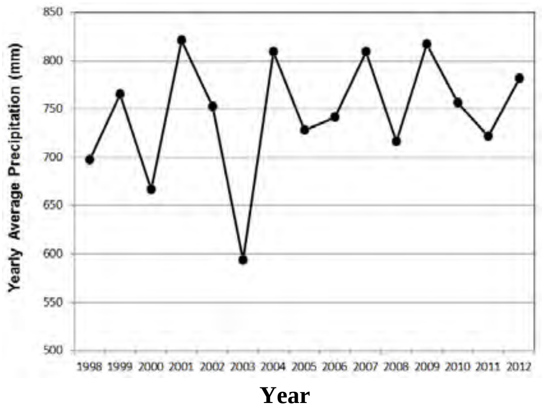
It is common sense that water demand is not the same in the rainy season and the dry season; more water is generally used in the dry season than the rainy season. Therefore, the water service amount planned as yearly average should be separated into different amounts for different seasons. The daily water service amount in the 7-month rainy season from April to October is set as 90 % of the yearly average amount, and then the daily water service amount for the dry season can be calculated by the following equation:

Daily water service amount in dry season / yearly average amount

$$= (12 - 0.9 \times 7) / 5 = 1.14$$

5.4.3 Rainfall specification

The setting of the rainfall was carried out using the results of 13 stations (rain gauges) from 1998 to 2012. Figure 5.4.1 shows the annual mean rainfall as a result of those calculations.



Source: the Project Team, Data: Calculation by Project member

Figure 5.4.1: Annual Mean Rainfall

The rainfall setting was carried out using the following procedure. The rainfall taken from each station was set up to the range of 7.4% to 9% in accordance with the results of the groundwater recharge (Ratio between rainfall and groundwater recharge in each sub-basin). The basic model setting is daily unit, and the results of the calculation were set in each cell in the model by using the Natural method of ArcGIS. The annual rainfall was set in the two time frames from April to October in the rainy season, and the dry season from November to March. The analysis was conducted two times in 16 years measuring the water demand of 16 years.

5.5 Results of future simulation

5.5.1 The fluctuation of groundwater

The analysis of the groundwater fluctuation by the groundwater model was performed in accordance with the three Scenarios, rainfall and groundwater recharge. The estimated groundwater fluctuation Figure was selected in the small towns of the 30 towns from sub-basins as shown below; (Figure below: Source: the Project Team, Data: Calculation by Project member)

[SB2-L] (Unit: vertical axis: Elevation (m), horizontal axis: year, same as below figure)

(ES-12: Initial value, S1: Scenario 1, S2: Scenario 2, S3: Scenario3, same as below figure)

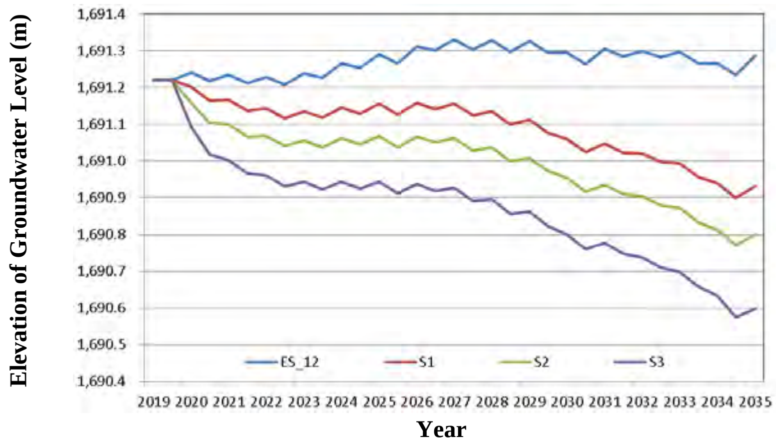


Figure 5.5.1: Estimated Groundwater Level Fluctuation (ES-12)

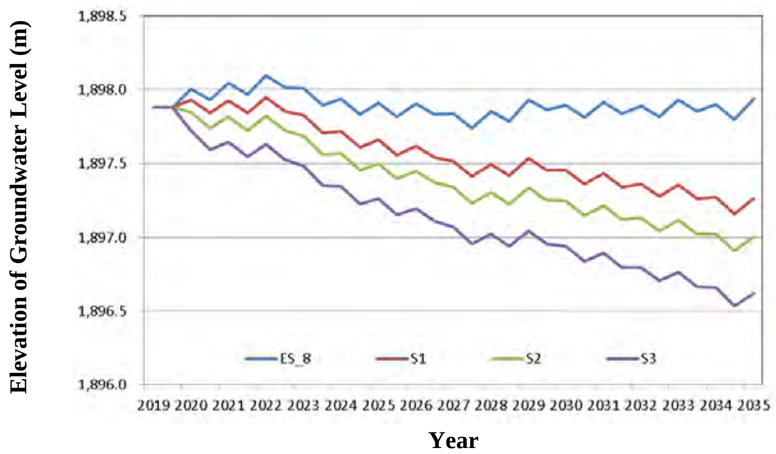


Figure 5.5.2: Estimated Groundwater Level Fluctuation (ES-8)

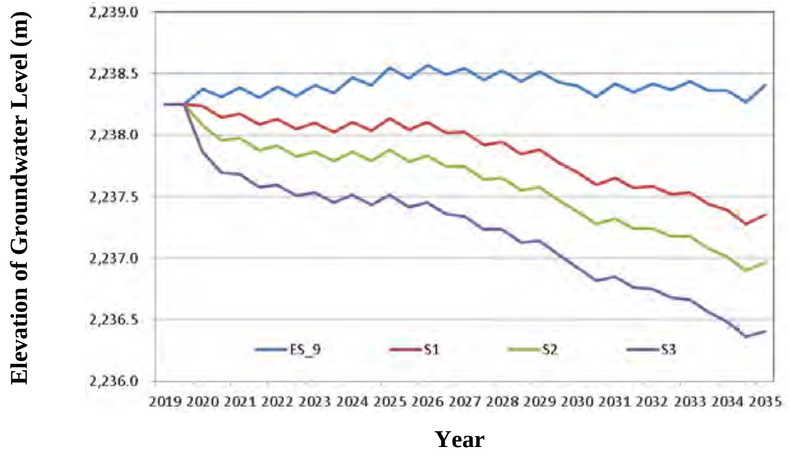


Figure 5.5.3: Estimated Groundwater Level Fluctuation (ES-9)

[SB3-L]

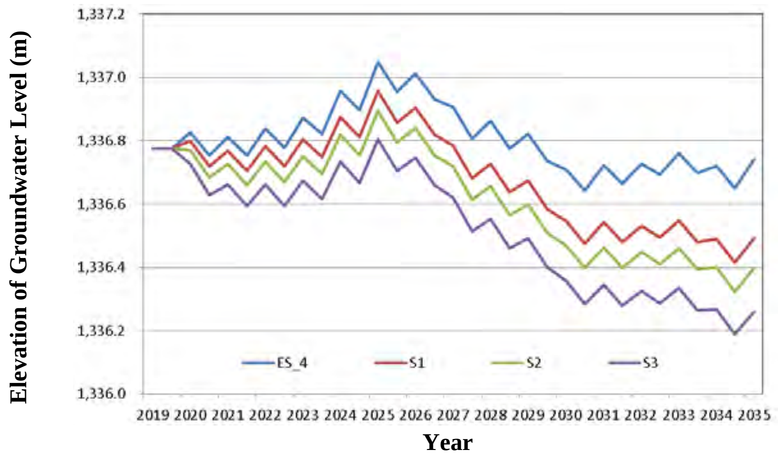


Figure 5.5.4: Estimated Groundwater Level Fluctuation (ES-4)

[SB3-R]

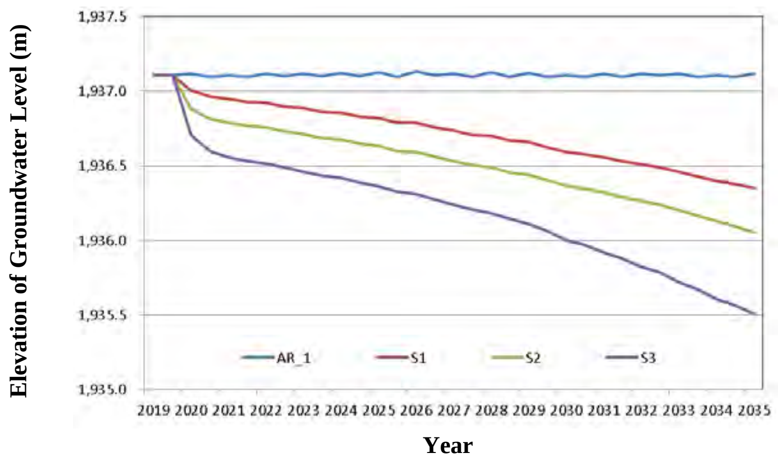


Figure 5.5.5: Estimated Groundwater Level Fluctuation (AR-1)

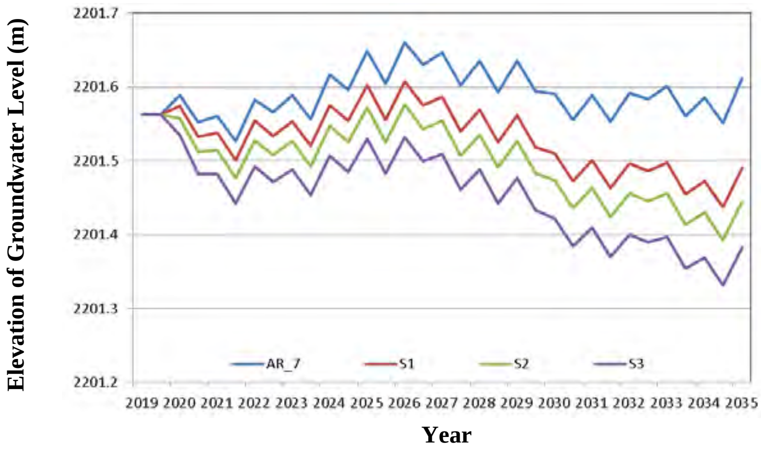


Figure 5.5.6: Estimated Groundwater Level Fluctuation (AR-7)

[SB-BSK-W]

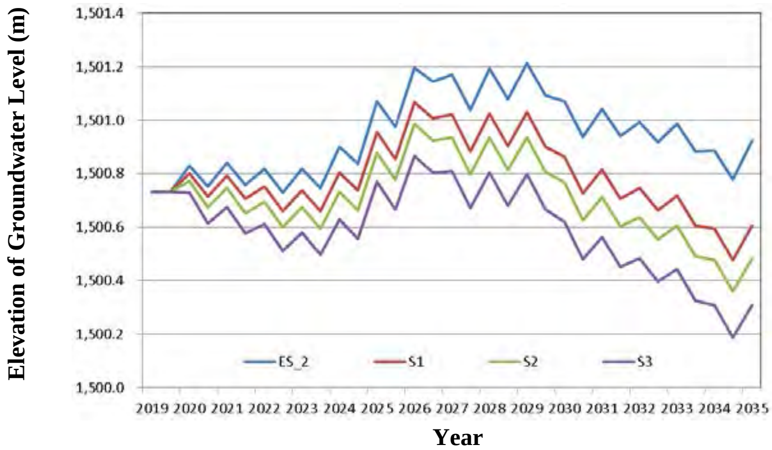


Figure 5.5.7: Estimated Groundwater Level Fluctuation (ES-2)

[SB4-L-U]

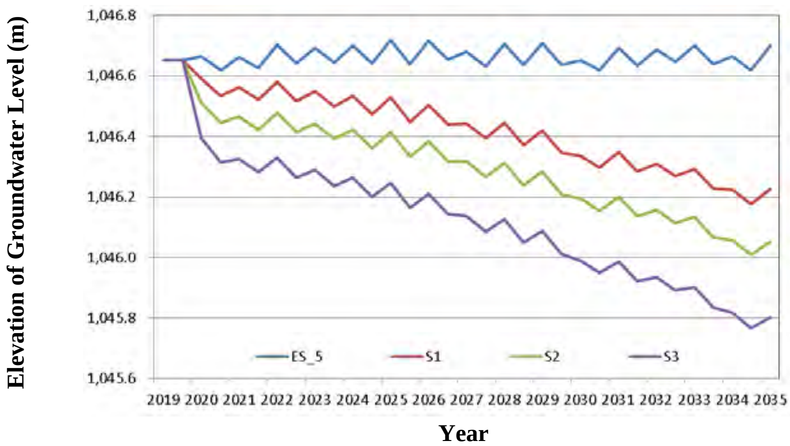


Figure 5.5.8: Estimated Groundwater Level Fluctuation (ES-5)

[SB4-R]

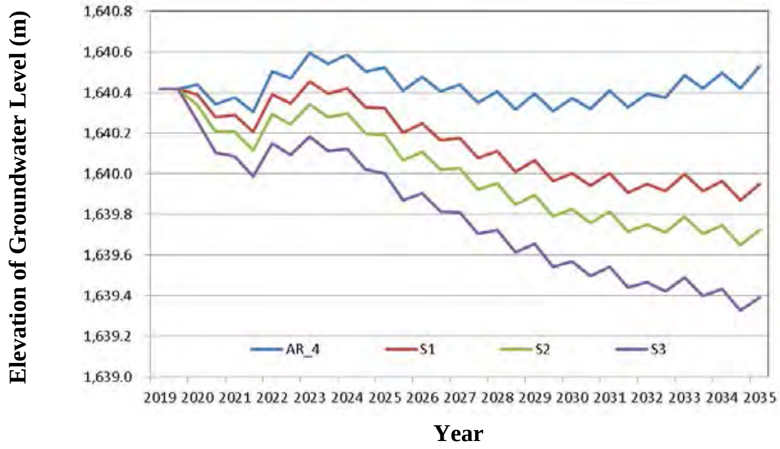


Figure 5.5.9: Estimated Groundwater Level Fluctuation (AR-4)

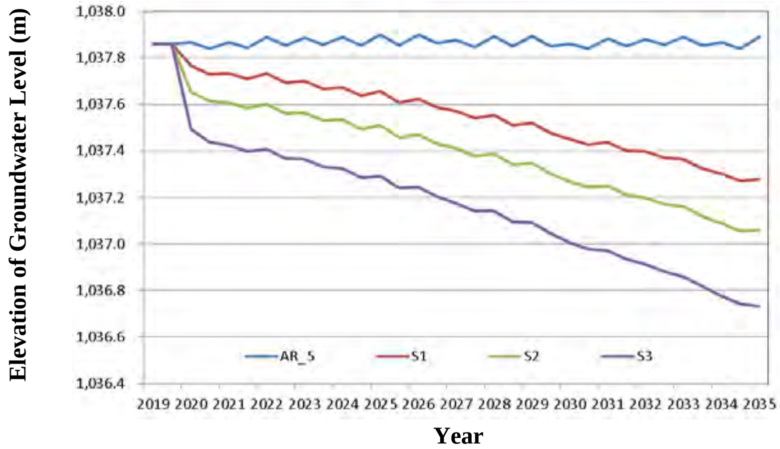


Figure 5.5.10: Estimated Groundwater Level Fluctuation (AR-5)

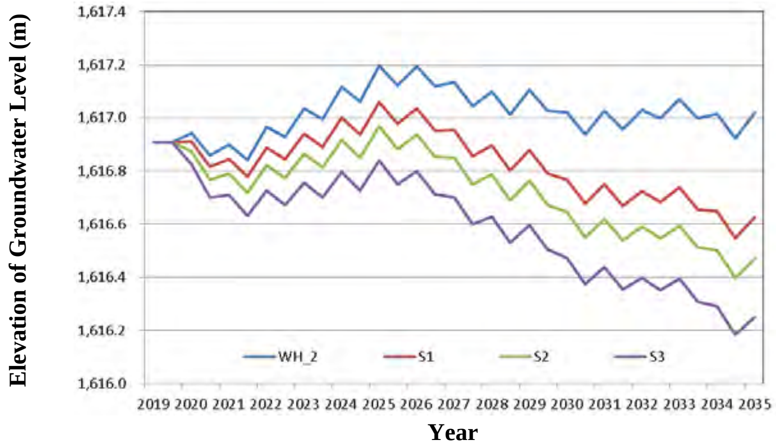


Figure 5.5.11: Estimated Groundwater Level Fluctuation (WH-2)

[SB5-R]

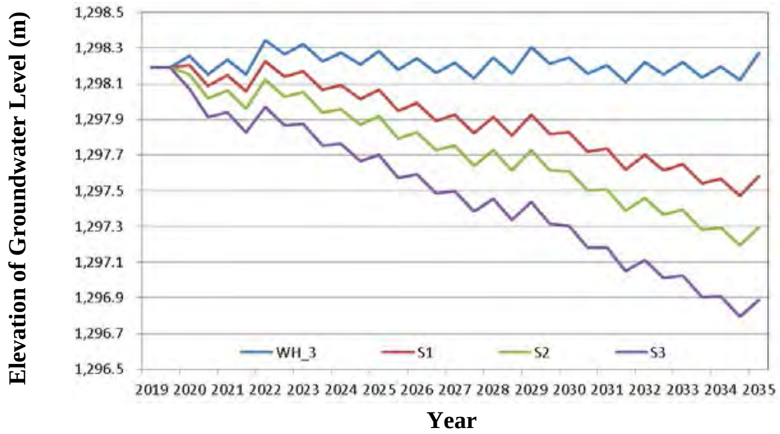


Figure 5.5.12: Estimated Groundwater Level Fluctuation (WH-3)

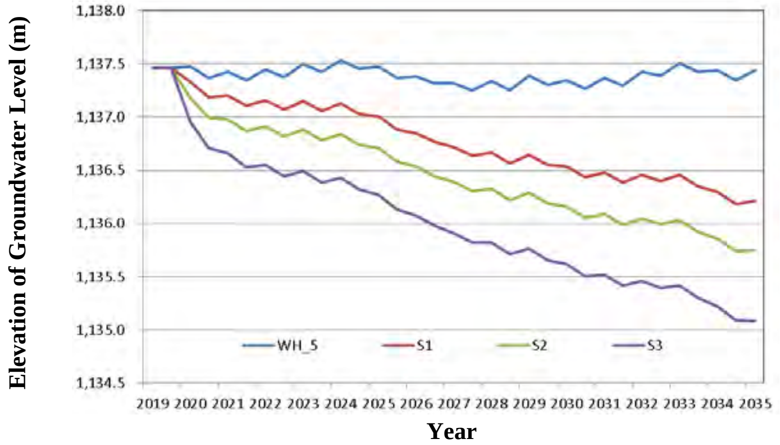


Figure 5.5.13: Estimated Groundwater Level Fluctuation (WH-5)

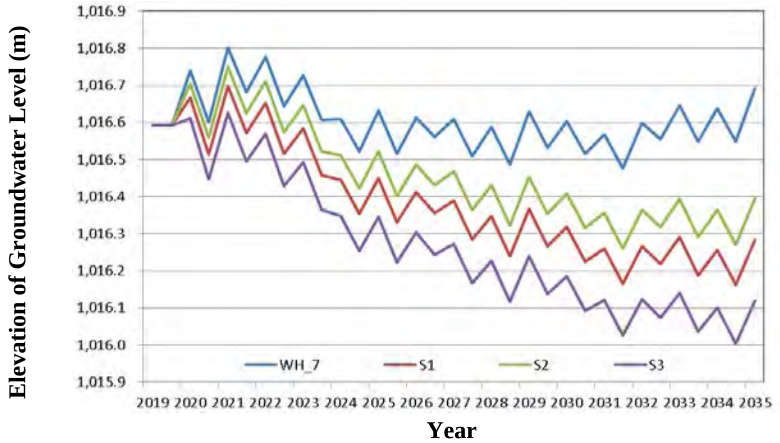


Figure 5.5.14: Estimated Groundwater Level Fluctuation (WH-7)

5.5.2 Result of drawdown of groundwater

The estimated drawdown of groundwater in the maximum water demand (yield) of Scenario_3 is shown in Table 5.5.1. The maximum drawdown of groundwater is 2.8 m.

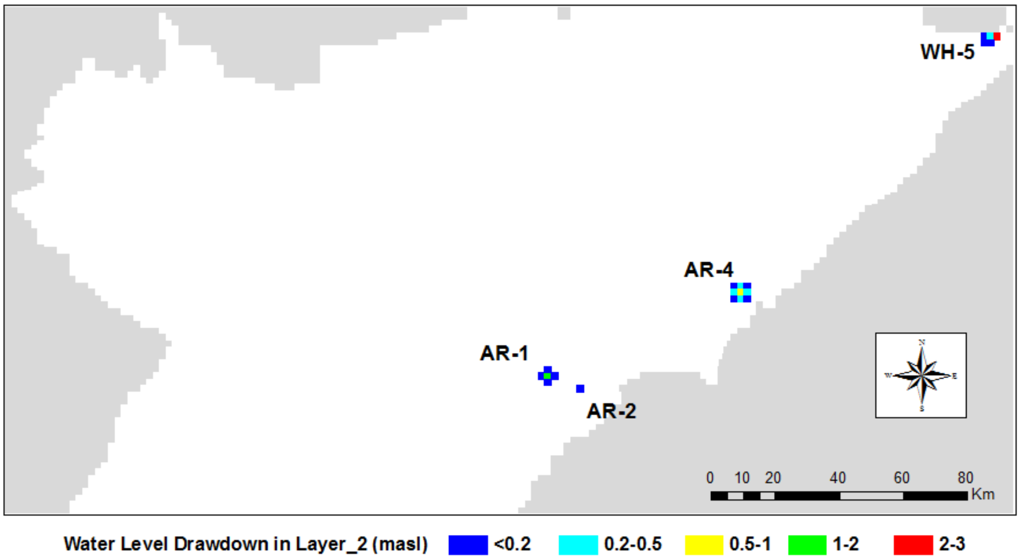
Table 5.5.1: Estimated Groundwater Drawdown in the Maximum Water Demand (Yield) of Scenario_3

Small town	Estimated Drawdown (m)	Small town	Estimated Drawdown (m)	Small town	Estimated Drawdown (m)
AR_1	1.59	ES_4	0.45	WH_2	0.66
AR_2	0.02	ES_5	0.85	WH_3	1.31
AR_3	2.80	ES_6	0.95	WH_4	0.50
AR_4	0.98	ES_7	0.47	WH_5	2.17
AR_5	1.11	ES_8	1.2	WH_6	0.18
AR_6	0.15	ES_9	1.89	WH_7	0.47
AR_7	0.19	ES_10	0.49	WH_8	0.13
ES_1	1.69	ES_11	0.63	WH_9	0.12
ES_2	0.54	ES_12	0.63	WH_10	0.19
ES_3	1.41	WH_1	0.23	WH_11	0.18

Source: the Project Team, Data: Calculation by Project member

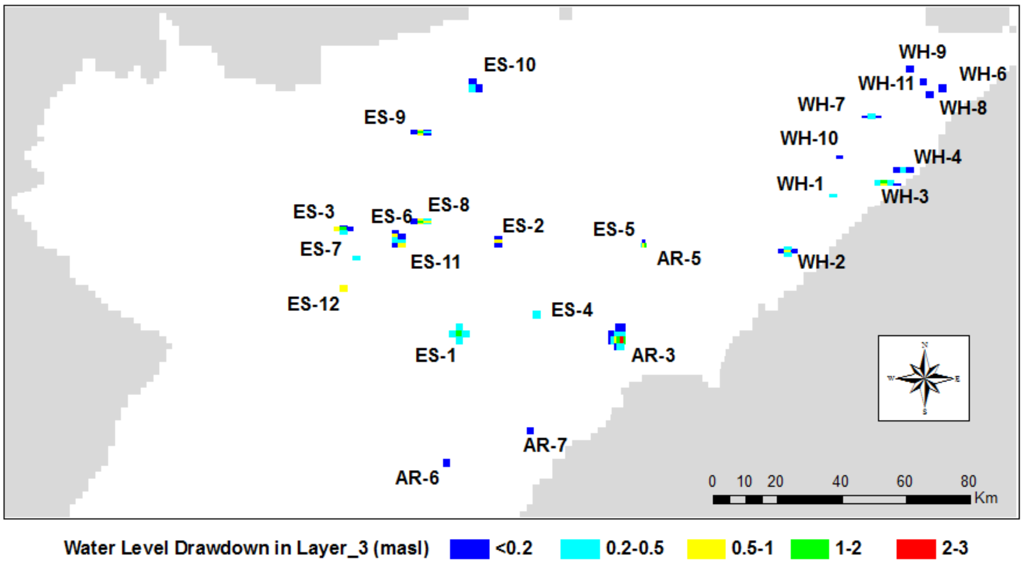
5.6 Effect of groundwater drawdown on surrounding areas

As mentioned in Table 5.5.1, the groundwater level decreases due to the increasing yield of wells; that is, pumping water out of wells will result in a lower groundwater level. Moreover, it is possible that the surrounding area will be affected by the decreasing groundwater level. In particular, the surrounding area of the large water demand (yield) area, such as small town AR-3 is probably affected by the maximum drawdown. Scenario 3 indicates the maximum drawdown from the estimated water demand (yield) of wells. Four of the drilled wells were at a level extracting water from the second geological layer and 26 wells were pumping from the third layer based on the estimated depth of wells. The surrounding areas affected by groundwater drawdown are illustrated in Figure 5.6.1 and Figure 5.6.2 in each layer respectively. The estimated drawdown of the groundwater indicates -2 to -3 m down in the surrounding areas of WH-5 and AR-3 of small towns. The groundwater level in the other areas will decrease by about -0.5 m.



Source: the Project Team, Data: Calculation by Project member

Figure 5.6.1: Drawdown Map of the Surrounding Area in the Second Layer (Scenario 3)



Source: the Project Team, Data: Calculation by Project member

Figure 5.6.2: Drawdown Map of the Surrounding Area in the Third Layer (Scenario 3)

5.7 Approaches to the evaluation of potential amount by the groundwater development

The potential amount of groundwater development covered in this section is not the static storage amount of groundwater in the field, but rather the sustainable yield at which each of the aquifer units can be utilized at. The groundwater recharge is the index for the storage of groundwater as mentioned in Chapter 4. The artificial discharge will not exceed the groundwater recharge according to the prediction of the groundwater usage up to 2035.

Groundwater fluctuation with quantitative changes occurs from the yield of the groundwater in the sub-basin. Possible negative impacts of significant water usage that may obstruct groundwater use include considerable decreases in groundwater level, degradation of water quality and land subsidence (rare in the Project area). Of course, pumping such quantities of water so as to cause such impacts is not an acceptable level of groundwater development. In that case, how should the suitable potential amount through groundwater development be calculated without having a negative impact on the potential to use groundwater in the project area?

In Ethiopia, it is difficult to calculate the potential amount through groundwater development in terms of the management of the groundwater level because there is insufficient monitoring data available for the ageing of groundwater. Therefore, some ideas were approached below for the sustainable yield of the groundwater.

5.7.1 Estimated yield and prediction of groundwater fluctuation

As mentioned above, the middle Awash River basin was divided into thirteen sub-basins. Aside from the future simulation, for the calculation of groundwater fluctuation, the yield of the three stages was assumed as the standard initial yield using the data of the existing wells and JICA wells in each sub-basin. The three stages of the initial yield are a 25% increase (small), a 70% increase (middle), and a 250% increase (Large). The drawdown of the groundwater for the yield of wells in the three stages which was estimated in the sub-basin is as follows in Table 5.7.1.

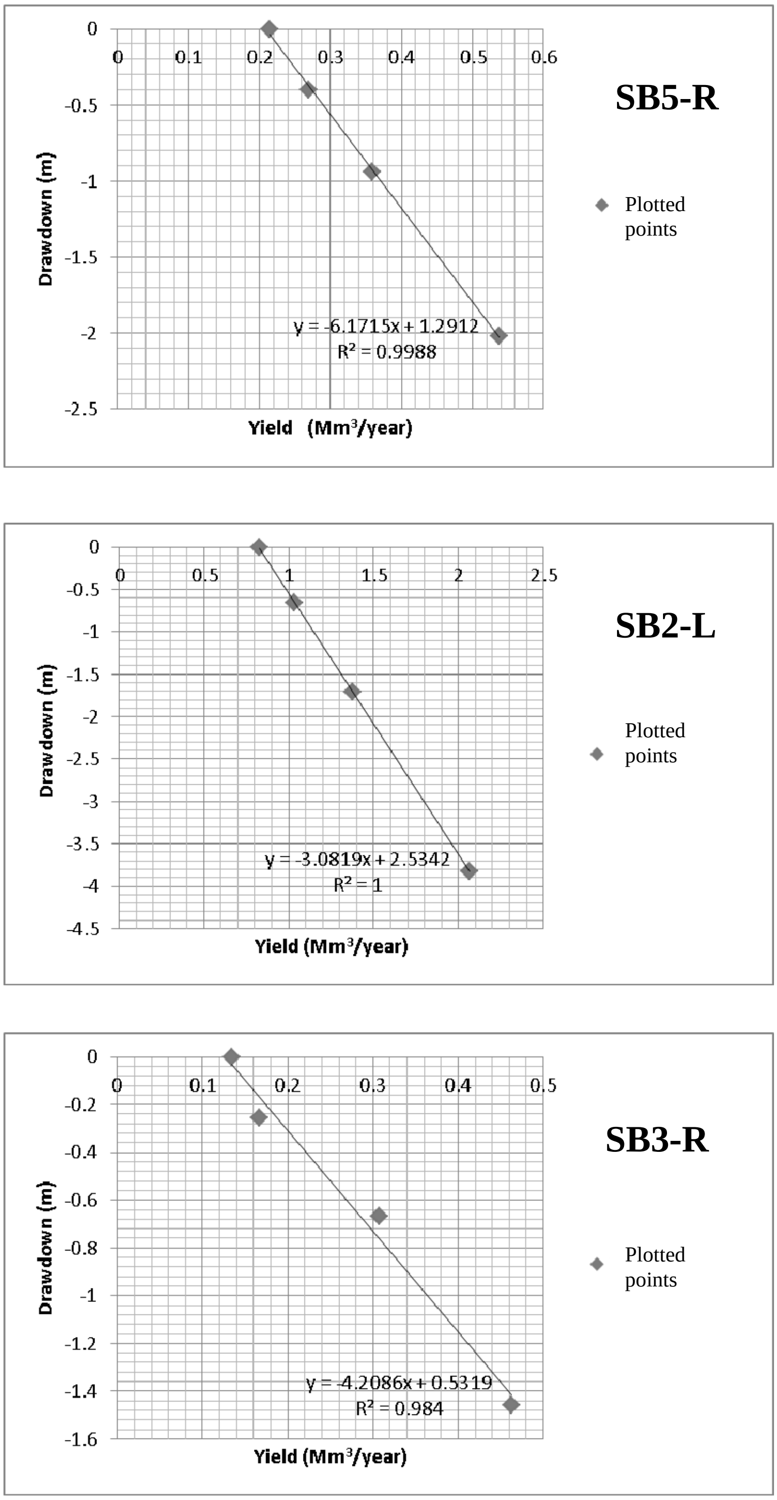
Table 5.7.1: Estimates Drawdown and Yield in Each Sub-Basin

Sub-basin		Assumed mean yield	Estimated mean drawdown
		Mm^3/year	m
SB2-L	AC	0.826	0
	S	1.032	-0.659
	M	1.376	-1.708
	L	2.064	-3.824
SB3-L	AC	0.095	0
	S	0.118	-0.369
	M	0.157	-0.823
	L	0.236	-1.735
SB3-R	AC	0.134	0
	S	0.167	-0.257
	M	0.308	-0.668
	L	0.463	-1.459
SB4-R	AC	0.132	0
	S	0.166	-0.467
	M	0.221	-1.117
	L	0.331	-2.425
SB-BSK-W	AC	0.221	0
	S	0.276	-0.141
	M	0.368	-0.647
	L	0.552	-1.667
SB5-L	AC	0.237	0
	S	0.297	-0.392
	M	0.396	-0.834
	L	0.594	-1.721
SB-BSK	AC	0.193	0
	S	0.241	-0.466
	M	0.321	-1.488
	L	0.482	-3.549
SB4-L-D	AC	3.154	0
	S	3.942	-1.912
	M	5.256	-5.222
	L	7.884	-11.857
SB5-R	AC	0.215	0
	S	0.269	-0.402
	M	0.359	-0.939
	L	0.538	-2.017

Source: the Project Team, Data: Calculation by Project member

For the results of the calculation, the correlation formulas of estimated drawdown and yield were created as shown in Figure 5.7.1 with the three sub-basins as the samples. The yield is highly correlated with the ground water drawdown. So when some drawdown values are decided, the yield will probably be estimated in response to the drawdown values.

The possible yield was predicted by the estimated drawdown using the correlation formulas calculated in each sub-basin.



Source: the Project Team, Data: Calculation by Project member

Figure 5.7.1: Correlation Chart of Estimates Drawdown and Yield in Three Sub-Basins

5.7.2 Estimation of the possible yield

The possible yield was estimated by the two methods in this section.

In the first method, the yield is calculated when the static groundwater level of wells in sub-basin decreases to the minimum groundwater elevation level in the sub-basin. The current elevation of the groundwater level is indicated in Figure 5.7.2. When the mean elevation of the groundwater level dips from the current elevation of the minimum groundwater level through the huge yield in the sub-basin, the groundwater will dry up. The initial static groundwater level is the first mean static groundwater level of wells. The permissive maximum drawdown is calculated using the difference between the elevation of the minimum groundwater level in the sub-basin and the mean static groundwater level of wells. The calculated permissive maximum drawdown values apply to the correlation formulas indicated above for each sub-basin of the estimated drawdown and yield. The maximum possible yield will be estimated by the formulas. The final results are shown in Table 5.7.2.

Table 5.7.2: Estimated Possible Yield (First Approach)

Sub-basin	Mean Elevation (E)	Mean static groundwater level elevation (SWL)	Minimum groundwater level elevation by contour map (WE)	Calculated maximum drawdown of groundwater (L= WE－SWL)	Calculated and estimated possible yield (Q)	Annual groundwater recharge (GWR)	Q/GWR [%]
	[m]	[m]	[m]	[m]	[10^6 m^3/year]	[10^6 m^3/year]	
SB2-L	1,794	1,751	1,600	-151	50	358.4	14
SB3-L	1,512	1,390	1,250	-140	12	37.8	32
SB3-R	1,801	1,664	1,400	-264	63	178.1	35
SB4-L-D	938	891	880	-11	8	15.4	52
SB4-R	1,719	1,565	1,000	-565	47	208.8	23
SB-BSK-W	1,151	976	950	-26	5	120.2	4
SB5-L	2,202	2,080	1,500	-580	123	330.8	37
SB-BSK	1,012	959	900	-59	5	25.3	20
SB5-R	1,235	1,156	800	-356	58	161.0	36

Source: the Project Team, Data: Calculation by Project member

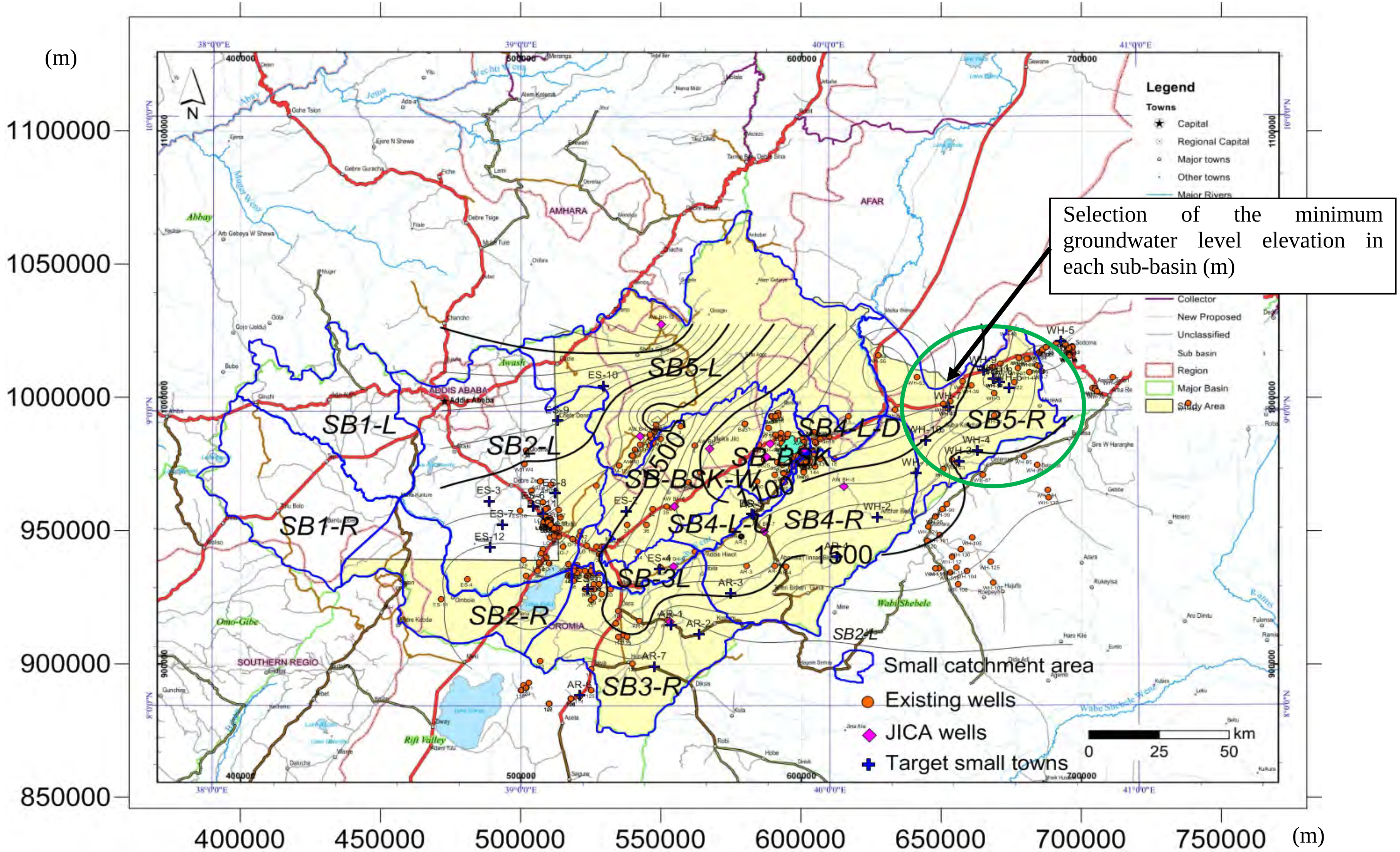
The results of the calculations indicate excessive values of the maximum drawdown of groundwater level in some sub-basins. A massive decrease in the groundwater level may occur in wells in relation to the well depth and/or pressure from the surrounding area.

In the second method, the differences between well depth and the static groundwater level replaces the drawdown values of groundwater. The calculated drawdown values apply to the correlation formulas indicated above for each sub-basin of the estimated drawdown and yield. The results of the calculation show the estimated possible yield in Table 5.7.3.

Table 5.7.3: Estimated Possible Yield (Second Approach)

Sub-basin	Mean drawdown of groundwater	Calculated and estimated possible yield (Q)	Annual groundwater recharge (GWR)	Q/GWR [%]
	[m]	[10^6 m^3/year]	[10^6 m^3/year]	
SB2-L	-225	73	358.4	20
SB3-L	-72	6	37.8	16
SB3-R	-73	18	178.1	10
SB4-R	-134	11	208.8	5
SB-BSK-W	-75	15	120.2	12
SB5-L	-123	26	330.8	8
SB-BSK	-100	8	25.3	32
SB5-R	-115	19	161.0	12

Source: the Project Team, Data: Calculation by Project member



Source: the Project Team, Data: reference ①, ②, 3) of ③

Figure 5.7.2: Groundwater Level Contour Map

The estimated possible yield was calculated in light of the current well conditions and groundwater level information. The groundwater level contour map and the possible yield will change when the depth of wells becomes deeper and the number of wells increases. Therefore, when estimating the possible yield using the current well information, we considered two approaches to the estimated values. The comparison between the estimated possible yield and the groundwater recharge is tabulated in Table 5.7.4. As mentioned in Chapter 4, regarding the total yield of 2035, the proportion of the estimated possible yield to the groundwater recharge is 1 to 5% (except for two sub-basins). The ratio of Table 5.7.4 indicates that it is possible to develop groundwater wells to the amounts estimated as possible yield in 2035. (One sub-basin of two is SB2-L, which includes the groundwater usage of Addis Ababa, making the total estimated yield at SB2-L in 2035 about 134 Mm^3. However, the estimated yield is 25 Mm^3 in 2035 when the water usage amount of Addis Ababa is excluded. This is below the possible yield. And the irrigation well drilled to 595 m in depth is counted for the yield of 100 L/sec in SB4-L-D. The proportion of the yield in SB4-L-D to the groundwater recharge is about 46%. So according to the calculation, the remaining estimated possible yield is limited in SB4-L-D, if this yield continues.)

Table 5.7.4: Proportion of Estimated Possible Yield to Groundwater Recharge (as of 2035)

Sub-basin	Calculated and estimated possible yield (Q) [10^6 m^3/year]	Annual groundwater recharge (GWR) [10^6 m^3/year]	Q/GWR [%]
SB2-L	50〜73	358.4	14〜20
SB3-L	6〜12	37.8	16〜32
SB3-R	18〜63	178.1	10〜35
SB4-L-D	8	15.4	52
SB4-R	11〜47	208.8	5〜23
SB-BSK-W	5〜15	120.2	4〜12
SB5-L	26〜123	330.8	8〜37
SB-BSK	5〜8	25.3	20〜32
SB5-R	19〜58	161.0	12〜36

Source: the Project Team, Data: Calculation by Project member

Reference

① Mainly well records mentioned in existing reports:

1) Hydrogeology (map) of the Nazret, EIGS, 1985
2) Evaluation of water resources of the Ada'a and Becho plains groundwater basin for irrigation development project, WWDSE, planned by MoWR, 2009
3) Allaidege plain groundwater resources assessment project, WWDSE planned by MoWR, 2009
4) Study and design of Lake Besaka level rise project Ⅱ, WWDSE, planned by MoWE, 2011
5) Growing lake with growing problems: integrated hydrogeological investigation on Lake Beseka, Ethiopia, ELENI AYALEW BELAY, 2009
6) Assessment and evaluation of causes for Beseka Lake level rise and design mitigation measures PartⅡ: Study for medium and long term solutions (Main report final), MoWIE and OWWDSE, 2014
7) Groundwater origin and flow along selected transects in Ethiopian rift volcanic aquifers, Seifu Kebede et all, 2008

② Well drilling records including well columnar section and pumping test record:

1) Existing well data including columnar section and pumping test record in West Hararge Zone
2) Existing well data including columnar section and pumping test record in Arsi Zone.
3) Existing well data including columnar section and pumping test record in East Shewa Zone
4) Well completion reports and well data in Arerti（Amhara Region）woreda, Lomme（Oromia Region） woreda
5) WWDSE, 2014 Irrigation data（Well depth 595m）

③ Others references

1) Editing: Japanese Association of Groundwater Hydrology, Science for brand-name spring water, 1994
2) Hydrogeological map of Ethiopia (1:2,000,000) compiled by Tesfaye Chernet and the Regional Geology Department, EIGS, 1988

④ Data (including photo on site) from field survey and interview, etc. by the Project Team

Chapter 6

Water Supply Plan of Small Towns

6 Water Supply Plan of Small Towns

6.1 Introduction

This chapter describes the following results of this survey.

a. Review of the results of basic survey

The results of surveys such as population for water supply, number of users coming from outside of water supply area, amount of water usage, number of private connections, condition of wear and tear (aging) of the existing water supply facilities, condition of commercial electric power supply, etc. as fundamental data for preparation of provisional water supply plan and operation and maintenance plan were reviewed.

b. Target year and estimated population

Setting of target year and population projection which are necessary for the projection of water demand were conducted, in which an increase in the number of private water connections was projected and also in the population using public taps and private connections was projected.

c. Water demand

Water demand of 30 small towns as of the target year was calculated based on the population projection mentioned above.

In addition, water demand was calculated adopting 20 L/c/d (public taps) and 30 L/c/d (private connection) as basic water demand in the interim report of this Project. After that, the Second Growth and Transformation Plan (hereafter referred to as “GTP2”) were published in August 2015, in which standard basic water demand is set as 40 L/c/d for urban area and 25 L/c/d for rural area.

Then, according to the request from Ministry of Water, Irrigation and Electricity (hereafter referred to as “MoWIE”) and Oromia Regional Water, Mineral and Energy Bureau (hereafter referred to as “OWMEB”), water demand was calculated again adopting standard basic water demand of GTP2 in this report.

d. Groundwater Development Plan

Based on the results of survey, evaluation of groundwater development potential was conducted. After examining the possibility of groundwater development, groundwater development plan was elaborated for all of the 30 small towns.

e. Provisional water supply plan of small towns

The validity and rationality of the 30 small towns in the provisional water supply plan was investigated. The result found that 19 of the 30 small towns were valid for developing water supply plans (including planning of water sources) based on the ground development plan.

f. Operation and maintenance plan for water supply facilities

Based on the results of survey concerning a framework (system) for operation and maintenance of water supply facilities in the target region and present situation of operation and maintenance of water supply facilities of target small towns, issues concerning operation and maintenance are compiled and operation and maintenance plan and capacity development plan are elaborated, in which operation and maintenance cost is calculated based on the provisional water supply plan for all of the 19 small towns and is compared with existing water rate.

6.2 Review of the results of basic survey

6.2.1 Population for water supply

Data on the populations of the target small towns fall into three categories. Data collect by:

- the Central Statistical Agency (hereafter referred to as "CSA") in the 2007 Census (includes both population and population growth rate data),
- woreda administration offices, and
- town (or kebele) administration offices.

Copies of documentary evidence of population data held by woreda administration offices and town administration offices were collected. However the documents only include total population data without any details such as of breakdowns, and are thought to be unreliable and missing critical information. Therefore, in general, CSA population projections shall be adopted in this water supply plan. And the data from woredas or towns shall be used only as reference information.

The reasons for adopting the CSA projection values and comparisons of each category of data are outlined in Table 6.2.1.

6.2.2 Users coming from outside of water supply area

There are users who come to fetch water from the outside of a water supply area in most small towns that have a water supply system.

However, since these users are not registered, it is difficult to get the exact number. In order to get the number of users, the only way is to interview staff of town water supply offices and water associations. However, such data lacks reliability because only vague numbers can be obtained. Moreover, the reported number of outside users changes depending on the respondent.

Moreover, the users outside a water supply area who are not currently receiving water supply may be on the receiving end of a new water supply project in the future. Therefore, it is considered desirable not to include the number of users outside a water supply area into the population of water supply plans developed in this Project.

Table 6.2.1: Comparison of Population Data

ID	Town	Woreda	Population Projection Based on the CSA 2007		Woreda Admin. Office		Town Admin. Office or Kebele Admin. Office		Adopted Data	Reason to Adopt
			Population	Year	Population	Year	Population	Year		
ES-1	Wonji Shewa Alemtena	Adama Zuria	8,525	2014	7,838	2013/2014	No Data		CSA projection	Woreda administration office data is unreliable.
ES-2	Geldiya	Adama Zuria	2,257	2014	784	2013/2014	1,344	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
ES-3	Dire	Adaa	6,811	2014	6,878	2012/2013	6,002	2011/2012	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
ES-4	Bofa	Boset	4,185	2014	2,028	2011/2012	5,260	2008/2009	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
ES-5	Bole	Boset	5,275	2014	2,349	2011/2012	14,060	2013/2014	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
ES-6	Ude Dhankaka	Adaa	5,763	2014	4,313	2012/2013	2,753	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
ES-7	Bekejo	Adaa	6,624	2014	7,130	2012/2013	7,130	2011/2012	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
ES-8	Kamise	Lome	4,846	2014	2,184	2013/2014	2,184	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
ES-9	Chefe Donsa	Gimbichu	8,386	2014	13,137	2013/2014	13,137	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
ES-10	Areda	Gimbichu	2,752	2014	2,880	2013/2014	1,465	2013/2014	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
ES-11	Biyo	Lome	2,708	2014	2,500	2013/2014	2,500	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
ES-12	Adulala	Liben Zukala	3,882	2014	3,577	2013/2014	6,000	2012/2013	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
AR-1	Sire	Sire	11,097	2014	10,216	2013/2014	9,240	2012/2013	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
AR-2	Bolo	Jeju	1,579	2014	4,000	2013/2014	3,000	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable. CSA population is adopted.
AR-3	Arboye	Jeju	7,272	2014	7,800	2013/2014	10,600	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable. CSA population is adopted.
AR-4	Aseko	Aseko	5,283	2014	7,750	2013/2014	7,750	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
AR-5	Golegota	Merti	7,377	2014	5,560	2013/2014	7,739	2012/2013	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
AR-6	Gonde	Tiyo	3,434	2014	2,598	2013/2014	2,236	2006/2007	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
AR-7	Arbe Gebeya	Lode Hitossa	2,433	2014	2,711	2013/2014	6,149	2010/2011	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
WH-1	Chorora	Anchar	2,729	2014	2,511	2013/2014	3,100	2013/2014	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
WH-2	Bedeyi	Anchar	2,945	2014	3,481	2013/2014	5,520	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
WH-3	Hardim	Guba Qoricha	5,905	2014	5,021	2013/2014	5,021	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
WH-4	Bube	Guba Qoricha	6,246	2014	5,920	2013/2014	5,920	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
WH-5	Mieso	Mieso	17,672	2014	12,293	2013/2014	18,000	2012/2013	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
WH-6	Hargeti	Mieso	3,365	2014	4,966	2013/2014	No Data		CSA Projection	Data of Woreda Admin. Office is unreliable.
WH-7	Bordede	Mieso	2,940	2014	6,029	2013/2014	5,517	2009/2010	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
WH-8	Kenteri	Mieso	1,752	2014	3,787	2013/2014	No Data		CSA Projection	Data of Woreda Admin. Office is unreliable.
WH-9	Aneno	Mieso	2,851	2014	5,245	2013/2014	2,515	2013/2014	CSA Projection	Since Woreda administration office data and Town administration office data have discrepancy, CSA population which is a mean value is adopted.
WH-10	Belo	Mieso	4,690	2014	4,859	2013/2014	5,224	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.
WH-11	Kora	Mieso	2,376	2014	2,366	2013/2014	2,360	2013/2014	CSA Projection	Both Woreda administration office data and Town administration office data are unreliable.

*1 Source: Calculated based on CSA Census 2007
*2 Geldiya Alan Qebeti shown in CSA 2007
*3 Ouda shown in CSA 2007
*4 Beli Abo shown in CSA 2007
*5 Areda Gora shown in CSA 2007
*6 Biyo Biliqe shown in CSA 2007
*7 Goro Bati shown in CSA 2007

Table 6.2.2: Number of Users Coming from Outside of Water Supply Area

ID	Small Town	Number of Users Outside Water Supply Area (as of 2014)*1	Source (Breakdown)*1
ES-1	Wonji Shewa Alemtena	5,060	Water Committee (1,012HH)
ES-2	Geldiya	2,000	Water Committee (400HH)
ES-3	Dire	850	Water Committee (170HH)
ES-4	Bofa	11,000	Town Water Supply Office
ES-5	Bole	5,533	Town Water Supply Office (3,815person from Nura Hera 02 and 1,718 person from Nura Hera 03)
ES-6	Ude Dhankaka	0	
ES-7	Bekejo	0	
ES-8	Kamise	2,600	Water Committee (from Beli Abo)
ES-9	Chefe Donsa	2,000	Town water Supply Office (from Harberseftu)
ES-10	Areda	1,750	water Committee (250HH from Enbus Indode, 40 HH from Burekoulaula, 50HH from Webermansur, 10HH from Somjona Kombolcha)
ES-11	Biyo	0	
ES-12	Adulala	5,816	Town Water Supply Office (from Adele Mecha)
AR-1	Sire	1,000	Town Water Supply Office (from Gesela Shashe and Borera)
AR-2	Bolo	11,500	Town water Supply Office (1,300HH from Hogesoboreno, 250HH from Kolob Bolo, 200HH from Utamo Doje, 300HH from Keloba Kalo and so on)
AR-3	Arboye	17,605	Water Committee (953HH from Senbeto Fenicha, 381HH from Egu Chuka, 774HH from Gure Tebeno, 702HH from Arijero Qere, 386HH from Shedare Chefa, 325HH from Wenjelo Wedeyimena, Total 3,521HH)
AR-4	Aseko	0	
AR-5	Golegota	0	
AR-6	Gonde	0	
AR-7	Arbe Gebeya	0	
WH-1	Chorora	2,000	Water Committee (400HH)
WH-2	Bedeyi	0	
WH-3	Hardim	4,000	Water Committee (800HH)
WH-4	Bube	400	
WH-5	Mieso	975	Town water Supply Office (195HH)
WH-6	Hargeti	0	
WH-7	Bordede	1,550	Water Committee (310HH)
WH-8	Kenteri	0	
WH-9	Aneno	0	
WH-10	Belo	250	Water Committee (50HH)
WH-11	Kora	4,250	Water Committee (850HH)

*1 Source: Results of interview to Town Water Supply Office or Water Committee

6.2.3 Amount of water usage

Table 6.2.3 shows the amount of water use by private connection and public tap of the existing water supply systems in target small towns.

Table 6.2.3: Amount of Water Use of Existing Water Supply Systems

ID	Small Town	Population *1	Number of Households *1	Population per Household *1	Amount of Water Use of Existing Water Supply Facilities									Remark
					Private Connection				Public Taps			Total		
					Number of Private Connections *2	Population	Amount of Water Use *3 (m^3/month)	Amount of Water Use per Person per Day (l/ capita/ day)	Population	Amount of Water Use *3 (m^3/month)	Amount of Water Use per Person per Day (l/ capita/ day)	Amount of Water Use *3 (m^3/month)	Amount of Water Use per Person per Day (l/ capita/ day)	
ES-1	Wonji Shewa Alemtena	8,525	2,039	4.18	44	184	691	125.2	8,341	31	0.1	722	2.8	
ES-2	Geldiya	2,257	509	4.44	232	1,030	2,363	76.5	1,227	452	12.3	2,815	41.6	
ES-3	Dire	6,811	1,457	4.67	91	425	1,088	85.3	6,386	859	4.5	1,947	9.5	
ES-4	Bofa	4,185	1,105	3.79	260	985	4,451	150.6	3,200	2,444	25.5	6,895	54.9	
ES-5/ AR-5	Bole/ Golegota	12,652	4,057	3.12	273	846	3,513	138.4	11,806	1,908	5.4	5,421	14.3	1 System Supplying to 2 Towns
ES-6	Ude Dhankaka	5,763	1,269	4.54	0	0	0	0.0	5,763	0	0.0	0	0.0	Borehole with Hand Pump
ES-7	Bekejo	6,624	1,358	4.88	30	146	219	50.0	6,478	771	4.0	990	5.0	
ES-8	Kamise	4,846	963	5.03	3	15	69	153.3	4,831	277	1.9	346	2.4	
ES-9	Chefe Donsa	8,386	2,655	3.16	921	2,910	6,169	70.7	5,476	246	1.5	6,415	25.5	
ES-10	Areda	2,752	556	4.95	0	0	0	0.0	2,752	330	4.0	330	4.0	
ES-11	Biyo	2,708	560	4.83	0	0	0	0.0	2,708	0	0.0	0	0.0	Borehole with Wind Pump
ES-12	Adulala	3,882	1,235	3.14	431	1,353	3,825	94.2	2,529	437	5.8	4,262	36.6	
AR-1	Sire	11,097	3,505	3.17	516	1,636	1,052	21.4	9,461	1,212	4.3	2,264	6.8	
AR-2	Bolo	1,579	403	3.92	56	220	488	73.9	1,359	238	5.8	726	15.3	
AR-3	Arboye	7,272	2,077	3.50	570	1,995	7,841	131.0	5,277	310	2.0	8,151	37.4	
AR-4	Aseko	5,283	1,587	3.33	67	223	351	52.5	5,060	1,039	6.8	1,390	8.8	
AR-6	Gonde	3,434	983	3.49	283	988	2,732	92.2	2,446	754	10.3	3,486	33.8	
AR-7	Arbe Gebeya	2,433	667	3.65	350	1,278	6,222	162.3	1,155	398	11.5	6,620	90.7	
WH-1	Chorora	2,729	566	4.82	146	704	516	24.4	2,025	121	2.0	637	7.8	
WH-2	Bedeyi	2,945	731	4.03	101	407	385	31.5	2,538	119	1.6	504	5.7	
WH-3	Hardim	5,905	1,231	4.80	90	432	118	9.1	5,473	426	2.6	544	3.1	
WH-4	Bube	6,246	1,238	5.05	13	66	56	28.3	6,180	488	2.6	544	2.9	
WH-5	Mieso	17,672	4,133	4.28	728	3,116	6,497	69.5	14,556	247	0.6	6,744	12.7	
WH-6	Hargeti	3,365	747	4.51	0	0	0	0.0	3,365	0	0.0	0	0.0	No Facility
WH-7	Bordede	2,940	742	3.96	162	642	1,402	72.8	2,298	416	6.0	1,818	20.6	
WH-8	Kenteri	1,752	401	4.37	0	0	0	0.0	1,752	0	0.0	0	0.0	No Facility
WH-9	Aneno	2,851	598	4.76	0	0	0	0.0	2,851	0	0.0	0	0.0	No Facility
WH-10	Belo	4,690	926	5.06	2	10	0	0.0	4,680	366	2.6	366	2.6	
WH-11	Kora	2,376	597	3.98	80	318	453	47.5	2,058	680	11.0	1,133	15.9	

*1 Source: Calculated Based on CSA Census 2007

*2 Source: Town Water Supply Office or Water Committee

*3 Source: Calculated Based on the Record of Water Meter Reading by Town Water Supply Office or Water Committee

6.2.4 Increase of the number of private connections

Water supply by private connections is performed in 24 out of 30 small towns. The number and diffusion rate of private connections for every town are shown in Table 6.2.4. To conduct water supply planning, it is necessary to estimate water demand after projecting the increase of the number of private connections in future.

Table 6.2.4: Transition of the Increase of the Number of Private Connections

ID	Town	Transition of Number of Private Connections											Remark
		Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
ES-1	Wonji Shewa Alemtena	Number of Private Connections *1						0	14	44	44	44	
		Number of Households *2						1,736	1,807	1,881	1,959	2,039	
		Diffusion Rate (%)						0.0	0.8	2.3	2.2	2.2	
ES-2	Geldiya	Number of Private Connections						no record	111	111	148	232	
		Number of Households							451	469	489	509	
		Diffusion Rate (%)							24.6	23.7	30.3	45.6	
ES-3	Dire	Number of Private Connections					no record	66	75	87	90	91	
		Number of Households						1,241	1,292	1,345	1,400	1,457	
		Diffusion Rate (%)						5.3	5.8	6.5	6.4	6.2	
ES-4	Bofa	Number of Private Connections				no record	98	98	98	116	198	260	
		Number of Households					904	941	979	1,020	1,061	1,105	
		Diffusion Rate (%)					10.8	10.4	10.0	11.4	18.7	23.5	
ES-5/ AR-5	Bole/ Golegota	Number of Private Connections						0	61	171	210	273	1 System Supplying 2 Towns
		Number of Households						3,455	3,597	3,745	3,898	4,058	
		Diffusion Rate (%)						0.0	1.7	4.6	5.4	6.7	
ES-6	Ude Dhankaka	Number of Private Connections										0	Borehole with Hand Pump
		Number of Households										1,269	
		Diffusion Rate (%)										0	
ES-7	Bekejo	Number of Private Connections							no record	21	24	30	
		Number of Households								1,290	1,324	1,358	
		Diffusion Rate (%)								1.6	1.8	2.2	
ES-8	Kamise	Number of Private Connections								no record	1	2	
		Number of Households									925	963	
		Diffusion Rate (%)									0	0	
ES-9	Chefe Donsa	Number of Private Connections					no record	512	521	757	813	921	
		Number of Households						2,261	2,353	2,450	2,550	2,655	
		Diffusion Rate (%)						22.6	22.1	30.9	31.9	34.7	
ES-10	Areda	Number of Private Connections										0	
		Number of Households										556	
		Diffusion Rate (%)										0	
ES-11	Biyo	Number of Private Connections										0	Borehole with Wind Pump
		Number of Households										560	
		Diffusion Rate (%)										0	
ES-12	Adulala	Number of Private Connections					no record	194	261	300	366	431	
		Number of Households						1,051	1,095	1,139	1,186	1,235	
		Diffusion Rate (%)						18.5	23.8	26.3	30.9	34.9	
AR-1	Sire	Number of Private Connections									no record	516	
		Number of Households										3,505	
		Diffusion Rate (%)										14.7	
AR-2	Bolo	Number of Private Connections									no record	56	
		Number of Households										403	
		Diffusion Rate (%)										13.9	
AR-3	Arboye	Number of Private Connections						no record	430	460	490	570	
		Number of Households							1,841	1,917	1,995	2,077	
		Diffusion Rate (%)							23.4	24.0	24.6	27.4	
AR-4	Aseko	Number of Private Connections									0	67	
		Number of Households									1,525	1,587	
		Diffusion Rate (%)									0.0	4.2	
AR-6	Gonde	Number of Private Connections	0	20	53	108	138	172	216	223	252	283	
		Number of Households	685	713	742	772	804	837	871	907	944	983	
		Diffusion Rate (%)	0.0	2.8	7.1	14.0	17.2	20.5	24.8	24.6	26.7	28.8	
AR-7	Arbe Gebeya	Number of Private Connections			no record	79	85	115	143	168	246	350	
		Number of Households				571	586	602	617	633	650	667	
		Diffusion Rate (%)				13.8	14.5	19.1	23.2	26.5	37.8	52.5	
WH-1	Chorora	Number of Private Connections						no record	28	35	99	146	
		Number of Households							524	538	552	566	
		Diffusion Rate (%)							5.3	6.5	17.9	25.8	
WH-2	Bedeyi	Number of Private Connections		no record	32	32	32	32	32	32	101	101	
		Number of Households			552	575	598	623	648	675	702	731	
		Diffusion Rate (%)			5.8	5.6	5.4	5.1	4.9	4.7	14.4	13.8	
WH-3	Hardim	Number of Private Connections							no record	18	47	90	
		Number of Households								1,136	1,182	1,231	
		Diffusion Rate (%)								1.6	4.0	7.3	
WH-4	Bube	Number of Private Connections		no record	12	12	12	12	12	12	12	13	
		Number of Households			1,034	1,061	1,088	1,117	1,146	1,176	1,206	1,238	
		Diffusion Rate (%)			1.2	1.1	1.1	1.1	1.0	1.0	1.0	1.1	
WH-5	Mieso	Number of Private Connections	no record	322	385	426	441	484	505	547	554	728	
		Number of Households		2,997	3,120	3,248	3,381	3,520	3,664	3,814	3,971	4,133	
		Diffusion Rate (%)		10.7	12.3	13.1	13.0	13.8	13.8	14.3	14.0	17.6	
WH-6	Hargeti	Number of Private Connections										0	
		Number of Households										747	No Facility
		Diffusion Rate (%)										0	
WH-7	Bordede	Number of Private Connections						no record	87	130	132	162	
		Number of Households							658	685	713	742	
		Diffusion Rate (%)							13.2	19.0	18.5	21.8	
WH-8	Kenteri	Number of Private Connections										0	
		Number of Households										401	No Facility
		Diffusion Rate (%)										0	
WH-9	Aneno	Number of Private Connections										0	
		Number of Households										598	No Facility
		Diffusion Rate (%)										0	
WH-10	Belo	Number of Private Connections								2	2	2	
		Number of Households								880	903	926	
		Diffusion Rate (%)								0	0	0	
WH-11	Kora	Number of Private Connections								no record	66	80	
		Number of Households									582	597	
		Diffusion Rate (%)									11.3	13.4	

*1 Source: Town Water Supply Office or Water Committee

*2 Source: Calculated Based on CSA Census 2007

6.2.5 The condition of wear and tear (aging) of the existing water supply facilities

a. Life time of water supply facilities

The usable life time of water supply facilities shown in the Ethiopian standard design criteria is shown in Table 6.2.5.

Table 6.2.5: Life Time of Water Supply Facilities

Description	Life Time (Years)
Spring Capping with Small Distribution System	25
Borehole	20
Motor Pump	10
Diesel Generator Set	10
Steel Storage Reservoir	25
Public Taps	25
Reservoir	50
DCI and Steel Pipes	40
UPVC Pipes	25

Source: Rural Water Supply and Sanitation Design Criteria (Rural Water Supply and Sanitation Department, Ministry of Water Resources, April 2005)

b. Used years of existing water supply facilities

Table 6.2.6 shows the number of years of use of water supply facilities and facilities which is necessary to be reconstructed/replaced due to exceeding its intended life span as of 2020, which is the target year of water supply plan. It is necessary to reflect these issues in the water supply plan.

Table 6.2.6: Used Years of Existing Water Supply Facilities

ID	Small Town	Number of Used Years as of 2014														Remark
		Borehole (Life Time*1: 20		Motor Pump (Life Time: 10 Years)		Diesel Generator Set (Life Time: 10 Years)		Transmission Pipes (Life Time: 40 Years)		Distribution Reservoir (Life Time: 50 Years)		Distribution Pipes (Life Time: 40 Years)		Public Taps (Life Time: 25 Years)		
		Number of Used Years	Necessity for Renewal*2	Number of Used Years	Necessity for Renewal	Number of Used Years	Necessity for Renewal	Number of Used Years	Necessity for Renewal	Number of Used Years	Necessity for Renewal	Number of Used Years	Necessity for Renewal	Number of Used Years	Necessity for Renewal	
ES-1	Wonji Shewa Alemtena	-		-		-		-		-		-		-		Supplied by Adama Town Water Supply and Sanitation Service Enterprise
ES-2	Geldiya	11		9	Yes	-		11		11		11		11		
ES-3	Dire system #1	17	Yes	3		-		17		17		17		17		
	Dire system #2	27	Yes	17	Yes	-		27		27		27		27	Yes	
ES-4	Bofa system #1	32	Yes	8	Yes	-		32		32		32		32	Yes	
	Bofa system #2	9		9	Yes	-		9		9		9		9		
ES-5/ AR-5	Bole/ Golegota	4		4	Yes	3		4		4		4		4		1 System Supplying to 2 Towns
ES-6	Ude Dhankaka	-		-		-		-		-		-		-		Borehole with Hand Pump
ES-7	Bekejo	17	Yes	27	Yes	27	Yes	17		17		17		17		
ES-8	Kamise	-		-		-		-		-		-		-		Supplied by Gimbichu-Fentale Water Supply Service Enterprise
ES-9	Chefe Donsa	-		2		-		31		31		31		31	Yes	
ES-10	Areda	13		12	Yes	10	Yes	13		13		13		13		
ES-11	Biyo	15	Yes	-		-		-		-		-		-		Borehole with Wind Pump
ES-12	Adulala	25	Yes	21	Yes	18	Yes	25		25		25		25	Yes	
AR-1	Sire system #1 (spring)	-		33	Yes	3		33		33		33		33	Yes	
	Sire system #2 (Borehole)	4		3		3		4		4		4		4		
AR-2	Bolo	8		14	Yes	14	Yes	8		8		8		8		
AR-3	Arboye	-		-		-		32		32		32		32	Yes	
AR-4	Aseko	-		5	Yes	6	Yes	5		5		5		5		
AR-6	Gonde	-		-		-		8		8		8		8		
AR-7	Arbe Gebeya	-		-		-		19		19		19		19	Yes	
WH-1	Chorora	12		12	Yes	12	Yes	12		12		12		12		
WH-2	Bedeyi	7		7	Yes	7	Yes	7		7		7		7		
WH-3	Hardim	20	Yes	19	Yes	2		20		20		20		20	Yes	
WH-4	Bube	-		4	Yes	4	Yes	8		8		8		8		
WH-5	Mieso system #1	37	Yes	6	Yes	2		37	Yes	37		37	Yes	37	Yes	
	Mieso system #2	13		2		-		13		13		13		13		
WH-6	Hargeti	-		-		-		-		-		-		-		No Facility
WH-7	Bordede	38	Yes	1		5	Yes	38	Yes	38		38	Yes	38	Yes	
WH-8	Kenteri	-		-		-		-		-		-		-		No Facility
WH-9	Aneno	-		-		-		-		-		-		-		No Facility
WH-10	Belo	10		10	Yes	1		10		10		10		10		
WH-11	Kora	10		10	Yes	1		10		10		10		10		

*1: Source: Rural Water Supply and Sanitation Design Criteria (Rural Water Supply and Sanitation Department, Ministry of Water Resources, April 2005)
*2: What exceeds life time as of target year 2020

6.2.6 Condition of commercial electric power supply

In order to know the situation of commercial electric power supply in the small towns, the information about the situation of power failure was collected by interviewing the stakeholders of every target town, as shown in Table 6.2.7. There are five small towns that currently have no electricity supply. There is a tendency that if the town is further from the capital of a zone or a national road, there is a greater likelihood of power failures occurring.

Table 6.2.7: Situation of Power Failures

ID	Small Town	Number of times of power failure a month in average (time/month)	Average span of each power failure (hour/time)	Average of power failures per month (hour/month)	Rate of power failure* (%)	Remark
ES-1	Wonji Shewa Alemtena	12.0	4.00	48.00	6.7%	
ES-2	Geldiya	2.0	24.00	48.00	6.7%	
ES-3	Dire	75.0	0.50	37.50	5.2%	
ES-4	Bofa	8.0	6.00	48.00	6.7%	
ES-5	Bole	10.0	6.00	60.00	8.3%	
ES-6	Ude Dhankaka	40.0	0.67	26.80	3.7%	
ES-7	Bekejo	20.0	3.00	60.00	8.3%	
ES-8	Kamise	0.0	0.0	0.0	100.0%	Un-electrified
ES-9	Chefe Donsa	18.7	7.7	143.2	19.9%	
ES-10	Areda	0.0	0.0	0.0	100.0%	Un-electrified
ES-11	Biyo	50.0	0.50	25.00	3.5%	
ES-12	Adulala	4.0	20.00	80.00	11.1%	
AR-1	Sire	8.0	16.50	132.00	18.3%	
AR-2	Bolo	4.0	12.00	48.00	6.7%	
AR-3	Arboye	5.0	24.00	120.00	16.7%	
AR-4	Aseko	12.0	24.00	288.00	40.0%	
AR-5	Golegota	15.0	6.00	90.00	12.5%	
AR-6	Gonde	20.0	2.00	40.00	5.6%	
AR-7	Arbe Gebeya	12.0	24.00	288.00	40.0%	
WH-1	Chorora	2.0	48.00	96.00	13.3%	
WH-2	Bedeyi	0.0	0.0	0.0	100.0%	Un-electrified
WH-3	Hardim	12.0	12.00	144.00	20.0%	
WH-4	Bube	0.0	0.0	0.0	100.0%	Un-electrified
WH-5	Mieso	14.0	2.8	38.9	5.4%	
WH-6	Hargeti	0.0	0.0	0.0	100.0%	Un-electrified
WH-7	Bordede	16.0	4.0	64.0	8.9%	
WH-8	Kenteri	5.0	36.00	180.00	25.0%	
WH-9	Aneno	4.0	48.00	192.00	26.7%	
WH-10	Belo	12.0	20.00	240.00	33.3%	
WH-11	Kora	5.0	12.00	60.00	8.3%	

*: (Average of power failures per month) ÷ 720hrs (24hrs x 30days)
Source: Results of interviews with Town Water Supply Office or Water Committee

6.3 Target year and estimated population

6.3.1 Target year

Target year shall be set as 2020 because water supply plan proposed by this project will be implemented after 2015.

6.3.2 Estimated population of each year

a. Population projection

Population for the water supply plan shall be the population of water supply area (population of the town) and excluding the population who comes to fetch the water from outside the town. The standard population and the standard number of households of this plan adopt the 2007 census population of CSA.

Population growth rate shall be adopted as 4.1%/year of the urban areas and 2.6%/year of rural areas of Oromia Region, based on Census 2007 data obtained from the CSA. The classification of urban areas and rural areas is based on the data of Oromia Industry and Urban Development Bureau. The classification and the population growth rate of target small towns are shown in Table 6.3.1.

The population projections for 2020, which is calculated based on the above mentioned population and growth rates, is shown in Table 6.3.1. The projection of the number of households by 2020 is shown in Table 6.3.1.

Table 6.3.1: Population Projection by 2020

ID	Town	Classification of Urban/ Rural*1	Population Growth Rate*2 (%)	Basic Population*2	Population Projection*3						
				2007	2014	2015	2016	2017	2018	2019	2020
ES-1	Wonji Shewa Alemtena	Urban	4.1	6,435	8,525	8,875	9,239	9,617	10,012	10,422	10,849
ES-2	Geldiya	Urban	4.1	1,704	2,257	2,350	2,446	2,547	2,651	2,760	2,873
ES-3	Dire	Urban	4.1	5,141	6,811	7,090	7,381	7,683	7,998	8,326	8,668
ES-4	Bofa	Urban	4.1	3,159	4,185	4,357	4,535	4,721	4,915	5,116	5,326
ES-5	Bole	Urban	4.1	3,982	5,275	5,492	5,717	5,951	6,195	6,449	6,714
ES-6	Ude Dhankaka	Urban	4.1	4,350	5,763	5,999	6,245	6,501	6,768	7,045	7,334
ES-7	Bekejo	Rural	2.6	5,535	6,624	6,797	6,973	7,155	7,341	7,532	7,727
ES-8	Kamise	Urban	4.1	3,658	4,846	5,045	5,252	5,467	5,691	5,925	6,167
ES-9	Chefe Donsa	Urban	4.1	6,330	8,386	8,730	9,088	9,460	9,848	10,252	10,672
ES-10	Areda	Urban	4.1	2,077	2,752	2,864	2,982	3,104	3,231	3,364	3,502
ES-11	Biyo	Urban	4.1	2,044	2,708	2,819	2,935	3,055	3,180	3,310	3,446
ES-12	Adulala	Urban	4.1	2,930	3,882	4,041	4,207	4,379	4,559	4,745	4,940
AR-1	Sire	Urban	4.1	8,376	11,097	11,552	12,025	12,518	13,032	13,566	14,122
AR-2	Bolo	Urban	4.1	1,192	1,579	1,644	1,711	1,781	1,855	1,931	2,010
AR-3	Arboye	Urban	4.1	5,489	7,272	7,570	7,880	8,204	8,540	8,890	9,254
AR-4	Aseko	Urban	4.1	3,988	5,283	5,500	5,725	5,960	6,205	6,459	6,724
AR-5	Golegota	Urban	4.1	5,568	7,377	7,679	7,994	8,322	8,663	9,018	9,388
AR-6	Gonde	Urban	4.1	2,592	3,434	3,575	3,721	3,874	4,033	4,198	4,370
AR-7	Arbe Gebeya	Urban	4.1	2,033	2,693	2,804	2,919	3,038	3,163	3,293	3,428
WH-1	Chorora	Rural	2.6	2,280	2,729	2,800	2,873	2,947	3,024	3,102	3,183
WH-2	Bedeyi	Urban	4.1	2,223	2,945	3,066	3,192	3,322	3,459	3,600	3,748
WH-3	Hardim	Urban	4.1	4,457	5,905	6,147	6,399	6,661	6,934	7,219	7,515
WH-4	Bube	Rural	2.6	5,219	6,246	6,409	6,575	6,746	6,922	7,102	7,286
WH-5	Mieso	Urban	4.1	13,339	17,672	18,396	19,150	19,936	20,753	21,604	22,490
WH-6	Hargeti	Rural	2.6	2,812	3,365	3,453	3,543	3,635	3,729	3,826	3,926
WH-7	Bordede	Urban	4.1	2,219	2,940	3,060	3,186	3,316	3,452	3,594	3,741
WH-8	Kenteri	Rural	2.6	1,464	1,752	1,798	1,844	1,892	1,942	1,992	2,044
WH-9	Aneno	Rural	2.6	2,382	2,851	2,925	3,001	3,079	3,159	3,241	3,326
WH-10	Belo	Rural	2.6	3,919	4,690	4,812	4,937	5,066	5,198	5,333	5,471
WH-11	Kora	Rural	2.6	1,985	2,376	2,437	2,501	2,566	2,633	2,701	2,771

*1 Source: Oromia Industry and Urban Development Bureau
*2 Source: CSA Census 2007
*3 Source: Calculated by Study Team

Table 6.3.2: Projection of the Number of Households by 2020

ID	Small Town	Population Growth Rate*1	Basic Number of Households*1	Projection of Number of Households*2						
		(%)	2007	2014	2015	2016	2017	2018	2019	2020
ES-1	Wonji Shewa Alemtena	4.1	1,539	2,039	2,122	2,210	2,300	2,394	2,493	2,595
ES-2	Geldiya	4.1	384	509	530	551	574	597	622	647
ES-3	Dire	4.1	1,100	1,457	1,517	1,579	1,644	1,711	1,782	1,855
ES-4	Bofa	4.1	834	1,105	1,150	1,197	1,246	1,298	1,351	1,406
ES-5	Bole	4.1	1,356	1,796	1,870	1,947	2,027	2,110	2,196	2,286
ES-6	Ude Dhankaka	4.1	958	1,269	1,321	1,375	1,432	1,490	1,552	1,615
ES-7	Bekejo	2.6	1,135	1,358	1,394	1,430	1,467	1,505	1,544	1,585
ES-8	Kamise	4.1	727	963	1,003	1,044	1,087	1,131	1,177	1,226
ES-9	Chefe Donsa	4.1	2,004	2,655	2,764	2,877	2,995	3,118	3,246	3,379
ES-10	Areda	4.1	420	556	579	603	628	653	680	708
ES-11	Biyo	4.1	423	560	583	607	632	658	685	713
ES-12	Adulala	4.1	932	1,235	1,285	1,338	1,393	1,450	1,509	1,571
AR-1	Sire	4.1	2,646	3,505	3,649	3,799	3,955	4,117	4,285	4,461
AR-2	Bolo	4.1	304	403	419	436	454	473	492	513
AR-3	Arboye	4.1	1,568	2,077	2,162	2,251	2,343	2,440	2,540	2,644
AR-4	Aseko	4.1	1,198	1,587	1,652	1,720	1,790	1,864	1,940	2,020
AR-5	Golegota	4.1	1,707	2,261	2,354	2,451	2,551	2,656	2,765	2,878
AR-6	Gonde	4.1	742	983	1,023	1,065	1,109	1,154	1,202	1,251
AR-7	Arbe Gebeya	4.1	557	738	768	800	832	867	902	939
WH-1	Chorora	2.6	473	566	581	596	611	627	644	660
WH-2	Bedeyi	4.1	552	731	761	792	825	859	894	931
WH-3	Hardim	4.1	929	1,231	1,281	1,334	1,388	1,445	1,505	1,566
WH-4	Bube	2.6	1,034	1,238	1,270	1,303	1,337	1,371	1,407	1,444
WH-5	Mieso	4.1	3,120	4,133	4,303	4,479	4,663	4,854	5,053	5,260
WH-6	Hargeti	2.6	624	747	766	786	807	828	849	871
WH-7	Bordede	4.1	560	742	772	804	837	871	907	944
WH-8	Kenteri	2.6	335	401	411	422	433	444	456	468
WH-9	Aneno	2.6	500	598	614	630	646	663	680	698
WH-10	Belo	2.6	774	926	950	975	1,000	1,027	1,053	1,081
WH-11	Kora	2.6	499	597	613	629	645	662	679	697

*1 Source: CSA Census 2007
*2 Source: Calculated by Study Team

b. Population at schools and medical institutions

According to the Ethiopian design standard, effective water shall include not only household water but also school water and medical facility water.

The schools and medical institutions in the target small towns have their own water supplies. Therefore the population that receives water supplies from such facilities is also projected, as shown in Table 6.3.3.

Table 6.3.3: Projection of Population Receiving Water Supply from Schools and Medical Institutions by 2020

ID	Small Town	Population Growth Rate (%)*1	Basic Population*2		Population Projection*3											
			2014		2015		2016		2017		2018		2019		2020	
			School*3	Medical Institution*4	School	Medical Institution	School	Medical Institution	School	Medical Institution	School	Medical Institution	School	Medical Institution	School	Medical Institution
ES-1	Wonji Shewa Alemtena	4.1	2,821	26	2,937	27	3,057	28	3,182	29	3,313	31	3,449	32	3,590	33
ES-2	Geldiya	4.1	409	17	426	18	443	18	461	19	480	20	500	21	521	22
ES-3	Dire	4.1	595	30	619	31	645	33	671	34	699	35	727	37	757	38
ES-4	Bofa	4.1	515	18	536	19	558	20	581	20	605	21	630	22	655	23
ES-5	Bole	4.1	1,563	48	1,627	50	1,694	52	1,763	54	1,836	56	1,911	59	1,989	61
ES-6	Ude Dhankaka	4.1	845	23	880	24	916	25	953	26	992	27	1,033	28	1,075	29
ES-7	Bekejo	2.6	792	28	813	29	834	29	855	30	878	31	900	32	924	33
ES-8	Kamise	4.1	331	7	345	7	359	8	373	8	389	8	405	9	421	9
ES-9	Chefe Donsa	4.1	3,001	49	3,124	51	3,252	53	3,385	55	3,524	58	3,669	60	3,819	62
ES-10	Areda	4.1	318	25	331	26	345	27	359	28	373	29	389	31	405	32
ES-11	Biyo	4.1	582	13	606	14	631	14	657	15	683	15	712	16	741	17
ES-12	Adulala	4.1	1,272	34	1,324	35	1,378	37	1,435	38	1,494	40	1,555	42	1,619	43
AR-1	Sire	4.1	2,863	30	2,980	31	3,103	33	3,230	34	3,362	35	3,500	37	3,644	38
AR-2	Bolo	4.1	285	27	297	28	309	29	322	30	335	32	348	33	363	34
AR-3	Arboye	4.1	4,172	69	4,343	72	4,521	75	4,706	78	4,899	81	5,100	84	5,309	88
AR-4	Aseko	4.1	1,686	21	1,755	22	1,827	23	1,902	24	1,980	25	2,061	26	2,146	27
AR-5	Golegota	4.1	1,011	60	1,052	62	1,096	65	1,141	68	1,187	70	1,236	73	1,287	76
AR-6	Gonde	4.1	680	20	708	21	737	22	767	23	799	23	831	24	865	25
AR-7	Arbe Gebeya	4.1	1,301	35	1,354	36	1,410	38	1,468	39	1,528	41	1,590	43	1,656	45
WH-1	Chorora	2.6	800	25	821	26	842	26	864	27	887	28	910	28	933	29
WH-2	Bedeyi	4.1	1,147	43	1,194	45	1,243	47	1,294	49	1,347	50	1,402	53	1,460	55
WH-3	Hardim	4.1	1,339	34	1,394	35	1,451	37	1,511	38	1,572	40	1,637	42	1,704	43
WH-4	Bube	2.6	826	25	847	26	870	26	892	27	915	28	939	28	964	29
WH-5	Mieso	4.1	3,867	49	4,026	51	4,191	53	4,362	55	4,541	58	4,727	60	4,921	62
WH-6	Hargeti	2.6	346	1	355	1	364	1	374	1	383	1	393	1	404	1
WH-7	Bordede	4.1	446	19	464	20	483	21	503	21	524	22	545	23	568	24
WH-8	Kenteri	2.6	325	2	333	2	342	2	351	2	360	2	370	2	379	2
WH-9	Aneno	2.6	214	1	220	1	225	1	231	1	237	1	243	1	250	1
WH-10	Belo	2.6	61	13	63	13	64	14	66	14	68	14	69	15	71	15
WH-11	Kora	2.6	345	17	354	17	363	18	373	18	382	19	392	19	402	20

*1 Source: CSA Census 2007

*2 Source: Result of survey by study team

*3 Total number of students, teachers and staffs

*4 Total number of staffs and beds

c. Projection of the diffusion rate of private connections by 2020

c.1 Projection of the diffusion rate of private connections by 2020

c.1.1 Logistic curve

Tendency of increase of private connections differ greatly among small towns as shown in the table. The main reason why private connections are not increasing is considered that the distribution pipeline does not cover the whole area of the town, the water does not come out due to the lack of supply capacity, etc.

It is considered that the number of private connections will be increased because distribution pipelines will cover the whole town with sufficient water supply capacity after implementing the project.

In order to project the diffusion rate of private connections, a model of the logistic curve formula is calculated based on the record of private connections in Chefe Donsa Town (ES-9) considered to have increased most naturally amongst target towns because pipelines cover the whole town with sufficient water supply capacity, as shown in Figure 6.3.1.

The logistic curve is calculated by the logistic curve formula and diffusion rates. The diffusion rates are shown in Figure 6.3.2.

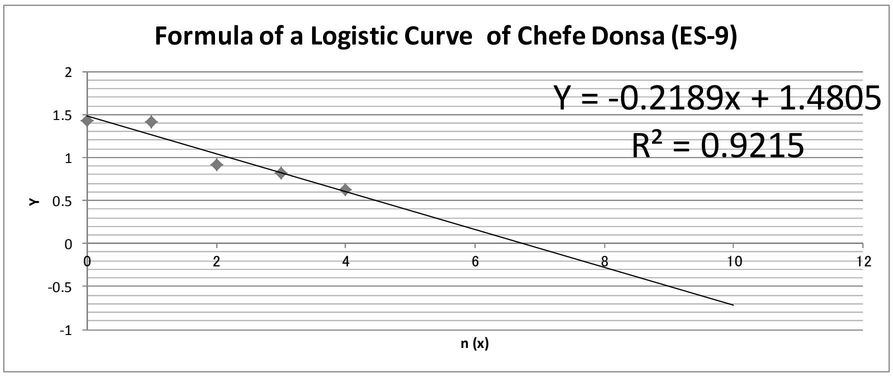
ES-9 Chefe Donsa

	n(x)	P	Y	k/pn-1	e^Y+1
2010	0	19.30	1.430633	4.18	5.181347
2011	1	19.60	1.411485	4.10	5.102041
2012	2	28.50	0.919793	2.51	3.508772
2013	3	30.60	0.818887	2.27	3.267974
2014	4	34.70	0.632252	1.88	2.881844

k:	100
ln(K/P−1)	Y
P	$K/(e^Y+1)$

Y=−an+b

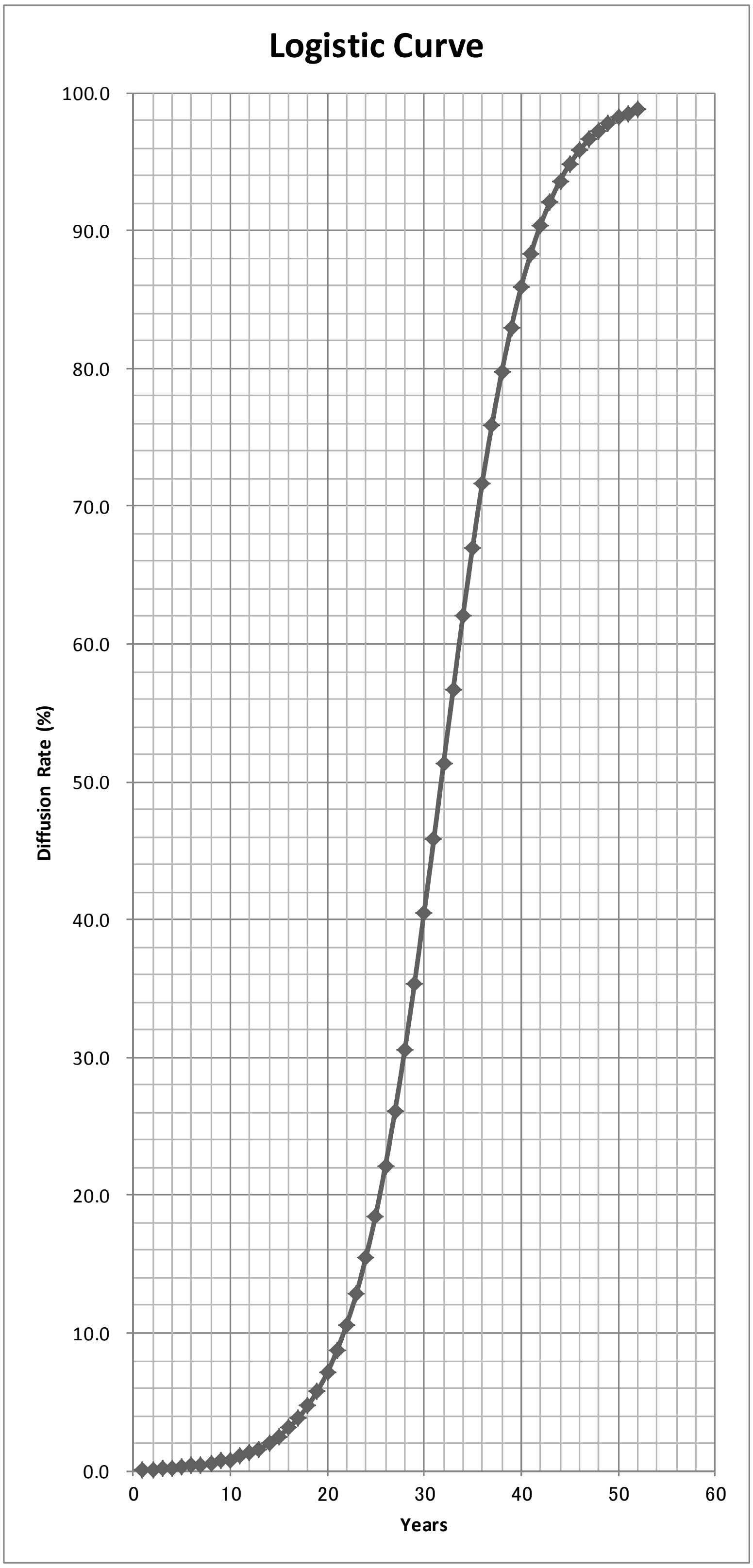
n(x)	Y
0	1.430633
1	1.411485
2	0.919793
3	0.818887
4	0.632252
5	
6	
7	
8	
9	
10	



Source: the Project Team

Figure 6.3.1: Logistic Curve Formula

Year	P (Diffusion rate)
1	0.1
2	0.1
3	0.2
4	0.2
5	0.3
6	0.4
7	0.4
8	0.5
9	0.7
10	0.8
11	1.1
12	1.3
13	1.6
14	2.0
15	2.5
16	3.1
17	3.8
18	4.7
19	5.8
20	7.1
21	8.7
22	10.6
23	12.8
24	15.5
25	18.5
26	22.1
27	26.1
28	30.5
29	35.3
30	40.5
31	45.8
32	51.3
33	56.7
34	62.0
35	67.0
36	71.7
37	75.9
38	79.7
39	83.0
40	85.9
41	88.3
42	90.4
43	92.1
44	93.6
45	94.8
46	95.8
47	96.6
48	97.2
49	97.8
50	98.2
51	98.5
52	98.8



Source: the Project Team

Figure 6.3.2: Model of Diffusion Rate

c.1.2 Projection of diffusion rate

A projection of diffusion rates of private connections in each small town up until 2020 is outlined in Table 6.3.4. These diffusion rates for the years up until 2020 were obtained by plotting the diffusion rate of 2014 (obtained by surveys by the Project Team) into the logistic curve, as shown in Figure 6.3.2, and calculating the diffusion rate over the next six years (namely up until 2020).

Table 6.3.4: Projection of Diffusion Rate of Target Small Towns by 2020

ID	Small Town	Diffusion Rate as of 2014			Projection of Diffusion Rate (%)					
		Total Number of Households *1	Number of Private Connections	Diffusion Rate (%)	2015	2016	2017	2018	2019	2020
ES-1	Wonji Shewa Alemtena	2,039	44	2.2	2.7	3.4	4.2	5.1	6.3	7.7
ES-2	Geldiya	509	232	45.6	51.1	56.5	61.8	66.8	71.5	75.7
ES-3	Dire	1,457	91	6.2	7.6	9.3	11.3	13.6	16.4	19.6
ES-4	Bofa	1,105	260	23.5	27.6	32.2	37.1	42.4	47.7	53.2
ES-5	Bole	1,796	120	6.7	8.2	10.0	12.1	14.7	17.6	21.0
ES-6	Ude Dhankaka	1,269	0	0.0	0.1	0.1	0.2	0.2	0.3	0.4
ES-7	Bekejo	1,358	30	2.2	2.7	3.4	4.2	5.1	6.3	7.7
ES-8	Kamise	963	3	0.3	0.4	0.4	0.5	0.7	0.8	1.1
ES-9	Chefe Donsa	2,655	921	34.7	39.9	45.1	50.6	56.0	61.3	66.4
ES-10	Areda	556	0	0.0	0.1	0.1	0.2	0.2	0.3	0.4
ES-11	Biyo	560	0	0.0	0.1	0.1	0.2	0.2	0.3	0.4
ES-12	Adulala	1,235	431	34.9	40.1	45.4	50.8	56.3	61.6	66.6
AR-1	Sire	3,505	516	14.7	17.6	21.0	24.9	29.2	33.9	39.0
AR-2	Bolo	403	56	13.9	16.7	20.0	23.7	27.9	32.5	37.4
AR-3	Arboye	2,077	570	27.4	31.9	36.8	42.1	47.4	52.9	58.3
AR-4	Aseko	1,587	67	4.2	5.2	6.4	7.8	9.5	11.6	14.0
AR-5	Golegota	2,261	151	6.7	8.2	10.0	12.1	14.7	17.6	21.0
AR-6	Gonde	983	283	28.8	33.4	38.5	43.8	49.2	54.6	60.0
AR-7	Arbe Gebeya	667	350	52.5	57.9	63.1	68.0	72.6	76.7	80.4
WH-1	Chorora	566	146	25.8	30.2	34.9	40.1	45.4	50.9	56.3
WH-2	Bedeyi	731	101	13.8	16.6	19.8	23.6	27.7	32.3	37.2
WH-3	Hardim	1,231	90	7.3	8.9	10.9	13.1	15.9	19.0	22.6
WH-4	Bube	1,238	13	1.1	1.3	1.6	2.0	2.5	3.1	3.8
WH-5	Mieso	4,133	728	17.6	21.0	24.9	29.2	33.9	38.9	44.2
WH-6	Hargeti	747	0	0.0	0.1	0.1	0.2	0.2	0.3	0.4
WH-7	Bordede	742	162	21.8	25.8	30.1	34.9	40.1	45.4	50.8
WH-8	Kenteri	401	0	0.0	0.1	0.1	0.2	0.2	0.3	0.4
WH-9	Aneno	598	0	0.0	0.1	0.1	0.2	0.2	0.3	0.4
WH-10	Belo	926	2	0.2	0.2	0.3	0.4	0.4	0.5	0.7
WH-11	Kora	597	80	13.4	16.2	19.3	23.0	27.1	31.6	36.5

*1 Source: Calculated by the Project Team Based on CSA Census 2007

*2 Source: Calculated by the Project Team

c.2 Population projection by connection

Population by connection in 2020 projected by the above mentioned method is shown in Table 6.3.5.

Table 6.3.5: Population Projection by Connection

ID	Small Town	Population per Household*1	Current Situation as of 2014						Projection of 2020					
			Number of households*1	Number of Private Connections*2	Diffusion Rate (%)	Total Population*1	Population Using Private Connection	Population Using Public Taps	Number of households	Number of Private Connections	Diffusion Rate (%)	Total Population	Population Using Private Connection	Population Using Public Taps
ES-1	Wonji Shewa Alemtena	4.18	2,039	44	2.20	8,525	184	8,341	2,595	200	7.70	10,849	836	10,013
ES-2	Geldiya	4.44	509	232	45.60	2,257	1,030	1,227	647	490	75.70	2,873	2,176	697
ES-3	Dire	4.67	1,457	91	6.20	6,811	425	6,386	1,855	364	19.60	8,668	1,700	6,968
ES-4	Bofa	3.79	1,105	260	23.50	4,185	985	3,200	1,406	748	53.20	5,326	2,835	2,491
ES-5	Bole	2.94	1,796	137	7.60	5,275	403	4,872	2,286	480	21.00	6,714	1,411	5,303
ES-6	Ude Dhankaka	4.54	1,269	0	0.00	5,763	0	5,763	1,615	6	0.40	7,334	27	7,307
ES-7	Bekejo	4.88	1,358	30	2.20	6,624	146	6,478	1,585	122	7.70	7,727	595	7,132
ES-8	Kamise	5.03	963	3	0.30	4,846	15	4,831	1,226	13	1.10	6,167	65	6,102
ES-9	Chefe Donsa	3.16	2,655	921	34.70	8,386	2,910	5,476	3,379	2,244	66.40	10,672	7,091	3,581
ES-10	Areda	4.95	556	0	0.00	2,752	0	2,752	708	3	0.40	3,502	15	3,487
ES-11	Biyo	4.83	560	0	0.00	2,708	0	2,708	713	3	0.40	3,446	14	3,432
ES-12	Adulala	3.14	1,235	431	34.90	3,882	1,353	2,529	1,571	1,046	66.60	4,940	3,284	1,656
AR-1	Sire	3.17	3,505	516	14.70	11,097	1,636	9,461	4,461	1,740	39.00	14,122	5,516	8,606
AR-2	Bolo	3.92	403	56	13.90	1,579	220	1,359	513	192	37.40	2,010	753	1,257
AR-3	Arboye	3.50	2,077	570	27.40	7,272	1,995	5,277	2,644	1,541	58.30	9,254	5,394	3,860
AR-4	Aseko	3.33	1,587	67	4.20	5,283	223	5,060	2,020	283	14.00	6,724	942	5,782
AR-5	Golegota	3.26	2,261	136	6.00	7,377	443	6,934	2,878	604	21.00	9,388	1,969	7,419
AR-6	Gonde	3.49	983	283	28.80	3,434	988	2,446	1,251	751	60.00	4,370	2,621	1,749
AR-7	Arbe Gebeya	3.65	667	350	52.50	2,433	1,278	1,155	778	626	80.40	2,838	2,285	553
WH-1	Chorora	4.82	566	146	25.80	2,729	704	2,025	660	372	56.30	3,183	1,793	1,390
WH-2	Bedeyi	4.03	731	101	13.80	2,945	407	2,538	931	346	37.20	3,748	1,394	2,354
WH-3	Hardim	4.80	1,231	90	7.30	5,905	432	5,473	1,566	354	22.60	7,515	1,699	5,816
WH-4	Bube	5.05	1,238	13	1.10	6,246	66	6,180	1,444	55	3.80	7,286	278	7,008
WH-5	Mieso	4.28	4,133	728	17.60	17,672	3,116	14,556	5,260	2,325	44.20	22,490	9,951	12,539
WH-6	Hargeti	4.51	747	0	0.00	3,365	0	3,365	871	3	0.40	3,926	14	3,912
WH-7	Bordede	3.96	742	162	21.80	2,940	642	2,298	944	480	50.80	3,741	1,901	1,840
WH-8	Kenteri	4.37	401	0	0.00	1,752	0	1,752	468	2	0.40	2,044	9	2,035
WH-9	Aneno	4.76	598	0	0.00	2,851	0	2,851	698	3	0.40	3,326	14	3,312
WH-10	Belo	5.06	926	2	0.20	4,690	10	4,680	1,081	8	0.70	5,471	40	5,431
WH-11	Kora	3.98	597	80	13.40	2,376	318	2,058	697	254	36.50	2,771	1,011	1,760

*1 Source: Calculated by Study Team Based on CSA Census 2007

*2 Source: Town Water Supply Office/ Water Committee

6.4 Water demand

6.4.1 Planning criteria

The planning criteria in this plan, which is shown in Table 6.4.1, is based on the Ethiopian design standards in principle. If the criteria is not clear or does not match actual conditions, the values or methods of the criteria shall be determined based on the actual conditions.

Table 6.4.1: Design Criteria of this Plan

No.	Item	Design Conditions		Standard to be Adhered to
1	Population Growth Rate	Urban	4.1%/Year	CSA Census 2007
		Rural	2.6%/Year	
2	Water Supply Unit	Household (Urban)	40.0L/c/d	Ethiopian Design Standard*1
		Household (Rural)	25.0 L/c/d	Ethiopian Design Standard*1
		School	5.0 L/c/d	Ethiopian Design Standard*2
		Medical Facility	25.0 L/c/d	Ethiopian Design Standard*2
3	Amount of Non-revenue Water	15 % of Amount of Revenue Water		Ethiopian Design Standard*2
4	Water Demand	Water Supplied Population × Water Supply Unit ÷ 87.0% ÷ 83.3%		Ethiopian Design Standard*2
5	Daily Ave. Water Supply Amount	Water Supplied Population × Water Supply Unit		
6	Daily Ave. Water Supply Amount per Capita	Daily Ave. Water Usage Amount ÷ Water Supplied Population		
7	Water Supply Ratio	Planning Daily Max. Water Supply Amount ÷ Water Demand		
8	Planning Effectiveness Ratio	87.0%（100%÷115%）		Ethiopian Design Standard*2
9	Planning Daily Ave. Water Supply Amount	Daily Ave. Water Supply Amount ÷ Planning Effectiveness Ratio		
10	Planning Loading Factor	83.3%（100%÷120%）		Ethiopian Design Standard*2
11	Planning Daily Max. Water Supply Amount	Planning Daily Ave. Water Supply Amount ÷ Planning Loading Factor		
12	Capacity of Reservoir	10,000 people or more	12h for Ave. Supply Amount	Ethiopian Design Standard*2
		Less than 10,000 people	15h for Ave. Supply Amount	

*1: The Second Growth and Transformation Plan (2015/16 - 2019/20)
*2: Rural Water Supply and Sanitation Design Criteria (Rural Water Supply and Sanitation Department, Ministry of Water Resources, April 2005)

6.4.2 Daily average water supply amount

Planning daily average water unit calculated based on population in 2020 and water supply unit are shown in Table 6.4.2.

Table 6.4.2: Daily Average Water Supply Amount

ID	Small town	Classification of Urban/ Rural*1	Planning water supply population as of 2020	Household water						School water			Medical facility water			Daily average water supply amount*3
				Public taps			Private connection									
				Population as of 2020	Water supply unit (L/c/d)	Total (m^3/day)	Population as of 2020	Water supply unit (L/c/d)	Total (m^3/day)	Population as of 2020	Water supply unit (L/c/d)	Total (m^3/day)	Population as of 2020	Water supply unit (L/c/d)	Total (m^3/day)	(m^3/day)
ES-1	Wonji Shewa Alemtena	Urban	10,849	10,013	40.0	400.5	836	40.0	33.4	3,590	5.0	18.0	33	25.0	0.8	452.7
ES-2	Geldiya	Urban	2,873	697	40.0	27.9	2,176	40.0	87.0	521	5.0	2.6	22	25.0	0.6	118.1
ES-3	Dire	Urban	8,668	6,968	40.0	278.7	1,700	40.0	68.0	757	5.0	3.8	38	25.0	1.0	351.5
ES-4	Bofa	Urban	5,326	2,491	40.0	99.6	2,835	40.0	113.4	655	5.0	3.3	23	25.0	0.6	216.9
ES-5	Bole	Urban	6,714	5,303	40.0	212.1	1,411	40.0	56.4	1,989	5.0	9.9	61	25.0	1.5	279.9
ES-6	Ude Dhankaka	Urban	7,334	7,307	40.0	292.3	27	40.0	1.1	1,075	5.0	5.4	29	25.0	0.7	299.5
ES-7	Bekejo	Rural	7,727	7,132	25.0	178.3	595	25.0	14.9	924	5.0	4.6	33	25.0	0.8	198.6
ES-8	Kamise	Urban	6,167	6,102	40.0	244.1	65	40.0	2.6	421	5.0	2.1	9	25.0	0.2	249.0
ES-9	Chefe Donsa	Urban	10,672	3,581	40.0	143.2	7,091	40.0	283.6	3,819	5.0	19.1	62	25.0	1.6	447.5
ES-10	Areda	Urban	3,502	3,487	40.0	139.5	15	40.0	0.6	405	5.0	2.0	32	25.0	0.8	142.9
ES-11	Biyo	Urban	3,446	3,432	40.0	137.3	14	40.0	0.6	741	5.0	3.7	17	25.0	0.4	142.0
ES-12	Adulala	Urban	4,940	1,656	40.0	66.2	3,284	40.0	131.4	1,619	5.0	8.1	43	25.0	1.1	206.8
AR-1	Sire	Urban	14,122	8,606	40.0	344.2	5,516	40.0	220.6	3,644	5.0	18.2	38	25.0	1.0	584.0
AR-2	Bolo	Urban	2,010	1,257	40.0	50.3	753	40.0	30.1	363	5.0	1.8	34	25.0	0.9	83.1
AR-3	Arboye	Urban	9,254	3,860	40.0	154.4	5,394	40.0	215.8	5,309	5.0	26.5	88	25.0	2.2	398.9
AR-4	Aseko	Urban	6,724	5,782	40.0	231.3	942	40.0	37.7	2,146	5.0	10.7	27	25.0	0.7	280.4
AR-5	Golegota	Urban	9,388	7,419	40.0	296.8	1,969	40.0	78.8	1,287	5.0	6.4	76	25.0	1.9	383.9
AR-6	Gonde	Urban	4,370	1,749	40.0	70.0	2,621	40.0	104.8	865	5.0	4.3	25	25.0	0.6	179.7
AR-7	Arbe Gebeya	Urban	3,428	672	40.0	26.9	2,756	40.0	110.2	1,656	5.0	8.3	45	25.0	1.1	146.5
WH-1	Chorora	Rural	3,183	1,390	25.0	34.8	1,793	25.0	44.8	933	5.0	4.7	29	25.0	0.7	85.0
WH-2	Bedeyi	Urban	3,748	2,354	40.0	94.2	1,394	40.0	55.8	1,460	5.0	7.3	55	25.0	1.4	158.7
WH-3	Hardim	Urban	7,515	5,816	40.0	232.6	1,699	40.0	68.0	1,704	5.0	8.5	43	25.0	1.1	310.2
WH-4	Bube	Rural	7,286	7,008	25.0	175.2	278	25.0	7.0	964	5.0	4.8	29	25.0	0.7	187.7
WH-5	Mieso	Urban	22,490	12,539	40.0	501.6	9,951	40.0	398.0	4,921	5.0	24.6	62	25.0	1.6	925.8
WH-6	Hargeti	Rural	3,926	3,912	25.0	97.8	14	25.0	0.4	404	5.0	2.0	1	25.0	0.0	100.2
WH-7	Bordede	Urban	3,741	1,840	40.0	73.6	1,901	40.0	76.0	568	5.0	2.8	24	25.0	0.6	153.0
WH-8	Kenteri	Rural	2,044	2,035	25.0	50.9	9	25.0	0.2	379	5.0	1.9	2	25.0	0.1	53.1
WH-9	Aneno	Rural	3,326	3,312	25.0	82.8	14	25.0	0.4	250	5.0	1.3	1	25.0	0.0	84.5
WH-10	Belo	Rural	5,471	5,431	25.0	135.8	40	25.0	1.0	71	5.0	0.4	15	25.0	0.4	137.6
WH-11	Kora	Rural	2,771	1,760	25.0	44.0	1,011	25.0	25.3	402	5.0	2.0	20	25.0	0.5	71.8

*1: The Second Growth & Transformation Plan (2015/16 - 2019/20)

*2: Urban Water Supply Design Criteria (Water Resources Administration Urban Water Supply and Sanitation Department, Ministry of Water Resources, January 31, 2006)

6.4.3 Planning daily average water supply amount and daily maximum water supply amount

Planning daily average water supply amount and planning daily maximum water supply amount was calculated using the effectiveness rate and planning loading factors shown in Table 6.4.3.

Table 6.4.3: Planning Daily Average Water Supply Amount and Daily Maximum Water Supply Amount

Unit: m3/day

ID	Small town	Daily ave. water supply amount a	Planned effectiveness rate b	Planning daily ave. water supply amount c=a÷b	Planned load factor d	Planning daily max. water supply amount e=c÷d
ES-1	Wonji Shewa Alemtena	452.7	87.0%	520.3	83.3%	624.6
ES-2	Geldiya	118.1	87.0%	135.7	83.3%	162.9
ES-3	Dire	351.5	87.0%	404.0	83.3%	485.0
ES-4	Bofa	216.9	87.0%	249.3	83.3%	299.3
ES-5	Bole	279.9	87.0%	321.7	83.3%	386.2
ES-6	Ude Dhankaka	299.5	87.0%	344.3	83.3%	413.3
ES-7	Bekejo	198.6	87.0%	228.3	83.3%	274.1
ES-8	Kamise	249.0	87.0%	286.2	83.3%	343.6
ES-9	Chefe Donsa	447.5	87.0%	514.4	83.3%	617.5
ES-10	Areda	142.9	87.0%	164.3	83.3%	197.2
ES-11	Biyo	142.0	87.0%	163.2	83.3%	195.9
ES-12	Adulala	206.8	87.0%	237.7	83.3%	285.4
AR-1	Sire	584.0	87.0%	671.3	83.3%	805.9
AR-2	Bolo	83.1	87.0%	95.5	83.3%	114.6
AR-3	Arboye	398.9	87.0%	458.5	83.3%	550.4
AR-4	Aseko	280.4	87.0%	322.3	83.3%	386.9
AR-5	Golegota	383.9	87.0%	441.3	83.3%	529.8
AR-6	Gonde	179.7	87.0%	206.6	83.3%	248.0
AR-7	Arbe Gebeya	146.5	87.0%	168.4	83.3%	202.2
WH-1	Chorora	85.0	87.0%	97.7	83.3%	117.3
WH-2	Bedeyi	158.7	87.0%	182.4	83.3%	219.0
WH-3	Hardim	310.2	87.0%	356.6	83.3%	428.1
WH-4	Bube	187.7	87.0%	215.7	83.3%	258.9
WH-5	Mieso	925.8	87.0%	1,064.1	83.3%	1,277.4
WH-6	Hargeti	100.2	87.0%	115.2	83.3%	138.3
WH-7	Bordede	153.0	87.0%	175.9	83.3%	211.2
WH-8	Kenteri	53.1	87.0%	61.0	83.3%	73.2
WH-9	Aneno	84.5	87.0%	97.1	83.3%	116.6
WH-10	Belo	137.6	87.0%	158.2	83.3%	189.9
WH-11	Kora	71.8	87.0%	82.5	83.3%	99.0

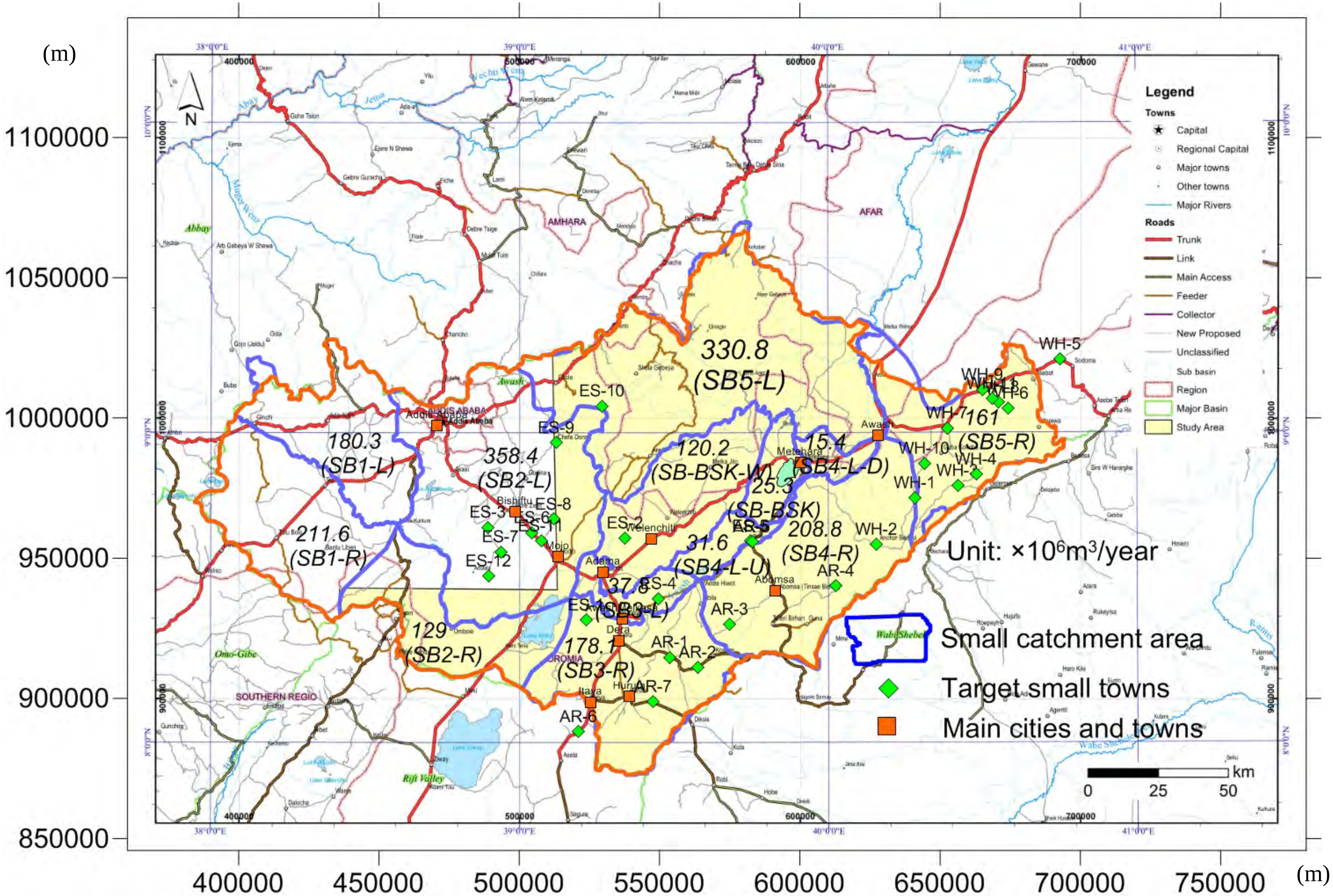
Source: Calculated by the Project Team

6.5 Groundwater development

6.5.1 Evaluation of groundwater potential

The target small towns are currently generally utilizing the deep wells and springs. In the water supply plan, groundwater with deep wells will be selected as the water source in the small towns. The advantage of groundwater as a potential potable water source is summarized as follows: 1) With regard to the quality of drinking water, generally, the water is clean and there are no issues, 2) the amount of water is steady throughout the year and the water does not dry up in the dry season, and 3) it is possible to use water sustainably.

The middle Awash river basin is divided into thirteen sub-basins, and the basic flow (groundwater recharge) was estimated using the annual rainfall, run-off coefficient of the river and basic flow index in the sub-basin (refer to Table 6.5.1). Figure 6.5.1 includes sub-basins with the annual mean groundwater recharge ($\times 10^6 m^3$/year) .



Source: the Project Team, Data: Result of hydrology analysis in this Project

Figure 6.5.1: Groundwater Recharge in Sub-Basin

Table 6.5.1: Result of Groundwater Recharge Estimation by Sub-basin

SL No ..	Sub-basin	Area (A) [km²]	Annual Rainfall (R) [mm/yr]	Runoff Coefficient (C) [-]	Base Flow Index (BFI) [-]	Annual Groundwater Recharge (GWR) [mm/yr]	Annual Groundwater Recharge (GWR) [10^6 m^3/yr]	GWR/R [%]
1	SB1-L	2,068	1,097	0.18	0.44	87.2	180.3	7.9%
2	SB1-R	2,508	1,075	0.17	0.46	84.4	211.6	7.8%
3	SB2-L	4,860	982	0.15	0.51	73.7	358.4	7.5%
4	SB2-R	1,859	867	0.18	0.43	69.4	129.0	8.0%
5	SB3-L	508	853	0.25	0.35	74.4	37.8	8.7%
6	SB3-R	2,743	832	0.17	0.46	64.9	178.1	7.8%
7	SB4-L-U	435	824	0.26	0.34	72.5	31.6	8.8%
8	SB4-L-D	312	548	0.28	0.32	49.3	15.4	9.0%
9	SB4-R	3,367	806	0.16	0.48	62.0	208.8	7.7%
10	SB5-L	5,710	779	0.14	0.53	57.9	330.8	7.4%
11	SB5-R	2,347	870	0.17	0.45	68.6	161.0	7.9%
12	SB-BSK-W	2,041	740	0.18	0.44	58.9	120.2	8.0%
13	SB-BSK	532	548	0.25	0.35	47.6	25.3	8.7%
All Basin		29,290	876	-	-	67.9	1,988.3	7.7%

Source: the Project Team, Data: Result of hydrology survey in this Project

A comparison was made between the groundwater recharge value in the each sub-basin and the estimated groundwater usage as of 2035 calculated by adding estimated groundwater pumping volumes for 2035 for estimates (by estimating water usage demand using 2035 population projections based on current pumping volume data) for the main medium to large cities and planned pumping volumes (based on an assumption of maximum water usage of the estimated water demand in 2035 using a maximum daily per capita water demand unit of 50 L/c/day) in the small towns in the target area. The main medium to large cities are Addis Ababa, Bishiftu (old name: Debre Zeit), Mojo, Adama (old name: Nazret), Huruta, Itaya, Welenchiti, Dera, Awash Melkasa, Abomsa, Metehara and Awash. However, as Adama, Metehara and Awash are using surface water and Hurta, Itaya, Welenchiti, Dera and Awash Melkasa are using the spring water, therefore the values from such towns and cities were excluded from the abovementioned calculation of estimated groundwater pumping volumes for 2035.

The ratio between the groundwater recharge and yield is shown in Table 6.5.2 as approximately equal to or less than 1% in the major sub-basin. Sufficient yields will be secured in the sub-basin. The results are displayed on Table 6.5.2.

The ratio between the groundwater recharge and yield in SB2-L of the sub-basin shows more than 35% because the big city and middle towns of Addis Ababa, Bishoftu and Mojo including the large yield are contained in this sub-basin as shown in Table 6.5.2. Although the yield of the existing well in the SB4-L-D is very large (yield: 100 L/sec), the area of sub-basin is narrow and the recharge of groundwater is low. So the ratio is about 45% in the SB4-L-D.

Table 6.5.2: Ratio between Groundwater Recharge and Yield

SL No.	Sub-basin	Yield in large and middle towns (Estimation as of 2035) (Y1)[$10^6 m^3$/year]	Yield in target small towns (Estimation as of 2035) (Y2)[$10^6 m^3$/year]	Amount of total yield [$10^6 m^3$/year] (Y=Y1+Y2＋Y3)	Groundwater recharge(GWR) [$10^6 m^3$/year]	Y/GWR [%]
3	SB2-L	120.90	2.25	123.15	358.4	34.4
5	SB3-L	-	0.25	0.25	37.8	0.7
6	SB3-R	-	1.65	1.65	178.1	0.9
7	SB4-L-U	-	0.32	0.32	31.6	1.0
9	SB4-R	0.36	1.46	1.82	208.8	0.9
11	SB5-R	-	2.06	2.06	161.0	1.3
12	SB-BSK-W	0.59	0.14	0.73	120.2	0.6

Source: the Project Team, Data: Result of calculation by the project member

6.5.2 Aquifer classification and characteristic

Table 6.5.3 shows the relationship between the geology and the classification of aquifers related to the groundwater productivity in the middle Awash River basin including the target small towns. The aquifers in the project area are shown as the following three types:

1) Alluvium and lacustrine deposits

2) Quaternary Pleistocene tuff, and welded tuff and basalt

3) Tertiary Pliocene, Miocene tuff, and welded tuff and basalt

The hydrogeological map was created in reference to the distribution of geology and the aquifer information. The location of the target small towns was indicated in the hydrogeological map, and the groundwater potential (estimated yield) will be secured in the target small towns using the hydrogeological map.

Table 6.5.3: Classification of Aquifer in the Middle Awash River Basin

Age			Stratigraphy	Lithology	Potential division	Aquifer Type	Remarks
Cainozoic	Quarternary	Holocene	Alluvium & Lacustrine deposits (Qal)	sand, clay, gravel, lacustrine	1C	Stratum water	Permeability is good in the sandy and gravelly materials, and is bad in the clay and clayey materials.
			Recent rhyolitic dome & lava flows (Qr2)	rhyolitic domes with obsidian lava flows	5	-	Distribution is very limited.
			Holocene basalts (Qb2)	glassy basalt & aphyric basalt and scoria cone	3C	Fissure water	Massive basalts. Permeability is a little high in the areas of porosity and scoria materials in relationship to the lower layer.
		Pleistocene	Fentale ignimbrite (Qi3)	pare green strongly welded tuff with fiamme	3B	Fissure water	Mainly the consolidated welded tuff. Permeability is moderately good in the fissures within the welded tuff.
			Fentale volcanic rocks (Qf)	Rhyolite, Trachyte, tuff & agglomerate	3C	Fissure water	The strata is highly porous, the distribution is limited around Fentale volcano.
			Boseti - Kone pumice fall (Qp2)	pumice fall	1C	Fissure water	Permeability is high. However, if there is no aquiclude in the lower layer, it is difficult to take water.
			Kone ignimbrite (Qi2)	greenish consolidated to welded fine tuff	3B	Fissure water	Mainly the consolidated welded tuff. Permeability is moderately good in the fissure parts.
			Pleistocene basalts (Qb1)	aphyric basalt and scoria cone	3B	Fissure water	Massive basalts. It is exspected that permeability is moderately high in the porous material.
			Sobebor volcanic sand (Qs)	tuff ring, maar deposits	5	-	Distribution is very limited.
			Zikwala trachytes (Zt)	Trachyte	3C	Fissure water	The strata are only distributed around the Zikwale volcano. The distribution is very limited.
			Chefe Donsa pyroclastic deposits (Qp1)	Pumice and tuff with intercalated with poorly welded tuff	1B	Fissure water	Permeability is high. However, if there is no aquiclude in the lower layer, it is difficult to take water.
			Pleistocene rhyolites (Qr1)	rhyolite	3C	Fissure water	Fissured rhyolite. However, it is a little difficult to take water in relationship to the lower layer.
			Dino ignimbrite (Qi1)	Greenish grey welded tuff with fiamme	3B	Fissure water	It is a good aquifer for the fissured welded tuff.
	Tertiary	Pliocene	Bofa basalts (Tb3)	aphyric basalt	3B	Fissure water	Massive basalts. It is respected that permeability is a little high in the void material.
			Chilalo Trachy basalts (Tt)	Trachytes and Trachybasalts	3B	Fissure water	Massive trachybasalts. It is a moderately good aquifer in the fissured parts and tuff breccia.
			Upper Nazret pyroclastic deposits (Ti3)	light to dark grey welded tuff with fiamme	3A	Fissure water	Welded tuff with fissured parts. Groundwater can be taken.
			Lower Nazret pyroclastic deposits (Ti2)	pumice and tuff	3A	Stratum water partly & Fissure	Permeability is high. There are cases for water intake.
			Pliocene rhyolites (Tr2)	rhyolite with pumiceous tuff	3B	Fissure water	It is a good aquifer for the pumiceous tuff and fissured materials.
		Miocene	Anchar basalts (Tb2)	aphyric basalt	3B	Fissure water	Permeability is high for fissured basalts. There are cases for water intake.
			Debre Birhan ignimbrite (Ti1)	upper conglomerate, tuff. sand, alternation & greenish compacted to welded fine	3C	Stratum water partly & Fissure	The distribution of the expected parts of stratum water is limited.
			Huse Ridge rhyolites (Tr1)	white-bluish gray rhyolite and tuff	3C	Fissure water	Massive rhyolites. There are few fissured parts.
			Alaji basalts (Tb1)	plagioclase aphyric basalt	3A	Fissure water	It is a good aquifer for the fissured parts of basalts.

6.5.3 Possibility of groundwater development

The possibility of groundwater development is estimated from medium to high productivity in accordance with the hydrogeological map based on the aquifer information and the lithology in the geological field survey. However, the fluoride concentration exceeds the Ethiopian standard (1.5 mg/L) around Lake Beseka, Koka and along the Awash River. The old Ethiopian standard of fluoride (3 mg/L) was exceeded in the area northwest of Lake Koka. On the other hand, the fluoride concentration is less than the standard (1.5 mg/L) in the West Hararge zone of the southeast and northwest areas along the rift valley ridge in the project area.

The productivity in the middle Awash river basin in reference to the yield and specific capacity of the existing and JICA wells is as follows: The yield is Low: less than 5 L/sec, Medium: 5 to less than 10 L/sec, and High: 10 L/sec or more. The specific capacity is Low: less than 2 L/sec/m, Medium: 2 to less than 4 L/sec/m, and High: 4 L/sec/m or more. The productivity was evaluated by using the combination of both items.

The yield ranges from medium to high and the specific capacity is the middle degree in the distributing area of the tuff, welded tuff and basalts for the age of Tertiary Miocene and Pliocene. The productivity indicates medium to high capacity on the whole. Low productivity is partly included in the rhyolites of the Miocene. The main strata distributes in the southeast and northwest area along the rift valley ridge.

The yield ranges from low to medium and the specific capacity ranges widely from low to high in the distributing area of the tuff, welded tuff and basalts for the age of Quaternary Pleistocene. The productivity indicates approximately medium capacity in this area and sometimes includes low capacity in the distributing area of rhyolites. Those strata distribute in the south area of Lake Koka. The others mainly distribute in the rift floor of the middle Awash river basin but also distribute in the south area of Mt. Fentale.

The productivity of alluvium and Lacustrine deposits is low on the whole and the yield is low to medium and specific capacity indicates a low yield. Those strata distribute around Lake Beseka, the northeast area of Lake Koka, and northeast of the project area.

The target small towns widely distribute along the rift floor and ridge area and the northwest area of Lake Koka except for the north Amhara Region and around Lake Besaka in the project area. The surface geology is wide ranging. However, the target aquifer is the fissured basalts and welded tuff of the Tertiary deposit for the wells. So the depth of the wells is a little deep on the whole.

The well specification and estimated hydrogeological information are shown in the following table (Table 6.5.4) by the hydrogeological conditions in the target small towns.

Table 6.5.4: Well Specification and Hydrogeology in Target Small Towns

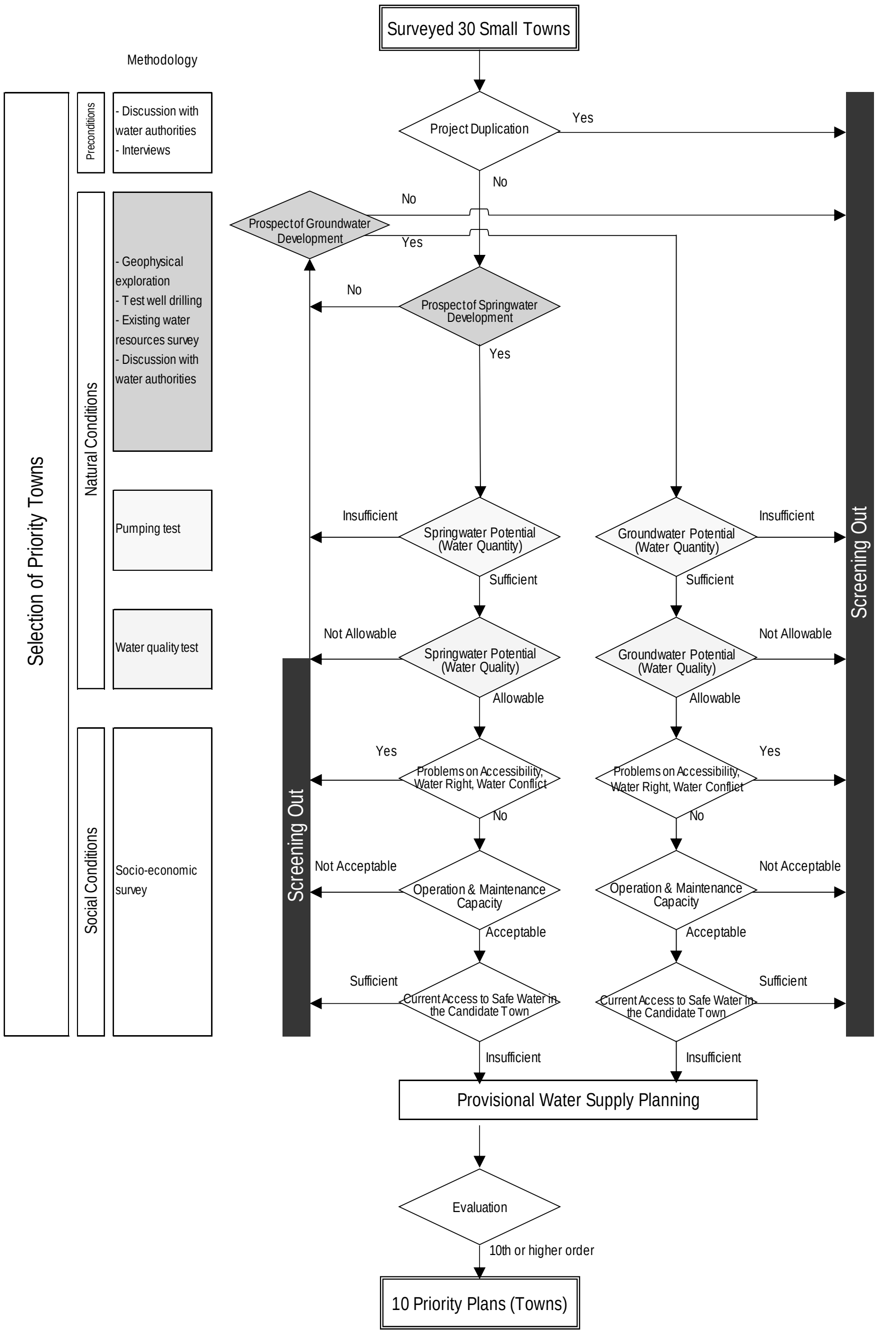
ID	Small towns	Distribution of small towns	Elevation	Estimated Aquifer	Items					
					Hydrogeological conditions	Estimated yield	Estimated static water level	Estimated specific capacity	Estimated well depth	Estimated screen length
			m			L/sec	m	L/sec/m	m	m
ES-1	Wonji Shewa Alemtena	Located near the Wonji plantation, northeast of Gedemsa caldera	1,546	Qr1/Qi1	Located in the northeast of Gedemsa caldera. Direction of the faults are assumed to be NNE-SSW. The target aquifer is Qi1 below Qr.	5～10	20	0-2	200	30
ES-2	Geldiya	Located in between Adama and Welenchiti	1,577	Ti3	Qp1 is distributed on the gentle slope of the base of mountain. The target aquifer is Ti3 below Qp1.	10～	70	2-4	200	30
ES-3	Dire	Located about 11km north of Mt Zikwala	1,917	Ti3/Tb1	Qp1 is widely distributed on the gentle slope at the base of mountain. The target aquifer is Ti3 below Qp1or Tb1.	10～	65	2-4	250	50
ES-4	Bofa	Located about 13km northeast of Awash Melkasa along the Adama-Asela Road	1,398	Tb3/Ti3/Tb1	Assumed the fault of the direction of NNE, the lower layer of Tb3 in JICA well. The target aquifer is Ti3 or Tb1	5～10	70	2-4	250	38
ES-5	Bole	Located in the middle area of Awash River in the center of project area	1155	Qi1/Tb3	Located in the floor of the middle Awash river basin. The target aquifer is Qi1 or Tb3.	5～10	130	2-4	250	38
ES-6	Ude Dhankaka	Located about 10km northwest of Mojo	1,889	Ti3/Tb1	Located in the lowland along the gentle slope of the base of mountain. The Qp1 is also distributed in lowlands. The target aquifer is Ti3 below Qp1or Tb1.	10～	65	2-4	300	50
ES-7	Bekejo	Located about 8km northeast of Mt.Zikwala, and about 8km southeast of Dire	1,753	Ti3/Tb1	Qp1 widely distributed on the gentle slope of the base of mountain. The target aquifer is Ti3 below Qp1or Tb1	10～	20	2-4	200	30
ES-8	Kamise	Located about 13km north of Mojo, and about 7km northeast of Biyo	1,891	Tt/Tb1	Is distributed in mountin valleys where rivers flow; Ti3 is also distributed; however, the target aquife	10～	50	2-4	350	50
ES-9	Chefe Donsa	Located about 20km south-souteast of Sendafa	2,326	Ti3	Ti3 is widely distributed on gentle slopes at the base of mountain. The artesian well was recognized by the study of the Oromia Region.	10～	Artesian well	-	200	30
ES-10	Areda	Located about 16km east-northeast of Chefe Donsa	2,490	Tb1	Located in highland areas where basalts are distributed, Ti1 covers the basalts, the target aquifer is T	5～10	170	2-4	250	38
ES-11	Biyo	Located about 7km northwest of Mojo	1,873	Ti3/Tr1/Tb1	Located in lowlands along gentle slopes at the base of mountains. The Qp1 is also distributed on the lowlands. The target aquifer is Ti3 below Qp1or Tb1.	10～	70	2-4	300	50
ES-12	Adulala	Located near east of Mt.Zikwala	1,700	Nwp/N1a	Located at the eastern base of Mt. Zikwala. Qp1 or Qt distributed. The aquifer is estimated as Ti3 or Tb1.	5～10	80	2-4	200	30
AR-1	Sire	Located about 20km east-northeast of Dera, halfway on Adama-Asela Road	1,827	Tb1	Located in the west area of the fault of the northeast-southwest direction, the target aquier is Tb1 in JICA well, Above Tb1, Qi1 and Tb3 distributes	10～	70	0-2	250	38
AR-2	Bolo	Located about 13km east-northeast of Sire	2,532	Qi1/Tb1	Qi1 is distributed along the river around the wide gentle slope. The target aqufer is fissured Qi1 or Tb1 below Qi1.	10	130	2-4	250	38
AR-3	Arboye	Located about 20km sourthwest of Abomsa	2,090	Qil	Qi1 is distributed on the surface, expected the fault of the WNW-ESE direction, target aquifer is the fissured Qi1	5～10	150	2-4	250	38
AR-4	Aseko	Located about 22km east of Abomsa	2,019	Tb1	It is a difficult area to develop (extract) groundwater. The target is NNE-SSW fault. It is expected the Tb1 exists below Tr1.	5～10	170	2-4	250	38
AR-5	Golegota	Located on the other side of Bole	1,156	Qi1/Tb3	Located in the floor of the middle Awash river basin. Qi1 or Tb3 is expected as the target aquifer.	5～10	130	2-4	250	38
AR-6	Gonde	Located about 11km north east of Asela, and along the Adama-Asela Road	2,262	Qi1/Tb3	Qp1 is distributed on the surface. Qi1 with fissured welded tuff distrubuted along the river. Qi1 and Tb3 below Qi1 are expected as the target aquifer.	5～10	50	2-4	150	22
AR-7	Arbe Gebeya	Located about 23km east of Iteya of the harfway of Adama-Asela Road	2,355	Tt	It is difficult area to develop (extract) groundwater; Tt is mainly distributed in this area, Qp1 is also distributed partly; there is a need to confirm the north-south fault.	5～10	150	2-4	250	38
WH-1	Chorora	Located about 30km south of Bordede of about 20km east from Awash along the Deredawa Road	1,670	Tb2	Tb2 is partly distributed on the surface. The target area is along the small valley where alluvium deposits are distributed. The target aquifer is fissured Tb2	5～10	50	2-4	150	22
WH-2	Bedeyi	Located about 25km of Arba River from Metehara plantation	2,095	Tb1	It is difficult area to develop (extract) groundwater. Tb1 is distributed on the surface. Fissured rock or faults are expected.	5～10	170	2-4	250	38
WH-3	Hardim	Located about 18km east of Chorora	1,616	Tb1	Located in highlands where Tb1 is distributed. Alluvium deposits are partly distributed along the river. The target aquifer is fissuerd Tb1.	10	20	2-4	150	22
WH-4	Bube	Located about 8km east-northeast of Hardim	1,924	Tb1	It is a difficult area to develop (extract) groundwater. The direction of the fault is expected to be NE-SW. The target aquifer is fissuerd Tb1.	0～5	40	2-4	200	30
WH-5	Mieso	Harfway of Awash-Diredawa Road	1,377	Qi1	Qi1 (a target aquifer) is distributed below Qb1, which is distributed on the surface.	5～10	80	2-4	150	22
WH-6	Hargeti	Located about 5km southeast of Kenteri	1,334	Qi1/Tb2	The northeast area where Tb2 may reach Qi1 through faulting. The target aquifer is Tb2	10	100	2-4	250	38
WH-7	Bordede	Located a little south area of about 20km east from Awash along the Deredawa Road	1,068	Ti2/Tb2	Qp1 is distributed on surface. The aquifer is Ti2 or Tb2	5～10	80	0-2	250	38
WH-8	Kenteri	Located about 2.5km east of Kora	1,268	Ti2/Tb2	Qb1 is distributed on the surface. Target aquifers Ti2 and Tb2 are commonly distributed below this surface layer (Qb1).	10	70	2-4	200	30
WH-9	Aneno	Located about 4km west-southwest of AdamiHara along the harfway of Awash-Deredawa Road	1,309	Qi1/Tb2	It is a difficult area for groundwater development. Qb1 or Qi1 are distributed on the suface. The target aquifer is probably Tb2.	0～5	160	2-4	300	45
WH-10	Belo	Located about 5km south of Bordede of about 20km from Awash along the DeredawaRoad	1,260	Qi1/Ti2	Qi1 or Ti2 is distributed on the surface、the target aquifer is possibly Ti2	5～10	80	2-4	200	30
WH-11	Kora	Located about 5km south of Adami-Hara of the harfway along the Awash-Diredawa Road	1,236	Ti2	Qb1is distributed on the surface. Ti2 below Qb1 most likely occurs for the target aquifer	10	70	2-4	200	30

Qb1: Pleistocene basalt, Qp1: Chefe Donsa pyroclastic deposits, Qr1: Pleistocene rhyolotes, Qi1: Dino ignimbrite, Tb3: Bofa basalts, Tt: Chilalo trachybasalts, Ti3: Upper Nazret pyroclastic deposits, Ti2: Lower Nazret pyroclastic deposits, Tb2: Anchar basalts
Ti1: Debre Birhan ignimbrite, Tr1: Huse Ridge rhyolites, Tb1: Alaji basalts

6.6 Water supply plan of small towns

6.6.1 Verification of rationality to elaborate water supply plan in small towns

In order to confirm planning rationality, surveyed 30 small towns were screened in accordance with the procedure shown in Figure 6.6.1 before elaborating provisional water supply planning. The results of screenings by criteria are mentioned as follows. Eleven towns were decided to be excluded from the original 30 small towns based on the results of the screening, as shown in Table 6.6.1.



Source: the Project Team

Figure 6.6.1: Procedure for Screening of 30 Small Towns

Table 6.6.1: Excluded Small Towns from Water Supply Planning

No.	ID	Small town	Reason to be excluded
1	ES-1	Wonji Shewa Alemtena	No groundwater development potential (water quality)
2	ES-3	Dire	No groundwater development potential (water quality)
3	ES-5	Bole	Overlapping with other projects
4	ES-7	Bekejo	No groundwater development potential (water quality)
5	ES-9	Chefe Donsa	Overlapping with other projects
6	ES-12	Adulala	Overlapping with other projects
7	AR-1	Sire	Overlapping with other projects
8	AR-5	Golegota	Overlapping with other projects
9	AR-7	Arbe Gebeya	Sufficient safe drinking water supply
10	WH-5	Mieso	Overlapping with other projects
11	WH-7	Bordede	Overlapping with other projects

Source: the Project Team

a. Preconditions

A precondition was set that there be no other water supply projects in the small towns for which provisional water supply plans are developed.

Activities for water supply planning or implementation are now underway through a National Program called "One WASH" with funds coming from the GoE and donor agencies. So existence of other projects in candidate small towns was confirmed to avoid duplication.

The results of this investigation into other projects are as shown in Table 6.6.2. Seven small towns which overlap with other projects shall be excluded from the target towns for water supply planning.

Table 6.6.2: Small Towns which Overlap with Other Projects

ID	Small town	Overlapping project
ES-5	Bole	Oromia Regional Government
ES-9	Chefe Donsa	Oromia Regional Government
ES-12	Adulala	One Wash Program
AR-1	Sire	One Wash Program
AR-5	Golegota	Oromia Regional Government
WH-5	Mieso	One Wash Program
WH-7	Bordede	Oromia Regional Government

Source: the Project Team

b. Natural conditions

The judgment item and judgment result of natural conditions are as stated below.

b.1 Prospect of groundwater development

The surveys such as geophysical survey, test well drilling, existing water source survey, etc., found none of the target small towns were suitable for spring water development, and conversely, that none of the small towns were unsuitable for groundwater development.

b.2 Groundwater potential (water quantity)

As the result of pumping test of test wells, etc., there was no small town judged as having no groundwater potential.

b.3 Groundwater potential (water quality)

The evaluation of potential water quality of the groundwater wells in target towns found that all but three towns passed the requirements of the Project. These three towns (see Table 6.6.3) were there excluded from the provisional water supply planning. Water quality evaluation was based on the results of the water quality analysis of existing wells carried out by the Project. If there was no existing well in the target small towns, water quality potential was evaluated based on the water quality concentration distribution map based on the water quality of the existing wells.

The water quality analysis found two water quality parameters exceeded Ethiopian water quality standards, fluoride and the total hardness. The Project Team judged total hardness exceeding the Ethiopian standard to not warrant exclusion from the Project groundwater development plans because total hardness is not classed as a toxic or disease causing substance under the Ethiopian water quality standards, rather a water quality parameter that affects the palatability of drinking water.

On the other hand, fluoride is a water quality parameter which influences health, and is classed as a toxic or disease causing substance under the Ethiopian water quality standards. The Ethiopian water quality standard for fluoride concentration was revised in October 2013 from 3.0 mg/L to 1.5 mg/L.

However, there are many existing wells over a vast area of the East Shewa Zone, a Project target area, with high fluoride concentrations that do not satisfy the new standard. Therefore, the Project considers areas that satisfy the old standard (3.0 mg/L), while not satisfying the new standard, to be potential areas for groundwater development in terms of water quality. Towns with groundwater that does not satisfy the old standard is excluded from the small towns for water supply planning, namely, it is considered that water quality potential does not exist in such areas.

Table 6.6.3: Small Towns judged to have Insufficient Water Quality to be excluded from the Water Supply Planning

ID	Small town	Fluoride (mg/L)*	Remark
ES-1	Wonji Shewa Alemtena	3.0～10.0	Assumption based on existing data of surrounding area
ES-3	Dire	4.49	
ES-7	Bekejo	3.14	

* New Ethiopian water quality standard: 1.5mg/L, old standard: 3.0mg/L

Source: Water quality survey result by the Project Team

c. Social conditions

c.1 Problems on accessibility, water rights and water conflict

As a result of the social survey conducted in the Project, it is judged that there is no problem with regard to accessibility, vested rights and conflicts to prevent project implementation.

c.2 Operation and maintenance capacity

Operation and maintenance of piped water supply systems is currently being performed by town water supply service offices or water committees in 23 small towns of the 30 surveyed small towns. And operation and maintenance has so far been continuously performed in these small towns. It is considered that there is no problem on the operation and maintenance in these small towns.

Capability on operation and maintenance of piped water supply systems of the remaining seven small towns (without O&M by town water supply office or a water association) is unknown. But in the representative interviews they answered that they intend to establish a water association and performing operation and management.

Therefore, some of small towns were deemed in need of formulating a capacity strengthening plan for operation and maintenance. But none of the 30 small towns were judged as having insufficient capacity for operation and maintenance of water supply facilities at this moment or in future.

c.3 Current access to safe water in the candidate town

One small town, Arbe Gebeya (AR-7), was deemed to have sufficient safe water to meet the projected water supply demand in 2020. Therefore, this town was excluded from the small towns for water supply planning. This decision was based on the calculated water demand under the projected population increase as of 2020 in comparison to the current capacity for water supply in the small towns.

Table 6.6.4: Small Towns judged to have Sufficient Water Supply and to not need Water Supply Planning Assistance

ID	Small town	Planning daily average water supply amount in 2020 (m^3/day)	Water supply amount as of 2014 (m^3/day)	Projected sufficiency rate in 2020 (%)
AR-7	Arbe Gebeya	168.4	220.7	131

Source: the Project Team

6.6.2 Outline of provisional water supply planning

a. Small towns for provisional water supply planning

The abovementioned screening process reduced the provisional water supply plan to a 19 small towns from the original 30. That is, 11 small towns were excluded from the water supply planning based on the above verification results.

The small towns for which provisional water supply plans will be developed are as shown in Table 6.6.5.

Table 6.6.5: Small Towns for which Provisional Water Supply Plans are developed

No.	ID	Town	Woreda	Zone
1	ES-2	Geldiya	Adama Zuria	East Shewa
2	ES-4	Bofa	Boset	East Shewa
3	ES-6	Ude Dhankaka	Adaa	East Shewa
4	ES-8	Kamise	Lome	East Shewa
5	ES-10	Areda	Gimbichu	East Shewa
6	ES-11	Biyo	Lome	East Shewa
7	AR-2	Bolo	Jeju	Arsi
8	AR-3	Arboye	Jeju	Arsi
9	AR-4	Aseko	Aseko	Arsi
10	AR-6	Gonde	Tiyo	Arsi
11	WH-1	Chorora	Anchar	West Hararge
12	WH-2	Bedeyi	Anchar	West Hararge
13	WH-3	Hardim	Guba Qoricha	West Hararge
14	WH-4	Bube	Guba Qoricha	West Hararge
15	WH-6	Hargeti	Mieso	West Hararge
16	WH-8	Kenteri	Mieso	West Hararge
17	WH-9	Aneno	Mieso	West Hararge
18	WH-10	Belo	Mieso	West Hararge
19	WH-11	Kora	Mieso	West Hararge

Source: the Project Team

b. Outline of water supply facilities

The Project developed water supply plans for the target towns covering construction of: water intake facilities (borehole, riser pipes, submersible motor pump, pumping cabin and diesel generator), transmission facilities (transmission pipelines), and distribution facilities (reservoir, distribution pipeline, public taps, cattle troughs and private connections).

c. Concept of both existing water supply facilities and new water supply facilities

Existing piped water supply facilities exist in 14 of 19 small towns.

The Project water supply plans are developed with a policy of constructing new water supply facilities capable of supplying the projected shortfall in water supply in the target year of 2020. To calculate this, first the current water supply capacity of each town was ascertained by surveying the existing water supply systems. This volume was then subtracted from the calculated water usage demand of each town based on projected population increase as of 2020.

However, as mentioned above (section 6.2.5), there are some existing water supply facilities which have been used for a considerable amount of time and have significant wear and tear. Therefore, the Project plans to replace or newly construct existing water supply facilities that exceed the lifespan specified in the Ethiopian design criteria as of the target year 2020. The planned construction program consists of new water supply facilities and an renewal plan of existing water supply facilities.

The total water supply volume and share of water supply volume between the existing water supply facilities and new water supply facilities as of 2020 in each small town is shown in Table 6.6.6.

Table 6.6.6: Share of Water Supply Volume between Existing Facilities and New Facilities

ID	Small town	Total		Allocation	
		Planning water supply population (2020) (person)	Planning daily maximum water supply amount (m^3/day)	Existing facility Actual water supply amount (m^3/day)	New facility Planning daily maximum water supply amount (m^3/day)
ES-2	Geldiya	2,873	162.9	93.8	69.1
ES-4	Bofa	5,326	299.3	229.8	69.5
ES-6	Ude Dhankaka	7,334	413.3	0.0	413.3
ES-8	Kamise	6,167	343.6	11.5	332.1
ES-10	Areda	3,502	197.2	11.0	186.2
ES-11	Biyo	3,446	195.9	0.0	195.9
AR-2	Bolo	2,010	114.6	24.2	90.4
AR-3	Arboye	9,254	550.4	271.7	278.7
AR-4	Aseko	6,724	386.9	46.3	340.6
AR-6	Gonde	4,370	248.0	116.2	131.8
WH-1	Chorora	3,183	117.3	21.2	96.1
WH-2	Bedeyi	3,748	219.0	16.8	202.2
WH-3	Hardim	7,515	428.1	18.1	410.0
WH-4	Bube	7,286	258.9	18.1	240.8
WH-6	Hargeti	3,926	138.3	0.0	138.3
WH-8	Kenteri	2,044	73.2	0.0	73.2
WH-9	Aneno	3,326	116.6	0.0	116.6
WH-10	Belo	5,471	189.9	12.2	177.7
WH-11	Kora	2,771	99.0	37.8	61.2

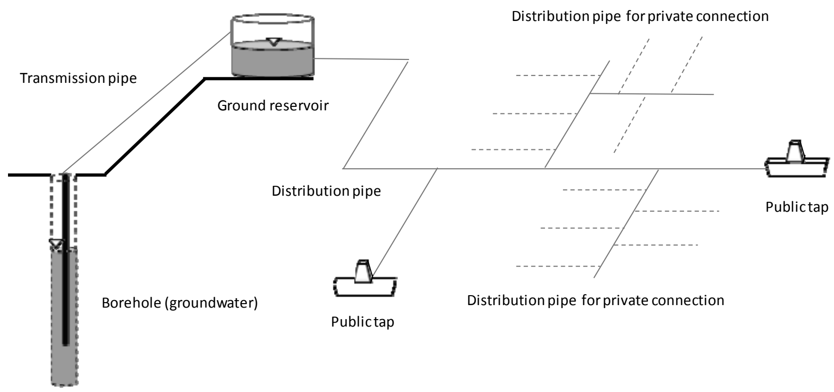
Source: the Project Team

6.6.3 Water supply scheme and scale for new water supply facilities

Water supply facilities to be newly constructed are divided roughly into the following two types.

a. Groundwater supply system with distribution reservoir on the ground

Unit consisting of groundwater source by borehole, submersible motor pump, distribution reservoir, public taps and private connections shall be planned. Assuming the elevation of construction site of distribution reservoir is higher than the elevation of construction site of public taps and private connections, and the specified water pressure is expected to be obtainable, then the distribution reservoir shall be planned on the ground. And water shall be distributed by gravity from the distribution reservoir to public taps and private connections.

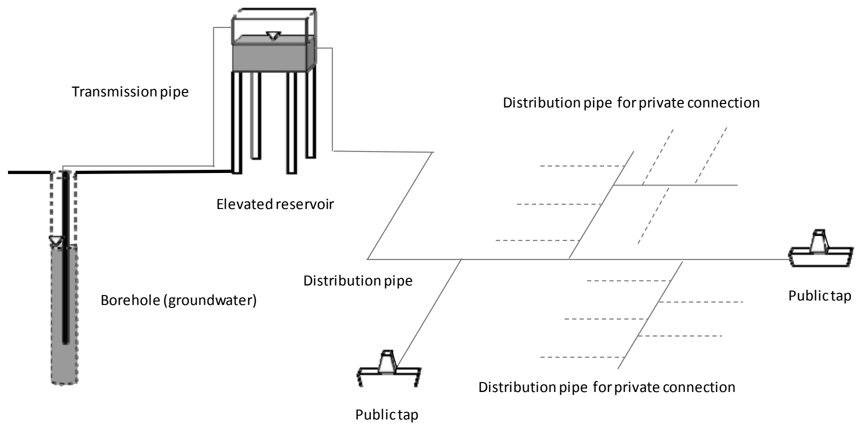


Source: the Project Team

Figure 6.6.2: Groundwater Supply System with Distribution Reservoir on the Ground

b. Groundwater supply system with elevated distribution reservoir

Unit consisting of groundwater source by borehole, submersible motor pump, distribution reservoir, public taps and private connections shall be planned. Assuming the elevation of construction site of distribution reservoir is lower than the elevation of construction site of public taps and private connections, specified water pressure is not expected to be obtainable. In such cases an elevated distribution reservoir shall be planned. And water shall be distributed by gravity from elevated distribution reservoir to public taps and private connections.



Source: the Project Team

Figure 6.6.3: Groundwater Supply System with Elevated Distribution Reservoir

6.6.4 Design criteria of water supply facilities

Water supply facilities follow the design of the existing water supply system, and its design shall be simple to ensure ease of operation and maintenance by water management organizations. The following points shall be considered when formulating the plan of a water supply system.

- In order to minimize operation and maintenance expense, water supply system without using large-sized power shall be adopted.
- Neither a complicated system nor a highly efficient system shall be adopted to ensure

ease of operation and maintenance by the water management organization.

- In order to reduce initial investment cost (construction cost), locally available materials, equipment and construction methods shall be adopted for construction. And the products generally available in the local market shall be adopted whenever possible.

6.6.5 Facility plan and general design

a. Intake facilities

a.1 Borehole

Numbers of boreholes to be installed shall be calculated by planning daily maximum water supply amount, assumed maximum intake volume and daily pumping hours by towns. Daily pumping hours shall be set as 10 hours.

The depth of the boreholes was set within a range of 150-350m based on the results of investigation in each small town using the results of the hydrogeological survey of the target area.

Materials of casing and screen pipes shall be steel. Diameter of casing and screen pipes shall be 8 inches and fit with submersible motor pump. Total length of screen pipe shall be estimated approximately 15% of borehole depth.

Success rate of borehole drilling shall be estimated as approximately 82% in accordance with the result of test well drilling, in which 9 boreholes were successful among 11.

Assumed borehole specifications are as shown in Table 6.6.7. And specifications of intake facilities are shown in Table 6.6.8.

Table 6.6.7: Specifications of Boreholes

ID	Small town	Specification of borehole						
		Depth	Casing pipes			Screen pipes		
		(m)	Material	Diameter (inch)	Length (m)	Material	Diameter (inch)	Length (m)
ES-2	Geldiya	200	steel	8	170	steel	8	30
ES-4	Bofa	250	steel	8	212	steel	8	38
ES-6	Ude Dhankaka	300	steel	8	250	steel	8	50
ES-8	Kamise	350	steel	8	300	steel	8	50
ES-10	Areda	250	steel	8	212	steel	8	38
ES-11	Biyo	300	steel	8	250	steel	8	50
AR-2	Bolo	250	steel	8	212	steel	8	38
AR-3	Arboye	250	steel	8	212	steel	8	38
AR-4	Aseko	250	steel	8	212	steel	8	38
AR-6	Gonde	150	steel	8	128	steel	8	22
WH-1	Chorora	150	steel	8	128	steel	8	22
WH-2	Bedeyi	250	steel	8	212	steel	8	38
WH-3	Hardim	150	steel	8	128	steel	8	22
WH-4	Bube	200	steel	8	170	steel	8	30
WH-6	Hargeti	250	steel	8	212	steel	8	38
WH-8	Kenteri	200	steel	8	170	steel	8	30
WH-9	Aneno	300	steel	8	255	steel	8	45
WH-10	Belo	200	steel	8	170	steel	8	30
WH-11	Kora	200	steel	8	170	steel	8	30

Source: the Project Team

Table 6.6.8: Specifications of Intake Facilities

ID	Small town	Daily maximum water supply amount for new facility	Maximum pumping rate per borehole		Pumping hours per day	Pumping volume per borehole	Number of boreholes	Intake pump	
								Quantity	Pumping rate
		(m^3/day)	(L/sec/set)	(m^3/hr/set)	(hrs/day)	(m^3/day/set)	(set)	(set)	(m^3/hr/set)
ES-2	Geldiya	69.1	12.5	45	10	450	1	1	7.0
ES-4	Bofa	69.5	7.5	27	10	270	1	1	7.0
ES-6	Ude Dhankaka	413.3	12.5	45	10	450	1	1	41.4
ES-8	Kamise	332.1	12.5	45	10	450	1	1	33.3
ES-10	Areda	186.2	7.5	27	10	270	1	1	18.7
ES-11	Biyo	195.9	12.5	45	10	450	1	1	19.6
AR-2	Bolo	90.4	12.5	45	10	450	1	1	9.1
AR-3	Arboye	278.7	7.5	27	10	270	2	2	14.0
AR-4	Aseko	340.6	7.5	27	10	270	2	2	17.1
AR-6	Gonde	131.8	7.5	27	10	270	1	1	13.2
WH-1	Chorora	96.1	7.5	27	10	270	1	1	9.7
WH-2	Bedeyi	202.2	7.5	27	10	270	1	1	20.3
WH-3	Hardim	410.0	12.5	45	10	450	1	1	41.0
WH-4	Bube	240.8	2.5	9	10	90	3	3	8.1
WH-6	Hargeti	138.3	12.5	45	10	450	1	1	13.9
WH-8	Kenteri	73.2	12.5	45	10	450	1	1	7.4
WH-9	Aneno	116.6	2.5	9	10	90	2	2	5.9
WH-10	Belo	177.7	2.5	9	10	90	2	2	8.9
WH-11	Kora	61.2	12.5	45	10	450	1	1	6.2

Source: the Project Team

a.2 Intake pump and power supply

Type of pump shall be submersible motor pump in order to intake from borehole. Considering sustainable operation and maintenance, the brand of submersible motor pump is planned to be those recommended in the Ethiopian standard design criteria and that have sole agents in Ethiopia such as Grundfos and Caprari.

The output of submersible motor pump was set in the range of 4.0 kW - 22.0 kW as a result of a calculation into the pumping rates and total head of pumps in the small towns.

Commercial electric power, which is cheaper, shall be used as much as possible. But since five of the (19) small towns (Kamise, Areda, Bedeyi, Bube and Hargeti) are not have access to (grid) electricity and power failures occur in the remaining small towns, diesel generators shall also be installed in all of the small towns.

The brand of the engine of a diesel generator takes into consideration the sustainability of future operation and maintenance to procure consumables such as oil, filters, etc. and spare parts. Lister (United Kingdom), Deutz (Germany), Perkins (United Kingdom), etc. which are recommended in Ethiopian standard design criteria and which sole agent exists in Ethiopia shall be considered.

The specifications of submersible motor pump and diesel generator is shown in Table 6.6.9.

Table 6.6.9: Specifications of Submersible Motor Pump and Diesel Generator

ID	Small town	Submersible motor pump					Diesel Generator
		Pumping rate		Total head	Output	Diameter	Output
		(m^3/hr)	(L/min)	(m)	(kW)	(mm)	(kVA)
ES-2	Geldiya	7.0	117	111	4.0	145	10.0
ES-4	Bofa	7.0	117	134	4.0	145	10.0
ES-6	Ude Dhankaka	41.4	690	102	15.0	150	34.0
ES-8	Kamise	33.3	555	135	18.5	150	42.0
ES-10	Areda	18.7	312	242	18.5	148	42.0
ES-11	Biyo	19.6	327	109	11.0	145	25.5
AR-2	Bolo	9.1	152	203	7.5	145	17.5
AR-3	Arboye	14.0	233	218	11.0	145	25.5
AR-4	Aseko	17.1	285	340	22.0	148	50.0
AR-6	Gonde	13.2	220	136	7.5	145	17.5
WH-1	Chorora	9.7	162	114	4.0	145	10.0
WH-2	Bedeyi	20.3	338	281	22.0	148	50.0
WH-3	Hardim	41.0	683	83	13.0	150	29.5
WH-4	Bube	8.1	135	87	3.0	135	7.5
WH-6	Hargeti	13.9	232	152	7.5	145	17.5
WH-8	Kenteri	7.4	123	112	4.0	145	10.0
WH-9	Aneno	5.9	98	244	5.5	96	13.5
WH-10	Belo	8.9	148	120	4.0	145	10.0
WH-11	Kora	6.2	103	123	4.0	145	10.0

Source: the Project Team

a.3 Pumping cabin

Enough space to set the control panel of submersible motor pump and diesel generator shall be kept. Main structure shall be reinforced concrete consisting of columns and beams. Wall shall be constructed by concrete block masonry.

b. Transmission facilities

b.1 Transmission pipes

Transmission pipes shall be installed from the borehole. It is not possible to decide diameter of transmission pipes at this moment because topographic survey has not been conducted as yet and it is difficult to calculate the loss of total head. However, a provisional transmission pipe diameter of 150 mm (6 inches) is set to minimize head loss.

Considering durability, especially for water leakage due to the breakdown of pipes and easiness for procurement, steel shall be adopted as the material of the transmission pipes.

c. Distribution facilities

c.1 Distribution reservoir

According to the Ethiopian design criteria, if the population supplied with water is less than 10,000, the reservoir capacity shall be sufficient to ensure an average of 15 hours of water supply per day. If population supplied with water is 10,000 or more, the capacity of the water reservoir shall be sufficient to ensure an average of 12 hours of water supply per day. This standard shall also be applied in this plan.

If high elevation area is available as construction site of reservoir tank to keep enough water head, the reservoir shall be ground-setting type; that is, constructed directly on the ground. If no high elevation sites are available, elevated-type reservoir shall be adopted. Ground-type reservoir shall be rectangular reinforced concrete structure. For elevated-type reservoir, main reservoir shall be fabricated by steel panels and mounting structure shall be reinforced concrete.

The size of reservoirs shall be set as standard types in 50 m^3 intervals within a size range of 50 – 300 m^3.

c.2 Distribution pipes

In order to determine the diameter of distribution pipes, it is necessary to carry out hydraulic calculation based on the elevation data of planned distribution pipelines. Because route survey is not carried out yet at present and the data about the height of a pipeline route is not obtained, diameter of distribution pipe for the provisional estimation shall be assumed to be 150 mm (6 inches) for primary distribution line, 75 mm (3 inches) for secondary distribution line and 40 mm (1.5 inches) for connecting pipes to public taps in order to minimize the head loss.

The cost of connection pipes to the private connection shall be borne by the private users and not be included in the provisional estimation for this water supply plan. However, to avoid issues of low water pressure occurring in peak hours in future, hydraulic calculation to determine the diameter of distribution pipes based on the results of route survey at the basic design stage in the future considering the rate of increase of private connection mentioned in 6.3.2, shall be conducted.

Considering durability, especially for water leakage due to the breakdown of distribution pipes and easiness for procurement, steel shall be adopted as the material of the transmission pipes. Estimated quantity of new distribution pipelines is shown in Table 6.6.10.

Table 6.6.10: Quantity of New Distribution Pipelines

ID	Small town	Quantity of distribution pipes		
		Primary	Secondary	Connecting
		150A	80A	40A
		(m)	(m)	(m)
ES-2	Geldiya	2,120	880	25
ES-4	Bofa	1,650	6,620	20
ES-6	Ude Dhankaka	3,730	2,180	940
ES-8	Kamise	3,670	1,040	390
ES-10	Areda	2,690	400	240
ES-11	Biyo	4,470	200	450
AR-2	Bolo	1,330	1,140	70
AR-3	Arboye	2,535	2,260	115
AR-4	Aseko	1,970	1,180	350
AR-6	Gonde	3,905	1,970	60
WH-1	Chorora	1,250	570	50
WH-2	Bedeyi	2,420	230	100
WH-3	Hardim	3,130	350	340
WH-4	Bube	2,330	750	450
WH-6	Hargeti	1,065	250	260
WH-8	Kenteri	530	170	45
WH-9	Aneno	940	520	95
WH-10	Belo	1,645	750	610
WH-11	Kora	1,055	255	40

Source: the Project Team

c.3 Public taps

Because the number of users per public tap is specified as 150 persons in Ethiopian design criteria, the number of public taps is calculated after computing the number of public tap users of the new water supply facilities in 2020. Although there are several types of public taps such as with two, four and six faucets, it is preferable to select a suitable type based on the population density, etc., after selecting the location of installation during implementation of the project. Public taps with four faucets shall be provisionally adopted.

There are four small towns with existing piped water supply systems that also have cattle troughs. In addition, there is a small town which wishes to install cattle troughs for livestock. Installation of cattle troughs shall be considered for these five small towns. Installation of cattle troughs for the remaining 14 small towns shall be considered based on the request from the town water supply service offices, water committees, users, etc. as the result of survey during implementation of the project.

6.6.6 Outline of water supply facility plan

a. Construction plan of new water supply facilities

Outline of construction plan of new water supply facilities is shown in Table 6.6.11.

Table 6.6.11: Outline of Construction Plan of New Water Supply Facilities

ID	Small town	Intake facility							Transmission facility	Distribution facility				
		Borehole		Submersible motor pump		Diesel generator		Pumping cabin	Transmission pipes	Distribution reservoir			Distribution pipes	Public taps
		Quantity (set)	Depth (m)	Quantity (set)	Output (kW)	Quantity (set)	Output (kVA)	Quantity (set)	Quantity (m)	Quantity (set)	Type	Capacity (m3)	Quantity (m)	Quantity (set)
ES-2	Geldiya	1	200	1	4	1	10	1	1,225	1	Ground	50	3,025	1
ES-4	Bofa	1	250	1	4	1	10	1	2,120	1	Elevated	50	8,290	1
ES-6	Ude Dhankaka	1	300	1	15	1	34	1	965	1	Ground	300	6,850	13
ES-8	Kamise	1	350	1	19	1	42	1	1,750	1	Ground	250	5,100	10
ES-10	Areda	1	250	1	19	1	42	1	4,275	1	Elevated	150	3,330	6
ES-11	Biyo	1	300	1	11	1	26	1	285	1	Ground	150	5,120	6
AR-2	Bolo	1	250	1	8	1	18	1	1,345	1	Elevated	100	2,540	2
AR-3	Arboye	2	250	2	11	2	26	2	650	2	Elevated	100	4,910	4
AR-4	Aseko	2	250	2	22	2	50	2	1,210	2	Ground	150, 100	3,500	9
AR-6	Gonde	1	150	1	8	1	18	1	2,175	1	Ground	100	5,935	2
WH-1	Chorora	1	150	1	4	1	10	1	625	1	Ground	100	1,870	2
WH-2	Bedeyi	1	250	1	22	1	50	1	1,130	1	Ground	150	2,750	4
WH-3	Hardim	1	150	1	13	1	30	1	1,645	1	Ground	300	3,820	10
WH-4	Bube	3	200	3	3	3	8	3	530	3	Ground	50	3,530	11
WH-6	Hargeti	1	250	1	8	1	18	1	1,070	1	Ground	100	1,575	7
WH-8	Kenteri	1	200	1	4	1	10	1	1,205	1	Elevated	50	745	4
WH-9	Aneno	2	300	2	6	2	14	2	1,495	2	Ground	50	1,555	6
WH-10	Belo	2	200	2	4	2	10	2	150	2	Ground	100, 50	3,005	9
WH-11	Kora	1	200	1	4	1	10	1	585	1	Ground	50	1,350	2

Source: the Project Team

b. Renewal plan of existing water supply facilities

Outline of renewal plan of existing water supply facilities is shown in Table 6.6.12.

Table 6.6.12: Outline of Renewal Plan of Existing Water Supply Facilities

ID	Small town	Intake facility							Transmission facility	Distribution facility				
		Borehole		Submersible motor pump		Diesel generator		Pumping cabin	Transmission pipes	Distribution reservoir			Distribution pipes	Public taps
		Quantity (set)	Depth (m)	Quantity (set)	Output (kW)	Quantity (set)	Output (kVA)	Quantity (set)	Quantity (m)	Quantity (set)	Type	Capacity (m3)	Quantity (m)	Quantity (set)
ES-2	Geldiya	-	-	1	4	-	-	-	-	-	-	-	-	-
ES-4	Bofa	1	250	2	4	1	10	-	-	-	-	-	-	11
ES-6	Ude Dhankaka	-	-	-	-	-	-	-	-	-	-	-	-	-
ES-8	Kamise	-	-	-	-	-	-	-	-	-	-	-	-	-
ES-10	Areda	-	-	1	19	-	-	-	-	-	-	-	-	-
ES-11	Biyo	-	-	-	-	-	-	-	-	-	-	-	-	-
AR-2	Bolo	-	-	1		-	-	-	-	-	-	-	-	-
AR-3	Arboye	-	-	-	-	1	26	-	-	-	-	-	-	7
AR-4	Aseko	-	-	1	22	-	-	-	-	-	-	-	-	-
AR-6	Gonde	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-1	Chorora	-	-	1	4	-	-	-	-	-	-	-	-	-
WH-2	Bedeyi	-	-	1	22	-	-	-	-	-	-	-	-	-
WH-3	Hardim	1	150	1	13	1	30	-	-	-	-	-	-	7
WH-4	Bube	-	-	1	3	-	-	-	-	-	-	-	-	-
WH-6	Hargeti	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-8	Kenteri	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-9	Aneno	-	-	-	-	-	-	-	-	-	-	-	-	-
WH-10	Belo	-	-	1	4	-	-	-	-	-	-	-	-	-
WH-11	Kora	-	-	1	4	-	-	-	-	-	-	-	-	-

Source: the Project Team

6.6.7 Provisional estimation for water supply plan

a. Method of provisional estimation

It is impossible to estimate exact construction cost based on the unit price of materials, labour and equipment because exact quantity of each construction item cannot be calculated due to very rough design level.

Provisional estimation is carried out based on the recent contract unit prices of similar borehole construction works with local contractor for JICA projects, unit price of estimation for similar construction works by Japan's Gant Aid Project, etc. Unit prices adopted in this estimation is shown in Table 6.6.13.

Table 6.6.13: Adopted Unit Prices for Provisional Estimation

No.	Facility	Specification	Unit	Adopted unit price (Birr)
1	Construction of boreholes			
	Mobilization	Including demobilization	set	119,096
	Drilling works	Finishing 8 inch dia.	m	2,269
	Installation of casing pipes	Steel, 8 inch dia.	m	2,682
	Installation of screen pipes	Steel, 8 inch dia.	m	3,094
	Others	Electric logging, pumping tests, filling gravel, etc.	set	138,055
2	Installation of riser pipes	Steel, 32mmdia.	m	459
		Steel, 65mmdia.	m	646
		Steel, 80mmdia	m	833
3	Installation of submersible motor pump	7.5kW or less	set	190,383
		11kW or less	set	238,081
		15kW or less	set	264,138
		22kW or less	set	372,758
		37kW or less	set	580,776
4	Construction of pumping cabin	RC structure, Concrete block wall, floor space 30.68m^2	set	192,221
5	Installation of diesel generator	20kVA or less	set	270,188
		37kVA or less	set	312,766
		50kVA or less	set	357,806
		100kVA or less	set	502,648
6	Installation of transmission pipes	Dia. 150mm (6 inch)	m	1,911
7	Construction of distribution reservoir	Ground type, RC structure, 50m^3	set	343,650
		Ground type, RC structure, 100m^3	set	687,300
		Ground type, RC structure, 150m^3	set	1,030,950
		Ground type, RC structure, 200m^3	set	1,374,600
		Ground type, RC structure, 250m^3	set	1,718,250
		Ground type, RC structure, 300m^3	set	2,061,900
		Elevated type, steel structure, 50m^3	set	780,750
		Elevated type, steel structure, 100m^3	set	1,561,500
		Elevated type, steel structure, 150m^3	set	2,342,250
8	Installation of distribution pipes	Primary distribution, GSP, 150mm (6inch) dia.	m	2,029
		Secondary distribution: GSP, 75mm (3 inch) dia.	m	1,391
		Connecting pipes, GSP, 40mm (1.5 inch) dia.	m	930
9	Construction of public taps	RC structure、4 faucet type	set	49,515

Source: the Project Team

b. Provisional implementation cost

b.1 Construction cost of new water supply facilities

Construction cost of new water supply facilities is estimated as shown in Table 6.6.14.

Table 6.6.14: Construction Cost of New Water Supply Facilities

Unit: 1000Birr

ID	Small town	Construction cost of new water supply facilities									
		Intake facilities					Transmission facilities	Distribution facilities			Total
		Construction of boreholes	Installation of riser pipes	Installation of submersible motor pump	Construction of pumping cabin	Installation of diesel generator	Installation of transmission pipes	Construction of distribution reservoir	Installation of distribution pipes	Construction of public taps	
ES-2	Geldiya	1,360	46	190	192	270	2,341	344	5,549	99	10,391
ES-4	Bofa	1,635	46	190	192	270	4,051	1,124	12,575	50	20,133
ES-6	Ude Dhankaka	1,913	57	264	192	313	1,844	2,062	11,475	792	18,912
ES-8	Kamise	2,185	44	373	192	358	3,344	1,718	9,256	594	18,064
ES-10	Areda	1,635	111	373	192	358	8,170	2,342	6,238	297	19,716
ES-11	Biyo	1,913	47	238	192	313	545	1,031	9,766	297	14,342
AR-2	Bolo	1,635	85	190	192	270	2,570	1,562	4,349	149	11,002
AR-3	Arboye	3,271	195	476	384	626	1,242	3,123	8,394	198	17,909
AR-4	Aseko	3,271	222	746	384	716	2,312	1,718	5,964	446	15,779
AR-6	Gonde	1,084	33	190	192	270	4,156	687	10,719	99	17,430
WH-1	Chorora	1,084	33	190	192	270	1,194	687	3,376	99	7,125
WH-2	Bedeyi	1,635	111	373	192	358	2,159	1,031	5,323	198	11,380
WH-3	Hardim	1,084	20	264	192	313	3,144	2,062	7,154	495	14,728
WH-4	Bube	4,079	79	571	577	811	1,013	2,406	6,189	545	16,270
WH-6	Hargeti	1,635	65	190	192	270	2,045	687	2,750	347	8,181
WH-8	Kenteri	1,360	46	190	192	270	2,303	781	1,354	198	6,694
WH-9	Aneno	3,822	148	381	384	540	2,857	687	2,719	297	11,835
WH-10	Belo	2,719	105	381	384	540	287	1,031	4,948	545	10,940
WH-11	Kora	1,360	46	190	192	270	1,118	344	2,533	99	6,152
	Total	38,680	1,539	5,960	4,801	7,406	46,695	25,427	120,631	5,844	256,983

Source: the Project Team

b.2 Renewal cost of existing water supply facilities

Renewal cost of existing water supply facilities is estimated as shown in Table 6.6.15.

Table 6.6.15: Renewal Cost of Existing Water Supply Facilities

Unit: 1000Birr

ID	Small town	Renewal cost of existing water supply facilities									
		Intake facilities					Transmission facilities	Distribution facilities			Total
		Construction of boreholes	Installation of riser pipes	Installation of submersible motor pump	Construction of pumping cabin	Installation of diesel generator	Installation of transmission pipes	Construction of distribution reservoir	Installation of distribution pipes	Construction of public taps	
ES-2	Geldiya	0	46	190	0	0	0	0	0	0	236
ES-4	Bofa	1,635	92	381	0	270	0	0	0	545	2,923
ES-6	Ude Dhankaka	0	0	0	0	0	0	0	0	0	0
ES-8	Kamise	0	0	0	0	0	0	0	0	0	0
ES-10	Areda	0	111	373	0	0	0	0	0	0	484
ES-11	Biyo	0	0	0	0	0	0	0	0	0	0
AR-2	Bolo	0	85	190	0	0	0	0	0	0	275
AR-3	Arboye	0	0	0	0	313	0	0	0	347	660
AR-4	Aseko	0	111	373	0	0	0	0	0	0	484
AR-6	Gonde	0	0	0	0	0	0	0	0	0	0
WH-1	Chorora	0	33	190	0	0	0	0	0	0	223
WH-2	Bedeyi	0	111	373	0	0	0	0	0	0	484
WH-3	Hardim	1,084	20	264	0	313	0	0	0	347	2,028
WH-4	Bube	0	26	190	0	0	0	0	0	0	216
WH-6	Hargeti	0	0	0	0	0	0	0	0	0	0
WH-8	Kenteri	0	0	0	0	0	0	0	0	0	0
WH-9	Aneno	0	0	0	0	0	0	0	0	0	0
WH-10	Belo	0	52	190	0	0	0	0	0	0	242
WH-11	Kora	0	46	190	0	0	0	0	0	0	236
	Total	2,719	733	2,904	0	896	0	0	0	1,239	8,491

Source: the Project Team

b.3 Implementation cost

Implementation cost including construction cost of new water supply facilities with renewal cost of existing water supply facilities is estimated as shown in Table 6.6.16.

Table 6.6.16: Implementation Cost

Unit: 1000Birr

ID	Small town	Implementation cost									
		Intake facilities					Transmission facilities	Distribution facilities			Total
		Construction of boreholes	Installation of riser pipes	Installation of submersible motor pump	Construction of pumping cabin	Installation of diesel generator	Installation of transmission pipes	Construction of distribution reservoir	Installation of distribution pipes	Construction of public taps	
ES-2	Geldiya	1,360	92	380	192	270	2,341	344	5,549	99	10,627
ES-4	Bofa	3,270	138	571	192	540	4,051	1,124	12,575	595	23,056
ES-6	Ude Dhankaka	1,913	57	264	192	313	1,844	2,062	11,475	792	18,912
ES-8	Kamise	2,185	44	373	192	358	3,344	1,718	9,256	594	18,064
ES-10	Areda	1,635	222	746	192	358	8,170	2,342	6,238	297	20,200
ES-11	Biyo	1,913	47	238	192	313	545	1,031	9,766	297	14,342
AR-2	Bolo	1,635	170	380	192	270	2,570	1,562	4,349	149	11,277
AR-3	Arboye	3,271	195	476	384	939	1,242	3,123	8,394	545	18,569
AR-4	Aseko	3,271	333	1,119	384	716	2,312	1,718	5,964	446	16,263
AR-6	Gonde	1,084	33	190	192	270	4,156	687	10,719	99	17,430
WH-1	Chorora	1,084	66	380	192	270	1,194	687	3,376	99	7,348
WH-2	Bedeyi	1,635	222	746	192	358	2,159	1,031	5,323	198	11,864
WH-3	Hardim	2,168	40	528	192	626	3,144	2,062	7,154	842	16,756
WH-4	Bube	4,079	105	761	577	811	1,013	2,406	6,189	545	16,486
WH-6	Hargeti	1,635	65	190	192	270	2,045	687	2,750	347	8,181
WH-8	Kenteri	1,360	46	190	192	270	2,303	781	1,354	198	6,694
WH-9	Aneno	3,822	148	381	384	540	2,857	687	2,719	297	11,835
WH-10	Belo	2,719	157	571	384	540	287	1,031	4,948	545	11,182
WH-11	Kora	1,360	92	380	192	270	1,118	344	2,533	99	6,388
	Total	41,399	2,272	8,864	4,801	8,302	46,695	25,427	120,631	7,083	265,474

Source: the Project Team

b.4 Notes concerning implementation cost

Implementation cost mentioned above is direct construction cost. So in case the project will be implemented by Japan's Grant Aid Project, indirect cost (common temporary works and site expenses), head office expense, and design and supervision cost (detail design cost, supervision cost and soft component cost) shall be estimated separately and included into the implementation cost additionally.

Assumed implementation cost implemented by Japan's Grant Aid calculated by average ratio of indirect cost and design and supervision cost against direct cost of the past similar construction works of Japan's Grant Aid Project is shown in Table 6.6.17.

Table 6.6.17: Assumed Implementation Cost by Japan's Grant Aid

Unit: 1000Birr

Item	Direct cost	Indirect cost	Design & supervision	Implementation Cost
Ratio against direct cost	-	37%	26%	173%
Amount	265,474	98,225	69,023	459,270

Source: the Project Team

6.6.8 Study of alternative water supply plan

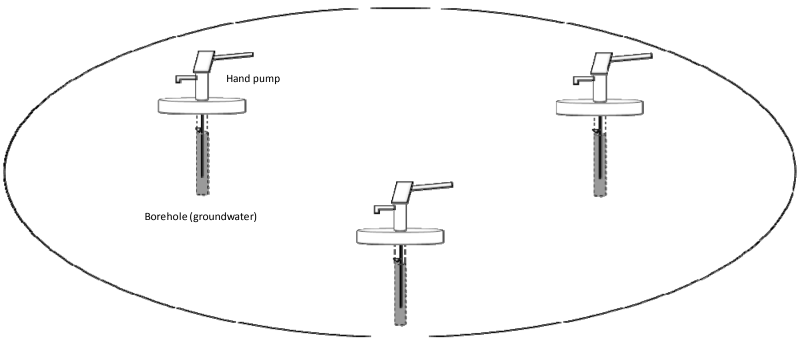
If piped water supply system will be applied for WH-6, WH-8, and WH-9, the following issues are of concern regarding sustainability:

(1) Benefit effect may be low because of insufficient population.

(2) Cost performance may be low because target small towns are Kebele (village) where population is very scattered.

(3) Capability of operation and maintenance is unforeseen because the towns do not currently have water supply facilities

For this reason, it is considered that the borehole with hand pump is recommendable as an alternative water supply plan.



Source: the Project Team

Figure 6.6.4: Groundwater Supply System with Hand Pump

a. Necessary numbers

Necessary numbers is calculated as shown in Table 6.6.18 in accordance with the Ethiopian design criteria mentioned that 300-350 persons per one borehole with hand pump.

Table 6.6.18: Necessary Numbers of Boreholes with Hand Pump

ID	Small town	Planned water supply population (2020) (person)	Necessary number of boreholes with handpump (set)	Served population per borehole with handpump (person)
WH-6	Hargeti	3,926	12	328
WH-8	Kenteri	2,044	6	341
WH-9	Aneno	3,326	10	333

Source: the Project Team

b. Specification and quantity of borehole

Thirty (30) L/min (0.5 L/sec) is enough for intake capacity because pumping capacity of hand pump is generally 10-20 L/min. For this reason, depth of borehole can be reduced compared with the borehole of piped water supply systems. Considering the hydrogeological condition of target area, borehole depth shall be assumed to be100 m.

Comparison of assumed intake capacity and borehole depth between piped water supply system and borehole with hand pump is shown in Table 6.6.19. Assumed specification and quantities of boreholes is shown in Table 6.6.20.

Table 6.6.19: Comparison of Assumed Intake Capacity and Borehole Depth between Piped Water Supply System and Borehole with Hand Pump

ID	Small town	Borehole for piped water supply system		Borehole for hand pump	
		Estimated yield (L/sec)	Estimated depth (m)	Estimated yield (L/sec)	Estimated depth (m)
WH-6	Hargeti	12.5	250	1.0	100
WH-8	Kenteri	12.5	200	1.0	100
WH-9	Aneno	2.5	300	1.0	100

Source: the Project Team

Table 6.6.20: Specification and Quantities of Boreholes

ID	Small town	Quantity per borehole							Total number of boreholes
		Borehole depth	Casing pipes			Screen pipes (15% of borehole depth)			
		Depth (m)	Material	Diameter (inch)	Length (m)	Material	Diameter (inch)	Length (m)	(set)
WH-6	Hargeti	100	uPVC	6	62	uPVC	6	38	12
WH-8	Kenteri	100	uPVC	6	70	uPVC	6	30	6
WH-9	Aneno	100	uPVC	6	55	uPVC	6	45	10

Source: the Project Team

c. Provisional estimation

Provisional estimation is carried out based on the recent contract unit prices of similar borehole construction works with local contractor for JICA projects, unit prices of estimation for similar construction works by Japan's Gant Aid Project, etc. Unit prices adopted in this estimation is shown in Table 6.6.21. Implementation cost is estimated as shown in Table 6.6.22.

Compared with the implementation cost of piped water supply system, implementation cost of borehole with hand pump is cheaper in WH-8 and WH-9. But implementation cost of piped water supply system is cheaper in WH-6.

Table 6.6.21: Adopted Unit Price

No.	Facilities	Specification	Unit	Adopted unit price (Birr)
1	Construction of boreholes			
	Mobilization	including demobilization	set	289,333
	Drilling works	Finishing diameter 6 inch	m	132
	Installation of casing pipes	uPVC, 6 inch	m	51
	Installation of screen pipes	uPVC, 6 inch	m	58
	Others	Electric logging, pumping test, gravel filling, etc.	set	190,042
2	Construction of platform		set	4,435
3	Installation of hand pump		set	16,896

Source: the Project Team

Table 6.6.22: Implementation Cost

Exchange rate: 1 US$ = 20.6298 Birr

ID	Small town	Borehole with hand pump		Piped water supply system
		Quantity (set)	Implementation cost (Birr)	Implementation cost (Birr)
WH-6	Hargeti	12	11,542,579	8,182,575
WH-8	Kenteri	6	5,938,701	6,693,520
WH-9	Aneno	10	9,645,979	11,835,317

Source: the Project Team

6.7 Operation and maintenance plan for water supply facility

6.7.1 Current organization and administration of existing water office

a. Organization for operation and maintenance of water supply facility in small towns

a.1 Town water supply service office

The Town Water Supply Service Offices (hereafter referred to as "TWSSOs") are established by the Town Water Boards. The members of these offices are comprised of representatives of the Town Administration Office, one person from OWMEB or the Zonal Water, Mineral and Energy Office (hereafter referred to as "ZWMEO") or the Woreda Water, Mineral and Energy Office (hereafter referred to as "WWMEO"), one person from the Health office, one person from the Women's Affair Office, one person from the Finance and Economic Development Office, one person from the branch of Ethiopia Electric Power Corporation (hereafter referred to as "EEPCO") in the town, one person from Education Office, two person from water users of the water supply service, and the general manager of the Town Water Supply Service Office. The manager and staff of the TWSSO are selected and employed by the Town Water Board.

a.2 Water committee

Members of the Water Committee (hereafter referred to as "WC") are elected among water users. Generally, the number of the committee members is approximately seven, which comprises a chairperson, secretary, cashier, auditor, store keeper, purchaser, and member. The term of office of the committee is two years; committee members are generally volunteers, but committee employees, such as operators, water fee collectors, and guards, are paid.

b. Current conditions of O&M in target small towns

b.1 Organization of operation and maintenance

TWSSO is organized in eight of the 30 surveyed small towns (ES-4, ES-5, ES-9, ES-12, AR-1, AR-5, AR-6, and WH-5).

There is no organization for operation and maintenance in three small towns (WH-6, WH-8, WH-9) where water supply facilities do not currently exist.

WCs exist in the remaining 19 small towns (ES-1, ES-2, ES-3, ES-6, ES-7, ES-8, ES-10, ES-11, AR-2, AR-3, AR-4, AR-7, WH-1, WH-2, WH-3, WH-4, WH-7, WH-10, WH-11).

b.2 Meeting, record and general assembly

Periodic meetings are held in all of TWSSOs and water committees except one water committee (ES-3). Meetings are usually held monthly. However, there are a few water committees that hold weekly meetings.

Revenue and expense was not recorded by the three WCs for borehole with hand pump of ES-6. Revenue and expense was not recorded monthly but every three months by the WCs of AR-7 and WH-10. Revenue and expense was recorded by other TWSSOs and WCs.

General assembly was not held in nine towns (ES-3, ES-4, ES-8, ES-11, AR-4, AR-6, AR-7, WH-4 and WH-7).

Table 6.7.1: Operation and Maintenance Management Organization, Meeting Situation and Income Record Documentation Situation

ID	Small town	Operation and Maintenance Management Organization	Meeting Situation (Yes/No) (frequency)	Monthly documentation of income record (Yes/No)
ES-1	Wonji Shewa Alemtena	water committee not formally established & Adama City WSSSE	no	no
ES-2	Geldiya	water committee	yes (4 times/year)	yes
ES-3	Dire	2 water committees for each borehole (BH1and BH2)	no for WC1, yes (24 times/year) for WC2	yes (both WC1 and WC2)
ES-4	Bofa	Bofa Town Water Supply Service Office	yes (12 times/year)	yes
ES-5	Bole	Bole-Golegota Town Water Supply Service Office	yes (12 times/year)	yes
ES-6	Ude Dhankaka	water committee	yes (12 times/year)	no
ES-7	Bekejo	water committee	yes (12 times/year)	yes
ES-8	Kamise	Water Committee/ Gimbichu-Fentale Rural Water Supply Service Enterprise	yes (12 times/year)	no
ES-9	Chefe Donsa	Chefe Donsa Town Water Supply Service Office	yes (24 times/year)	yes
ES-10	Areda	Water Committee	yes (24 times/year)	yes
ES-11	Biyo	Water Committee	yes (12 times/year) before breakdown of windmill borehole	yes
ES-12	Adulala	Adulala Town Water Supply Service Office	yes (24 times/year)	yes
AR-1	Sire	Sire-Merfe Water Management Board	yes (12 times/year)	yes
AR-2	Bolo	water committee	yes (12 times/year)	yes
AR-3	Arboye	water committee	yes (48 times/year)	yes
AR-4	Aseko	water committee	yes (24 times/year)	yes
AR-5	Golegota	Bole-Golegota Town Water Supply Service Office	yes (12 times/year)	yes
AR-6	Gonde	Gonde-Iteya Water Management Board	yes (12 times/year)	yes
AR-7	Arbe Gebeya	water committee	yes (12 times/year)	no, 4 times/year
WH-1	Chorora	water committee	yes (12 times/year)	yes
WH-2	Bedeyi	water committee	yes (24 times/year)	yes
WH-3	Hardim	water committee	yes (24 times/year)	yes
WH-4	Bube	water committee	yes (12 times/year)	yes
WH-5	Mieso	Mieso Town Water Supply Service Office	yes (12 times/year)	yes
WH-6	Hargeti	not applicable	not applicable	not applicable
WH-7	Bordede	water committee	yes (12 times/year)	yes
WH-8	Kenteri	not applicable	not applicable	not applicable
WH-9	Aneno	not applicable	not applicable	not applicable
WH-10	Belo	water committee	yes (52 times/year)	no (4 times/year)
WH-11	Kora	water committee	yes (10 times/year)	yes

Source: the Project Team

b.3 Operator

Operators exist only for water supply facilities with a motorized pump, whose total number is 26 persons. There are 9 operators who have more than 10 years of experience, 5 operators who have less than 3 years of experience, and 2 of them have less than a year of experience, where the shortest period is 2 months. Twenty-two (22) operators were trained in the past. The training period of this training varies between 2 days and 10 months.

b.4 Collection of water tariff

Table 6.7.2 shows the water tariff of target small towns. The charging system is volumetric except for boreholes with hand pumps, of which the charging system is a fixed rate. In case a motorized pump is used, it will require some costs for power supply so that water tariff becomes more expensive than the gravity system. The tariff for water supply facilities using a diesel generator is approximately two times those using public power supply. The tariff for water supply facilities using two sets of motor pump with a diesel generator is approximately two times those that use only one set.

The rate of collection of water tariff is 100%, except for 7 towns (ES-5, ES-9, ES-12, AR-5, AR-7, WH-4, and WH-5). Interviewees of 22 towns answered that the set water tariff is insufficient to conduct operation and maintenance. TWSSOs and WCs besides 4 towns (ES-1, ES-8, ES-11 and WH-2) maintain their funds at the local bank. Amount of remaining fund is exceeding 100,000 Birr in 8 organizations, which maximum amount is 1,300,000 Birr at AR-6. Hence, there is no remaining fund at AR-2.

Table 6.7.2: Water Tariff of Target Towns

Water source	Power	Number of motor pump	Small town ID	Tariff			
				System	Unit	Min.	Max.
Spring	Gravity	0	AR-3, AR-6, AR-7	Volumetric	Birr/m^3	1.50	5.00
Spring	Public power supply	1	ES-9, AR-4	Volumetric	Birr/m^3	5.00	9.00
Spring	Generator	1	WH-4	Volumetric	Birr/m^3	20.00	21.00
Borehole	Public power supply	1	ES-2, ES-3, ES-4, ES-12, AR-2, WH-5	Volumetric	Birr/m^3	6.00	8.70
Borehole	Generator	1	ES-5, AR-5, ES-7, ES-10, WH-1, WH-3, WH-7, WH-10, WH-11	Volumetric	Birr/m^3	16.00	25.00
Borehole	Generator	2	WH-2	Volumetric	Birr/m^3	38.00	42.00
Borehole	Windmill	0	ES-11	Volumetric	Birr/m^3	8.00	10.00
Borehole	Manual	0	ES-6	Fix	Birr/month/household	10.00	10.00
Supplied from outside	–	–	ES-1, ES-8	Volumetric	Birr/m^3	5.00	6.25

Source: the Project Team

b.5 Supporting system for operation and maintenance

OWMEB is responsible for whole operation and maintenance system as shown in Figure 6.7.1.

In case the WC requires support for operation and maintenance, the water committee requests the WWMEO first. In case the WWMEO does not have the capacity to solve the problem, the WWMEO will request support from the ZWMEO.

In case the TWSSO requires support for operation and maintenance, the TWSSO will directly request the ZWMEO.

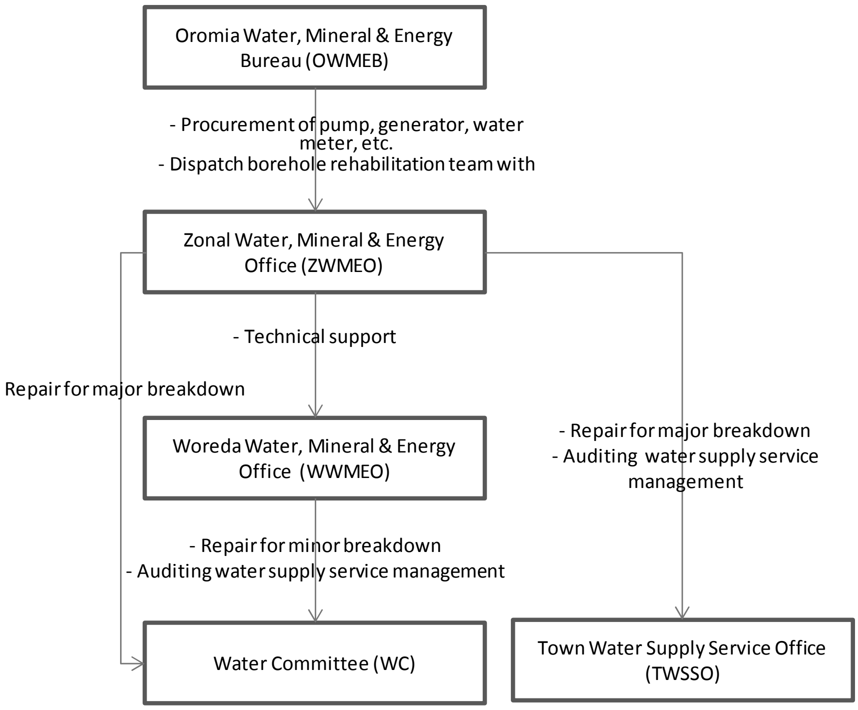


Figure 6.7.1: Support Structure for Maintenance Management

b.6 Procedure of repairing works

There are barely any mechanical and electrical technicians who can repair pumps, generators, electric control panels, etc. in the WWMEO; thus, most of the repairing work is conducted by the ZWMEO.

The ZWMEO does not have equipment, such as cranes for dismantling and installation of submersible pumps and service rigs for rehabilitation of boreholes. In case such equipment is required, ZWMEO request OWMEB to dispatch crane and service rig teams.

TWSSOs and WCs will bear (cover) the costs of necessary materials and fuels for transport and repair.

Most new pumps and generators for replacement are purchased by the OWMEB because these are expensive and shall be imported.

In case TWSSOs and WCs have insufficient funds for the equipment, the OWMEB supplies the equipment free of charge. In this case, the OWMEB sometimes supplies used equipment.

c. Ability and actual performance of water committee/ office for O&M

Table 6.7.3 shows type and number of staffs of O&M organization in small towns. Staffs of water committee are operators, accountants, guards, water fee collector at public taps, etc. Table 6.7.4 shows revenue and expense for the past three years and remainder of the funds for water supply and facilities, as of January 2014.

The remainder of the funds for water supply and facilities for every TWSSO is over 300,000 Birr. It seems that good management of water supply service is maintained; however, the remainder of funds for water supply and facilities of every WC except ES-2 is less than 100,000 Birr, including a WC whose remainder is zero. There is some difference of magnitude of water supply service between the TWSSO and the WC. Judging remaining amount, it seems that management of water supply service is not good in most of the WC.

The terms of office of the committee members elected among water users by democratic way is two years. Due to change of the members, the management know-how is not accumulated. In case taking over the management from the old to the new committee is not proper, some past records may be missing. The management of water supply service by the water committees seems amateurish because they do not have management know-how or experience.

The entire staff of the TWSSO, including the manager, is semi-permanently employed by the Water Management Board, and the management know-how is accumulated depending on the experience. The management of water supply service by the TWSSO seems professional. It is considered that this difference between the TWSSO and the WC is apparent in the actual management (results) of water supply services.

Table 6.7.3: Type and Number of Staff of O&M Organization

ID	Town	Organization for O&M	Member of committee	Number of staff	Total	Remark
ES-1	Wonji Shewa Alemtena	None	0	3	3	Supplied by Adama City Water Supply and Sewerage Service Enterprise
ES-2	Geldiya	Water committee	7	7	14	
ES-3	Dire	Water committee	14	7	21	One water committee each for 2 motorized boreholes
ES-4	Bofa	Town water supply service office	0	11	11	
ES-5/ AR-5	Bole/ Golegota	Town water supply service office	0	24	24	
ES-6	Ude Dhankaka	Water committee	21	3	24	one water committee each for 3 boreholes with hand pump
ES-7	Bekejo	Water committee	7	6	13	
ES-8	Kamise	Water committee	5	2	7	Supplied by Gimbichu-Fentale Rural Water Supply Service Enterprise
ES-9	Chefe Donsa	Town water supply service office	0	18	18	
ES-10	Areda	Water committee	7	3	10	
ES-11	Biyo	Water committee	7	3	10	
ES-12	Adulala	Town water supply service office	0	11	11	
AR-1	Sire	Town water supply service office	0	11	11	
AR-2	Bolo	Water committee	7	3	10	
AR-3	Arboye	Water committee	7	14	21	
AR-4	Aseko	Water committee	7	10	17	
AR-6	Gonde	Town water supply service office	0	18	18	
AR-7	Arbe Gebeya	Water committee	7	4	11	
WH-1	Chorora	Water committee	7	4	11	
WH-2	Bedeyi	Water committee	7	9	16	
WH-3	Hardim	Water committee	7	6	13	
WH-4	Bube	Water committee	7	3	10	
WH-5	Mieso	Town water supply service office	0	11	11	
WH-6	Hargeti	None	0	0	0	No facility
WH-7	Bordede	Water committee	7	7	14	
WH-8	Kenteri	None	0	0	0	No facility
WH-9	Aneno	None	0	0	0	No facility
WH-10	Belo	Water committee	7	4	11	
WH-11	Kora	Water committee	7	5	12	

Source: the Project Team

Table 6.7.4: Revenue, Expense and Remaining Funds (unit: Birr)

ID	Small town	2011		2012		2013		Remaining funds as of Jan. 2014
		Revenue (Birr)	Expense (Birr)	Revenue (Birr)	Expense (Birr)	Revenue (Birr)	Expense (Birr)	
ES-2	Geldiya	118,140	61,768	120,900	53,506	151,535	93,449	322,000
ES-3	Dire	NA	NA	NA	NA	244,805	225,048	71,500
ES-4	Bofa	355,588	260,324	356,873	594,025	578,727	461,405	535,000
ES-5/ AR-5	Bole/ Golegota	589,138	449,392	795,501	640,118	1,068,191	851,937	465,147
ES-6	Ude Dhankaka	NA	NA	NA	NA	7,200	3,600	3,600
ES-7	Bekejo	NA	NA	NA	NA	84,309	71,326	61,500
ES-9	Chefe Donsa	230,265	229,030	279,487	207,305	279,525	286,812	145,000
ES-10	Areda	NA	NA	NA	NA	35,790	33,438	2,332
ES-11	Biyo	NA	NA	5,708	6,667	NA	NA	NA
ES-12	Adulala	222,687	156,347	239,088	448,303	258,774	291,711	335,720
AR-1	Sire	208,167	140,612	279,698	198,421	435,322	233,566	382,072
AR-2	Bolo	NA	7,440	NA	NA	94,122	NA	0
AR-3	Arboye	165,840	145,527	135,389	135,354	75,308	118,527	10,500
AR-4	Aseko	16,439	16,439	49,933	41,693	100,428	82,109	27,400
AR-6	Gonde	527,865	673,039	651,153	358,640	581,297	353,885	1,300,500
AR-7	Arbe Gebeya	19,429	9,408	24,187	11,634	NA	NA	15,200
WH-1	Chorora	54,195	52,680	85,000	78,230	111,290	89,142	40,500
WH-2	Bedeyi	NA	NA	100,084	100,399	135,014	99,032	10,000
WH-3	Hardim	318,075	NA	265,560	119,469	132,780	NA	25,000
WH-4	Bube	NA	NA	NA	NA	NA	NA	15,000
WH-5	Mieso	392,033	101,439	384,336	147,034	76,221	152,642	316,586
WH-7	Bordede	309,520	53,088	158,030	27,084	184,334	283,160	55,000
WH-10	Belo	NA	NA	NA	NA	NA	NA	16,000
WH-11	Kora	NA	NA	NA	NA	88,469	70,929	92,000

Remark: The revenue and expense of ES-6 is for one Water Committee of borehole with hand pump. The Town Water Supply Service Office of AR-6 supplies water to wide areas including Gonde Town and surrounding 16 Kebeles.
Source: the Project Team

6.7.2 Issues of water supply office

a. Poor organization for operation and maintenance

Organization for operation and maintenance of water supply facilities does not exist in three small towns, where water supply facilities do not exist, of the 19 small towns for which provisional water supply plans are developed. It is necessary to organize Water Committees and develop the capability of operation and maintenance of water supply facilities about these three small cities during implementation of the Project.

Moreover, there are three small towns where organization for operation and maintenance of boreholes with hand pumps exist but organization for operation and maintenance of piped water supply does not exist. In those small towns, existing organization shall be re-organized and trained for operation and maintenance of water supply facilities using a piped water supply system.

Although organization for operation and maintenance of piped water supply system exists in the remaining 13 small towns (of the 19 small towns), the number of staff shall be increased, re-organized and trained because construction of new water supply facilities is included in the scope of this water supply planning.

b. Inadequate water tariff setting

It is considered that water rate is appropriate in TWSSO because the amount of remaining funds of all TWSSOs exceeds 300,000 Birr. However, it is considered that the water rate is not appropriate in some of Water Committees because the amount of remaining funds is less than 100,000 Birr, except in one small town where the water committee has no remaining funds. It is considered that setting of water rate is not appropriate and necessary to revise water rate where remaining funds are not increasing.

c. Lack of operation and maintenance capability of Water Management Organization

c.1 Lack of capacity for operation and maintenance of water supply facilities

Most of operators do not maintain operation records of water supply facilities such as hours of operation (the time when facilities were started and stopped), consumption of fuel, oil, electricity (kWh), and flow meter readings at start and stop; thus, unaccounted water cannot be estimated by comparing with consumed volume recorded by water meter.

Therefore, capacity development for operations is necessary as mentioned below.

1) Capacity on preparation of operation record
2) Capacity on preparation of water production record
3) Capacity on maintenance management and inspection of water supply facilities

c.2 Lack of capacity for administration of water supply service

Most WCs do not maintain a proper record of consumed volume read by water meter, record of revenue and expense, etc. Therefore, the situation of management of water supply service cannot be evaluated in a timely manner.

The term of office of the members of committee is two years. Due to change of the members, the know-how of the management is not accumulated. Therefore, capacity development for new members of water committees is necessary every two years, including:

1) Capacity on documentation of water consumption volume and water tariff record based on water meter
2) Capacity on water tariff bill and receipt preparation
3) Capacity on collecting water tariff and accounting management
4) Capacity on preparing monthly and annually income reports
5) Capacity on understanding and improving ineffective water volume by comparing water consumption volume and water production records

6.7.3 Operation and maintenance plan

a. Operation and maintenance system

a.1 Roles of stakeholders for operation and maintenance

Stakeholders and their roles in respect to the operation and maintenance system of water supply facilities in Oromia Region at present is shown in Table 6.7.5. Since there is no information that this operation and maintenance system has changed, this system shall be adopted for this operation and maintenance plan for 19 small towns for which provisional water supply plans are developed.

Table 6.7.5: Stakeholders and Their Roles on Operation and Maintenance System of Water Supply Facilities

Name of Organization	Administrative Body	Role	Activity
Oromia Regional Water, Mineral and Energy Bureau	Regional Government	-Making regional water supply plan -Implementation of major water supply project -Technical guidance to substructure -Supporting major maintenance works	-Procurement of pumps, diesel generators, water meter, etc. -Dispatch borehole maintenance team -Dispatch submersible pump removal and installation team
Zonal Water, Mineral and Energy Office	Regional Government	-Making zonal water supply plan -Implementation of water supply project -Technical guidance to substructure -Supporting major maintenance works	-Repairing major breakdown such as borehole, pump, diesel generator, etc. -Supporting management of Town water Supply Service Office
Woreda Water, Mineral and Energy Office	Woreda Administration Office	-Making Woreda water supply plan -Implementation of water supply project -Supporting minor maintenance works -Monitoring and supporting management	-Repairing minor breakdown such as hand pumps etc. -Supporting management of water committee
Urban Water Supply and Sewerage Service Enterprise	City Administration Office	-Providing water supply and sewerage service to big cities	-Providing water supply and sewerage service -Operation and maintenance of facility
Town Water Supply Service Office	Town Administration Office	-Providing water supply service to small towns	-Operation and maintenance of facility
Water Committee	Community (Residents)	-Providing water supply service to rural Kebeles	-Operation and maintenance of facility

Source: the Project Team

a.2 Supporting structure for operation and maintenance

Operation and maintenance of water supply facilities shall be mainly conducted by TWSSO or WC as shown in Table 6.7.5. But it is necessary to be supported by OWMEB because capacity of TWSSO and WC is weak. Present supporting structure of operation and maintenance of water supply facilities is shown in Figure 6.7.1. Since there is no information that this supporting structure has been changed, this structure shall be adopted for this operation and maintenance plan.

b. Organization of operation and maintenance

b.1 Organization plan

The organizations directly responsible for operation and maintenance of water supply facilities are TWSSO or WC. It is preferable to establish TWSSO because members of WC change every two years and know-how of operation and maintenance is not accumulated. But there are no small towns that fulfil the conditions of Oromia regional government to establish TWSSO except ES-4 and AR-6. Table 6.7.6 shows the operation and maintenance organizations in each of the 19 small towns in this plan.

Table 6.7.6: Operation and Maintenance Organizations in 19 Small Towns

ID	Small town	O&M Organization	
		Existing	This Plan
ES-2	Geldiya	Water Committee	Water Committee
ES-4	Bofa	Town Water Supply Service Office	Town Water Supply Service Office
ES-6	Ude Dhankaka	Water Committee	Water Committee
ES-8	Kamise	Water Committee	Water Committee
ES-10	Areda	Water Committee	Water Committee
ES-11	Biyo	Water Committee	Water Committee
AR-2	Bolo	Water Committee	Water Committee
AR-3	Arboye	Water Committee	Water Committee
AR-4	Aseko	Water Committee	Water Committee
AR-6	Gonde	Town Water Supply Service Office	Town Water Supply Service Office
WH-1	Chorora	Water Committee	Water Committee
WH-2	Bedeyi	Water Committee	Water Committee
WH-3	Hardim	Water Committee	Water Committee
WH-4	Bube	Water Committee	Water Committee
WH-6	Hargeti	None	Water Committee
WH-8	Kenteri	None	Water Committee
WH-9	Aneno	None	Water Committee
WH-10	Belo	Water Committee	Water Committee
WH-11	Kora	Water Committee	Water Committee

Source: the Project Team

b.2 Manpower plan

Increasing of staff for new water supply facilities to be constructed shall be planned in the small towns where existing water supply facilities exist.

Employment of staff such as operators, security guards, public tap mangers, etc. who directly work for operation and maintenance besides the seven members of WC elected by the resident users shall be planned for the three small towns where WC will be newly established.

Table 6.7.7: Manpower Plan

ID	Small town	O&M Organization	Existing Manpower			Additional manpower						Total		
			Committee member	Employee	Total	Committee member	Employee				Total	Committee member	Employee	Total
							Operator	Guard	Tap manager	Total				
ES-2	Geldiya	Water Committee	7	7	14	0	1	1	1	3	3	7	10	17
ES-4	Bofa	Town Water Supply Service Office	0	11	11	0	1	1	1	3	3	0	14	14
ES-6	Ude Dhankaka	Water Committee	0	0	0	0	1	1	13	15	15	0	15	15
ES-8	Kamise	Water Committee	5	2	7	2	1	1	10	12	14	7	14	21
ES-10	Areda	Water Committee	7	3	10	0	1	1	6	8	8	7	11	18
ES-11	Biyo	Water Committee	7	3	10	0	1	1	6	8	8	7	11	18
AR-2	Bolo	Water Committee	7	3	10	0	1	1	2	4	4	7	7	14
AR-3	Arboye	Water Committee	7	14	21	0	2	2	4	8	8	7	22	29
AR-4	Aseko	Water Committee	7	10	17	0	2	2	9	13	13	7	23	30
AR-6	Gonde	Town Water Supply Service Office	0	18	18	0	1	1	2	4	4	0	22	22
WH-1	Chorora	Water Committee	7	4	11	0	1	1	2	4	4	7	8	15
WH-2	Bedeyi	Water Committee	7	9	16	0	1	1	4	6	6	7	15	22
WH-3	Hardim	Water Committee	7	6	13	0	1	1	10	12	12	7	18	25
WH-4	Bube	Water Committee	7	3	10	0	3	3	11	17	17	7	20	27
WH-6	Hargeti	Water Committee	0	0	0	7	1	1	7	9	16	7	9	16
WH-8	Kenteri	Water Committee	0	0	0	7	1	1	4	6	13	7	6	13
WH-9	Aneno	Water Committee	0	0	0	7	2	2	6	10	17	7	10	17
WH-10	Belo	Water Committee	7	4	11	0	2	2	9	13	13	7	17	24
WH-11	Kora	Water Committee	7	5	12	0	1	1	2	4	4	7	9	16

Source: the Project Team

c. Operation and maintenance cost

An appropriate operation and maintenance cost consisting of operation cost and renewal cost shall be calculated based on the water supply facility plan and organization structure of operation and maintenance.

c.1 Facility operation cost

c.1.1 Operation expense

Sixteen of the nineteen (all but three) small towns are already electrified. Power shall be purchased from commercial electric power company basically because operation cost of submersible motor pump using commercial electric power is cheaper than using diesel generator as a power source. However, since power failures have occurred frequently as already stated, supply of electric power is not stable. For this reason, diesel generators shall be installed as a backup and power will be supplied by diesel generator in case commercial electric power is cut off. Operation cost shall be calculated based on the existing situation of power failure of each small town.

c.1.2 Salary

Since all the employed TWSSO staffs receive pay for their labour, all the personnel salaries and personnel expenses shall be included in the operation cost. Personnel salaries and personnel expenses of committee members of WC, who are volunteers without any salary and are replaced every two years, shall not be included in the operation cost. But the personnel salaries and personnel expenses of staff such as operators, public tap managers, etc., employed by the WC shall be included in the operation cost.

c.1.3 Repair cost

Assuming repairing cost will be 1,000 Birr/time and sudden breakdown will be occurred five times a month, 5,000 Birr/month shall be included in the operation cost.

c.1.4 Miscellaneous expenses

Five-hundred Birr/month for communication charge and 500 Birr/month for office materials (paper, toners, etc.) cost shall be included in the operation cost.

c.2 Renewal cost

Since the life time of motor pumps and diesel generators is set as 10 years in the Ethiopian design criteria, depreciation cost under a 10-year depreciation period shall be included in the operation cost.

For other water supply facilities, life time is set as 20 years for boreholes, 40 years for distribution reservoirs, 25 years for public taps, etc. But assuming that renewal of those facilities will be supported by OWMEB, renewal cost of those facilities is not included in operation cost.

6.7.4 Operation and maintenance cost

Result of the calculation of operation and maintenance cost for new water supply facilities by abovementioned method is shown in Table 6.7.8.

As the result of calculation of five small towns, ES-2, ES-4, ES-8, AR-3, and AR-5, operation and maintenance cost exceeded the present water rate. Due to this operation and maintenance cost is only a rough estimation at this moment because borehole is not constructed yet and route survey for pipeline is not conducted yet, it is necessary to calculate operation and maintenance cost again to compare with existing water rate carefully in the basic design stage of implementation.

Table 6.7.8: Operation and Maintenance Cost

ID	Small town	Preconditions: Water source	Preconditions: Intake system	Preconditions: Rate of power failure	Preconditions: Specification of pump (kW)	Preconditions: Pump operation hours (hrs/day)	Preconditions: Power consumption KWH/month	Diesel Generator: Output (kVA)	Diesel Generator: Fuel consumption (L/hour)	Diesel Generator: Fuel consumption (L/month)	Operation cost: Power cost: Power cost (Birr/month)	Power cost: Fuel cost (Birr/month)	Power cost: Total (Birr/month)	Power cost: Total (Birr/month)	Labour cost: Operator (Birr/month)	Labour cost: Guard (Birr/month)	Labour cost: Tap manager (Birr/month)	Repair cost (Birr/month)	Miscellaneous expense (Birr/month)	Total (Birr/month)	Renewal cost (Birr/month)	Operation cost + renewal cost (Birr/month)	Daily average water supply amount (m^3/day)	Daily average water supply amount (m^3/month)	Water cost (Birr/m^3)	Existing water rate (Birr/m^3)
ES-2	Geldiya	Borehole	Pumping	6.7%	4.0	10	1,200	10.0	2.2	44.2	830	924	1,754	1,754	400	400	400	5,000	1,000	8,954	4,220	13,174	50	1,500	8.8	7.0
ES-4	Bofa	Borehole	Pumping	6.7%	4.0	10	1,200	10.0	2.2	44.2	830	924	1,754	1,754	400	400	400	5,000	1,000	8,954	4,220	13,174	50	1,500	8.8	4.0
ES-6	Ude Dhankaka	Borehole	Pumping	3.7%	15.0	10	4,500	34.0	7.1	78.8	3,062	1,647	4,709	4,709	400	400	5,200	5,000	1,000	16,709	5,287	21,996	299	8,970	2.5	-
ES-8	Kamise	Borehole	Pumping	100.0%	18.5	10	5,550	42.0	7.1	2,130.0	53	44,517	44,570	44,570	400	400	4,000	5,000	1,000	55,370	6,456	61,826	241	7,230	8.6	6.3
ES-10	Areda	Borehole	Pumping	100.0%	18.5	10	5,550	42.0	7.1	2,130.0	53	44,517	44,570	44,570	400	400	2,400	5,000	1,000	53,770	7,014	60,784	135	4,050	15.0	25.0
ES-11	Biyo	Borehole	Pumping	3.5%	11.0	10	3,300	25.5	3.9	41.0	2,264	857	3,121	3,121	400	400	2,400	5,000	1,000	12,321	4,978	17,299	142	4,260	4.1	12.5
AR-2	Bolo	Borehole	Pumping	6.7%	7.5	10	2,250	17.5	3.2	64.3	1,511	1,344	2,855	2,855	400	400	800	5,000	1,000	10,455	4,543	14,998	65	1,950	7.7	14.0
AR-3	Arboye	Borehole	Pumping	16.7%	11.0	10	3,300	25.5	3.9	195.4	1,962	4,084	6,046	12,092	800	800	1,600	5,000	1,000	21,292	10,807	32,099	202	6,060	5.3	2.0
		Borehole	Pumping	16.7%	11.0	10	3,300	25.5	3.9	195.4	1,962	4,084	6,046													
AR-4	Aseko	Borehole	Pumping	40.0%	22.0	10	6,600	50.0	9.7	1,164.0	2,802	24,328	27,130	54,260	800	800	3,600	5,000	1,000	65,460	14,028	79,488	247	7,410	10.7	9.0
		Borehole	Pumping	40.0%	22.0	10	6,600	50.0	9.7	1,164.0	2,802	24,328	27,130													
AR-6	Gonde	Borehole	Pumping	5.6%	7.5	10	2,250	17.5	3.2	53.8	1,528	1,124	2,652	2,652	400	400	800	5,000	1,000	10,252	4,113	14,365	96	2,880	5.0	5.0
WH-1	Chorora	Borehole	Pumping	13.3%	4.0	10	1,200	10.0	2.2	87.8	775	1,835	2,610	2,610	400	400	800	5,000	1,000	10,210	4,113	14,323	70	2,100	6.8	18.0
WH-2	Bedeyi	Borehole	Pumping	100.0%	22.0	10	6,600	50.0	9.7	2,910.0	53	60,819	60,872	60,872	400	400	1,600	5,000	1,000	69,272	7,014	76,286	146	4,380	17.4	38.0
WH-3	Hardim	Borehole	Pumping	20.0%	13.0	10	3,900	29.5	7.1	426.0	2,219	8,903	11,122	11,122	400	400	4,000	5,000	1,000	21,922	4,974	26,896	298	8,940	3.0	19.0
WH-4	Bube	Borehole	Pumping	100.0%	3.0	10	900	7.5	2.2	660.0	53	13,794	13,847	41,541	1,200	1,200	4,400	5,000	1,000	54,341	12,176	66,517	175	5,250	12.7	20.0
		Borehole	Pumping	100.0%	3.0	10	900	7.5	2.2	660.0	53	13,794	13,847													
		Borehole	Pumping	100.0%	3.0	10	900	7.5	2.2	660.0	53	13,794	13,847													
WH-6	Hargeti	Borehole	Pumping	100.0%	7.5	10	2,250	17.5	3.2	960.0	53	20,064	20,117	20,117	400	400	2,800	5,000	1,000	29,717	4,382	34,099	100	3,000	11.4	-
WH-8	Kenteri	Borehole	Pumping	25.0%	4.0	10	1,200	10.0	2.2	165.0	678	3,449	4,127	4,127	400	400	1,600	5,000	1,000	12,527	4,220	16,747	53	1,590	10.5	-
WH-9	Aneno	Borehole	Pumping	26.7%	5.5	10	1,650	13.5	2.4	192.2	893	4,017	4,910	9,820	800	800	2,400	5,000	1,000	19,820	8,908	28,728	84	2,520	11.4	-
		Borehole	Pumping	26.7%	5.5	10	1,650	13.5	2.4	192.2	893	4,017	4,910													
WH-10	Belo	Borehole	Pumping	33.3%	4.0	10	1,200	10.0	2.2	219.8	609	4,594	5,203	10,406	800	800	3,600	5,000	1,000	21,606	8,548	30,154	129	3,870	7.8	20.0
		Borehole	Pumping	33.3%	4.0	10	1,200	10.0	2.2	219.8	609	4,594	5,203													
WH-11	Kora	Borehole	Pumping	8.3%	4.0	10	1,200	10.0	2.2	54.8	817	1,145	1,962	1,962	400	400	800	5,000	1,000	9,562	4,220	13,782	44	1,320	10.4	19.0

*1 Operation cost: Operation hours of diesel generator is calculated based on the rate of power failure by every small town
Price of diesel is 20.9 Birr/L.
Power rate: basic price: 22.558 Birr/month, 0.6088 Birr/KWH (less than 50KWH), 0.6943 Birr/KWH(50KWH or more)
*2 Labour cost: Personnel expense only for new employees for new water supply facilty
Personnel expense of committee members is not be included because they are basically work for free.
Salary of operator, guard and tap manager is 400 Birr/month/person.
*3 Miscellaneous expense: Communication charges and office expenses are included.
*4 Renewal cost: Renewal cost is calculated based on 10 years depreciation for submersible pump and diesel generator.
Source: the Project Team

6.7.5 Capacity development plan

Considering abovementioned issues of operation and maintenance, capacity development plan for WC in order to realize sustainable operation and maintenance of water supply facilities shall be as shown in Table 6.7.9. Capacity development to WC shall be conducted by WWMEO and supported by ZWMEO and OWMEB.

Table 6.7.9: Capacity Development Plan for Operation and Maintenance

Timing	Item	Activity			Method	Target
Before construction ~ Under construction	Formulating organization	1	Explanation to residents about action to be taken by residents for project implementation	Conducting general assembly, explaining project scope and role of residents and confirming resident's intention to participate in the project.	General assembly	Residents
		2	Formulating O&M organization	After carrying out the workshop and examining the present problem, the management method of a water management organization was examined. Regarding small towns where the existing water management organization does not exist, members of a water management organization shall be elected by a democratic method.	Work shop	Residents
		3	Elaborating and revising of Internal regulation of O&M organization	Conducting problem analysis of existing water use and O&M for water supply facilities and, elaborating and revising internal regulation of water management organization.	Work shop	O&M organization
		4	Elaborating water rate revision plan	Examining the minimum water charge to realize sustainable operation and maintenance and planning of proposal of water rate revision, timing of revision of water rate, etc.	Work shop	O&M organization
		5	Notification to residents	Conducting general assembly to explain and reach agreement of setting and revising water rates including the residents' duty to pay.	General assembly	Residents
Under construction ~ After construction	Capacity development	6	Technical training (O&M organization)	Training for facility operators of O&M organizations on how to operate and maintain water supply facilities.	Lecture/ OJT	O&M organization
		7	Technical training (O&M organization)	Training for accountants of O&M organizations regarding administration of water supply enterprise.	Lecture	O&M organization

Source: the Project Team

Chapter 7

Environmental and Social Consideration

7 Environmental and Social Consideration

7.1 Introduction

The purpose of the environment and social consideration study is to assist the Ethiopian counterpart personnel in estimating the environmental and social impact of the installation of facilities designed by the Project, based on the JICA Environment and Social Consideration Guidelines and the Ethiopian Environment Impact Assessment (EIA) Guidelines. Alternative plans and mitigation strategies will also be studied if the impacts are inevitable. The summary of the environmental impact assessment study will be used as feedback for the study team.

7.2 Outline of the Project components

The initial (pre-Project) water supply plan was to supply water to 30 rural towns in 16 Woredas. However, for various reasons, outlined below, the target number of towns—for which JET developed water supply plans in the Project—was reduced to 19. Several of the 11 excluded towns were found to already be on the receiving end of water supply projects such as by the government of Oromia and the One WASH program by UNICEF. Other towns were excluded because the groundwater showed high fluoride concentrations exceeding Ethiopian water quality standards, as well as towns that already had a water supply exceeding the targeted water supply for the estimated population in 2020. The water source for all of the 19 target towns of the plan is groundwater. The Arboya town in Jeju woreda of 19 small towns shows the planned maximum water supply volumes (550 m^3/day) of 2020.

Please refer to the supporting report for detailed information of the water supply plans in each town.

7.3 Basic environmental and social conditions

7.3.1 General information of natural environmental condition

Awash National Park is located within the Awash river basin, which is the main target area of this project, however, all of the target towns—as well as all of the drilling sites and facilities planned in the Project—are located outside of this national park. Moreover, there are no other protected (sanctuaries, conservation) areas—as stipulated by domestic or international agreements—within the target area, therefore, the Project is not considered to have any impact in this respect.

Ethiopian law (Council Ministries Regulations No. 163/2008) prohibits people from living in protected areas (national parks). Therefore, although there some illegal squatters, by their nature they contain no settlements or villages.

For further details of natural environmental conditions in the target area such as regarding weather, hydrology, geology and hydrogeology, please refer to prior chapters of this report.

7.3.2 General information of social condition

There are national, state and private farms for sugar production and two logistic centres like Adama and Mojo. Recently, a toll express way has been opened to traffic from the outskirts of Addis Ababa to the east of Adama. Furthermore, construction of a railway between Addis Ababa and the Republic of Djibouti has been completed up to around Mieso Town (as of August 2015). Accordingly, economic activities are flourishing in surrounding areas based on those construction projects. On the other hand, traffic infrastructure development is still inadequate in some areas and it is difficult to reach such areas like Kamise and Bedeyi in the rainy season due to unpaved roads. Those towns are expected to be paved in future.

The enrolment rate of primary schools in the target towns is around 70% on average. The ratio is lower than the average of Oromia Region. Especially in West Hararge zone, the enrolment rate is around 50% which is relatively low. The results were caused by several reasons including lack of educational facilities and teachers, people’s awareness of education and so on. Fetching water is one of the biggest reasons for being absent and/or dropping out of school in some towns.

There are no cultural and traditional architecture or heritage assets in the target areas.

Please refer to supporting report for other characteristics of social conditions in the target area including population, ethnic and religious composition, water-related diseases and agriculture.

7.4 Classification of environmental category

The water supply plans do not involve any aspects that affect environmental and social facets in the target area. As a result, the plan is categorized as environmental category B. The decision was made by considering the contents, scale of the Project and natural environmental and social conditions in the area.

7.5 Environmental system and organization in Ethiopia

The enabling legislation for EIA in Ethiopia is the EIA proclamation of 2002 (Environmental Impact Assessment Proclamation, Proclamation No.299/2002). There is no Oromia regional guideline for environmental impact assessment procedures so projects conducted in the region should follow the federal guidelines as needed. The final decision maker for projects in the Oromia Region is the Environment Protection Core Process (EPCP, Oromia Land and Environmental Protection Bureau (OLEPB).

According to the federal guidelines, reviewing projects on water supply and hygiene are classified into schedule 1 and schedule 2 projects as shown in Table 7.5.1. As shown in the outline of the Project components, there is no component to correspond to schedule 1 in the plans of this project. Amount of water supply proposed in the project is less than 2,000 m^3/day in every towns. Furthermore, the Project does not correspond to involuntary resettlement, appropriation of land, occurrence of secondary pollution source, damage and loss of ruins and cultural assets and adverse impacts on the natural protected areas. The Project corresponds to the town water supply plan in schedule 2 requiring preliminary or partial assessment study (PA) which is the initial environmental examination in the JICA guidelines.

Table 7.5.1 List of Projects that Require a Preliminary Study

Schedule 1 (Projects that require full EIA)	Schedule 2 (Projects that require PA)
• Construction of dams, impounding reservoirs with a surface area of 100 ha • <u>Groundwater development for industrial, agriculture or urban water supply greater than 4,000 m^3/day</u> • Canalization • Drainage plans in towns close to water bodies	• <u>Rural water supply and sanitation</u> • Land drainage (small scale) • Sewerage system • Rain water harvesting

7.6 Alternatives include zero options

There are no alternatives for the water supply plans because the plans have already been considered from several angles in the project. Instead of alternatives, the Project Team recommends monitoring some aspects at construction and operation phases. In this section, positive and negative impacts are compared between a zero option ('do nothing') scenario and the Project plans as summarized below.

- In the zero option alternatives, there would be risks of lack of safe water and increased risks of water-related diseases in the target areas in the future.

- In the plans, there is a possibility of adverse impacts such as those associated with an increased use of groundwater, loss of job opportunities such as water retailers, new conflicts caused by unfair water distribution and noise and vibration occurring in construction phase. Such concerns, however, can be controlled and mitigated by appropriate measures.
  On the other hand, numerous positive impacts are expected such as improved access rate to safe water, creation of job opportunities like water committee, increase of social capital, increase of enrolment at elementary schools and decrease of water related diseases.

7.7 Scoping and TOR of environmental and social consideration

An environmental and social consideration survey was conducted for the likely adverse impacts that can be caused by implementing the proposed water supply plans.

It is not necessary to conduct additional surveys on groundwater levels because results of the drilling test and pumping test are available.

The likely adverse impacts expected to occur in the construction phase are air pollution from heavy vehicles and noise/vibration from construction sites. A survey list for the evaluation on the extent of the adverse impacts has been prepared. It is recommended to conduct an environmental survey based on Ethiopian national standards during the implementation phase of the plans.

The likely adverse impacts expected to occur in the operation phase are ethnic conflicts caused by water distribution and a decrease in the groundwater level due to aging. A survey for evaluating the extent of the adverse impacts was conducted and the results have been summarized.

Please refer to the supporting report for detailed information.

7.8 Results of survey

There are water retailers in several towns. A survey was conducted for evaluating the impact on water retailers when the plans are implemented. The survey found that all the water retailers in the survey can be categorized into two types; one group has their own business such as kiosk owners who buy water from other towns and sell the water to people in their own town. The other group has their own water tap in their house and resells water in line with demand. According to the survey, the impact is expected to be negligibly small.

When the plan is implemented, a survey for air pollution by heavy vehicles and noise from construction sites is recommended. This should follow the Ethiopian national environmental standards (Council of Ministries Regulations No. 163/2008). However, according to observations at each site, the effect caused by vehicles can be mitigated by complying with legal speed limit.

An interview survey was conducted in Bordede Town and surrounding areas where there is concern of ethnic conflict over water. Several conflicts concerning water were reported in the area in the past. According to interviews with people in the area, most of the conflicts result from land issues in the towns and water problems can occasionally prompt them to start fighting. In consideration of the interviews results, the plans will not make the situation worse. However, conflict still exists in the area so the plan and implementation should emphasize fair water distribution.

7.9 IEE, mitigation measures and plan of environmental monitoring

According to the survey, no content is predicted to be categorized into *A* and *B*. These are defined as significant negative impact is expected and negative impact is expected to some extent by JICA EIA guideline, respectively. Category *C*, which is defined as the extent of negative impact is unknown, has several contents like air pollution, noise/vibration and soil waste in the construction phase and local economy, amount/quality of groundwater and local conflict in the operation phase.

The mitigation measures are basically feasible. It is recommended to set restrictions for heavy vehicles in the construction phase, to maintain water supply facilities in adequate condition and to monitor the groundwater level.

Monitoring sheets for air pollution, noise/vibration and groundwater level were prepared for the environmental monitoring plan. Construction companies and Oromia Water, Mineral and Energy Bureau (OWMEB) shall be responsible for construction activities and the concerned bodies shall set up a system for handling complaints.

7.10 Discussions with stakeholder

There is no water committee in the following five towns in the target area: Hargeti Town, Kenteri Town, Kamise Town, Aneno Town and Wonji Shewa Alemtena Town. These towns have no water committee because there are no public water services or very limited water services. Water committees should be formed as needed in the future for appropriately operating water supply facilities based on their ownership.

In the plans drawn by the Project, no serious impacts like involuntary resettlement and/or land expropriation are foreseen, therefore necessity of a stakeholder meeting is likely not high.

7.11 Conclusions

The environmental and social assessment found that the construction and operation phase are categorized as having an unknown or negligibly small negative impact. Appropriate mitigation measures and monitoring will be conducted as necessary.

The water supply plans proposed by the Project do not foresee any serious impact such as compensation for involuntary resettlement, the occurrence of secondary pollution source (generation of new environmental pollution sources derived from hazardous substances and heavy metals), damage and loss of ruins and cultural assets, and/or adverse impact on the natural protected areas.

In conclusion, implementation under the proposed water supply plan is unlikely to significantly degrade the social environment or the natural environment in the Project area.

Chapter 8

Evaluation of Provisional Water Supply Plans and Selection of Priority Small Towns

8 Evaluation of Provisional Water Supply Plans and Selection of Priority Small Towns

8.1 Introduction

Priority small towns are selected as mentioned below in accordance with the policy to select about 10 small towns out of 19 small towns, where provisional water supply plan is elaborated, based on the evaluations of groundwater development potential (water quantity and water quality), difficulty of access to safe drinking water, benefit effect, O&M capacity, and environmental and social impacts.

8.2 Groundwater development potential

8.2.1 Potential of water quantity

Potential of water quantity is evaluated according to the estimated yield based on the result of the hydrogeological survey. Estimated yield evaluations are ranked from highest potential, rank "A" (10 L/sec or more), followed by rank "B" (5-10 L/sec) and rank "C" (0-5L/sec).

Table 8.2.1: Result of Water Quality Potential Evaluation

ID	Small town	Yield (L/sec)	Evaluation
ES-2	Geldiya	10～	A
ES-4	Bofa	5～10	B
ES-6	Ude Dhankaka	10～	A
ES-8	Kamise	10～	A
ES-10	Areda	5～10	B
ES-11	Biyo	10～	A
AR-2	Bolo	10～	A
AR-3	Arboye	5～10	B
AR-4	Aseko	5～10	B
AR-6	Gonde	5～10	B
WH-1	Chorora	5～10	B
WH-2	Bedeyi	5～10	B
WH-3	Hardim	10～	A
WH-4	Bube	0～5	C
WH-6	Hargeti	10～	A
WH-8	Kenteri	10～	A
WH-9	Aneno	0～5	C
WH-10	Belo	0～5	C
WH-11	Kora	10～	A

Source: the Project Team

8.2.2 Potential of water quality

In case there is an existing borehole in the target small town, water quality potential is evaluated by analysing the water quality of the borehole in this survey. In case no borehole exists in the target small town, water quality potential is evaluated by the concentration map prepared by this study.

Parameters exceeding Ethiopian water quality standards are fluoride and total hardness. For fluoride, relationship between fluoride concentration distribution and location of small towns is shown in the figure below.

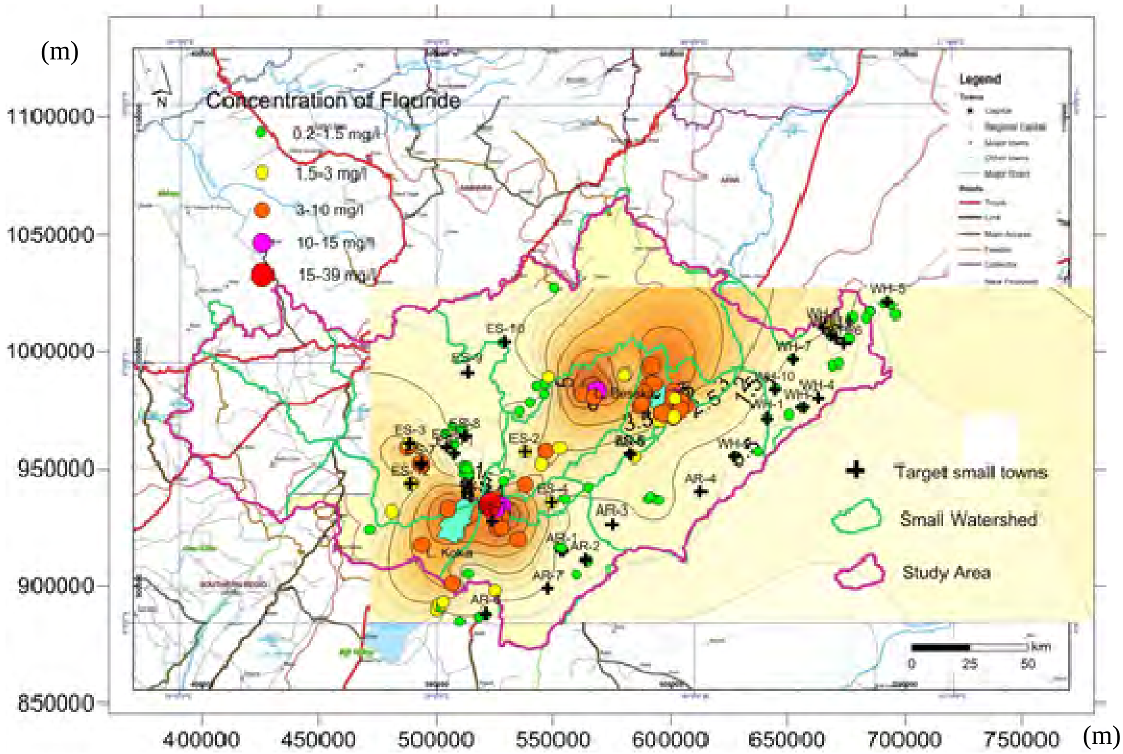


Figure 8.2.1: Relationship between Fluoride Concentration Distribution and Location of Small Towns

Fluoride is a water quality parameter that influences human health and is included as a toxic and/or disease causing parameter in Ethiopian water quality standards. Ethiopian water quality standards were revised in October 2013, at which time fluoride was revised from 3.0 mg/L (old standard) to 1.5 mg/L. However, there are areas of high fluoride concentrations around Lake Koka and Mt. Zikwala and the fluoride concentration of many existing boreholes does not satisfy the new standard value. For this reason, small towns where fluoride concentrations do not satisfy the new standard values but satisfy the old standard value (3.0 mg/L) were not excluded from small towns to develop provisional water supply plans, as mentioned in Chapter 6 of this report.

In addition, total hardness is not a parameter related to toxicity or disease but to palatability under the Ethiopian water quality standards.

Considering the above situation, rank of water quality evaluation is set as “A” in case all of the water quality parameters do not exceed Ethiopian standards, “B” in case total hardness exceeds the Ethiopian standard value but fluoride does not exceed the new Ethiopian standard (1.5 mg/L), and “C” in case concentration of fluoride exceeds the new Ethiopian standard but does not exceed the old Ethiopian standard (3.0 mg/L).

Table 8.2.2: Result of Water Quality Potential Evaluation

ID	Small town	Fluoride (mg/L)	Total hardness (mg/L)	Evaluation
ES-2	Geldiya	1.69	106	C
ES-4	Bofa	1.96	130	C
ES-6	Ude Dhankaka	0.71	250	A
ES-8	Kamise	< 1.5 (Estimate)	< 300 (Estimate)	A
ES-10	Areda	0.79	204	A
ES-11	Biyo	< 1.5 (Estimate)	< 300 (Estimate)	A
AR-2	Bolo	0.73	202	A
AR-3	Arboye	< 1.5 (Estimate)	< 300 (Estimate)	A
AR-4	Aseko	< 1.5 (Estimate)	< 300 (Estimate)	A
AR-6	Gonde	< 1.5 (Estimate)	< 300 (Estimate)	A
WH-1	Chorora	0.54	272	A
WH-2	Bedeyi	0.50	354	B
WH-3	Hardim	0.71	400	B
WH-4	Bube	< 1.5 (Estimate)	< 300 (Estimate)	A
WH-6	Hargeti	< 1.5 (Estimate)	< 300 (Estimate)	A
WH-8	Kenteri	< 1.5 (Estimate)	< 300 (Estimate)	A
WH-9	Aneno	< 1.5 (Estimate)	< 300 (Estimate)	A
WH-10	Belo	0.65	78	A
WH-11	Kora	0.50	656	B

*1 Ethiopian Water Quality Standard (New:1.5mg/L, Old:3.0mg/L)
*2 Ethiopian Water Quality Standard: 300mg/L
Source: the Project Team

8.3 Difficulty of access to safe drinking water

8.3.1 Current volume of safe drinking water supply

The current volume of safe drinking water supply is the volume of water available for use per person per day in the small towns. It is calculated from the volume of water supply from existing facilities based on the records of water meter readings for every public tap and private connection of water committees (hereafter referred to as "WCs") or town water supply service offices (hereafter referred to as "TWSSOs") in each small town. It is evaluated as rank "A" for 0-10 L/c/d, rank "B" for 10-20 L/c/d and rank "C" for 20 L/c/d or more; namely, towns with less access to safe water are ranked as higher priority.

Table 8.3.1: Safe Drinking Water Supply Volume

ID	Small town	Amount of water use per person per day as of 2014 (L/c/d)	Evaluation
ES-2	Geldiya	41.6	C
ES-4	Bofa	54.9	C
ES-6	Ude Dhankaka	0.0	A
ES-8	Kamise	2.4	A
ES-10	Areda	4.0	A
ES-11	Biyo	0.0	A
AR-2	Bolo	15.3	B
AR-3	Arboye	37.4	C
AR-4	Aseko	8.8	A
AR-6	Gonde	33.8	C
WH-1	Chorora	7.8	A
WH-2	Bedeyi	5.7	A
WH-3	Hardim	3.1	A
WH-4	Bube	2.9	A
WH-6	Hargeti	0.0	A
WH-8	Kenteri	0.0	A
WH-9	Aneno	0.0	A
WH-10	Belo	2.6	A
WH-11	Kora	15.9	B

Source: the Project Team

8.3.2 Sufficiency rate of safe drinking water

Evaluation of sufficient rate of safe drinking water shall be the ratio of present water supply volume against projected water demand as of 2020. Present water supply volume used for this calculation is the same above (section 8.3.1), that is based on the records of water meter readings of public taps and private connections by WCs and TWSSOs.

Projected water demand of 2020 is calculated based on the basic water demand of the Second Growth and Transformation Plan (GTP2), as described in Chapter 6.

The sufficiency rate of safe drinking water is calculated based on the ratio of the water supply volume of existing water supply facilities divided by planned daily average water supply volume. The ranking is evaluated as "A" for 0-30%, "B" for 30-60% and "C" for 60-100%.

Table 8.3.2: Sufficiency Rate of Safe Drinking Water

ID	Small town	Planned daily average water supply amount as of 2020 (m^3/day)	Water supply amount as of 2014 (m^3/day)	Sufficiency rate as of 2020 (%)	Evaluation
ES-2	Geldiya	135.7	93.8	69	C
ES-4	Bofa	249.3	229.8	92	C
ES-6	Ude Dhankaka	344.3	0.0	0	A
ES-8	Kamise	286.2	11.5	4	A
ES-10	Areda	164.3	11.0	7	A
ES-11	Biyo	163.1	0.0	0	A
AR-2	Bolo	95.5	24.2	25	B
AR-3	Arboye	458.5	271.7	59	B
AR-4	Aseko	322.3	46.3	14	A
AR-6	Gonde	206.6	116.2	56	B
WH-1	Chorora	97.7	21.2	22	A
WH-2	Bedeyi	182.3	16.8	9	A
WH-3	Hardim	356.6	18.1	5	A
WH-4	Bube	215.7	18.1	8	A
WH-6	Hargeti	115.2	0.0	0	A
WH-8	Kenteri	61.0	0.0	0	A
WH-9	Aneno	97.1	0.0	0	A
WH-10	Belo	158.2	12.2	8	A
WH-11	Kora	82.5	37.8	46	B

Source: the Project Team

8.4 Beneficial impact

8.4.1 Beneficial impact

Generally the larger the target population of the water supply plan, the higher the beneficial impact. Table 8.4.1 shows the projected population of each small town as of 2020, which is the planned target year, calculated based on the 2007 census population. It is evaluated as rank "A" for 10,000 or more, rank "B" for 5,000-10,000 and rank "C" for 0-5,000.

Table 8.4.1: Projected Population as of 2020

ID	Small town	Projected population as of 2020	Evaluation
ES-2	Geldiya	2,873	C
ES-4	Bofa	5,326	B
ES-6	Ude Dhankaka	7,334	B
ES-8	Kamise	6,167	B
ES-10	Areda	3,502	C
ES-11	Biyo	3,446	C
AR-2	Bolo	2,010	C
AR-3	Arboye	9,254	B
AR-4	Aseko	6,724	B
AR-6	Gonde	4,370	C
WH-1	Chorora	3,183	C
WH-2	Bedeyi	3,748	C
WH-3	Hardim	7,515	B
WH-4	Bube	7,286	B
WH-6	Hargeti	3,926	C
WH-8	Kenteri	2,044	C
WH-9	Aneno	3,326	C
WH-10	Belo	5,471	B
WH-11	Kora	2,771	C

Source: the Project Team

8.4.2 Cost effectiveness

Oromia regional government is prioritizing the authorization of townships status in towns where continuous growth is expected. The conditions for acquiring township status are:

(1) population of 2,000 or more,

(2) geographical conditions suitable for continuous growth as a town,

(3) having natural resources such as water,

(4) sufficient schools and hospitals for the human population and veterinary clinics for livestock,

(5) more than 51% of households obtain labour incomes from sources other than agriculture,

(6) 35% or more of annual expenditure is covered by town tax revenues, and

(7) the town market(s) is held at a specified place and at specified and periodical times.

Towns are ranked from 1, 2A, 2B, 3A, 3B, 3C, 4A, 4B, to 4C in order of population and tax revenue (1 being the most populous and highest tax revenue).

Communities which do not qualify for town status are classified as villages (Kebele). Such communities do not meet the abovementioned conditions, and it is judged that cost effectiveness is low.

Towns ranked 1 to 3C are evaluated as “A”, and 4A to 4C are evaluated as “B”, while Kebele are evaluated as “C”. Such town rankings are classified in a list issued by the Oromia Regional Industry and Urban Development Bureau.

Table 8.4.2: Classification of Target Small Towns as Towns or Kebele

ID	Small town	Qualification	Grade	Evaluation
ES-2	Geldiya	Town	4-C	B
ES-4	Bofa	Town	4-C	B
ES-6	Ude Dhankaka	Town	4-C	B
ES-8	Kamise	Town	4-C	B
ES-10	Areda	Town	4-C	B
ES-11	Biyo	Town	4-C	B
AR-2	Bolo	Town	4-C	B
AR-3	Arboye	Town	4-A	B
AR-4	Aseko	Town	4-C	B
AR-6	Gonde	Town	4-C	B
WH-1	Chorora	Kebele	-	C
WH-2	Bedeyi	Town	4-C	B
WH-3	Hardim	Town	4-C	B
WH-4	Bube	Kebele	-	C
WH-6	Hargeti	Kebele	-	C
WH-8	Kenteri	Kebele	-	C
WH-9	Aneno	Kebele	-	C
WH-10	Belo	Kebele	-	C
WH-11	Kora	Kebele	-	C

Source: the Project Team

8.5 O&M capacities

8.5.1 O&M organization

Sixteen (16) of the 19 target small towns have existing organizations for operation and maintenance as shown inTable 8.5.1. Among these, there are 2 small towns where a TWSSO is performing operation and maintenance. And in the remaining 14 small towns, WC is performing operation, maintenance and management.

TWSSOs are performing operation and maintenance for 7 water supply systems among 30 original small towns as described in Chapter 6. The financial situation of these TWSSOs is considered to be healthy as all of them have over 300,000 birr in financial reserves. On the other hand, the financial reserves of all but one (ES-2) WC is less than 100,000 birr, with some water committees even having no financial reserves. Although there is a difference in water supply scale compared to TWSSOs, the financial situation of WCs is not good judging from their financial reserves. The term of members of WCs is set as 2 years. Due to the replacement of WC members every 2 years, the know-how of operation and maintenance is not accumulated. Moreover, the past records, etc. of operation and maintenance may be lost when the hand-over (from old to new members) procedure is not conducted well. While the system of electing WC members from amongst water users every 2 years is a democratic system, this has the negative consequence of meaning know-how (knowledge and skills) are not accumulated within the organization.

Since the personnel of TWSSO are semi-permanently employed from the town water board, know-how is accumulated according to experience. It is considered that this difference is also apparent in the differing financial situations of WCs and TWSSOs.

The TWSSOs are judged to have a higher operation and maintenance capability than WCs, as mentioned above. Therefore, the O&M capacity is evaluated as rank “A” for TWSSO, rank “B” for WC and rank “C” for towns with “no organization”.

Table 8.5.1: Existing Organization for Operation and Maintenance in Target Small Towns

ID	Small town	Existence of organization	Type	Evaluation
ES-2	Geldiya	Exists	Water committee	B
ES-4	Bofa	Exists	Town water supply service office	A
ES-6	Ude Dhankaka	Exists	Water committee	B
ES-8	Kamise	Exists	Water committee	B
ES-10	Areda	Exists	Water committee	B
ES-11	Biyo	Exists	Water committee	B
AR-2	Bolo	Exists	Water committee	B
AR-3	Arboye	Exists	Water committee	B
AR-4	Aseko	Exists	Water committee	B
AR-6	Gonde	Exists	Town water supply service office	A
WH-1	Chorora	Exists	Water committee	B
WH-2	Bedeyi	Exists	Water committee	B
WH-3	Hardim	Exists	Water committee	B
WH-4	Bube	Exists	Water committee	B
WH-6	Hargeti	No	-	C
WH-8	Kenteri	No	-	C
WH-9	Aneno	No	-	C
WH-10	Belo	Exists	Water committee	B
WH-11	Kora	Exists	Water committee	B

Source: the Project Team

8.5.2 Willingness to pay water tariff

It is assumed that operation and maintenance of water supply facilities will be performed smoothly if the intention to pay water tariff in a community is high. Therefore, intention to pay water tariff is evaluated according to the results of a sample household survey of water use conducted in this Project for every small town. It is evaluated by percentage of households who answered “having intention to pay” in this Project.

Towns where the percentage of the persons who answered "having intention to pay” was 90% or more were ranked as "A", 80-90% as “B” and 80% or less as “C”.

Table 8.5.2: Willingness to Pay Water Tariff

ID	Small town	Percentage of the persons who answered "having intention to pay" (%)	Evaluation
ES-2	Geldiya	78	C
ES-4	Bofa	96	A
ES-6	Ude Dhankaka	83	B
ES-8	Kamise	100	A
ES-10	Areda	91	A
ES-11	Biyo	96	A
AR-2	Bolo	100	A
AR-3	Arboye	100	A
AR-4	Aseko	91	A
AR-6	Gonde	100	A
WH-1	Chorora	91	A
WH-2	Bedeyi	78	C
WH-3	Hardim	100	A
WH-4	Bube	91	A
WH-6	Hargeti	87	B
WH-8	Kenteri	65	C
WH-9	Aneno	65	C
WH-10	Belo	83	B
WH-11	Kora	74	C

Source: the Project Team

8.6 Environmental and social impacts

8.6.1 Environmental impact

Since it is hard to consider the water supply plans in the Project as having a positive impact on the natural environment, a “demerit” style assessment system of environmental impact, starting from full marks for a “zero option scenario” is adopted.

In case of "impact is negligible or of no concern", it is assessed as “A”. In cases where "one or more concern exists", it is assessed as "B". And in case where “two or more concerns exists", it is assessed as “C”. The result of evaluation is shown in Table 8.6.1.

Table 8.6.1: Environmental Impact

ID	Small town	Result of survey	Evaluation
ES-2	Geldiya	"impact is negligible or of no concern"	A
ES-4	Bofa	"impact is negligible or of no concern"	A
ES-6	Ude Dhankaka	"impact is negligible or of no concern"	A
ES-8	Kamise	"impact is negligible or of no concern"	A
ES-10	Areda	"impact is negligible or of no concern"	A
ES-11	Biyo	"impact is negligible or of no concern"	A
AR-2	Bolo	"impact is negligible or of no concern"	A
AR-3	Arboye	"impact is negligible or of no concern"	A
AR-4	Aseko	"impact is negligible or of no concern"	A
AR-6	Gonde	"impact is negligible or of no concern"	A
WH-1	Chorora	"impact is negligible or of no concern"	A
WH-2	Bedeyi	"impact is negligible or of no concern"	A
WH-3	Hardim	"impact is negligible or of no concern"	A
WH-4	Bube	"impact is negligible or of no concern"	A
WH-6	Hargeti	"impact is negligible or of no concern"	A
WH-8	Kenteri	"impact is negligible or of no concern"	A
WH-9	Aneno	"impact is negligible or of no concern"	A
WH-10	Belo	"impact is negligible or of no concern"	A
WH-11	Kora	"impact is negligible or of no concern"	A

Source: the Project Team

8.6.2 Social impact

About social impact, both positive and negative impacts are conceivable. Therefore, “B” is set as the basic point, in other words the “zero option scenario”. Therefore, areas assessed as having highest priority for water facility development, “A”, are areas where positive social impact can be most expected (such as areas where fetching water is the number one cause of school truancy and areas where three or more of the top five causes of illness of all patients are water-borne diseases).

In case the social impact is assessed to be "positive", it is ranked “A”. In case the social impact is assessed to be "negligible or non-existent", it is ranked "B". And in cases where "one or more concern exists", it is ranked “C”. The result of the social impact assessment is shown in Table 8.6.2.

Table 8.6.2: Social Impact

ID	Small town	Result of survey	Evaluation
ES-2	Geldiya	"negligible or non-existent"	B
ES-4	Bofa	"negligible or non-existent"	B
ES-6	Ude Dhankaka	"positive"	A
ES-8	Kamise	"negligible or non-existent"	B
ES-10	Areda	"negligible or non-existent"	B
ES-11	Biyo	"positive"	A
AR-2	Bolo	"positive"	A
AR-3	Arboye	"positive"	A
AR-4	Aseko	"negligible or non-existent"	B
AR-6	Gonde	"negligible or non-existent"	B
WH-1	Chorora	"positive"	A
WH-2	Bedeyi	"positive"	A
WH-3	Hardim	"negligible or non-existent"	B
WH-4	Bube	"positive"	A
WH-6	Hargeti	"positive"	A
WH-8	Kenteri	"positive"	A
WH-9	Aneno	"positive"	A
WH-10	Belo	"negligible or non-existent"	B
WH-11	Kora	"negligible or non-existent"	B

Source: the Project Team

8.7 Scoring criteria for selecting priority small towns

Major items of evaluation shall be the abovementioned five issues: (1) groundwater development potential, (2) difficulty of access to safe drinking water, (3) beneficial impact and cost effectiveness, (4) operation and maintenance capacity, (5) environment and social impact. The scoring of the evaluation was weighted according to the order of relative importance of each issue, with a maximum total score of one hundred points. In some cases, where a criteria was judged to be of greater importance compared to other criteria, special weighted “priority” points were awarded. The criteria for the scoring are as follows:

- Since the water supply plan itself will not be realized when groundwater development possibility is low, it is necessary to give top priority to groundwater development potential.
- Since the urgency of project implementation is high when it is difficult for the residents to access safe water, the 2nd highest priority shall be given to difficulty of access to safe drinking water.
- Since the sustainability of (newly constructed) water supply facilities cannot be guaranteed in cases where there is insufficient capacity for operation and maintenance, such capacity is the 3rd priority.
- Since the project implemented by the fund such as Japan’s Grant Aid etc. shall have high beneficial impact and cost effectiveness in order to use funds effectively, the 4th priority shall be given to the beneficial impact and cost effectiveness.
- Since the impact of the water supply plans on the environment and society is considered to be small compared with the other four items, it was taken as the final ranking.

The abovementioned criteria judged to be of greater importance compared to other criteria for which special weighted “priority” points were awarded are as follows:

- Since highest priority is to successfully strike groundwater in the drilling, a maximum of ten “priority” points are awarded according to potential of water quantity.
- Volume of access to safe drinking water varies depending on the situation in each area.

However, sufficiency rate of safe drinking water is the ratio against water demand and is similar to difficulty of access to safe drinking water in the target year. For this reason, five "priority" points shall be awarded according to sufficiency rate of safe drinking water.

- In order to measure an investment effect, it is judged that cost effectiveness has larger impact than the beneficial impact. Therefore five "priority" points are awarded to cost effectiveness.
- It is judged that an operation and maintenance organization that actually exists and is performing O&M activities is a stronger indicator of a high capacity of operation and maintenance rather than the willingness to pay. Therefore, ten "priority" points shall be awarded for towns with an operation and maintenance organization.
- Although evaluation of environmental impact is assessed only by negative impact, evaluation of social impact is assessed by both positive and negative impact. Therefore four assessed points shall be given to social impact.

Standard of allotment of points for selecting priority small towns is shown in Table 8.7.1.

Table 8.7.1: Scoring Criteria for Selecting Priority Small Towns

	Item	Small item	Maximum score	Classification	Points	Criteria	Remark
1	Groundwater development potential		30				
	Quantity	Pumping capacity	20	A	20	≧ 10 L/sec	
				B	12	5 - 10 L/sec	
				C	4	0 - 5 L/sec	
	Quality	Water quality analysis result	10	A	10	Not exceeding Ethiopian standard	Total hardness is categorized as palatability properties not the toxic and/or disease causing substances in Ethiopian water quality standard
				B	6	Total hardness exceeds the Ethiopian standard (300mg/L). However, fluoride does not exceed the Ethiopian standard.	
				C	2	Fluoride exceeds the new Ethiopian standard (1.5mg/L) but does not exceed the old standard (3.0mg/L).	
2	Difficultness to get safe drinking water		25				
	Safe water supply volume	Water supply volume per person per day	10	A	10	0-10 L	Record of water meter reading
				B	9	10-20 L	
				C	3	>20 L	
	Sufficient rate of safe drinking water	Sufficient rate of safe drinking water	15	A	10	0-30%	Based on the basic water demand of GTP-2 (Urban: 40L/c/d, Rural: 25L/c/d)
				B	6	30 - 60%	
				C	2	60-100%	
3	Effectiveness of benefit & cost performance		15				
	Effectiveness of benefit	Population as of 2020	5	A	5	≧ 10,000	Projection based on the Census 2007
				B	3	5,000-10,000	
				C	1	0-5,000	
	Cost performance	Town grade	10	A	10	Grade 3	Based on the town list of Oromia Industry and urban development 2014
				B	8	Grade 4	
				C	2	Not town, Kebele	
4	O&M Potential		20				
	O&M organization	Type of organization	15	A	15	Town Water Supply Service Office	Results of existing water facility conditions survey
				B	9	Water Committee	
				C	0	Does not exist	
	Intention to pay water tariff	Percentage of respondents who answered "I have an	5	A	5	90-100 %	Results of water use survey
				B	3	80-90%	
				C	1	<80%	
5	Environment and Social Impact		10				
	Impact for environment		3	A	3	No negative impact is expected	
				B	2	More than one negative impact is expected	
				C	1	More than two negative impacts are expected	
	Social impact		7	A	7	Positive impact is expected	
				B	4	No negative impact is expected	
				C	1	More than one negative impact is expected	
	Total		100				

Source: the Project Team

8.8 Conclusion

As a result of prioritization based on the overall scoring according to the abovementioned criteria, 10 high priority small towns were selected as shown in Table 8.8.1. Moreover, further details of the scoring for each criterion in each town are shown in Table 8.8.2.

Table 8.8.1: High Priority Small Towns

Priority	ID	Small town	Woreda	Zone
1	ES-6	Ude Dhankaka	Adaa	East Shewa
2	ES-11	Biyo	Lome	East Shewa
3	WH-3	Hardim	Guba Qoricha	West Hararge
4	AR-4	Aseko	Aseko	Arsi
5	ES-8	Kamise	Lome	East Shewa
6	AR-2	Bolo	Jeju	Arsi
7	ES-10	Areda	Gimbichu	East Shewa
8	WH-1	Chorora	Anchar	West Hararge
9	WH-2	Bedeyi	Anchar	West Hararge
10	WH-6	Hargeti	Mieso	West Hararge
11	AR-6	Gonde	Tiyo	Arsi
12	WH-8	Kenteri	Mieso	West Hararge
13	WH-4	Bube	Guba Qoricha	West Hararge
14	AR-3	Arboye	Jeju	Arsi
15	WH-10	Belo	Mieso	West Hararge
16	WH-11	Kora	Mieso	West Hararge
17	ES-4	Bofa	Boset	East Shewa
18	WH-9	Aneno	Mieso	West Hararge
19	ES-2	Geldiya	Adama Zuria	East Shewa

Source: the Project Team

Table 8.8.2: Results of the Scoring and Order of Prioritization of Target Small Towns

		Results of Scoring for Prioritizing Target Small Town																																Priority
		1							2								3						4						5				6	
Major items		Groundwater development potential (30)							Difficulty of getting safe drinking water (25)								Effectiveness of benefit & cost performance (15)						O&M Potential (20)						Environment and Social Impact (10)				Total (100)	
Items		Water quantity (20)			Water quality (10)				Safe water supply volume (10)			Sufficient rate of safe drinking water (15)					Effectiveness of benefit (5)			Cost performance (10)			O&M organization (15)			Intention to pay water tariff (5)			Environment (3)		Social (7)			
Criteria		pumping capacity	classification	points	Fluoride Ethiopian standard:1.5mg/L, Ethiopian old standard:3.0mg/L	Total Hardness Ethiopian standard (300mg/L)	classification	points	Water supply volume per person per day in 2014	classification	points	Planning average daily water supply volume as of 2020 (m^3/day)	Water supply volume as of 2014 (m^3/day)	Sufficient rate as of 2020 (%)	classification	points	Projected population in 2020	classification	points	Grade of Town	classification	points	Existence of OM organization	classification	points	Percentage of respondents who answered "I have an intention to pay"	classification	points	classification	points	classification	points		
ID	Name of small town	(L/sec)		(0~20)	(mg/L)	(mg/L)		(0~10)	(L/c/d)		(0~10)					(0~15)			(0~5)			(0~10)			(0~15)	(%)		(0~5)					(0~100)	
ES-2	Geldiya	10~	A	20	1.69	106	C	2	41.6	C	2	135.7	93.8	69	C	3	2,873	C	1	4-C	B	8	WC*3	B	9	78	C	1	A	3	B	4	53	19
ES-4	Bofa	5~10	B	12	1.96	130	C	2	54.9	C	2	249.3	229.8	92	C	3	5,326	B	3	4-C	B	8	TWSSO*4	A	15	96	A	5	A	3	B	4	57	17
ES-6	Ude Dhankaka	10~	A	20	0.71	250	A	10	0.0	A	10	344.3	0.0	0	A	15	7,334	B	3	4-C	B	8	WC	B	9	83	B	3	A	3	A	7	88	1
ES-8	Kamise	10~	A	20	< 1.5(estimate)	< 300(estimate)	A	10	2.4	A	10	286.2	11.5	4	A	15	6,167	B	3	4-C	B	8	WC	C	0	100	A	5	A	3	B	4	78	5
ES-10	Areda	5~10	B	12	0.79	204	A	10	4.0	A	10	164.3	11.0	7	A	15	3,502	C	1	4-C	B	8	WC	B	9	91	A	5	A	3	B	4	77	7
ES-11	Biyo	10~	A	20	< 1.5(estimate)	< 300(estimate)	A	10	0.0	A	10	163.1	0.0	0	A	15	3,446	C	1	4-C	B	8	WC	B	9	96	A	5	A	3	A	7	88	2
AR-2	Bolo	10~	A	20	0.73	202	A	10	15.3	B	6	95.5	24.2	25	B	9	2,010	C	1	4-C	B	8	WC	B	9	100	A	5	A	3	A	7	78	6
AR-3	Arboye	5~10	B	12	< 1.5(estimate)	< 300(estimate)	A	10	37.4	C	2	458.5	271.7	59	B	9	9,254	B	3	4-A	B	8	WC	B	9	100	A	5	A	3	A	7	68	14
AR-4	Aseko	5~10	B	12	< 1.5(estimate)	< 300(estimate)	A	10	8.8	A	10	322.3	46.3	14	A	15	6,724	B	3	4-C	B	8	WC	B	9	91	A	5	A	3	B	4	79	4
AR-6	Gonde	5~10	B	12	< 1.5(estimate)	< 300(estimate)	A	10	33.8	C	2	206.6	116.2	56	B	9	4,370	C	1	4-C	B	8	TWSSO	A	15	100	A	5	A	3	B	4	69	11
WH-1	Chorora	5~10	B	12	0.54	272	A	10	7.8	A	10	97.7	21.2	22	A	15	3,183	C	1	Kebele	C	2	WC	B	9	91	A	5	A	3	A	7	74	8
WH-2	Bedeyi	5~10	B	12	0.50	354	B	6	5.7	A	10	182.3	16.8	9	A	15	3,748	C	1	4-C	B	8	WC	B	9	78	C	1	A	3	A	7	72	9
WH-3	Hardim	10~	A	20	0.71	400	B	6	3.1	A	10	356.6	18.1	5	A	15	7,515	B	3	4-C	B	8	WC	B	9	100	A	5	A	3	B	4	83	3
WH-4	Bube	0~5	C	4	< 1.5(estimate)	< 300(estimate)	A	10	2.9	A	10	215.7	18.1	8	A	15	7,286	B	3	Kebele	C	2	WC	B	9	91	A	5	A	3	A	7	68	13
WH-6	Hargeti	10~	A	20	< 1.5(estimate)	< 300(estimate)	A	10	0.0	A	10	115.2	0.0	0	A	15	3,926	C	1	Kebele	C	2	None	C	0	87	B	3	A	3	A	7	71	10
WH-8	Kenteri	10~	A	20	< 1.5(estimate)	< 300(estimate)	A	10	0.0	A	10	61.0	0.0	0	A	15	2,044	C	1	Kebele	C	2	None	C	0	65	C	1	A	3	A	7	69	12
WH-9	Aneno	0~5	C	4	< 1.5(estimate)	< 300(estimate)	A	10	0.0	A	10	97.1	0.0	0	A	15	3,326	C	1	Kebele	C	2	None	C	0	65	C	1	A	3	A	7	53	18
WH-10	Belo	0~5	C	4	0.65	78	A	10	2.6	A	10	158.2	12.2	8	A	15	5,471	B	3	Kebele	C	2	WC	B	9	83	B	3	A	3	B	4	63	15
WH-11	Kora	10~	A	20	0.50	656	B	6	15.9	B	6	82.5	37.8	46	B	9	2,771	C	1	Kebele	C	2	WC	B	9	74	C	1	A	3	B	4	61	16

*1 Ethiopian Water Quality Standard (New:1.5mg/L, Old:3.0mg/L)
*2 Ethiopian Water Quality Standard: 300mg/L
*3 Water Committee
*4 Town Water Supply Service Office
Source: the Project Team

Chapter 9

Conclusion and Recommendations

9 Conclusions and Recommendations

9.1 Conclusions

From the results of the Project activities, we reached the conclusions outlined in this chapter. The process of how each of the small towns' water supply plans were concluded for prioritizing implementation, as well as details of the water supply plans of small towns, and the natural and socio-economic situations in the Middle Awash River Basin.

9.1.1 Natural conditions

1) The study area is bounded by the limits of $38^{0}00'$ – $40^{0}00'$ east longitude and $8^{0}00'$ – $9^{0}30'$ north latitude, and its coverage area is approx. 29,000 km^2. The study area lies to the southeast of the Ethiopian capital, Addis Ababa, and includes Adama, the provincial capital of Oromia Region (which is located about 80 km southeast of Addis Ababa). The area is topographically characterized by a depression zone with steep marginal faults along its edges and with some highland areas. The study area is a basin within the middle Awash River area called the middle Awash River Basin (which lies within the independent Awash River Basin).

2) The average annual mean rainfall at 20 meteorological stations for the 30 years is 876 mm, while the average annual point rainfall at Addis Ababa is 1,283 mm, and at Metehara in the most downstream area of the Awash River is 508 mm. The Project area is characterized by three distinct seasons of dry season, small rainy season, and main rainy season. The annual evaporation of 11 meteorological stations varies between 1,622 mm and 3,023 mm. The maximum temperature reaches more than 36 °C at the downstream regions in the monthly records. The temperature drops less than 10 °C in the high lands.

3) The Awash River flows from the direction of northwest to the southeast and northeast direction in the central Project area. Lake Koka exists in the upstream of the middle Awash River Basin, and Lake Beseka also exists in the downstream. Peak runoffs are observed during the period from the middle of August to the beginning of September. Annual mean runoffs is 27.8 m^3/sec to 64.1 m^3/sec from upstream to downstream. The Lake Koka releases constant discharge of approximately 35 m^3/sec in dry season, and annual runoff height at the downstream end of the Middle Awash is 69 mm.

4) The middle Awash River Basin is divided into 13 sub-basins in accordance with the small catchment area and small topographic line. The main purposes of the hydrological analysis is to estimate annual groundwater recharge in the middle Awash River Basin. Therefore, the groundwater recharge was estimated in the 13 sub-basins through the use of the annual mean rainfall, the runoff coefficient and BFI (Base Flow Index) value for the calculation of the base flow amount. The estimated annual groundwater recharge ranges between 47 mm and 87 mm and is equivalent to 7.4%–9.0% of the annual rainfall.

5) The Awash River Basin area with Afar Basin and Rift Valley Lakes Basin belongs to the "African Rift". The African Rift originates from Aden Junction and continues in the direction of SW (southwest)- SSW (south-southwest) traverse longitudinally the eastern African countries such as Djibouti, Eritrea, Ethiopia, Kenya, Uganda, and Tanzania. The Project area is located in the northern sector of the Main Ethiopian Rift (hereafter refer to as "MER"), and the northeast of the Project area broadens northward into the Afar Rift.

The geological tectonic direction in the rift escarpment of MER has been changed from NE (northeast) - SW (southwest) to ENE (east-northeast) - WSW (west-southwest), and it is made aperture at the Aden junction in the Afar Rift.

6) The oldest volcanic activities are basalt and rhyolite flows in Oligocene, by middle Miocene, the rift was formed in some parts with containment basaltic flows. In Pliocene, an immense pyroclastic flow covered the northern part of the study area. In Pleistocene, Wonji Fault Belt (WFB), which is the main spreading axis of MER, is formed at the rift floor, and the floor basalt and rhyolite are erupted along WFB. The volcanic activities are characterized by peralkaline fissure basaltic eruptions and rhyolitic eruptions which make volcanoes and calderas. Fault system in northern area is characterized by the development of continuous major faults which has big displacement with minor parallel faults, and fault zones associated with volcanic activity in the rift floor.

7) The history of volcanic activity in the middle Awash River Basin is that the large rhyolitic calderas and volcanic chains composed of separate basaltic lava domes are observed. The volcanic activities are mainly recognized in late Pliocene to early Pleistocene stage and in the middle Pleistocene to recent stage. Those basaltic rocks consist of basalt lavas and thick basaltic pyroclastics which show subaqueous volcanism in both stages. The rhyolitic activity in late Pliocene to early Pleistocene stage formed huge mountain body and calderas in this stage.

8) A reliable hydrogeological map was created based on a detailed geological map. Therefore, in the preliminary survey of geology in the field, the middle Awash River Basin was divided into four areas in accordance with the aspects of geology and distribution. The strata of each area were correlated based on the specific geology (a key bed), and the correlation chart was described. Finally, the stratigraphy in the entire area was created and the geological map was completed in the middle Awash River Basin (Map scale of 1:250,000 in the entire area and 1:100,000 in Lake Beseka area).

9) The main aquifer is classified into 3 types in the middle Awash River Basin; 1) Alluvium and lacustrine deposits, 2) Quaternary Pleistocene tuff, and welded tuff and basalt, and 3) Tertiary Pliocene, Miocene tuff, and welded tuff and basalt. The aquifer potential can be divided into the following classes in accordance with the standard of Ethiopia in conjunction with the correlation of strata and aquifer information of the existing wells and JICA new wells. The hydrogeological map can be created in light of the geological map in consideration with the following aquifer classes;

   1)=1C, 2)＝3B~3C, 1B～1C, 3)＝3C~3A　(A: high, B: moderate, C: low)

10) The groundwater table contour map was created based on data of the static water level showing the confined aquifer, except the unconfined aquifer, partly using the information of JICA wells and existing wells. The direction of flow line is assumed to be from the southeast and the northwest of rift valley highland to the rift floor of the northeast to the southwest along the Awash River. It is considered the groundwater flows along the geography.

11) According to the hydrogeological map and cross-sections, the geology indicated that the high productivity of groundwater is the Tertiary Miocene basalts and Pliocene pyroclastic deposits. These strata are mainly distributed on the surface in the northwest and southeast area along the rift valley ridge, and these strata were also found in the floor of the middle

Awash River basin in its subsurface.

12) The proportion of the estimated yield of 2035 to the groundwater recharge is 1 to 5% in the comparison of groundwater usage in terms of groundwater recharge and yield in regard to the groundwater potential in the sub-basins. This percentage excludes the water usage of the large city, Addis Ababa, in the calculation; however, even if the water usage of the city is included in the calculation, the ratio of this sub-basin is 35%.

13) The possible and useful yield (possibility amount of groundwater by the development) is 4% to 52% of the groundwater recharges values in each sub-basin which was determined by the calculation of the permissive groundwater drawdown in the sub basins through the use of the correlation formula between the estimated yield and groundwater drawdown by the groundwater model.

14) Regarding the existing wells and JICA wells, analysis items, except fluorine, did not exceed the Ethiopian standard in most of the wells. The total hardness and calcium were detected exceeding the Ethiopian standard, along the Rift Valley ridge in the south of the Project area (including 3 target small towns) mainly in the existing wells and springs, however, it is about 10 points.

15) From the results of water quality testing on wells, geological judgment says that the fluoride concentration tends to be high in almost all areas of Plio-Pleistocene welded tuff and in the distributed area of Pleistocene and Holocene acidic volcanic rocks (low-lying areas of the Rift Valley basin, Lake Beseka and Koka area). The relationship between well depth and the concentration of fluoride shows that the entire Project area exhibits a declining trend of the concentration of fluoride when the wells become deeper. However, such analysis also needs to take into consideration the above geological findings.

9.1.2 Hydrology, Geology and Hydrogeology Analysis around Lake Beseka

1) Lake Beseka is located in the Fentale District of Oromia Region at about 130 km east from Addis Ababa. The lake has a watershed area of 532 km^2 and is topographically isolated from the Middle Awash River Basin. The water surface level of the lake started rising from the 1960s and adverse effects thereby have been reported since 1970s. The national highway, railway, irrigated farms, and residential areas around the lake have submerged in water flooded due to the lake level rise. The lake water level has increased about 12 m and the lake surface area has expanded from 3.6 km^2 to 55 km^2 since late 1960s.

2) The expansion of Lake Beseka has occurred at a corresponding timing with intensive development of irrigation projects in the lake watershed diverting the Awash River water. Almost all of existing studies and researches conclude that excess water from large-scale irrigation projects have caused this lake expansion to some extent.

3) Progresses of the surveys and analyses on topography, geology, geological structures and hydrogeology are reported in this Project. In addition to these, i) analysis on surface temperature of the Lake Beseka, ii) water quality analysis for water samples in and around the Lake Beseka, and iii) water balance analysis with estimated irrigation return flow, are undertaken in order to validate the rationality of widely recognized cause of the Lake Beseka expansion, i.e. excess irrigation water.

4) Topography around Lake Beseka is divided into 7 classes, which are alluvial lower plain, Basalt lower plain, middle plain, upper plain, acidic rock dome, gorge and lake by taking into consideration the characteristics of this area such as volcanic ejecta, deposits and geological structure.

5) The geology consists of Birenti-Hada rhyolites (Tr), Older ignimbrite (Ti), and Nura Hira basalts (Tb) of Tertiary Pliocene, Dino ignimbrite (Qi1), Sobebor volcanic sand beds (Qs), Pleistocene basalts (Qb1), Kone ignimbrite (Qi2), Fentale volcanic rocks (Qf), Fentale ignimbrite (Qi3) of Quaternary Pleistocene and Holocene basalts (Qb2), and Alluvium deposits of Quaternary Holocene from the lower part. A detailed geological map and cross-sections of an Awash River sub-basin, which extends from the northwestern foot of Mt. Fentale to the Nura Hira farm including Lake Beseka, was prepared at a scale of 1:100,000 (532 km^2).

6) Hydrogeological conditions; the geological stratum indicates middle to high water permeability, and it is a fractured rock groundwater along fissures and cracks.

7) The groundwater flow around Lake Beseka was discussed using the existing wells of less than 100 m depth or more than 100 m depth because of the differences of groundwater level by the geology and depth of the speculated aquifer. The groundwater level contour map for existing wells less than 100 m depth shows a SW to NE flow direction, and the wells more than 100 m depth shows a south to north flow direction. There is a difference of groundwater flow by the aquifer depth.

8) Fluoride concentration in the water around Lake Beseka is high and exceeds the Ethiopian standard. There is no correlation between fluoride concentration and depth.

9) Temperature analyses based on the infrared data of Landsat images suggest the continuous rise of the lake surface temperature. This strongly implies the continuous inflow of high-temperature spring water from western or southwestern side of the Lake Beseka as the cause of Lake Beseka expansion rather than intrusion of excess irrigation water.

10) Water quality analysis in and around the Lake Beseka revealed that the current water quality of the lake, classified into $NaHCO_3$ or Na_2SO_4/NaCl type, is very similar to those of surrounding groundwater and springs, mainly classified into $NaHCO_3$ type. In view of chemical evolution, the lake water has clearly evolved from spring water and no effects of river water (irrigation water) are found. The trace of intrusion of irrigation water (or Awash River water) can be found from the slightly detected calcium ion only in the southern shore where the Lake Beseka faces the Abadir farm.

11) The water balance analysis is undertaken to see whether or not the return flow from the irrigation projects developed in late 1960s can explain the lake expansion without contradictions. The result shows that the lake surface area cannot reach up to currently observed level even if the possible maximum return flow is applied with extreme assumptions.

9.1.3 Socio-economic conditions, water supply plan of small towns, and project evaluation for the selection of priority small towns

1) The middle Awash River Basin consists of 3 regions (the area of each region is: Oromia

55%, Afar 25%, and Amhara 20%) with a population of about 6.5 million as of 2007, (including 2.7 million in Addis Ababa). The main industries are agriculture, manufacturing, and services in middle Awash Basin.

2) The largest ratio of ethnic groups in Oromia Region of the project area is Oromo people, who make up about 88% of the total population. The Oromiffa language, the most common language, is spoken by about 84% of the population. The Muslim faith is the largest religion (about 50% of the population) in Oromia Region of Project area. Oromia Region is divided into 18 zones, and the target small towns of this Project are in East Shewa Zone, Arsi Zone, and West Hararge Zone.

3) The main agricultural (the predominant industry in Oromia) crops are teff and wheat, which are dominant on both an area and a yield basis. Goats (31%), cattle (26%) and sheep (22%) are the dominant livestock in all Woredas. Chickens share approximately 13% in the numeral basis. The number of camels is larger in Merti (Arsi zone) and Mieso (West Hararge zone) compering with other zones.

4) The average number of primary schools per Woreda is 41 in the target small towns. The attendance rate for the primary schools is about 73% for the overall objective Woredas.

5) Number of target small towns are 30. At first, the target small towns were screened for the verification of rationality to elaborate water supply plan. As the results, 19 small towns were selected for the provisional water supply plan, finally in consideration with the water quality (Old Ethiopian standard of Fluoride: equal to or more than 3.0 mg/L) of the groundwater development potential, other projects, and the current access to safe water.

6) The water supply unit adopts the 40 L/c/day at urban and 25 L/c/day at rural based on the GTP II as the design criteria of water demand for the provisional water supply plan. The water supply facilities consisting of water intake facilities, transmission facilities, and distribution facilities.

7) Water resources of the intake facilities were planned with wells. The possibility of well development was considered; and it was concluded that the groundwater development can be carried out in terms of the groundwater recharge, utilization plans, and possibility of groundwater usage.

8) The total budget of the water supply plans for 19 small towns consist of the new construction cost of water supply facilities and rehabilitation cost of the existing water supply facilities, is $265,474 \times 10^3$ ETB.

9) The operation and maintenance plan of the water supply facility was discussed based on the issues of the current water management organization. The strengthen items for the water supply facility is to clarify the relevant people, to share the roles and to establish the supporting structure and so on. Moreover, the organization plan and manpower plan shall be formulated in the operation and maintenance organization.

10) The project evaluation of the target small towns was carried out for the selection of priority small towns concerning the next items. They are groundwater development potential (quantity and water quality), difficulty of access to safe drinking water (Safe drinking water supply volume and sufficiency rate of safe drinking water), benefit effect

(comparison of population and cost effectiveness), O&M capacities (O&M organization and willingness to pay water tariff), and effect to the environmental and social consideration according with the construction of water supply facility. As the results of the analysis, 19 small towns were ranked in order by the score with standard.

11) The environmental and social impacts by the installation of facilities designed by the Project were considered based on the JICA Environment and Social Consideration Guidelines, and the Ethiopian Environment Impact Assessment (EIA) Guidelines. In conclusion, the implementation under the proposed water supply plan is unlikely to significantly degrade the social environment or the natural environment.

9.2 Lessons learned and recommendations

9.2.1 Introduction

The main existing geological map and hydrogeological map in the middle Awash River Basin is Kazmin et al; Nazret map and description, 1978; and Hydrogeology (Map) of the Nazret, EIGS, 1985. Thirty years have passed since those maps were created. Therefore, our project works toward the completion of the new geological map and hydrogeological map based on the collected new data and analysis. And also, we have drawn up a water supply plan for the small towns of Oromia Region using the hydrogeological map. During the Project, some issues were encountered, therefore, recommendations are arranged for the improvement of the groundwater development.

9.2.2 Actual use of groundwater database

Ministry of Water and Energy (MoWE) at the time had conducted the project of Ethiopia National Ground Water Information System (ENGWIS) from 2009 to 2010, which attempted to establish the network-based/centralized groundwater information system. During the project, water sources data were collected and arranged, however, the data has not been updated after the project. Training for the utilization of ENGWIS, targeting the water resources management department staff in the ministry and regional government was conducted only one time in 2013. After that, trainings of the use of ENGWIS have not been carried out. The Project team confirmed the data of 763 wells of the middle Awash river basin in ENGWIS, however, the arrangement of this data was unsatisfactory, and most of it did not have sufficient accuracy. The main problems are; no coordinate data, no aquifer information, and no static water level (SWL) and pumping test data, and so on. Accurate hydrogeological maps play an important role for the groundwater development. The groundwater information including the aquifer coefficient is the basic data for accurate hydrogeological mapping. At the time of establishing and operating ENGWIS, sufficient discussions on the importance of a groundwater database for Ethiopia have been carried out, however, going forward further specific discussions will be necessary. One of the issues in regard to the data collection is that the data centralization for ENGWIS has not been proceeded because each regional government has collected and input the data using its own unique format. The second issue for the data collection is that the system to centralize the data from the zones/woredas to the MoWIE is not functioning as an organizational structure. In terms of the Issues, The main recommendations subjects for these discussions are given below;

- To improve the system, the exact groundwater information, which must be obtained from each region, must first be determined. Then it must be ensured that this data is obtained without any error. The format of the data and actual items that need to be obtained should be determined in collaboration with AAU, MoWIE and GSE.

- Strengthening the organization is not only for the regions, but also for the zones. The system of the groundwater management is ensured in the zonal offices by having zonal staff who understand the importance of the groundwater database. This will also allow the zonal staff to be able to train and give advice to the woreda-level staff. To that end, the guidance for the zones should be carried out regularly by the ministry staff with the regional staff. It is favorable to distribute the software license for ENGWIS to the regional staff as well as the zonal staff.
- On the whole, it is necessary to establish the institutional aspect and budget as national project by clarification the position of ENGWIS in the MoWIE when an implementation timeline of these technical, operational and information aspects has been determined, or an actual road map has been determined. It would then be able to contribute to achieving the national target for the UAP and so on. For this purpose at first, it is immediately necessary to additionally assign capable personnel to implement the specific operations and technical activities of ENGWIS in the MoWIE. Moreover, the staff at MoWIE and regional water bureaus need to be given training continuously with regard to the method of collection and contents of data. In any event, there is a need to secure the budget for possible work.

9.2.3 Recommendations to the Ethiopia side of good practices for the drilling wells monitoring and improvement of drilling technology

Delays and other troubles from well drilling have occurred frequently in the middle Awash River Basin as well as the Rift Valley Lakes Basin. One of the reasons for these troubles is that the Rift Valley area is difficult to drill in. However, the other reasons for delays are as follows;

1) Machine troubles from the drilling company occurred frequently. In case of machine troubles, it takes a long time to get the spare parts and repair each machine because there is no preparation in advance of the specific spare parts. And also the spare parts are not genuine parts, so the repairs are conducted repeatedly. Moreover, each drilling team does not have access to sufficient basic machines such as compressors. Therefore, as several drilling teams utilize only one compressor, there is a long wait to perform the drilling works. Regarding casing after drilling, the drilling team members sometimes have little experience using uPVC. The accidents of falling uPVC happen when the top of the casing lacks a trap.

2) Lost circulation and the collapse of porous walls have occurred frequently because there are many difficult areas for drilling due to the geological conditions. In these collapse areas, the method of drilling is usually casing drilling (the collapse of the wall protected by casing). However, there are very few Ethiopian companies which have thick casing for deep drilling. Therefore, it is difficult for them to deal with collapses due to a lack of appropriate skills and experience. The drilling company uses the DTH method for drilling extensively, but it is inexperienced in the mud rotary method.

Good practices are shown with the following items in consideration of the above issues;

- In the Rift Valley area, taking into consideration Ethiopian drilling technology, it takes two to three months to complete drilling to 300 m in depth, including the pumping test.

- In selection of drilling company, the number of drilling machines the company possesses and spare parts storage conditions add technical points to the selection evaluation (the storage materials need to be checked in detail). It is important to take into account of the technical points as well as to keep costs low.
- With regard to drilling, possible issues on site work and purchase of new parts, etc. need to be estimated and a spare fund should be set up accordingly.
- When drilling 200 m or deeper, it is favorable to use steel casing. In areas where collapses frequently occur, the casing cannot be installed to the drilling depth due to a bend of a hole or gravel, etc. In that case, the casing installed is pulled out from the hole, and after reaming, the casing is reinstalled. When the casing is installed using uPVC, it is difficult to complete the well drilling. In particular, DTH drilling is difficult because uPVC was probably broken during installation. In addition, it is difficult to install by pushing or rolling. On the other hand, it is a little bit easier to install the steel casing compared with the uPVC, because the steel casing can be pushed or rolled (twisted) to be inserted into a bend in the well hole or to be inserted in a gravel section. Moreover, during well washing, the high pressure of the air can be released and the slime in the hole is removed immediately. This is an advantage of the steel casing.

Suggestions to the Ethiopian side are as follows;

- It is necessary to carry out a long-term training for private companies involved at the center of MoWIE to enhance their well drilling capabilities. For this training, the geological engineers from the private companies are to work in collaboration with the engineers of MoWIE. This training seeks to incorporate high level drilling technology and pumping tests for the available data of ENGWIS. The instructor should be an engineer of the enterprise, a private company or EWTI with a high skill level. EWTI is an important instructor because of the technical assistances of the drilling technology by Japan with hard and soft assistances. In the past a committee had been established for the purpose of improving drilling technology. If this committee still exists, it is favorable to take advantage of this committee effectively.
- It is necessary to input the unit price in consideration with the drilling in difficult geological areas such as African Rift. As high costs are an issue for drilling, it is advisable to secure a budget of 1.5 times more than the drilling cost in African Rift for drilling in Addis Ababa in consideration of the ceiling of the drilling cost.
- The drilling contractors need to be ranked based on an evaluation system that looks at their performance in a training session provided by MoWIE. This will aid in increasing the motivation of the private drilling companies. It is important for MoWIE to use the ranking system to gain an accurate understanding of the level of the drilling companies.

9.2.4 Effective utilization of the water supply plan

The water supply population and unit water supply demand which are basic data of the water supply plan have been discussed within the Project Team and with JICA. The orientation of the main discussions is as follows;

- The water supply population values adopted, in principle, by the Project Team were the population values multiplied by the population growth rates based on the census of 2007. The Project Team interviewed small towns that did not have census data to obtain a water supply population value.

- The number of users coming from outside of the water supply area is not added to the water supply population because there is no evidence for these numbers. The data was based only on the interviews with staff at town water supply offices and water associations. The water supply area in this Project does not include anything outside of the water supply area in small towns.
- Water demand units adopt same values between public tap and private connections as 40 L/c/day in urban; 25 L/c/day in rural. The diffusion rate of private connections leading up to the target year (2020) is calculated by using the logistic curve between years and diffusion rate in each small town.

The effective utilization of the water supply plan based on the above data is suggested following the items listed below;

- Among 19 small towns, 9 were not selected as priority water supply plans. However, the water supply plans were prepared for all 19 small towns. Therefore, the outputs can be applicable for water supply planning by the Oromia Region.
- As for securing groundwater resources in the water supply plans for other small towns than the 30 target towns, the hydrogeological map created in this Project can be applied and the groundwater potential can be checked by this map.

9.2.5 Groundwater development and management

It became easier to obtain the aquifer potential in the middle Awash River Basin by the creation of hydrogeological map in this Project. It can be predicted to have the high possibility regarding the groundwater development by the comparison between the groundwater recharge in the current basin and the estimated yield by the groundwater development from now. The estimated possible yield is calculated as 4 to 52% of the groundwater recharge by the estimated groundwater drawdown which the dry condition does not occur in the groundwater table. However, there are high concentration areas of fluoride in the Project area. Therefore, it is important to closely observe not only the water quantity but also quality in the Project area. The groundwater development and management plans are recommend below in terms of these situations.

- It is important to comprehend the fracture zone by the tectonic activity of faults at the distributed Miocene basalts in regard to the groundwater development of the northwest and southeast highland along the rift valley ridge. These basalts occur for the subsurface geology in the central area of the middle Awash River Basin, and there are many drilling cases for the groundwater development. However, the groundwater level is sometimes deep, for example depth is more than 150 m in the central area. In that case, it desires to install the casing of more than 8 inch diameter with high capacity submersible pump.
- The groundwater productivity in the area between the southeast of the Project area along the rift valley ridge and the Awash River area may be moderate. However, careful attentions shall be paid for selection of the drilling points for the groundwater development, because these areas are located in the recharge area of groundwater flow and faults are not distributed clearly in there areas compared to the rift valley ridge.
- The area between the northwest of the Project area along the rift valley ridge and the Awash River area is that the Tertiary Miocene basalts and Pliocene pyroclastic deposits distributes widely. So it is a high possibility area to make groundwater development.

Recently, high yield areas by wells of the more than 300 m in depth in these areas are also found. However, some wells which catch the shallow water strike are also found, so it is one of selection to stop drilling up to 200 m deep for applications.

- As mentioned in Chapter 4, the high concentration areas of fluoride distributes around the Lake Beseka and Lake Koka, and also dotted at the east-northeast to west-southwest directions along the Awash River. Moreover, the high concentration areas of fluoride concentrate in the northwest of Lake Koka. The geological common points are that the area of high fluoride concentration is recognized around the body of the rhyolitic volcano of the new age relatively in the Quaternary Pleistocene (for example the Volcano of Gedemsa, Zikwala, Boseti, and Fentale). It desires to avoid these area to select the groundwater development points. However, if the drilling points have no other choice but these areas, it is important to set the depth of the well at greater depth (more than 250 m in deep), to seal the upper part of the drilling wells and to make its screens also deeper as an approaches. Moreover, it is difficult to grasp the complex distribution of the contaminated groundwater by fluoride due to the groundwater in the project area is fissure water. It is also consider that fluoride contamination has infiltrate into the lower part along the fissures. As it is described above, there are many uncertain data regarding fluoride issues, therefore at present, it is desired to select an alternative plan in preference to the groundwater development as much as possible in the areas of high fluoride concentration. In the future, the areas with high fluoride concentration should be selected clarifying the mechanism of fluorine generation, and then it is desired to determine the drilling method to be performed in each area through a new project.

- It is high possibility to make groundwater development in the middle Awash River Basin except the area which has few fractured rocks and the area of high concentration of fluoride. It is possible to obtain the estimated possible yield compared to the groundwater recharge in the sub-basins. However, the groundwater storage conditions are controlled by the rainfall and so on. Therefore, as the groundwater recharge will be changed, the groundwater have to be managed from now. The management of the groundwater remains generally the management of the groundwater level. However, cases of monitoring wells in Ethiopia are very few. Therefore, the continuous measurement of groundwater level is being conducted in the JICA wells in the Project. The Project team suggest to manage the groundwater by the management and observation of groundwater level continuously in JICA wells experimentally in the middle Awash River Basin from now. Moreover, it needs to obtain the monitoring data of the yield and water quality in the wells management. The main monitoring items are shown in Table 9.1 (yellow color is the monitoring items).

Table 9.1: Monitoring Items

Drilling Well Information Form

Positional Information (Initial inforamation)

Well No.			
Small Town or Kebele			
Woreda			
Zone			
Well Coordination	E	by	GPS Survey
(UTM)	N	by	GPS Survey
*Datum: Adindan			
Ground level	m	by	SRTM
Level of well top	m	by	

Drilling Information (Initial information)

Drilling depth		m	
Drilling diameter	From	To	Remarks
14"ø	m	m	
10 5/8"ø	m	m	Tricone bit
	m	m	
Loss circulatiton			
Drilling duration			
Well driller			

Well Information (Initial information)

Well depth		m	
Casing and screen			
Diameter	From	To	Type and opening rate
"ø	m	m	GI Casing
"ø	m	m	28% Johnson Screen
"ø	m	m	GI Tail Pipe
	m	m	
	m	m	
Static water level	Initial data	m	Next data m
Pump type			
Pump position			
Engin type	32HP(China Engine)		
Discharge pipe	2½"ø		
Completion date			
Designer			

Pumping Test Information

Parameter	Initial data		Next data	
Sc	m^2/day		m^2/day	
B	day/m^2		day/m^2	
C	day^2/m^5		day^2/m^5	
T (Theis)	m^2/day		m^2/day	
T (Cooper-Jacob)	m^2/day		m^2/day	
T (Recovery)	m^2/day		m^2/day	
S (Theis)				
S (Copper-Jacob)				
Step	Discharge	Drawdown 1	Discharge2	Drawdown2
Duration 120min, 1	L/min	m	L/min	m
2	L/min	m	L/min	m
3	L/min	m	L/min	m
4	L/min	m	L/min	m
5	L/min	m	L/min	m
Continuous	Discharge	Duration	Draw down	
Initial	L/min	min	m	
Next	L/min	min	m	
Recovery	Duraion			
	150 min			
Test duration				
Hydrogeologist				

Geological Information (Initial information)

Summary of geological section	Thickness	Depth
	m	m
	m	m
	m	m
	m	m
	m	m
	m	m
	m	m
	m	m
	m	m
	m	m
Aquifer name		
Main aquifer	Confined	
Facies	From	To
	m	m
	m	m
	m	m
Hydrogeologist		

Water Quality Information

	Initial	Next	
pH (6.5-8.5)			mg/L
Hardness (0-300)			mg/L
TDS (0-1000)			mg/L
Turbidity (5)			NTU
EC (-)			mg/L
F (1.5)			mg/L
HNO3 (50)			mg/L
Fe (0.3)			mg/L
As (0.01)			mg/L
chloride（250）			mg/L
Date			
Analysis agency			

Attached
Columnar section and well structure

Management representative

9.2.6 Countermeasure for the control of Lake Beseka level rise

- The countermeasure for the control of Lake Beseka level rise is that it is almost impossible to trap irrigation return flow before reaching the Lake Beseka. The most practical way to mitigate the influence of irrigation return flow is to install drainage facilities in the Lake Beseka and strive, as far as possible, to release the same amount as there is incoming in the return flow. The existing drainage facilities have sufficient capacity as the countermeasure against irrigation return flow.