The Federal Democratic Republic of Ethiopia
Ministry of Water, Irrigation and Electricity

THE PROJECT FOR GROUNDWATER RESOURCES ASSESSMENT IN THE MIDDLE AWASH RIVER BASIN IN THE FEDERAL DEMOCRATIC REPUBLIC OF ETHIOPIA

FINAL REPORT
EXECUTIVE SUMMARY

December 2015

Japan International Cooperation Agency

Kokusai Kogyo Co., Ltd.

Composition of the Report

Executive Summary

Main Report

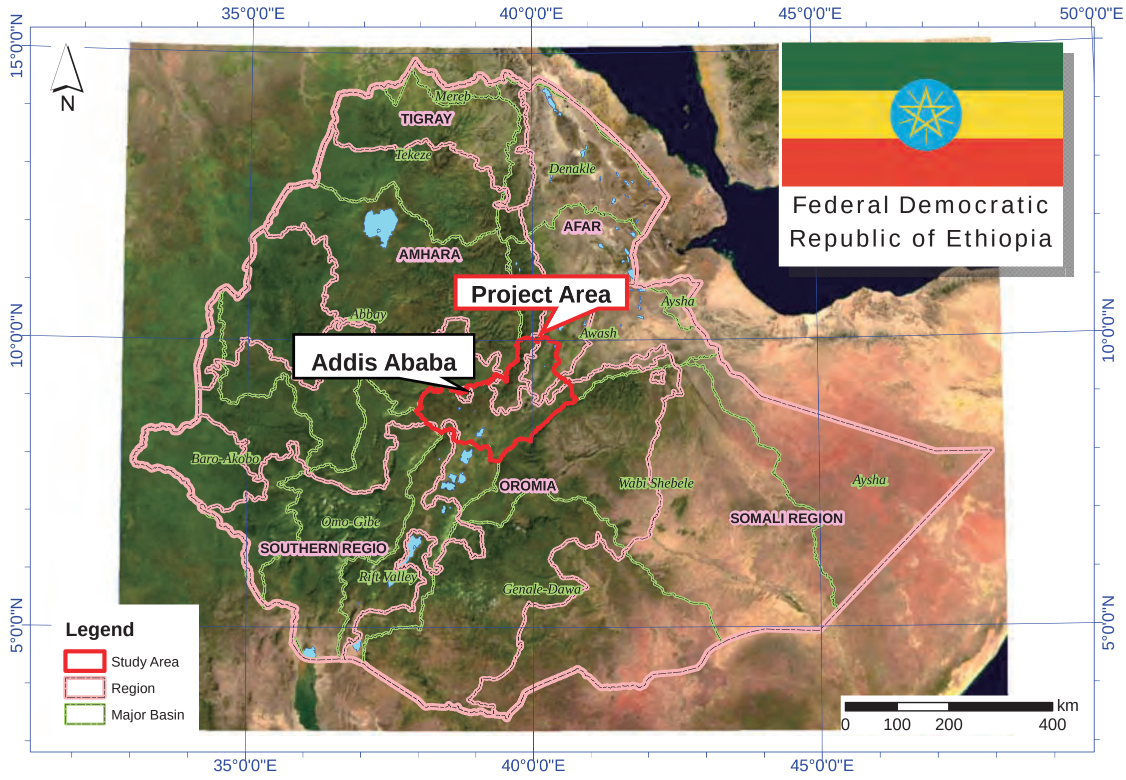
Supporting Report

Data Book

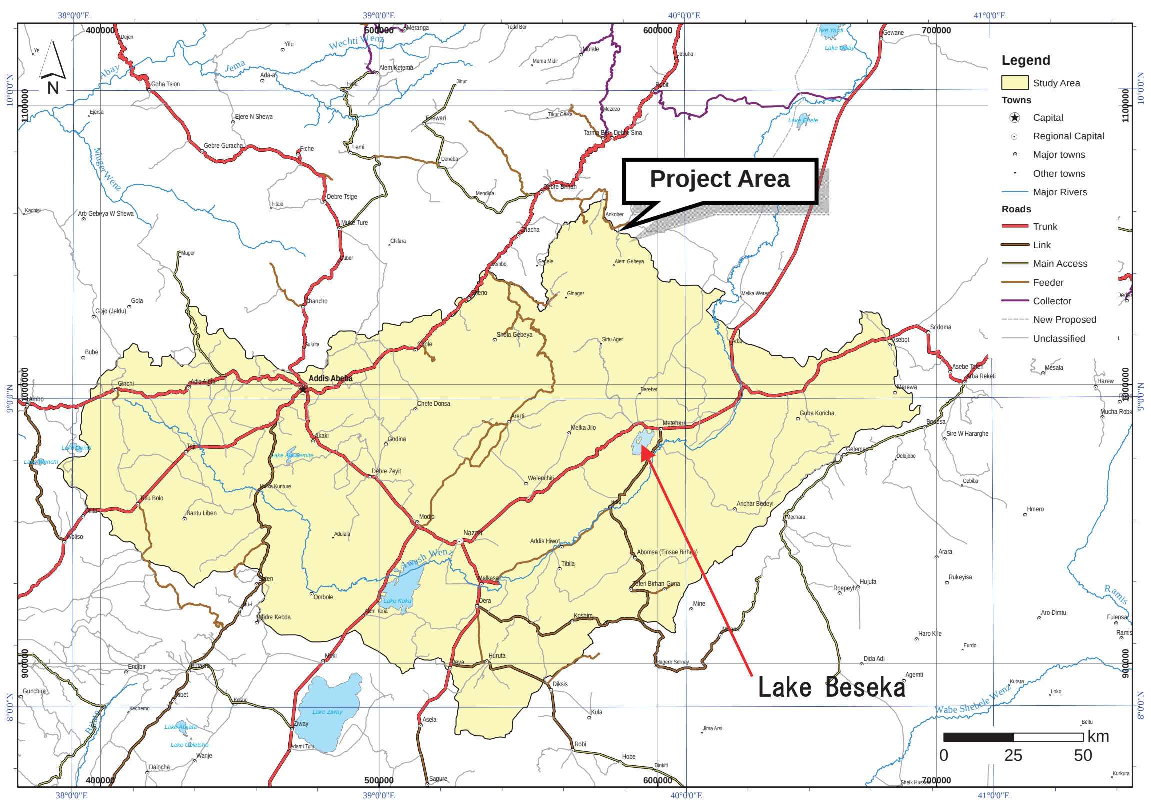
Geological and Hydrogeological Maps

This Report is prepared based on the price level and exchange rate of July 2015.
The exchange rate is:

US$1.0 = ETB20.6298 = JPY123.80



Location of the Study Area



The Middle Awash River Basin

LOCATION MAP

Outlines of the Project

1. Background of the Project

- The access ratio to improved drinking water sources in Ethiopia is 42% in 2008, which is far lower than the average coverage rate of 60% in Sub-Saharan Africa.
- In 2011, the Government of Ethiopia (GoE) formulated a national development plan called the Growth and Transformation Plan (GTP) for the term from 2010/11 to 2014/15.
- To achieve the goal stipulated in the GTP, the GoE is aiming to improve the national average water supply access rate to 100% and 98% in urban and rural areas, respectively, through Universal Access Program (UAP) and UAP2.
- It is important to develop groundwater sources that have a generally stable quantity and relatively good quality for this achievement.
- For better groundwater development in the Middle Awash river basin, a plan shall be formulated based on the information of groundwater recharge and flow mechanisms and stored/developable amount.
- Under such circumstances, the GoE requested the Government of Japan (GoJ) to support a technical cooperation project for development of geological and hydrogeological maps on a scale of 1:250,000 in the Middle Awash river basin and formulation of a provisional water supply development plan in small towns in Oromia Region.

2. Purpose of the Project

- Production of geological and hydrogeological maps in the Middle Awash river basin with scale of 1 to 250,000,
- Assessment of groundwater potential in the Middle Awash river basin,
- Study on the cause of water level rise in Lake Beseka,
- Formulation of provisional water supply plans and selection of priority plans therefrom, and
- Enhancement of the capacities for the groundwater development planning and implementation of the Groundwater Directorate (GD) of the Ministry of Water, Irrigation and Electricity (MoWIE) as well as Oromia Regional Water, Mineral and Energy Bureau (OWMEB),

3. Project Area

- The Project area is the Middle Awash river basin with coverage area of approx. 29,000 km^2. Out of this, the area subject to the map production and water supply planning are approx. 20,000 km^2 and 15,000 km^2, respectively.

4. Schedule and Organization

- The Project commenced in October 2013 and completed in December 2015.
- The JICA Project Team consisted of 12 members.
- The counterpart agencies (C/P) were GD of MoWIE, Ethiopia Water Technology Institute (EWTI) and OWMEB. The Steering Committee (SC) was organized adding

Geological Survey Ethiopia (GSE), Addis Ababa University (AAU) and JICA Ethiopia Office to the C/P agencies.

5. Natural and Socio-economic Conditions

5-1 Geographic features

- The Project area is located about 180 km east of the capital Addis Ababa. It is bounded by the limits of 38^{o}00' – 40^{o}00' east longitude and 8^{o}00 – 9^{o}30' north latitude.
- The area belongs to African Rift and is topographically characterized by the depression zone. The area forms an independent basin.

5-2 Hydrometeorology and water quality

- The average annual mean rainfall at the Middle Awash river basin is 876 mm. The basin is located in the climate area characterized by three distinct seasons: Bega (dry season; October-January), Bleg (small rainy season; February-May), and Kiremt (main rainy season; June-September).
- The annual evaporation amount varies between 1,600 mm and 3,000 mm by observatories.
- The maximum temperature reaches more than 36 ^{o}C in the downstream reaches and temperature drops less than 10 ^{o}C in the high lands.
- The fluoride concentrations of existing wells, springs and lake water often exceed the Ethiopian standard. Other water quality items mostly meet the standard.
- The fluoride concentrations exceed the Ethiopian standard in many existing wells especially around Lake Koka, Lake Beseka, and the western adjacent catchment of Lake Beseka catchment. There is a declining trend of the concentration of fluoride when the wells become deeper.

5-3 Geology and hydrogeology

- The area is widely covered by Pleistocene to Holocene volcanic deposits.
- Three (3) types of aquifers were identified in this Study. They are i) alluvium and lacustrine deposits, ii) Quaternary Pleistocene tuff, and welded tuff and basalt, and iii) Tertiary Pliocene. Miocene tuff, and welded tuff and basalt.

5-4 Socioeconomic conditions

- The census in 2007 shows the population around 6.5 million in the Middle Awash river basin in which around 2.7 million is from Addis Ababa.
- Oromo people occupy 88% of the population in Oromia Region.
- The Muslim is the largest religion (48%) in Oromia Region followed by Ethiopia orthodox (30%) and protestant (18%).
- Oromia Region is the largest region in the country, and agriculture is the basic industry. Eighty percent (80%) of regional population is engaged in agriculture, and agriculture contribution reaches 42% of GRDP.

6. Production of Geological and Hydrogeological Maps

6-1 Geological map

- Geological classification and stratigraphy were examined based on the reconnaissance, review of existing data/information, and data from 11 new wells in this Project.
- Geological maps and cross-sections were produced for the extent of 20,000 km^2 with planar scale of 1 to 250,000.
- Another detailed geological survey was undertaken for the Lake Beseka catchment (520 km^2) and geological map of 1 to 100,000 was prepared.

6-2 Hydrogeological map

- Information on groundwater level, aquifer thickness, yield and water quality, etc. were obtained from exiting data and 11 new wells.
- Aquifer units were classified based on the above information.
- Hydrogeological maps and cross-sections were then produced for the extent of 20,000 km^2 with planar scale of 1 to 250,000.
- Hydrogeological map and cross-sections were prepared in the scale of 1 to 100,000 for Lake Beseka catchment.

7. Groundwater Potential

7-1 Estimation of groundwater recharge

- The Middle Awash river basin was divided into 13 sub-basins and annual groundwater recharge was estimated for each sub-basin based on the relationship among base flow of the river, catchment area and rainfall.
- The estimated annual groundwater recharge is between 47 mm and 87 mm and proportion to the annual rainfall amount is between 7.4% and 9.0%.

7-2 Evaluation of groundwater potential

- A comparison was made between the groundwater recharge in each sub-basin and estimated groundwater usage as of 2035.
- The estimated groundwater usage in 2035 is between 1% and 5% of the annual groundwater recharge in most of sub-basins. It is therefore considered that groundwater wells drilled in these sub-basins will produce a sufficient pumping yield.
- However, 35% of the recharge is estimated to be used in 2035 in the sub-basin which includes Addis Ababa. Other sub-basin showed the usage of around 50% of recharge.
- Increase in groundwater usage by 2035 was estimated based on the projected population. The groundwater drawdown by 2035 was then estimated to 0.02 m – 2.8 m under the condition with conceivable maximum usage (unit water consumption of 50 L/c/d).
- A mathematical model was employed to estimate the allowable groundwater development amount to secure the sustainability in the groundwater cycle in the sub-basins. The result showed the allowable amount of 4% to 52% of the groundwater recharge in sub-basins.

8. Study on Causes of Water Level Rise in Lake Beseka

- The water surface level of Lake Beseka in the Middle Awash river basin has rapidly increased about 12 m since late 1960s.
- Almost all of existing studies and researches conclude that excess water from large-scale irrigation projects have caused this.
- It was concluded that this rapid water level rise could not be explained by irrigation return flow only, through the analyses on water surface temperature by satellite images, water quality, and water balance.
- The satellite image analysis showed the continuous increase of the lake surface temperature. This suggests the inflow of hot groundwater from the adjacent catchment in the west of the lake catchment.

9. Provisional Water Supply Planning and Prioritization

- Provisional water supply plan for 19 small towns in Oromia Region was formulated after screening out 11 towns from 30 considering the project duplications, qualitative potential of groundwater, and comparison of demand and supply, etc.
- Provisional water supply plan consists of intake facilities (boreholes, casing/screen pipes, submergible pump, power supply), transmission facilities (pipes), distribution facilities (reservoirs, pipes, public taps, cattle troughs).
- The target year was set at 2020. The design per capita consumption was set at 40 L/c/d and 25 L/c/d for urban and rural area, respectively, following the current Ethiopian standard.
- The formulated provisional water supply plans were prioritized from the aspects of i) groundwater potential, ii) difficulty of access to safe drinking water, iii) beneficial impact, iv) O&M capacities, and v) environmental/social impacts.
- The priority towns were selected as follows:

Priority	Town	Woreda	Zone
1	Ude Dhankaka	Adaa	East Shewa
2	Biyo	Lome	East Shewa
3	Hardim	Guba Qoricha	West Hararge
4	Aseko	Aseko	Arsi
5	Kamise	Lome	East Shewa
6	Bolo	Jeju	Arsi
7	Areda	Gimbichu	East Shewa
8	Chorora	Anchar	West Hararge
9	Bedeyi	Anchar	West Hararge
10	Hargeti	Mieso	West Hararge

10. Recommendations

Following points are recommended for effective use of the Project's outputs:

- Actual use of groundwater database: Three (3) essential points are recommended for more effective function of existing Ethiopia National Groundwater Information System (ENGWIS).
- Improvement of drilling technology: Two (2) essential points are recommended for

enhancement of drilling capacity by the Ethiopian parties.

- Effective utilization of the water supply plan: Recommendations are made for effective use provisional water supply plans formulated in this Project by Oromia regional authorities.
- Groundwater development and management: Attentions to be paid in groundwater development in the Middle Awash river basin are pointed out both from qualitative and quantitative aspects of groundwater. Also, recommendations for better groundwater management are made to Ethiopian side.
- Countermeasures against lake level rise in Lake Beseka: A measure to cope with water level rise in the lake is proposed.

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Abbreviations

AAU	Addis Ababa University
AGRAP	Alidge Groundwater Resources Assessment Project
AIDS	Acquired Immune Deficiency Syndrome
ALOS	Advanced Land Observing Satellite
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
ASTER-GDEM	ASTER-Global Digital Elevation Model
BFI	Base Flow Index
CAD	Computer Aided Design (System)
CDE	Center for Development and Environment, Ministry of Agriculture
CFC	Chloride Fluoride Carbon
CREC	China Railway Engineering Corporation
CSA	Central Statistical Agency
CSE	The Conservation Strategy of Ethiopia
C/P	Counterpart (organization or personnel)
DB	Datebase
DCI	Ductile Cast Iron
DEM	Digital Elevation Model
DF/R	Draft Final Report
DTH	Down-the-hole Hammer
DWL	Dynamic Water Level
EA	Environmental Assessment
EC	Electric Conductivity
EEPCO	Ethiopia Electric Power Corporation
EGRAP	Ethiopian Groundwater Resources Assessment Program
EIA	Environmental Impact Assessment
EIGS	Ethiopian Institute of Geological Survey, now renamed as Geological Survey of Ethiopia (GSE)
EL	Elevation
ELC	Elc electroconsult milano and Geotermica italiana pisa, Italia (an Italian Consultant)
ELSA	Equilibrium Lake Surface Area
EMA	Ethiopia Mapping Agency
ENGDA	Ethiopian National Groundwater Database
ENGWIS	Ethiopian National Groundwater Information System
EPA	Environmental Protection Agency, now renamed as Ministry of Environment and Forest (MEF)
EPC	Environmental Protection Council
ERA	Ethiopian Road Authority
ERC	Ethiopian Railway Corporation
ESA	Ethiopian Standard Agency
ESIA	Environmental and Social Impact Assessment
ET	Evapotranspiration
EWCA	Ethiopian Wildlife Conservation Authority
EWTEC	Ethiopia Water Technology Center, now renamed as Ethiopia Water Technology Institute (EWTI)
EWTI	Ethiopia Water Technology Institute, formerly known as Ethiopia Water Technology Center (EWTEC)
F/R	Final Report
FAO	Food and Agriculture Organization of the United Nations
FAO-AGLW	FAO Water Resource, Development and Management Services
FDM	Finite Difference Method
FEM	Finite Element Method
GD	Groundwater Directorate (of MoWIE)

GDP	Gross Domestic Product
GHB	General Head Boundary
GIS	Geographical Information System
GL	Ground Level
GNI	Gross National Income
GPS	Global Positioning System
GSE	Geological Survey of Ethiopia
GSP	Galvanized Steel Pipe
GTP	Growth and Transformation Plan
GWR	Groundwater Recharge
HIV	Human Immunodeficiency Virus
IAEA	International Atomic Energy Agency
IC/R	Inception Report
IEE	Initial Environmental Examination
IMF	International Monetary Fund
INGEIS	Instituto de Geocronología y Geología Isotópica (Institute of Geochronology and Geology, Argentine)
ISO	International Standard Organization
ISODATA	The Iterative Self-Organizing Data Analysis Technique
IT/R	Interim Report
ITCZ	Inter-tropical Convergence Zone
JICA	Japan International Cooperation Agency
LEL	Local Evaporation Line
LMWL	Local Meteoric Water Line
M&E	Monitoring and Evaluation
M/M	Minutes of Meeting
MCM	Million Cubic Meter
MDGs	Millennium Development Goals
MEF	Ministry of Environment and Forest, formerly known as Environmental Protection Agency (EPA)
MER	Main Ethiopian Rift
MOA	Ministry of Agriculture
MoWR	Ministry of Water Resources, now renamed as Ministry of Water, Irrigation and Electricity (MoWIE)
MoWE	Ministry of Water and Energy, now renamed as Ministry of Water, Irrigation and Electricity (MoWIE)
MoWIE	Ministry of Water, Irrigation and Electricity, formerly known as Ministry of Water, Irrigation and Energy(MoWIE), Ministry of Water and Energy (MoWE) or Ministry of Water Resources (MoWR)
MSE	Metehara Sugar Estate
MWL	Meteoric Water Line
NASA	National Aeronautics and Space Administration, USA
NGI	National Groundwater Institute
NGO	Non-Governmental Organization
NMA	National Meteorology Agency
OLEPB	Oromia Land and Environmental Protection Bureau
ORP	Oxidation and Reduction Potential
O(R)WMEB	Oromia (Regional) Water, Material and Energy Development Bureau
OWNP	One WASH National Program
OWWDSE	Oromia Water Works Design and Supervision Enterprise
P/R	Progress Report
PA	Preliminary (Environmental) Assessment
PASDEP	Plan for Accelerated and Sustained Development to End Poverty
PC	Personal Computer

PPP	Purchasing Power Parity
PRSP	Poverty Reduction Strategy Paper
PVC	Polyvinyl Chloride
R/D	Record of Discussions
REA	Regional Environmental Agencies
RESTEC	Remote Sensing Technology Center of Japan
RVLB	Rift Valley Lakes Basin
SC	Steering Committee
SCM	Steering Committee Member or Steering Committee Meeting
SDPRP	Sustainable Development and Poverty Reduction Program
SEA	Strategic Environmental Assessment
SFGS	Streamflow Gauging Station
SP	Spontaneous potential
SPOT	Satellite Pour l'Observation de la Terre (French Satellite for Earth Observation)
SRTM	Shuttle Radar Topography Mission
SS	Suspended Solids
TDS	Total Dissolved Solids
TEM	Transient (or Time-domain) Electromagnetic Method
TIR	Thermal Infrared
TM	Thematic Mapper
TOR	Terms of Reference
TU	Tritium Unit
TWSSO	Town Water Supply Service Office
TWSSSE	Town Water Supply and Sewerage Service Enterprise
UAP	Universal Access Program
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNICEF	United Nations Children’s Fund
uPVC	Unplasticized Polyvinyl Chloride
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
UTM	Universal Transversal Mercator
VES	Vertical Electrical Sounding
VIP	Ventilation Improved Pit
WASH	Water Supply, Sanitation and Hygiene Program
WB	World Bank
WC	Water Committee
WFB	Wonji Fault Belt
WHO	World Health Organization
WSDP	Water Sector Development Program
WSSM	Water Supply and Sanitation Master Plan
WWDSE	Water Works Design and Supervision Enterprise
WWMEO	Woreda Water, Mineral and Energy Office
ZWMEO	Zonal Water, Mineral and Energy Office

Project Photos (1/5)

Discussion of IC/R

The discussions held on 5 Nov. 2013 were participated by Ministry of Water, Irrigation and Electricity and Geological Survey of Ethiopia. The M/M was exchanged on 11 Nov

Project Introduction

Introducing the outline of the Project to the stakeholder when purchasing the hydrological information.

Site Visit (1)

Discussion between counterparts and experts regarding the construction period of the railway during the site visit to Lake Beseka.

Site Visit (2)

Currently, the water is being discharged to Awash River by a canal at the eastside of the lake as a countermeasure for water level rise.

Geophysical Survey (1)

The observation drilling sites were selected based on the resistivity information (200 m depth) of underground obtained from the geophysical survey (VES).

Geophysical Survey (2)

The observation drilling sites were selected based on the resistivity information (400 m depth) of underground obtained from the geophysical survey (TEM).

Project Photos (2/5)

Geological Survey (1)

The C/P from MoWIE has accompanied the experts in the geological survey for at least 3 months to finalize the geological map.

Geological Survey (2)

Megacha highly welded tuff that overlies Bofa Basalt to the west of Bofa.

Socio-Economic Survey

Focus Group discussions regarding water use status at Kinteri Town of Oromia Region.

Water Usage Inventory Survey (1)

Survey of existing water facilities at Geldiya Town in Oromia Region.

Water Usage Inventory Survey (2)

Situation at the public water tap of Areda Town of Oromia Region. Twenty litres of water cost around 2 Japanese Yen.

Sampling for IAEA Analysis

The tubing method of sampling Helium gas using copper pipe was instructed in order to facilitate IAEA stable isotope analysis.

Project Photos (3/5)

First C/P Meeting

Discussions on P/R1 held on 24 April 2014, with participants from the Ministry of Water, Irrigation and Electricity and Oromia Region. The M/M was exchanged later.

Site Visit by JICA (1)

Outcrops of rhyolite observed along the Arba River, a tributary of the Awash River. Discussions about geology were had with the C/Ps.

Site Visit by JICA (2)

The topographical and geological field survey was carried out in April 2014 at the Study area with Dr. Suzuki, Professor of Okayama University in Japan.

Wonji Sugar Plantation

This large-scale national sugar plantation is located about 10 km south of Adama Town. The photo shows an interview in regard to the general conditions of the plantation.

Metehara Sugar Plantation

This large-scale national sugar plantation is located about 5 km south of Metehara Town. Its area is more than 10,000 ha. The photo shows a well within the plantation.

Observation Well Drilling (1)

Clay balls made of mixed bentonite and straw are thrown into well AWBH-3 to prevent circulation loses and wall collapses between the surface and a depth of 30 m.

Project Photos (4/5)

Observation Well Drilling (2)

Well cleaning at AWBH-11: High-pressured air is sent into the well to discharge the remaining mud after the completion of the well.

Observation Well Drilling (3)

Pumping test at AWBH-1: The volume of pumped groundwater is measured by reading the water level (cm) which overflows the triangular notch tank.

Sampling for Water Quality Test (1)

Water for quality testing was sampled in existing wells, springs, river water, lake water, and so on. The water quality was classified by analysis. The photo shows the sampling of a deep well in East Shewa

Sampling for Water Quality Test (2)

The photo shows the sampling of spring water at the west side of Lake Beseka. The results of analysis of the spring flowing into Lake Besaka are different from that of other springs.

Sampling for Water Quality Test (3)

Water quality sampling was undertaken in the irrigation farm. The result shows the similar characteristic as south shore of Lake Beseka with high HCO_3 which caused by the vegetation.

Discussion of Progress Report 2

Discussion of P/R2 was held on 24th July 2014 attended by the C/P from Ministry of Water, Irrigation and Energy and Oromia Region. The M/M was exchanged later.

Project Photos (5/5)

GIS Workshop

GIS Workshop was held on 30th January 2015 at MoWIE. The theme was about the outline of GIS database for groundwater resources assessment.

Tone Spring

Tone spring is located at the southwest of Lake Beseka. The discharge volume could not be measured since it is submerged though the spring can be observed.

Environmental and Social Consideration

Situation during an interview at Department of Education at Woreda Office in Mojo. The information/data related to water fetching situation enrollment rate was collected.

Discussion of Interim Report

Discussion of IT/R was held on 11th July 2015. The contents have been discussed with the Deputy Minister of MoWIE. The M/M was exchanged later.

Technology Transfer Seminar

The Technology Transfer Seminar was held on 27th October 2015. The presentation includes the output, tasks and recommendations. The seminar was attended by C/Ps (MoWIE, EWTI, GSE, OWMEB and AAU) and NGOs.

Discussion of Draft Final Report

Discussion of DF/R was held on 27th October 2015 and the utilization method of this reports after the Project period have been discussed. The M/M was exchanged later.

Chapter 1

Project Summary

1 Project Summary

1.1 Background of the Project

The access ratio to improved drinking water sources in Ethiopia is 42% (96% in urban and 32% in rural areas) (UNICEF/WHO, 2008), which is far lower than the average coverage rate of 60% in Sub-Sahara Africa. Therefore, urgent action needs to be taken to secure safe water in Ethiopia. In 2011, the Government of Ethiopia (hereinafter referred to as "GoE") formulated a national development plan called the Growth and Transformation Plan (GTP). In 2011, the GoE revised its Universal Access Program (UAP), which was originally issued in 2006 as a strategy for the water and sanitation sector. The updated UAP (UAP2) aims to improve the national average water supply access rate from 91.5% (estimation of UAP, 2010) to 100% in urban areas and from 65.8% (estimation of UAP, 2010) to 98% in rural areas by 2015 based on a water consumption per capita of 20 liters and 15 liters per day in urban and rural areas, respectively.

To achieve the aforementioned goal, it is important to develop groundwater sources that have a generally stable quantity with only slight seasonal fluctuations and relatively good quality. For better groundwater development in the Middle Awash River Basin, the plan shall be formulated based on the information of groundwater recharge and flow mechanisms and stored/developable amount (groundwater potential).

Under such circumstances, the GoE has requested the Government of Japan (hereinafter referred to as "GoJ") to support a technical cooperation project for development of geological and hydrogeological maps on a scale of 1:250,000 in the Middle Awash River Basin and formulation of a provisional water supply scheme development plan in small towns.

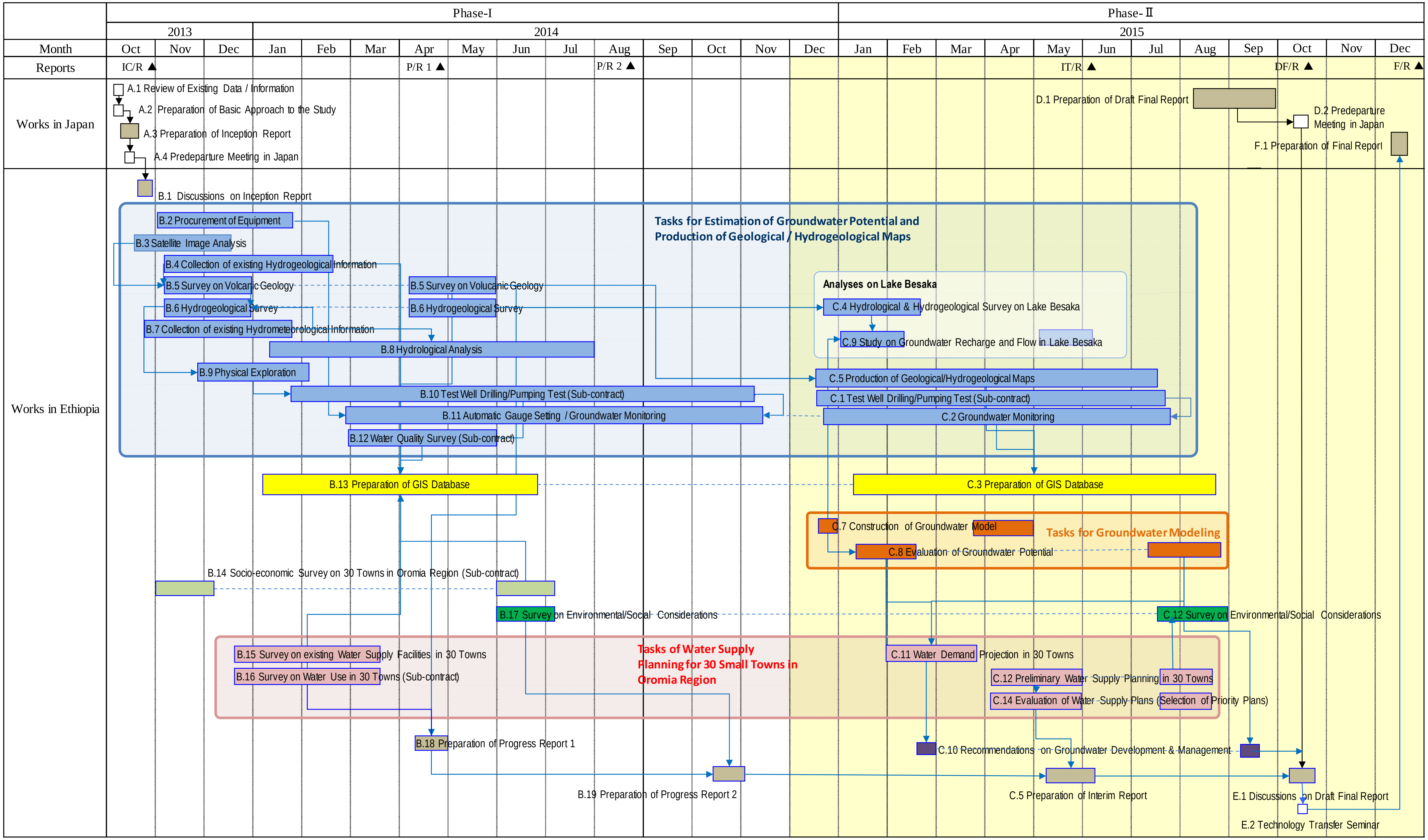
1.2 Objectives of the Project

The objective of the Project is as follows;

- Creation of geological and hydrogeological maps on a scale of 1:250,000 in the Middle Awash River Basin
- Assessment of groundwater development potential
- Investigation and analysis of the Lake Beseka water level rise
- Formulation of provisional water supply facility scheme plans and selection of the priority plans in small towns in the Oromia Region
- Enhancement of the capacities for the groundwater development planning and implementation of the Groundwater Directorate (hereafter referred to as "GD") of Ministry of Water, Irrigation and Electricity (hereafter referred to as "MoWIE") and Oromia Regional Water, Mineral and Energy Bureau (hereafter referred to as "OWMEB")

1.3 Work schedule

This Project, which commenced in October 2013, was completed in December 2015. The work plan of the Project is shown in Figure 1.3.1:



Source: the Project Team, Data: JICA Instruction Document

Figure 1.3.1: Workflow of the Project

1.4 Project area and target areas

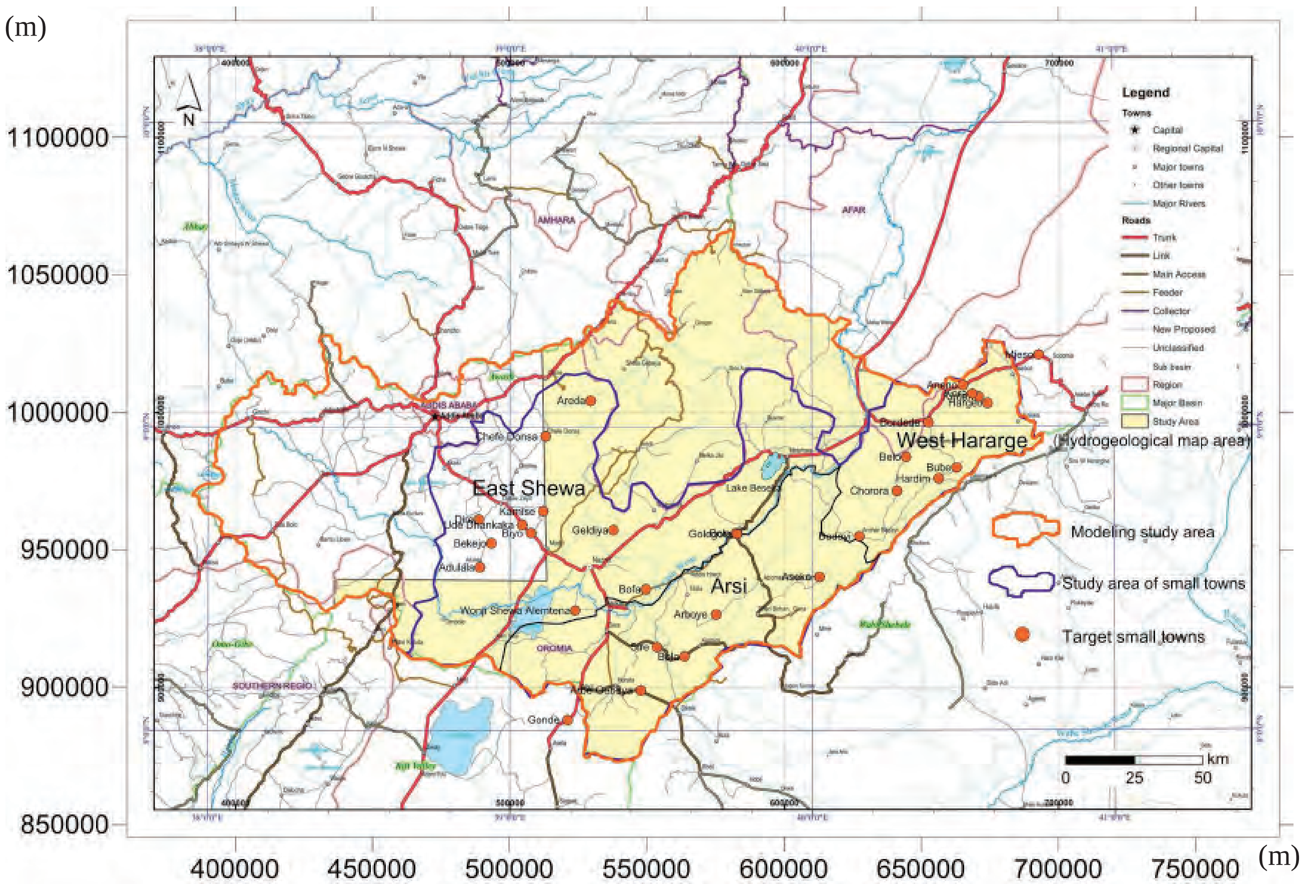
1.4.1 Project area

The Project area is the Middle Awash River Basin. Its coverage area is approx. 29,000 km^2, and the areas subject to the hydrogeological map production and the water supply planning are approx. 20,000 km^2 and 15,000 km^2, respectively. The Project area is shown in Figure 1.4.1.

1.4.2 Target towns

Thirty (30) small towns in the three zones, which are the target towns for the provisional water supply plan in the Oromia Region, were selected with technical notes exchanged between the JICA Team and OWMEB.

- East Shewa Zone: Adama Zuriya woreda (2; Number of target small towns; same as above), Ada A worera (3), Boset woreda (2), Lume woreda (2), Gimbicheu woreda (2), Liben Chikuala woreta (1)
- Arsi Zone: Sire woreda (1), Jeju woreda (2), Aseko woreda (1), Merti woreda (1), Tiyo woreda (1), Lodenhetosa woreda (1)
- West Hararge Zone: Anchar woreda (2), Guba Qoricha woreda (2), Mieso woreda (7)



Source: the Project Team, Data: OWMEB

Figure 1.4.1: Project Area

1.5 Project team and persons involved

1.5.1 Project team

The members of the Team are listed in Table 1.5.1 below.

Table 1.5.1: JICA Project Team

Position or Speciality	Name
Team Leader / Groundwater Resources Development and Management	Toshiyuki MATSUMOTO
Deputy Team Leader / Hydrometeorology/Project Evaluation	Kensuke SAKAI
Hydrogeology / Water Quality Analysis	Hisayuki UKISHIMA
Small Town Water Supply Scheme Development / Water Use Planning / O&M Planning	Satoshi ISHIDA
Groundwater Modelling	Peifeng LEI
Volcanic Geology	Masahiko IKEMOTO
Geophysical Exploration	Mitsuyoshi SAITO
Test Well Drilling	Masatoshi TANAKA
GIS/Database	Yoshimizu GONAI
Environmental & Social Consideration	Shingo ARAI
Socio-economic Analysis	Yosuke YAMAMOTO
Coordinator / Hydrometeorology	Makoto TOKUDA

Source: the Project Team, Data: JICA Instruction Document

1.5.2 Persons of the Ethiopian side involved

The steering committee members and C/P personnel of the Project are shown in Table 1.5.2 and Table 1.5.3 respectively.

Table 1.5.2: List of Steering Committee Members

Name	Position	Organization	Remarks
Ato. Kebede Gerba	State Minister	MoWIE	Chair Person
Ato. Tesfaye Tadesse	GD Director	MoWIE	C/P
Ato. Zebene Lakew		MoWIE	C/P
Ato. Hundie Melka	Chief Geologist	Geological Survey of Ethiopia(GSE)	Member
Ato. Muhuddin Abdela		GSE	Member
Ato. Demissie Alamirew		GSE	Member
Ato. Fekadu Lebecha		OWMEB	C/P
Prof. Tenalem Ayenew		Addis Ababa University (AAU)	Member
Mr. Itsuro Takahashi		JICA Ethiopia Office	Member
JICA Project Team members		JICA Project Team	Member

Source: the Project Team, Data: MoWIE、GSE, OWMEB、AAU、JICA Ethiopia office

Table 1.5.3: List of C/P Personnel

Name	Position	Organization	Remarks
Ato. Tesfaye Tadesse	GD Director	MoWIE	Project director, SCM
Ato. Zebene Lakew		MoWIE	Project coordinator, SCM
Ato. Ketema W/agegnehu		MoWIE	
Ato. Fekadu Lebecha		OWMEB	SCM
Ato. Tamiru Fekadu	Course coordinator	EWTI	

Source: the Project Team, Data: MoWIE、OWMEB、EWTI

Chapter 2

Natural and Socio-Economic Conditions in the Middle Awash River Basin

2 Natural and Socio-Economic Conditions in the Middle Awash River Basin

2.1 Introduction

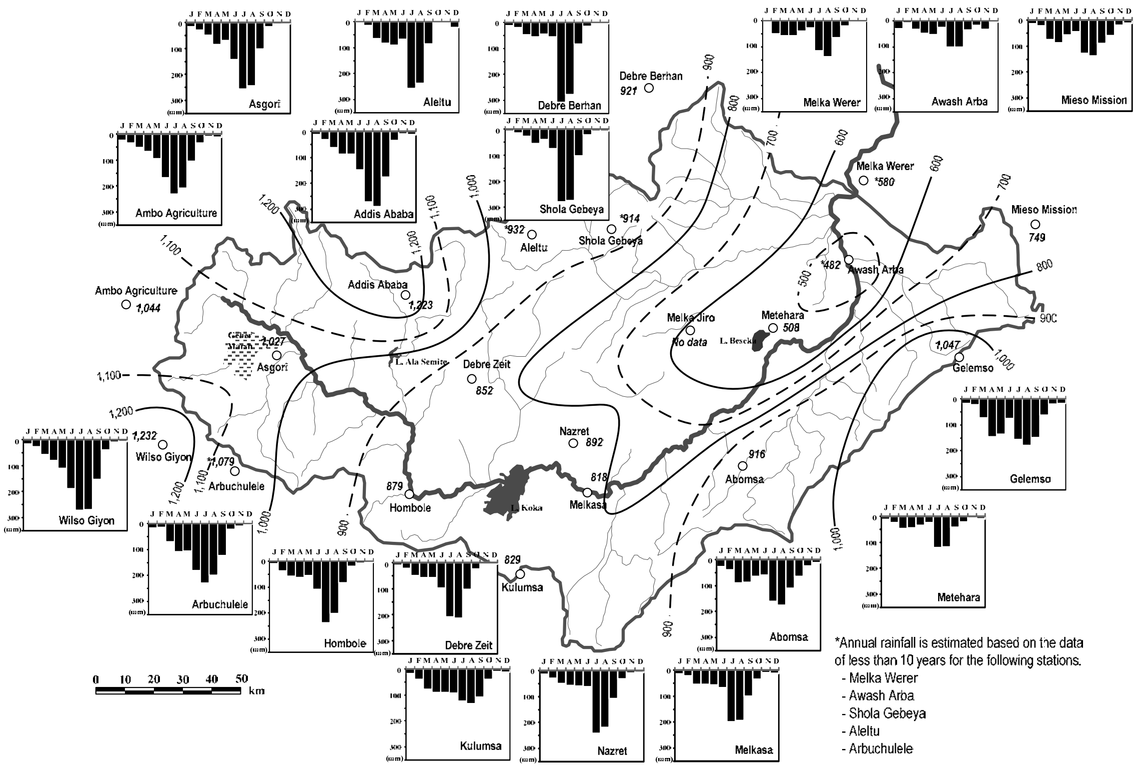
The Project area is bounded by the limits of $38^{0}00'$ – $40^{0}00'$ east longitude and $8^{0}00'$ – $9^{0}30'$ north latitude, and is located southeast area of the capital Addis Ababa. The area is topographically characterized by a depression zone with steep marginal faults along its edges and high land partly within the middle Awash River area called the middle Awash River Basin (which lies within the independent Awash River Basin). The middle Awash River Basin consists of three Regions (the area of each region is: Oromia 55%, Afar 25% and Amhara 20%)

2.2 Meteorology and Hydrology

2.2.1 Review of meteorology data

a. Rainfall

The average annual mean rainfall at the Middle Awash River Basin for the period of 1983–2012 is 876 mm, while no significant tendency in annual rainfall in the Middle Awash River Basin is indicated. Isohyetal map of the Middle Awash River Basin is generated as shown in Figure 2.2.1.



Source: the Project Team, Data: NMA's daily rainfall data

Figure 2.2.1: Isohyetal Map of the Middle Awash River Basin

According to Figure 2.2.1, prominent peaks of monthly rainfall can be seen in July and August. Small rainfall peaks are found in March and April in many observatories. The Middle Awash River Basin is located in the climate area characterized by three distinct seasons: Bega (dry season; October–January), Bleg (small rainy season; February–May), and Kiremt (main rainy season; June–September).

b. Evaporation

The annual evaporation varies between 1,622 mm at Debre Berhan (outside the Awash but adjoining) and 3,023 mm. Evaporation shows its minimal value in the main rainy season, July to September. There is no dominant peak of monthly evaporation and the amount is constantly high during dry and minor rainy seasons.

c. Temperature

Maximum temperature is observed in the late small rainy season or in the beginning of the main rainy season, i.e., from May to June, at every observatory. In the main rainy season, although the maximum temperature reduces, the minimum temperature is higher. The maximum temperature reaches more than 36 °C at the stations of downstream regions. The temperature drops less than 10 °C in the high lands such as Addis Ababa.

In terms of relative humidity, the peak is observed in the main rainy season and annual mean value ranges 60–65% except for the points in dry regions.

2.2.2 Review of hydrological data

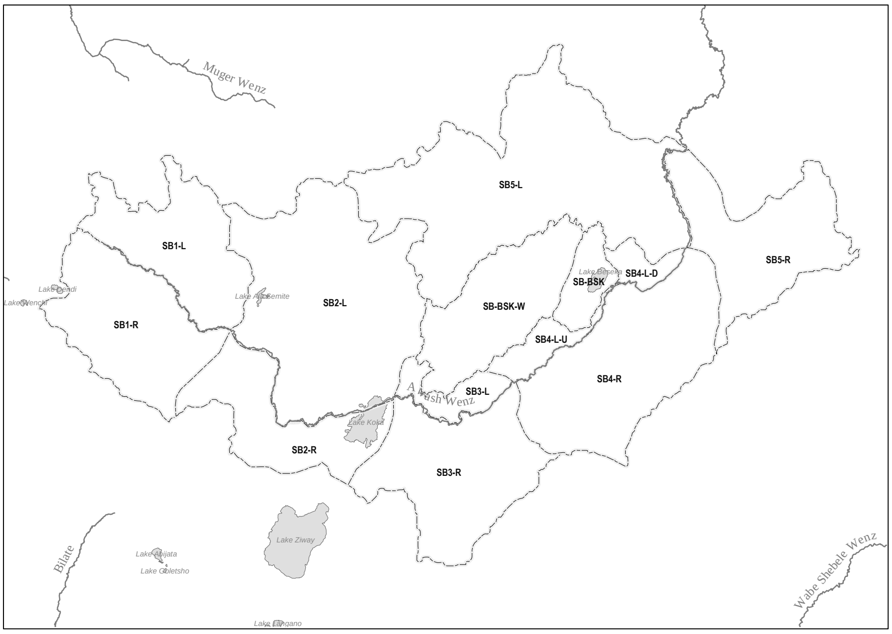
a. Analysis of flow data

According to the data of the Middle Awash River Basin:

- Peak runoffs are observed during the period from the middle of August to the beginning of September while peak of rainfall is observed in July and August;
- The Lake Koka releases constant discharge of approximately 35 m^3/sec in dry season;
- Annual runoff height at Melka Werer, the downstream end of the Middle Awash, is 69 mm, and this is less than 8% of the annual basin mean rainfall of 876 mm (1983 – 2012).

b. Hydrological analysis

One of the main purposes of the hydrological analysis in this Project is to evaluate the available groundwater resources in the Middle Awash River Basin. The Middle Awash River Basin is divided into 13 sub-basins as shown in Figure 2.2.2. First, river flow at selected discharge stations in the Middle Awash River Basin is analyzed to obtain base flow amount (or index), which is considered to be equivalent to groundwater recharge. The relationship between base flow amount and catchment area is then analyzed. Second, total river runoff at the selected discharge stations is compared with the stations' basin mean rainfall amount to analyze the relationship between runoff coefficient and catchment area. Further, the groundwater recharge in the sub-basins is estimated by applying the relationships analyzed above.



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

Figure 2.2.2: Basin Division for Groundwater Recharge Estimation

b.1 River flow analysis

The ratio of the groundwater component in a river flow is defined as base flow index (hereafter referred to as "BFI"). As hydrological stations subject to BFI calculation, the 12 stations are selected. The graph shows high correlation (r > 0.70) between catchment area and BFI.

b.2 Water balance analysis

BFI is the percentage of base flow to the total river runoff. Therefore, the groundwater recharge amount can be quantitatively estimated if the river runoff amount is available.

Runoff coefficient at 12 stations is calculated as the percentage of annual river runoff to annual basin mean rainfall.

In general, the larger the catchment area, the smaller is the runoff coefficient. This can be said for the Middle Awash River Basin. The relationship between catchment area and runoff coefficient is indicated as the high correlation.

b.3 Result of groundwater recharge estimation

The annual groundwater recharge in the divided 13 sub-basins (see Figure 2.2.2) is estimated in the same procedure as that in 12 stations' catchments. In this estimation, both BFI and runoff coefficient (C) are assumed to be the function of catchment area.

Then, annual basin mean rainfall is multiplied by the runoff coefficient and BFI, which are estimated using the relational formula estimated by 12 stations analysis. The annual groundwater recharge is estimated as in Table 2.2.1.

Table 2.2.1: 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)		GWR/R [%]
						[mm/yr]	[10^6 m^3/yr]	
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

The estimated groundwater recharge ranges between 47 mm/year and 87 mm/year and is equivalent to 7.4%–9.0% of the annual rainfall.

2.3 Physiography, Geology and Geological structure

2.3.1 Physiography

The study area belongs to African Rift. The African Rift originates from the Aden Junction and continues in the direction of SW- SSW traverse longitudinally through the eastern African countries such as Djibouti, Eritrea, Ethiopia, Kenya, Uganda, and Tanzania.

2.3.2 Geology

The geological survey was carried out in the divided five areas (Geology around Lake Beseka was described in Chapter 3). The outline of the geology in each survey area is as follows;

a. Adama town, Mt. Boseti and its surrounding areas

Adama town–Mt. Boseti and its surrounding areas are located in the central MER. The rift floor is widely covered by Pleistocene to Holocene volcanic deposits. The lowest unit, named Alaji basalts, is observed at the scarps of the eastern margin and the NE-SW trending faults. Alaji basalts is distributed widely in the survey area and has a chronological age of 24-23Ma according to Chernet et. al, 1998, 14.4Ma according to Kuntz et al., 1975, 28-15Ma according to Morbideli et al., 1975, and 21.06±1.5Ma, 14.94±1.5Ma, 17.4±1.-0Ma according to Kazumin, et al., 1978. Chefeco rhyolites and Pliocene rhyolites overlie Alaji basalts and have formed hilly topography. Nazret pyroclastic deposits are mainly observed at the scarps of the rift margin. Chilalo trachybasalts is observed at the northern foot of Mt. Chilalo. Bofa basalts from Late Pliocene to Pleistocene is well observed at the area, and has a chronological age of 1.21Ma by Kazmin et.al, 1978, and 6.1-4.4 Ma by Morton et al., 1979. Pleistocene, Dino ignimbrite, Quaternary rhyolites, Chefe Donsa pyroclastic deposits and Pleistocene basalts are widely observed on the rift floor. In the Late Pleistocene period, pumice fall from Mt. Boseti, and Fentale ignimbrite are widely distributed on the rift floor and fault scarps. In Holocene, rift floor basalts from volcanic activities in the eastern side of Mt. Boseti.

b. Kone – Mt. Fentale and its surrounding areas

Kone-Mt. Fentale and its surrounding areas are located in the central MER. The basin floor is widely covered by volcanic deposits from the Pleistocene to Holocene periods. WFB (Wonji Fault Belt) is well developed on the floor and margin of the MER in the area. Therefore, Pliocene – Pleistocene strata are generally observed at the scarps of these faults. The lowest unit, named Birenti-Hada rhyolites, is observed at the foot of Mount Bosena. Bofa basalts overlies Birenti-Hada rhyolites at the southern foot of Mt. Bosena, and is widely observed at a gentle slope at the lava plateau. Dino ignimbrite is observed at the northern foot of Kone caldera, the western foot of Mt. Fentale, and is widely distributed at the flat plain of the southeastern plateau. Dino ignimbrite has a chronological age of 1.5 Ma according to Mobidelli et. al, 1975, and 1.51 Ma according to Kazmin, et al, 1978. Tuff ring, Pleistocene basalts, Kone ignimbrite, Kone pumice fall, Fentale volcanic rocks and Fentale ignimbrite are observed in the surroundings of Kone caldera and Mt. Fentale. In Holocene, rift floor basalts and recent obsidian flows from volcanic activity are observed in the southwest of Lake Besaka.

A more detailed geological survey was carried out around Lake Besaka. The details are described in Chapter 3.

c. Mojo town – Arerti town – Debre Birhan town and its surrounding areas

Mojo town-Arerti town, Debre Birhan town and its surrounding areas are located in the central Ethiopian plateau and the central MER. The plateau area is mainly covered by Miocene volcanic deposits and the basin floor is widely covered by Pleistocene deposits. The lowest unit, named Kesem basalts, is observed at the Kesem River. In Debre Birhan, ignimbrite, which consists of ignimbrite and conglomerated stone that is cemented by white ash, overlies Kesem basalts and is widely observed at the northern plateau of the Kesem River. Tarmaber-Megezeze basalts forms a high mountain range, and has a chronological age of 13 Ma according to Zanettin, et al, 1974, and 10.4 Ma according to Chernet et al, 1998. In Pliocene, Bokan rhyolites, Nazret pyroclastic deposits, and Tulu Rie basalts are observed on the basin floor. Nazret pyroclastic deposits are widely observed at the southern flat plain of the Kesem River. Tulu Rie basalts, contrasted as a part of the Bofa Basalt, is observed at the surrounding Mojo area, and has a chronological age of 2.7±0.1 Ma according to INGEIS-Buenos Aires, and 1.44±0.03 Ma according to Chernet et. al, 1998. In Pleistocene, Dino ignimbrite, Chefe Donsa pyroclastic deposits, Zkikala trachyte, Maar deposits, Boseti Pumice Fall, and Fentale ignimbrite are observed at the basin floor.

d. Awash town – Asebe Teferi town and its surrounding areas

Awash town-Asebe Teferi town and its surrounding areas are located in the central MER. The basin floor is widely covered by Holocene deposits. WFB is well developed on the floor and margin of the MER in the area. Therefore Pliocene – Pleistocene strata are generally observed at the scarps of these faults. The lowest unit, named Alaji basalts, is observed at the southern mountain chain. Huse Ridge rhyolites and Anchar basalts overlie Alaji basalts, and are observed at the southern mountain chain with a NE-SW trend. Anchar basalts has a chronological age of 12.4 Ma, according to Kazmin et.al, 1978. Gara Gumbi rhyolites is observed on the basin floor of the remaining hills. Also, Adele rhyolitic tuffs and Bofa basalts are widely observed at the basin floor. In Pleistocene, Dino ignimbrite, Dofan basalts, Asebot welded tuff, Awash acidic volcano-sedimentary rocks and Fentale ignimbrite are widely distributed on the basin floor.

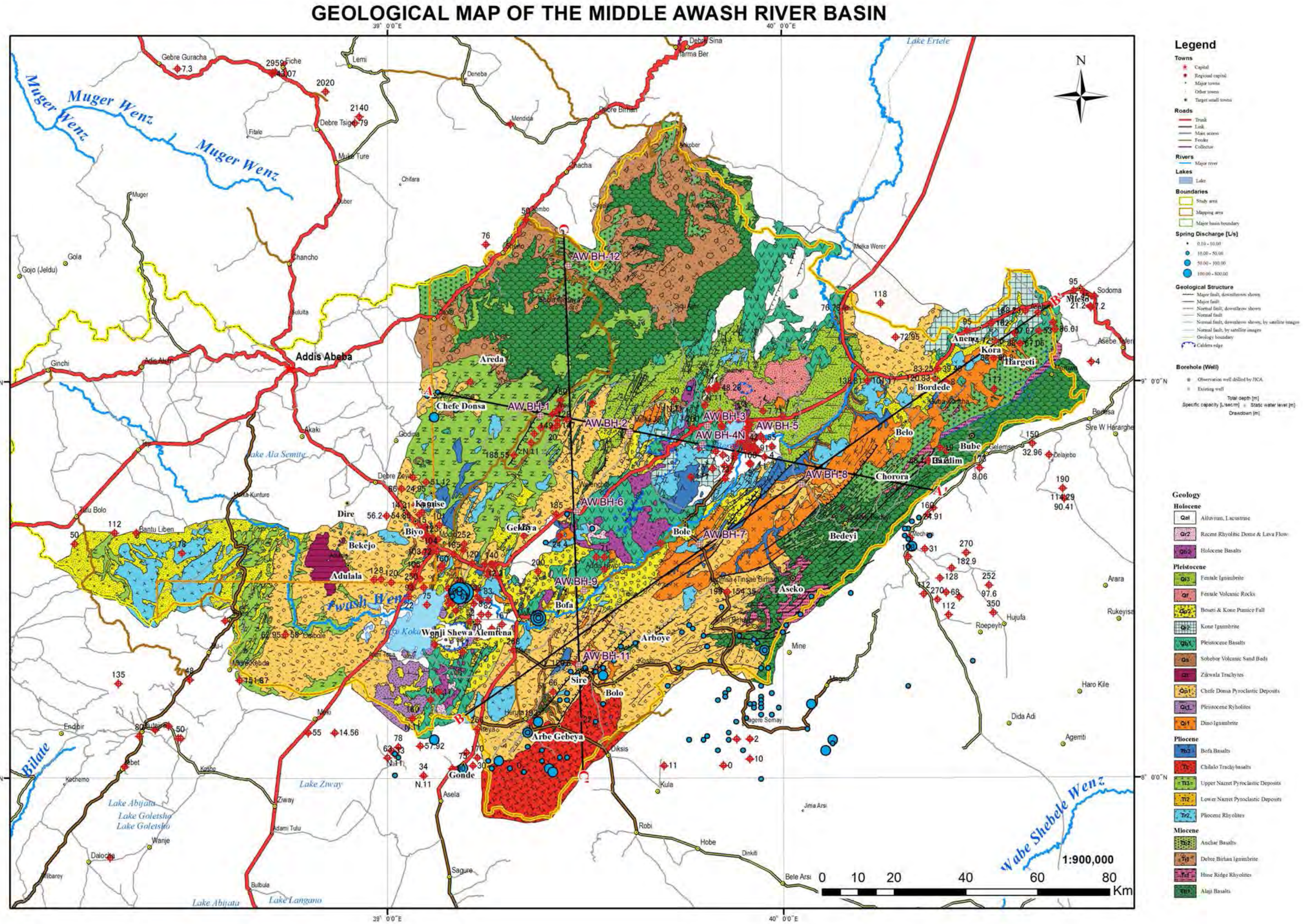
Correlation chart of each stratigraphy is shown in Table 2.3.1.

And the geological map of study area is shown in Figure 2.3.1 and the geological cross section is shown in Figure 2.3.2.

Table 2.3.1: Correlation of Stratigraphy in the Study Area

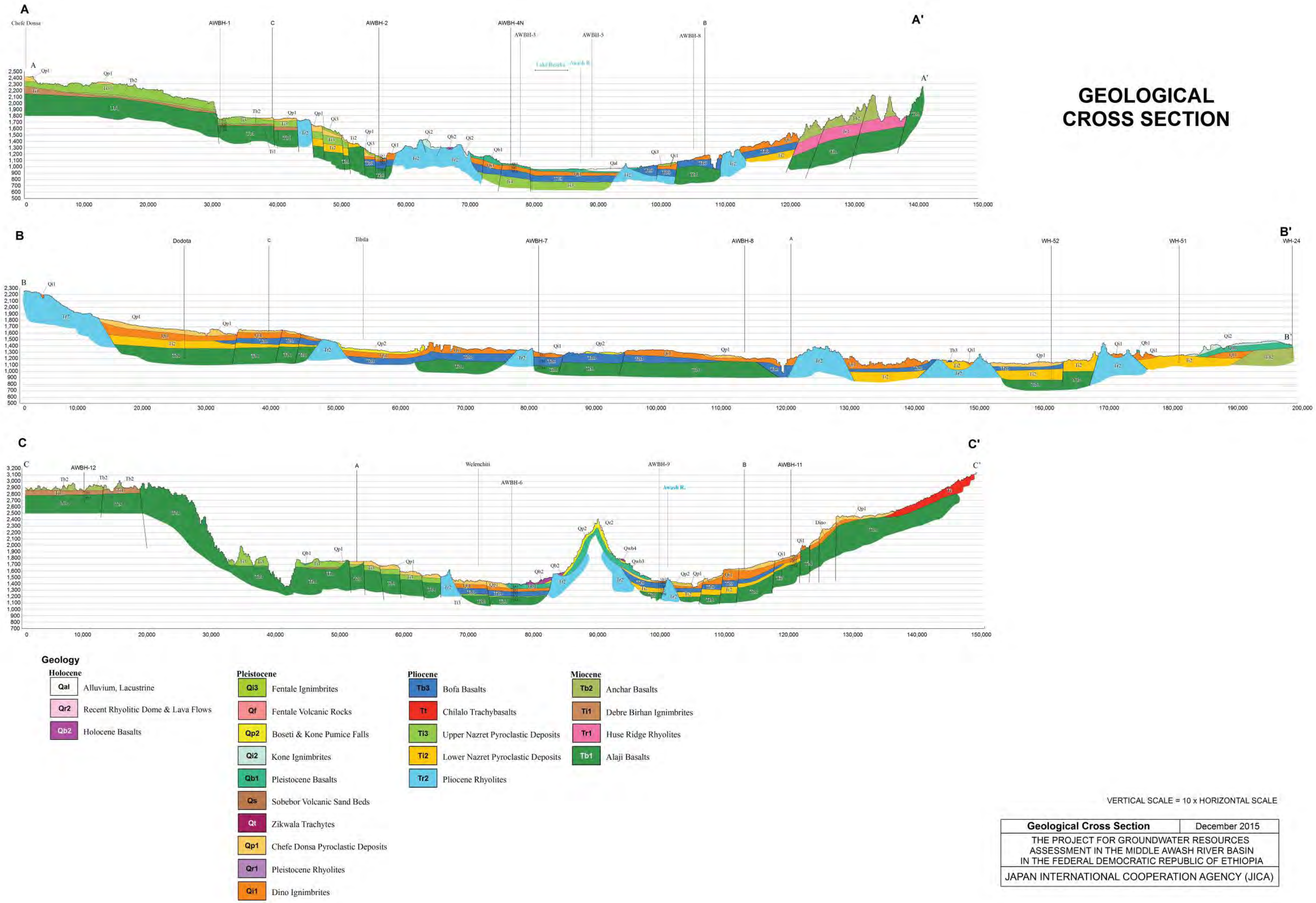
Age			Areas: Nazret-Mt.Boseti	Areas: Kone-Mt.Fantale	Areas: Mojo-Arerti-Debre Birhan	Areas: Awash-Asebe Teferi	Areas: Lake Besaka (1:100,000)	Stratigraphy of the whole study area	Age
Cainozoic	Quarternary	Holocene	Alluvium	Alluvium	Alluvium	Alluvium	Alluvium (Qa)	**Alluvium (Qal)**	
			Recent rhyolitic domes & lava flows	Recent rhyolitic domes & lava flows				**Recent rhyolitic domes & lava flows (Qr2)**	
			Holocene basalts	Holocene basalts			Holocene basalts (Qb2)	**Holocene basalts (Qb2)**	
		Pleistocene basalt	Fantale ignimbrite	Fantale ignimbrite	Fantale ignimbrite	Fantale ignimbrite	Fentale ignimbrite (Qi3)	**Fentale ignimbrite (Qi3)**	168,000±38,000 y (OWWDSE ,2013)
				Fantale volcanic rocks			Fentale volcanic rocks (Qf)	**Fentale volcanic rocks (Qf)**	
			Boseti pumice falls	Kone pumice falls	Boseti pumice falls			**Boseti-Kone pumice fall deposits (Qp2)**	
				Kone ignimbrite		Asebot welded tuffs	Kone ignimbrite (Qi2)	**Kone ignimbrite (Qi2)**	
			Pleistocene basalts	Pleistocene basalts	Pleistocene basalt	Dofan basalt	Pleistocene basalts (Qb1)	**Pleistocene basalts (Qb1)**	Zikwala olivine basalt : 0.61±0.03Ma (Morton et.al.,1979)
				Tuff ring deposits	Maar deposits		Sobebor volcanic sand beds (Qs)	**Sobebor volcanic sand beds (Qs)**	
					Zikwala Trachytes			**Zikwala Trachytes (Qt)**	0.85±0.05Ma, 0.92±0.04Ma, 1.28±0.15Ma (Morton et al.,1979)
			Chefe Donsa pyroclastic deposits		Chefe Donsa pyroclastic deposits	Awash Arba Volcano-sedimentary rocks		**Chefe Donsa pyroclastic deposits (Qp1)**	Chefe Donsa pyroclastic deposits : 1.71±0.04 Ma(Morrton et al.,1979), 2.24±0.3 Ma(IGGI-Pisa)
			Pleistocene rhyolites					**Pleistocene rhyolites (Qr1)**	
			Dino ignimbrite	Dino ignimbrite	Dino ignimbrite	Dino ignimbrite	Dino ignimbrite (Qi1)	**Dino ignimbrite (Qi1)**	Dino ignimbrite: 1.5my (Mobidelli et al., 1975), 1.51 Ma (Kazmun, et al.,1978)
	Tertiary	Pliocene	Bofa basalt	Bofa basalts	Tulu Rie basalts	Bofa basalt	Nura Hira basalts (Tb)	**Bofa basalts (Tb3)**	Tulu Rie basalt: 2.7±0.1 Ma(INGEIS-Buenos Aires), 1.44±0.03 Ma(Chernet et al., 1998) Bofa : 1.21 Ma (Kazumin, et al., 1978), 6.1-4.4 Ma(Morton et al.,1979)
			Chilalo Trachybasalts					**Chilalo Trachybasalts (Tt)**	
			Nazret pyroclastic deposits: Upper		Nazret pyroclastic deposits: Upper		Old ignimbrite (Ti)	**Upper Nazret pyroclastic deposit (Ti3)**	Nwp : 3.5±0.1 Ma, 3.2±0.1 Ma(IGGI-Pisa), 4.7±0.7 Ma, 5.4±0.2 Ma(INGEIS-Buenos Aires), 3.32±0.06 Ma, 3.11±0.06 Ma(Morton et al., 1979)
			Nazret pyroclastic deposits: Lower		Nazret pyroclastic deposits: Lower	Adele rhyolitic tuffs		**Lower Nazret pyroclastic deposits (Ti2)**	
			Chefeko rhyolites	Birenti-Hada rhyolites	Mt. Bokan rhyolites	Gara Gumbi rhyolites	Birenti-Hada rhyolites (Tr)	**Pliocene rhyolites (Tr2)**	
		Miocene			Tarmaber-Megezeze basalts	Anchar basalts		**Anchar basalts (Tb2)**	Anchar : 12.4 Ma (Kazumin et.al., 1978) Mt. Megezeze: 13Ma, (Zanettin et al., 1974), 10.4Ma, (Chernet et al., 1998)
					Debre Birhan ignimbrite			**Debre Birhan ignimbrite (Ti1)**	
						Huse Ridge rhyolites		**Huse Ridge rhyolites (Tr1)**	
			Alaji basalts		Kesem basalts	Alaji basalts		**Alaji basalts (Tb1)**	24-23Ma (Chernet et al., 1998), 14.4 Ma (Kuntz et al., 1975), 28-15 Ma (Morbidelli et al., 1975), 21.06±1.5 Ma, 14.94±1.5 Ma, 17.4±1.0 Ma (Kazumin, et al., 1978)

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



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

Figure 2.3.1: Geological Map of Study Area



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

Figure 2.3.2: Geological Cross-Section of Study Area

2.3.3 Correlation of stratigraphy with previous studies

Results of correlation of stratigraphy established in this study and the previous documents listed below.

Documents and maps	Study area
Kazmin & Berhe (1978)	Nazret area
Alidge Groundwater Resources Assessment Project (2009)	Alidge, Awash area
Oromia Water Works Design & Supervision Enterprise (2013)	Beseka area
GSE (1985)	Dire Dawa area
GSE (2010)	Debre Birhan area
GSE (2010)	Akaki-Beseka area
F. Mazzarini et al (1999)	Debre Zeyt area
JICA (2012)	Rift valley lake zone

2.3.4 Geological structure and volcanic activity

a. Fault system

The MER (Main Ethiopian Rift) is an area of graben showing intense tensional tectonism and the related emplacement of volcanic products. The study area is located in a very complex junction of three important rift structures, two oceanic, the Red Sea and the Gulf of Aden and one continental, the East African Rift (Elc Electroconsult and Geotermica Italiana, 1987).

Boccaletti et al. (1999) summarized the previous study of structural setting of the MER as follows. The occurrence of two distinct fault systems in the MER is recognized; i) a mainly NE to NNE-trending border fault system that defines the rift margins and ii) a N to NNE-trending fault system that is mainly composed of right-stepping en-echelon faults constituting the so-called “Wonji Fault Belt (WFB)” (Mohr, 1960).

b. Active structures

The Wonji Fault Belt (WFB) is formed by several segments of Quaternary volcano-tectonic activity and these segments are disposed en-echelon left laterally (Gibson and Tazieff, 1970).

The general structural pattern of the whole MER suggests the occurrence of a recent sinistral component of displacement along the rift axis. Nearly NNE-trending right-stepping en-echelon segments of the WFB located within the rift zone are arranged obliquely to the Rift margins. This setting is interpreted as evidence of the occurrence of some left-lateral shearing along the Rift (Boccaletti et al., 1999). Kazmin and Barhe (1978) describe the characteristics of the WFB in the study area. The southernmost segment, about 10km wide, extends along the eastern shore of Lake Ziway up to Gedemsa Caldera. It consists of numerous faults and open fractures situated 500 to 1,000m apart. This segment is marked by extensive eruptions of basalts, mainly from the Tulu Moye center and by the large silicic center of Gedemsa. There is no visible continuation of this axial segment in the north of Gademsa. It is substituted by the next segment, which is displaced about 10km to the east. This segment widens to 20km to the north and is marked by the two large silicic centers of Boseti and Kone as well as extensive fissure basalt eruptions. In the north of Kone Caldera, it is substituted by the third segment, which starts from the Fentale.

2.4 Hydrogeology

2.4.1 Hydrogeological basic data collection

a. List of references

The geological map, hydrogeological map in relation to the hydrogeology and main reports have been collected for the references of the Study. Those reports and maps are collected mainly from Geological Survey of Ethiopia (hereafter referred to as "GSE"), Ministry of Water Irrigation and Electricity (hereafter referred to as "MoWIE"), and Water Works Design and Supervision Enterprise (hereafter referred to as "WWDSE") and so on.

b. Existing well data

The collected existing well data are: i) Ethiopia National Groundwater Information System (hereafter referred to as "ENGWIS") inventories managed by Ministry of Water, Irrigation and Electricity (hereafter referred to as "MoWIE"); ii) Well records mentioned in existing reports, and iii) Well drilling records including well columnar sections and pumping test records.

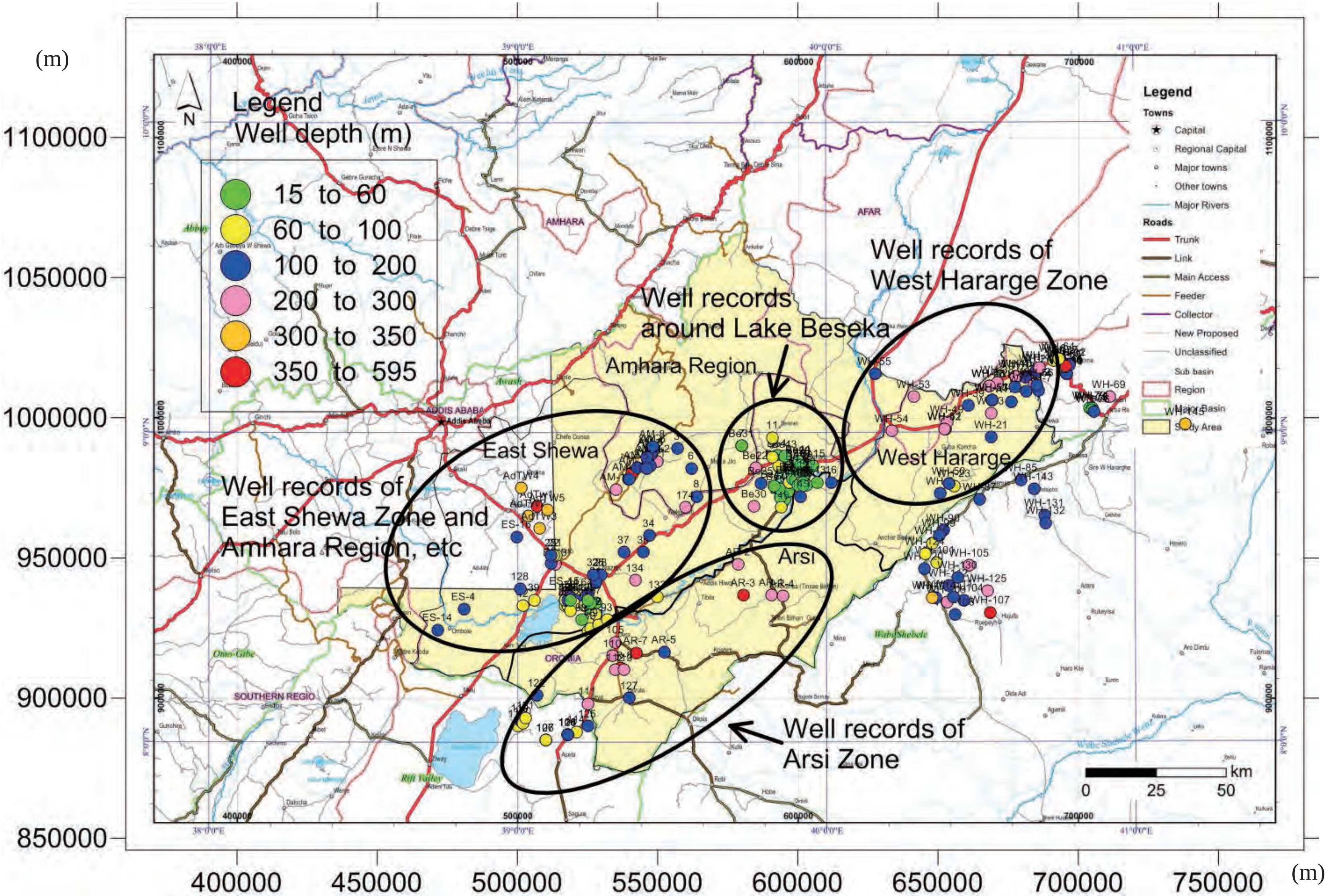
The number of basic data in groundwater has been arranged in the Table 2.4.1 below.

Table 2.4.1: Number of Data by Parameter in Well Database (with coordinates)

Parameter	Number of information
Static Water Level (SWL)	339
Dynamic Water Level (DWL) or Draw down (m)	154
Yield	305
Transmissivity (T)	55
Specific Capacity (Sc)	150
Water Quality Data	128
Geological Columnar Section	87

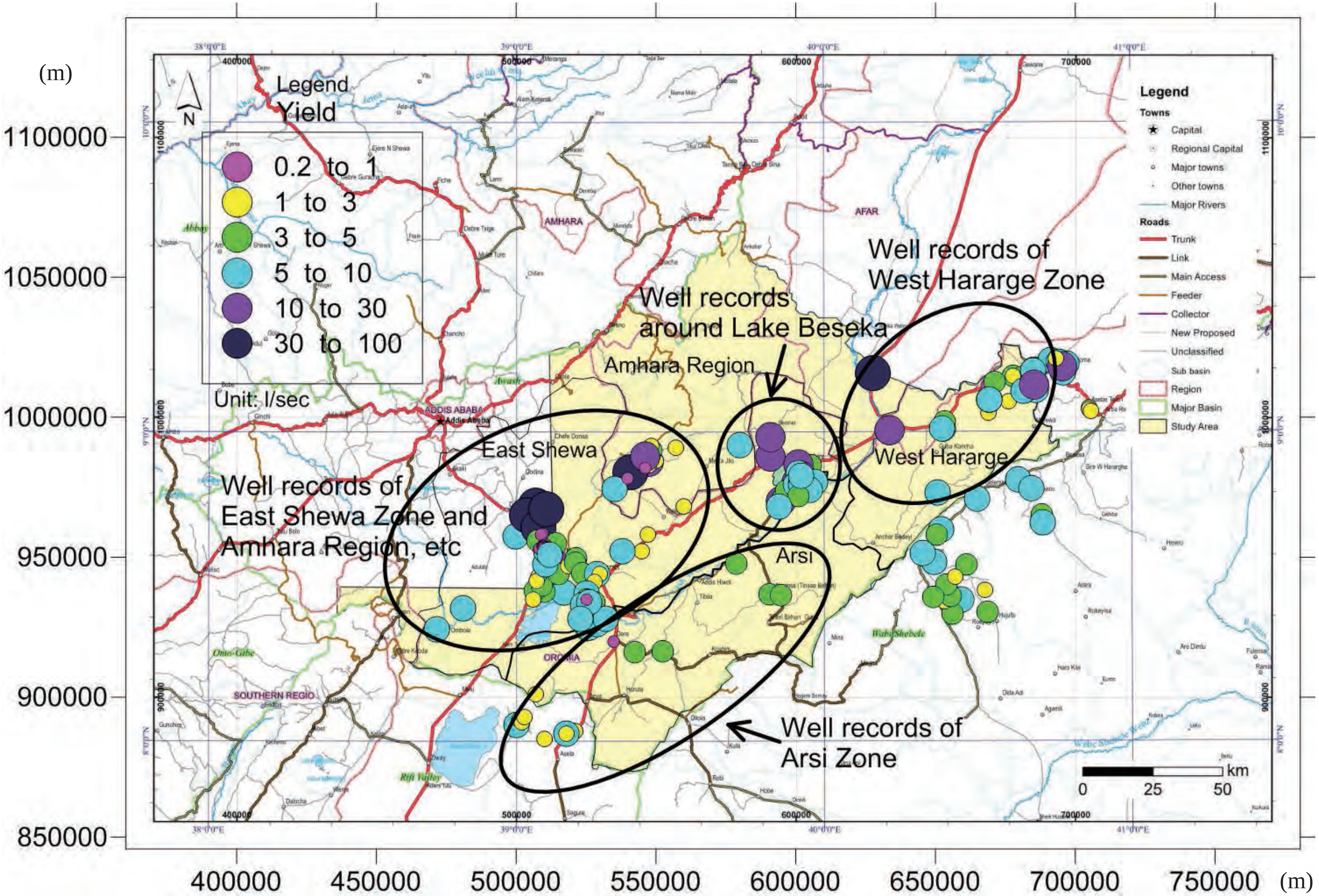
Source: the Project Team, Data: reference①, ②

The location map of the existing wells for the well inventory in each Study area is shown in Figure 2.4.1. The yield data of each existing well is also shown in Figure 2.4.2.



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

Figure 2.4.1: Location Map of Existing Wells



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

Figure 2.4.2: Yield of Existing Wells

2.4.2 Aquifer by existing well

The columnar sections were described based on the lithological data of existing wells. The sample of columnar section includes the screen position and static water level. The existing columnar sections were utilized by themselves. The layers were assumed to be aquifers (depth of screens, grey bars next to column) and their assumed composition ratios and geological units are shown in Table 2.4.2.

Table 2.4.2: Aquifer Lithology and Composition Ratio of Existing Wells

ID	Lithology	Main description in lithology	No.	Composition ratio	Main geological units (existing data)
1	Basalt	Trachytic basalt, Vesicular basalt, Highly weathered and fractured basalt, Massive basalt, Scoriacious basalt	40	29	Miocene Basalts (Anchar, Alaji basalts), Bofa basalts. Pleistocene basalts, Holocene basalts
2	Scoria	Black scoria, Fine gravel with sand	9	7	Distribute with basalt
3	Ignimbrite	Weathered ignimbrite, Fresh ignimbrite, Massive ignimbrite, Boulder ignimbrite	26	19	Nazret pyroclastic deposits, Pliocene rhyolits, Dino ignimbrite.
4	Rhyolite	Highly fractured rhyolite, Weathered rhyolite	6	4	Debre Birhan ignimbrite and Huse Ridge rhyorites, Dino ignimbrite
5	Tuff	Tuff, Indurated tuff, Unwelded tuff, Pumiceous tuff	9	7	Nazret pyroclastic deposits, Dino ignimbrite
6	Phonolite	Fractured phonolite,	4	3	Nazret pyroclastic deposits, Anchar basalts.
7	Welded tuff	Welded tuff	8	6	Kone ignimbrite, Fentale ignimbrite,
8	Pumice	Moderately weathered pumice	7	5	Nazret pyroclastic deposits, Chefe Donsa pyroclastic deposits.
9	Ash	Ash, Volcanic ash	10	7	Nazret pyroclastic deposits, Chefe Donsa pyroclastic deposits.
10	Pyroclastics	Highly weathered Pyroclastics, Pumicious pyroclastics, Volcanic breccia	4	3	Nazret pyroclastic deposits
11	Trachyte	Trachyte	2	1	Chilalo Trachy basalts.
12	Sand, gravel (lower part)	Pumiceous sand, agglomerate, Silica rich sand, Fine to coarse sand with pebble	8	6	Nazret pyroclastic deposits.
13	Lacustrine, Alluvium	Sand and gravel	5	4	Alluvium, Lacustrine deposits

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

The layer of the longest screen is selected as main aquifer in the screen positions and is correlated with aquifer coefficient. The discharge (yield), Specific capacity (Sc) and Transmissivity (T) of each aquifer are shown in Table 2.4.3.

Table 2.4.3: Main Aquifer Information of Existing Wells

Described layer name	Collected data															
	Yield(ℓ/sec)				Specific Capacity(ℓ/sec/m)				Transmissivity(m^2/day)				Depth(m)	
	No	Maxmum	Minimum	Mean	No	Maxmum	Minimum	Mean	No	Maxmum	Minimum	Mean	No	Mean
Basalt	23	60	0.76	12.9	22	56.7	0.067	4.9	18	40800	0.0032	4689	27	190.7
Scoria	1	5.3	5.3	5.3	1	4.53	4.53	4.53	2	14758	378	7568	2	136.5
Ignimbrite (Pumice Flow Deposits, Welded Tuff etc.)	20	25	0.51	7.3	18	89.2	0.0054	8.24	14	6947	0.071	924	20	188.9
Rhyolite	4	11.8	5	8.2	4	2.16	0.61	1.25	4	348.07	34.39	129	5	159.8
Tuff	–	–	–	–	–	–	–	–	1	217.8	217.8	217.8	3	92.3
Phonolite	2	50	20	35	2	44.64	0.521	22.58	2	39528	102.4	19815	3	233.7
Welded tuff	1	4	4	4	–	–	–	–	3	996.2	60.4	595	3	34.6
Pumice	4	16.68	1.6	7.1	4	7.14	0.311	2.44	1	16.56	16.56	16.56	4	113
Ash	4	12	1	4.1	1	12	12	12	–	–	–	–	4	55.9
Pyroclastics	3	30	1	11.8	1	7.14	7.14	7.14	–	–	–	–	3	264.3
Sand/Gravel	5	9.2	2	4.9	5	6.66	0.17	2.26	–	–	–	–	5	95.6
Lacustrine deposit	5	4.5	1.3	2.6	3	0.65	0.06	0.34	–	–	–	–	5	75.4
Alluvium	3	8	6	6.8	2	1.6	0.6	1.1	1	965.9	965.9	965.9	3	44

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

2.5 Socio-economic conditions

2.5.1 Socio-economic conditions in the Middle Awash River Basin

a. Population and demographic characteristics

The more than 32 million people are living in Oromia Region as of 2013, and the area in Oromia Region is the largest region in Ethiopia. The statistics in 2007 shows the population around 6.5 million in the Middle Awash River Basin (in which around 2.7 million is from Addis Ababa).Tthe ratio between male and female is balanced in both city and rural area.

Ratio of ethnic groups in Oromia Region is Oromo people (around 88%), Amhara (around 7%) Gurage (around 1%) and others (4%).

The Muslim is the largest religion (around 48 %) in Oromia Region followed by Ethiopian orthodox (around 30%) and y protestant (around 18%) and others (around 4%).

In Oromia Region, the local people mainly speak Oromiffa language (around 84%) though there are some people speak Amhara language(around 11%) as national common language.

b. Local administrative divisions

Ethiopia is composed of 9 regional government and 2 administrative cities except Addis Ababa. Each region is composed of many zones. Each zone is composed of many woredas. Each woreda is composed of several towns and regional kebeles. Oromia region is divided into 18 zones.

c. Regional economy

Oromia region is the largest region in the country, and agriculture is the basic industry after Addis Ababa. In 2012, 80% of regional population was engaged in agriculture, and agriculture contribution reaches 42% of total regional GDP.

More than 80 % of the male population is engaged in agriculture. The female population is engaged in other industries except agriculture.

In Oromia Region, there are not only agriculture resources but also tourism resource such as Awash National Park and Sodere hot springs, and water resource such as Awash River and Rift Valley lakes.

c.1 Agriculture

The main crops of agriculture production in Oromia Region are cereals. The other grains such as pulses and oilseeds are relatively little. The agriculture products in large quantities are sugarcane, coffee, potatoes, khat (preference crops) and cut flowers. In the middle of Awash River Basin, the national farms in large scale for sugarcane lie in Wonji/Wonji Shewa and Metehara. In case of livestock, main animals are cattle, sheep, goats, and poultry chickens.

c.2 Condition of social infrastructure (road, electricity, etc.)

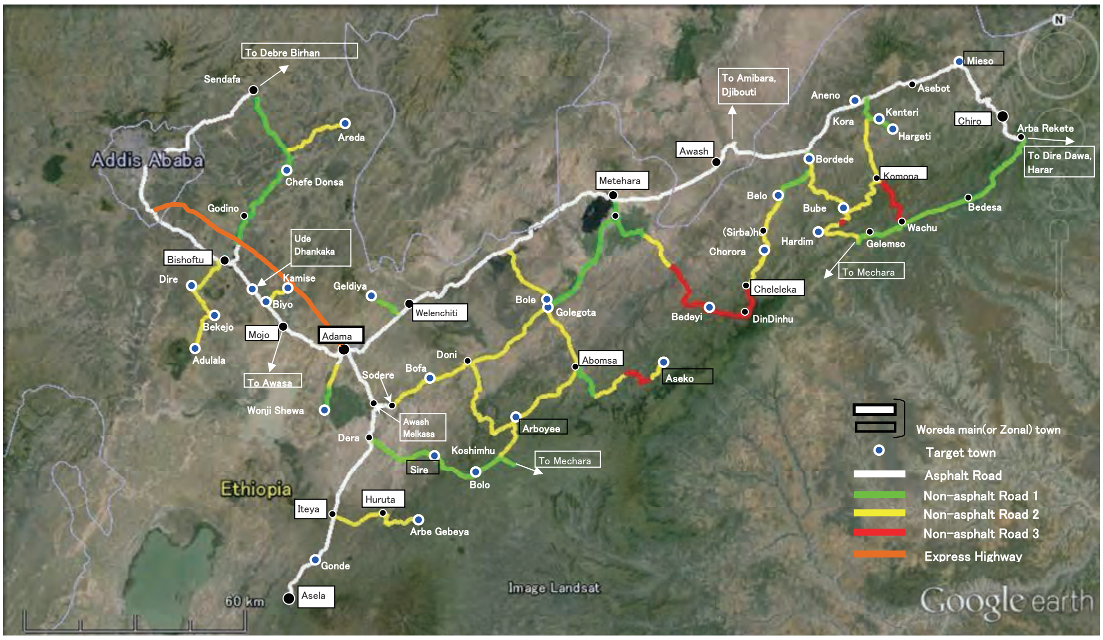
c.2.1 Road condition

Improvement of infrastructure to develop rural area economy is very important. The current road condition in the Middle Awash River Basin is described below.

Table 2.5.1: Characteristics of Legend between the Target Towns (for Access Route Map)

Type	Item	Characteristics
(white bar)	Asphalt Road	It is the most comfortable road to travel on. It is possible to travel at speeds of 50～80km/hr.
(green bar)	Non-asphalt road 1	Although it is non-asphalt road, the road surface is kept flat with heavy machineries. It is comfortably travelable all year. It is possible to travel at speeds of 30～50km/hr.
(yellow bar)	Non-asphalt road 2	It is non-asphalt road, and it is assumed that long time passed since its last road maintenance. The road surface is bumpy and it takes a long time to transit. It is possible to travel at speeds of 15～30km/hr.
(red bar)	Non-asphalt road 3	There would be considerable difficulty in passing this type of non-asphalt road. The road surface is very bumpy and there are many large and small stones on the road. Besides, the road is very steep. It is possible to travel at speeds of 10～15km/hr, however, it is not passable in the rainy season.

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



Source: the Project Team, Data: Google Earth

Figure 2.5.1: Location and Access Road for 30 Target Towns in Oromia Region

c.2.2 Electricity

The electricity of Oromia Region is mainly covered by the supply source of hydroelectric power. The power producer is Ethiopia National Electric Power Corporation. However, the electric supply are still insufficient at major cities such as Adama and Bishoftu which causing a sudden black-outs especially in West Hararge zone.

2.5.2 Socio-economic conditions in the woredas with target small towns

In order to understand the current condition for the Project O&M performance, socio-economy and water supply of every woreda water management bureaus, interview surveys were conducted in 15 woredas for 30 target towns. The woredas are 6 in the East Shewa zone, 6 in the Arsi zone and 3 in West Hararge.

a. Ethnic group, Education

Oromo people, the most common people in Oromia region, is the majority for all Woredas sharing 80% or more in 13 Woredas out of 15. Amhara people is the second majority. They share 30% in Sire Woreda and some 10% in other Woredas.

Average number of primary schools per Woreda is 41. Attendance ratio for primary school is about 73% in average for all objective Woredas. The rate is lower in West Hararge, that reaches about 50% only. Average number of children with age of 7 to 14 per primary school ranges between 400 to 900.

b. Agriculture and land use

The area of agricultural land reaches about 44% and forest covers about 16%. Sixty (60) percent of the land is therefore shared by these two types.

In terms of main crops, teff and wheat are dominant both in area and yield bases. Teff shares about 27% and wheat shares about 20% in cropping area. The former shares about 19% and the latter shares about 28% in yield amount.

Goats (31%), cattle (26%) and sheep (22%) are the dominant livestocks in all Woredas. Chickens share approx. 13% in the numeral basis. Number of camels is larger in Merti (Arsi zone) and Mieso (West Hararge zone).

c. Health and Hygiene

The reporting numbers of water-related diseases at the health center of every 15 woredas for target towns are shown as diarrhea and malaria are the major diseases. Both share about 38% each. Typhoid, which shares about 21%, is also the major disease.

Simple pit for the hygiene facility is dominant in the objective woredas,

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 Ararti（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 3

Hydrology and Hydrogeology Analysis around Lake Beseka

3 Hydrology and Hydrogeology Analysis around Lake Beseka

3.1 The Lake Beseka Issues

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.

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.

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.

In this Project, the survey and analysis on topography, geology, geological structures and hydrogeology around Lake Beseka are undertaken. 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.

3.2 Topography, geology and geological structure

3.2.1 Topography

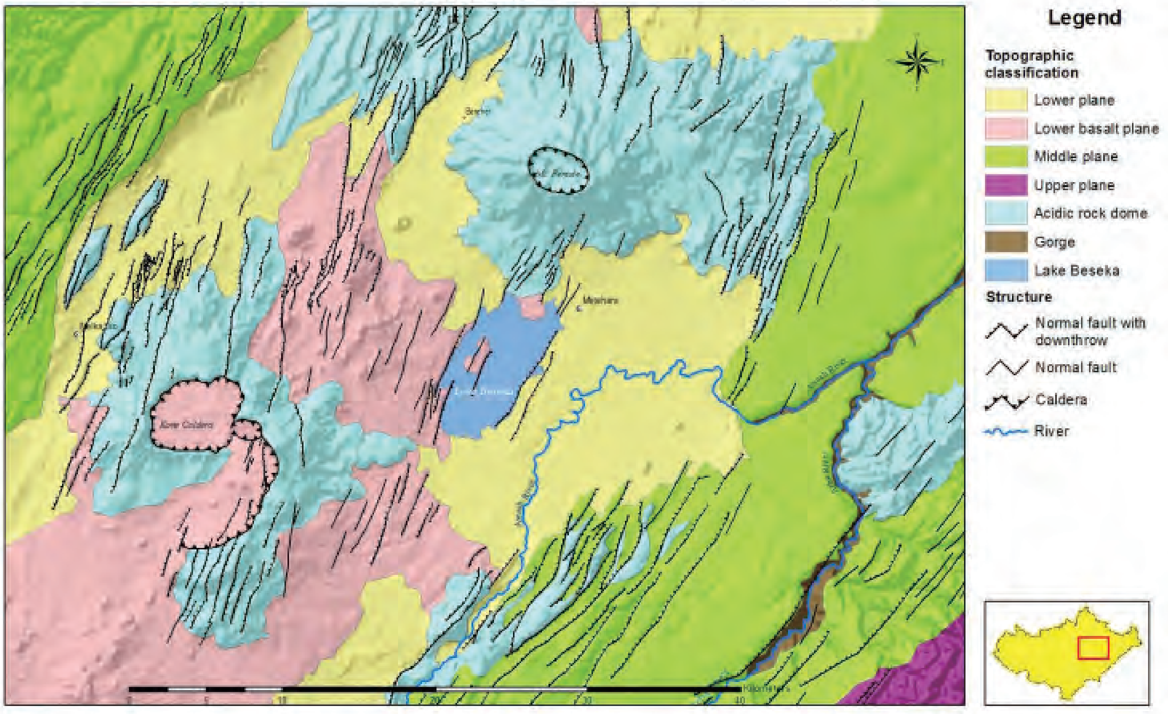
The topography around Lake Beseka is divided into seven classes taking volcanic ejecta, deposits and geological structure into consideration. Each characteristic is explained in Table 3.2.1. A topographic classification map is shown in Figure 3.2.1.

Table 3.2.1: 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

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

Figure 3.2.1: Topographic Classification Map around Lake Beseka (background: shaded relief map created from ASTER DEM data)

3.2.2 Geology

A detailed geological field survey was conducted and the geological map of the area was revised. A geological map and sections of Lake Beseka area (detailed study area) are shown in Figure 3.2.2 and Figure 3.2.3.

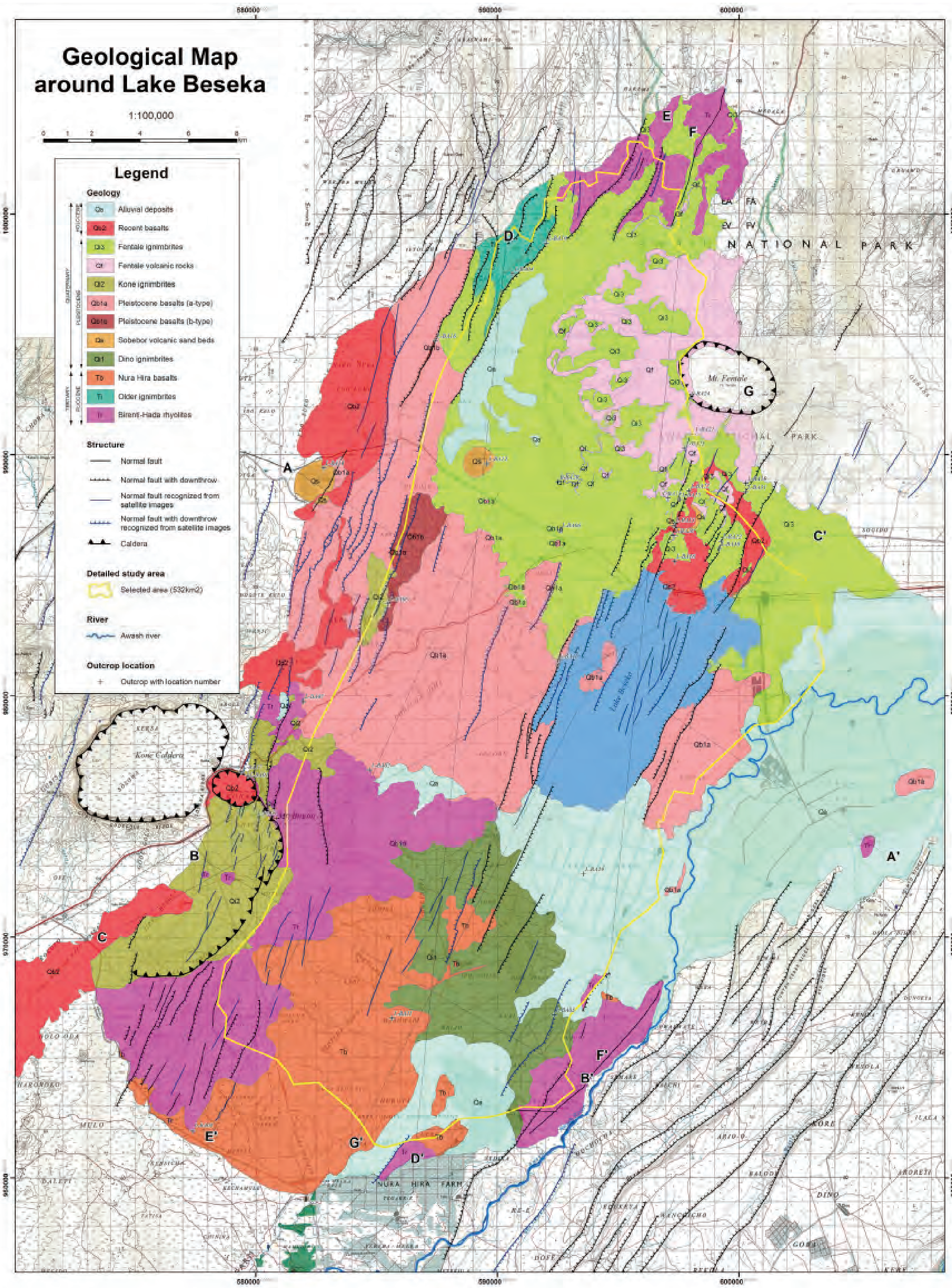
Geological units are classified as shown in below:

Table 3.2.2: Classification of Geological Units around Lake Beseka

Geologic Time	Geological Unit	Characteristics
Quaternary Holocene	Alluvial deposits	● Mainly a flood plain deposit of the Awash ● Most of the area is now utilized for plantations
	Recent basalts	● Black vesicular aphyric basalt ● Youngest volcanic ejecta ● Located at the southern foot of Mt. Fentale and reaches Lake Beseka ● Little vegetation on and maintains its original shape ● Very low viscosity and spatter cones & lava tunnels are developed
Quaternary Pleistocene	Fentale ignimbrites	● Composed of greenish gray to whitish gray welded to unwelded tuff and pumice erupted from Mt. Fentale ● Distributed at the slope & foot of Mt. Fentale and surroundings ● Includes a lot of lapilli & develops glassy (obsidian) lens structure
	Fentale volcanic rocks	● Composed of acidic rocks which form the main body of Mt. Fentale

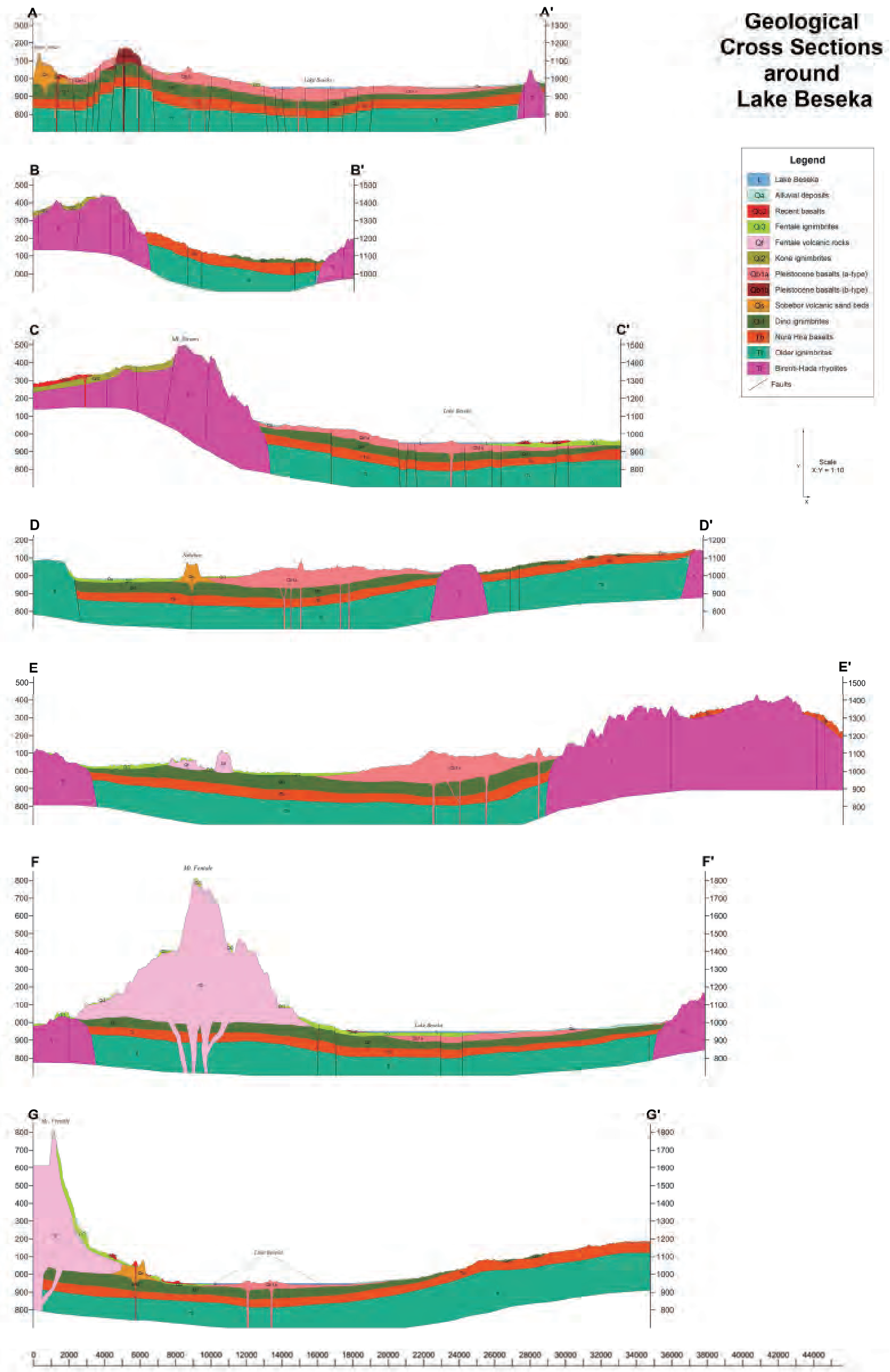
Geologic Time	Geological Unit	Characteristics
		● Composed of rhyolite and trachyte lavas in which phenocrysts of alkali feldspar and hornblende are scattered ● Lava surface is block type with a diameter from several dozen cm to about 1 m ● Lavas are very glassy and are black to deep green in color
	Kone ignimbrites	● Composed of greenish gray to gray colored highly welded tuff to unwelded tuff and pumice mainly distributed east of Kone caldera ● Contains lots of hornblendes of 1-3 mm & foreign lapilli of up to several cm
	Pleistocene basalts	● Composed of basalts and scoria mainly in the west and east of Lake ● Divided into a-type and b-type <u>a-type</u> ➢ Occupies most of the area ➢ Contain lots of olivine and pyroxene phenocrysts of 0.5-1 mm with black with fine grained matrix ➢ Lava is very vesicular near surface & often filled with the secondary mineral (zeolite) <u>b-type</u> ➢ Only in the west part of Lake catchment ➢ 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
	Sobebor volcanic sand beds	● Observed at only 3 locations arranged so as to draw a gentle arc shape ● Forms an independent hill (tuff ring) ● Vast in hill size and have big craters with 0.5 to 1 km-diameter ● Composed of thick layers of yellowish brown volcanic sand and silt with lamina with 2 to 10 cm-thickness ● Lamina inclines towards the outside from the center 20 to 30 degrees
	Dino ignimbrites	● An extension of the widely distributed welded tuff mainly distributed SE out of the Lake catchment between the right bank of the Awash & the Arba ● Thinly (max. about 5 m thick) distributed at SW of Lake Beseka ● Forms flat topography ● The tuff is greenish gray colored and weakly welded ● Includes hornblende
Tertiary Pliocene	Nura Hira basalts	● Composed of black aphyric basalt lavas ● Newly named considering petrology, topography & stratigraphy ● Topography by this is flat/continuous and covered by thicker shrubs ● Most of the basalts of this unit are aphyric
	Older ignimbrites	● Widespread ignimbrites composed of greenish to greenish gray highly welded tuff to slightly welded tuff and pumice ● Outcrops in the NNE-SSW trending located at the northwest area ● Expanding out of the Lake catchment further westwards ● Composed of several flow units with different welding grades
	Birenti-Hada rhyolites	● Distributed in the west to the southwest of the detailed study area ● Gray to greenish gray in color ● Matrix is fine grained and often glassy with flow structures ● Scattered with hornblende and feldspar phenocrysts ● Platy joints develop around the surface and massive inside the lava body ● Obsidian bands develop from around Mt. Bilenti to the southwards

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



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

Figure 3.2.2: Geological Map around Lake Beseka



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

Figure 3.2.3: Geological Section around Lake Beseka

3.2.3 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). 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. 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)) in north of Lake Beseka.

3.3 Hydrogeology

3.3.1 Aquifer classification and groundwater Flow

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. 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 classification of aquifers was conducted as shown in Table 3.3.1.

Fluoride concentration in the water around Lake Beseka is high and exceeds the Ethiopian standard. There is no correlation between fluoride concentration and depth.

Table 3.3.1: 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

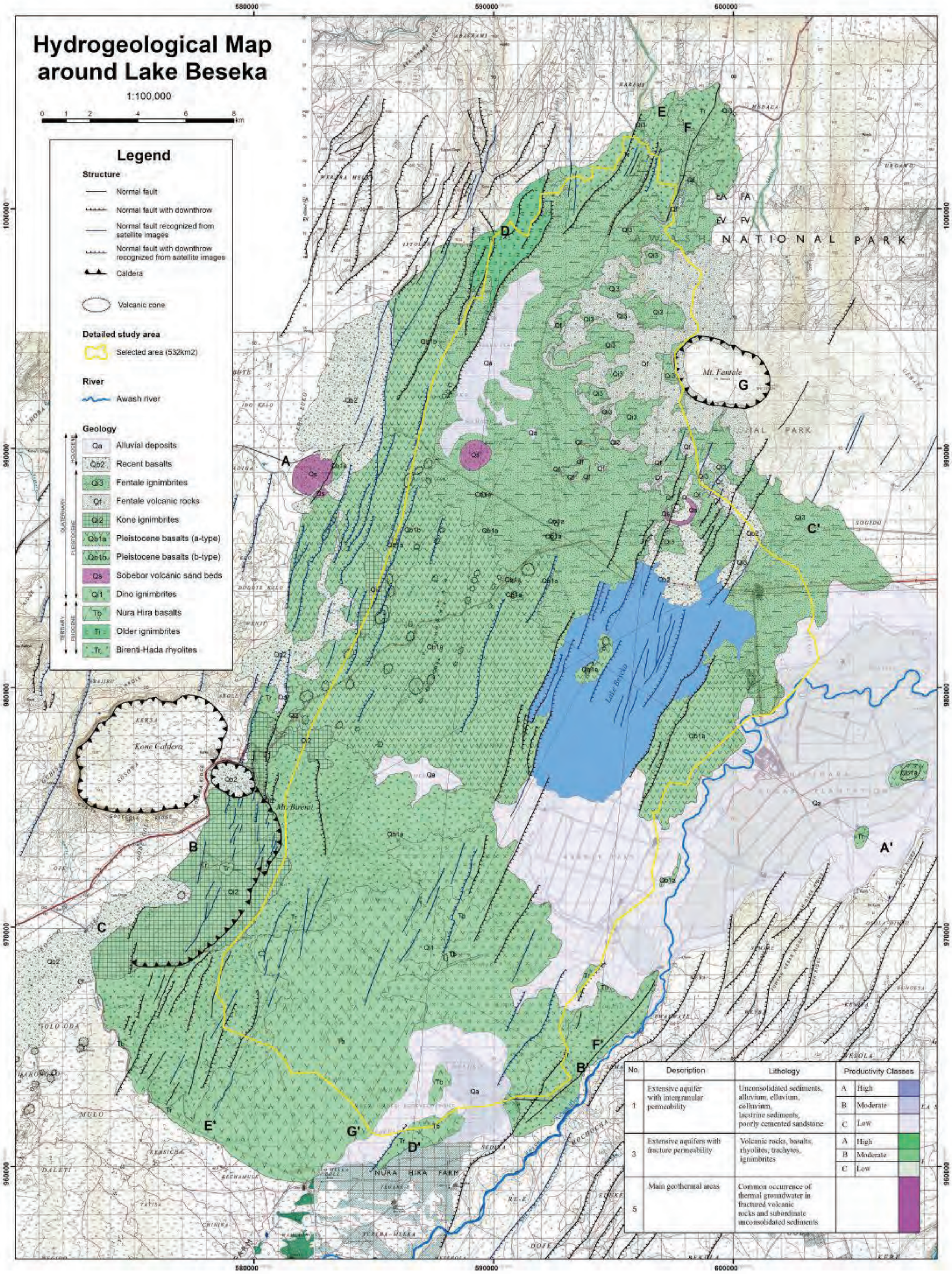
Geologic age	Aquifer unit name	Code	Hydrogeological characteristics
			around Lake Beseka. The record of yield is sparse, but there are partial records of 8 to 12 L/sec. • Therefore, these groups of basalt are considered to have moderate permeability.
	Dino Ignimbrite	Qi1	• "Dino Ignimbrites (Qwi)" corresponded 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 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), 2) and result of analysis in this Project

3.3.2 Hydrogeological map and cross-sections

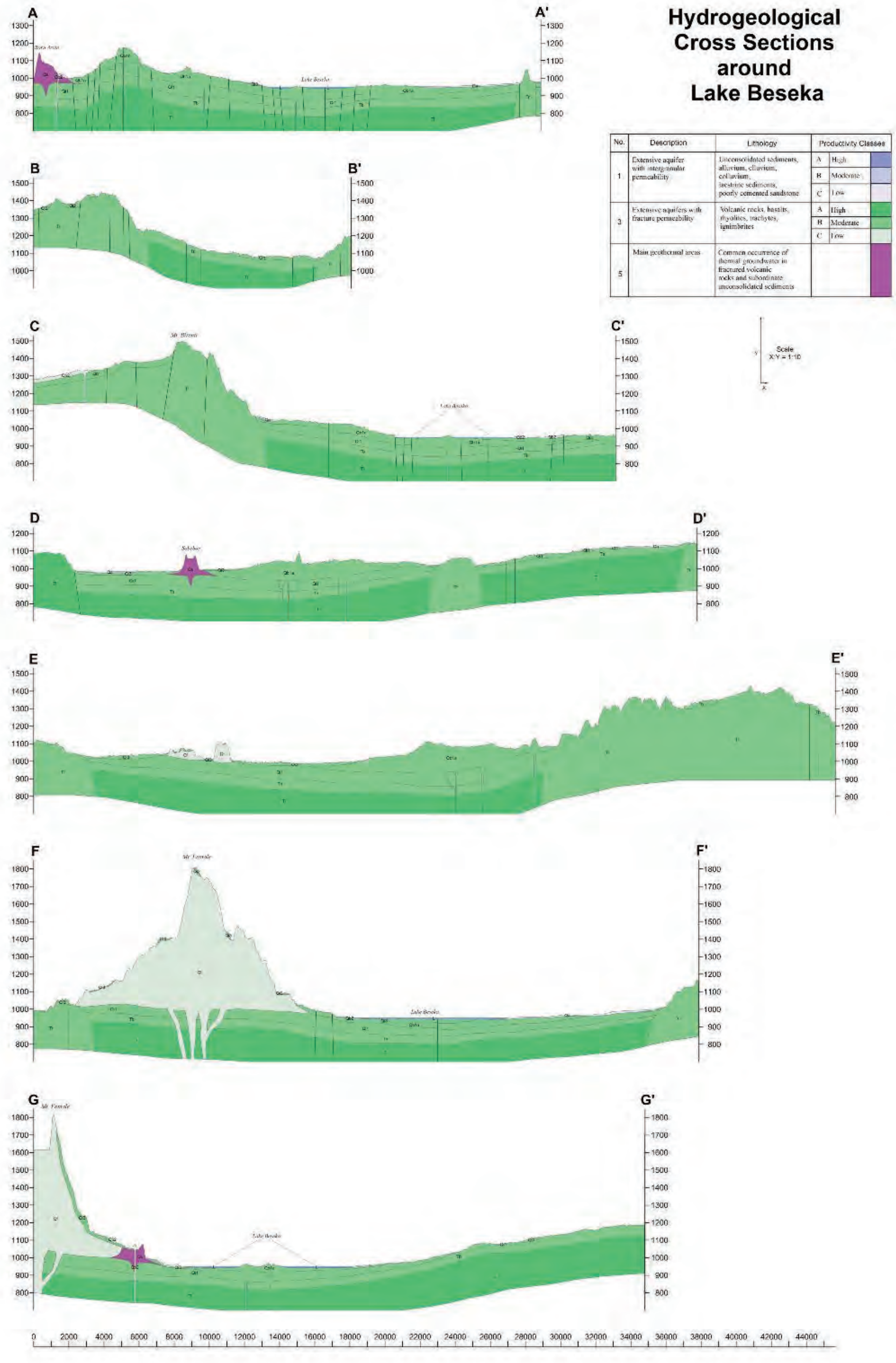
The hydrogeological map and cross-sections for the Lake Beseka area were prepared as shown in Figure 3.3.1 and Figure 3.3.2.

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), 2), 3) and result of analysis in this Project

Figure 3.3.1: Hydrogeological Map around Lake Beseka



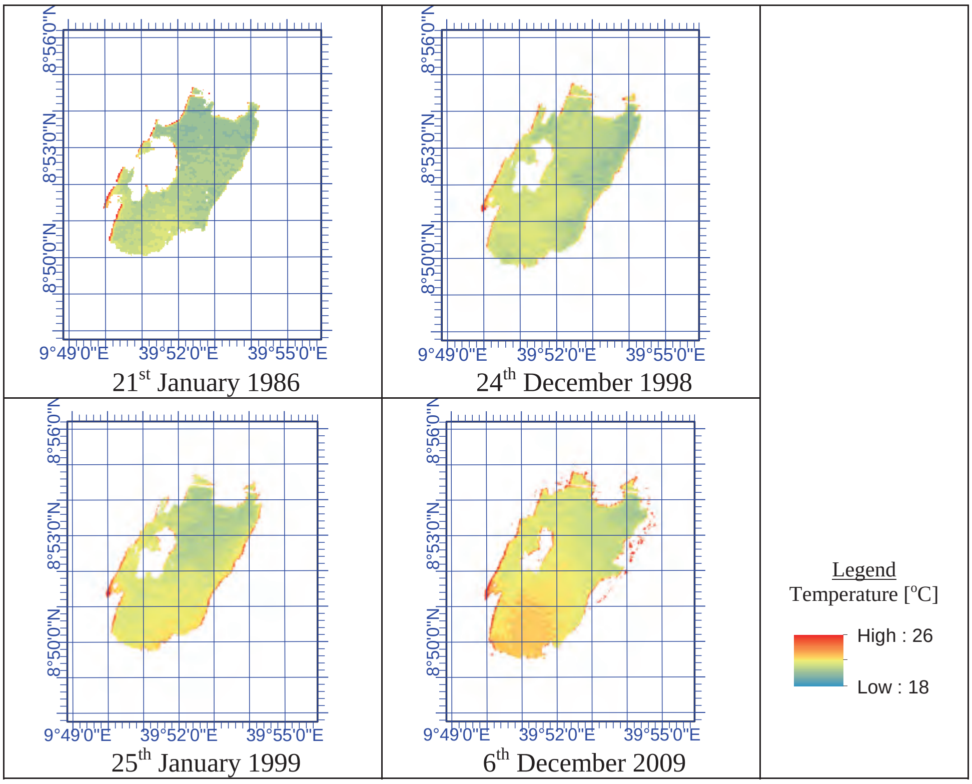
Source: the Project Team, Data: reference 1), 2), 3) and result of analysis in this Project

Figure 3.3.2: Hydrogeological Section around Lake Beseka

3.4 Inflow situation of springs and irrigation water

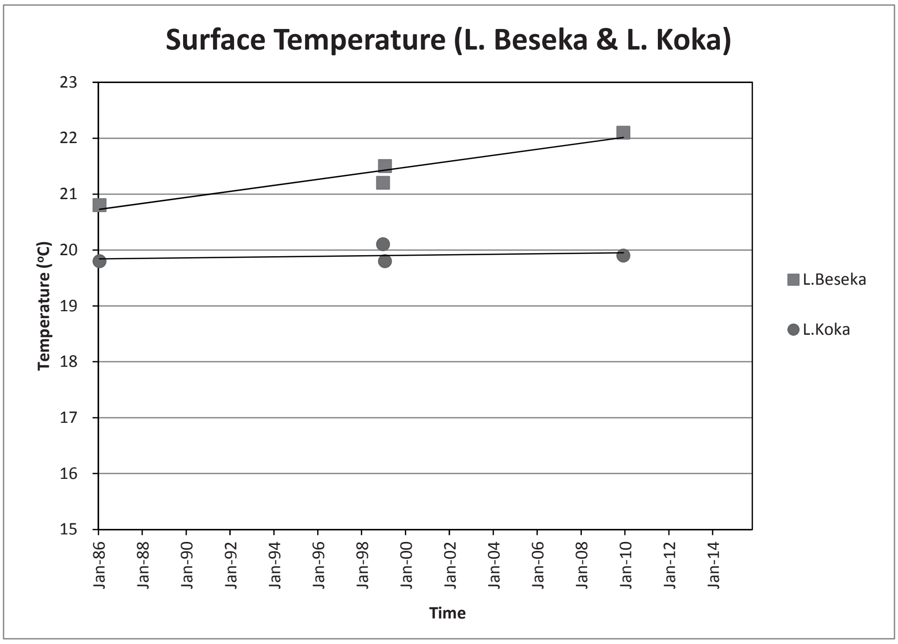
3.4.1 Ageing of spring inflow by satellite image analysis

Historical changes of the lake surface temperature were analyzed based on the infrared data of Landsat images. The results are shown in Figure 3.4.1 and Figure 3.4.2.



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

Figure 3.4.1: Surface Temperature Distribution of Lake Beseka



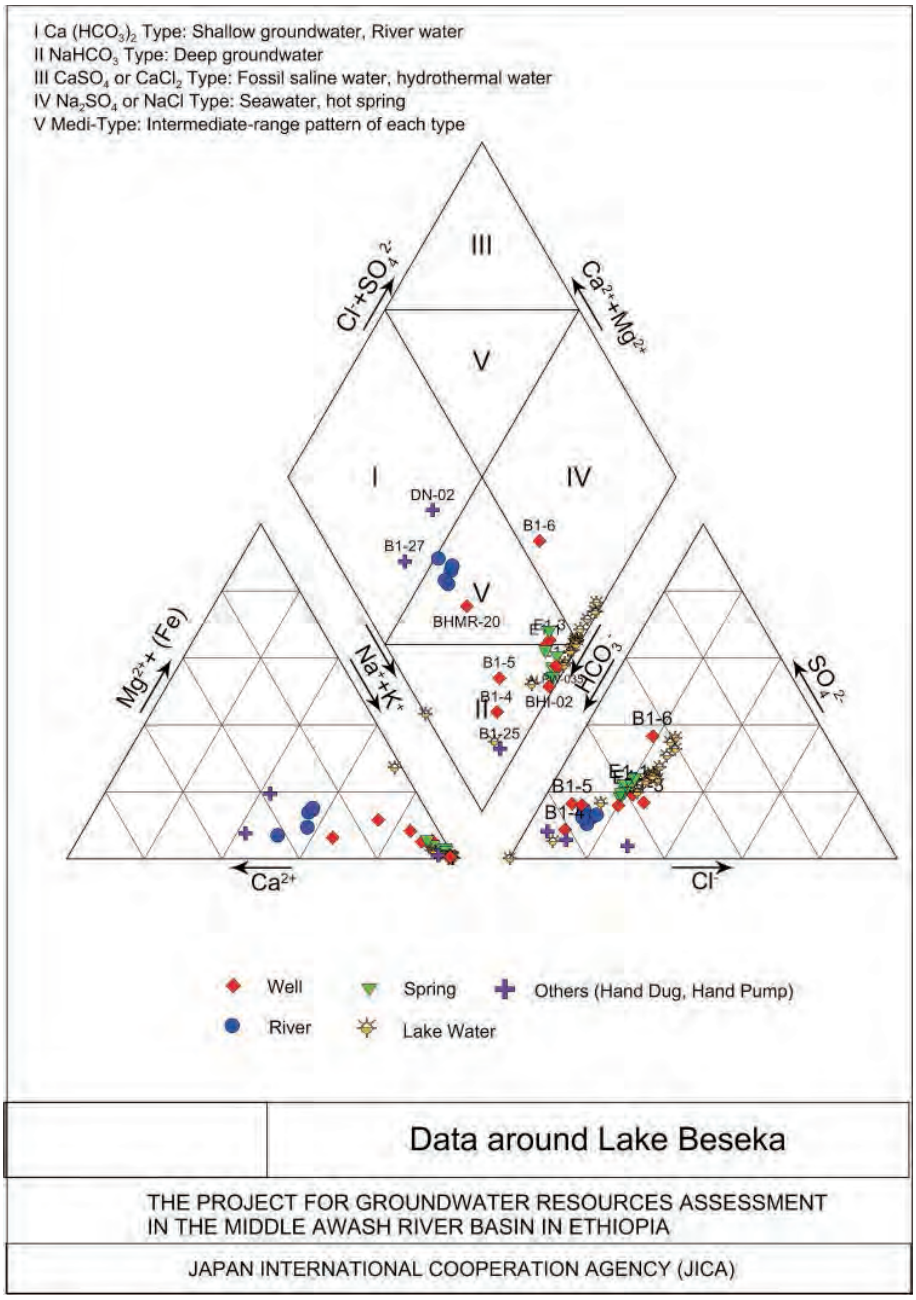
Source: the Project Team, Data: Result of analysis in this Project

Figure 3.4.2: Comparison of Surface Temperatures between Lake Beseka and Lake Koka

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.

3.4.2 Results of water quality testing

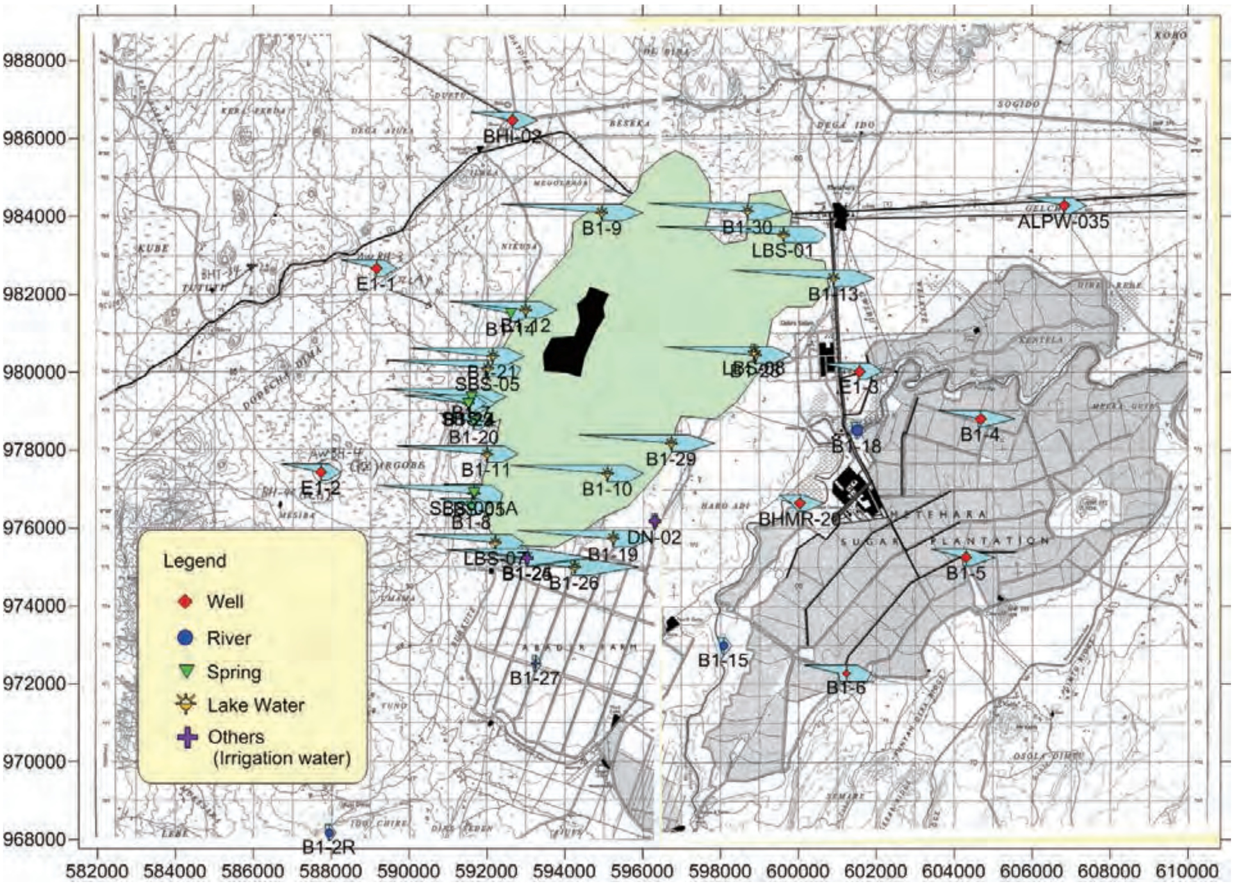
Based on the results of the water quality testing around Lake Beseka, the Trilinear Diagram is prepared as shown in Figure 3.4.3 using the main ions.



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

Figure 3.4.3: Trilinear Diagram around Lake Beseka

Figure 3.4.4 shows the water sampling points and existing data points with the hexadiagram.



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

Figure 3.4.4: Hexadiagram at Sampling Points around Lake Beseka

The analysis 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.

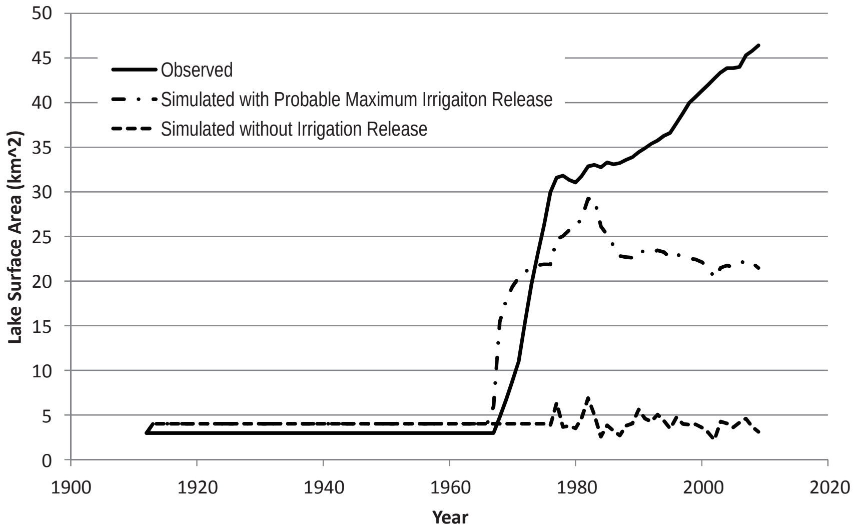
3.4.3 Estimation of irrigation return flow

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.



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

Figure 3.4.5: Simulated Time Series of the Lake Surface Area with Irrigation Return Flow

3.5 Summary

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.

References

1) Hydrogeology (Map) of the Nazret, EIGS, 1985
2) Study and design of Lake Besaka level rise project II, WWDSE, planned by MoWE, 2011
3) Gibson I.L. (1970): “A pantelleritic welded ash-flow tuff from the Ethiopian Rift Valley” - Contr. Mineral and Petrol., 28, 89-111.

Chapter 4

Groundwater Potential

4 Groundwater Potential

4.1 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 map.

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 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. The evaluation of productivity is carried out by a combination of both of the specific capacity and yield as A to C. Table 4.1.1 below shows the aquifer classification and information (by the yield and specific capacity calculated by the pumping test) of the existing wells and JICA wells. Table 4.1.2 includes the evaluation of aquifer potential (aquifer classification and productivity) in reference to the aquifer information of Table 4.1.1.

The hydrogeological map is created based on these evaluations.

Table 4.1.1: 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

Table 4.1.2: Aquifer Classification and Productivity

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

Source: the Project Team, Data: reference ④

4.2 Groundwater recharge and yield

The middle Awash river basin is divided into thirteen sub-basins, and the basic flow (groundwater recharge) was estimated

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 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. 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.

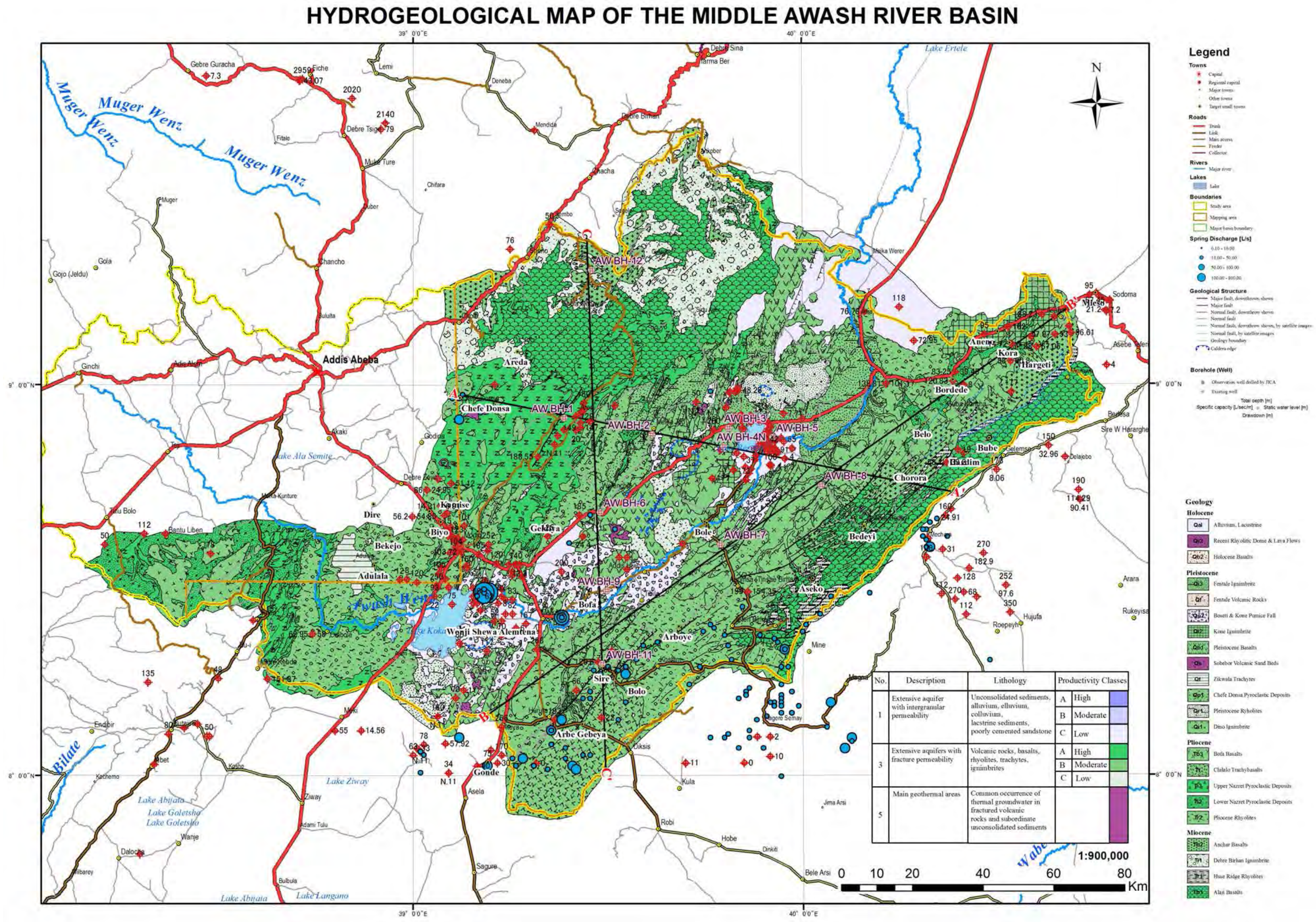
The ratio between the groundwater recharge and yield (well pumping capacity) is as approximately 1 to 5% in the major sub-basins for which data was obtained. Therefore, it is considered that groundwater wells drilled in these sub-basins will produce a sufficient pumping yield.

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.

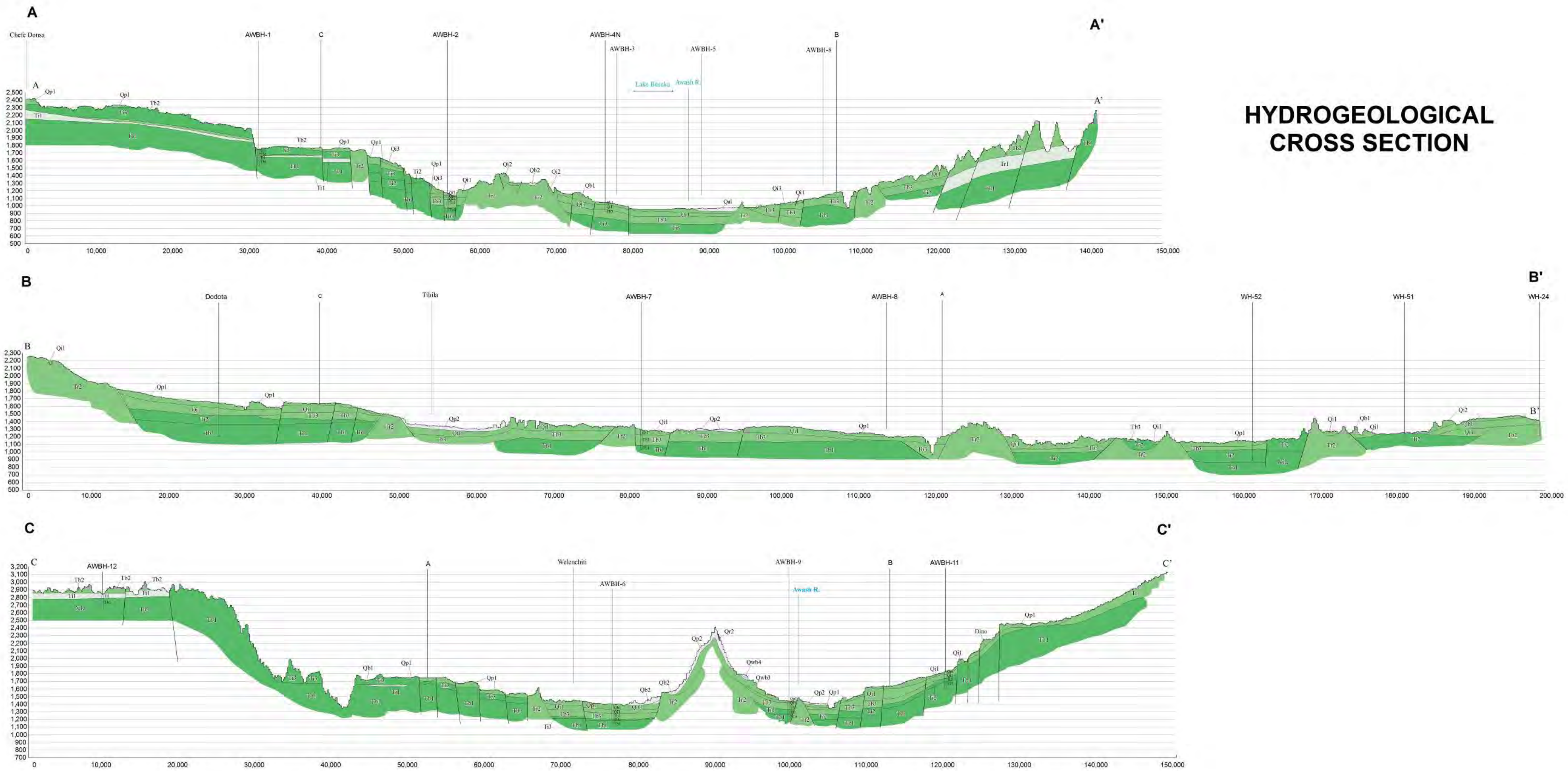
The hydrogeological map and cross-sections are shown in Figure 4.3.1 and Figure 4.3.2.

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



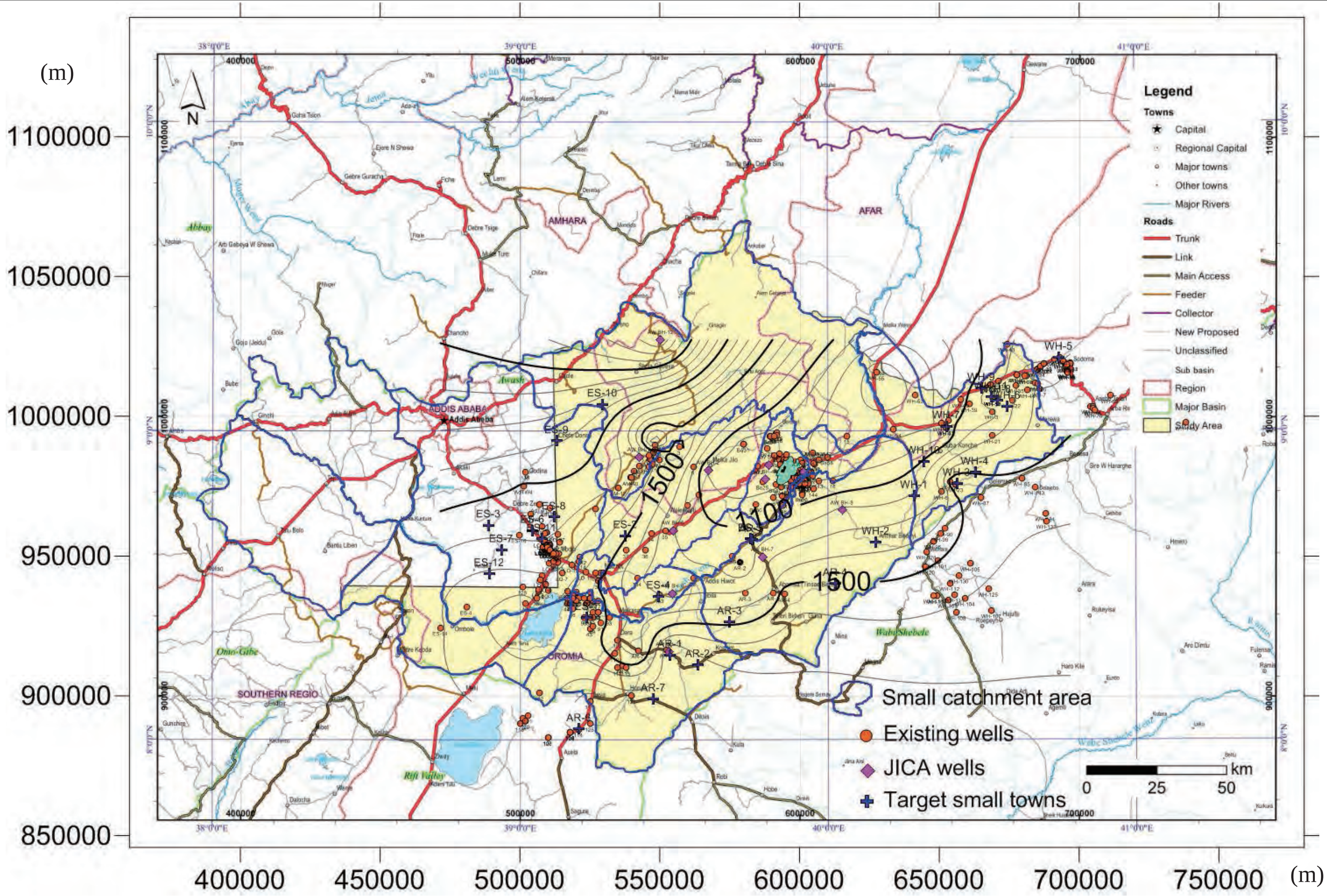
No.	Description	Lithology	Productivity Classes		
1	Extensive aquifer with intergranular permeability	Unconsolidated sediments, alluvium, elluvium, colluvium, lacstrine sediments, poorly cemented sandstone	A	High	
			B	Moderate	
			C	Low	
3	Extensive aquifers with fracture permeability	Volcanic rocks, 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			

VERTICAL SCALE = 10 x HORIZONTAL SCALE

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

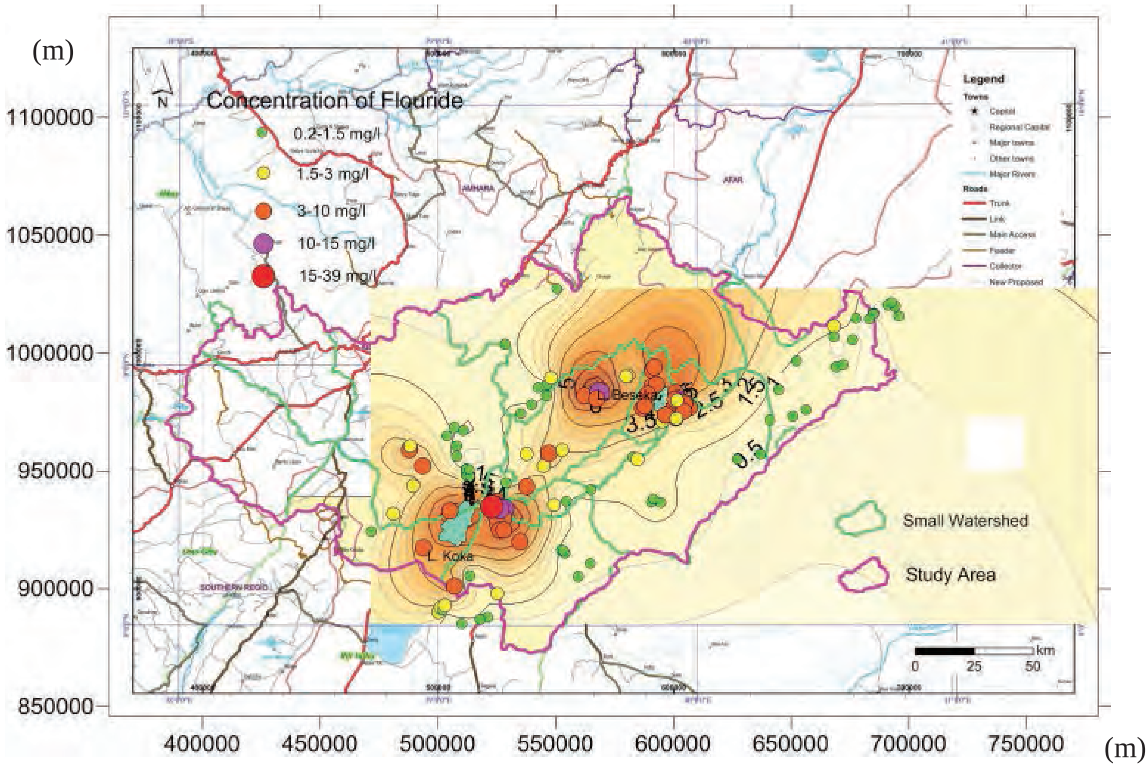
4.4 Water quality testing

4.4.1 Analysis items, methodology and analysis results

The water quality testing consists of the general testing and isotope analysis. In the first and second phases a total of 104 samples for the general testing 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 isotope analysis is carried out on JICA test wells. The analysis of isotopes has been entrusted to the International Atomic Energy Agency :IAEA). General water quality tests are analysed on site for 12 parameters and in laboratory for the 22 parameters respectively.

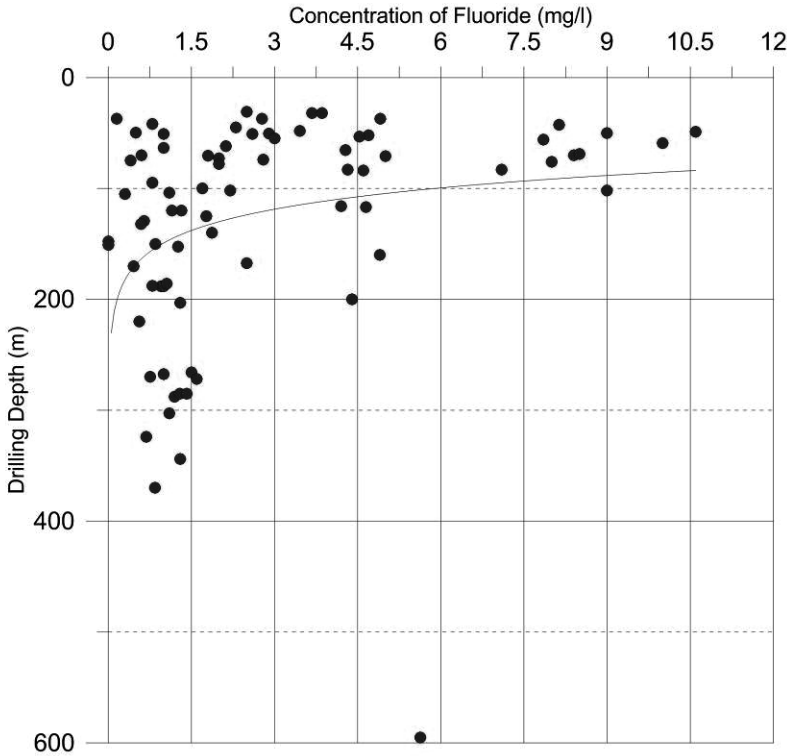
By comparing these results with the Ethiopian standards and WHO guidelines, it is found that there are few analysis items, besides fluoride, that exceed either standard in most of the wells. The total hardness and calcium of existing wells and springs mainly in 10 points exceed the Ethiopian standard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

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) (refer to Figure 4.4.1). 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 (refer to Figure 4.4.2). However, such analysis also needs to take into consideration the above geological findings.



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

Figure 4.4.1: Distribution Map of Concentration of Fluoride in Study Area



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

Figure 4.4.2: Relationship between Well Depth and Concentration of Fluoride

4.4.2 Characteristics of the water quality

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

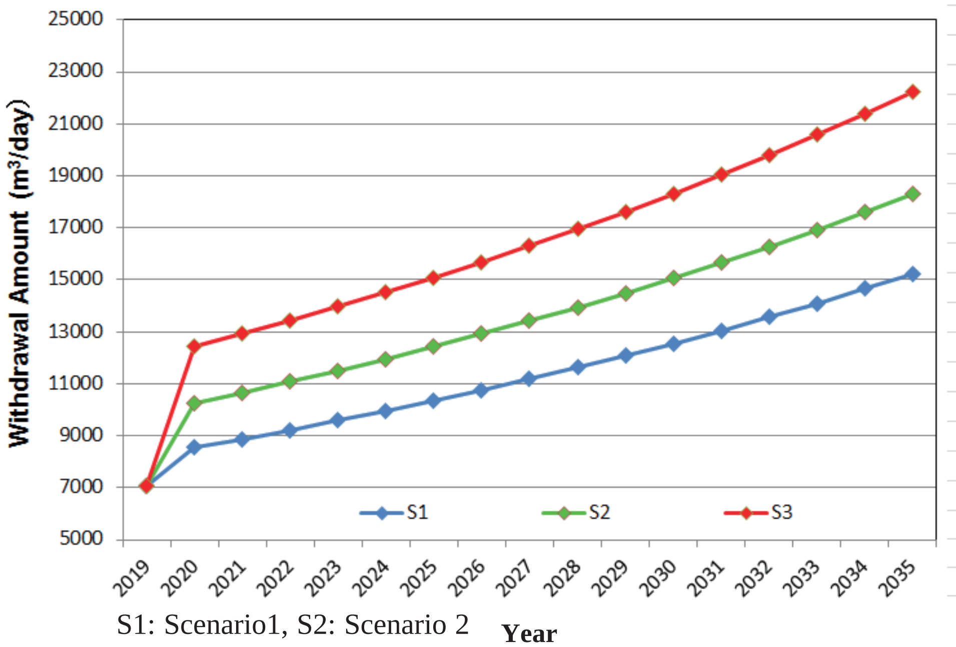
The groundwater models were calibrated (explained in the Supporting Report of the Final report) which were then used to calculate the impact of well construction and usage for water supply on groundwater levels (depletion and replenishment relationship) and also on the groundwater environment. The analysis of transient flow was executed by setting the parameter, period specification, and rainfall specification. The potential amount by the groundwater development was evaluated by the relationship between the yield and drawdown of groundwater using the groundwater modeling.

5.2 Future pumping scenarios

The groundwater modelling simulations covered all of the original 30 target small towns. The estimated drilling depth of each small town is 150m-300m deep. The estimated years of the analysis of the groundwater fluctuation was set from 2020 to 2035 (2019; standard year, 2035; final year for the analysis) in the target small towns. 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)

Total amount of changes in Scenario 1 to 3 from 2019 to 2035 are shown in the following Figure 5.2.1.



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

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

Figure 5.2.1: Aging Figure of Estimated Water Demand (Yield) of Each Scenario

5.3 Results of future simulation

5.3.1 Result of drawdown of groundwater

The estimated drawdown of groundwater in the maximum water demand (yield) of Scenario_3 is shown in Table 5.3.1. The maximum drawdown of groundwater is 2.8 m.

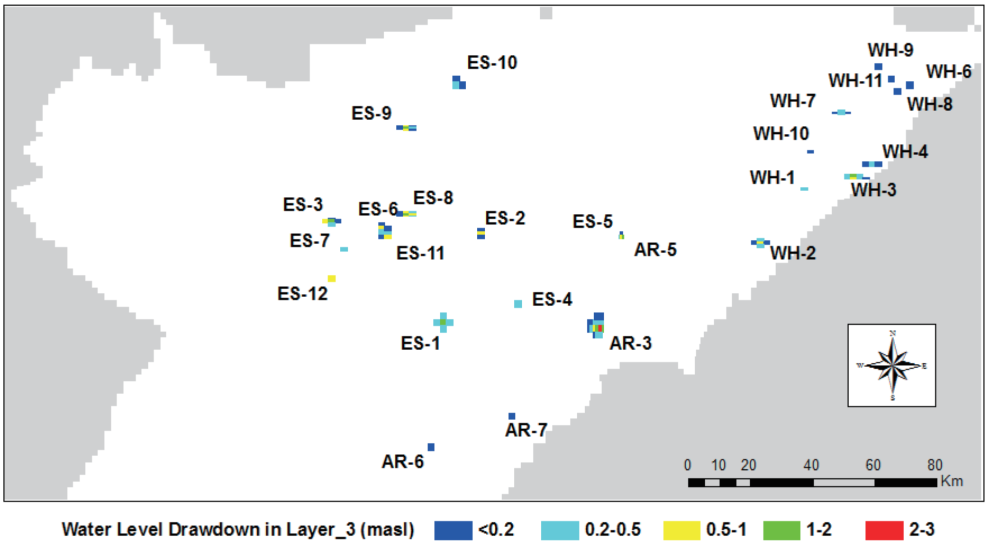
Table 5.3.1: Estimated Groundwater Drawdown in the Maximum Water Demand (Yield) of Scenario_3

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

5.4 Effect of groundwater drawdown on surrounding areas

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. 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 (refer to Figure 5.4.1).



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

Figure 5.4.1: Drawdown Map of the Surrounding Area in the Third Layer (Scenario 3)

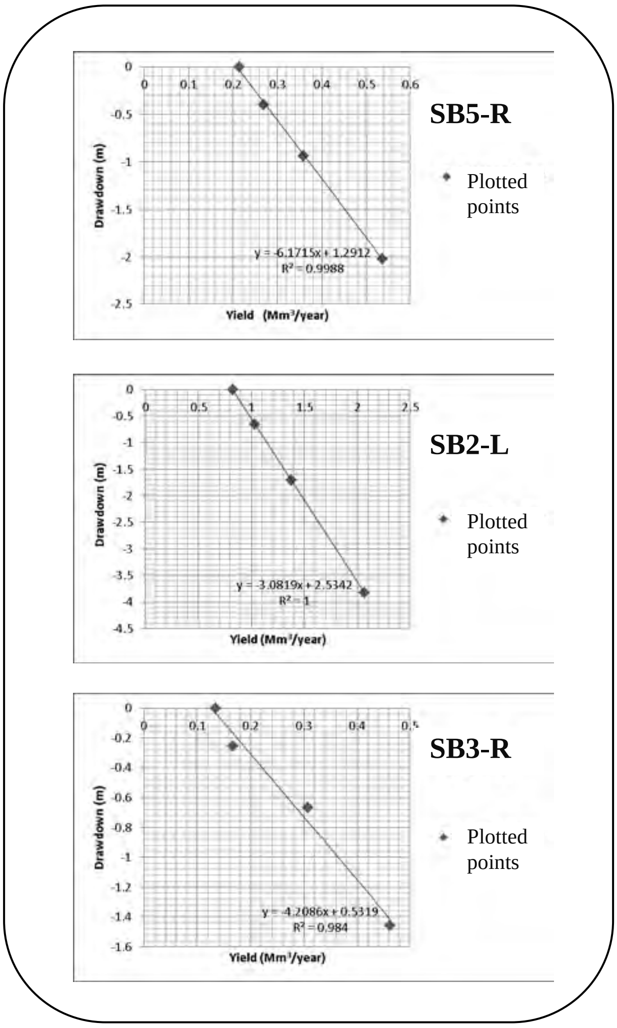
5.5 Approaches to the evaluation of potential amount by the groundwater development

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 without having a negative impact at which each of the aquifer units can be utilized at. Some ideas were approached below for the sustainable yield of the groundwater.

5.5.1 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.

For the results of the calculation, the correlation formulas of estimated drawdown and yield were created as shown in Figure 5.5.1 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.



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

Figure 5.5.1: Correlation Chart of Estimates Drawdown and Yield in Three Sub-Basins

5.5.2 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 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.

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 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 5.5.1.

Table 5.5.1: 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

Chapter 6

Water Supply Plan of Small Towns

6 Water Supply Plan of Small Towns

6.1 Results of basic survey

6.1.1 Population for water supply

The 2007 population census by the Central Statistical Agency (CSA) is adopted in this water supply plan.

The projected population as of 2014 is between 17,700 in Mieso and 1,600 in Bolo. Mean value and median are 5,132 and 4,438, respectively.

6.1.2 Users coming from outside of water supply area

According to the interview with town water supply offices and water associations, the number of users who come to fetch water from the outside of water supply area ranges between 17,600 in Arboye and 0 in Ude Dhankaka and 10 small towns. However, since the data lacks reliability and there is a difficulty for rational estimation of the number of outside users after implementation of the water supply plans, 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.

6.1.3 Amount of water usage

Amount of water use by private connection and public tap of the existing water supply systems in target small towns was surveyed. The survey was undertaken through interview with town water supply offices and water associations supplementing with reviewing existing records on water meter reading.

Number of private connections is between 921 in Chefe Donsa and 0 in Ude Dhankaka and 5 towns. Unit water consumption through private water connection ranges between 162 L/c/d in Arbe Gebeya and 9 L/c/d in Hardim, with mean vale and median of 80 L/c/d and 73 L/c/d, respectively.

Public taps are installed in 25 towns out of 30. Unit water consumption through them ranges between 25.5 L/c/d in Bofa and 0.1 L/c/d in Wonji Shewa Alemtena. Mean value and median are 5.6 L/c/d and 4.2 L/c/d, respectively.

6.1.4 Increase of the number of private connections

The number and diffusion rate of private connections for every town are surveyed. According to the survey result, for instance, the number of private taps had been increased from 512 (diffusion rate: 22.6%) in 2010 to 921 (34.7%) in 2014 in Chefe Donsa.

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

Conditions of existing water supply facilities were surveyed. Necessities for reconstruction or replacement of life-expired facilities were assessed based on the survey. The following table summarizes the result of the assessment.

Table 6.1.1: Wear and Aging Conditions of Existing Water Supply Facilities

Facilities (Life Time)	Number of towns with the facility	Number of towns with necessity for replacement
Borehole (20 years)	20	9
Motor Pump (10 years)	23	18
Diesel Generator Set (10 years)	16	9
Transmission Pipes (40 years)	26	2
Distribution Reservoir (50 years)	26	0
Distribution Pipes (40 years)	26	2
Public Taps (25 years)	26	10

Source: the Project Team, Data: Results of the survey by the Project Team

6.1.6 Condition of commercial electric power supply

The information about the situation of power failure was collected by interviewing the stakeholders of every target town. There are five small towns that currently have no electricity supply. The rate of power failure ranges between 4% in Ude Dhankaka and 40% in Aseko and Arbe Gebeya. 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. Mean value and median of power failure rate are 14.4% and 8.9%, respectively.

6.2 Target year and estimated population

6.2.1 Target year

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

6.2.2 Estimated population of each year

a. Population projection

After classifying target towns into urban and rural areas, population growth rate of 4.1%/year for the urban areas and 2.6%/year for rural areas was adopted.

The projected population ranges between 22,500 in Mieso and 2,000 in Bolo and Kenteri as of 2020 with mean and median of 6,434 and 5,399, respectively. The number of households in 2020 is between 5,300 in Mieso and less than 500 in Kenteri with mean and median of 1,630 and 1,329, respectively.

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. Therefore the population that receives water supplies from such facilities is also projected.

The population for water supply in schools is projected at between 5,300 (Arboye) and 70 (Belo) in 2020. That in medical facilities is projected at between 90 (Arboye) and less than 5 (Hargeti, Kenteri and Aneno).

c. Projection of the diffusion rate by connection types

Based on the basic survey results, diffusion rate of private connections was projected and then water supplied population as of 2020 was estimated by connection types (private taps or public taps). Population with private taps was projected at between 10,000 (Mieso) and less than 10 (Kenteri) with mean value and median of 1,937 and 1,403, respectively. On the other hand, projected population with public taps ranges between 12,500 (Mieso) and less than 700 (Geldiya, Arbe Gebeya) with mean value and median of 4,497 and 3,721, respectively.

6.3 Water demand

6.3.1 Planning criteria

The planning criteria in this plan are 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.

In terms of standard basic water demand, 40 L/c/d and 25 L/c/d are applied for urban and rural areas, respectively, referring to the Second Growth and Transformation Plan (GTP2) published in August 2015,

6.3.2 Daily average water supply amount

Daily average water unit was calculated based on population in 2020. The estimated daily average water supply amount is between 926 m^3/day (Mieso) and 53 m^3/day (Kenteri) with mean value and median of 248 m^3/day and 193 m^3/day, respectively.

6.3.3 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 (87%) and planning loading factors (83.3%).

The planning daily maximum water supply amount is between 1,280 m^3/day (Mieso) and 73 m^3/day (Kenteri). Mean value and median are 342 m^3/day and 267 m^3/day, respectively.

6.4 Groundwater development

6.4.1 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 annual groundwater recharge (m^3/year) was estimated in each sub-basin. The annual groundwater recharge in a sub-basin was then compared to groundwater usage in 2035 estimated in the Project.

As the result, the annual groundwater recharge is much more than groundwater usage in each sub-basin. Sufficient yields will therefore be secured in all target towns.

6.4.2 Aquifer classification and characteristic

The hydrogeological map was created in this Project 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.

6.4.3 Possibility of groundwater development

The well specification and hydrogeological conditions are estimated for every target town. The yield of more than 5 L/sec is estimated at all target towns except for 2 (Bube and Aneno). The estimated well depth is between 150 m to 300 m.

6.5 Water supply plan of small towns

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

In order to confirm planning rationality, surveyed 30 small towns were screened from the aspects of project duplication, natural conditions (prospect of groundwater development, groundwater potential (quantity/quality)), and social conditions (accessibility, water rights, conflicts, O&M capacity, access to safe water).

As the result, planning rationalities were confirmed for the following 19 small towns and provisional water supply plans were formulated for them.

Table 6.5.1: 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

6.5.2 Outlines of provisional water supply plans

a. Outlines 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).

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

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.

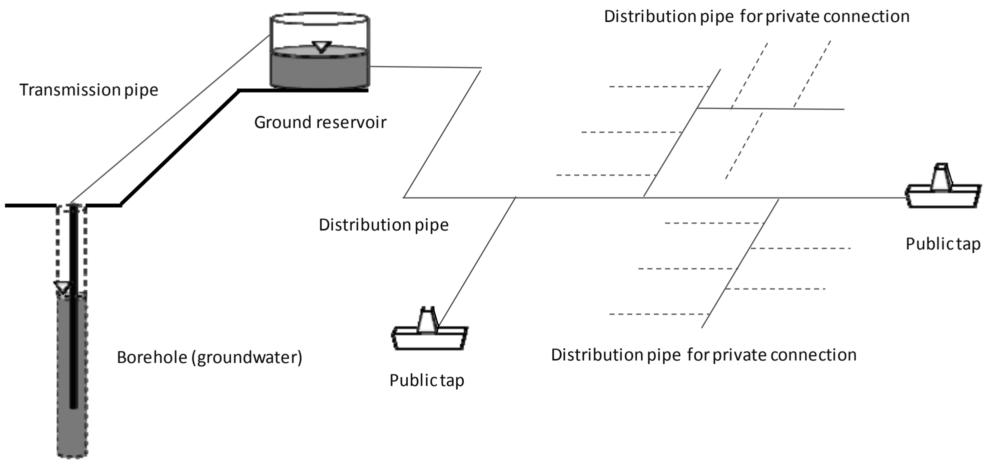
However, there are some existing water supply facilities which have been used for a considerable amount of time and have significant wear and tear. Therefore, the Project plans to replace or newly construct existing water supply facilities that exceed the lifespan specified in the Ethiopian design criteria as of the target year 2020.

6.5.3 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.

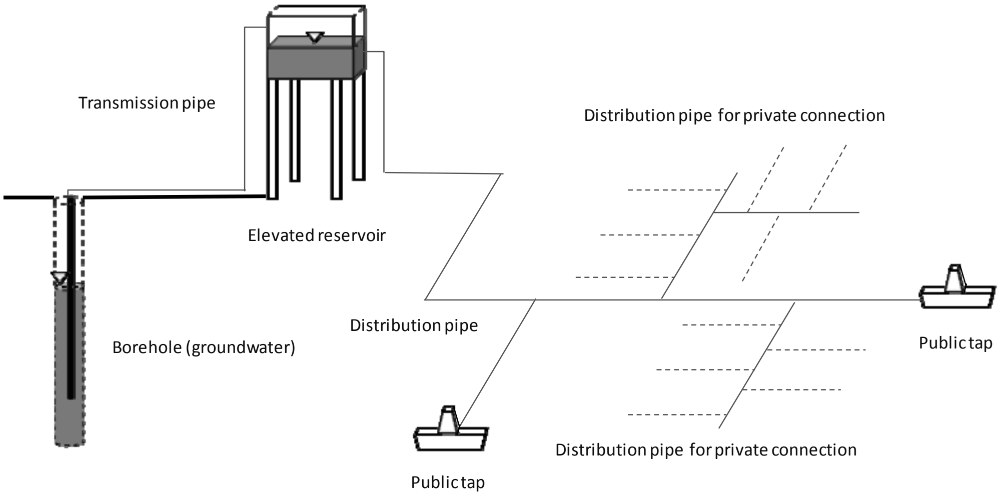


Source: the Project Team

Figure 6.5.1: 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 6.5.2: Groundwater Supply System with Elevated Distribution Reservoir

6.5.4 Outlines 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 6.5.2.

Table 6.5.2: 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 6.5.3.

Table 6.5.3: 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

6.5.5 Provisional cost estimation for water supply plans

a. Method of provisional estimation

Provisional estimation is carried out based on the recent contract unit prices of similar borehole construction works with local contractor for JICA study, unit price of estimation for similar construction works by Japan's Gant Aid Project, etc.

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 6.5.4.

Table 6.5.4: 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 6.5.5.

Table 6.5.5: 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 6.5.6.

Table 6.5.6: 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 6.5.7.

Table 6.5.7: 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

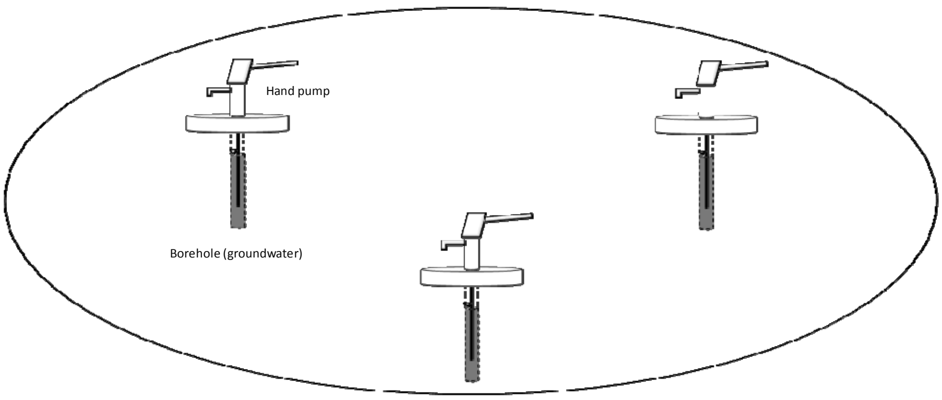
Source: the Project Team

6.5.6 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 6.5.3: Groundwater Supply System with Hand Pump

a. Necessary numbers

Necessary numbers is calculated as shown in Table 6.5.8 in accordance with the Ethiopian design criteria mentioned that 300-350 persons per one borehole with hand pump.

Table 6.5.8: 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.

Assumed specification and quantities of boreholes is shown in Table 6.5.9.

Table 6.5.9: 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 study, unit prices of estimation for similar construction works by Japan's Gant Aid Project, etc. Implementation cost is estimated as shown in Table 6.5.10.

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 6.5.10: 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

6.6 Operation and maintenance plan for water supply facility

6.6.1 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 setting of water rate is not appropriate in some water committees and necessary to revise water rate to secure sufficient remaining funds.

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. Thus, unaccounted water cannot be estimated.

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

6.6.2 Operation and maintenance plan

a. 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 6.6.1. 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 6.6.1: 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

b. Organization of operation and maintenance

b.1 Organization plan

Table 6.6.2 shows the proposed operation and maintenance organizations in each of the 19 small towns in this plan.

Table 6.6.2: 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 6.6.3: Manpower Plan

ID	Small town	O&M Organization	Existing Manpower			Additional manpower						Total		
							Employee							
			Committee member	Employee	Total	Committee member	Operator	Guard	Tap manager	Total	Total	Committee member	Employee	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

6.6.3 Operation and maintenance cost

Result of the calculation of operation and maintenance cost for new water supply facilities is shown in Table 6.6.4.

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. 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 6.6.4: 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

6.6.4 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 6.6.5. Capacity development to WC shall be conducted by WWMEO and supported by ZWMEO and OWMEB.

Table 6.6.5: 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 Basic environmental and social conditions

7.1.1 Natural environmental condition

Awash National Park is located within the Middle 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.

7.1.2 Social condition

Economic activities are flourishing in surrounding areas based on the construction projects of toll expressway as well as railway. 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.

There are no cultural and traditional architecture or heritage assets in the target areas.

7.2 Classification of environmental category

The water supply plans are 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.

7.3 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, 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.

7.4 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.

7.5 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 (refer to Supporting Report).

7.6 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. 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. 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. In consideration of the interviews results, the plans will not make the situation worse.

7.7 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.

7.8 Discussions with stakeholder

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.

7.9 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 Method and scoring criteria for selecting priority small towns

Priority small towns are selected in accordance with the policy to select about 10 small towns out of 19 small towns, where provisional water supply plan is elaborated.

Major items of evaluation shall be following 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.

Standard of allotment of points for selecting priority small towns is shown in Table 8.1.1.

Table 8.1.1: 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

8.2 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 8.2.1.

Table 8.2.1: 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

Chapter 9

Conclusion and Recommendations

9 Conclusions and Recommendations

9.1 Conclusions

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 in the southeast area of the Ethiopian capital, Addis Ababa.

2) The average annual mean rainfall at 20 meteorological stations for the 30 years is 876 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) Annual mean runoffs of the middle Awash River Basin is 27.8 m^3/sec to 64.1 m^3/sec from upstream to downstream. 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 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 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.

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. Fault system in northern area is characterized by the development of continuous major faults which has big displacement with minor parallel faults.

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.

8) 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. 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;

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. 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 were also found in the floor of the middle Awash River basin in its subsurface with the significant fissures and cracks.

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 in 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. 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) Topography around Lake Beseka is divided into 7 classes by taking into consideration the characteristics of this area such as volcanic ejecta, deposits and geological structure.

4) The geology consists of Birenti-Hada rhyolites (Tr) of Tertiary Pliocene, ignimbrite, basalts, volcanic rocks of Quaternary Pleistocene and basalts, and Alluvium deposits of Quaternary Holocene from the lower part. A detailed geological map and cross-sections of an Awash River sub-basin was prepared at a scale of 1:100,000 (532 km^2) in detail.

5) Hydrogeological conditions; the geological stratum indicates middle to high water permeability, and it is a fractured rock groundwater along fissures and cracks.

6) 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. There is a difference of groundwater flow by the aquifer depth.

7) Fluoride concentration in the water around Lake Beseka is high and exceeds the Ethiopian standard. There is no correlation between fluoride concentration and depth.

8) Temperature analyses based on the infrared data of Landsat images suggest the continuous rise of the lake surface temperature.

9) 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.

10) The result in the water balance analysis 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.

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.

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. It was concluded that the groundwater development can be carried out in terms of the groundwater recharge, 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, difficulty of access to safe drinking water, benefit effect, O&M capacities, 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 Recommendations

a. 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. 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 regard to the first issue, 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. Regarding the second issue, 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. Finally, 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. After that, it is immediately necessary to additionally assign capable personnel to implement the specific operations and technical activities of ENGWIS in the MoWIE.

b. 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.

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. 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.

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. The instructor should be an engineer of the enterprise, a private company or EWTI with a high skill level.

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. It is important for MoWIE to use the ranking system to gain an accurate understanding of the level of the drilling companies.

c. Effective utilization of the water supply plan

The effective utilization of the water supply plan 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.

d. 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. 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. These basalts occur for the subsurface geology in the central area of the middle Awash River Basin. 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 large 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. 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.

The high concentration areas of fluoride distribute around the Lake Beseka and Lake Koka, and also dotted at the east-northeast to west-southwest directions along the Awash River. 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 principle. 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.

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.

e. Countermeasure for the control of Lake Beseka level rise

The countermeasure for the control of Lake Beseka level rise is that 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.