No. 16

BASIC DESIGN STUDY REPORT
ON
THE PROJECT FOR ZANZIBAR URBAN WATER SUPPLY DEVELOPMENT
IN
THE UNITED REPUBLIC OF TANZANIA

March 2005

JAPAN INTERNATIONAL COOPERATION AGENCY
NJS CONSULTANTS CO., LTD

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PREFACE

In response to a request from the Government of Tanzania, the Government of Japan decided to conduct a basic design study on the Project for Zanzibar Urban Water Supply Development and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Tanzania a study team from 23rd October to 12th November 2004.

The team held discussions with the officials concerned of the Government of Tanzania, and conducted field study at the study area. After the team returned to Japan, further studies were made. Then, a mission was sent to Tanzania in order to discuss a draft basic design, and as this result, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of Tanzania for their close cooperation extended to the team.

March 2005

Seiji Kojima
Vice-President
Japan International Cooperation Agency

March 2005

LETTER OF TRANSMITTAL

We are pleased to submit to you the basic design study report on the Project for Zanzibar Urban Water Supply Development, Tanzania.

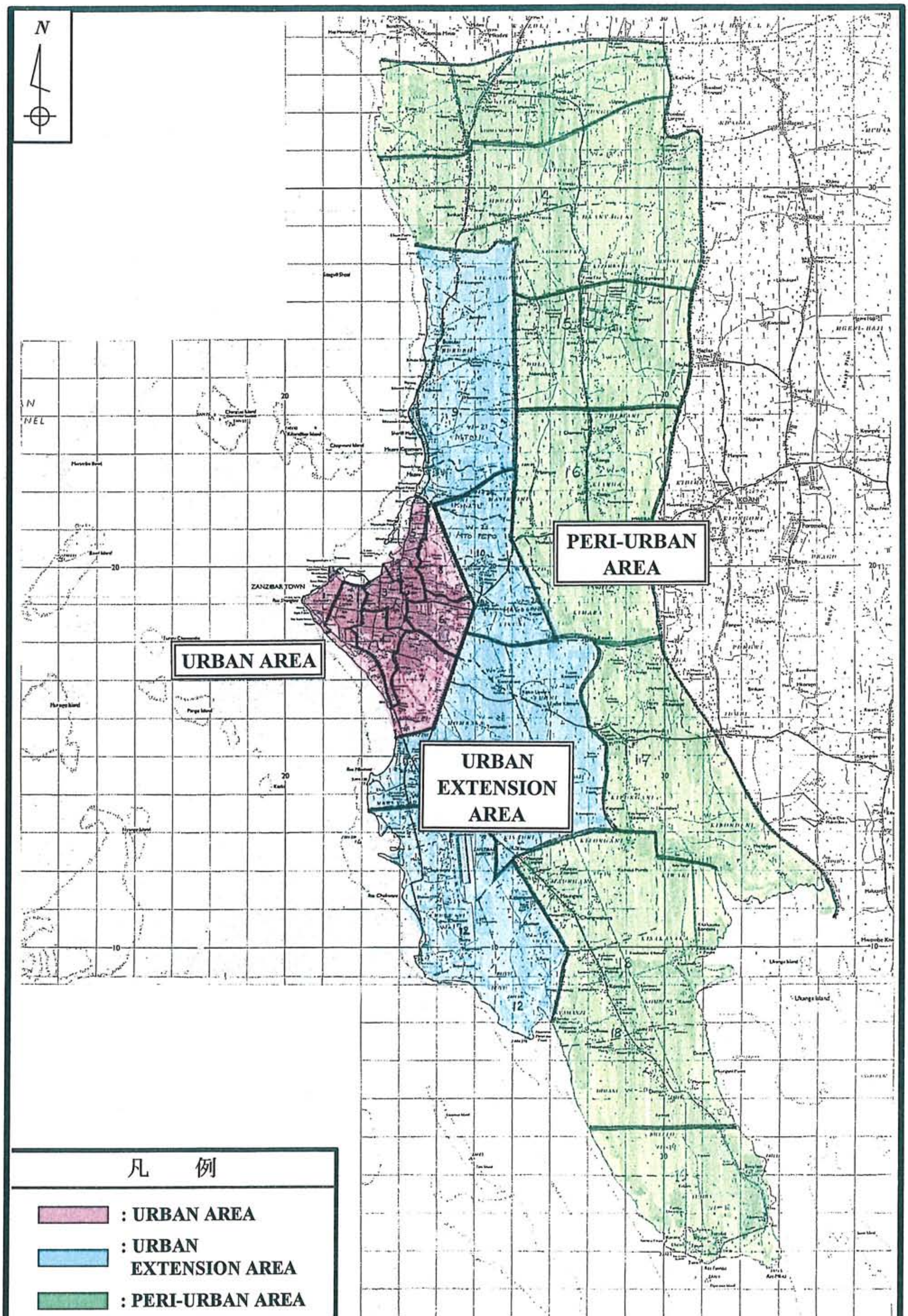
This study was conducted by NJS Consultants Co., Ltd., under a contract to JICA, during the period from October 2004 to March 2005. In conducting the study, we have examined the feasibility and rationale of the project with due consideration to the present situation in Tanzania and formulated the most appropriate basic design for the project under Japan's grant aid scheme.

Finally, we hope that this report will contribute to further promotion of the project.

Very truly yours,

Hiroki Fujiwara
Project Manager,
Basic Design Study Team on
the Project for Zanzibar Urban Water Supply Development, Tanzania

NJS Consultants Co., Ltd.



Location Map

Perspective

Summary

Summary

The United Republic of Tanzania (hereinafter Tanzania) consists of Zanzibar and Tanganyika. Zanzibar is a group of islands on the Indian Ocean and Tanganyika is on the continent. Zanzibar has population of 980,000, which 30% of the total population live in Zanzibar City. Fall of export price of clove and suspension of development assistance from international donors due to the political instability after 1995 stalled economical development and enlarged the economical gap to Tanganyika.

Water supply development in Zanzibar started in 1920 using springs as water sources. By 1990 total length of water pipes reached 100 km and 7 clear water reservoirs were developed. Due to the lack of funds, the Government of Zanzibar could not rehabilitate and expand the old facilities, which do not meet the current water demands. The 10% of urban population of Zanzibar do not receive drinking water supply. The present water supply experiences frequent disruption of the service. Contamination of drinking water by sewage through the old damaged pipes is suspected to cause high occurrence of water related infectious diseases. The improvement of the water supply system has the highest priority in public health projects.

The Government of Zanzibar has adopted an Economy Recovery Program, prioritising safe water supply for meeting Basic Human Needs. Under the above circumstances, the Government of Zanzibar requested a grant aid program to improve water supply facilities in Zanzibar Urban area.

In response to the above request, Japanese Government dispatched preliminary study team to Zanzibar in order to confirm the requested project; justification, effectiveness and scope of the grant aid scheme and to study current situation of the sector and capacity of implementation agency in 2002. This study confirmed that the necessity of the project implementation, but also pointed out that non-collection of water tariffs is the cause of the major difficulty in the operation and maintenance of the water supply and recommended the introduction of tariff collection as prerequisite for the grant aid project. Water Policy on Zanzibar has passed by the Zanzibar House of Representative in 2004 and the Zanzibar side meets the above precondition, Japanese Government dispatched a basic design study team to Zanzibar as follows;

1) Field survey from 23 October 2004 to 26 November 2004
2) Explanation of draft final report in March 2005

The original request and proposed facilities are shown in the following table.

No.	Item	Original Request	Basic Design	Remarks
A	Facilities			
A 1	Distribution Stations			
A 1-1	Saateni Station			
(1)	Construction of underground reservoir	4,000 $m^3 \times 1$	—	Revision of supply areas
(2)	Renewal of elevated tanks	450 $m^3 \times 2$	—	Done by DWD*
(3)	Construction of new elevated tanks	450 $m^3 \times 2$	—	Revision of supply areas
(4)	Renewal of transmission pumps	540 $m^3/hr \times 2$ 250 $m^3/hr \times 2$	Approx.400 $m^3/hr \times 2$ Approx.200 $m^3/hr \times 2$	Including one stand-by each
(5)	Disinfection facility	1 set	1 set	Renewal
A 1-2	Welezo Station			
(1)	Construction of reservoirs	4,000 $m^3 \times 1$ 3,000 $m^3 \times 2$	Approx.4,000 $m^3 \times 2$	Revision of supply areas
(2)	Disinfection facility	1 set	1 set	
A 1-3	Dole Station	—		Revision of supply areas
(1)	Construction of reservoir		Approx.1,200 $m^3 \times 1$	
(2)	Disinfection facility	1 set	1 set	
A 1-4	Kinuni Station	—		Revision of supply areas
(1)	Construction of reservoirs		Approx.2,700 $m^3 \times 1$	
(2)	Disinfection facility	1 set	1 set	
A 2	Construction of wells	100 $m^3/hr \times 6$	58.4 $m^3/hr \times 11$ (incl. 1stanby well)	
A 3	Pipeline construction			
A 3-1	Transmission pipes	Total Approx.20km	Total Approx.24km	Revised according to the result of route survey
A 3-2	Distribution pipes	Total Approx.35km	Total Approx.20km	
B	Equipment			
B1	Water Analysis	1 set	—	By utilisation of the existing equipment
B2	Workshop	1 set	Pickup trucks: 4 units	・for pump maintenance ・for disinfection chlorine supply ・for pipe maintenance ・for facility maintenance

* DWD: Department of Water Development,Zanzibar

This basic study projected the water demand and supply balance in year 2010, the result shows that there will be deficit of approximate 14,000 m^3/d. The study team proposed new groundwater development in Kizimbani, Kianga, Kimara and M.Mchomeke areas to make up for this deficit. The safe yield of proposed new wells is estimated at 60 m3/hr, thus production flow of the new wells is set at 58.4 m3/hr.

The current water supply system has only two distribution stations with reservoirs, namely Saateni and Welezo. In order to distribute additional flow from the proposed new wells effectively, two new distribution stations, Dole and Kinuni, are proposed to supply water to North and South/East region of the study area. The new reservoirs are proposed for Dole, Kinuni and Welezo stations to secure uninterrupted water supply. New disinfection facilities are proposed for all the distribution stations.

The existing four transmission pumps in Saateni station are very old and suffer from wear and damages.

Obtaining repair parts for the pumps is very difficult and it deemed necessary to renew the existing pumps and related electrical equipment. New Pumps will have capacity to meet the requirement of the proposed new supply system.

One of the existing elevated tanks at the Saateni station is being repaired by DWD. DWD intends to repair the other elevated tank as soon as the above repair work is finished. The proposed new system will use the existing elevated tanks and no new reservoirs are required.

New transmission pipelines from the proposed wells to the reservoirs are proposed. Badly damaged existing transmission pipeline from Chunga wells to Welezo reservoirs will be replaced to prevent water losses. The flow from those wells will be lead to the new Kinuni reservoir.

The proposed distribution pipelines will form trunk distribution pipelines, whose role is to supply sufficient water to the whole service area. The proposed pipelines will be connected to the existing minor distribution pipelines at appropriate intervals. House connections will not be tapped directly into the proposed pipelines.

The proposed scope of the Project is summarised in following table.

1. Facilities

Facility	Item	Specification	Number			Remarks
			Phase1	Phase2	Total	
(1) Well Pump Stations	Wells	Well diameter: 250 mm Well depth: 60 - 70 m	6	5	11	New (incl. 1 standby well)
	Well Pumps	Submersible Pump 58.4 m^3/hr	6	5	11	
	Electrical equipment	Transformer, control panels, instrumentation	6	5	11	
	Well Pump House	For Power distribution/Control Panels	6	5	11	
(2) Transmission/ Distribution Facilities						
Saateni Station	Transmission pumps	Horizontal Centrifugal Pump 400m3/hr X 40m X 75kW 200m3/hr X 40m X 45kW	 2 2	 - -	 2 2	Renewal (incl. 1standby) (incl. 1standby)
	Electrical equipment	Instrumentation/control panels	1	-	1	Renewal
	Disinfection Facility	Powder Disinfectant Solution Tank/Drip	1	-	1	Renewal
Welezo Station	Reservoirs	Reinforced concrete, V=4,000m^3	2	-	2	New
	Disinfection Facility	Powder Disinfectant Solution Tank/Drip	1	-	1	New
Kinuni Station	Reservoirs	Reinforced concrete, V=2,700m^3	-	1	1	New
	Disinfection Facility	Powder Disinfectant Solution Tank/Drip	-	1	1	New
Dole Station	Reservoirs	Reinforced concrete, V=1,200m^3	-	1	1	New
	Disinfection Facility	Powder Disinfectant Solution Tank/Drip	-	1	1	New
(3) Transmission Pipelines		DCIP φ150 - φ600	Approx. 13 km	Approx. 11 km	Approx. 24 km	New
(4) Distribution Pipeline		DCIP φ300 – φ700	Approx. 9.6 km	Approx. 10.3 km	Approx. 20 km	New

2. Equipment

Facility	Item	Specification	Number			Remarks
			Phase1	Phase2	Total	
(1) Maintenance equipment	Pickup trucks		4	-	4	New

3. Soft Component

(1) Engineering training for facility operation
(2) Management training for institutional development
(3) Support for public education programme

The scale of the proposed Project requires the Project implementation to be divided into 2 phases (2 single-year projects) with separate benefits will be brought in each phase. In phase 1, 9.5 months are required for detailed design and tendering (6.5 months and 3 months respectively), followed by 12 months construction period. Phase 2 will spend 9 months on detailed design and tendering, and 12 months for construction. The total Project cost is estimated to be 1,990 million Yen. The expenses to be borne by the Government of Japan and the Government of Tanzania respectively are 1,988 million Yen and 2 million Yen.

The Project is aimed at improving the living environment of study area through supplying safe drinking water. It will help to achieve the Basic Policies of Water Sector in "ZANZIBAR VISION 2020", which are intended to secure safe drinking water to all the people and sectors economically through appropriate water resource management. The Project will expand and improve the existing water supply system, including renewal of the old facilities. The soft component program will provide support for DWD to achieve the above project objectives by strengthening its management system, providing knowledge and technology for operation of the new facility, conducting public education to involve people of Zanzibar as an active customer, and creating a sustainable business situation.

This Project will increase water production and renew the old facilities in order to meet the increasing water demand and to secure the safe drinking water supply. Direct and indirect benefits of the Project are as follows;

- Meeting the water demand of the target year by increasing the water production from 40,100 m^3/d to 54,100 m^3/d.
- Improving reliability and safety of water supply by providing uninterrupted service for the customers experiencing service disruptions
- Improving health condition of people in Zanzibar by reducing water related infectious diseases, such as diarrhoeas and cholera.
- Supporting economic development of Zanzibar and securing income of residents by tourism development enhanced by safe drinking water supply

This project will bring large benefits as described above and improve basic human needs of Zanzibar residents, thus conforming the Japanese grant-aid policy.

The study team recommends the Zanzibar Government to implement the following actions;

a. To establish the new water authority and build the organization for tariff collection, operation and maintenance. Then collect enough money to maintain the water supply system and manage the water works properly.

b. To repair/replace the existing facilities including borehole pumps, roof of Saateni Station, pipelines made of asbestos. Especially to conduct a non revenue water reduction measures.

c. To expand the distribution network to meet the population growth and urban expansion.

d. To make necessary measures to protect the water sources, such as the prohibition of building construction and garbage disposal near the water source.

e. To treat or discharge the wastewater increased by this project in accordance with the Ministry of States, Regional Administration and local Government and/or Zanzibar Municipal Council.

f. Items related to this project;

- To prepare the budget for the cost undertaken by Tanzanian side. They shall be disbursed based on the implementation schedule.
- To obtain/issue necessary permission/licence for the implementation of the works for the project.
- To organize the implementation team for the project from the beginning of the detailed design to understand the project components and to master technology.

g. Secure budget for providing new house connections to new users.

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Basic Design Study on The Project for Zanzibar Urban Water Supply Development in Tanzania

Final Report

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Abbreviations

A/P	Authorization to Pay
AfDB	African Development Bank
B/A	Banking Arrangement
BHN	Basic Human Needs
CEC	Commission of the European Communities
DWD	Department of Water Development,Zanzibar
E/N	Exchange of Notes
EAC	East African Community
EIA	Environmental Impact Assessment
FINNIDA	Finnish International Development Agency
GDP	Gross Domestic Product
GNI	Gross National Income
GNP	Gross National Product
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
KfW	German Bank for Reconstruction and Development
LWL	Low Water Level
MFEA	Ministry of Finance & Economic Affairs

MFEA	Ministry of Finance & Economic Affairs
MOF	Ministry of Finance
MWCEL	Ministry of Water, Construction, Energy and Lands
NGO	Nongovernmental Organization
OAU	Organization of African Unity
ODA	Official Development Assistance
OECD	Organization for Economic Cooperation and Development
QC	Quality Control
UNDP	United Nations Development Program
UNICEF	United Nations International Children's Emergency Fund
ZWSA	Zanzibar Water Supply Authority

Chapter 1 Basic Concept of the Project

Chapter 1 Basic Concept of the Project

1-1 Present Condition of Water Sector

1-1-1 Present Condition and Need for the Project

Water supply development in Zanzibar started in 1920 using springs as water sources. By 1990 total length of water pipes reached 100 km and 7 clear water reservoirs were developed. Due to the lack of funds, the Government of Zanzibar could not rehabilitate and expand the old facilities, which do not meet the current water demands. The 10% of urban population of Zanzibar do not receive drinking water supply. The present water supply experiences frequent disruption of the service. Contamination of drinking water by sewage through the old damaged pipes is suspected to cause high occurrence of water related infectious diseases. The improvement of the water supply system has the highest priority in public health projects.

1-1-2 National and Sector Development Plans

The Zanzibar National Development Plan, which is named ZANZIBAR VISION 2020, has been developed by Zanzibar Ministry of Finance and Economic Affairs in January 2000 with assistance from UNDP. Policy goals of water sector development are presented as follows.

“Basic Policies of Water Sector are intended to secure safe drinking water to all the people and sectors economically through appropriate water resource management. It will help social and economic development of Zanzibar. The water policies are:

a. Develop effective water supply and management system to secure affordable and reliable water supply
b. Rain water catchments will be protected as a drinking water recharging area
c. Community formation for water supply rights
d. Sustainable and fair water supply for urban and rural areas
e. Appropriate maintenance for water supply facilities
f. Water supply technology reinforcement in wells, dams, pumps and pipes
g. Establishment of rainwater recharging and harvesting technology
f. Establishment of effective water rates collection system”

1-1-3 Social and Economic Conditions

United Republic of Tanzania (hereinafter Tanzania) was established in 1964 as a result of the merger of Zanzibar and Tanganyika. Tanzania adopted economic liberalization and structural adjustment policies since 1986 and achieved some success. Multiple political parties have been introduced since 1992 and the President Mkapa was elected in 1995 and re-elected in 2000 general election. In Zanzibar, serious political conflicts are emerged at the both elections. 2000 election recorded causalities and the first refugees from Tanzania. At present, the political situation is stable and Tanzania enjoys relatively good economic growth in East Africa.

Tanzania adopts non-alliance foreign policy and assumes a leadership role at OAU (Organization of African Unity), UN etc., emphasizing concept of the united Africa and independence for colonized area. It has a stable relationship with the near-by nations and contributed for the stability of Victoria Lake area, including Congo, and for solving dispute over Burundi. Tanzania together with Kenya and Uganda agreed on the framework of East African

Community (EAC) in November 1999 and the Community is formally launched in January 2001. In March 2004, Customs Union agreement was signed among EAC countries. Tanzania is the chair of South Africa Development Community since August 2003. Tanzania assumes an important role in diplomatic relations of East Africa based on its stable foreign policy.

Agricultural production consists of approximately 50% of GDP in Tanzania. Its major products are maize, casava, rice, beans, coffee and cotton. Gold and diamonds are produced in relatively small scale. Sisal, tobacco and agricultural product processing are the main industries. Earning from Tourism has increased steadily and is regarded as a potential foreign currency earner.

Based on 2002 Census, the population of Tanzania is 35,200,000; GNI is 9,600,000,000 (source: World Bank 2002); per Capita GNP is 280 US$ (source: World Bank 2002); economic growth is 5.8% (source: World Bank 2002). As a one of least developed countries whose per Capita GNP is less than 1 dollar per day, Tanzania government tackles poverty reduction through World Bank's Poverty Reduction Strategy initiative. This strategy included safe drinking water supply consists as a one of the core strategies.

Population of Zanzibar is 982,000 based on the 2002 Census. GDP is 270,000,000 dollars (254,700,000,000 Tsh) in 2002; per Capita GDP is 274 US$ (259,000 Tsh). As a part of Tanzania Poverty Reduction Plan, Zanzibar Poverty Reduction Plan has been formulated. It emphasizes safe drinking water supply as a priority issue. In this respect, water supply related budget for the Ministry of Water Construction Energy and Lands has been increasing since 2002 fiscal year. Water policy related budget of the ministry is also approved as requested.

The study area, Urban and West district of Zanzibar, includes the Stone Town of Zanzibar which is inscribed by the UNESCO body as a World Heritage site in 2000. The population of Urban district is 206,000 (Male: 99,000, Female: 107,000); population increase in the past fourteen years is 1.9%; average household has 5.4 members. West district has population of 184,000 (Male: 91,000, Female: 93,000). Its population increase in the past fourteen years is 9.2%; average household has 4.9 members. The West district experiences high population increase comparing to the Urban district. (The national account of Zanzibar, Office of Chief Government Statistician, June 2004)

Over 80,000 tourists visited Zanzibar in 2001. Their stay lasts 4 days in average. Lack of basic tourist infrastructure limits annual increase of tourism earning by mere 1%. (The National Accounts of Zanzibar, Second Edition, June 2004, Office of Chief Government Statistician)

1-2 Request from Recipient Country

The present water supply experiences frequent disruption of the service due to the aged water facilities and insufficient supply capacity. Contamination of drinking water by sewage through the old damaged pipes is suspected to cause high occurrence of water related infectious diseases. The Government of Zanzibar has adopted an Economy Recovery Program, prioritizing safe water supply for meeting Basic Human Needs. Under the above circumstances, the Government of Zanzibar requested a grant aid program to improve water supply facilities in Zanzibar Urban area.

In response to the above request, Japanese Government dispatched preliminary study team to Zanzibar in order to confirm the requested project; justification, effectiveness and scope of the grant aid scheme and to study current situation of the sector and capacity of implementation agency in 2002. This study confirmed that the necessity of the project implementation, but also pointed out that non-collection of water tariffs is the cause of the major difficulty in the operation and maintenance of the water supply and recommended the introduction of tariff collection as prerequisite for the grant aid project. Basic water policy for tariff collection has passed the Zanzibar House of Representative in 2004, which was regarded as a first step for the implementation of the Project; Japanese Government dispatched a basic design study team to Zanzibar.

The original request and proposed scope of the project are shown in the following table.

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(3)	Construction of new elevated tanks	450 $m^3 \times 2$	—	Revision of supply areas
(4)	Renewal of transmission pumps	540 m^3/hr×2 250 m^3/hr×2	Approx.400 m^3/hr×2 Approx.200 m^3/hr×2	Including one stand-by each
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B1	Water Analysis	1 set	—	By utilisation of the existing equipment
B2	Workshop	1 set	Pickup trucks: 4 units	・for pump maintenance ・for disinfection chlorine supply ・for pipe maintenance ・for facility maintenance

1-3 Activities of Other Donors

Activities of other donors were suspended once after the political instability in 1995. Most of the projects were implemented by international aid agencies such as UNDP. The Finland government (FINNIDA) developed the urban water supply development plan. Rural water supply plan was implemented by African Development Bank (AfDB). The German development bank (KfW) implemented Zanzibar sewerage, drainage and solid wastes plan. Japanese Government has provided small-scale grant aids for rural water supply schemes through UNDP. UNICEF, USAID, DFID and Chinese Government have extended grant aids for water supply schemes in Zanzibar.

UNDP has played leading roles in assisting the development of water sector in Zanzibar. UNDP has supported formation of Water Policy, which in principle introduced user-pay. UNDP has already submitted water tariff collection improvement plan to DWD but presently this plan is suspended waiting for establishment of the Zanzibar Water Supply Authority that is a part of water related laws submitted to the House of Representatives. After the water related law passes the House of Representative, UNDP is expected to submit recommendation for capacity enhancement on revenue collection.

KfW has implemented Phase I of the Zanzibar urban sewerage, drainage and solid wastes plan in 1994 and 1995. It cleaned and rehabilitated the existing sewerage pipes in Stone Town. The sewerage and drainage systems will be extended to the other urban area in Phase II construction, which is expected to start in 2005.

Chapter 2　Contents of the Project

Chapter 2 Contents of the Project

2-1 Basic Concept of the Project

The Zanzibar Government has been working on the basic policies set out in "ZANZIBAR VISION 2020", which is formulated by Ministry of Finance and Economic Affairs in January 2000. The Basic Policies of Water Sector in "ZANZIBAR VISION 2020" are intended to secure safe drinking water to all the people and sectors economically through appropriate water resource management, while it enables economical growth and development of the Zanzibar. The existing water supply system only manages to satisfy the fraction of the water demand in the study area, thus causing insufficient water supply pressure and deterioration in supply water quality.

The Project is aimed to improve the existing water supply of the study area through developing 11 new wells with 14,000 m^3/d total production, and extending water pipelines. With implementation of this Project, the water supply system will manage to meet the water demand in the Project target year of 2010. The Project will also renew the old facilities, and will support DWD in training its staff to effectively operate, maintain and manage the improved water supply system. Thus, it will enable DWD to secure safe and reliable water supply to 460,000 people in the study area.

The facilities to be constructed under this Project are set out in the Table below.

No.	Item	Original Request	Basic Design	Remarks
A	Facilities			
A 1	Distribution Stations			
A 1-1	Saateni Station			
(1)	Construction of underground reservoir	4,000 m^3×1	—	Revision of supply areas
(2)	Renewal of elevated tanks	450 m^3×2	—	Done by DWD
(3)	Construction of new elevated tanks	450 m^3×2	—	Revision of supply areas
(4)	Renewal of transmission pumps	540 m^3/hr×2 250 m^3/hr×2	Approx.400 m^3/hr×2 Approx.200 m^3/hr×2	Including one stand-by each
(5)	Disinfection facility	1 set	1 set	Renewal
A 1-2	Welezo Station			
(1)	Construction of reservoirs	4,000 m^3×1 3,000 m^3×2	Approx.4,000 m^3×2	Revision of supply areas
(2)	Disinfection facility	1 set	1 set	
A 1-3	Dole Station	—		Revision of supply areas
(1)	Construction of reservoir		Approx.1,200 m^3×1	
(2)	Disinfection facility	1 set	1 set	
A 1-4	Kinuni Station	—		Revision of supply areas
(1)	Construction of reservoirs		Approx.2,700 m^3×1	
(2)	Disinfection facility	1 set	1 set	
A 2	Construction of wells	100 m^3/hr×6	58.4 m^3/hr×11 (incl. 1stanby well)	
A 3	Pipeline construction			
A 3-1	Transmission pipes	Total 20km	Total 24km	According to the results of route survey
A 3-2	Distribution pipes	Total 35km	Total 20km	
B	Equipment			
B1	Water Analysis	1 set	—	By utilisation of the existing equipment
B2	Workshop	1 set	Pickup trucks: 4 units	・for pump maintenance ・for disinfection chlorine supply ・for pipe maintenance ・for facility maintenance

2-2 The Basic Design of the Requested Japanese Assistance

2-2-1 Design Policy

2-2-1-1 Project Objectives

- Sector Objectives: Improve the living environment of study area through additional safe drinking water
- Project Objectives: Provide reliable safe drinking water supply for study area

2-2-2 Basic Plan

2-2-2-1 Basic Water Supply Parameters

(1) Target Year

Target year is set at 2010. The request from Tanzania government proposed 2015 as target year based on the Zanzibar Urban Water Supply Plan by FINNIDA. The expected completion of the proposed facilities will be around December 2007. As the proposed project will be an immediate improvement project, facilities are designed for 2010 population allowing a few years population growth after completion.

(2) Study Area

Study areas are Zanzibar Urban and West districts. This area is divided into the following three areas according to the existing land use and population growth, based on the FINNIDA master plan.

1) Urban area

This area covers most of the Zanzibar Urban area. The area (15 km^2) includes the Stone Town and surrounding urban area. The most of the government offices, port facilities and hotels are located in this area. The area has limited open area and slow population growth. According to the 2002 Census, 98% of the population are connected to the piped water supply.

2) Urban extension area

This area covers remaining Zanzibar Urban district, and West district surrounding the above urban area. This area (70 km^2) has very high population growth and receives migrant population from the surrounding cities. Development of executive residential area is also observed. Still many residents use common standposts. 90% of the population are connected to the piped water supply. (2002 Census)

3) Peri-urban area

The peri-urban area covers the remaining Zanzibar West district, which is an agricultural area far from the Stone Town. It has low population growth. This area (155 km^2) is mainly served by standposts, but electricity is not available in some area. 77% of the population are served by the piped water supply according to the 2002 Census.

(3) Design Service Population

The Censuses were performed only four times (1967, 1978, 1988, 2002) in Zanzibar. The future population is predicted based on those Census data. Census data and population projection are shown in Table 2-1 and Figure 2-1.

Arithmetic series and exponential series of population predictions are prepared based on two combinations of Census data: 1967 and 2002, 1988 and 2002. The results of 2010 population predictions are in the range from

245,000 to 560,000. The exponential series tend to give large predictions. Those predictions are regarded too large. Thus the prediction using arithmetic series based on the latest Censuses (1988 and 2002) will be used for this project. The population in year 2010 and 2015 will be 495,000 and 560,000 respectively, which is slightly higher than the prediction (483,000) by FINNIDA.

The present population of the study area (Zanzibar Urban and West districts) is estimated at 430,000 in 2005.

Table 2-1 Comparison of Various Population Predictions

Year	Actual	FINNIDA	Arithmetical series		Exponential series	
			1967-2002	1988-2002	1967-2002	1988-2002
1967	94,849					
1978	142,041					
1988	208,571					
2002	391,002					
2005			416,387	430,094	429,884	447,366
2010			458,694	495,248	526,195	559,933
2015		483,000	501,002	560,402	644,083	700,825
x	y		y=ax+b	y=ax+b	y=ax+b	y=abX
A			8461.5	13030.8	2.67508E-30	3.6635E-34
B			-16548921	-25696659.6	1.041259818	1.045910798

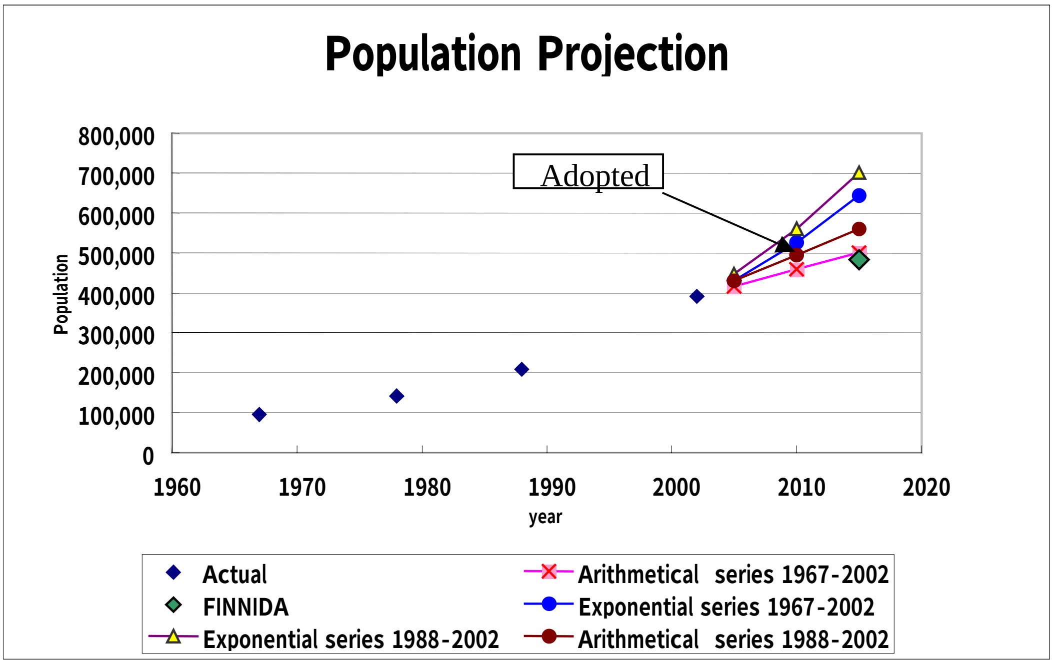

Figure 2-1 Population Projection

Table 2-2 Population Distribution among the Areas

	Census		Prediction	Remarks	
	1988	2002	2010	Ratio	2010/2002
Urban area	157,626	206,292	234,101 → 234,000	47%	1.13
Urban extension	18,570	139,179	208,098 → 208,000	42%	1.50
Peri Urban	32,375	45,531	53,049 → 53,000	11%	1.16
Total	208,571	391,002	495,248 → 495,000	100%	1.27

(4) Water Demand

1) Unit Water Consumption

Per Capita water demand is calculated as follows.

(Per Capita Water Demand) = (Effective Water) + (Ineffective Water)

(Effective water) = (Domestic Demand) + (Commercial Demand) + (Institutional Demand) + (Industrial Demand)

(Commercial, Institutional, Industrial) = (Per Capita Domestic Demand) x (Water Demand Ratio per category)

(Per Capita Domestic Demand with house connection) = (Per Capita Domestic Demand with house connection) x (Ratio per connection type)

(Unaccounted-for water) = (Effective Water) x (UFW ratio)

Those ratios are mostly taken from FINNIDA master plan.

Table 2-3 Per Capita Water Demand with House Connection

Unit: L/day/capita

Year	2005	2010	2015	Remarks
Per Capita Domestic Demand	55	60	65	

Table 2-4 Domestic Water Demand according to the Connection Types

	House Connection	Yard Connection	Stand Post	Remarks
Urban area	100%			
Urban extension area / Peri-urban area	40%	40%	20%	

Table 2-5 Water Demand Proportions for Various Uses

Use	Ratio	(Domestic demand as 1)	Remarks
Domestic	65%		
Commercial	15%	23%	Only in Urban area
Institutional	10%	15%	Only in Urban area and Urban extension areas
Industrial	10%	15%	Only in Urban area
Total effective	100%		
Unaccounted for Water	30%		
Total	130%		

Table 2-6 Per Capita Water Demand

Unit: L/day/capita

	Ratio	2010	
		Urban area	Urban extension area / Peri-urban area
Domestic	1	60	38
Commercial	0.23	14	
Institutional	0.15	9	6
Industrial	0.15	9	
Sub-total		92	44
UFW	0.3	28	13
Total		119 →120	57 →55

2) Peak Factors

Peak factors are based on the FINNIDA master plan.

(Daily Maximum Flow) / (Daily Average Flow) = 1.35

(Hourly Maximum Flow) / (Daily Maximum Flow) = 1.2

3) Target Water Pressure

The FINNIDA master plan recommends water supply pressure for floor levels (from ground to 7^{th}) from 16 meter to 34-meter water head. It does not specify the minimum pressure requirement. At present, most of the area could not get water pressure more than 5 meter during the day due to the problem in the distribution systems (Preliminary study report 2002). Assuming that multi-storey buildings have pumps and elevated tanks, target water pressure is set at 15 meter water head while the minimum water pressure will be 5 meter water head, which is commonly used as design target in Tanzania.

4) Flow Calculations

The FINNIDA master plan recommends pipe flow velocity will be from 0.9 m/sec to 1.8 m/sec. Hazen-Williams formula will be used for calculating head losses based on the Japanese Water Facility Design Criteria.

$$H=10.666 \cdot C^{-1.85} \cdot D^{-4.87} \cdot Q^{-1.85} \cdot L$$

H: Friction Losses (m)

C: Velocity coefficient (110: for DI and PVC pipes, including fitting losses)

D: Pipe diameter (m)

Q: Flow (m^3/s)

L: Pipe length (m)

Maximum Flow Velocity: 3.0 m/sec

5) Design Water Supply Flow

Table 2-7 Design Water Supply Flow

	Area	2010	Remarks
Population			
	Urban	234,000	
	Urban Ex	208,000	
	Peri Urban	53,000	
	Total	495,000	
Service Population			
	Urban	229,320	
	Urban Ex	187,200	
	Peri Urban	40,810	
	Total	457,330	
Service Ratio			
	Urban	98%	
	Urban Ex	90%	
	Peri Urban	77%	
	Total	92%	
Per Capita Water Demand			
l/day/capita	Urban	120	
	Urban Ex	55	
	Peri Urban	55	
Total Water Demand			
Daily Average	Urban	27,518	
m^3/day	Urban Ex	10,296	
	Peri Urban	2,245	
	Total	40,059	40,100
Daily Maximum	Urban	37,150	
m^3/day	Urban Ex	13,900	
	Peri Urban	3,030	
	Total	54,080	54,100
Hourly Maximum	Urban	44,580	
m^3/day	Urban Ex	16,680	
	Peri Urban	3,636	
	Total	64,895	64,900
Cf. Service Population with House Connection			House connection and yard piping
Urban	1	229,320	
Urban Ex	0.8	149,760	
Peri Urban	0.8	32,648	
Total		411,728	
Service Ratio		83%	

Total Water Demand (Daily Maximum) 54,100 m^3/day
Current Water Production (Daily Maximum) 40,100 m^3/day
Deficit 14,000 m^3/day

6) Selection of Pipe Materials

Small diameter PVC and HDPE pipes are produced locally in Tanzania and commonly used in Zanzibar. Imported ductile iron pipes are used for large diameter pipelines. Those pipes have advantages due to the relatively low prices and maintenance skills of those pipes already acquired by DWD staff. PVC, HDPE and ductile iron pipes will be considered for use in this project

Transmission pipeline will have maximum water pressure of 10kg/cm^2. PVC pipes which stand this high pressure is relatively expensive. Thus ductile iron pipes will be used for transmission pipelines.

Distribution pipelines will have maximum pressure less than 6kg/cm^2. Locally produced PVC and HDPE pipes with diameter less than 250 mm is readily available with reasonable prices. Comparing PVC and HDPE pipes, PVC is superior in joint connectivity and security with diameter over 200 mm. For this reason, HDPE pipes are only used for pipeline with diameter less than 150 mm in Japan. PVC pipes will be used for distribution pipelines with diameter less than 250 mm. Pipelines with over 300 mm diameters will use ductile iron pipes.

Table 2-8　Pipe Selection

Type	Diameter	Material	Remarks
Transmission pipes	150mm～600mm	Ductile Iron	High water pressure
Distribution pipes	200mm～250mm	PVC	Available locally in Tanzania
	300mm～700mm	Ductile Iron	

2-2-2-2 Water Resource Development Plan

In planning of water sources development, the following basic concepts are developed.

a) Total development volume of water sources:

Based on Section 5) “Design Water Supply Flow” of 2-2-1, total development flow of water sources shall equal to the shortage amount (14,000 m^3/day) that equals to difference between the sum of pumping rate of the existing wells and the daily maximum water demand in year 2010.

b) Water quality:

Quality of water sources shall satisfy the Zanzibar Drinking Water Quality Standards (ZDWQS)

c) Other constraints:

・To avoid saltwater intrusion in groundwater

・To avoid negative influence of new wells to the existing wells

Considering these premises, the development plan of water sources is established.

(1) Well Facility Planning

The Project area has unique characteristics in aquifer condition and has several constrains including saltwater intrusion. Therefore, by investigating these conditions, project well facilities are planned. The selection of well field for project wells and the aquifer characteristics in the project area are stated below.

1) Selection of well fields of project wells

For selection of well fields of project wells, the following conditions are discussed.

a) Saltwater intrusion area

UNDP (1987) specified saltwater intrusion areas on their hydrogeological map that the phenomenon can be naturally observed, depending on well depths. In the east side of the Zanzibar, saltwater intrusion areas are extended up to inland areas of some 2 to 4 km away from the seashore. In these areas, DWD have abandoned some of their deep wells due to changing of water quality from fresh water to saline water. Therefore, the basic design avoids the saltwater intrusion areas as well fields of new wells and selected the more inland areas.

b) High potential areas for groundwater development recommended by UNDP

The study of UNDP (1987) selected the Bumbwi Corridor area (refer to Figure 2-2) as a high potential area for groundwater development that extended in the North-South direction in the central area of the Unguja Island. DWD also planned the proposed sites for new wells in the Corridor area in the grant aid request plan. The Corridor area has no access road at present. Therefore, the basic design selected the neighbouring areas of the Corridor with good access roads because the area had a watershed boundary with the highest water level in a groundwater basin based on the UNDP hydrogeological map and is located in the inland area.

c) High potential areas for groundwater development recommended by FINNIDA

FINNIDA (1991) recommended the five (5) high potential areas (refer to Figure 2-2) for groundwater development, based on the groundwater development study that carried out pumping tests, water quality analyses, and construction of two test wells in every five sub-area, referring to the results of the UNDP study. Of these sub-areas, the Kizimbani North area located in the most northern side was cancelled by the consideration that it was inappropriate construction sites of new wells due to no access road.

Considering the above conditions, the basic design selected the four (4) sub-areas of Kizimbani, Kianga, Kimara, and M.Mchomeke as groundwater development area. Of these four sub-areas, the M.Mchomeke area has 8 existing deep wells for water supply concentrated in a small area. The well spacing is approximately from 100 to 500 m. In one of these existing wells, the drawdown was measured by recovery of ground water level after stoppage of pumping. It was only 2 meter, although the existing well pumps groundwater in large of quantity, 80 m^3/hour. According to pumping test data in the existing wells, the transmissivity of the aquifers in the area is 4,831 m^2/day. It is regarded as very large, thus, groundwater condition is evaluated as very good.

Based on the above conditions, M.Mchomeke area was selected as the well field for a new well because the aquifer is estimated to have large groundwater storage capacity even if one additional well was constructed near the existing wells.

2) Results of Electric Resistivity Survey

In the selected sites, electric resistivity survey was conducted. The results shows that the areas are covered by four to five geological layers and have some limestone layers. The fracture zones in limestone could not be revealed from analysis of the survey but it was confirmed to have the potential for groundwater development. In addition, since there are some well sites such as the M.Mchomeke area that we did not perform the survey, more detailed survey in the detailed study stage should be planned.

<u>KIZIMBANI Area</u>

Geological structures in the area are formed by four to six layers. In the area near the Bumbwi Corridor, there was limestone layer that could form aquifer. It is estimated to have groundwater development potential. However, hilly area in the western side is not appropriate for groundwater development because there are thick layers of clay and/or silt with apparently low resistivity values.

Table 2-9 Representative Result of Electric Resistivity Survey in KIZIMBANI Area

No.	Apparent Resistivity Value (Ohm-m)	Estimated Geological Layer	Layers Thickness
1	42	Surface Soil	1 m
2	84	Clay/Silt Layers	3.8 m
3	17.5	Weathered Limestone	27.2 m
4	27	Weathered Limestone	Unclear

Note: Geological layers are described from ground surface to deeper portion. Of the results of vertical electrical sounding (VES) points, the example of C-4 VES point with high groundwater development potential is shown.

<u>KIANGA Area</u>

Geological structures in the area are formed by four to eight layers. As the overview of the area, the geological structures are interpreted that limestone is interbeded in middle portion. Limestone is underlain by impervious layers of sandstone and clayey sand. It is interpreted that the area near the Bumbwi Corridor has higher potential for groundwater development.

Table 2-10　Representative Result of Electric Resistivity Survey in Kianga Area

No.	Apparent Resistivity Value (Ohm-m)	Estimated Geological Layer	Layers Thickness
1	48	Surface Soil	1.3 m
2	16	Weathered Limestone/Sand layers	6 m
3	47.5	Weathered Limestone	36.7 m
4	9.5	Sandy clay/ Weathered Limestone	23 m
5	38	Limestone	45 m
6	16	Clayey Layers	Unclear

Note: Geological layers are described from ground surface to deeper portion. Of the results of vertical electrical sounding (VES) points, the example of B-8 VES point with high groundwater development potential is shown.

KIMARA Area

Geological structures in the area are made of 3 to 8 layers and drastically change in the East-West direction. These changes may be controlled by geological structures with the North-South direction. Sounding data shows that there are potential sites for groundwater development.

Table 2-11　Representative Result of Electric Resistivity Survey in Kimara Area

No.	Apparent Resistivity Value (Ohm-m)	Estimated Geological Layer	Layers Thickness
1	240	Surface Soil	1.3 m
2	40	Weathered Limestone/Sand layers	6 m
3	66	Weathered/Consolidated Limestone	36.7 m
4	10	Clayey sand / Limestone	23 m

Note: Geological layers are described from ground surface to deeper portion. Of the results of vertical electrical sounding (VES) points, the example of A-5 VES point with high groundwater development potential is shown.

3) Aquifer Characteristics of Groundwater

According to the old survey report (J.H. Johnson: 1981-1984), groundwater aquifers are composed by consolidated limestone (M_1 formation) of Cenozoic era, Tertiary period, Miocene age, consolidated/coral limestone and sand layers (Q_3, Q_2 formations) of Quaternary period underlain by sand, maar, sandy clay, and clayey sand layers (M_2, M_3) of Cenozoic era, Tertiary period, Miocene age. Limestone of groundwater aquifers is formed in valleys of the old Rufiji River Delta developed in Tertiary period. At fractured portion in limestone, plenty of groundwater recharged by rainfall that fell on the Unguja Island discharges toward the seashore. The delta valleys had narrow width and stretched along old river courses as thread. If drilled boreholes encounter limestone in well construction, they may be able to obtain large yield. Otherwise, their yield shall become very small. The failure ratio of well construction, 20 % shall be derived from this reason.

In this area, transmissivity values of aquifers have large ranges from 158 to 15,000 m^2/day. Moreover, thickness of limestone layers changes with ranges from 2.8 m to 36 m. As thickness of limestone in the main aquifer is not consistent, flux of groundwater discharge and its layers thickness change largely in places. As well yield is determined by transmissivity values and thickness of aquifers, it largely changes. Therefore, representative values of hydrogeological conditions in aquifers cannot be determined. In the above report, in the aquifers that groundwater development was inappropriate, pumping tests were not carried out and only well structures and column sections are shown.

In the project area that is dominated by these aquifer conditions, several constrains are investigated. The details are shown in the Table below.

Table 2-12 Constrains for Groundwater Development

Constrains	Conditions Possible to be Estimated	Conditions Impossible to be Estimated
1. Avoidance of salt water intrusion into groundwater	In determination of groundwater development areas, saltwater intrusion areas as natural phenomenon are excluded. In addition, dynamic water level is kept in more than 6.2 m above mean sea level, based on water levels of the existing wells.	
2. Seasonal variation of groundwater levels	According to the monitored data, the maximum seasonal variation shall be 7.8 m.	
3. Aquifer conditions	Conditions are not uniform.	Fractures of limestone and aquifer thickness are not uniform. Therefore, the aquifer conditions are different in places. As transmissivity and coefficient of permeability are not uniform, groundwater theory cannot be applied. Therefore, drawdown and well yield cannot be determined.
4. Safe flux of screens	According to Johnson Div. (1987), V= 0.03 m/sec	

Well production potential was examined by aquifer conditions. As mentioned in the above, investigations on constrains for groundwater development prevent us to determine production potential by using groundwater theoretical formula (Jacob Modified Equation) due to no uniformity of hydrogeological conditions including transmissivity values (T), permeability coefficients (K), Storage coefficients (S) even if they can be calculated.

Therefore, the well production potential was calculated by safe flux of screens. For this purpose, it is necessary to plan standard specifications for new wells. The standard specifications for new wells were determined based on the depths of the nearest existing wells.

a) Depth of New Well

The survey results reveal that salinity levels of the most existing wells are low. However, deep wells may to draw salt water, and on the other hand, shallow wells may not provide necessary well yield or may not reach the depth of fractured limestone. Electric resistivity survey was carried out in planned well fields. Results of the survey generally give information on the outlines of geological structures and the occurrence of saltwater intrusion and unsuitable sites for groundwater development covered by impervious and thick layers including clay and silt. However, it is difficult to locate fractured limestone.

For this reason, in case to determine specifications of new wells, it is desired to refer the specifications of the existing wells in inland areas whose conditions of geology and groundwater situations and land elevations approximately correspond to proposed well fields. In this way depth of project wells was determined.

Specifications of the existing wells for water supply located in inland areas near proposed well sites are shown below.

Table 2-13 Specifications of the Existing Wells located near the Proposed Well Sites

Well Number	Well Location	Operating Condition	Well Depth (m)	Casing Diameter (mm)	Year Constructed	Elevation (m)
U-051	M. Mchomeke	Operating	69.00	250	2002	43
U-001	M. Mchomeke	Operating	70.03	250	-	40
U-50	M. Mchomeke	Pump breakdown	63.00	200	2002	43
U-033	M. Mchomeke	Operating	52.97	200	2000	43
Dole	Dole	Operating	56.00	200	2003	55
U-004	Kianga	Operating	49.00	200	2000	32.08
U-009	Chunga	Operating	45.20	250	1979	16.4
U-026	Chunga	Operating	46.00	250	1995	17
U-008	Chunga	Operating	45.20	250	1979	18

① KIZIMBANI area

Kizimbani Area, a proposed site for new wells, has elevation of about 45 m while M. Mchomeke Area, where the existing wells for Zanzibar City’s water supply are located, has elevation of 40 m to 43 m. Both areas have almost similar elevation. The Depth of the existing wells in M.Mchomeke area is from 53 m to 70 m. Supposing that groundwater levels of both areas are similar, project well depth for Kizimbani area is designed to be 70 m, same as the maximum depth of the existing wells.

Planned Well Depth: 70 m

② KIANGA area

Kianga area is located 1 to 2 km north of the existing wells and in midpoint between the existing well sites of Kizimbani and Kianga. Its elevation is also the mean between both well sites. Therefore, depth for project wells is supposed to be 60 m by adopting an intermediate value of depth of the existing wells in both areas.

Planned Well Depth：60 m

③ KIMARA area

Kimara area is located 1 to 2 km north of the existing Chunga well site and its elevation is higher than that of the Chunga site by about 10 m. Therefore, the depth of new wells is planned to be 60 m by adding 10 m to the depth of the existing wells.

Planned Well Depth：60 m

④ M. MCHOMEKE area

M. Mchomeke area has 5 existing deep wells for water supply with 100 m to 300 m spacing between the wells. The past study shows that there is a good aquifer with high transmissibity values ranging from 200 m^2/day to 4,831 m^2/day. The results of the observation performed by this study show that the drawdown in the U-051 well was only about 2 m at 84 m^3/day pumping rate. If one new well is additionally planned in the adjacent area of the existing wells, it is judged that it can pump up groundwater without interfering the other wells. As the existing wells have the depth of from 63 m to 70 m, the new well is planned to have depth of 70 m by adopting the maximum depth.

Planned Well Depth：70 m

b) Estimated Static Water Level

Since there were no existing wells near the proposed well field for new wells, groundwater level was estimated by relationship between ground levels and groundwater levels of the existing wells. The new wells with the same elevation as the existing wells are supposed to have the same groundwater levels of the existing wells. Moreover, in case that a project well at intermediate elevation of the two existing wells is planned, its groundwater level is estimated to have an intermediate depth of the two existing ones. The groundwater levels of the new wells are estimated as shown below.

Table 2-14 Estimated Groundwater Level of Project Wells

Propose well field and Project Well No.	(1) Ground Level （GL:m）	(2) Estimated Groundwater Level （SWL）(GL: m)	(3) SWL below GL (m)
KIZIMBANI （N-3, N-4, N-5）	+45	+23.0	22
KIANGA (N-6, N-7, N-8, N-9)	+30.0～+36.0	+23.0	7～13
KIMARA (N-10, N-11, N-12)	+23.0～+26.0	+19.0	4～7
M.MCHOMEKE (N-13)	+43.0	+23.0	20

(Note: SWL: Static Water Level, GL: Ground Level)

c) Casing Diameter of Project Wells

Casing diameter of the existing wells ranges from 200 mm (8”) to 250 mm (10”) and their majority are 250 mm. According to the Japanese Guideline for Designing Water Supply Facilities (2000), the minimum diameter of well casing is 250 mm for pumping rate less than 1,500 m^3/day (62.5m^3/day). Therefore, the casing diameter for new wells is planned as 250 mm.

Casing Diameter of New Wells : 250 mm

d) Screen Length of New Wells

Screen length of the new wells was determined by the mean aquifer thickness in the existing wells. The thicknesses of aquifers were obtained by adopting thicknesses of fractured limestone below dynamic water level at the pumping tests, based on the existing well records. The obtained data were averaged to obtain a mean value. The thickness of aquifers in the existing 8 deep wells has the range of 8 m to 33 m and their average is 21 m. Therefore, this average was used to be the average length of screens in the new wells. This length is 30 % of total well length corresponding to the standard specifications (groundwater level, drawdown, aquifer length, and material strength of well casing and screen, etc.) based on the many experiences in the past.

Screen Length of Project Wells: 21 m

e) Slit Width of Screens in New Wells

Available slit width for 250 diameter screens ranges from 0.75 mm to 3.0 mm. New screens will have 1mm in slit width that is generally adopted in the Zanzibar area since a large slit width may cause flow of sand into screens.

Screen Slit Width of Project Well: 1 mm

f) Well Structure

Well structure is designed to have the same diameter from the top of casing to well bottom. Telescope type well casing with a small casing diameter in deeper portion was not adopted due to the tendency to have incrustation at high flux into screen and difficulty to insert pump facility into deeper portion if water level lowers in the future by the progress of groundwater development. In addition, the well structure is planned to have gravel packing. The space between casings and boreholes is specified to be more than 50 mm.

g) Materials of Casings and Screens

The chief of water section of DWD requested materials of casings and screens to be made of unplasticized polyvinyl chloride (uPVC) as steel casing pipes installed in the past were corroded. This is considered that steel materials may be corroded by inflow of salt water into the existing wells at the time of drought. Although new wells are planned in the inland so as to avoid salt-water intrusion, durable uPVC are adopted as a material for well casing and screen considering long-term use of wells.

h) Investigation of Well Yield Potential in View of Safe Flux into Screen

"Groundwater and Wells, Johnson Division (Dr. Fletcher G. Driscoll: 1987)" recommended that safe flux of screens in the conditions of not turbulent but laminar flow to be V=0.03 m/sec based on many previous experiences. Well yield is estimated based on the safe flux.

Calculation of well yield potential per well

Potential well yield (Q) = Surface area of screens x Opening ratio of screens x Safe flux into screens x (1-clogging ratio of screens)

$$Q = D \times \pi \times L \times Op \times V \times (1-C) \times 60 \times 60$$

Q: Potential well yield (m^3/hr)

D: Screen diameter (m)

L: Effective screen length (m) (=screen length (21m) x effective length ratio)

Op: Opening ratio of screens (%)

V: Safe flux of screens (0.03 m/sec)

C: Clogging ratio of screens (%)

According to the screen specifications of the existing deep wells for water supply, opening ratio of screens is specified to be 7.9 % of effective area of screens in case of 1 mm slit width in screen diameter of 250 mm. Also, effective length per a unit of screen (3 m) shall be equivalent to 88 % of total effective area of screens as it includes sleeve for connection. Clogging ratio of screens is percentage that screens are clogged by packed gravel. Based on previous experience, the clogging ratio of 40 % to 50 % is adopted.

Potential Well Yield

Q = 61 to 74 m^3/hr. (Well yield has the ranges of 61 to 74 m^3/hr, depending on clogging ratios of 40 to 50 %.)

Well yield of the new wells is estimated to be 60 m^3/day. The value is the same as recommended value by FINNIDA (1991).

Well Yield of New Wells: 60 m^3/hour

i) Number of New Wells

Necessary pumping flow of the new wells amounts to be 14,000 m^3/day and well yield of each new well is estimated to be 60 m^3/hr by the above study. To secure the planned water supply volume, it shall be necessary that 10 project wells continuously operate for 24 hours. Number of project wells shall be 11 by adding a standby well in Kizimbani Area for Dole Service Area to planned 10 deep wells.

Project wells are planned for operation of 24 hours, every day and the pumping cannot be stopped. Otherwise, water supply shall be suffered by shortage of water in case of breakdown of submersible pumps without a standby well. Therefore, a standby well is planned. The survey of pump operation shows that three out of the 24 existing wells do not operate due to breakdown of well pumps. The ratio of pump breakdowns against the sum of the existing wells is 13 %. By the above consideration, it is necessary to add a standby well.

Number of Planned Project Wells: 10 Wells for continuous use + a standby well = 11 Project Wells

Plannned pumping flow of the new well is ;

14,000m^3/day x 1/10 wells = 1,400 m^3/day・well = 58.4m^3/hr・well

Summarizing the results stated in the above, number of the new wells is shown below,

Table 2-15 Proposed Sites and Number of New Wells

Proposed Construction Sites	Planned Number of Wells	Elevation
KIZIMBANI Area	3 wells (including one standby)	45 m
KIANGA Area	4 wells	27～38 m
KIMARA Area	3 wells	23～26 m
M.MCHOMEKE Area	1 wells	43 m
Total	11 wells (including one stand-by)	23～45 m

4) Failure Ratio of Well Construction

Well construction in the Unguja Island has been carried out by DWD using their three drilling rigs, and by construction firms in the past. Well drilling had failure cases in the past such as small well yields because of unfavourable underground geological condition.

In the formulating construction plan of new wells, failure ratio was examined. Failure ratio of well construction carried out by DWD and their reasons are shown below.

Table 2-16 Failure Rates of Well Construction by DWD

Construction Year	Number of Drilled Wells	Number of Succeeded Wells	Number of Failure Wells	Failure Ratio of Well Construction	Reason
2002	7	5	1 (+1 due to saline water*)	17	Well yield<50m^3/hr *Saline water.
2003	8	5	3	60	Well yield<50m^3/hr
2004	25	22	3	14	Well yield<50m^3/hr
Total	40	32	7 (+ 1 well with saline water*)	21.9	

*Note: failure due to saline water is to be avoided in the project because the project conducts vertical electric sounding and utilizes the data of UNDP study.

DWD regarded wells as failure in case of the saline water or the well yield less than 50 m^3/hr. The well yield for new wells to be 60 m^3/hr and it is the similar to the above value of DWD failure criteria. However, the cases of saline water intrusion shall be neglected in the project because the construction sites are selected in the inland area without saltwater intrusion phenomenon and based on analyzed results of electric resistivity survey. Limestone in aquifers is distributed in many places but the occurrence and extension of limestone with fractured zones could not be identified before drilling. Therefore, failure ratio based on the past records shall be applied on new well construction. According to the DWD records of well drilling in the past three years, failure ratio becomes approximately 20 %. Therefore, failure ratio of 20% is adopted for the project.

5) Comparison between Requested Plan and Basic Design for Well Facilities

Comparative table between the requested plan and this basic design for the project is shown below.

Table 2-17 Comparison between the Requested and Proposed Wells

Plan	Planned Pumping Rate	Number of Wells	Proposed Construction Sites	Reasons of Change
Requested Wells	100 m^3/hr	6 wells	Bumbwi Corridor	Pumping rate is limited. No access roads for the requested wells.
Proposed Wells	58.4 m^3/hr	11 wells (including one standby)	4 sub-areas near Bumbwi Corridor (FINNIDA's recommendation)	

The 100 m^3/hr well yield of the requested plan is regarded too large based on the observation of inflow of sand particles through screens in the existing wells with high production flow ranging from 80 m^3/hr to 100 m^3/hr. This shall be caused by higher flux of groundwater into screens because pumping rate of the existing deep wells is fairly high. The inflow of sand damages impeller of submersible pumps and reduces life span of submersible pumps due to overload of motors.

Taking safe side, it shall be important to reduce pumping rate to less than 60 m^3/hr. In the project, planned pumping rate was designed to be 58.4 m^3/hr from this viewpoint.

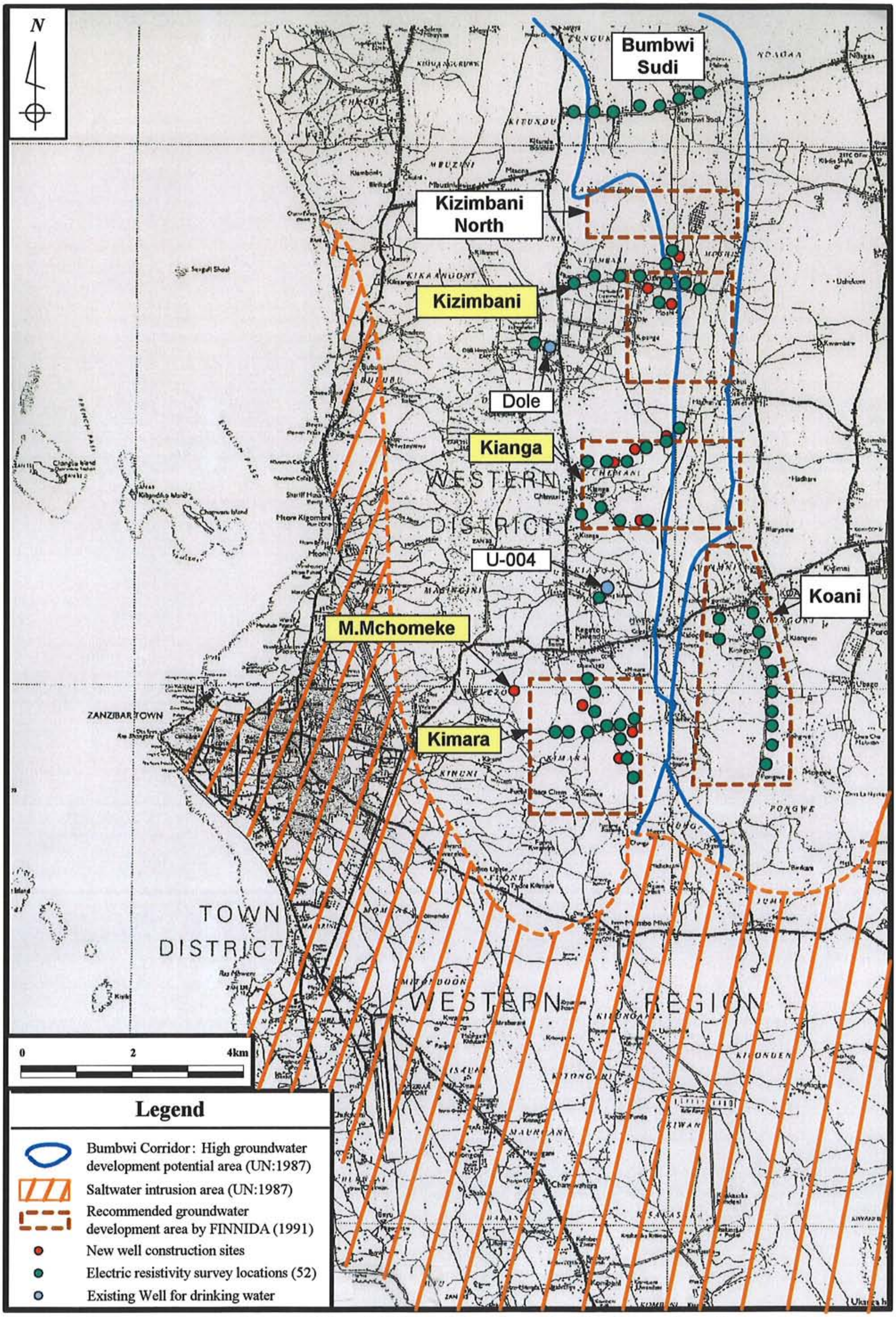

Figure 2-2 Proposed New Wells and Electric Resistivity Survey Locations

6) Summary of Specifications of New Wells

Specifications of new wells are summarized below.

Table 2-18 Specifications of Proposed Wells

Well No.	Service Area	Well field	Number of Project Wells		Well Depth (m)	Borehole Diameter (mm)	Casing Diameter (mm)	Screen Length (m)
			Phase1	Phase2				
N-3～N-5	Dole	Kizimbani		3	70	350	250	21
N-6～N-9	Welezo	Kianga	4		60	350	250	21
N-10, N-12	Kinuni	Kimara		2	60	350	250	21
N-11	Welezo	Kimara	1		60	350	250	21
N-13	Welezo	M.Mchomeke	1		70	350	250	21

(2) Environmental Impact Assessment (EIA)

Environmental Impact Assessment on the proposed groundwater development is carried out. The potential for groundwater development has been studied for the entire area of the Unguja Island by the past studies. In this study, the potential is examined in the study areas.

1) Groundwater Development Potential in the Unguja Island

In the Unguja Island, surface water disappears under ground in the limestone area of Quaternary period. Therefore, no surface water is discharged to the sea. Many streams flow in limestone caves and disappear. Several streams only appear on ground surface as springs after infiltrating to underground. Therefore, groundwater in the Unguja Island is in unconfined condition and discharges with slow speed toward the seashore. Groundwater recharge is only by rainfall that raises water level. Remaining discharge factor is evapotranspiration releasing from ground surface and tree leaves. FINNIDA study (1994) and Halcrow (1994) 's estimation is shown below,

Estimation of groundwater development potential by FINNIDA (1994)

Minimum mean yearly rainfall is approximately 1,100 mm in the drought year of 10% rainfall probability. Observation of groundwater level recovery in the past indicates that 30 % of rainfall actually recharges groundwater. Aquifers distributed in the seashore areas of the Unguja Island can be excluded from groundwater recharge area because groundwater development is difficult by the risk of saltwater intrusion. Moreover, as to minimise negative impact on island's environment by the project, the study introduces reduction coefficient of 20 %. As a result, groundwater development potential in the island comes to 105.6×10^6 m^3/year.

Unguja Island: Area ($1{,}600\times10^6$ m^2) x Rainfall (1.1 m) x Recharge ratio for groundwater (30%) x 0.2

= 105.6×10^6 m^3/year.

The study estimates that sustainable groundwater development is possible up to 100 million m^3/year.

Estimation of Groundwater Development Potential by Halcrow (1994)

Total water demand in the year of 2015 is estimated to be 57.2×10^6 m^3 as the sum of those of city residents, rural population, agricultural irrigation, tourism industry, and the other industries. The water demand corresponds to half of safe groundwater yield estimated by FINNIDA (1994) and one sixth of the values calculated by Halcrow (1994).

According to the past studies considering water balance in the Unguja Island, the groundwater development potential was large enough and it was judged to be able to cover water demand until the year of 2015.

2) Environmental Impact Assessment against Groundwater Extraction for the Project

Environment impact of groundwater extraction of the proposed volume in the project area is evaluated. Groundwater discharges to the sea in a groundwater basin. The boundary of groundwater basin is determined by geological structure and the height of groundwater level. Considering these factors, the boundaries of groundwater basin including groundwater development areas were determined. Figure 2-3 shows the groundwater basin.

<u>Establishment of Boundary of Groundwater Basin</u>

As shown in Figure 2-3, boundaries of groundwater basin in the western and the north sides were according to Hydrogeological Map made by FINNIDA (1994). Eastern boundary of groundwater basin was determined by the estimated groundwater watershed and the groundwater flow directions based on groundwater table of the hydrogeological map. Southern boundary of groundwater basin was determined by approximate locations of project wells and the contour lines of groundwater levels, considering that project wells draw groundwater from upper stream of groundwater flow.

<u>Area of Groundwater Basin for Groundwater Development</u>

Basin area measured by the planimeter: 74 km^2.

<u>Estimation of Groundwater Development Potential</u>

Of the above two studies on groundwater development potential, FINNIDA (1997) estimates it assuming more severe conditions. Therefore, the potential was estimated by the FINNDA method.

Q = 74×1,000,000 (Area of groundwater basin)×1.1 (yearly rainfall with 10% probability)×0.3×0.5

= 11,800,000 m^3/year

Groundwater Development Potential: 11,800,000 m^3/year

<u>Groundwater Extraction by Existing and Planned New Wells</u>

Groundwater extraction by the existing and project wells distributed in the groundwater basin was estimated. The extraction volume is shown in Table 2-19. In the basin, there are only a few irrigation wells besides the above wells, no industrial parks and residential development with own water sources.

Table 2-19 Water Balance between Groundwater Development Potential and Groundwater Extraction

Description	Area	Water Volume (m^3/year)	Remarks
Groundwater Development Potential: A	Proposed Groundwater Basin	11,800,000	
Groundwater Extraction of Existing Wells	Chunga	2,172,480	
	Kianga	700,800	
	M.Mchomeke	2,794,440	
	Dole	210,240	
Groundwater Extraction of Project Wells	Construction Well fields	5,256,000	
Total Groundwater Extraction: B		11,133,960	B/A =94 %

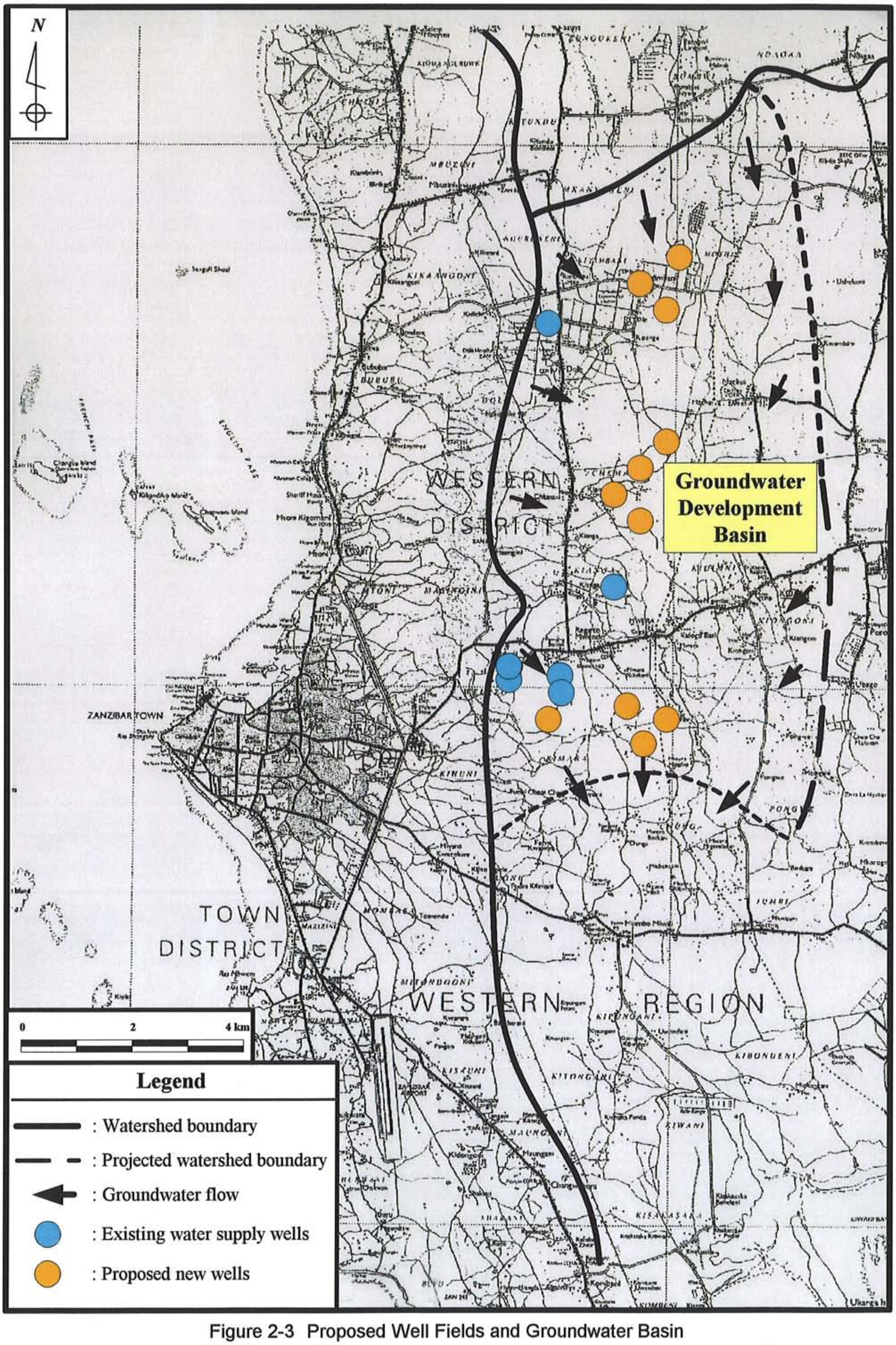

Figure 2-3 Proposed Well Fields and Groundwater Basin

Environmental Impact of Groundwater Extraction by New Wells

Table 2-19 indicates water balance between the estimated groundwater development potential and the groundwater extraction by the existing and new wells. The groundwater recharge is much larger than the groundwater extraction. Therefore, the groundwater development may not give a significant impact on the environment. It shall not have an impact on the environment even if irrigation wells in addition to the existing and new wells pump up groundwater.

(3) Well Pumps

1) Capacity and Number of Well Pumps

① Design Flow

Total Design Flow for New Wells = Daily Maximum Flow - Current Water Production (Daily Maximum)

$= 54{,}100 m^3/d - 40{,}100 m^3/d$

$= 14{,}000 m^3/d$

② Number of New Wells

Operating 10 wells + Stand-by 1 well = 11 wells

③ Capacity per well

q = 14,000m^3/d/24hr/10 wells = 58.4m^3/hr/well

2) Type of Well Pumps

- Pumps will be submersible pump same as the existing well pumps.
- Electrical equipment is to be housed in pump house for ease of maintenance works.

3) Total Head of Well Pumps

The head losses of transmission pipelines are calculated based on the transmission pipeline plan in Section 2-2-3. The total heads of well pumps are calculated as follows.

H= Actual Head + Head Losses

= (Reservoir Water Level – Well Low Water Level) + Transmission Pipeline Losses + Pump Piping Losses

Dole Service Area　N-3,4,5: 110m

Welezo Service Area　N-6,7,8,9: 100m　N-11,13: 90m

Kinuni Service Area　N-10,12: 70m

4) Proposed Well Facilities

Table 2-20 Proposed Well Facilities

Item	Specification	Number		Remarks
		Phase1	Phase2	
[Mechanical Equipment]				New
Well Pumps	Submersible Pump N-3,4,5：For Dole Service Area ϕ125 x 58.4m^3/hr x 110m x 37kW N-6,7,8,9：For Welezo Service Area ϕ125 x 58.4m^3/hr x 100m x 37kW N-11,13：For Welezo Service Area ϕ125 x 58.4m^3/hr x 90m x 30kW N-10,12：For Kinuni Service Area ϕ125 x 58.4m^3/hr x 80m x 30kW	 - 4 2 -	 3 - - 2	 Include a stand-by
Piping and Valves around Pumps	Discharge pipes, Valves, Flow Meters	1	1	11 wells
[Electrical Equipment]				New
Transformers	Oil/Self-cooling 33 or 11kV／415V, 50kVA	6	5	Breaker Lightning arrestors
Power distribution/Control Panel	Steel/Indoor/Self-standing For 37kW motor (with soft starter) For 30kW motor (with soft starter) For 22kW motor (with soft starter)	 4 2 -	 3 - 2	 For N-3,4,5,6,7,8,9 For N-11,13 For N-10,12
Water Level Detector	Electrode	6	5	Low water level detection
Power and Instrumentation Cables		1	1	11 wells
[Civil and Architecture]				New
Wells	Well Diameter: ϕ250mm Design Well Depth: Dole Service Area N-3,4,5: 70m Welezo Service Area N-6,7,8,9,11: 60m Welezo Service Area N-13: 70m Kinuni Service Area N-10,12: 60m	 - 5 1 -	 3 - - 2	
Well Pump House	For Power distribution/Control Panels	6	5	

2-2-2-3 Water Transmission and Distribution Facilities

(1) Service Areas

In addition to the existing Saateni service area and Welezo service area, a new reservoir will be constructed in Dole at 100 m elevation in order to supply water to the north area, which includes Bububu area which is to be a new site for the government offices and experiences rapid population growth. This area will be called Dole Service area.

For south and east parts of the study area, in order to facilitate water supply to Urban Extension area whose population is growing rapidly, a new reservoir is proposed. The location of the reservoir is Kinuni area at the east of Urban area near the proposed new wells to be constructed in the central area, avoiding possible salinization of wells mainly observed in south area. This Kinuni Service area also includes area served by the existing Mbweni and Magogoni wells and the Dimani spring. Those service areas are shown in Figure 2-4.

Daily maximum demand and population for the above service areas in year 2010 are shown in Table 2-21. Those service areas are further divided into the 19 zones according to the land uses in order to analyze water demand in details.

Table 2-21 Daily Maximum Demand and Population for Service Area

Zone No.	Total Demand (Daily Max.) m^3/day	SAATENI Service Area m^3/day	WELEZO Service Area m^3/day	DOLE Service Area m^3/day	KINUNI Service Area m^3/day
Urban					
1	1,894	1,894			
2	3,343	3,343			
3	4,324	4,324			
4	2,507	1,504	1,003		
5	4,197	1,049	3,148		
6	6,344		6,344		
7	8,004		8,004		
8	6,537		6,537		
Urban Ext.					
9	3,950		1,707	2,243	
10	3,030		2,730		300
11	6,399				6,399
12	521				521
Peri-Urban					
13	369			369	
14	583			583	
15	234			234	
16	793		793		
17	474				474
18	461				461
19	117				117
Total	**54,080**	**12,115**	**30,265**	**3,428**	**8,272**
Service Population	**457,330**	**74,781**	**256,675**	**18,213**	**107,661**

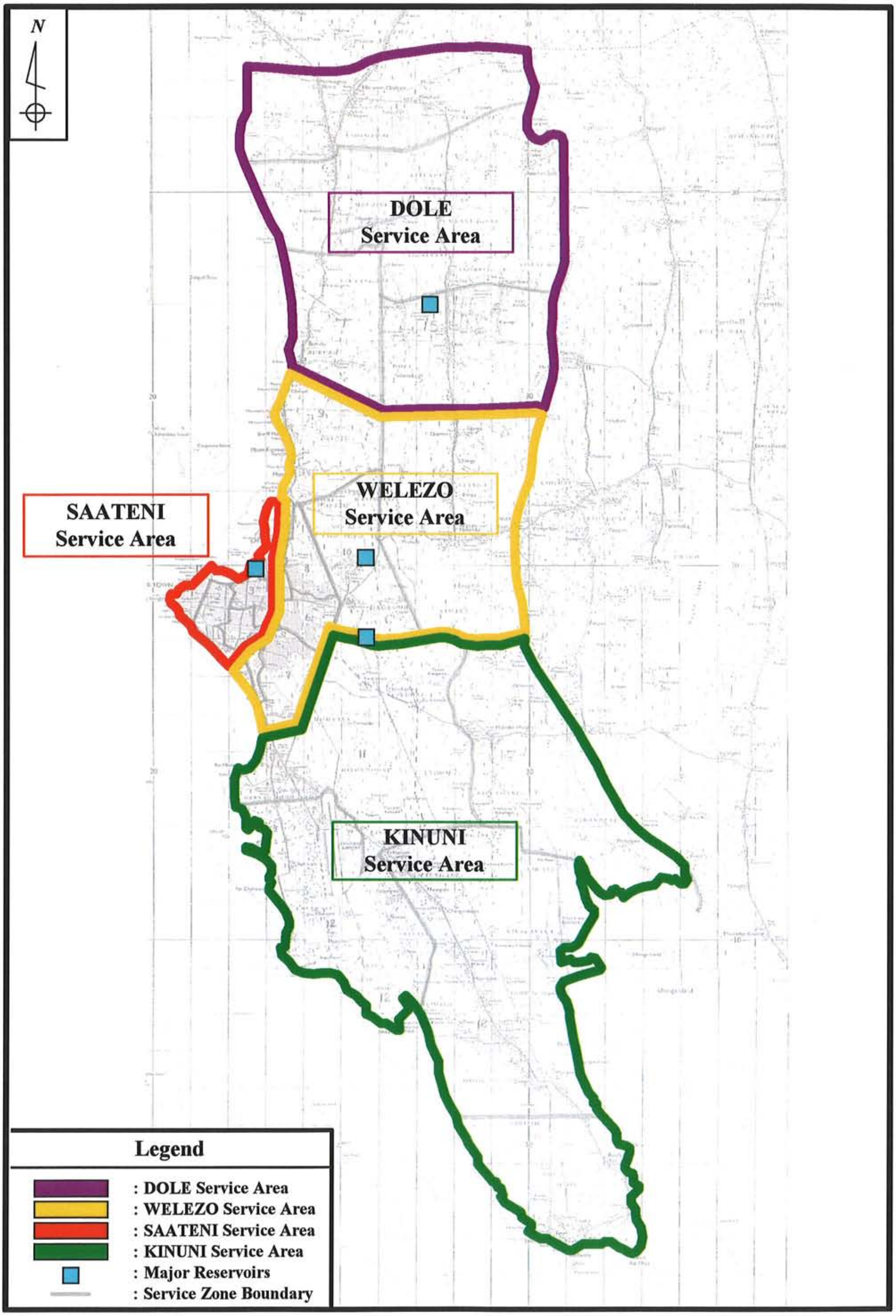

Figure 2-4 Service Areas

(2) Transmission Pipeline Plan

1) Development Strategy for Transmission Pipeline

Transmission pipes will be laid mainly in the existing roads to facilitate maintenance works. Diameters of the pipelines are designed to maintain flow velocity around 1 m/s in order to prevent excessive head losses. Badly damaged existing transmission pipeline from Chunga wells to Welezo reservoirs will be replaced to prevent water losses. The flow from those wells will be lead to the new Kinuni reservoirs. The part of this pipeline will also be used by the new wells.

2) Transmission Pipeline Plan

The proposed transmission pipelines from the proposed wells to the reservoirs are shown in Figure 2-5. Length of transmission pipelines is shown in Table 2-22 according to the service areas.

Table 2-22 Length and Diameter of Transmission Pipelines (m)

	Service Area	**SAATENI**	**WELEZO**	**KINUNI**	**DOLE**	**Total**
Diameter	**Material**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**
150	DI	0	2,000	1,300	700	4,000
200	DI	0	1,900	500	3,800	6,200
250	DI	0	2,500	0	0	2,500
300	DI	0	2,300	2,700	0	5,000
400	DI	0	2,100	2,000	0	4,100
600	DI	0	2,200	0	0	2,200
Total Length		**0**	**13,000**	**6,500**	**4,500**	**24,000**

3) Additional Facilities for Transmission Pipelines

The following additional facilities for transmission pipelines will be constructed.

a) Intermediate Sluice Valve

For maintenance works of well pumps and transmission pipelines, emergency valve operation for cross-boundary water supply, sluice valves will be installed.

b) Air Valves

Transmission pipeline routes have some ups and downs. Air valves will be installed at summits of pipelines before and after invert crossing of underground structure such as culverts to release air automatically and prevent air binding and pressure build-up.

c) Drain Pipes

In order to remove debris left in pipelines after pipe and well pump maintenance works, drainpipes will be installed to the transmission pipelines. Drainpipes will be located at the near end of the pipelines and at the rivers and channels.

d) Appurtenances

Other fittings connect with the existing pipes.

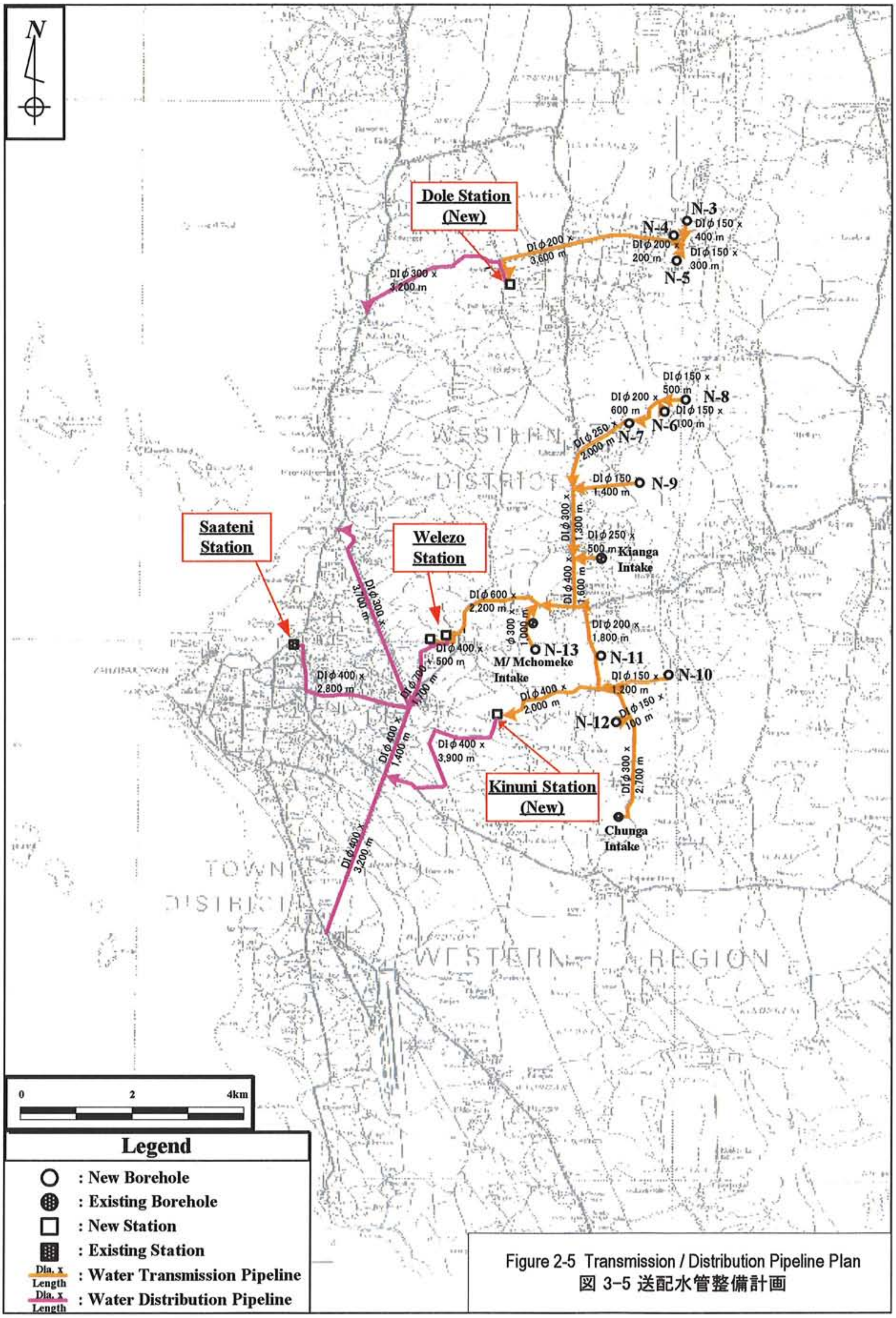

Figure 2-5 Transmission / Distribution Pipeline Plan
図 3-5 送配水管整備計画

(3) Water Reservoir Plan

1) Development Strategy for Reservoirs

Reservoir development plan is prepared based on the FINNIDA master plan (1991). The reservoirs are designed for the following purposes.

a) Attenuate Diurnal Fluctuation of Water Demand

Reservoir capacity required to attenuate diurnal fluctuation of water demands is 17.5% of daily water demand (FINNIDA Master Plan).

b) Uninterrupted Water Supply during Pump stops due to Power Failures

17.5% of daily water demand will be stored in the reservoirs in order to secure uninterrupted water supply during 3 hours pump stops during the peak hours (FINNIDA Master Plan).

c) Storage required for Fire Flow Demand

Reservoir capacity required for specifically fire fighting is 1% of daily demand (FINNIDA Master Plan).

The required reservoir capacity, the sum of the above 3 items, is 36%, equivalent to 8.6 hours of daily water demand.

2) Reservoir Plan

New reservoirs are proposed to secure 8.6 hours of daily demand in each service area. The proposed reservoirs are shown in Table 2-23.

Table 2-23 Proposed Reservoirs

Service Area		Dole	Welezo	Saateni	Kinuni	Remarks
Daily Maximum Flow	m^3/d	3,428	30,265	12,115	8,272	
Required Reservoir Volume (A)	m^3	1,228	10,845	4,341	2,964	=Qday.max.x8.6/24 (8.6hrs 分)
Existing Reservoirs (B)	m^3	(40x2)*	2,250x1 420x1 120x1(Begamoja)	2,250x1 1,000x2 90x1(Mbao)	250x1(Dimani)	
	Total		2,790	4,340	250	
Balance	m^3	1,228	8,055	1	2,714	=A-B
Proposed Reservoirs		**1,200m^3x1**	**4,000m^3x2**	**Not required**	**2,700m^3x1**	

Note) ＊: The existing reservoir is designed for the vocational school and hospitals.

3) Necessity of Elevated Tanks

After the implementation of the proposed project, Saateni service area will be served through two elevated reservoirs. In order to secure continuous water supply during power failures, elevated tanks shall store 2 - 3 hours of daily demand.

Daily Average Demand of SAATENI Service Area = Daily Maximum Demand x 1/1.35＝12,115/1.35＝8,974 m^3/d

Required elevated tank capacity = 8,974ｘ (2~3) hours / 24 = 748～1,121m^3

・Existing elevated tank = 450m^3ｘ2 = 900m^3 ＞ 748m^3 (2 hours of daily average demand)

Thus, new-elevated tanks are not required.

4) Transmission Pump Plan (Saateni Service Area)

Deteriorated transmission pumps from the ground and underground tanks to the elevated tanks in Saateni Station will be renewed under this project. Pump capacity is calculated as follows.

- Design Flow:

  Hourly Maximum Flow = Daily Maximum Flow x 1.2 = 12,115m^3/d x 1.2 = 14,538m^3/d

- Pump Configuration

  Configuration will be same as the existing pumps.

  Small pumps: 1 operation + 1 stand-by, Large pumps: 1 operation + 1 stand-by

- Pump Sizing

  200m^3/hr x 2 (include 1 stand-by)

  400m^3/hr x 2 (include 1 stand-by)

5) Disinfection Facilities

Every reservoir will have disinfection facilities to disinfect drinking water.

・Disinfection type: Solution of powder disinfectant / drip dosing method

(The same method being used at the Saateni Station)

・Application: At the inlet of each reservoir

6) Additional Facilities for Reservoirs

The following facilities will be provided for the proposed reservoirs.

a) Water Level Meters

One water level meters will be installed to each reservoirs for efficient reservoir operation.

7) Proposed Reservoir Facilities

Table 2-24 Proposed Reservoir Facilities

Item	Specification	Number		Remarks
		Phase1	Phase2	
Saateni Station				
[Mechanical Equipment]				Renewal
Transmission Pumps	Horizontal Bidirectional Centrifugal Pump 400m3/hr x 40m x 75kW 200m3/hr x 40m x 45kW	 2 units 2 units		 Include 1 stand-by Include 1 stand-by
Pipes and Valves for Pumps	Discharge pipes, valves, flow meters, mechanical water level meter	1 set		
Disinfection Facility	Powder Disinfectant Solution Tank/Drip	1set		
[Electrical Equipment]				Renewal
Instrumentation Panel	Indoor Steel Wall-mounted Type (Arrestor preinstalled)	1 unit		
Low Voltage Panel	Indoor Steel Wall-mounted Type (Arrestor preinstalled)	1 unit		
Transmission Pump Control Panel 1	Indoor Steel Wall-mounted Type 75kW with auto-trans starter	2 units		
Transmission Pump Control Panel 2	Indoor Steel Wall-mounted Type 45kW Star-delta starter	2 units		
Level Sensor	Float type	5 sets		Reservoir, elevated tank level detection
Power and Instrumentation Cables		1 set		
[Civil and Architectural]				
Roof for Pump House		1 set		Renewal
Welezo Station				
[Civil and Architectural]				
Reservoir	Volume: 4,000m^3	2		New
Structure	Reinforced Concrete			
Dimensions	22.5 mW x 17.2 m L x 5 m H x 2 tanks			
High / Low Water Level	74.9m/69.9 m (elevation)			
[Mech. / Elect. Equipment]				
Disinfection Facility	Powder Disinfectant Solution Tank/Drip	1set		New
Kinuni Station				
[Civil and Architectural]				
Reservoir	Volume: 2,700m^3		1unit	New
Structure	Reinforced Concrete			
Dimensions	22.5 mW x 12.5 m L x 5 m H x 2 tanks			
High / Low Water Level	55.0m/50.0 m (elevation)			
[Mech. / Elect. Equipment]				
Disinfection Facility	Powder Disinfectant Solution Tank/Drip		1set	New
Dole Station				
[Civil and Architectural]				
Reservoir	Volume: 1,200m^3		1 unit	New
Structure	Reinforced Concrete			
Dimensions	14.6 mW x 8.9 m L x 5 m H x 2 tanks			
High / Low Water Level	103.7m/98.7 m			
[Mech. / Elect. Equipment]				
Disinfection Facility	Powder Disinfectant Solution Tank/Drip		1set	New

(4) Distribution Pipeline Plan

1) Development Strategy for Distribution Pipelines

Through the preliminary study and the site survey of this study, the areas that experience water supply disruptions are investigated and shown in Figure 2-6. While the most of the problem areas are within the Welezo service area, Saateni service area also has low-pressure area. Thus even in the Zanzibar Urban area, the existing pipes laid from 1950's to 1970's do not have sufficient capacities.

In order to solve the above problems, different strategies were developed for Urban area and Urban Extension/Peri-Urban area.

① Urban Area (SAATENI Service Area, A Part of WELEZO Service Area)

Urban area, which includes the Stone Town, is a built-up area with the fixed land use plan. Its future population growth is relatively small. Proposed distribution pipelines (main pipes) are designed to achieve the minimum water pressure of 5-meter water head.

② Urban Extension/Peri-Urban Area (WELEZO Service Area, DOLE Service Area, KINUNI Service Area)

Most of this area does not have fixed land use plan and future distribution of its population is not clear. Thus only minimum distribution pipelines (main pipes) enabling distribution of increased water production from the proposed wells are proposed for this area.

2) Distribution Pipeline Plan

Proposed distribution pipelines following the above strategy are shown in Figure 2-5. Lack of proper pipe replacement plan encouraged duplicated small diameter pipelines in the some routes in order to meet the increasing water demand. Those pipes are regarded as minor distribution pipes, which house connections are directly tapped into. The proposed distribution pipelines will form trunk distribution pipelines, whose role is to supply sufficient water as well as to maintain the minimum water pressure in Urban area. The proposed pipelines will be connected to the existing minor distribution pipelines at appropriate intervals. House connections will not be tapped directly into the proposed pipelines.

The proposed pipeline replaces the existing asbestos cement pipeline from Welezo station to Saateni Station. The most of the other existing pipelines will be used even after the completion of the proposed project since house connections are tapped into those pipes. The total length of the existing pipes to be abandoned after the project completion is estimated to be 3 km, 1.5% of the total length of the existing distribution pipelines.

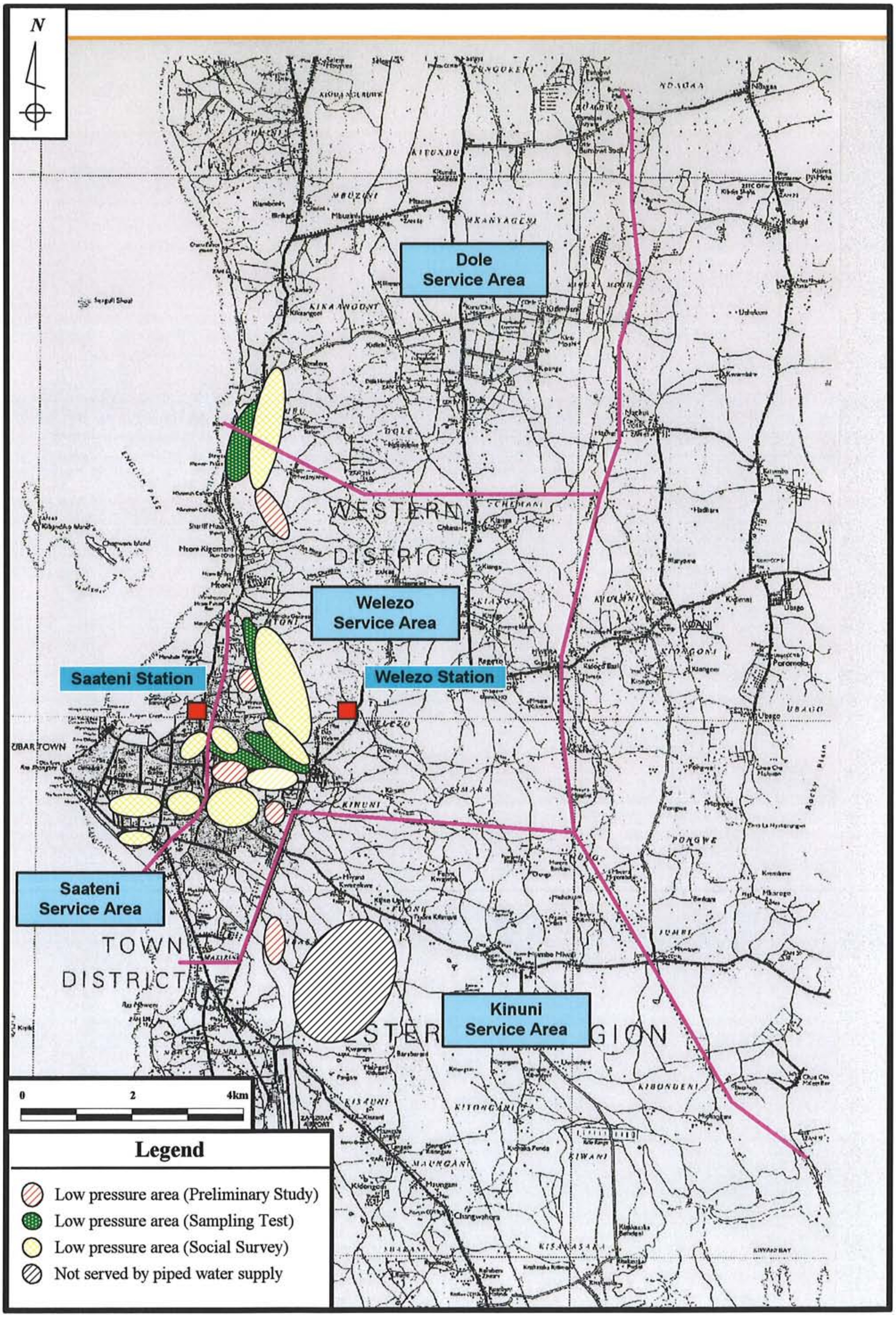

Figure 2-6 Areas with Service Disruptions

Length of the proposed distribution pipelines is shown in the Table 2-25.

Table 2-25 Length of Proposed Distribution Pipeline (m)

Service Area		**SAATENI**	**WELEZO**	**KINUNI**	**DOLE**	**Total**
Diameter	**Material**	**(m)**	**(m)**	**(m)**	**(m)**	**(m)**
200	PVC	0	0	0	0	0
250	PVC	0	0	0	0	0
300	DI	0	3,700	0	3,200	6,900
400	DI	0	4,200	7,100	0	11,300
700	DI	0	1,700	0	0	1,700
Total Length		**0**	**9,600**	**7,100**	**3,200**	**19,900**

3) Results of Water Supply System Simulation

In order to analyze problems of the existing water supply systems and to confirm the proposed pipelines rectify the problems in the most efficient manner, computer simulation of the existing and the future water supply systems are developed using EPANET as a simulation program. The results of the simulation of the existing system at the morning peak-demand hour are shown in Figure 2-7. Red nodes in the Figure show the points with no water pressure, thus experiencing supply disruption. Distribution of the red nodes overlaps that of service disruption area shown in Figure 2-6.

The simulation results of the future water supply system in 2010 are shown in Figure 2-8. Even at the peak-demand hour, the minimum water pressure (5m) is achieved in the Urban area. Most of the Urban Extension/Peri-Urban area will enjoy the improved water pressure during the peak-hours, thus service disruption will be minimized.

4) Additional Facility for Distribution Pipelines

a) Sluice Valve

Sluice valves will be installed at the pipe junctions, connection pipes to the existing pipelines, etc. to facilitate maintenance works of the distribution pipelines.

b) Flow Meters

In order to appropriate water distribution, flow meters will be installed mainly at the outlets of the reservoirs.

c) Pressure Reducing Valves

Pressure reducing valves will be introduced to control water pressure in the low elevation sections of Welezo and Dole service areas, which have reservoirs at the high elevations. The pressure reducing valves will be placed on the proposed distribution pipeline maintaining the water pressure less than 60 m.

d) Drain Pipes

In order to remove debris left in pipelines after pipe maintenance works, drainpipes will be installed to the distribution pipelines. Drainpipes will be located at the near end of the pipelines and at the rivers and channels.

e) Appurtenances

Other fittings connect with the existing pipes.

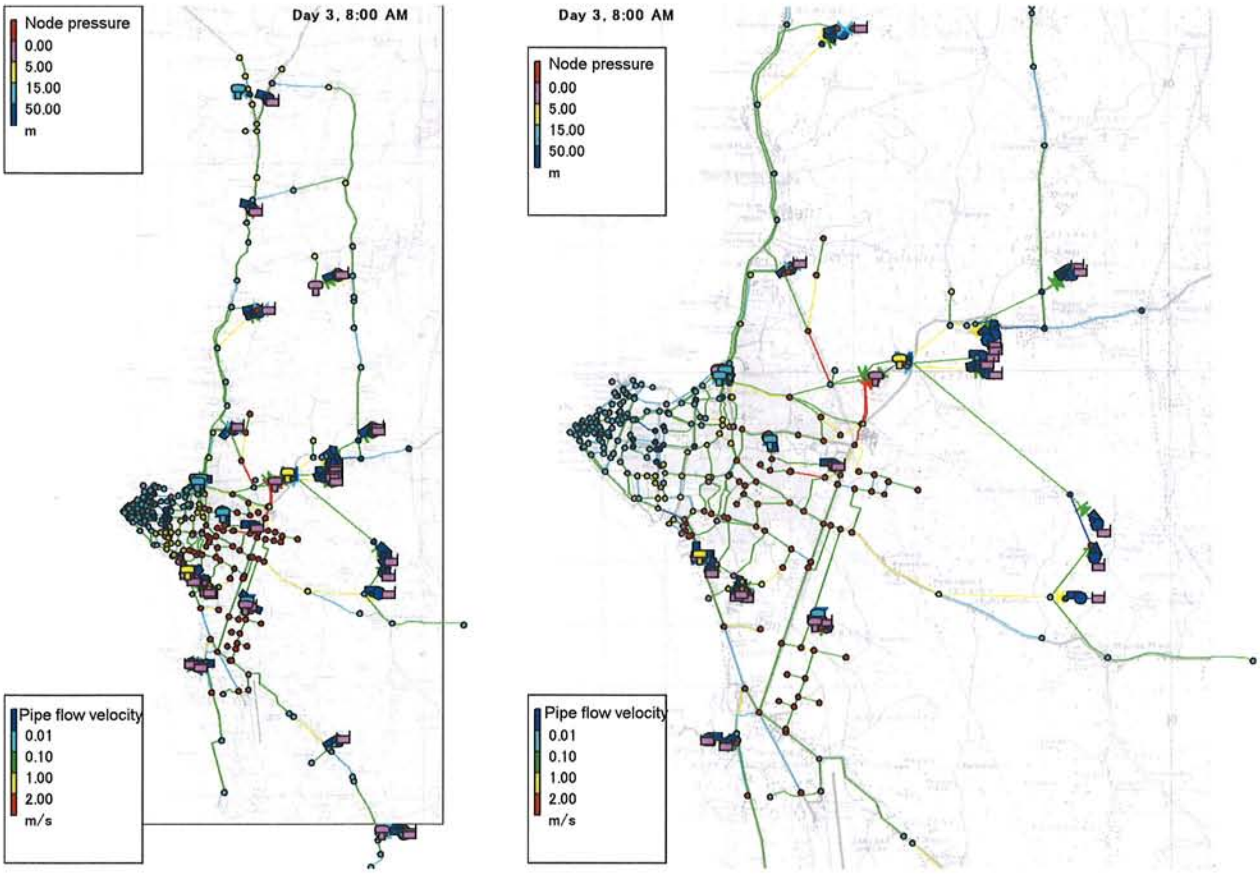

Figure 2-7 Simulation Results of the Existing Pipe Network (Peak Hour in 2004)

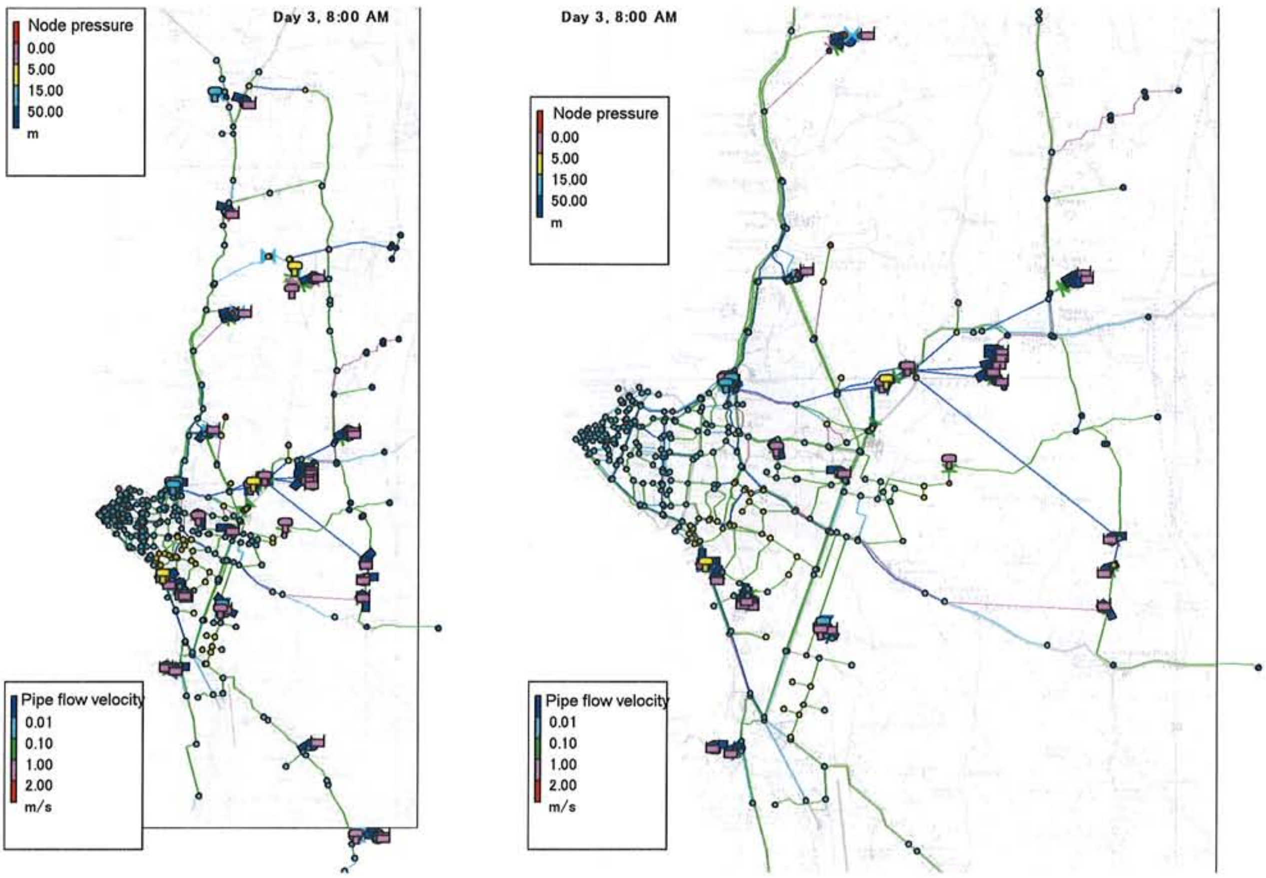

Figure 2-8 Simulation Results of the Future Pipe Network (Peak Hour in 2010)

5) Proposed Facilities for Distribution Pipelines

Table 2-26 Proposed Facilities for Distribution Pipelines

Item	Specification	Number		Remarks
		Phase1	Phase2	
[Civil Facilities]				
Flow Meters	Axial-flow Propeller Type			New
	Dole Service Area: ϕ300	-	1 set	
	Welezo Service Area: ϕ300	1 set	-	
	Welezo Service Area: ϕ400	3 sets	-	1 set to be installed at connection pipe to Saateni elevated tanks.
	Saateni Service Area: ϕ300	2sets	-	
	Kinuni Service Area: ϕ400	-	1set	
Pressure Reducing Valves	Automatic Water-Pressure Driven Type			New
	Dole Service Area: ϕ200	-	1 set	
	Welezo Service Area: ϕ500	1 set	-	

2-2-2-4 Equipment Procurement Plan

Among the requested water quality laboratory equipment and maintenance equipment, DWD emphasized that urgent need for four pickup trucks. The study team evaluated this need and found out that DWD needs 3.5 – 4.8 trucks for routine operation and maintenance works, 1 truck for non-routine works. Thus, procurement of four trucks is regarded as a high priority.

	Purpose	Department	Work load/Manpower	Required trucks
1	Pump Maintenance	Plant and Mechanics	The existing well pumps - 27: After completion of this project - 38 Manpower: 250, Manpower working in the study area is 41.	*1) 38 trucks x 1/6 = 6.2 /month 6.3 trucks/month/21.4 = 0.3 trucks Required trucks: 0.3
2	Chemical Transportation, Water Quality Sampling	Water resources	The existing reservoirs: 2, After completion of the project - 4 Manpower: 77, Manpower working in the study area is 5.	*2) Chemical Transportation: 2 days/week Sampling: 1 day/week Required trucks: 0.6
3	Pipeline Maintenance	Water Supply	Length of the existing pipelines: 230km 126 pipe repair works in 9 month (2004): 14 repairs/month Manpower: 88, Manpower working in the study area is 26.	*3) 14 repairs/month x 2 x (2 - 3) /21.4 = 2.6 - 3.9 Required trucks: 2.6 - 3.9
4	Facility Maintenance	Planning & Design / Administration	Planning/Design: 7 + Administration: 37	*4) No routine works (Required trucks: 1)
Total				3.5～4.8 + (1)

*1) Pump requires maintenance works once in 6 months.
38 x 1/6 ＝ 6.3 pumps/month
Pump maintenance works consist of taking-out (1 hour), re-installation (1 hour), and transportation (1 hour). Within the working hours (8 hours/day), actual operation hours for truck is 4 hours/day, thus using one truck, DWD maintain one pump in a day. Saturday and Sunday are off for the government agencies; working days are 30 day/month x 5/7 = 21.4 days.
6.3 trucks/month/ 21.4 = 0.3 trucks are required.

*2) Chemical Transportation is required once per every week for each reservoir.
Within one day, one truck loads, unloads and transports disinfection chemical for 2 reservoirs. It will take 2 days per week for 4 reservoirs.)
Drinking water sampling at the reservoirs could be done at the time of chemical loading and unloading. Sampling at wells and springs in the region could be done in one day per week.
Thus 0.6 trucks are required. (3 days per week (5days))

*3) Pipeline repairs were done at average 14 locations/month in 2004. Repair of one pipe damage will take 2 – 3 days in average. (source: DWD workshop) It does take 2 trucks for 2 - 3 days for transportation of engineers, labours, materials and tools in order to repair one pipe break, the required trucks are 14 x 2 x (2 - 3)/21.4 = 2.6 - 3.9 trucks.

*4) Although facility maintenance works does not have clear routine works, design of pipeline extension, regional water resource management, and customer service (attending complains) do require one truck.