LOCAL GOVERNMENT DIVISION
MINISTRY OF LOCAL GOVERNMENT, RURAL DEVELOPMENT
AND COOPERATIVES
THE PEOPLE'S REPUBLIC OF BANGLADESH

THE PREPARATORY SURVEY REPORT ON THE GROUND WATER INVESTIGATION AND DEVELOPMENT OF DEEP GROUND WATER SOURCE IN URBAN AND RURAL AREAS IN THE PEOPLE'S REPUBLIC OF BANGLADESH

SEPTEMBER 2012

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

EARTH SYSTEM SCIENCE CO. LTD. (JAPAN)

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SUMMARY

1. OUTLINE OF BANGLADESH

(1) LAND AND NATURAL CONDITIONS

Bangladesh is located in South Asia and bordered mostly with India except for the short border by Myanmar and the coast line facing Bengal Bay, and occupies about 147,570 km^2 of land. The population is 149.8 million persons (2011, Bangladesh Bureau of Statistics: BBS). Topography is characterized by deltaic plains and flood plains formed by the Padoma River, the Jamuna River and the Meghna River originated from the Himalayas. Although most of the land is distributed in the lowlands and the elevation is less than 20 m, the Chittagong Hills appears in the eastern area and mountainous land is distributed in the north eastern area.

The climate is classified as a Tropical Monsoon climate zone. The rainy season is from May to October and the dry season is from November to April. The target area of the Project is the western side of the nation where annual precipitation is relatively low, less than 2,000 mm. The highest temperature was observed in April and the highest monthly average temperature is 36.3 degrees Celsius at Chuadanga. The lowest monthly average temperature (9.5 degrees Celsius at Srimangal Upazila in Mauluvibazar) was observed in January. The regional difference of temperature is small.

Surface geology consists of the Dupi Tila Formation, the Madhupur Clay and the Alluvial Deposits. The Dupi Tila Formation was deposited in a period from the Pliocene to the Pleistocene and distributed in the hill area. Madhupur Clay accumulated in the Pleistocene and forms the plateau. The Alluvial deposits are of Holocene and divided into deltaic sediments and flood sediments. No geological formations in the older age crop out. They are covered by the three formations described above.

(2) SOCIO-ECONOMY

Per capita Gross Domestic Product (GDP) of Bangladesh is 1,700 US$/capita in 2011, and the economic growth is 6.3%. The highest industrial GDP in 2011 is the tertiary industry, and the percentage is 53% (primary industry: 18.4%, and secondary industry: 28.6%).

The Consumer Price Index was 80.74 in1991, 163.17 in 2005 and 242.48 in 2010 (assuming the index in 1995-1996 as 100). The consumer price is increasing year by year.

The primary income source is farming at 41.0% of the sample households. Casual work (18.7%), own business etc. (13.7%), retail (11.3%) and so on are given as other income sources.

The median monthly household income is 7,500 BDT in the dry season and 5,500 BDT in the rainy season. About 50% of the households have monthly income between 4,001-8,000 BDT. The difference of household income between households with the highest income and the lowest income is large in each village. The difference is at least 4,000 BDT.

The primary water source is shallow tube wells with arsenic contamination of less than 0.05 mg/L at 42% of the households, and about 41% of the households use shallow tube wells with arsenic contamination more than 0.05 mg/L or shallow tube wells in which arsenic concentrations are not checked.

All the target villages have safe water devices. Water user committees are present in 13 villages, but in some cases the land owner bears all the necessary costs and the users do not pay. The safe water devices in 21 villages are free of charge.

The time to reach the water source is less than 3 minutes at about 55% of the households, and queuing time is less than 1 minute at about 81% of the households. Fetching water is the work for adult women (91.7%). Adult women and girls account for 95% of the work.

(3) INFRASTRUCTURE

The major means of traffic in Bangladesh is roads, water transport and trains. The national and regional highways are well developed, and there is no problem in driving during the rainy season. Regarding feeder road type-B and rural roads, sometimes the width of the roads is narrow and the roads are unpaved. Therefore, it is difficult to drive large vehicles even in the dry season. About water transport, construction of bridges is not well developed. Therefore, when going to the Study area, it is needed to use a ferry or cross the Jamuna Bridge, although using the bridge is a roundabout way. Regarding trains, the national railway connects 44 districts.

(4) ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

The Study team examined the adverse impact when DPHE constructs the deep tube well using the procured equipment, and concluded it is likely to have minimal or little adverse impact on the environment and society. Therefore it is classified as "Category C". Implementation of the soft component is likely to have no negative impact on the environment and society.

2. BACKGROUND AND OUTLINE OF THE PROJECT

(1) SUPERIOR PLAN

The Government of Bangladesh formulated the National Policy for Safe Water Supply & Sanitation in 1998 targeting to realize a basic level of water supply to the whole nation and to reduce the number of users of each tube well from 105 to 50 people in the near future. The National Water Policy (1999) advocated supplying safe and affordable water. In 2004, the National Policy for Arsenic Mitigation was formulated emphasizing the realization of safe water supply to the poor people. Deep wells have been constructed since 2000 as an alternative source of the water supply. They are now the main source of water supply in the areas contaminated by arsenic. Reflecting this situation, the National Strategy for Accelerated Poverty Reduction (FY 2009-2011) gave deep groundwater the status of importance in studying the development possibility as an alternative water source.

The Sector Development Plan (FY2011-25) (SDP) that was officially launched in December 2011. SDP shows the development plan for the water supply and sanitation sector for 15 years up to 2025. The development plan is divided into three (3) stages, the short term, the middle term and the long term. The target of each stage is shown in *Table 1.*

Table 1 Target of each Stage of SDP

Stage	Target
Short Term (FY 2011-15)	- WSS services to all but at least basic levels improved. - Institutions strengthening initiated, regulatory framework developed and legislations enacted.
Middle Term (FY 2016-20)	- WSS services level improved - Institutions strengthened and sub-sector SWAp operational.
Long Term (FY 2021-25)	- WSS services level further improved. - Institutions further strengthened and sector SWAp operational.

(2) CURRENT SITUATION AND ISSUE

Although Bangladesh attained 97% of water supply coverage in 1990s, it was largely decreased due to arsenic contamination of shallow ground water which was the main water source. DPHE has been developing arsenic free deep ground water using two (2) of its own drilling rigs as well as contractor's rigs. However, one of them is already aged and the other has no capacity to drill gravel layers distributed above the deep aquifer. Contractor's rigs are also not capable of drilling gravel layers.

Therefore, a deep aquifer has not been developed in the area and a lot of community people are left out from a safe water supply. In order to overcome this situation, it is required to develop deep wells by providing drilling rigs capable of penetrating gravel layers to the depth of 400 m, related equipment, supporting vehicles and geophysical survey equipment.

(3) PURPOSE OF THE PROJECT

The project aims to provide drilling rigs which are capable of penetrating gravel layers and to improve water supply coverage by safe water through acceleration of development of deep groundwater, and to develop the ability of staff of DPHE for the technique of deep wells.

3. SUMMARY OF THE SURVEY RESULTS AND CONTENTS OF THE PROJECT

(1) SUMMARY OF THE SURVEY RESULTS

In response to the request from the Government of Bangladesh, Japan International Cooperation Agency (JICA) despatched the preparatory survey team to Bangladesh in the periods from 18 November 2011 to 30 January 2012 and 28 July to 3 August 2012. The team carried out a field survey on the selection of the target villages, natural conditions (the field reconnaissance, geological survey, geophysical survey and water quality analysis) and village socio-economic survey in Dhaka, Khulna and Rajshahi Divisions.

A summary of the field survey and the study in Japan are as described below.

1) Selection of the Target Villages

A total of 30 villages were selected as the target villages in the study. Three (3) criteria were used for the selection: they are shown in Table 2. As village wise data are not available, Unions were selected at first, then, villages were selected from the selected Unions using the data of DPHE district offices.

Table 2 Criteria and Evaluation Score for Selection of Unions

Craiteria	Score 1	Score 2	Score 3	Score 4
A: Ratio of well contaminated by arsenic	A < 25%	25 ≦ A < 50%	50 ≦ A < 75%	75% ≦ A
B: Ratio of arsenicosis patients per 1,000 residents	B < 0.5 person	0.5 ≦ B < 1.0 person	1.0 ≦ B < 2.0 persons	2.0 persons ≦ B
C: Water supply coverage	60% ≦ C	40 ≦ C < 60%	20 ≦ C < 40%	C < 20%

2) Outline Design

The basic policy on the design in the Project is as described below. The appropriate scale and specifications are decided as the equipment procurement project for DPHE.

- Among the requested equipment such as drilling rigs and related tools and materials, the geophysical survey equipment and supporting vehicles, equipment of which verification are confirmed will be procured.
- Necessary equipment will be included in the procurement plan, even though such equipment is not requested: But it was requested during the discussion.
- The technical transfer (Soft Component) is planned on the deep well drilling and geophysical survey to be carried out by DPHE using the procured equipment.

(2) CONTENTS AND SCALE OF THE PROJECT

1) Equipment to be procured

The equipment and materials to be provided by the project are as shown in Table 3.

Table 3 Equipment and Materials to be Provided by the Project

No.	Equipment	Specification/Contents	Quantity
1	**Drilling Rig and Related Equipment**		
(1)	Truck-mounted drilling rig	For production wells Drilling depth: Maximum 400m	1
(2)	Truck-mounted drilling rig	For handpump wells Drilling depth: Maximum 400m	1
(3)	Truck mounted unit for air lifting and pumping test	For production well	1
(4)	Truck mounted unit for air lifting and pumping test	For handpump well	1
2	**Vehicles**		
(1)	Cargo truck with 5 ton crane	For production well	1
(2)	Cargo truck with 3 ton crane	For production well	3
(3)	Pickup truck	For production well	2
3	**Geophysical Survey Equipment**		
(1)	Resistivity survey equipment with analysis software	—	1
(2)	Borehole logging equipment with analysis software	—	1
4.	**Equipment and Materials for Workshop**	-	1 lot
5.	**Materials for Well construction to be Drilled in the Technical Transfer**		1 lot
6.	**Spare Parts**		1 lot (for 2 years)

2) Soft Component (Technical Transfer)

The soft component program will be carried out to the drilling team of DPHE and staff of the private companies on the planning and management of the deep well drilling works. In addition, technical transfer of the geophysical survey will be carried out to the staff of DPHE in the soft component program.

Regarding deep well drilling techniques, technical transfer of these will be done by a drilling engineer to be dispatched by the supplier.

The expected output of the soft component is summarized in Table 4.

Table 4 Expected Output of Soft Component

Output	Deep Well Drilling	Geophysical Survey
1	Acquisition of skill for formulating an appropriate drilling plan (including Well Design, Process Planning, Quality Control Plan and Procurement Plan) and skill for operation management for the engineers of DPHE	Acquisition of a skills for formulation of an appropriate geophysical survey plan for the engineers of DPHE
2	Acquisition of skills for making an appropriate pumping test plan, operation management of pumping test and analysis of the test results for the engineers of DPHE	Acquisition of survey skills using procured geophysical survey equipment for the engineers of DPHE
3	Acquisition by the engineers of DPHE of skills for formulating the appropriate equipment maintenance plan and skills for operation management	Acquisition of interpretation skills of the geophysical survey and acquisition of skills to prepare the drilling plan at the target area for the engineers of DPHE
4	Acquisition of evaluation skills for drilling works, pumping tests and equipment operation	Acquisition of an ability for appropriate maintenance of the geophysical survey

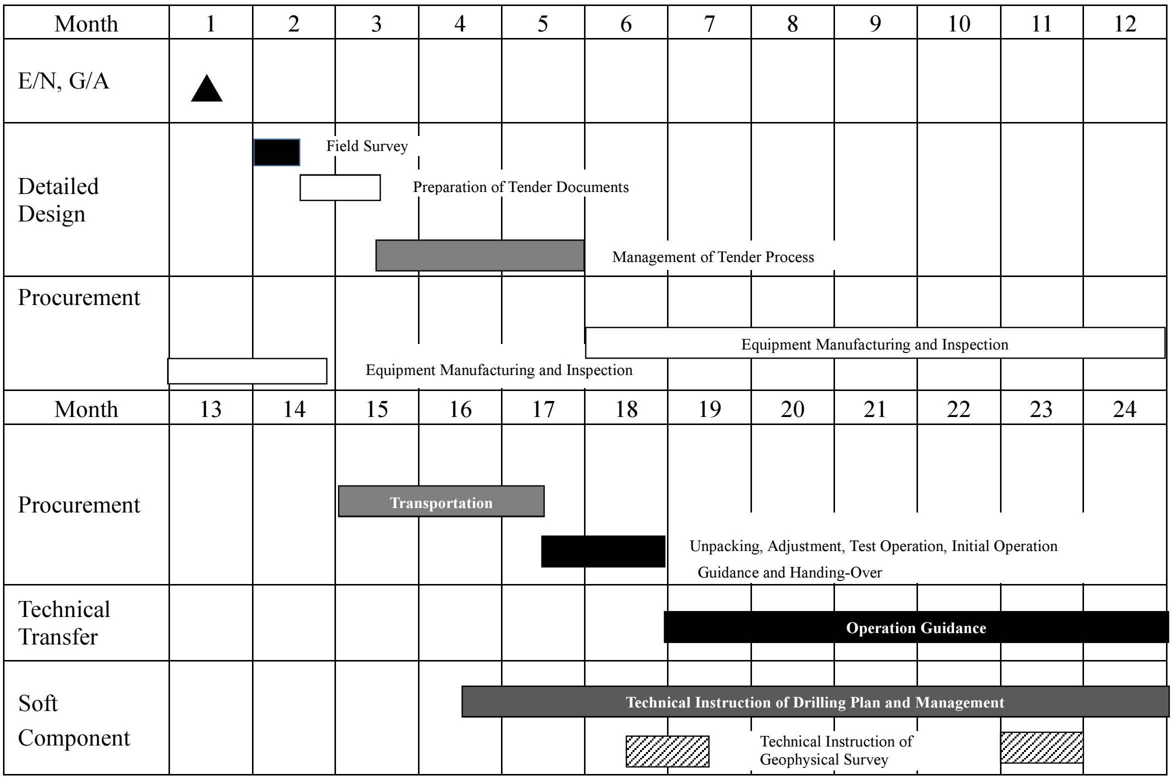
	management for the engineers of DPHE	equipment for the engineers of DPHE
5	Acquisition of skills for preparing a regular action plan progress report for the engineers of DPHE	

4. IMPLEMENTATION SCHEDULE AND IMPLEMENTATION COST OF THE PROJECT

(1) IMPLEMENTATION SCHEDULE

The implementation period of the project is 24 months after conclusion of the Exchange of Notes (E/N) and the Grant Agreement (G/A). The implementation schedule is shown in Table 5.

Table 5 IMPLEMENTATION SCHEDULE



(2) IMPLEMENTATION COST

The implementation cost of the Bangladesh side is estimated as 328.9 million BDT.

5. RELEVANCE AND EFFECTIVENESS OF THE PROJECT

(1) RELEVANCE

The recipient of the project is community people including poor people. Water supply coverage by the existing water supply facilities is 58.6% in the target area. About 216 thousand persons in the nine (9) Paurashava and 35 villages will directly receive benefit by implementing the project. In addition, it is expected that there will be a decreasing in number of arsenicosis patients and generation ratio of water borne diseases and socio-economically positive spreading impact, because safe water will become available.

In Bangladesh, the National Policy for Safe Water Supply & Sanitation (1998) advocated to provide a basic level of water supply service to all nationals. And deep ground water was considered as the main alternative water source against the arsenic contaminated shallow ground water. Furthermore, the Sector Development Plan (2011-2025) launched in December 2011 set the development target as 2025. It meets the national goal to accelerate the development of deep ground water in the target area where deep ground water is the only alternative source for improving the capacity of DPHE on deep ground water development.

Since the target area of the Project is mainly rural areas, the implementation of the Project contributes to improvement of the life of community people and stabilization of the people's livelihood from the viewpoint of basic human needs to supply safe arsenic free water to the people. Taking measures against arsenic contamination of ground water is one of Japan's strategic assistance issues. Therefore, the implementation of the Project meets Japan's assistance policy.

(2) EFFECTIVENESS

Deep wells are constructed in the Project after procurement of the drilling rigs and related equipment: 25 production wells in nine (9) District Paurashavas and 35 handpump wells in 35 villages. In addition, capacity of DPHE to develop deep ground water will be improved by technical transfer. Through these inputs, the quantitative effectiveness shown in Table 6 is expected.

Table 6 Quantitative Effect of the Project

Index		Base Line (2012)	Target (2019)	Quantitative Effect
Water supply coverage in target District Paurashavas and villages	Served Population	1,252,172 persons	1,468,597 persons	+ 216,425 persons
	Water Supply Coverage	58.6 %	63.6 %	+ 5.0%

The implementation of the Project is expected to have the following qualitative effects.

- The growth rate of arsenicosis patients and the prevalence of waterborne diseases are decreased as the quality of drinking water is improved.
- Working hours and learning time of the women and children who have mainly been engaged in fetching water are increased since the fetching work of water is decreased.

From the above, it is evaluated that the relevance to implementation of the Project is high and great effectiveness is expected.

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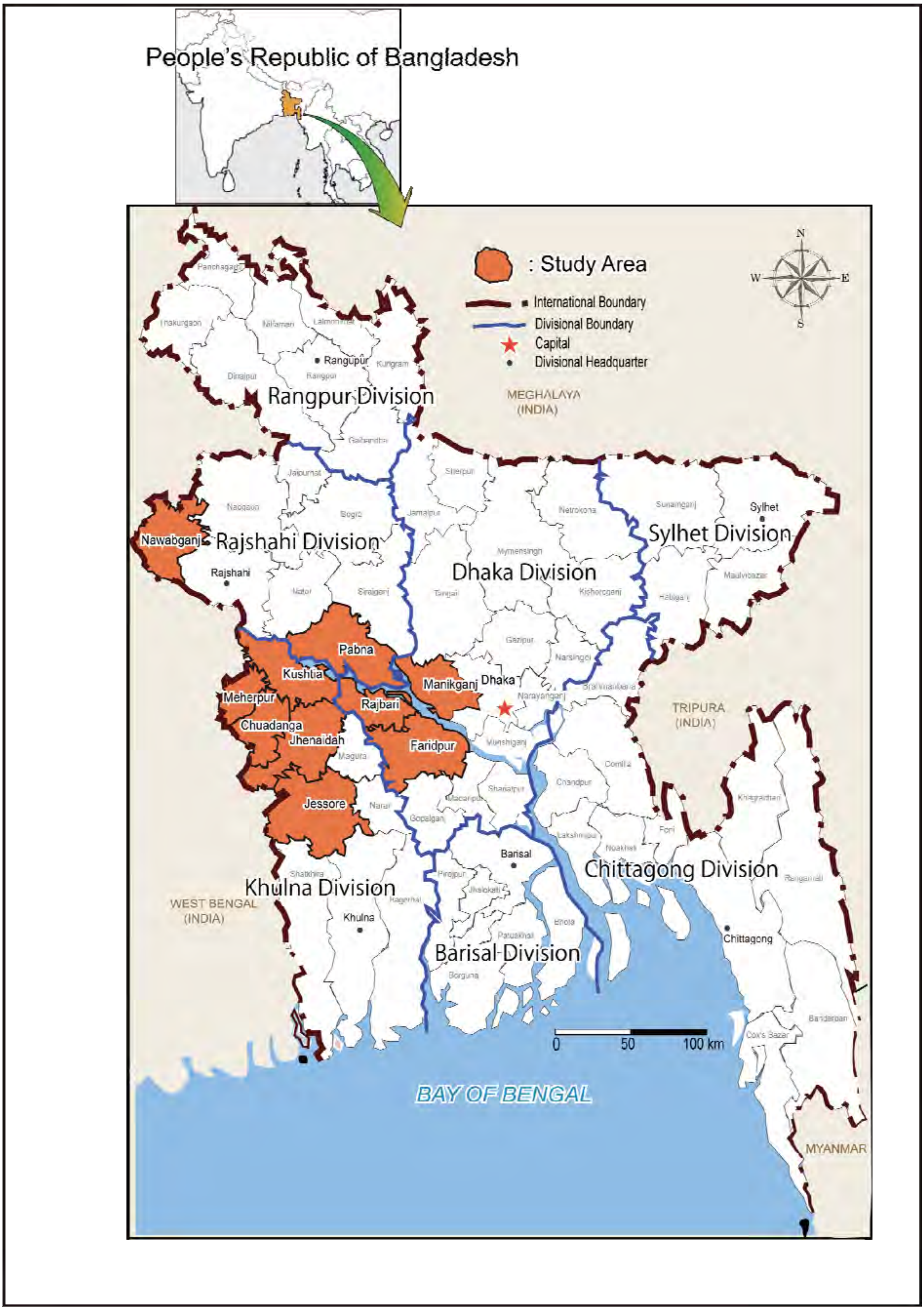

LOCATION MAP OF THE STUDY AREA

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ABBREVIATIONS

ADB	Asia Development Bank
AIRP	Arsenic and Iron Removal Plant
API	American Petroleum Institute
ASTM	American Society of Testing and Materials
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Project
BBS	Bangladesh Bureau of Statistics
BDT	Bangladesh Taka
BGS	British Geological Survey
BHN	Basic Human Needs
BS	British Standard
BWSPP	Bangladesh Water Supply Program Project
CMC	Carboxy Methyl Cellulose
DANIDA	Danish International Development Agency
DFID	Department for International Development
DIN	Deutsches Institut fur Normung
DPHE	Department of Public Health Engineering
EIA	Environmental Impact Assessment
FY	Fiscal Year
GDP	Gross Domestic Product
GoB	Government of Bangaladesh
GPS	Global Positioning System
IEE	Initial Environmental Evaluation
JEC	Japanese Electrotechnical Committee
ISO	International Organization for Standardization
JCS	Japanese Cable Makers' Association Standard
JICA	Japan International Cooperation Agency
JIS	Japan Industrial Standards
JPY	Japanese Yen
LGD	Local Government Division
MDG(s)	Millennium Development Goal(s)
NGO	Non-government Organization
NPSWSS	National Policy for Safe Water Supply & Sanitation
OJT	On-the Job Training

O&M	Operation and Maintenance
PTO	Power-Take-Off
RHSWSP	Rural Hygiene, Sanitation and Water Supply Project
PSU	Project Supporting Unit
SDP	Sector Development Plan
SGP	Steel Garvanized Pipe
SHEWA-B	Sanitation, Hygiene Education and Water Supply in Bangladesh
SP	Spontaneous Potential
STK	Steel Tube Kozo
STPG	Steel Tube Pipe General
STWSSSP	Secondary Towns Water Supply and Sanitation Sector Project
UNICEF	United Nations Children's Fund
USA	United States of America
USD	United States Dollar
WHO	World Health Organization
WSSPS II	Water Supply and Sector Program Support II

CHAPTER 1 BACKGROUND OF THE PROJECT

1.1 BACKGROUND OF THE REQUEST

The government of Bangladesh started development of water supply by shallow ground water in 1970s and attained the 97% of water supply coverage in 1990s. However, it was largely decreased due to arsenic contamination of shallow ground water which was the main water source. Such area is distributed in 40 Upazilas shown in Table 1.1.1 according to the data in Situation Analysis of Arsenic Mitigation 2009 (LGD/JICA 2010). About 5.26 million people are not served safe water in these 40 Upazila.

DPHE has been developing arsenic free deep ground water using two (2) own drilling rigs as well as contractor's rigs. However, one of them is already aged and the other has no capacity to drill gravel layers distributed above the deep aquifer. Contractor's rigs are also not capable of drilling gravel layers.

Therefore, a deep aquifer has not been developed in the area and a lot of community people are left out from the safe water supply. In order to overcome these situations, the government of Bangladesh requested a Japan's Grant Aid Project to provide drilling rigs capable of drilling to 400 m of depth penetrating gravel layers, supporting vehicles and geophysical survey equipment as well as technical transfer on the deep well drilling techniques and geophysical survey technique.

Table 1.1.1 Upaizilas Distributed in Arsenic Contaminated Area and Distribution Area of Gravel Layers

Division	District	Upazila	Division	District	Upazila
Dhaka	Faridpur	Faridpur Sadar	Khulna	Jhenaidah	Harina Kunda
		Madhukhali			Jhenaidah Sadar
	Manikganj	Dauratpur			Kaliganj
		Ghior			Kotchandpur
		Harirampur			Maheshpur
		Saturia			Shailkupa
		Shibalaya		Kushtia	Bheramara
		Singair			Dauratpur
	Rajbari	Balia Kandi			Khoksa
		Goalandaghat			Kumarkhali
		Pangsha			Kushtia Sadar
		Rajbari Sadar		Meherpur	Gangni
Khulna	Chuadanga	Alamdanga			Meherpur Sadar
		Chuadanga Sadar	Rajshahi	Nawabganj	Nachole
		Damurhuda			Nawabganj Sadar
		Jiban Nagar			Shibganj
	Jessore	Gagher Para		Pabna	Bera
		Chaugachha			Ishwardi
		Jessore Sadar			Pabna Sadar
					Santhia
					Sujanagar

1.2 CONTENTS OF THE REQUEST

In order to overcome situations mentioned above, the government of Bangladesh requested Japan's Grant Aid to procure drilling rigs which enable the construction of deep wells penetrating gravel layers. The contents of the request are shown in Table 1.2.1.

Table 1.2.1 Contents of the Request

No.	Equipment	Specification	Quantity
1	**Drilling equipment**		
(1)	Truck-mounted drilling rig	For production wells Drilling diameter: max 20” Drilling depth: max 400m	1
(2)	Truck-mounted drilling rig	For handpump wells Drilling diameter: max 4” Drilling depth: max 400m	1
(3)	Truck-mounted air compressor	–	2
2	**Supporting Vehicles**		
(1)	Cargo truck with crane	–	2
(2)	Pick up truck	–	2
3	**Geophysical survey equipment**		
(1)	Resistivity survey equipment with analysis software	–	1
(2)	Logging equipment with analysis software	–	1

1.3 NATURAL CONDITION

1.3.1 METROLOGY AND HYDROLOGY

(1) Meteorology

An overview of the climate in Bangladesh is different between the dry season (November to April) and the rainy season (May to October). Meteorological monitoring data were collected by the Bangladesh Meteorological Department (BMD) in 34 meteorological stations in Bangladesh. A distribution map of the average annual precipitation and monthly temperature in Bangladesh is shown in Figures 1.3.1 to 1.3.3, and the average monthly precipitation and temperatures in the Study Area are shown in Figure 1.3.4.

The distribution of annual precipitation was observed in the clear regional characteristics showing that a lower precipitation zone was found in the western part of Bangladesh and a higher zone in the eastern part (Figure 1.3.1). The Study Area is mainly located in the lower precipitation zone where annual precipitation is less than 2,000 mm / year.

The maximum average monthly precipitation was 1029.7 mm at Teknaf of Cox’s Bazar district in July, and the minimum average monthly precipitation was 1.6 mm at Mongla of the Bagerhat district in December. The values of average monthly precipitation were not different at each station in the Study Area (Figure 1.3.4).

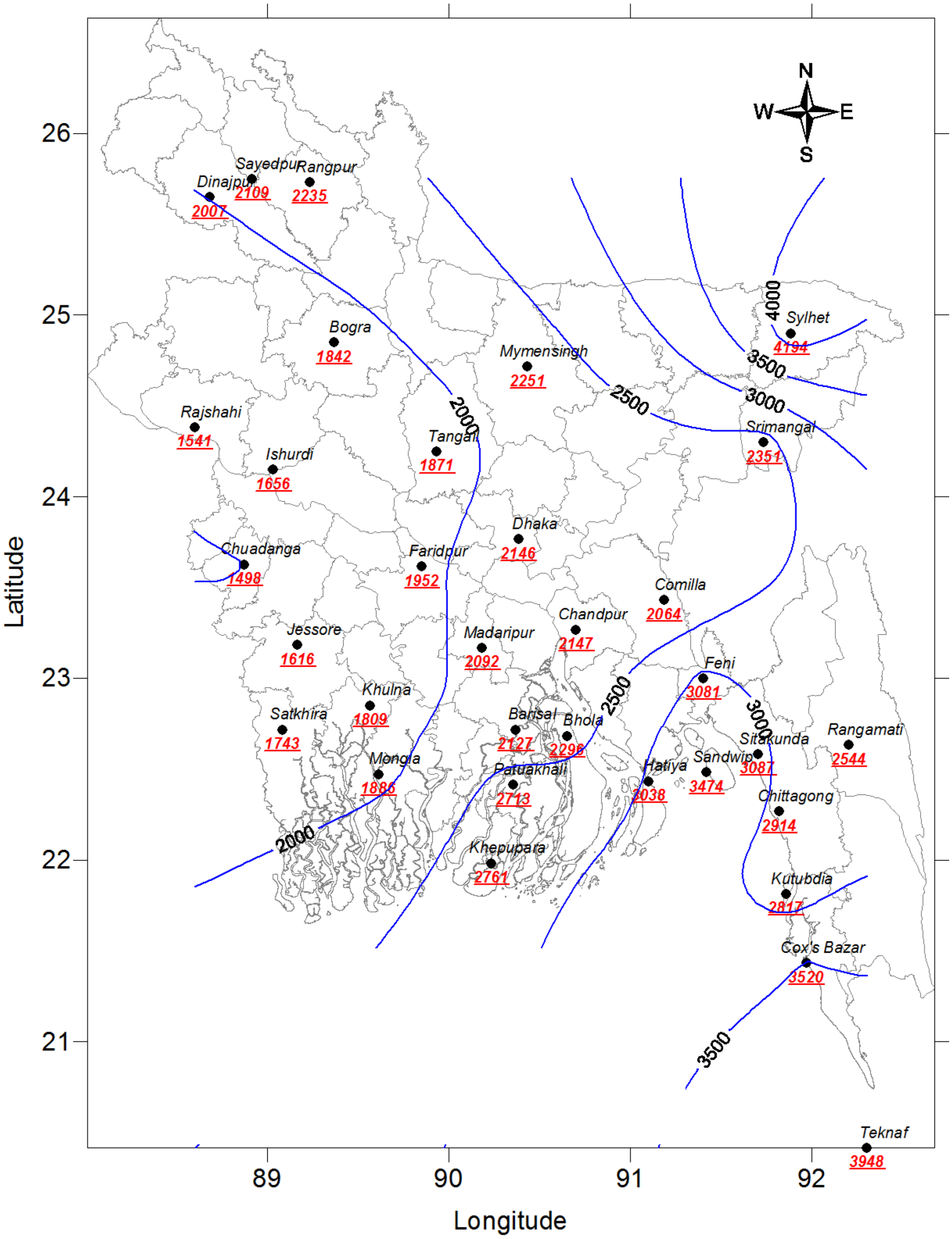
The distributions of maximum and minimum temperature were observed by different regional characteristics between the dry and rainy season. The average maximum temperature in April was found as a higher zone in the western part and a lower zone in the eastern part (Figure 1.3.2), on the other hand the average minimum temperature in January was found as a higher zone in the southern part and a lower zone in the north-western part (Figure 1.3.3). The Study Area is located in the higher and lower temperature zones in summer and winter seasons respectively.

The maximum average monthly temperature was 36.3 ºC at Chuadanga Sadar of Chuadanga district in April, and the minimum average monthly temperature was 9.5 ºC at Srimangal of Maulvibazar district in January. The values of average monthly temperature were not different at each station in the Study Area (Figure 1.3.4).

(2) Hydrology

The river system in Bangladesh is shown in Figure 1.3.5. There are a large number of rivers in Bangladesh and most of the sources flow from India. Among the major rivers are found three streams which are the Ganges (Padma), Brahmaputra (Jamuna) and Meghna Rivers.

Most rivers flow into the Brahmaputra River in the north-western part of Bangladesh, and all rivers flow into the Meghna River in the north-eastern part of Bangladesh. These two big rivers also join into the Ganges River downstream. However all rivers directly run off into the Bay of Bengal in the southern part of Bangladesh.



(Unite: mm / year)

Figure 1.3.1 The Average Annual Precipitation

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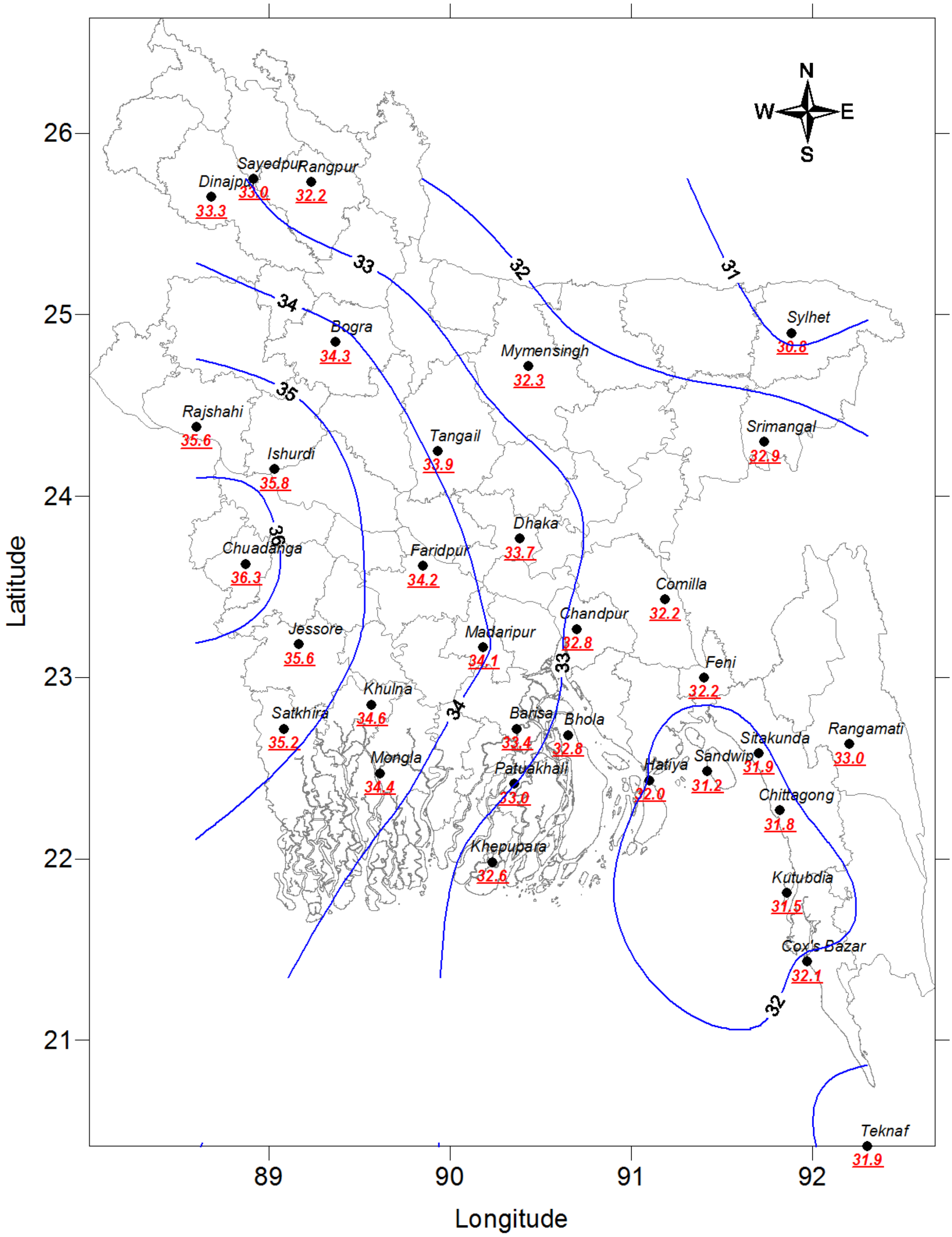

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Figure 1.3.2 The Average Maximum Temperature in April

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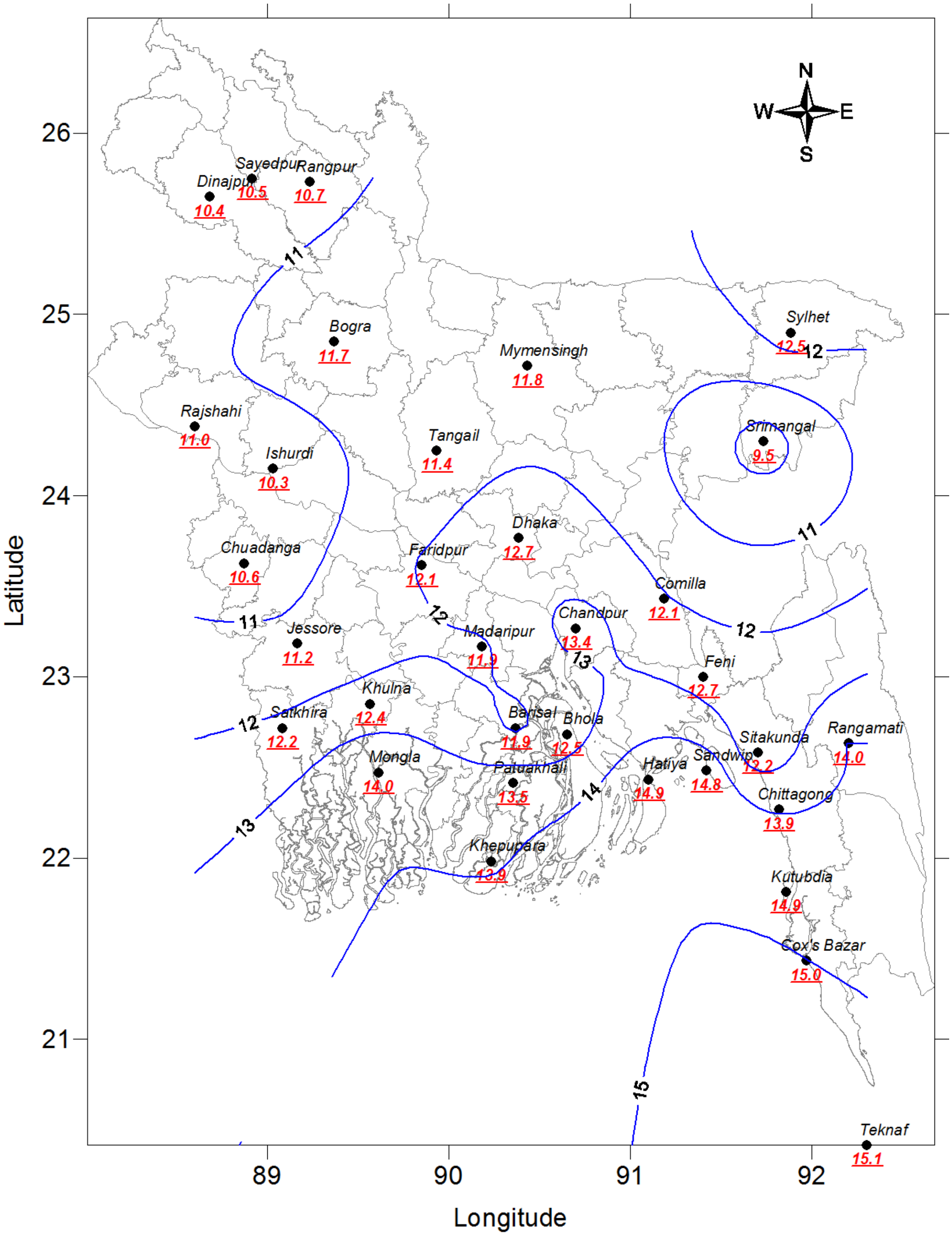

Figure 1.3.3   The Average Minimum Temperature in January

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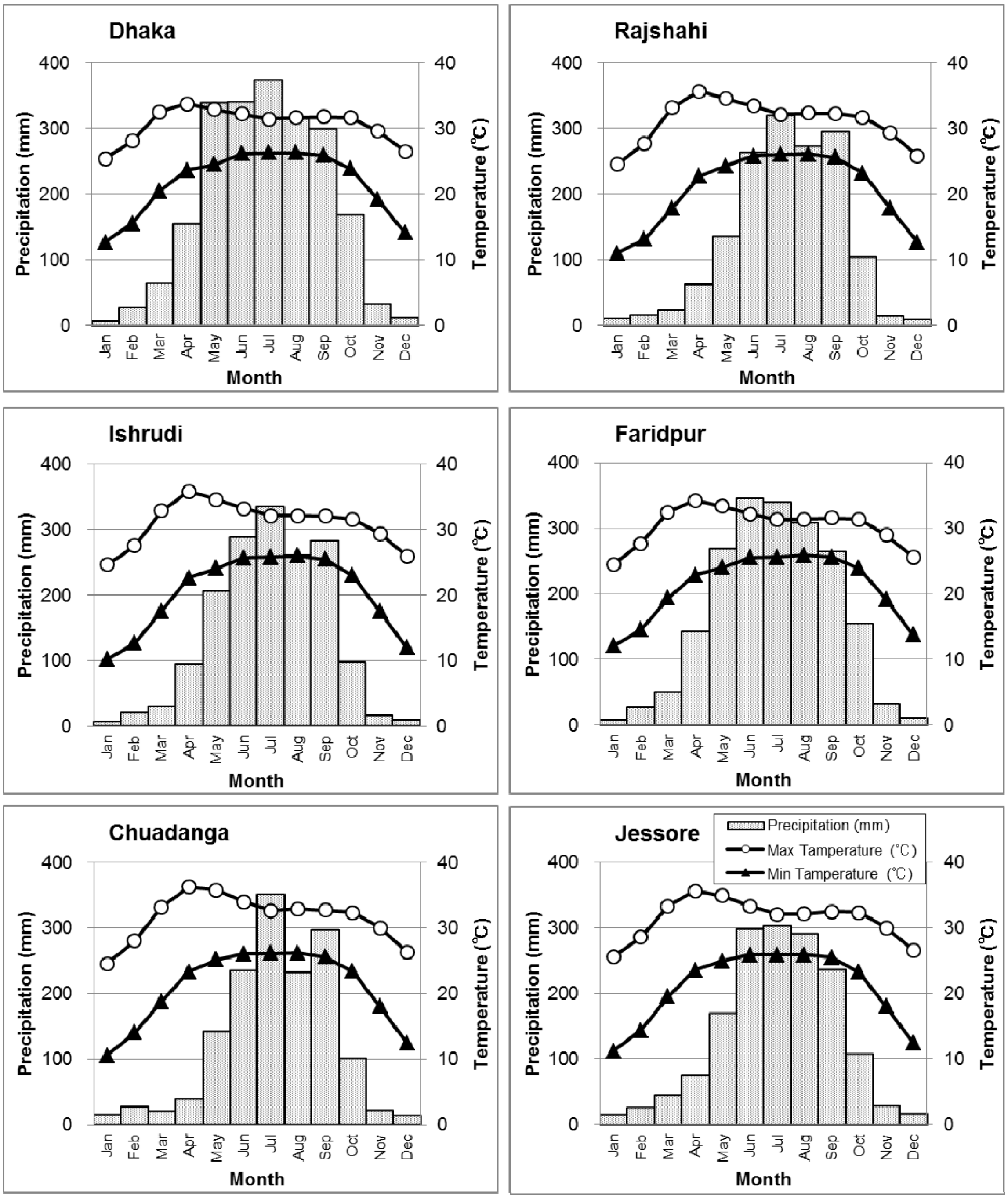


Figure 1.3.4 Average Monthly Precipitation and Temperatures in The Study Area

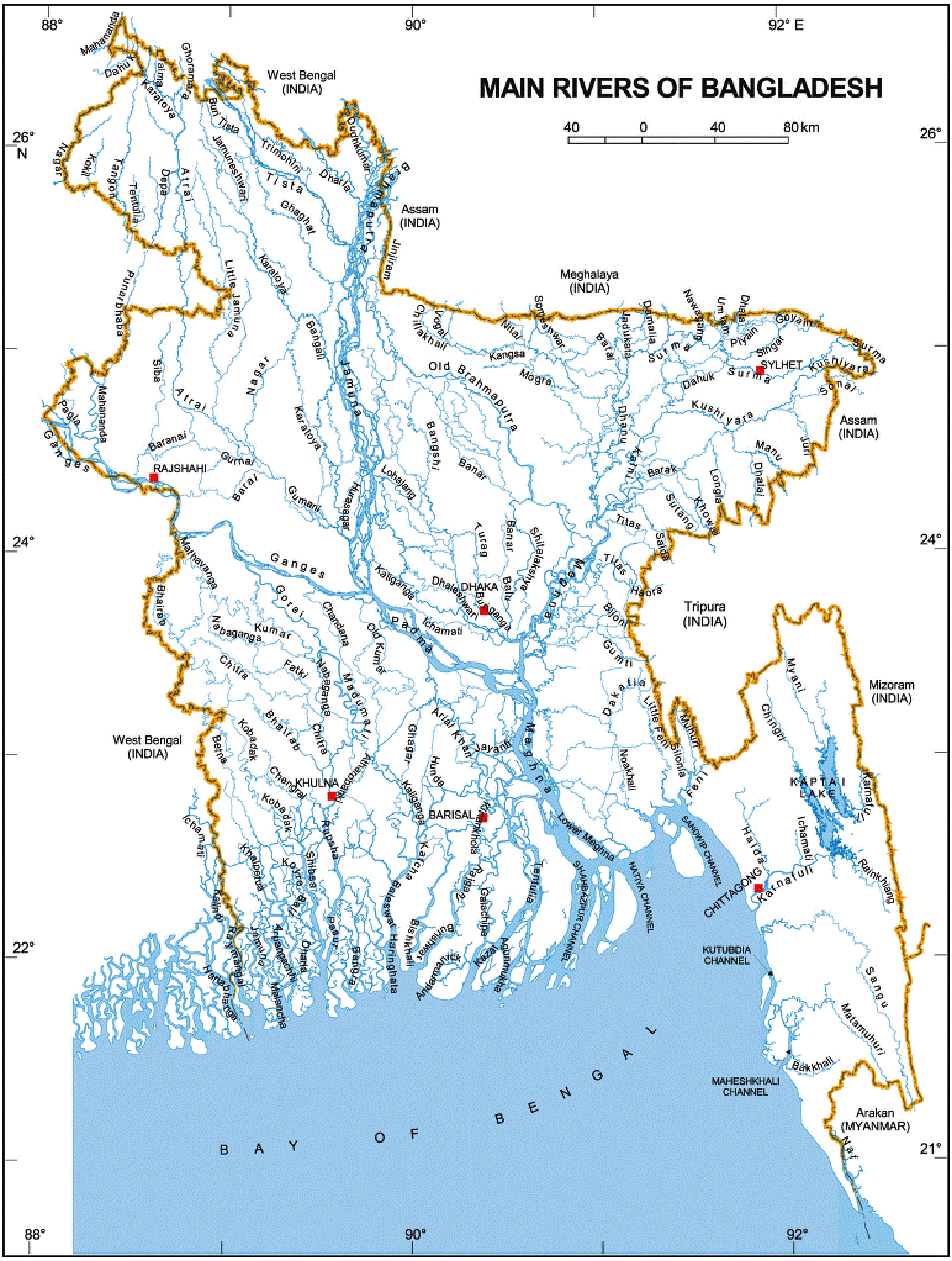


Figure 1.3.5 River System in Bangladesh

1.3.2 TOPOGRAPHY AND GEOLOGY

(1) Topography

A topographic map is shown in Figure 1.3.6. The topography of Bangladesh is mainly composed of deltaic and flood plains. There are two typical table lands (Madhpur Tract and Barind Tract) in the flood plain of the northwestern to central part of Bangladesh. And hilly areas are distributed in the eastern border of Sylhet division and the southeastern region of Chittagong Hill Tracts in Bangladesh.

Most of the area in Bangladesh is located on lowlands within the elevation of 20 m above sea level. The maximum elevation in Bangladesh is around 1,000 m above sea level in the southeastern border area of Chittagong hill tracks.

(2) Geology

The surface geology in Bangladesh is mainly composed of three geological formations which are Dupi Tila formation, Madhupur Cray and recent Alluvium sediments in chronological order (Table 1.3.1). These surface geological conditions are closely related to topographic conditions. The Dupi Tila formation was deposited in the Pliocene to Pleistocene epoch, and is outcropped in the hill area. Madhupur Cray was deposited in the Pleistocene epoch, and composes the table lands. Recent Alluvium sediments were deposited in the Holocene epoch, and are divided into Deltaic sediment and Flood deposits. Other elder rocks are not outcropped and underlie these three formations.

Table 1.3.1 Generalized Stratigraphy of Bangladesh (K.M. Ahmed et al. 2004)

Age	Formation	Lithology
Holocene	Alluvium	Grey clay, silt, fine sand with occasional peat and gravel.
Pleistocene	Madhupur Clay	Reddish brown mottled clay and silt
Plio- Pleistocene	Dupi Tila	Yellowish brown fine to medium sand

1.3.3 HYDROGEOLOGY

(1) Aquifers in the Study Area

The aquifer system in Bangladesh is not fully understood due to few investigations of detailed subsurface geology. Detailed subsurface geological investigations with soil core sampling were conducted by BGS/DPHE (2001) and JICA (2002) in the arsenic affected area. According to their results, the aquifer in the Study Area is divided into three (3) layers (Table 1.3.2). BGS/DPHE (2001) and JICA (2002) classified the second aquifer as the shallow aquifer and the lowest aquifer as the deep aquifer. In this Study, the analysis of the aquifers was carried out following the classification applied in these studies.

Table 1.3.2 Subsurface Geology and Aquifer Classification

Geologic Age	JICA (2002)			BGS/DPHE (2001)	This Study
	Subsurface Geology	Lithology	Aquifer Classification	Aquifer Classification	Aquifer Classification
Holocene	A formation	clay, silt, very fine sand, fine sand	First Aquifer (Shallow Aquifer)	Upper shallow aquifer	Shallow Aquifer
	B formation	fine sand, medium sand			
Late Pleistocene	C formation	sand, gravel	Second Aquifer (Middle Aquifer)	Lower shallow aquifer	
Plio-Pleistocene	D formation	clay, silt, sand, gravel	Third Aquifer (Deep Aquifer)	Deep aquifers	Aquiclude (Clay, Silt) / Deep Aquifer (Sand, Gravel)
	E formation	silt, sand			Deep Aquifer

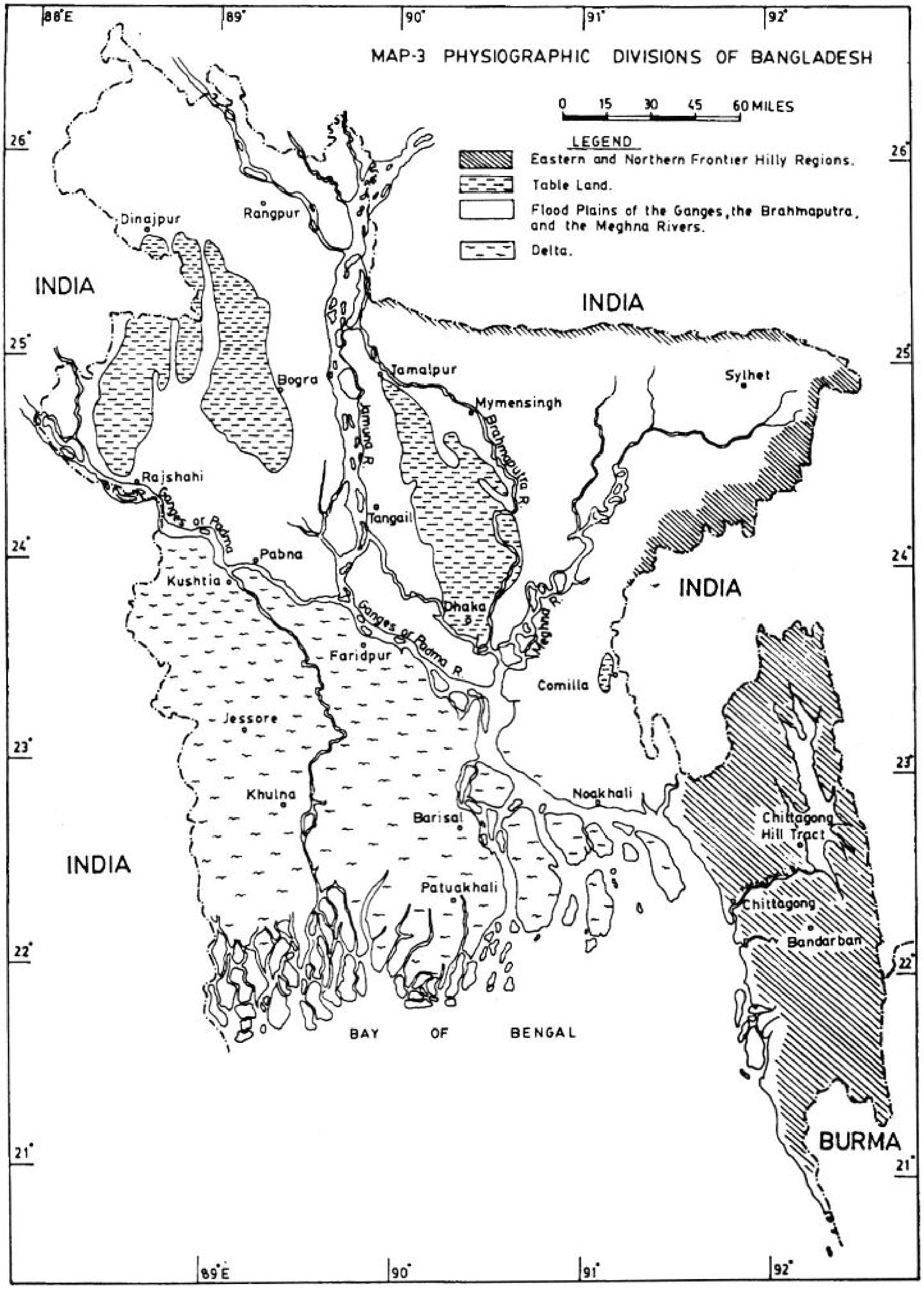
However the definitions of the “Deep Aquifer” and the “Deep Tube Well” have been confused in

Bangladesh. Understanding of "Deep Tube Well" by DPHE depends on depth only earlier. However, the separation from the shallow aquifer by an impermeable layer is also considered after arsenic identification. A deep tube well should be installed in the real deep aquifer which underlies the impermeable clayey layer. But some "Deep Tube Wells" were installed at the shallow aquifer level such as 100 to 150 m. In case of an agricultural deep tube well, these are deeper than agricultural shallow tube wells, but not as deep as 100 m. Ground water for agricultural use was certainly extracted from the shallow aquifer. In the Study, aquifer analysis will be conducted using the aquifer classification by former detailed investigations (BGS/DPHE, 2001 and JICA, 2002).

Most of the shallow tube wells for domestic and agricultural use are installed in the A formation of the first aquifer which is a high arsenic contaminated zone. Some of the shallow tube wells for domestic use and most of the "agricultural deep tube wells" are installed in the B formation of the first aquifer which has better permeability and less contamination by arsenic in comparison with the A formation. The second aquifer (the C formation) has good permeability due to coarser sediments including gravel, but arsenic was detected in some specific areas, for example Chowgacha upazila of the Jessore district. And the thickness of the ravel layer in the C formation varies from 60 m to 140 m from place to place. The D and E formations of the third aquifer are the main target zone of the deep tube well for drinking purposes as an alternative safe option in the arsenic affected area.

The D formation consists of various strata, such as clay layers, silt layers, sand layers, and gravel layers. The clay layers and the silt layers of the D formation function as aquiclude, and are considered to be classified the shallow aquifer located above the D formation, and deep aquifer located below the D formation hydrogeologically. However, according to previous investigations, it is admitted that there are areas which have no aquiclude. In those areas, since the clear aquiclide which bars ground water flow does not exist between shallow aquifers and deep aquifers, it is thought that especially the ground water from the shallow aquifer polluted by arsenic requires caution in use of deep aquifers.

The gravel layers (mainly the C formation) which prevent the use of ground water from the deep aquifer seems to be distributed up to a depth of about 250 m maximum in the Study Area according to the results of electrical sounding of this Study and the existing data. The deep aquifer that is under the gravel layers was detected by electrical sounding. The bottom of the deep aquifer may be at a depth of about 350 m or deeper. The result of electrical sounding carried out in this Study is shown in the next table.



Data Source: F.H. Khan (1991) Geology of Bangladesh

Figure 1.3.6 Topography in Bangladesh

(2) Considerations about Hydrogeological Structure by Electric Prospecting

1) Outline of the Prospecting

Vertical electric sounding was carried out for 61 sights in 30 villages. A list of the sounding sights is shown in Table 1.3.4 and the locations of the sounding sights are shown in Figure 1.3.7.

2) Specification and Quantity of the Prospecting

Specification and quantity of the prospecting are follow.

- Target: 30 Villages
- Prospecting Line Length: 1000 m, Target Depth 500 m
- Quantity: Total 61 sights
- Equipment: OYO McOHM Profiler 4 and Power Booster
- Analysis Software: Interpex IX1D ver.3

3) Result of the Prospecting

Generally resistivity of a stratum depends on the component ratio of mineral contents, compactness and porosity. Water content and water quality in the porosity also influence resistivity. Larger porosity makes smaller resistivity, and smaller porosity makes larger resistivity.

The strata up to the depth of 500 m in the Study Area consist of gravel layer (gravel and sand layer), sandy soil layer, silt layer, clay layer etc. Gravel layers (gravel and sand layers) have the largest resistivity, sandy soil layers have the second largest resistivity, silt layers have the third and clay layers have the fourth.

The resistivities observed in the Study Area are in the range of 9 to 380 (ohm-m). The resistivities of more than 120 (ohm-m) are considered to be the dry surface layers above the ground water level, and 118 (ohm-m) is the highest value under the ground water level.

Although it is difficult to classify the geology only by its resistivity value, it is assumed that the resistivities of the clay layers are less than 15 (ohm-m), those of the silt layers are 15 to 20, sandy soil layers are 20 to 40, and gravel layers (gravel and sand layers) have resistivities more than 40 under the ground water level with consideration of the existing data. Table 1.3.3 shows the relationship between the geology and its resistivity under the ground water level.

Table 1.3.3 Relationship between Geology and Its Resistivity Under Ground Water Level

Aquiclude			
Resistivity (Ω-m)	< 10	10 - 15	15 - 20
Geology	Clay Layer		Silt Layer
	Clay	Silty Clay	Silt
Code	C	lyC	l

Aquifer					
Resistivity (Ω-m)	20 - 25	25 - 35	35 - 40	40 - 70	70 <
Geology	Sand Layer			Gravel Layer	
	Fine Sand	Medium Sand	Coarse Sand	Sand with Gravel	Sand and Gravel
Code	fS	mS	cS	SwG	SG

Based on the measurement data obtained by the prospecting and the existing hydrogeological data, the hydrogeological structure of the Study Area was considered. It can be clearly detected in many prospecting points that the boundary between the gravel layers (gravel and sand layers) distributed from a depth of 100 m to 200 m equivalent to the C formation and the clay layers distributed below the C formation. It is described in the geological strata which are discernible by the prospecting results. Detailed results of each site are shown in attachment-5.

(i) Surface to the top of gravel layers (gravel and sand layers)

Most of the ground surface in the Study Area is covered by a clay layer. The resistivities of the surface layers are varied largely depending on whether the surface is dry or wet. The thickness of the clay layer is observed as different by region.

According to the existing data, it is thought that gravel layers are distributed from a depth of around 100 m downward. There are few sites which can be read clearly from the upper surface of the gravel layer because the geology changes gradually from sand layer to gravel layer.

(ii) Gravel layers (gravel and sand layers)

The particle sizes and ratio of gravels in the gravel layers (gravel and sand layers) are considered to be different by region. The resistivities of the gravel layers are also affected by the difference of the particle size and ratio of gravel. The resistivities in the range of about 40 to 120 (ohm-m) are considered to be equivalent to the gravel layers (gravel and sand layers) in the Study Area.

According to the prospecting results, the bottoms of the gravel layers (gravel and sand layers) are considered to be located at about 120 to 170 meters depth in Faridpur, Manikganj and Rajibari district of the eastern part of the Study Area. On the other hand, the bottoms of the gravel layers reach 250 meters depth in some area of Jessore and Chuadanga district. About the depth of the bottoms of the gravel layers in the Study Area, there is a tendency that the southern part is deeper than the northern part in the north-south direction. Moreover, the western part is deeper than the eastern part in the east-west direction.

On the other hand, in some areas of the Nawabganj District, the strata which indicates the relatively high resistivities in the range from 40 to120 (ohm-m) are observed at the depth of 50m. According to the staff of drilling companies in Bangladesh, the gravel layers and highly-consolidated sand layers are distributed in relatively shallow depths in the Nawabganj District. There is a possibility that the relatively high resistivities indicate highly-consolidated sand layers as well as gravel layers in the Nawabganj District.

Based on the prospecting result and the existing data, a contour map of the bottom elevation of the gravel layers (Figure 2.2.9) was prepared. According to this map, the bottom elevations of the gravel layers are around 150 m in the eastern part and around 200 m in the western part of the Study Area. Thus, the distributions of gravel layers (gravel and sand layers) in the Study Area are shallow in the eastern part and deep in the western part.

(iii) The stratum under the gravel layers (clay layer, silt layer and sand layer)

The boundary of the gravel layers (gravel and sand layers) and the strata (clay layers, silt layers and sand layers) below the gravel layers can be distinguished from resistivity curves by the prospecting results. The sandy soil layer is considered to be "deep aquifer" in the strata below the gravel layers. There are points where the bottoms of sandy soil layers are detected by the prospecting. The bottoms of some points reach the depth of 350 meters. It is difficult to detect the bottom if the sandy soil layer is distributed in a deeper zone.

Table 1.3.4 List of the Prospecting Sites

Division	District	Upazila	Union	No.	Site Name	Longitude(E)	Latitude(N)
Dhaka	Faridpur	Faridpur Sadar	Aliabad	1-1	Bilmamudpur No.1	89.859750	23.580750
				1-2	Bilmamudpur No.2	89.858583	23.569683
			Kaijory	2-1	Purbo Gangabardi No.1	89.796517	23.564367
				2-2	Purbo Gangabardi No.2 (Tula Shachia)	89.812083	23.548617
			Krishna Chandrapur	3-1	Bhadukdia No.1	89.718933	23.569283
				3-2	Bhadukdia No.2	89.714283	23.574550
			Majchar	4-1	Dayarampur No.1	89.788367	23.626050
				4-2	Dayarampur No.2	89.787033	23.619650
	Manikganj	Harirampur	Kanchanpur	5-1	Kutirhat No.1(Maluchi)	89.864133	23.754750
				5-2	Kutirhat No.2(Kusiarchar)	89.870883	23.753633
	Rajbari	Rajbari Sadar	Dadshi	6-1	Pakurikanda No.1	89.669500	23.739800
				6-2	Pakurikanda No.2(Boklarpur)	89.677833	23.750483
Khulna	Chuadanga	Alamdanga	Baradi	7-1	Ampnagar No.1	88.855767	23.761517
				7-2	Ampnagar No.2	88.855000	23.753450
			Jehala	8-1	Betbaria No.1	88.889550	23.691500
				8-2	Betbaria No.2	88.891633	23.691900
		Damurhuda	Howli	9-1	Boro Dudhpatila No.1	88.805283	23.544667
				9-2	Boro Dudhpatila No.2	88.809950	23.552600
			Natipota	10-1	Boalmari No.1	88.669783	23.633533
				10-2	Boalmari No.2	88.662933	23.640000
	Jessore	Chaugachha	Chaugachha	11-1	Bergobindapur No.1	89.010167	23.229700
				11-2	Bergobindapur No.2	89.002783	23.229367
			Jagadishpur	12-1	Marua No.1	89.071750	23.267933
				12-2	Marua No.2	89.080917	23.271467
			Patibila	13-1	Purahuda No.1	89.042733	23.276300
				13-2	Purahuda No.2	89.054383	23.282033
			Phulsara	14-1	Baruihati No.1	89.071833	23.261700
				14-2	Baruihati No.2	89.076033	23.260800
	Jhenaidah	Jhenaidaha Sadar	Padmakar	15-1	Achintanagar No.1	89.288183	23.543117
				15-2	Achintanagar No.2	89.277633	23.546600
		Maheshpur	Fatepur	16-1	Krishna Chandrapur No.1	88.911967	23.386833
				16-2	Krishna Chandrapur No.2	88.901333	23.387250
	Kushtia	Bheramara	Dharampur	17-1	North Bhabanupur	88.946833	24.030017
				17-2	North Bhabanupur No.2 (South Bhabanupur)	88.952733	24.016550
			Junidah	18-1	Jagshar No.1	88.954450	24.053583
				18-2	Jagshar No.2	88.939483	24.055917
			Mokarimpur	19-1	Nawda Khemediar No.1	88.984500	24.058717
				19-2	Nawda Khemediar No.2 (Fakirabad)	88.976967	24.063800
		Daulatpur	Pragpur	20-1	Pakuria No.1	88.751467	24.053567
				20-2	Pakuria No.2	88.749417	24.047550
	Meherpur	Meherpur Sadar	Amjhupi	21-1	Alampur No.1	88.685950	23.801633
				21-2	Alampur No.2	88.690783	23.793533
			Kutubpur	22-1	Subidpur No.1	88.661033	23.811533
				22-2	Subidpur No.2	88.650817	23.818067
Rajshahi	Nawabganj	Nawabganj Sadar	Char Anupnagar	23-1	Anupnagar No.1	88.301550	24.510017
				23-2	Anupnagar No.2	88.291300	24.521083
			Maharajpur	24-1	Moharaipur No.1	88.228267	24.598367
				24-2	Moharaipur No.2	88.221200	24.616350
			Ranihati	25-1	Ghoraparakhia No.1	88.189317	24.618783
				25-2	Ghoraparakhia No.2	88.182617	24.616883
		Shibganj	Chhatrajitpur	26-1	Satrajitpur No.1	88.188683	24.646650
				26-2	Satrajitpur No.2	88.194033	24.648067
	Pabna	Bera	Masumdia	27-1	Khanae Bari No.1	89.639817	23.888783
				27-2	Khanae Bari No.2	89.638700	23.893367
			Natun Bharenga	28-1	Morichapara No.1	89.655717	23.997867
				28-2	Morichapara No.2	89.652667	24.001083
			Paurashabha	29-1	Shanila No.1	89.610933	24.062267
				29-2	Shanila No.2(Jordao)	89.613533	24.062900
				29-3	Shanila No.3 (Bangabaria)	89.617233	24.062283
			Ruppur	30-1	Boronagaon No.1	89.653217	23.889367
				30-2	Boronagaon No.2 (Chorpara)	89.638100	23.901100

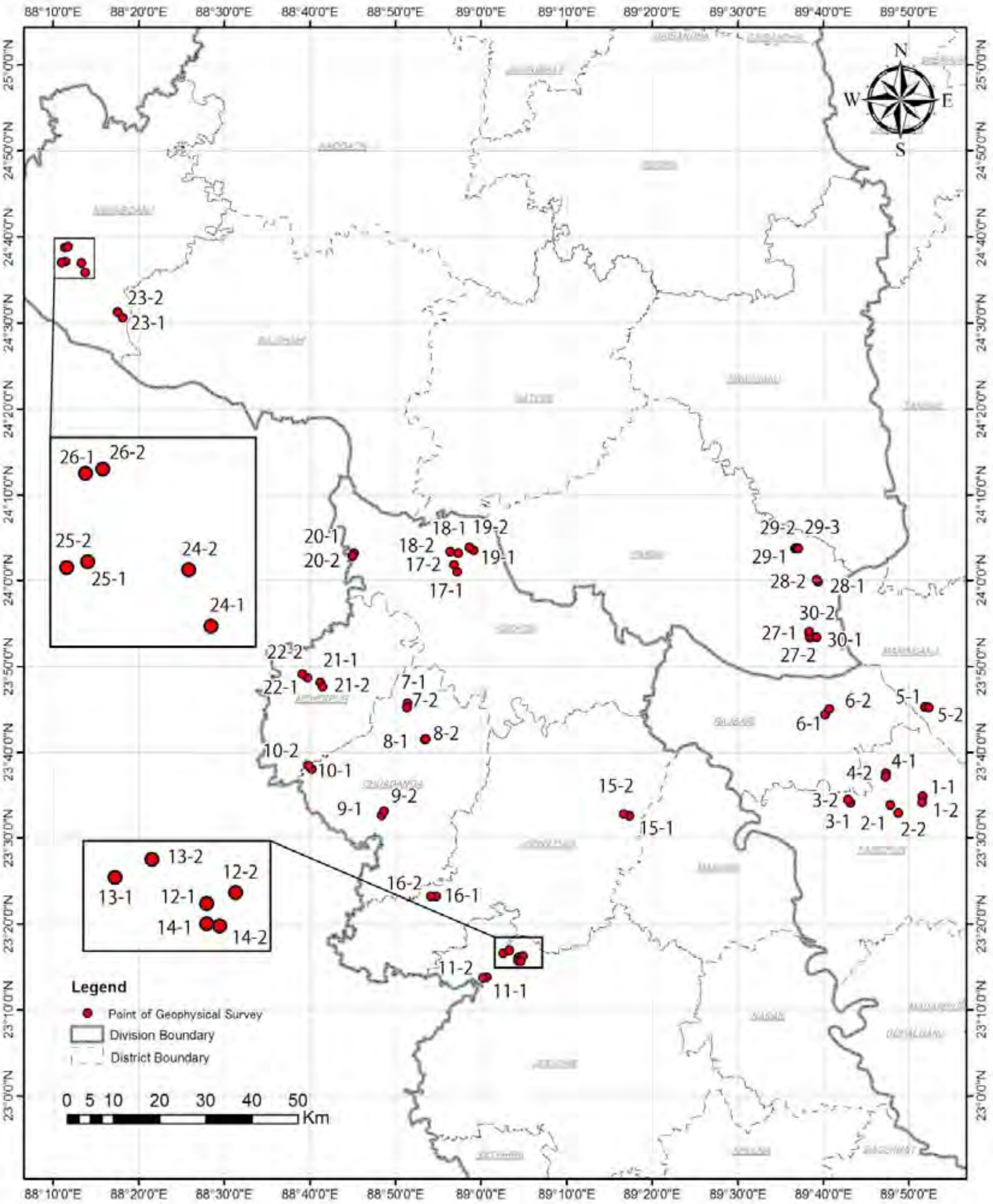


Figure 1.3.7 Locations of the Prospecting Sites

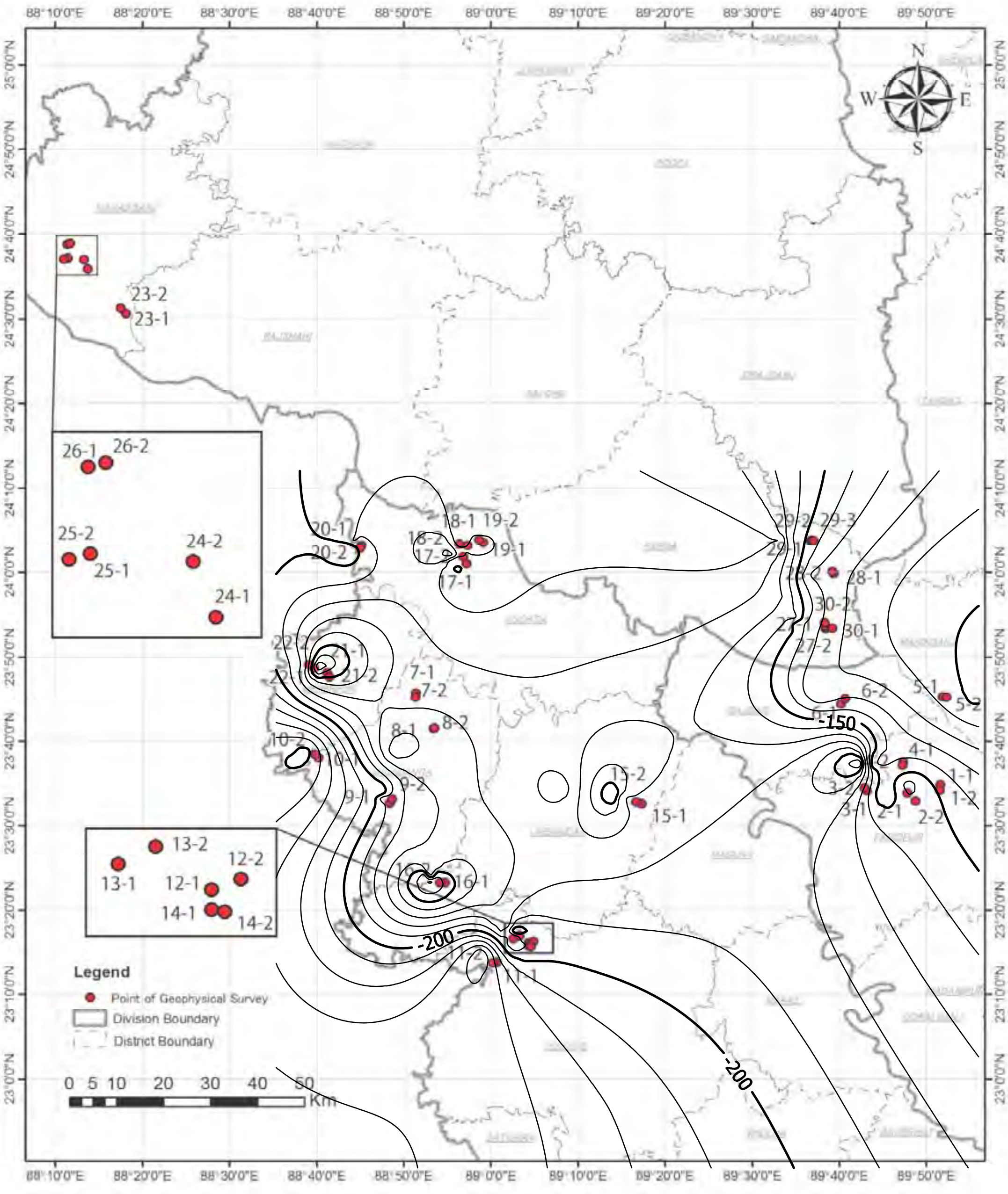


Figure 1.3.8　Contour Map of Bottom of Gravel Layers (Gravel and Sand Layers)

THE PREPARATORY SURVEY ON THE GROUND WATER INVESTIGATION AND DEVELOPMENT OF DEEP GROUND WATER SOURCE IN URBAN AND RURAL AREAS	JICA

1.3.4 WATER QUALITY

Arsenic contamination in ground water that exceeds the Bangladesh drinking standard (0.05mg/L) was widely detected in the most parts of Bangladesh (Figure 1.3.9). Especially highly contaminated areas were found in the southern part and northeastern part of Bangladesh. And arsenic concentration in the shallow zone is clearly higher than the deeper zone. On the other hand, highly contaminated ground water in the deeper zone was found in a limited area. The Study Area is also one of the highly contaminated areas in the shallow zone.

In this study, water quality analysis was carried out for the 30 villages. The analysis result is shown in Table 1.3.6.

(1) Water Quality Analysis (Part-1)

1) Purpose

To grasp the water quality of the existing water sources in the Study Area.

2) Target Villages

30 villages shown in Table 2.1.7.

3) Specifications

(i) Sample Collection

Samples are collected from 2 tube wells in each target village. Samples should be collected from deep tube wells. However, If there is no deep tube well in the target villages, samples will be collected from shallow tube wells.

6 of the collected samples are analyzed by another organization also responsible for analysis, which is ordered by the Study Team for cross checking.

(ii) Water Quality Analysis

Collected samples are analyzed from the 25 items shown in Table 1.3.5 and the results are reported.

Table 1.3.5 Items of Water Quality Analysis

Aspects	Items
Microbial aspects	Escherichia coli, Total coliform bacteria
Chemicals that are on health significance	Arsenic(As), Fluoride(F), Nitrate (NO_3^-), Nitrite(NO_2^-)
Acceptability aspects	Total hardness, Calcium(Ca), Magnesium(Mg), Iron(Fe), Chloride (Cl), Total dissolved solids (TDS), Manganese(Mn), Ammonia(NH_3), Sodium(Na), Sulfate(SO_4) , pH, Taste, Odour, Colour, Turbidity, Temperature
Items related to the characteristics of ground water	Potassium(K), Bicarbonate(HCO_3), Electric Conductivity(EC)

4) Result of the Analysis

The results of the water quality analysis are shown in Appendix-5. The outline of the result (maximum, minimum, average and median of analysis items) and Bangladesh standard for drinking water quality (henceforth the Bangladesh standard) and guideline value for drinking water quality of WHO (henceforth the WHO guideline) are shown in Table 1.3.6.

(i) Arsenic

43 samples had an arsenic content more than the Bangladesh standard value（0.05 mg/L）, 51 in 60 samples had more than the WHO guideline value (0.01 mg/L). The maximum value was 2.06 mg/L, the minimum value was 0.00 mg/L, the average value was 0.23 mg/L and the

median value was 0.13 mg/L. Figure 1.3.10 shows the relationship between well depth and arsenic content. It indicates that relatively large values were detected in wells of less than 60 m. All the samples that have more than 0.2 mg/L are from wells of less than 60 m.

(ii) Microbial aspects

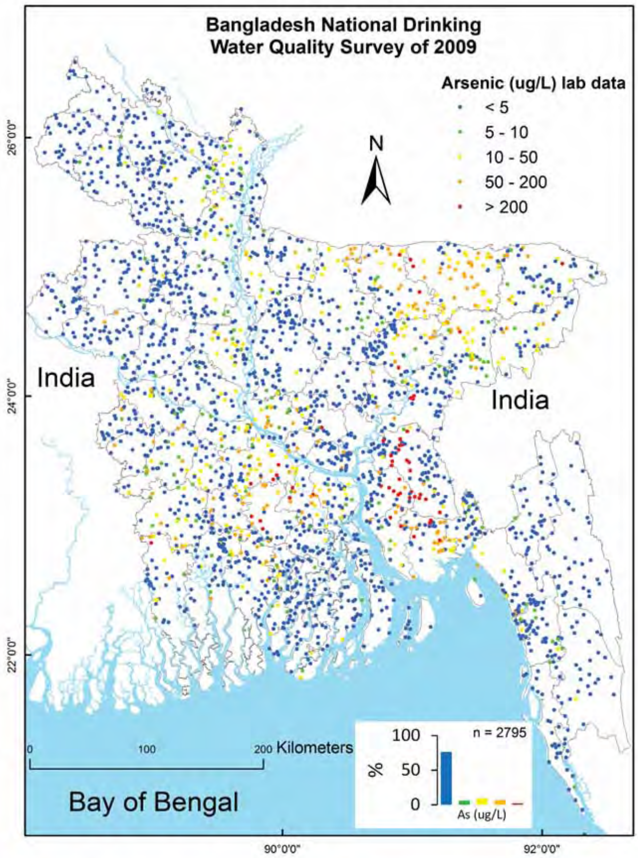
Total coliform bacteria and Escherichia.coli. were not detected in all samples.

(iii) Chemicals that are of health significance (except arsenic)

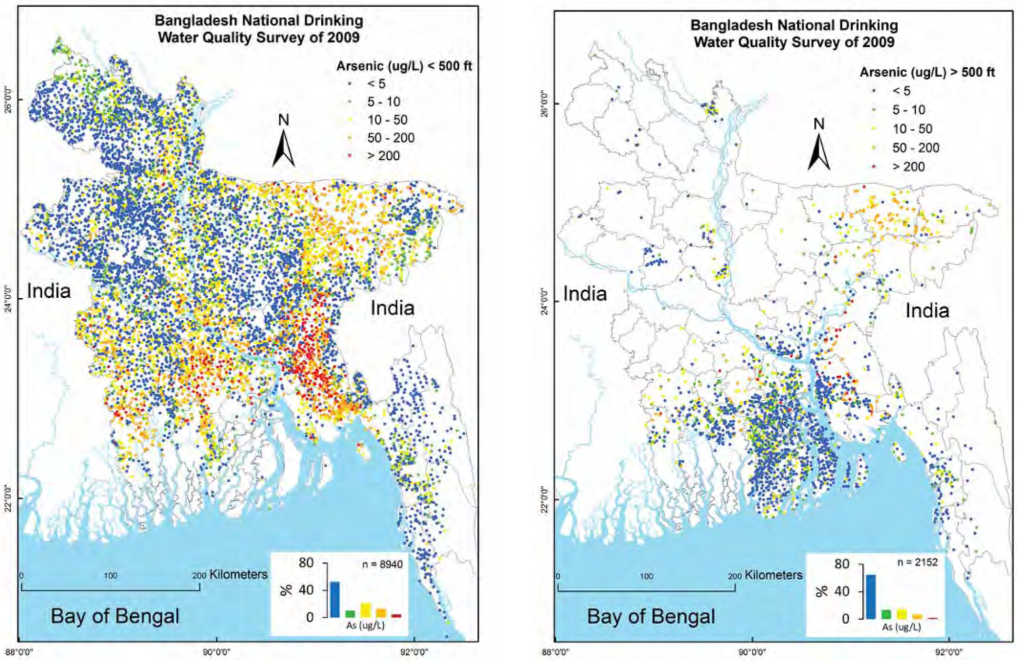
Fluoride content more than 1.0 mg/L of the Bangladesh standard were not detected in the all samples.

Two (2) samples had a nitrate content of more than 10 mg/L of the Bangladesh standard and all samples met the WHO guideline value (50 mg/L) for nitrate content.

9 samples had a nitrite content of more than 1 mg/L of the Bangladesh standard and 14 samples had more than 0.2 mg/L of the WHO guideline. Figure 1.3.11 shows the relationship between well depth and nitrite content. It indicates that large values are detected in shallow wells as well as arsenic.



Arsenic concentration by Laboratory



Arsenic concentration by Field Kit (left; Shallow zone, right; Deeper zone)

Data Source: UNICEF (2011)

Figure 1.3.9 Arsenic Contamination in Bangladesh

Table 1.3.6 Outline of Result of Water Quality Analysis

Items	Unit	Bangladesh Standard	WHO Guideline	Number of samples that don`t meet the criteria		Max.	Min.	Ave.	Med.
				Bangladesh Standard	WHO Guideline				
Total Coliform Bacteria	cfu/100 mL	0	0	0	0	0	0	0	0
Escherichia Coli.(Fecal Coli.)	cfu/100 mL	0	0	0	0	0	0	0	0
Arsenic (As)	mg/L	0.05	0.01	43	51	2.06	0.00	0.23	0.13
Fluoride (F^-)	mg/L	1	1.5	0	0	0.95	0.10	0.25	0.22
Nitrate (NO_3)	mg NO_3/L	10	50	2	0	47	0.2	3.78	1
Nitrite (NO_2)	mg NO_2/L	1	0.2	9	14	5.9	0.02	0.80	0.135
Manganese (Mn)	mg/L	0.1	-	55	-	2.6	0.09	0.79	0.68
Total Hardness (as $CaCO_3$)	mg/L	200-500	-	3	-	550	230	369	360
Calcium (Ca^{2+})	mg/L	75	-	59	-	358	64	136.7	120.5
Magnesium (Mg^{2+})	mg/L	30-35	-	30	-	70	19	36.7	35.5
Iron (Fe)	mg/L	0.3-1	-	52	-	41.2	0.11	6.6	3.95
Chloride (Cl^-)	mg/L	150-600	-	0	-	130	5	25	13
Total Dissolved Solid (TDS)	mg/L	1000	-	0	-	892	248	397	382
Ammonia (NH_3)	mg/L	0.5	-	42	-	9.5	0.18	1.43	0.76
pH	-	6.5-8.5	-	0	-	8.4	7.5	7.8	7.8
Taste	-	Not Offensive	-	1	-	-	-	-	-
Odour	-	Odourless	-	0	-	-	-	-	-
Colour	TCU (Hazen)	15	15	0	0	14	1.6	5.7	4.75
Turbidity	NTU	10	5	24	29	237	0.21	26.8	4.5
Temperature (T)	oC	20-30	-	0	-	23.8	23.2	23.5	23.5
Electrical Conductivity (EC)	mS/m	-	-	-	-	178.5	49.7	79.5	76.7
Sodium (Na^+)	mg/L	200	-	0	-	89	2	29	24.5
Potassium (K^+)	mg/L	12	-	2	-	16	2.1	4.7	4
Bicarbonate (HCO_3^-)	mg/L	-	-	-	-	290	140	214	210
Sulphate (SO_4^{2-})	mg/L	400	-	0	-	33	1	3.12	1

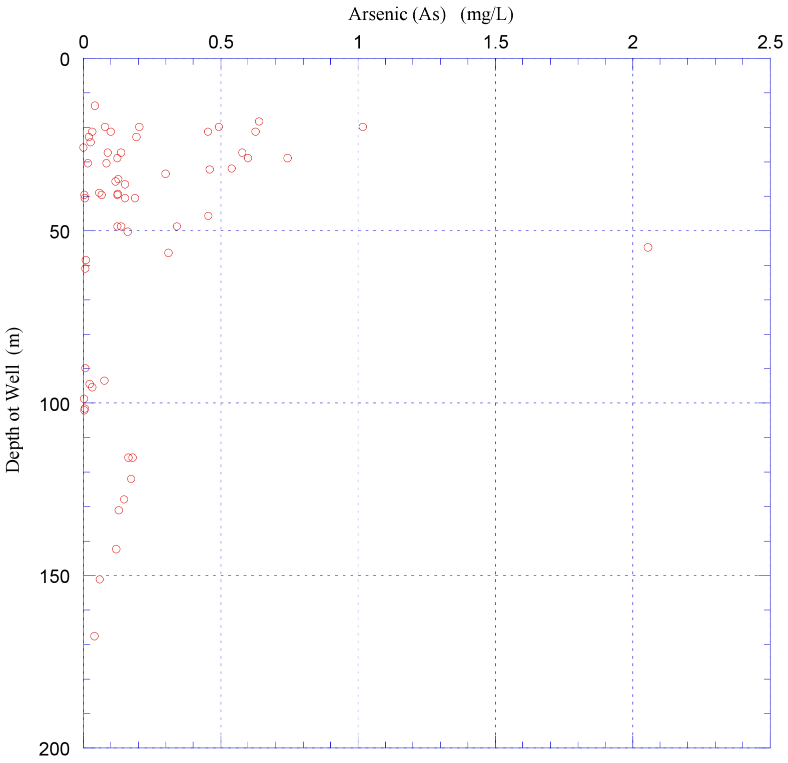


Figure 1.3.10 Relationship between Well Depth and Arsenic Content

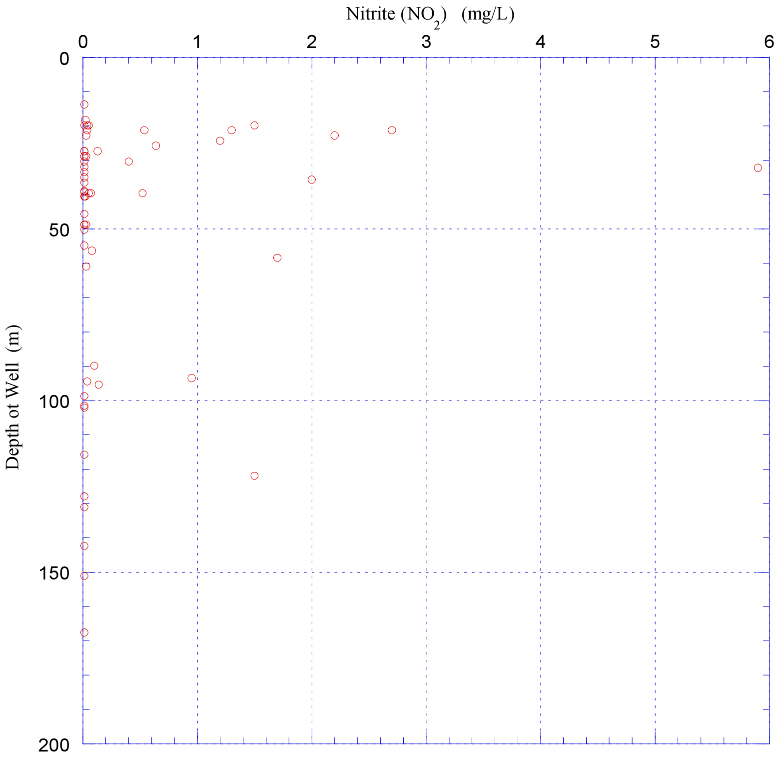


Figure 1.3.11 Relationship between Well Depth and Nitrite Content

(iv) Acceptability aspects and Items related to the characteristics of ground water

The items which had a content more than the values of the Bangladesh standard are as follows.

Calcium: 59 samples, Manganese: 55, Iron: 53, Ammonia: 42, Magnesium: 30,
Turbidity: 24, Potassium: 2, Taste: 1

The relationships with well depth are shown in Figures 1.3.12, 1.3.13 and 1.3.14 about calcium, manganese, and iron.

For all the analyzed items, a tendency indicating large values in shallow wells was recognized.

All samples meet the Bangladesh standard for chloride, TDS, pH, Temperature, Sodium, Colour and Sulphate. All samples also meet the WHO guideline for Colour and Turbidity.

For electric conductivity and bicarbonate, the Bangladesh standard has not been estabslished. Electric conductivity values range from 49.7 to 178.5 mS/m, and the average is 79.5 mS/m while the median is 76.7 mS/m. Bicarbonate values range from 140 to 290 mg/L, and the average value is 214 mg/L with the median being 210 mg/L.

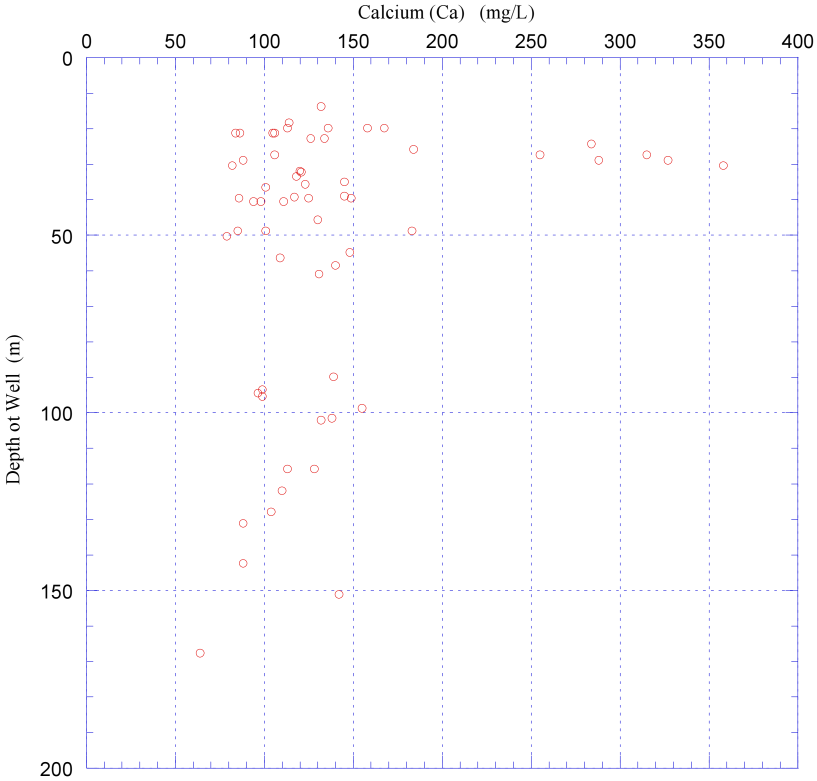


Figure 1.3.12 Relationship between Well Depth and Calcium Content

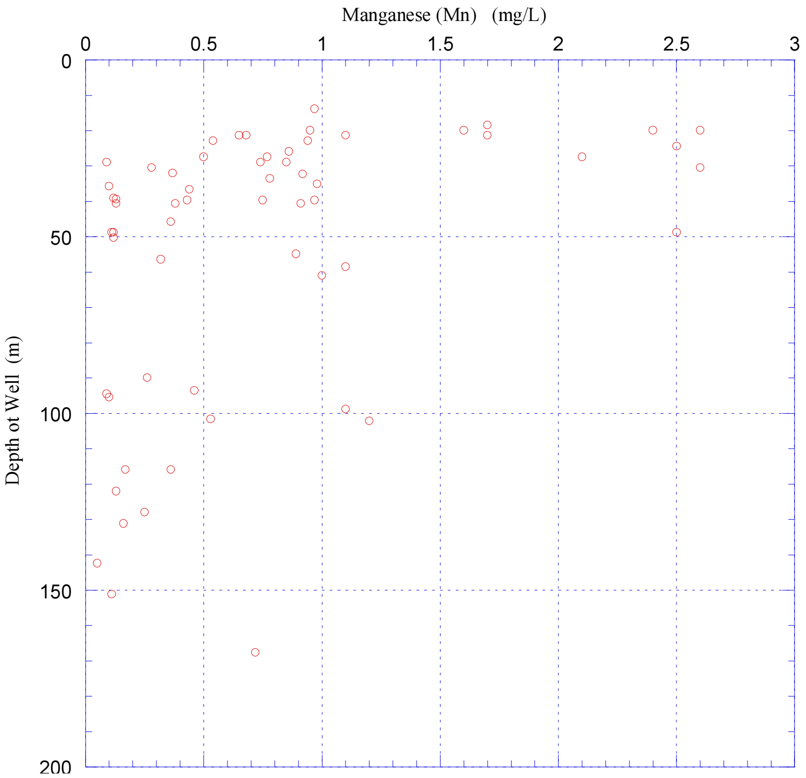


Figure 1.3.13　Relationship between Well Depth and Manganese Content

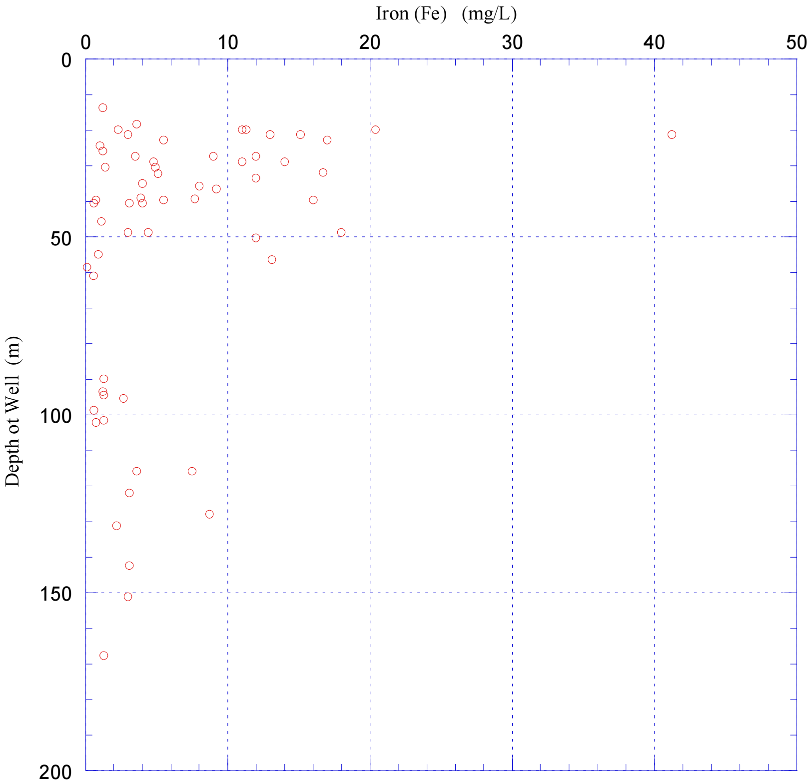


Figure 1.3.14　Relationship between Well Depth and Iron Content

(v) Evaluation of Water Quality Analysis

i) For drinking water

For items involving health significance including arsenic, 14 samples satisfied the Bangladesh standard and 6 samples satisfied the WHO guideline. Only 6 samples satisfied both the Bangladesh standard and the WHO guideline for items pertaining to health significance including arsenic.

There is no sample that satisfied the Bangladesh standard for all the 23 analysis items of the standard values set.

ii) Water quality classification by major dissolved components

Figure 1.3.15 shows a trilinear diagram that was made from the analysis results of 7 items of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^- and SO_4^{2-} those are major dissolved components in ground water and surface water.

59 samples are type I (bicarbonate calcium type) and 1 sample is type III (non bicarbonate calcium type) by classification of the Piper trilinear diagram. Type I often exists in shallow ground water and surface water so water from the existing wells in the Study Area seem to be shallow ground water which remains a relatively short time.

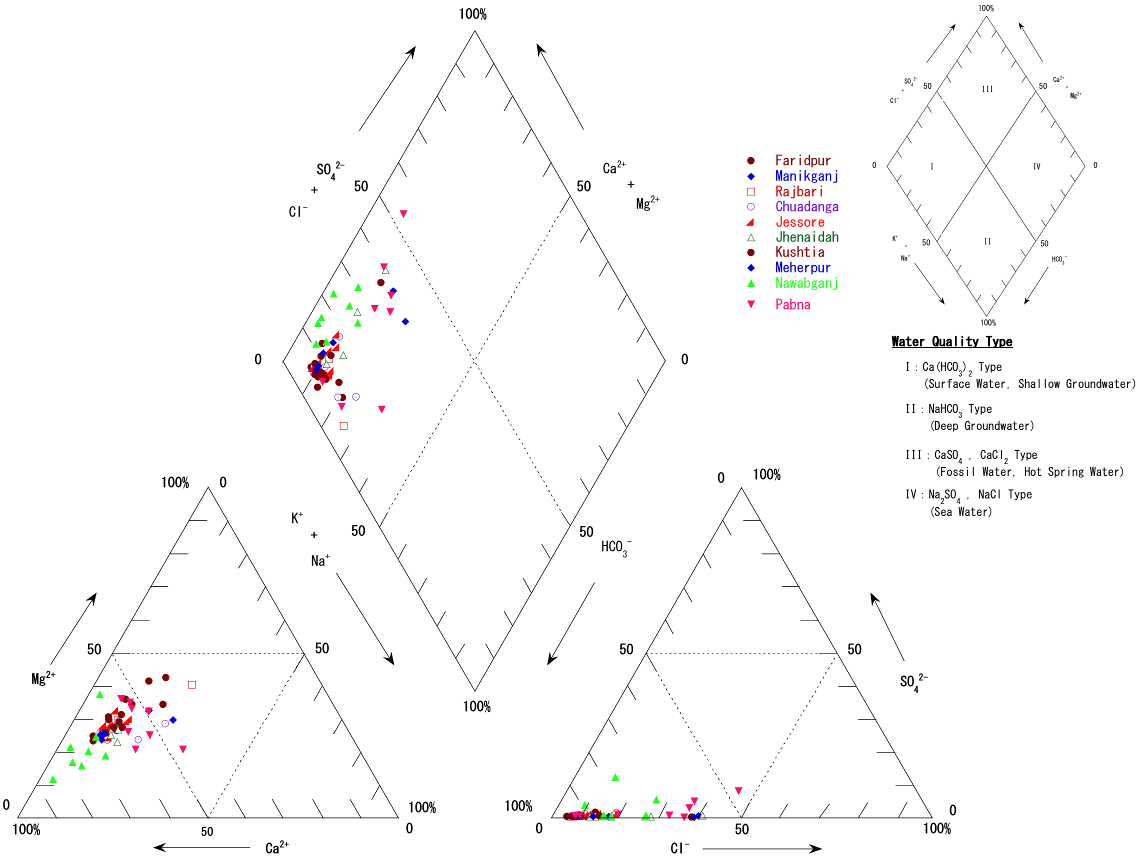


Figure 1.3.15 Result of Water Quality Analysis (Piper Trilinear Diagram)

(2) Water Quality Analysis (Part-2)

1) Purpose

For accuracy confirmation of the above-mentioned (1) water quality analysis (Part-1), the same sample as the sample collected by (1) water analysis (Part-1) was analyzed, and a cross-check of the analysis results was performed.

2) Target Villages

The following six villages were the target for water quality analysis (Part-2) among the 30 villages of the above-mentioned (1) water quality analysis.

Table 1.3.7 Target Villages for Water Quality Analysis (Part-2)

Village ID No.	Division	District	Upazila	Union	Village
1	Dhaka	Faridpur	Faridpur Sadar	Aliabad	Bilmamudpur
9	Khulna	Chuadanga	Damurhuda	Howli	Boro Dudhpatila
12		Jessore	Chaugachha	Jagadishpur	Marua
16		Jhenaidah	Maheshpur	Fatepur	Krishna Chandrapur
19		Kushtia	Bheramara	Mokarimpur	Nawda Khemediar
21		Meherpur	Meherpur Sadar	Amjhupi	Alampur

3) Specifications

a) Sample Collection

The third party analysis organization instructed by the Study Team was provided with a sample about the sample collected from one tube well per each village in the six above-mentioned villages among the samples collected by the above-mentioned (1) water quality analysis.

b) Water Quality Analysis

About the collected samples, the water quality analysis of the 25 items shown in Table 1.3.5 like the above-mentioned (1) water quality analysis was conducted, and a comparison examination was carried out with the results of the water analysis.

4) Result of Water Quality Analysis

The results of the water quality analysis of Part-2 with the above mentioned results of Part-1 is shown in Table 1.3.8.

The values of arsenic and iron exceeded the Bangladesh standard value in all 6 samples. For arsenic and iron, the comparison results of Part-1 and Part-2 are described below.

(i) Arsenic

In all samples, the results of Part-1 were larger than those of Part-2. Figure 1.3.16 shows the comparison between Part-1 and Part-2. It indicates that result of Part-1 is about 1.4 times larger than that of Part-2 on average.

(ii) Iron

In all samples, results of Part-1 were larger than those of Part-2. Figure 1.3.17 shows the comparison between Part-1 and Part-2. It indicates that the results of Part-1 are about 1.5 times larger those of Part-2 on average.

Table 1.3.8 Comparison between Results of Part-1 and Part-2

	Parameter	Unit	Bangladesh Standard	Results																	
				1-1			9-2			12-1			16-2			19-1			21-1		
				Bilmamudpur			Boro Dudhpatila			Marua			Krishna Chandrapur			Nawda Khemediar			Alampur		
				Part-1(a)	Part-2(b)	a/b	Part-1(a)	Part-2(b)	a/b	Part-1(a)	Part-2(b)	a/b	Part-1(a)	Part-2(b)	a/b	Part-1(a)	Part-2(b)	a/b	Part-1(a)	Part-2(b)	a/b
1	Total coliform Bacteria	cfu/100 mL	0	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
2	Escherichia coli.	cfu/100 mL	0	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-	0	0	-
3	Arsenic (As)	mg/L	0.05	0.161	0.141	114%	0.129	0.089	145%	0.121	0.1	121%	0.123	0.086	143%	0.007	0.004	175%	0.164	0.081	202%
4	Fluoride (F)	mg/L	1.0	0.17	<0.01		0.18	<0.01		0.12	<0.01		0.32	<0.01		0.32	<0.01		<0.018	<0.01	
5	Nitrate (NO_3)	mg NO_3/L	10.0	0.3	3.8	8%	0.5	<0.01		<0.10	3		0.3	0.5	60%	<0.10	<0.01		<0.10	<0.01	
6	Nitrite (NO_2)	mg NO_2/L	<1.0	<0.016	0.014		<0.016	0.025		<0.016	0.005		<0.016	0.011		0.10	<0.001		<0.016	0.028	
7	Manganese (Mn)	mg/L	0.10	0.12	0.083	145%	0.16	0.17	94%	<0.05	0.058		0.12	0.05	240%	0.26	0.07	371%	0.17	0.3	57%
8	Total hardness	mg/L	200-500	330	328	101%	265	284	93%	300	292	103%	325	340	96%	430	380	113%	350	348	101%
9	Calcium (Ca)	mg/L	75.0	79	75	105%	88	108	81%	88	92	96%	101	108	94%	139	134	104%	113	120	94%
10	Magnesium (Mg)	mg/L	35.0	51	34	150%	22	18	122%	30	20	150%	31	24	129%	38	28	136%	27	22	123%
11	Iron (Fe)	mg/L	0.3-1.0	12	7.51	160%	2.2	1.53	144%	3.1	2.35	132%	4.4	3.17	139%	1.3	1.02	127%	3.6	2.36	153%
12	Chloride (Cl)	mg/L	150-600	14	14	100%	5	8	63%	8.0	10	80%	13	10	130%	9.0	9	100%	10	7	143%
13	TDS	mg/L	1000.0	351	412	85%	267	312	86%	285	335	85%	892	402	222%	412	474	87%	352	412	85%
14	Ammonia (NH_3)	mg/L	0.50	7.8	6.65	117%	0.23	0.97	24%	0.76	0.58	131%	1.1	1.04	106%	0.49	0.08	613%	0.84	0.28	300%
15	pH	-	6.5-8.5	7.5	7.69	98%	7.8	7.54	103%	7.8	7.59	103%	7.8	7.7	101%	7.9	7.62	104%	7.9	7.59	104%
16	Taste	-	Not Offensive	Tasteless	Tasteless	-	Tasteless	Tasteless	-	Tasteless	Tasteless	-	Tasteless	Tasteless	-	Tasteless	Tasteless	-	Tasteless	Tasteless	-
17	Odour	-	Odourless	Odourless	Odourless	-	Odourless	Odourless	-	Odourless	Odourless	-	Odourless	Odourless	-	Odourless	Odourless	-	Odourless	Odourless	-
18	Color	TCU (Hazen)	15	5.0	<0.01		3.2	<0.01		4.9	<0.01		3.8	<0.01		2.4	<0.01		2.5	<0.01	
19	Turbidity	NTU	10	25	145	17%	3.8	12	32%	1.2	30	4%	4.2	41	10%	3.8	16	24%	0.70	14	5%
20	Temperature (T)	°C	20-30	23.5	20.8	113%	23.6	20.8	113%	23.5	20.8	113%	23.6	20.8	113%	23.6	20.8	113%	23.5	20.8	113%
21	Electric Conductivity	mS/m	-	70.2	82.6	85%	53.5	62.5	86%	57.0	66.9	85%	178.5	80.4	222%	82.3	94.8	87%	70.4	82.1	86%
22	Sodium (Na)	mg/L	200	34	23.7	143%	13	8.55	152%	14	9.17	153%	21	16	131%	28	20.4	137%	17	12.95	131%
23	Potassium (K)	mg/L	12.0	10	2.78	360%	3.5	3.08	114%	3.4	2.55	133%	3.1	2.96	105%	2.7	2.72	99%	4.0	4	100%
24	Bicarbonate (HCO_3)	mg/L	-	205	420	49%	160	120	133%	160	320	50%	200	400	50%	245	420	58%	210	414	51%
25	Sulfate (SO_4)	mg/L	400	1.0	2	50%	1.0	3	33%	1.0	1	100%	1.0	1	100%	1.0	3	33%	1.0	2	50%

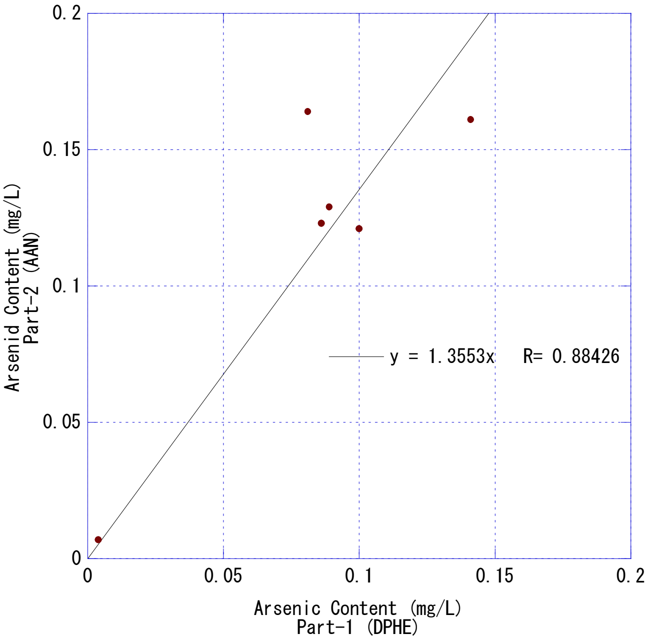


Figure 1.3.16　Comparison of Arsenic Content

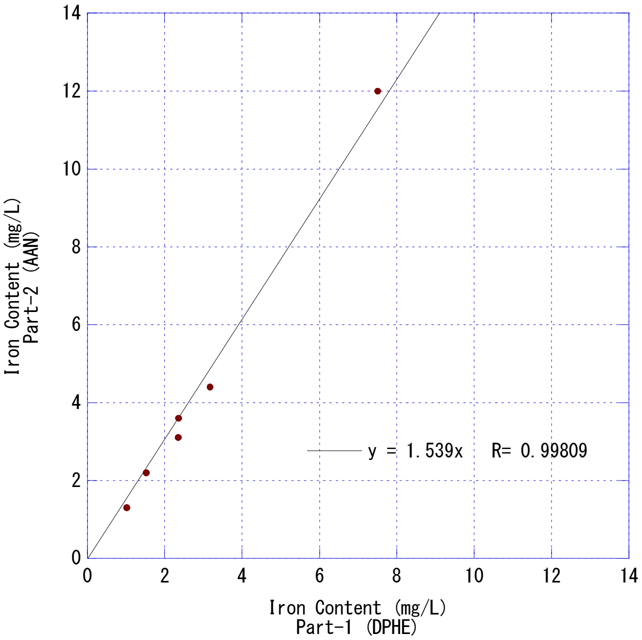


Figure 1.3.17　Comparison of Iron Content

1.4 SOCIO-ECONOMIC SURVEY

1.4.1 OBJECTIVES AND METHOD

A socio- economic survey was conducted from the middle to the end of December, 2011 in the 30 target villages of this Study. Objectives of the socio-economic survey are

- to collect baseline data on socio-economic conditions,
- to seek capability of community people on operation and maintenance of water supply facilities,
- to collect data for the Project evaluation.

Implementation of the survey was sub-contracted out to a local Non-governmental Organization (NGO). Two (2) kinds of questionnaires, one for key informants of the study villages and the other for village households were prepared by the JICA Study Team. An orientation and pretest were carried out, and contents of the questionnaires were well understood among the field survey staff, before the implementation of the survey. A total number of 30 samples from the village key informants (one (1) sample from each village) and 300 samples from the sample households (10 sample from each village) were collected.

1.4.2 SURVEY ITEMS

Table 1.4.1 shows survey items.

Table 1.4.1 Survey Items of Socio-Economic Condition

Survey Items	Survey Contents
Basic Information of the target villages	Population, Number of households, Amount of household income and expenditure, Major sources of income, Seasonal variation of income, Existence of cash income, Existence of water management committee, Existing organizations in the target village, Decision-making mechanism in the target village, Global Positioning System (GPS)
Water use situation of the residents in the target villages	Present water sources, Consumed quantity of water in the dry season and the rainy season Uses of water, Perception on water quality, Problems and requests about water supply, Amount of water charge and Present status of operation and maintenance (O&M) of the existing safe water devices in the dry season and in the rainy season
water use situation of surrounding villages	Water charge, Present status of O&M of the existing safe water devices
Residents' willingness about water supply	Willingness to pay and save for water charge, Willingness about O&M of safe water devices
Related matters of gender consideration	Difference in the role about the water, Difference in the participation to decision-making in thehousehold, The burden of fetching water, Needs about the water

1.4.3 SURVEY RESULT

(1) Population and Number of Households

Table 1.4.2 shows population and number of households data which were obtained from the survey. As a comparison, the population data of Census 2001 is also shown in the table.

Table 1.4.2 Population and Number of Households

No.	District	Upazila	Union	Name of Village	Population (people)			Number of Household
					The survey result	Adjusted (*1)	Census 2001	The survey result
1	Faridpur	Faridpur Sadar	Aliabad	Bilmamudpur (Natundangi Para)	1,125 (2010)	1,260	8,968	225
2			Kaujory	Purbo Gangabardi	7,500 (2011)	7,500	2,565	1,500
3			Krishnanagar	Bhadukdia	950 (2011)	950	566	205
4			Majchar	Dayarampur	9,000 (2010)	10,080	3,562	1,500
5	Manikganj	Harirampur	Kanchanpur	Kutirhat	1,600 (2011)	1,600	1,374	220
6	Rajbari	Rajbari Sadar	Dadshi	Pakurikanda	2,025 (2010)	2,268	1,105	276
7	Chuadanga	Alamdanga	Baradi	Ampnagar	4,000 (2011)	4,000	1,494	373
8			Jehala	Betbaria	1,500 (2011)	1,500	775	160
9		Damurhuda	Howli	Boro Dudhpatila	5,000 (2011)	5,000	999	600
10			Natipota	Boalmari	1,700 (2011)	1,700	559	337
11	Jessore	Chaugachha	Chaugachha	Bergobindapur	1,200 (2011)	1,200	2,521	400
12			Jagadishpur	Marua	5,000 (2011)	5,000	1,179	800
13			Patibila	Purahuda	2,000 (2011)	2,000	300	328
14			Phulsara	Baruihati	600 (2011)	600	774	120
15	Jhenaidah	Jhenaidah Sadar	Padmakar	Achintanagar	1,500 (2011)	1,500	2,013	455
16		Maheshpur	Fatepur	Krishna Chandrapur	1,400 (2011)	1,400	1,212	150
17	Kushtia	Bheramara	Dharampur	North Bhabanupur	5,310 (2011)	5,310	2,005	1,148
18			Junidah	Jagshar	3,856 (2010)	4,319	4,362	919
19			Mokarimpur	Nawda Khemediar	4,500 (2010)	5,040	2,569	550
20		Daulatpur	Pragpur	Pakuria	2,200 (2011)	2,200	3,512	450
21	Meherpur	Meherpur Sadar	Amjhupi	Alampur	3,200 (2010)	3,584	2,109	600
22			Kutubpur	Subidpur	3,580 (2010)	4,010	4,245	750
23	Nawabganj	Nawabganj Sadar	Char Anupnagar	Anupnagar	9,500 (2010)	10,640	5,406	1,300
24			Maharajpur	Moharajpur	33,350 (2010)	37,352	4,285	5,970
25			Ranihati	Ghoraparakhia	6,000 (2010)	6,720	4,706	1,500
26		Shibganj	Chhatrajitpur	Satrajitpur	23,500 (2010)	26,320	700	4,500
27	Pabna	Bera	Masumdia	Khanae Bari	3,000 (2010)	3,360	1,700	500
28			Natun Bharenga	Morichapara	2,500 (2010)	2,800	2,510	450
29			Paurashava	Shanila	6,000 (2010)	6,720	8,373	1,000
30			Ruppur	Boronagaon	700 (2010)	784	640	150
				Study Area Total	-	166,716	77,088	27,436

*1: Adjusted population= 2010 data*annual population growth (1.12)

Since the population data were collected either in 2010 or 2011, an estimated population in 2011 was calculated regarding data which were collected in 2010. It shall be noted that population data from the survey and the data from the 2001 Census shows a big difference in some villages. Some possible reasons about this are: Some of the 2001Census data includes Mauza, not only the village itself, and there could be demographic changes such as separation and combining of villages in the 10 years.

(2) Income Sources

Figure 1.4.1 and 1.4.2 show distributions of the primary income sources and the secondary income sources among the sample households. Farming is the biggest income source (41.0 %), and it is followed by casual work (18.7 %), own work and so on (13.7 %), retail (11.3 %), salaried employee, fishing, remittance, pension, and livestock farming. 58.2 % of the sample households answered that they had secondary income sources. In the second income sources, farming occupies the highest percentage (21.6 %). Farming is followed by casual work (13.4 %), own work and so on, retail, salaried employee, livestock farming, remittance, fishing, and pension.

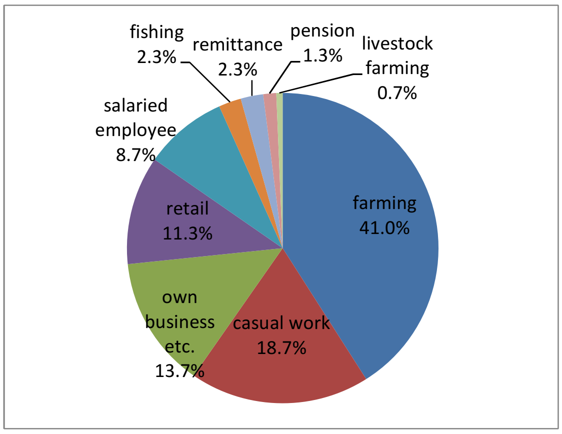


Figure 1.4.1 Primary Income Sources among Sample Households

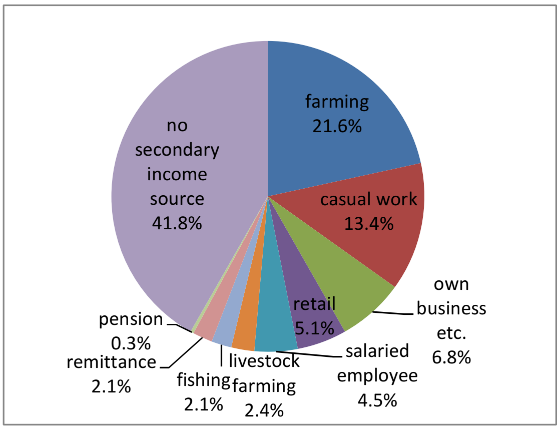


Figure 1.4.2 Secondary Income Sources among Sample Households

Even though farming occupies the highest percentage (41.0 %) in the 30 villages as a whole, each village has a different tendency on the distribution of income sources. Figure 1.4.3 indicates occupancies of different kinds of income sources in each village.

As the figure below shows, farming occupies 80 % of the primary income sources in Bhadukdia village, Ampnagar village, Betbaria village and so on. On the other hand, other income sources rather than farming occupy the primary income sources in some villages such as Moharajpur village, Khanae Bari village and Morichapara village.

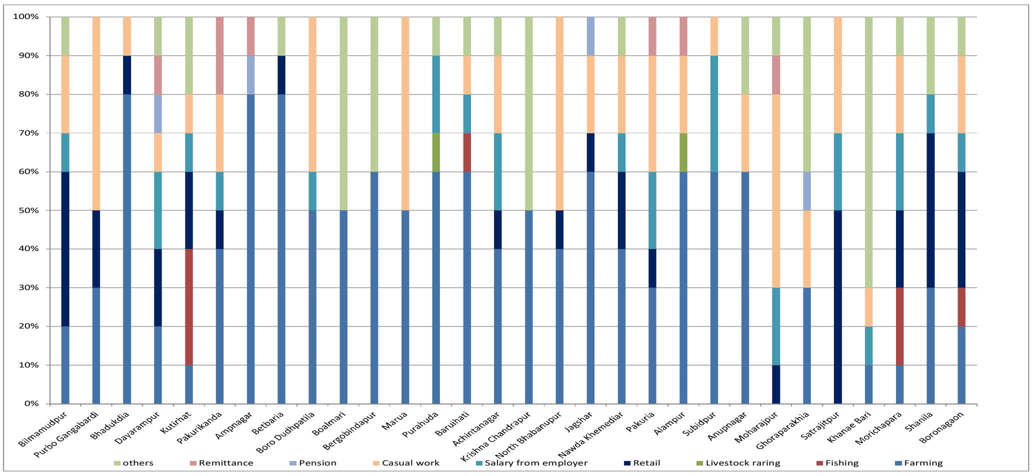


Figure 1.4.3 Distribution of Income Sources in the Target Villages

(3) Level of Household Income and Expenditure

1) Tendency of Household Incomes in the Target Villages

Monthly household income varies in a range from 1,000 to 100,000 BDT in the dry season and 0 to 100,000 BDT in the rainy season among the sample households. The number of the sample households is about the same among 4,001-5,000 BDT, 5,001-6,000 BDT, 6,001-7,000 BDT, and 7,001-8000 BDT and 52.3% of the sample households have monthly income of 4,001-8,000 BDT in the dry season and 49.0% in the rainy season. The percentage of the sample households whose income is less than 4,000 BDT is 9.7% in the dry season and 22% in the rainy season. The percentage of the sample households whose income is more than 10,001 BDT is 22% in the dry season and 16.3% in the rainy season. The median monthly household income is 7,500 BDT in the dry season and 5,500 BDT in the rainy season. 49.3 % of the sample households stated that they had more income in the dry season than that in the rainy season. Thirty seven percent of the sample households stated their income in the dry season was the same as that in the rainy season. In the rest of 12.3 % of the sample households, income in the rainy season exceeded income in the dry season.

There is a relatively big income difference between the household with the highest income and the household with the lowest income in each village. The difference between these is at least 4,000 BDT (Bilmamudpur village and Betbaria village) in the dry season and 5,000 BDT (Bilmamudpur village, Achintanagar village and Morichapara village) in the rainy season. The biggest difference is 96,000 BDT in the dry season and 97,000 BDT in the rainy season (both in Khanae Bari village).

The blue line indicated in Figure 1.4.4 is the village wise median value of monthly household income in the dry season. In the figure, the village on the left edge is the village with the lowest median value. The village with the lowest median value is Krishna chandrapur village, and the value is 4,000 BDT. As the line goes to the right, the median value increases. The highest median value is 10,000 BDT and three (3) villages (Bergobindapur village, Purahuda village, and Khanae Bari village) have the value. In case of the rainy season, the lowest median value is 3,500 BDT (Pakuria village and Krishna Chandrapur village). The highest median value is 9,750 BDT (Parahuda village).

There are some households whose incomes are much higher than other households in some villages. These households cause an increase in the village wise average income. The red line in Figure 1.4.4 shows the village wise average value of monthly household income in the dry season. In case the blue line and the red line are far away from each other it means income differences among the sample households are large. For example, in case of Khanae Bari village, its median value is 10,000 BDT, but its average income value is 17,200 BDT as seen from Figure 1.4.4. The rainy season has the same tendency about difference in household incomes in each village, and the difference in mean value and average value.

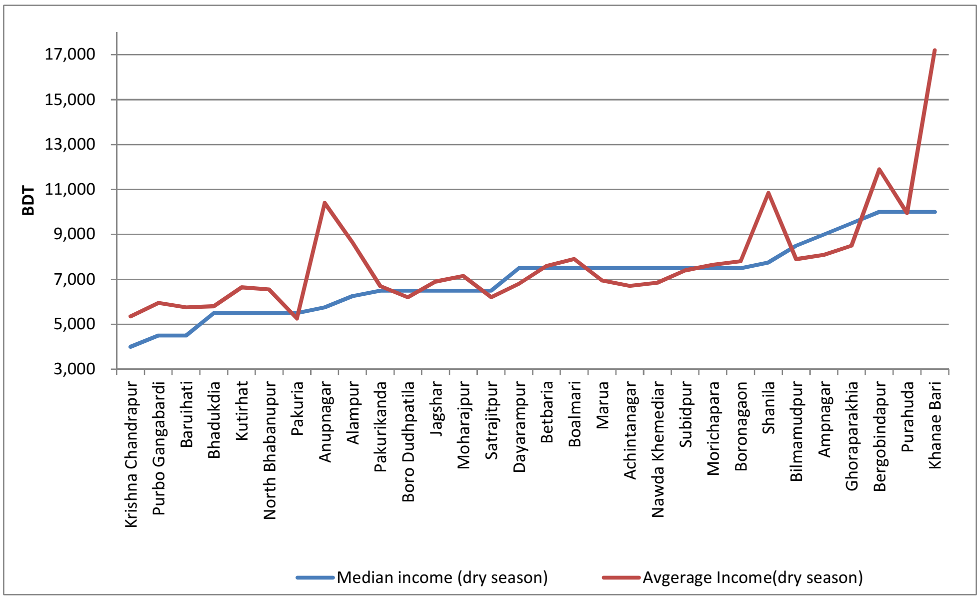


Figure 1.4.4 Village-Wise Median Income and Average Income in Dry Season

2) Comparison of Low Income Group and High Income Group

This section considers the difference between the low income group and high income group. Here, the sample households whose income are less than 4,000 BDT are defined as the low income group, and the sample households whose income are more than 10,001 BDT are defined as the high income group. As mentioned, 9.7% of the sample households belong to the low income group. In case of the rainy season, the percentage is 22%. The percentage of the sample households who belong to the high income group is 22% in the dry season and 16.3% in the rainy season. Figure 1.4.5 and Figure 1.4.6 show the primary income sources of these two (2) groups.

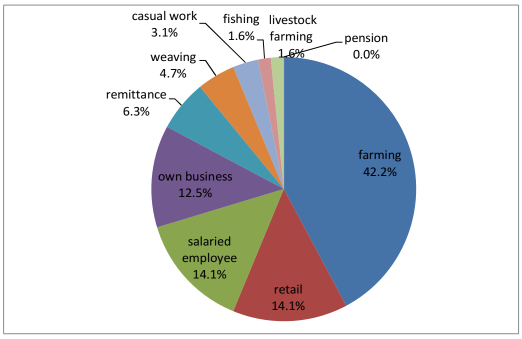


Figure 1.4.5 Primary Income sources of Sample Households with Income More than 10,001 BDT (High Income Group)

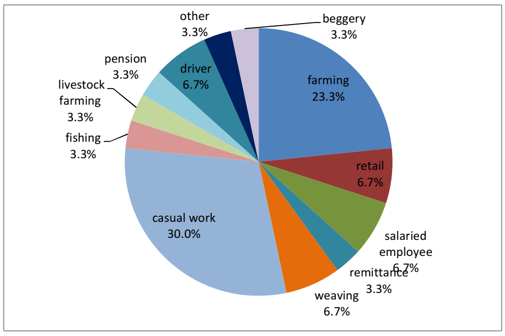


Figure 1.4.6 Primary Income sources of Sample Households with Income Less than 4,000 BDT (Low Income Group)

In the high income group, farming occupies the highest percentage (42.2%) as the primary income source. The second highest income source is retail and salaried employee (14.1%) followed by own business and so on (12.5%). In the low income group, casual work occupies the highest percentage (30%), and the second highest income source is farming (23.3%). They are followed by retail, salaried employee, and weaving (6.7%).

Regarding secondary income sources, it was revealed that the low income group tends to have no secondary income sources. 57.1% of the respondents in the low income group do not have secondary income sources. On the contrary, that of the high income group is 27.7%. Obviously this is considered as a possible reason of low income in the low income group.

The second possible reason of the income difference between the two (2) groups is category of business. As clearly seen from Figure 1.4.5 and Figure 1.4.6, the percentage of casual work is much higher in the low income group than that in the high income group (30% in the low income group and 3.1% in the high income group). On the other hand, the percentage of farming is about 19 points higher in the high income group (42.2% in the high income group and 23.3% in the low income group). From this, it could be interrupted that farming tends to be classified as a higher income source than casual work.

The third possible reason is work environment. The income can be very different depending on the situation even in the same kind of income source because the work is about the same in both groups as can be seen from Figure 1.4.5 and Figure 1.4.6. As an example, in case of farming, the income could be different depending on the land productivity and products which they cultivate. As another example, in case of weaving, the income could be different depending on the situation whether weaving is the major industry in the area or not. In the high income group, it was revealed that all the sample households whose primary income source is weaving belong to one (1) village (Khanae Bari village). Half of the sample households in the village answered that their primary income source is weaving. It could be interpreted that weaving is important in this area, so infrastructure is well developed to earn enough income by weaving. In the low income group, the primary income source of the villages which have weaver is farming. It is considered that infrastructure is not developed as much as in the situation of the high income group.

3) Expenditure

Monthly household expenditure varies in a range from 600 to 40,000 BDT among the sample households. Figure 1.4.7 shows distribution of monthly household expenditure.

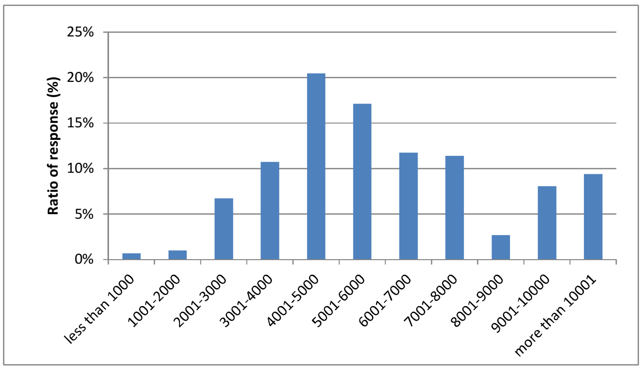


Figure 1.4.7 Distribution of Monthly Expenditure

20.5 % of the sample households stated that their monthly expenditures were between 4,001-5,000 BDT, and it occupies the highest percentage. The second highest range is 5,001-6,000 BDT and 17.1 % of the sample households are in this range. 10.7% of the sample households belong to 3,001-4,000 BDT. About 11% of the sample households belong to 6,001-7,000 BDT and 7,001-8,000 BDT. There are very small numbers of the sample households whose monthly expenditure is less than 2,000 BDT. It is to be noted that there are more than 15 % of the households whose expenditure is more than 9,001 BDT.

By comparing the income and expenditure, it was confirmed that in 50% of the sample households, either the amount of monthly expenditure was the same as the monthly income, or monthly expenditure exceeded the monthly income. A possible reason for this is micro finance. Use of micro finance is very common in Bangladesh. During the survey, the survey team confirmed some households who used microfinance. There is a possibility that villagers lend money, and use their cash income for the repayment. To cover necessary expenditure, they lend money again, and continue this cycle.

(4) Present Status of Operation and Maintenance (O&M) on Existing Safe Water Devices

It was revealed that all the 30 target villages have some sort of community-based safe water devices. This section mentions about the current situation of O&M on these community-based safe water devices. In the Study Area, it was confirmed that various kinds of persons and organizations participated in O&M. Main participants are water user committee, land owner, village leader, mojit committee and school management committee.

1) Existence of Water User Committee

It was confirmed that 13 villages had water user committees.

Figure 1.4.8 shows how often committee meetings are held in those 13 villages.

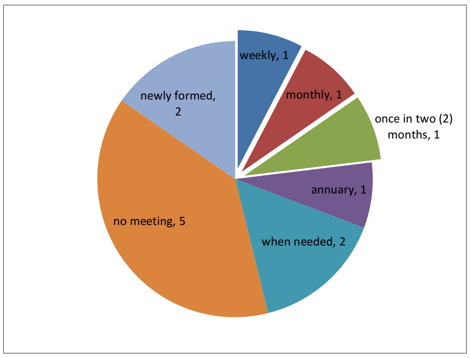


Figure 1.4.8 Frequency of Water User Committee Meeting

From Figure 1.4.8, it is interpreted that there are committees which are active and not so active. In three (3) villages (Village No.: 1, 16, and 29), committee meetings were frequently held on regular bases such as weekly, monthly or once in two (2) months. These three (3) villages could be said they are active. However, in the rest of 10 villages (village No.: 7, 8, 11, 12, 14, 21, 22, 23, 27, and 30), it is hard to say that committees are actively having meetings. One (1) village holds a meeting on a regular basis, but it is annually. Committee meetings have not been held since their foundation in five (5) villages. There are two (2) villages which answered that they did not decide how often they were going to have a committee meeting even though they recently founded water user committees.

In 17 villages, water user committees are not founded. The following table shows some of the reasons why they do not form water user committees.

Table 1.4.3 Reasons of No Water User Committees

Reasons of no water user committees	Number of village	Name of village
lack of initiative and lack of awareness	6	Bhadukdia, Pakurikanda, Nawda Khemediar, Moharajpur, Ghoraparakhia, Satrajitpur
no need to organize water user committees since the facilities had been built by DPHE, and DPHE should be responsible for O&M	3	Purbo Gangabardi, Dayarampur, Kutirhat

These reasons show lack of ownership, and lack of communication between constructors of the safe water devices such as DPHE and international donors, and villagers.

2) Responsible persons/organizations on O&M

The above section, (4) Existence of Water User Committee, revealed that 17 villages did not have water user committees in the Study Area. Moreover, some water user committees do not have meetings actively even if the committees exist. Concerning these situations, Figure 1.4.9 and Figure 1.4.10 show responsible persons of O&M regarding existing safe water devices in the villages with water user committees and without the committees respectively.

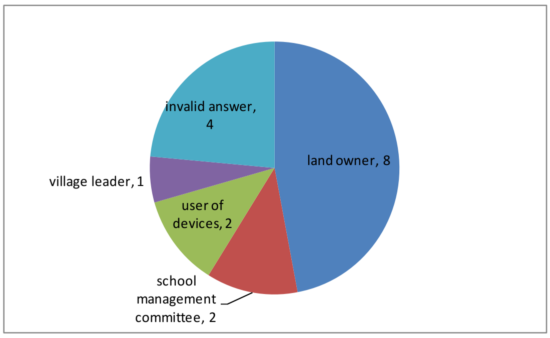


Figure 1.4.9 Responsible Persons /Organizations of O&M in Villages without Water User Committees

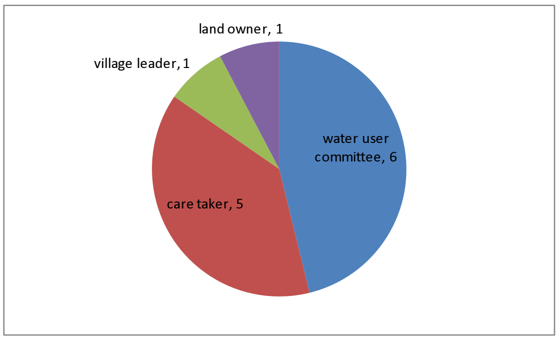


Figure 1.4.10 Responsible Persons /Organizations of O&M in villages with Water User Committees

As Figure 1.4.9 shows, eight (8) villages (Village No.: 2, 3, 4, 9, 13, 17, 19, and 20) answered that the land owner was the responsible person for O&M. This answer occupies nearly half of the answers. In case of villages with water user committees, water user committees are the responsible organizations at nearly half of the villages (village No.: 7, 8, 11, 12, 14, and 22) as Figure 1.4.10 shows. There are five (5) villages (village No.: 16, 21, 23, 27, and 29) which answered the caretaker was the responsible person. It is reasonable to think that caretakers belong to water user committees. Therefore, it can be said that water committees are getting involved in O&M at a high rate in case water user committees exist regardless whether the appropriate O&M is taken or not. At the same time, it should be strongly emphasized that two (2) villages answered the village leader and the land owner is the responsible person for O&M. This means that persons who are outside of the water user committee take care of the safe water device even though the water user committee exists.

3) Decision Maker on Water Related Matters

Figure 1.4.11 show the distribution of the decision maker on water related matters.

15 villages answered that the village leader was the decision maker. Water user committees make a decision in eight (8) villages (village No.: 1, 8, 11, 12, 14, 21, 27, and 29). There are five (5) villages that they make a decision through a meeting with either male villagers or both male and female members. There are four (4) villages (village No.: 7, 16, 23, and 30) which answered that the village leader was the decision maker even though they had water user committees.

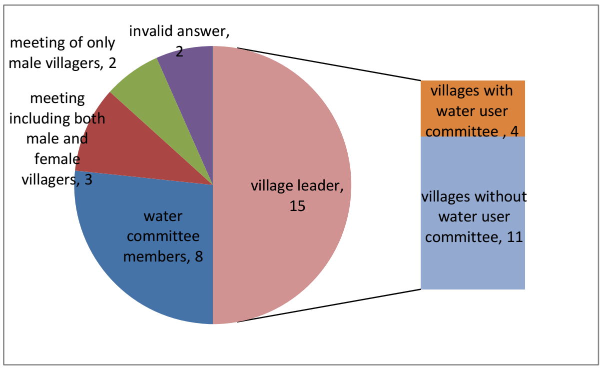


Figure 1.4.11 Decision Maker on Water Related Matters

4) Water Charge

21 key informants stated that use of the safe water devices were free of charge in their villages as indicated in Figure 1.4.12.

Only four (4) key informants answered that users were charged a monthly flat rate (village No.: 21, 22, 23 and 27). The monthly flat rate per household varies from 10 to 80 BDT. As perception of the amount which they pay, about 93.6 % of the respondents who pay less than 50 BDT think the amount of money is fair, cheap or very cheap. On the other hand, that percentage decreases to 40 % in the sample households who pay

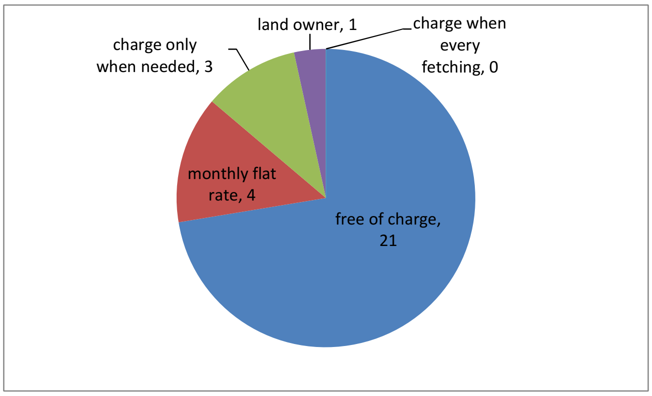


Figure 1.4.12 Method of Water Charge

50 BDT and above. 60 % of the respondents who pay 50 BDT and above feel the amount of money is either expensive or very expensive.

One (1) key informant stated that land owner bore all the necessary costs for O&M.

5) Response to Breakdown of Safe Water Devices

Regarding the latest safe water devices, 18 villages answered that they had experienced breakdown of the safe water devices (Village No.: 2, 4, 5, 9, 11, 12, 14, 15, 19, 21, 23, 24, 25, 26, 27, 28, 29, and 30). Figure 1.4.13 shows the distribution of responses to the breakdown of the devices.

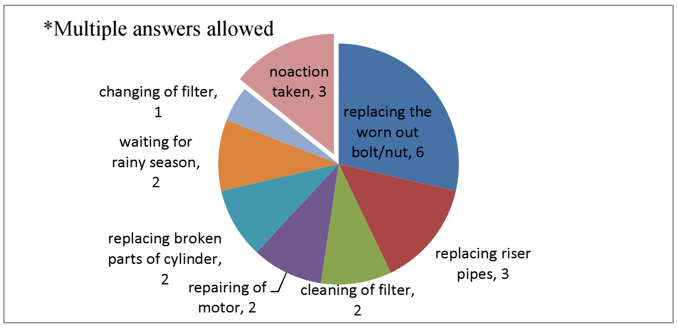


Figure 1.4.13 Contents of Repair Works

In the villages which experienced breakdown of the devices, 15 villages took some actions to repair the safe water devices. However, three (3) villages had not taken any actions. In villages which took some actions, the highest reason of malfunction of the devices is replacing the worn out bolt or nut. The second highest problem they faced was breakdown of the riser pipe. Two (2) villages answered that they were waiting for the recovery of ground water level in the rainy season because the devices had been out of order due to drying up of the water sources in the dry season.

6) Person/Organization Who did Repair Work

Figure 1.4.14 shows person/organization who did repair work. Valid answers were obtained in 14 villages. As shown in Figure 1.4.14, repair work was done by the community in seven (7) villages, and requesting the repair to private plumber/mechanics in four (4) villages, to DPHE in two (2) villages and NGO in one (1) village.

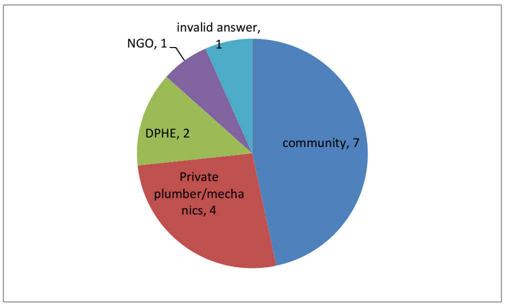


Figure 1.4.14 Persons/Organizations Which Did Repair Works

7) Fund for Repair Works

As mentioned in the above section, 4) Water Charge, use of community-based safe water devices is free of charge in the majority of the villages. Figure 1.4.15 shows the percentage of the source of the repair cost.

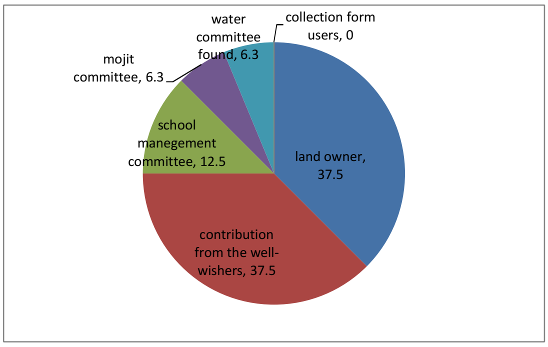


Figure 1.4.15 How Raised Cost for Repair Works

As Figure 1.4.15 indicates, there is no village which collects the fund from users of the devices. On the one hand, land owners and well-wishers bear the cost at a high percentage (75.0%). There are also some cases that the cost is born by committees other than water user committee such as school management committee and mojit committee.   The percentages are 12.5% and 6.3% respectively.

8) Willingness to pay for safe water

Eighty nine (89) per cent of the sample households expressed their willingness to pay for safe water.   In 17 villages, more than 90% of the respondents expressed their will to pay for safe water.   At the same time, it should be noted that in some villages, about half of the sample households do not express willingness to pay for safe water, as is seen from Figure 1.4.16.

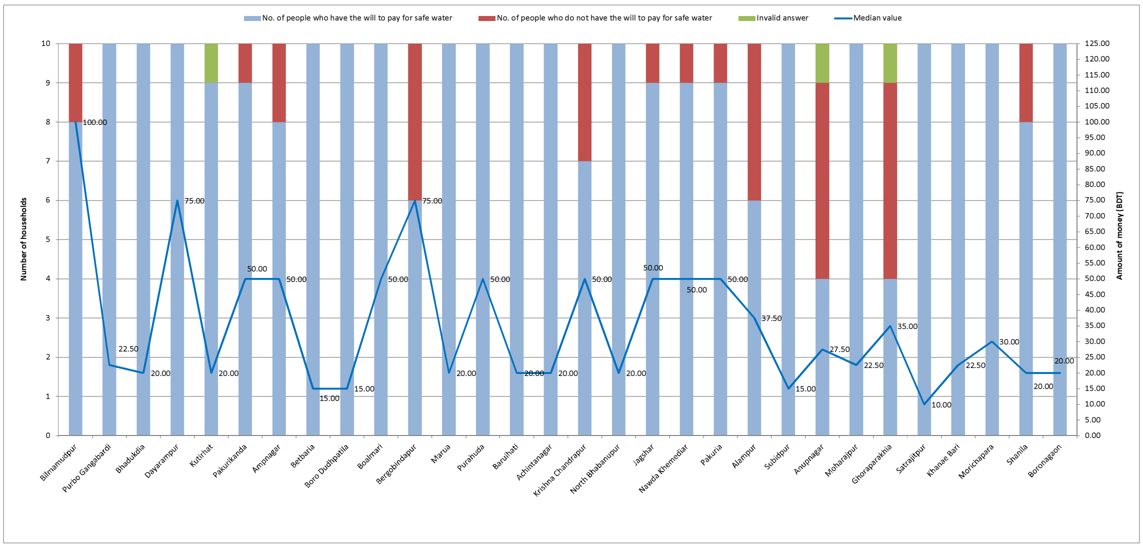


Figure 1.4.16   Number of Respondents who Express Willingness to Pay for Safe Water and Village-wise Median Monthly Amount

Among the sample households who expressed willingness to pay, the minimum value of willingness to pay was 5 BDT per month, and the maximum value was 400 BDT per month. The most frequent value was 50 BDT per month, and 59 respondents stated this value. Figure 1.4.16 shows village-wise distribution of willingness to pay and median monthly value of willingness to pay.

The median value varies from 10 to 100 BDT as shown in Figure 1.4.16.   The village-wise median values could be classified into three (3) groups.   The first group is the villages with willingness to pay above 75 BDT.   Bilmamudpur village, Dayarampur village and Bergobindapur village belong to this group.   The second group is the villages with willingness to pay of 50 BDT.   Eight (8) villages such as Pakurikanda village and Ampnagar village belong to the group.   The third group is villages with willingness to pay around 20 BDT.   15 villages such as Purbo gangabardi village and Bhadukdia village belong to this group.   The same as household income, there are households who show relatively high amount of willingness to pay and a low amount of willingness to pay in each village.   In case of household income, a household with a high income causes the village-wise average income to increase dramatically as mentioned in (3) Level of Household Income and Expenditure, 1) Tendency of Household Incomes in the Target Villages.   Unlike household income, the difference between the highest and the lowest values of willingness to pay is relatively small in case of willingness to pay.

It is to be noted that no significant relationship was observed between household income and the amount of willingness to pay.

As mentioned in (4) Present Status of Operation and Maintenance (O&M) on Existing Safe Water Devices, 4) Water Charge section, 60 % of households who pay more than 50 BDT per month for water think the amount of money is either expensive or very expensive. Considering that, it might be difficult for the villagers to pay more than 50 BDT per month continuously even though some of the households express willingness to pay more than 50 BDT.

(5) Source of Water

Figure 1.4.17 indicates the distribution of the primary water sources. The distribution of each water source is very similar in both seasons.

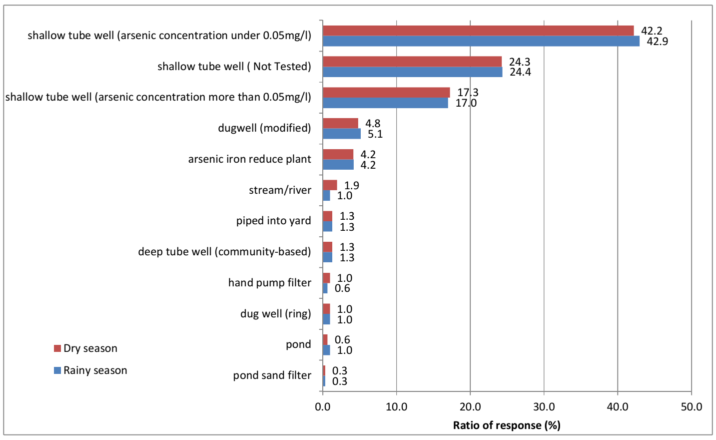


Figure 1.4.17 Primary Water Sources for Domestic Use

The highest primary water source is the shallow tube well with an arsenic concentration under 0.05 mg/l (the safe shallow tube well) in both seasons: Their percentages are 42.2% in the dry season and 42.9% in the rainy season. The second highest primary water source is the shallow tube well of which the arsenic concentration has not been checked (the shallow tube well (not tested)): The percentage is 24.3 % in the dry season and 24.4 % in the rainy season. It was confirmed that around 17% of the sample households used the shallow tube well with an arsenic concentration more than 0.05 mg/l (the arsenic contaminated shallow tube well) in both seasons. However, the percentage who use the arsenic contaminated shallow tube well could be increased vastly in case water quality of the shallow tube well (not tested) is checked because an arsenic concentrations of approximately 24% of shallow tube wells have not been checked.

(6) Time taken for water fetching

The range of time for fetching water varies from 0 to 50 minutes in the dry season and from 0 to 30 minutes in the rainy season. Figure 1.4.18 shows the distribution of water fetching time.

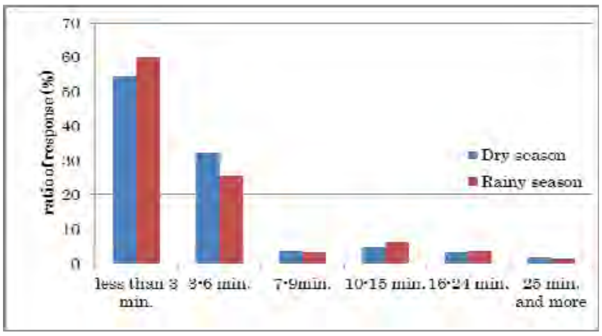


Figure 1.4.18 Distribution of Fetching Time of Water

As Figure 1.4.18 shows, more than half of the sample households reach their water sources within three (3) minutes. 86.7% and 85.3% of the sample households reach their water sources in less than seven (7) minutes, in the dry season and the rainy season, respectively.

The remaining 13.3% and 14.7% of the sample households take more than seven (7) minutes to reach their water sources in the dry season and the rainy season, respectively.

Figure 1.4.19 shows the primary water source among those households.

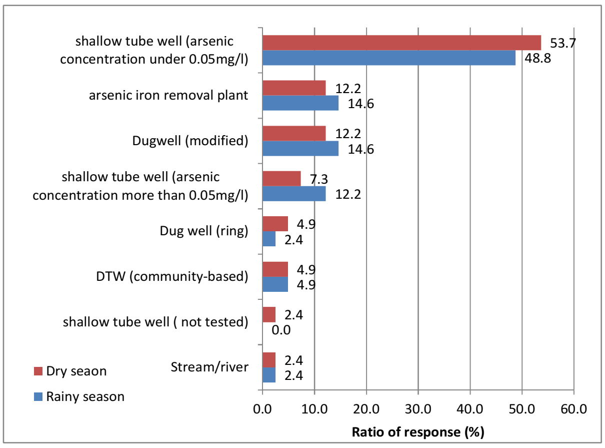


Figure 1.4.19 Primary Water Sources of Sample Households who Take Seven (7) and More Minutes to Reach to Water Sources

The highest primary water source is the safe shallow tube well. It is the same as the result of the whole sample households (refer to Figure 1.4.17). However, the percentages are about eight (8) to 10 points higher than that of the whole sample households (in case of the whole sample households, the percentage is about 42%). The second highest primary water sources are Arsenic Iron Removal Plants (AIRP), and dug wells (modified). These percentages are about seven (7) to 10 points higher than that of the whole sample households. The respondents who use the arsenic contaminated shallow tube well are 7.3% in the dry season and 12.2% in the rainy season. In case of the whole sample of households, the percentages are 17.3% in the dry season and 17.0% in the rainy season. These show that the sample households who take more than seven (7) minutes to reach their water sources tend to choose safe water sources. For example, there is a household who takes 30 minutes to fetch water from the stream/river. There is an AIRP which is inactive and an arsenic contaminated shallow tube well nearby the house. This shows the household avoids the arsenic contaminated water sources.

It is to be noted that there are 24 households who spend 10 and more minutes to reach the water source in both seasons. When attention is paid to those 24 households, it is confirmed that all of them seek arsenic safe water sources even though there are also arsenic contaminated water sources nearby their houses. This kind of household is confirmed in 23 villages out of the 30 target villages. The total numbers of this kind of household are small, but the existence of this kind of household is meaningful because these households possibly take a role as the initiative of activities to minimize arsenic contamination.

Regarding waiting time at the water source, 82.7% and 81.3% of the sample households answered it was less than one (1) minute in the dry season and the rainy season, respectively.

(7) Water Consumption of Domestic Water

Figure 1.4.20 shows the distribution of per capita domestic water consumption. Daily water consumption varies from 1.3 L/capita/day to 81 L/capita/day in the dry season and 1 L/capita/day to 62.9 L/capita/ day in the rainy season.

Median daily consumption is 11.2 L/capita/day in dry season and 10 L/capita/day in the rainy season. In both seasons, more than 25 % of the sample households belong to the consumption group of 5-9 L/capita/day. The figure shows a relatively wide distribution between less than 5 L/capita/day to 24 L/capita/day. The percentage of the sample households which use 30 L/capita/day is very small among the sample households.

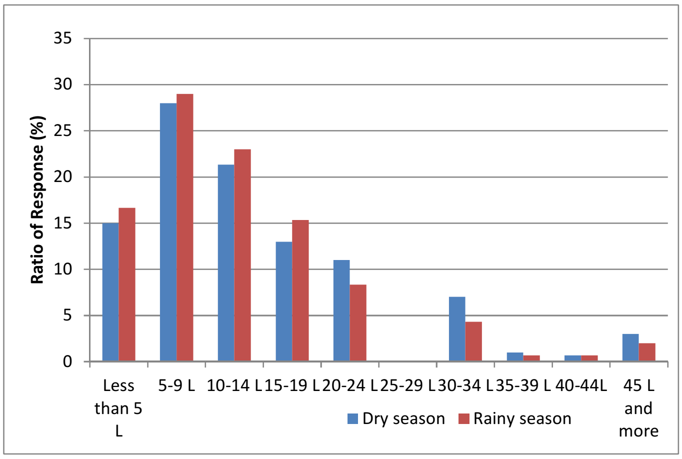


Figure 1.4.20 Distribution of Sample Households by Daily Per Capita Consumption of Domestic Water

(8) Perception on Water Quality

Figure 1.4.21 shows the distribution of perception on water quality.

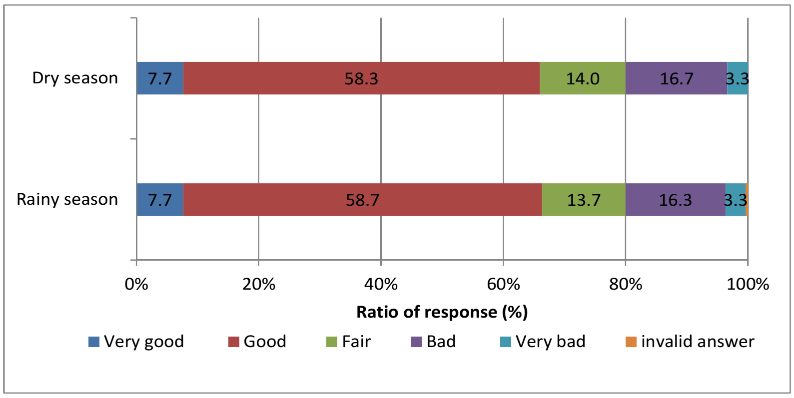


Figure 1.4.21 Perception on Water Quality

As shown in Figure 1.4.21, no seasonal change in water quality is observed. It was revealed that 66% of the sample respondents think water quality is either good or very good.

The percentage of the respondents who think the water quality is either bad or very bad is about 20.0%in the both seasons. Reasons of dissatisfaction are shown in Figure 1.4.22.

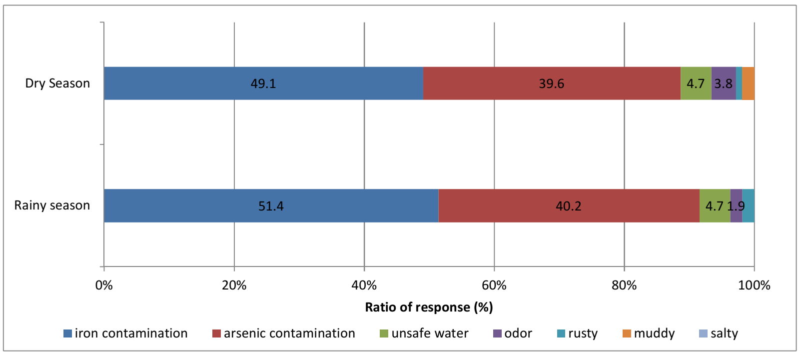


Figure 1.4.22 Reasons of Dissatisfaction on Water Quality

Around 40% of the respondents stated arsenic was the cause of dissatisfaction in both seasons. Arsenic contamination is obviously a major cause of dissatisfaction. However, it was revealed that iron contamination was the bigger cause of dissatisfaction on water quality than arsenic contamination. About a half of the respondents stated iron contamination as the cause of dissatisfaction of water quality. Arsenic and iron contaminations count around 90% of the causes of the dissatisfaction of water quality.

About 41% of the respondents use the shallow tube well (not tested) and the arsenic contaminated shallow tube well as mentioned in (5) Source of Water section. Figure 1.4.23 shows perception on water quality among those respondents.

63.2% of the shallow tube well (not tested) users answered that the water quality was either good or very good. Even in the arsenic contaminated shallow tube well users, 22% of them think that way. Considering this situation, it seems that some of the respondents do not have the right information about arsenic contamination, or they do not change their behavior even though they have the right information about arsenic contamination.

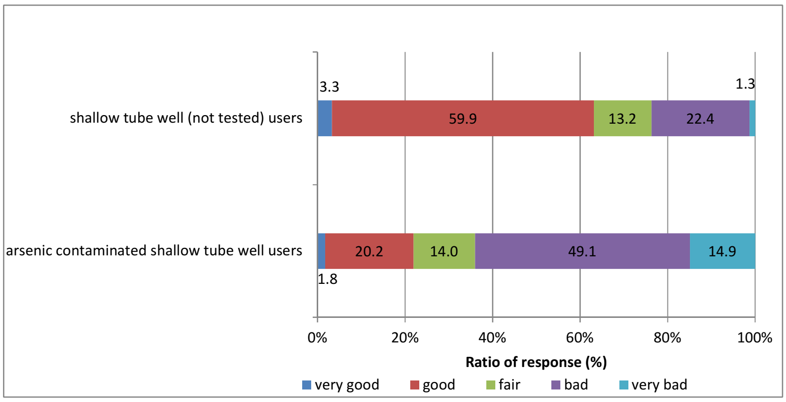


Figure 1.4.23 Perception on Water Quality Among Shallow Tube Well (Not Tested) Users and Arsenic Contaminated Shallow Tube Well Users

(9) Priority Ranking in Improvement of Living Conditions about Social Infrastructure

Figure 1.4.24 is priority ranking in improvement of living condition which community people need.

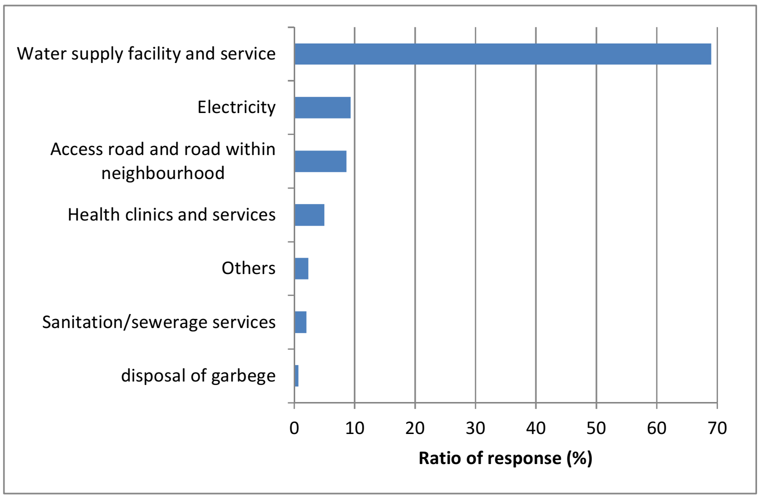


Figure 1.4.24 First Priority in Improvement of Living Conditions

Sixty-nine (69) percent of respondents answered improvement on water supply and service as their first priority. There is more than a 60-point difference between the highest and the second highest priorities. Improvement on electricity service is the second, but the percentage is only about 9.3%.

(10) Responsible Persons for Water Fetching

Figure 1.4.25 and 1.4.26 show the primary and the secondary responsible persons for water fetching.

As Figure 1.4.25 shows, 91.7% of the respondents answered that the adult woman was the primary responsible person for water fetching. It is followed by adult man (4%) and girl child (3.3%). There is no respondent who answered that boy child was the primary responsible person for water fetching. Adult woman and girl child count 95% of the primary responsible persons. This clearly shows water fetching is a burden for females. 42.3% of the sample households answered that they had a secondary responsible person for water fetching.

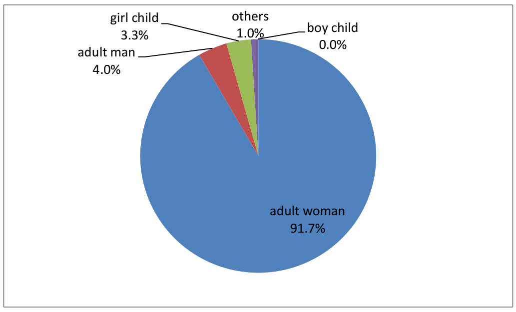


Figure 1.4.25 Primary Responsible Persons for Water Fetching

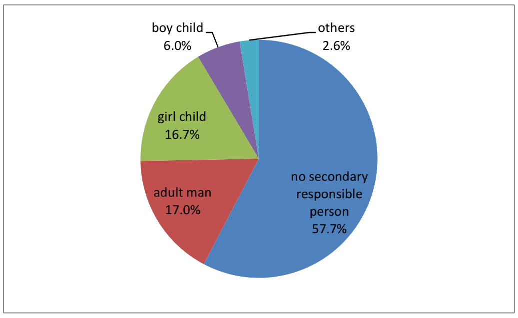


Figure 1.4.26 Secondary Responsible Persons for Water Fetching

(11) Needs about Water Supply According to Sex

Figure 1.4.27 and 1.4.28 show the distribution of type of needs of water supply according to sex.

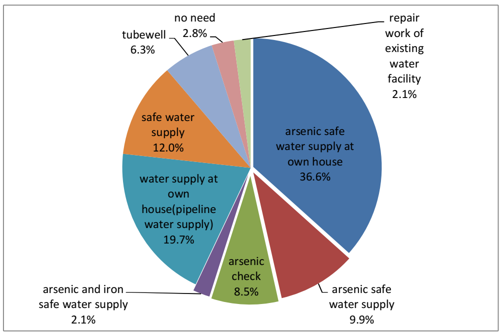


Figure 1.4.27 Needs about Water Supply in Female Respondents

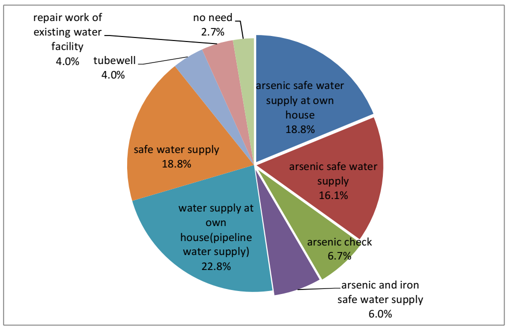


Figure 1.4.28 Needs about Water Supply in Male Respondents

57.1% of the female respondents and 47.6% of the male respondents answered improvement on arsenic related matters which are:

- Arsenic safe water supply at own house or nearby their houses,
- Arsenic safe water supply (location of the facility is not specified),
- Arsenic concentration check, and
- Arsenic and iron safe water supply.

In those respondents, 36.6% of the female respondents clearly stated that they want to have arsenic safe water supply at their houses or nearby their houses. This occupies the highest percentage. In case of the male respondents, this answer occupies the second highest percentage (18.8%). Currently, the majority of the sample households can obtain water in a very short time. This result shows that the respondents especially women think they would like to have the arsenic safe water device without changing the current situation.

At the same time, needs of safe water supply and pipeline water supply are also high. 19.7% of the female respondents and 22.8% of the male respondents wanted the pipe water supply at their houses. These show that villagers are hoping to have arsenic safe water supply at or near their house so that they can obtain safe water without changing their current situation that they can reach their water sources in a very short time.

1.4.4 CONSIDERATION

Observations which are obtained from the survey are mentioned below.

(1) Items which are Expected to be Improved when Deep Tube Well is Constructed

Two items which are expected to be improved when a deep tube well is constructed are mentioned below.

The first point is about the number of people who use a safe water source. The number of people who can obtain arsenic safe water will be increased since people who currently use the arsenic contaminated water source and a water source in which arsenic concentration is not known to obtain water. The survey revealed that there are 41% of the sample households who use the arsenic contaminated shallow tube well and the shallow tube well (not tested) water sources. Construction of the deep tube well will bring a great benefit to those villagers.

The second point is about arsenic patients. Since villagers are able to use arsenic safe water, the number of people who suffer from arsenic poisoning is expected to decrease.

A decrease in the number of arsenic poisoning will benefit in reducing medical fees. It is also expected to contribute to increase manpower. Therefore, household income is expected to be increased too.

(2) Value of Conducting Enlightenment Activity and Training on Operation and Maintenance of the Facility

The result of the survey shows the great value of conducting an enlightenment activity and training on O&M of the facility. Table 1.4.4 shows the matters which are expected when the deep tube well is constructed without and with an enlightenment activity and training on operation and maintenance.

It is very important to get understanding from villagers regarding the importance of using arsenic safe water sources and necessity of paying a user fee for O&M of the facilities to use the water facilities for a long time. Moreover, there is a possibility for reoperation of existing safe water devices in case DPHE or other organizations conduct an enlightenment activity and villagers conduct appropriate O&M. It will help the villagers to repair existing inactive safe water devices. It will be a great help to increase the number of people who use arsenic safe water sources.

Table 1.4.4 Tendency of the Sample Households and Benefit of Conducting Enlightenment Activity and Training on Operation and Maintenance

Current Tendency	Matters which are Expected when Deep Tube Well is Constructed	Benefit from Enlightenment Activity and Training on Operation and Maintenance
Short distance to water source	Villagers will be unwilling to use the deep tube well which are at some distance from their houses.	Villagers will understand the importance of using arsenic free water source and the number of people who use deep tube well or other arsenic safe water sources will increase.
No waiting time at the water source	Villagers will unwilling to use the deep tube well at which we they have to wait a long line.	By recognizing the importance of using arsenic safe water source, the number of people who use deep tube well will be increased even though there will be some waiting time. Moreover, in case other safe water devices will be reactive by the appropriate repair works, the number of villagers per deep tube well and other safe water devices will increase.
No charge to obtain water	Villagers will be unwilling to pay for operation and maintenance and it will be difficult to collect enough user fee	Explanation about benefit of using deep tube well such as improvement of health condition will lead villagers to understand to pay user fee and contribute to sustainability of the facility.
Some households are satisfied with the water quality although they use the arsenic contaminated shallow tube well or the shallow tube well (not tested)	Villagers will not recognize the full advantage of using deep tube well since they do not have enough knowledge about arsenic	From a perspective of human security, villagers have the right to get the appropriate information about arsenic. Enlightenment activity will be able to give a great opportunity for villagers to know about arsenic. Moreover, the activity will be a trigger to change their behavior to avoid arsenic. Like this, enlightenment activity is beneficial to maximize the output of the Project.
All the target villages have safe water devices. 13 villages have water user committees, but the rest do not. Even in the villages with water user committees, land owners tend to bear the all responsibility including financial aspect. There are some cases that no action is taken when the facility has a breakdown.	There is a possibility that water user committee will not be formed even the deep tube well is constructed. There is another possibility that villagers do not take appropriate action when a repair work is needed	Training on O&M has four very important meanings. The first is to clarify who is responsible for O&M. The second is to clearly tell about the item which villagers should take care. The third is to clarify procurement method of spare parts. The fourth is to clarify the support system and contact information of DPHE when villagers have something to discuss with DPHE or when they need a support from DPHE. The training on O&M will be beneficial to increase villager's initiatives.

(3) Positive Aspects for Operation and Maintenance

The survey revealed some positive aspects for efficient O&M of the facility. The first aspect is that the majority of the sample households have a cash income throughout the year. Figure 1.4.29 shows cash income throughout the sample households. In 17 villages, more than 90% of the sample households answered that they have cash income throughout the year. This is a beneficial condition to collect O&M fees every month. In case of a handpump, the cost needed for spare parts is estimated about 3,000 BDT per year. The Bangladesh government adopted a policy which reduces the number of people for one well to 50 in the near future as mentioned in the earlier section. In the Study Area, the average number of people living in a household is about five (5). Therefore, about 10 households use a well based on the policy. In this case, a household needs to pay 25 BDT per month. This amount is about 0.3% of the median value of household income in the dry season (7,500 BDT), and about 0.5% of that in the rainy season (5,500 BDT). Generally, the limit of water fee is 5% of the household income. Therefore, the cost needed for spare parts is way below the limit.

Regarding Bhadukdia village, Boro Dudhpatila village, Parahuda village, Alampur village and Anupnagar village, the villages have three (3) or four (4) sample households which do not have cash income in more than four (4) months. Therefore, it will be difficult to collect a user fee every month. Consideration regarding the user fee collecting method is needed for the five villages.

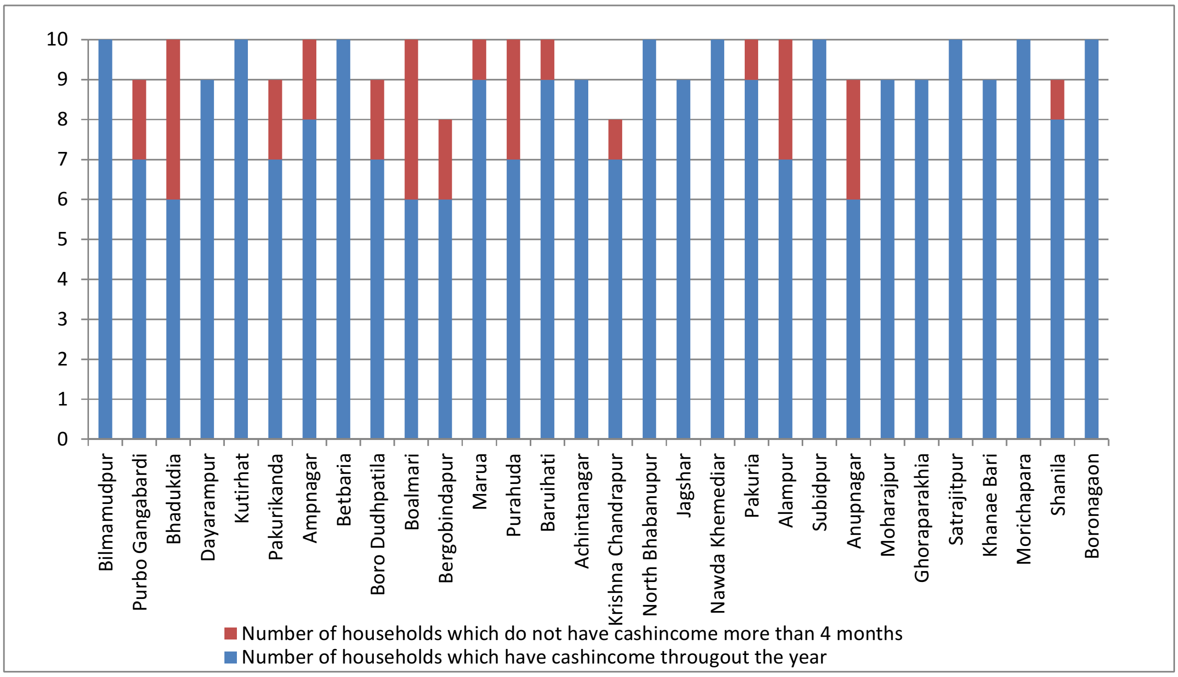


Figure 1.4.29 Village Wise Distribution of Cash Income

The second aspect is the participants in decision making mechanism. Figure 1.4.30 shows the decision maker in the sample households.

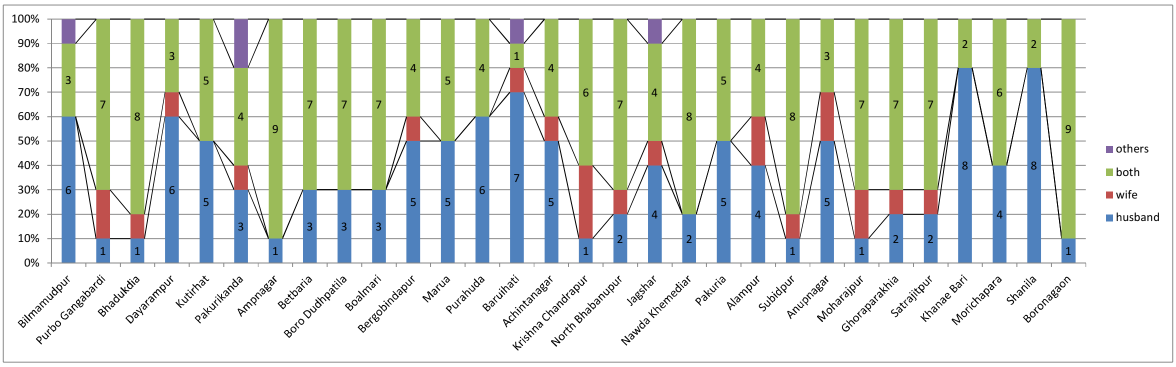


Figure 1.4.30 Village Wise Participants on Decision Making Process in Household

Figure 1.4.30 shows women participate in the decision making process in many villages such as Purbo Gangabardi village and Bhadukdia village. In these villages, it will be beneficial to involve women in an enlightenment activity and training on O&M. By doing so, the opinion of women, in charge of water fetching, will be revealed and actual needs and difficulty of operation and maintenance will be clear. This will enable to provide a water facility which is easy to use for villagers, and so villagers can use the facility for a long time. Moreover, it is extremely important that women, in charge of water fetching, understand the importance of using arsenic safe water.

The third aspect is that 71.1% of the sample households have school children. This shows a possibility of conducting an enlightenment activity for children in school education. Generally, it is effective to educate children in this kind of enlightenment activity. This is because by talking about what they learn at school to their family, the family also can learn about arsenic and the importance of using arsenic safe water sources.

The fourth aspect is that there are households which will be able to be key persons of O&M. There are 24 households who take more than 10 minutes to reach their water sources. It was confirmed that they are choosing arsenic safe water sources although there are the arsenic contaminated shallow tube well and the arsenic contaminated shallow tube well water source nearby their houses. This kind of household exists in 23 villages. Although the number is not large, these households can be the key persons of an arsenic mitigation activity.

1.4.5 CONCLUSION

Arsenic contamination is a very complicated problem. As well known, arsenic does not have smell, color or taste. There are some people who do not feel any symptoms even after drinking arsenic contaminated water for a long time. By conducting this Project, the number of people who use arsenic contaminated and arsenic concentration unchecked water sources is expected to decrease. Moreover, the number of arsenic patients will decrease. This will create manpower, and therefore income will increase. As mentioned in "1.4.4 Consideration", conducting an enlightenment activity and training on O&M have very important meaning to maximize the effect of the Project. Under a circumstance which a safe water device is not available, conducting an enlightenment activity just causes people fear because people have to use arsenic contaminated water devices knowing the fear of taking arsenic contaminated water. If people do not have enough knowledge to have a safe water device, existence of the safe water device does not have a strong power to solve the arsenic problem. By conducting enlightenment activities and training of O&M, this Project would lead to a great benefit for the community people.

1.5 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

The content of the Project is procurement of drilling rigs and related items, and construction of the facility is not included. Therefore, implementation of the Project is likely to have no negative impact on the environment and society.

However, when the Project is implemented, the Bangladesh side (DPHE) will construct deep tube wells using the procured rigs based on the action plan which is prepared in the Study. Therefore, the team conducted environmental studies and considered social circumstances in the Study Area.

1.5.1 EIA FRAMEWORK OF BANGLADESH

There are mainly four (4) national policies on environmental issues. They are described below.

- The Bangladesh Environment Conservation Act, 1995

  Focusing on environmental conservation, improvement of environmental policy, and mitigation of environmental pollution.

- Environmental Conservation Rules 1997

  The revised version of The Bangladesh Environment Conservation Act, 1995. The process to obtain the Environmental Certificate and categories of business are described.

- EIA Guidelines for Industries

  Describes the process of Environmental Impact Assessment, (EIA), and Initial Environmental Examination, (IEE)

- Environment Conservation (Amendment) Act 2010

  Defining and declaring ecologically critical areas, environmental clearance for heavy industry and so on.

According to Environmental Conservation Rules 1997 and EIA Guidelines for industries, a project implementation organization is requested to obtain an Environmental Clearance Certificate from the Ministry of Environment. As per rules, the projects are categorized into four (4) classes: Green, Orange-A, Orange-B and Red. Category Green is for a project which will have the least negative impact on the environment in the four (4) categories. Category Green is followed by Orange-A, Orange-B, and Red. Category red is for a project which will have the largest impact on the environment in the four (4) categories. Table 1.5.1 shows the examples of businesses in each category.

Table 1.5.1 Example of Business of Each Category

Impact	Category	Example of Business
Small	Green	Assembling and manufacturing of TVand telephones, book-binding, production of artificialleather goods, musical instruments etc.
↕	Orange-A	Production of shoes and leather goods (capital up to 500,000 BDT), production of plastic and rubber goods (excluding PVC), construction of restaurants etc.
	Orange-B	Production of PVC items and aluminum products, production of bricks/tiles, production of cosmetics, processing fish/meat/food, construction of public toilet PVC etc.
Large	Red	Production of urea fertilizer, production of chemical dyes, all mining projects, production of iron and steel, production of waste incinerator, water/power and gas distribution/line laying/relaying/extention etc.

Figure1.5.1 shows the process to obtain the environmental certificate of each category.

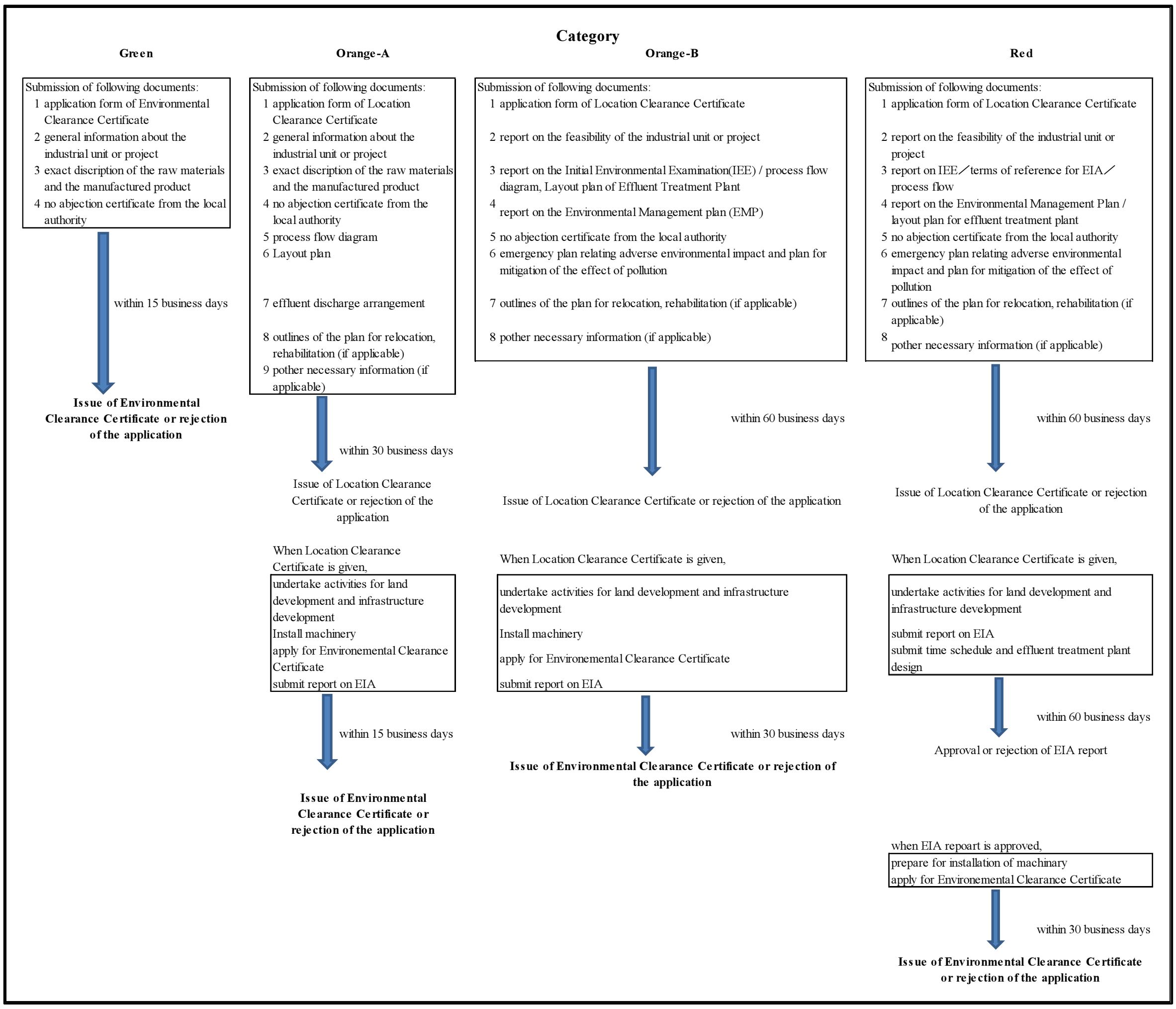


Figure 1.5.1 Process to Obtain the Environmental Certificate

The project implementation organization which falls into the Green category is required to submit the necessary documents to the Ministry of Environment and an Environment Clearance Certificate will be issued within 15 business days. Businesses categorized other than Green category, at first, have to obtain a Location Clearance Certificate. The Process and necessary documents to obtain the Certificate differ depending on the categories. The process is described in Figure 1.5.1. After a Location Clearance Certificate is issued, an Environmental Clearance Certificate will be issued within the periods mentioned in the figure regarding projects which are categorized as Orange-A and Orange-B. In case of the Red category, the project implementation organization needs to pass the EIA report, and then, an Environmental Clearance Certificate will be issued after submission of the necessary documents.

1.5.2 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS OF THE PROJECT

(1) Summary of Project Components Related to Environmental and Social Considerations

Two kinds of wells to be drilled based on the action plan: a production well which will be the water source for the piped scheme and a handpump well. Table 1.5.2 shows the specifications of the wells.

Table 1.5.2 Basic Design and Number of Wells to be Drilled Using Action Plan

Specifications of Well	Production Well	Hand Pump Well
Drilling diamater	First step：28 inches Second step：24 inches Third step：20 inches	Fisrt step：17-1/2 inches Second step：14-3/4 inches Third step：10-5/8 inches
Well diamater	6 inches	2 inches
Drilling depth	Maximum 450 m	Maximum 450 m
Number of wells to be drilled	25	35
Duration of drilling for one well	60 days/well	45 days/well

During the work, the area of 30 m x 30 m and the access road (with about 3.5 m) are needed. The area and road will be removed except for the constructed well after the work.

(2) Environmental and Social Consideration Scoping

The Study Team implemented Initial Environmental Examination (IEE) to check whether the categorization is appropriate or not following the “Guideline for Environmental and Social Considerations (2010)” of JICA. JICA classifies projects into four categories according to the extent of environmental and social impacts, taking into account an outline of project, scale, site condition, etc. Definition of each category is as follows.

Category A: Proposed projects are classified as Category A if they are likely to have significant adverse impacts on the environment and society.

Category B: Proposed projects are classified as Category B if their potential adverse impacts on the environment and society are less adverse than those of Category A projects.

Category C: Proposed projects are classified as Category C if they are likely to have minimal or little adverse impact on the environment and society.

Since the adverse impact on the environment by construction of the project is considered to be minimal or little, it is categorized as “Category C”. The target areas to conduct the environment and social considerations of this Study are the villages which are included in the Action Plan. Some members of the Study Team visited some of the sites and conducted environmental and social consideration checks. The Study Team evaluated the environmental and social considerations with DPHE.

Table1 1.5.3 indicates the result of IEE checklist evaluation. The IEE checklist is based on the JICA guidelines.

Table 1.5.3 IEE Checklist

	S/N	Impacts	Const-ruction	Operation	Description
Social Environment	1.	Involuntary Resettlement	D	D	- The drilling sites are basically public land or government owned land therefore, no land acquisition and involuntary resettlement are expected. - According to the explanation from DPHE and interview at the sites, in case that the site is a private land, the land will be provided smoothly through an arrangement by the village. Therefore, there will be no conflict regarding preparation of land for drilling site.
	2.	Local eocnomy such as employment and livelihood	D	D	Implementation of the Project will lead to decrease in arsenic related deseases by using arsenic safe water. Health condition of community people will be improved, and it will has positive impacts on local economy.
	3.	Land use and utilization of local resources	D	D	The maximum size of a drilling site is 30 m by 30m. After the completion of the well, the land could be used except around the well. Therefore, there will be no negative Impact regarding land use and resource use of the land.
	4.	Local communities and decision-making institutions	D	D	Organization for operation and maintenance of the water supply facility is expected to be organized by implementation of the Project. Therefore, it will have positive impacts on local communities and decision-making institutions.
	5.	Existing infrastructures and services	D	D	No negative impact will be expected on existing infrastructure and service by construction work of the well.
	6.	The poor/ indigenous/ethnic/minority/women/childnen	D	D	Implementation of the Project will contribute to reduce the burden on water fetching role of women and also will bring positive impacts because community people are able to use safe and clean water.
	7.	Misdistribution of benefit and social cost	D	D	Communiy people are able to share safe and clean water source. There will be no negative impact on community people.
	8.	Histrical/cultural heritage	D	D	No historical/cultural heritage was confirmed in all the sites, therefore, no problem will occur.
	9.	Local conflict of interests	D	D	Water supply facility will be managed by water user committee or Paurashava. According to DPHE and authorized people of villages, no conflict on water related matters should happen, and no conflict will be expected in the future.
	10.	Water usage,Water rights, Communal rights	D	D	Water supply facility will be managed by villages, therefore, it will have positive impacts on the target villages.
	11.	Sanitation	D	D	Implementation of the Project will promote safe and clean water supply and therefore, it will contribute to improvement of public health of community people.
	12.	Health Hazards/Risk, Infectious Diseases such as HIV/AIDSHIV/AIDS	D	D	Implementation of the Project has no relation with infectious diseases such as HIV/AIDS. Therefore, no problem will occur.

	S/N	Impacts	Const-ruction	Operation	Description
Natural Environment	13.	Important/valuable geographical and geological features/resources	D	D	There is no important/valuable geographical and geological features in all the sites.
	14.	Soil erosion	D	D	No soil erosion will be expected since all the sites are on flat land and no large amount of water will be discharged.
	15.	Amount and quality of ground water	D	D	Appropriate ground water yield is determined by the pumping test. Therefore, no negative impact is expected on ground water in the surrounding area.
	16.	Amount of natural reservoir/flow	D	D	Wells to be constructed by the Project will pumped up from the deep aquifer. Therefore, there is no hydrological and hydralical relationship with surface water.
	17.	Coastal zone	D	D	All the sites are located inland, so that there is no seashore. Therefore, no problem will occur.
	18.	Flora, Fauna,Biodiversity	D	D	There is a need to cut down not a lot but some trees in some sites. However the level is not severe so that it will have no negative impact on the environment.
	19.	Meteorology/ climate	D	D	The construction site is small as metioned in S/N 3. Therefore, there will be no negative impact on meteorology. Exhaust gas emission during the construction work also will have no negative impact on meterology.
	20.	Aesthetic landscape	D	D	In some sites, there is a need to cut down some trees, but the level is not severe. Therefore, there is almost no impact on the aesthetic landscape.
	21.	Global warming	D	D	CO_2 gas will be emitted from the constrution vehicles, but the level is not large enough to have negative impact on global warming.
Public Hazard	22.	Air pollution	D	D	Construction vehicles will emit exhaust gas during the construction work. However the level is not severe, so no problem will occur.
	23.	Water pollution	D	D	There is no possibility of discharge of construction water to the surrounding area. Therefore, water pollution will not occur.
	24.	Soil contamination	D	D	Soil contaminants will not be used during the construction work.
	25.	Disporse	D	D	There is a possibilty of soil disposal, but the amout is expected to be small, and the disposal could be transported to nearby designated discharge areas.
	26.	Increase of noise and vibration	D	D	Some level of noise and vibration is expected during the construction work. However, the level is not severe and they are only for the construction work period. Therefore, no problem will occur.
	27.	Ground level subsudence	D	D	No land subsidence is expected since the appropriate amount of abstruction of ground water is decided.
	28.	Offensive odor	D	D	Some offensive odor is expected from the construction vehicles, but the level is not severe and it is only for the construction period. Therefore, there will be no problem.
	29.	Sedimentation	D	D	There is no possibility of discharge of construction water to surrounding areas. Therefore, there will be no negative effect to lakes, stream beds, and slashes.
	30.	Trrafic accidents	D	D	Trrafic of vehicles for construction may increase during the construction period, but will not be frequent. Traffic control persons will be allocated as needed to avoid a traffic accident. Therefore, no problem is expected.

Grade:

A: Serious impact(s) is (are) expected

B: Less serious impact(s) is (are) expected

C: Impact not known without further research

D: Negligible impacts are expected or no impact is expected

(3) Categorization

From Table1.5.3, implementation of the Project is likely to have minimal or little adverse impact on the environment and society, and it will bring positive impacts such as water related diseases among community people by use of safe and clean water. Therefore the Project is classified as "Category C".

(4) Environment and Social Considerations on Target villages of Soft Component Part of the Project

As a soft component of the Project, technical transfer of drilling technique is planned to be conducted at three (3) sites in the target villages. The target villages for the soft component are indicated in Table 1.5.4.

Table 1.5.4 Target Village for Soft Component

Devision	District	Upazila	Union	Village
Dhaka	Faridpur	Faridpur Sadar	Paurashava	—
Khulna	Jossore	Chaugachha	Jagadishpur	Marua
Rajshahi	Pabna	Bera	Paurashava	Shanila

All the sites are public land, therefore, no problem regarding land acquisition will occur.

A mud rotary drilling method will be applied, therefore there is no possibility of emission of dust from the drilling work. A small amount of dust might be emitted when the packs of bentonite and cement are opened. However, the amount will not affect surrounding areas. therefore, no problem will occur.

Some level of vibration from vehicle traffic and engines of vehicles during the construction work. No problem will occur since the construction work will not continue for a long time.

Considering all the various factors together, implementation of the soft component is likely to have no negative impact on the environment and the society.

(5) Deregulation Plan Effect on the Environment

There is no specific matter which should be considered for implementation of the action plan.

(6) Stakeholder Meeting

The Study Team explained the content and aim of the Study to the representative and related personnel of the target villages. All the villages have a positive feeling of the project and they promised to cooperate in the Study.

CHAPTER 2 CONTENTS OF THE PROJECT

2.1 BASIC CONCEPT OF THE PROJECT

2.1.1 OVERALL GOAL AND PROJECT PURPOSE

The Government of Bangladesh formulated the National Policy for Safe Water Supply and Sanitation in 1998 targeting to realize a basic level of water supply to the whole nation and to reduce the number of users of each tube well from 105 to 50 people in the near future. The National Water Policy (1999) advocated supplying safe and affordable water. In 2004, the National Policy for Arsenic Mitigation was formulated and advocated to supply safe water to poor households. The policy also emphasized the importance of prevention against overdevelopment of the deep aquifer and contamination control, and giving priority to surface water as the source of water supply instead of ground water. Although the pond sand filters (PSF) of which water sources were surface water were constructed by the project (UNICEF, JICA), the functioning ratio is very low (58.9%), compared with the deep wells (95%) due to drying up of the water source and difficulty of operation and maintenance (Situation Analysis of Arsenic Mitigation 2009, LGD/JICA 2010). Deep wells have been constructed since 2000 as the alternative source of the water supply. They are now the main source of water supply in the areas contaminated by arsenic. Reflecting this situation, the National Strategy for Accelerated Poverty Reduction (FY 2009-2011) gave deep ground water the status of importance in studying its development possibility as an alternative water source.

The Sector Development Plan (FY2011-25) (SDP) was officially launched in December 2011. SDP shows the development plan for the water supply and sanitation sector for 15 years up to 2025. The development plan is divided into three (3) stages, the short term, the middle term and the long term. The target of each stage is shown in Table 2.1.1.

Table 2.1.1 Target of Each Stage of SDP

Stage	Target
Short Term (FY 2011-15)	- WSS services to all but at least basic levels improved. - Institutions strengthening initiated, regulatory framework developed and legislations enacted.
Middle Term (FY 2016-20)	- WSS services level improved - Institutions strengthened and sub-sector SWAp operational.
Long Term (FY 2021-25)	- WSS services level further improved. - Institutions further strengthened and sector SWAp operational.

Standards for evaluation of water supply coverage are defined as shown in Table 2.1.2.

Table 2.1.2 Bangladesh Standards for Evaluation of Water Supply Coverage

Bangladesh Basic Standard	Bangladesh Improved Standard
Water supply facilities to all to be provided to achieve the government's target by 2011	Water supply facilities to be provided to achieve the targets set in the NPSWSS 1998.
Individual or shared water supply facilities of the following types <Urban and Rural> ● Piped water supply to households with multiple taps, yard connections or shared connections ● Public standpipes shared by, at most, 100 persons ● Safe water points, like handpump tubewells ring wells, PSFs, protected springs and rainwater harvesting system; public water points are shared by, at most, 100 persons	Individual or shared water supply facilities of the following types <Urban> ● Piped water supply to households with multiple taps, yard connections or shared connections. ● Public standpipes shared by, at most, 50 persons. <Rural> ● Piped water supply to households with multiple taps, yard connections or shared connections.

Bangladesh Basic Standard	Bangladesh Improved Standard
and private water points by 5 persons.	● Public standpipes shared by, at most, 50 persons. ● Safe water points, like handpump tubewells ring wells, PSFs, protected springs and rainwater harvesting system; public water points are shared by, at most, 50 persons and private water points by 5 persons.

About 970 thousand water sources have been constructed in the arsenic contaminated areas by DPHE responsible organization for rural water supply in Bangladesh and development partners. Most of them are shallow wells (about 760 thousand wells) and deep wells (about 175 thousand wells). Since shallow wells are not available in the arsenic contaminated areas, deep wells supply safe water as an alternative water source to community people (Situation Analysis of Arsenic Mitigation 2009, LGD/JICA 2010).

However development of safe ground water in the deep aquifer by drilling rigs owned by DPHE has been hampered by existence of gravel layers distributed above the deep aquifer in the target area.

A ground water study by JICA, “The study on the ground water development of deep aquifers for safe drinking water supply to arsenic affected areas in western Bangladesh” was carried out during the period from 2000 to 2002. The study confirmed the existence of arsenic free ground water in the deep aquifer distributed more than 200m depth below the gravel layer. At the same time, the study also revealed the continuity of the deep aquifer by interpreting the results of test well drilling and existing well data. Therefore, the possibility exists for arsenic free water in the deep aquifer distributed in the area where no test well was drilled.

Considering this situation, DPHE has been developing deep ground water. It is necessary for obtaining safe ground water in the target area to construct deep wells which reach the deep aquifer penetrating gravel layers distributed at the base of the shallow aquifer. However, construction of a deep well is less progressed because the drilling rigs owned by DPHE are not capable of penetrating gravel layers.

The Project aims to provide drilling rigs which are capable of penetrating gravel layers and to improve water supply coverage by safe water through acceleration of development of deep ground water, and to develop the ability of staff of DPHE for the technique of deep wells drilling and geophysical survey.

If the equipment is provided by the implementation of the Project, the Bangladesh side will drill 25 production wells and 35 handpump wells in five (5) years following the Action Plan prepared in the study. Water supply coverage in the target Paurashavas and villages will increase from 58.6% in 2012 to 63.6% in 2019 when the Action Plan is completed.

2.1.2 GENERAL DESCRIPTION OF THE PROJECT

(1) Examination of the Request

As mentioned in 2.1.1, the Project aims at providing drilling rigs which enable the development of deep ground water, related materials, supporting vehicles and geophysical survey equipment, to develop the capacity of DPHE’s staff on drilling techniques of deep well and ground water exploration techniques. The request from the Bangladesh side related to the above was confirmed by the Minutes as shown in Table 2.1.3.

Table 2.1.3 Request Confirmed by Minutes

No.	Equipment	Specification	Quantity
1	**Drilling equipment**		
(1)	Truck-mounted drilling rig	For production wells Drilling diameter: max 20” Drilling depth: max 400m	1
(2)	Truck-mounted drilling rig	For handpump wells Drilling diameter: max 4” Drilling depth: max 400m	1
(3)	Truck-mounted air compressor	—	2
2	**Supporting Vehicles**		
(1)	Cargo truck with crane	—	2
(2)	Pick up truck	—	2
3	**Geophysical survey equipment**		
(1)	Resistivity survey equipment with analysis software	—	1
(2)	Logging equipment with analysis software	—	1

It was confirmed by discussions between DPHE and the Study Team after signing of the minutes that the number of some requested equipment is insufficient and some equipment is necessary for implementation of the Project even it is not included in the request. Based on the results of discussions, the contents of the request were revised as shown in Table 2.1.4.

Table 2.1.4 Revised Request

No.	Equipment	Specification/Contents	Quantity	
I. Items in the Original Request			**Original**	**Altered**
1	**Drilling Rig and Related Equipment**			
(1)	Truck-mounted drilling rig	For production wells Drilling depth: Maximum 400 m	1	1
(2)	Truck-mounted drilling rig	For handpump wells Drilling depth: Maximum 400 m	1	1
(3)	Truck-mounted air compressor	—	2	2
2	**Supporting Vehicles**			
(1)	Cargo truck with 5 ton crane	—	2	4
(2)	Pickup truck	—	2	2
3	**Geophysical Survey Equipment**			
(1)	Resistivity survey equipment with analysis software	—	1	1
(2)	Borehole logging equipment with analysis software	—	1	1
II. Equipment and Materials Added				
1. Equipment and Materials for Pumping Test		-	—	1 lot
2. Water tank lorry		Tank capacity : 5 m^3	—	2
3. Equipment and Materials for Workshop		-	—	1 lot

The revised request was carefully examined by both a field survey in Bangladesh and the Study in Japan and then the equipment and materials to be provided by the Project were decided as shown in Table 2.1.5. Detailed examination results are described in “2.2.2 Equipment Plan in this Chapter.”

Table 2.1.5 Equipment and Materials to be Provided by the Project

No.	Equipment	Specification/Contents	Quantity
1	**Drilling Rig and Related Equipment**		
(1)	Truck-mounted drilling rig	For production well. Drilling depth: Maximum 400m	1
(2)	Truck-mounted drilling rig	For handpump well. Drilling depth: Maximum 400m	1
(3)	Truck mounted unit for air lifting and pumping test unit	For production well	1
(4)	Truck mounted unit for air lifting and pumping test unit	For handpump well	1
2	**Supporting Vehicles**		
(1)	Cargo truck with 5 ton crane	For production well	1
(2)	Cargo truck with 3 ton crane	For production well	1
(3)	Cargo truck with 3 ton crane	For handpump well	2
(4)	Pickup truck	For production well	1
(5)	Pickup truck	For handpump well	1
3	**Geophysical Survey Equipment**		
(1)	Resistivity survey equipment with analysis software	—	1
(2)	Borehole logging equipment with analysis software	—	1
4.	**Equipment and Materials for Workshop**	-	1 lot
5.	**Materials for Well Construction to be Drilled in the Technical Transfer**		1 lot
6.	**Spare Parts**		1 lot (for 2 years)

(2) Deep Ground Water Development Plan by the Bangladesh Side

1) Target Area of the Study

The Study Area is area where arsenic contamination is confirmed and where deep ground water development is prevented because gravel layers are distributed. A total of 30 villages shall be selected as the target of the Study. However, necessary data for selection of the target villages are available only Upazila level, no village-wise data are publicly opened. Therefore, target villages were selected in the following procedure.

2) Selection of Target Villages

(i) First step

Upazilas where gravel layers are distributed are selected by using the data prepared by the JICA experts. A total of 66 Upazilas were selected: 697 Unions were included in these 66 Upazilas.

(ii) Second step

Target Unions were selected using the data cited in “Situation Analysis of Arsenic Mitigation 2009 (LGD/JICA 2010)”. The criteria for the selection are shown in Table 2.1.6. As a result, 30 Unions in 10 Districts were distributed in three (3) Divisions.

Table 2.1.6 Criteria and Score for Selection of 30 Target Villages

Criteria	Score 1	Score 2	Score 3	Score 4
A Ratio of wells contaminated by arsenic (%)	A < 25	25 ≦ A < 50	50 ≦ A < 75	75 ≦ A
B Number of arsenicosis patient per 1000 people (people)	B < 0.5	0.5 ≦ B < 1.0	1.0 ≦ B < 2.0	2.0≦ B
C Water supply coverage (%)	60 ≦ C	40 ≦ C < 60	20 ≦ C < 40	C < 20

During this selection, it was revealed in this step that Nawabganj District was additionally considered as a difficult area to construct deep wells due to distribution of gravel layers.

And it was also confirmed that candidate Unions in Narayanganj District will be managed by Dhaka Water Supply and Sewerage Authority (DWASA). Therefore, they were excluded from the candidate and target Unions were selected in other Districts. Although gravel layers are distributed in Comilla District, deep wells are easily constructed by using the drilling rigs of DPHE. Accordingly, Comilla district was also excluded from the target.

In the selection, the following principles were applied.

- Unions where 50 wells or more are functioning were excluded.
- Unions where the number of arsenicosis patients was 9 or less were excluded.
- Unions with a score "6" or less were excluded. However, Unions with more than 50 arsenicosis patient were selected.
- The number of Unions selected in a District was four (4) or less to avoid concentration in a District.

Finally, 30 Unions were selected in descending order from the Union with the highest score to the 30th score.

iii) Third step

A member of the Study Team visited the branch offices of DPHE asking for the proposal of three (3) villages from each Union as candidates of the target village. Data to select a village from each Union were collected from those offices.

Three (3) villages proposed in each Union were evaluated using meaningful criteria such as ratio of wells contaminated by arsenic, number of arsenicosis patient and number of deep wells. The result was discussed with DPHE and agreed as the target villages (Table 2.1.7).

A geophysical survey (Schlumberger method) and a socio-economic survey were carried out in the 30 villages.

Table 2.1.7 30 Villages Selected as the Target of the Study

Division	District	Upazila	Union	Village
Dhaka	Faridpur	Faridpur Sadar	Aliabad	Bilmamudpur
			Kaijory	Purbo Gangabardi
			Krishnanagar	Bhadukdia
			Majchar	Dayarampur
	Manikganj	Harirampur	Kanchanpur	Kutirhat
	Rajbari	Rajbari Sadar	Dadshi	Pakurikanda
Khulna	Chuadanga	Alamdanga	Baradi	Ampnagar
			Jehala	Betbaria
		Damurhuda	Howli	Boro Dudhpatila
			Natipota	Boalmari
	Jessore	Chaugachha	Chaugachha	Bergobindapur
			Jagadishpur	Marua
			Patibila	Purahuda
			Phulsara	Baruihati
	Jhenaidah	Jhenaidah Sadar	Padmakar	Achintanagar
		Maheshpur	Fatepur	Krishna Chandrapur
	Kushtia	Bheramara	Dharampur	North Bhabanupur
			Junidah	Jagshar
			Mokarimpur	Nawda Khemediar
		Daulatpur	Pragpur	Pakuria

Division	District	Upazila	Union	Village
	Meherpur	Meherpur Sadar	Amjhupi	Alampur
			Kutubpur	Subidpur
Rajshahi	Nawabganj	Nawabganj Sadar	Char Anupnagar	Anupnagar
			Maharajpur	Moharajpur
			Ranihati	Ghoraparakhia
		Shibganj Sadar	Chhatrajitpur	Satrajitpur
	Pabna	Bera	Masumdia	Khanae Bari
			Natun Bharenga	Morichapara
			Paurashava	Shanila
			Ruppur	Boronagaon

3) Drilling Plan of the Bangladesh Side

DPHE has the following basic principle on the drilling of deep wells in the arsenic contaminated area.

- District Paurashava: Deep wells for water sources of the piped water supply are mainly drilled (production wells).
- Villages: Deep wells for handpump wells are basically drilled (handpump well).

According to the plan, a total of 43 production wells and 256 handpump wells will be drilled up to the year 2017. However, in case of Paurashava, there are two areas, the urban area and the rural area, therefore, suitable types of wells will be selected considering each situation.

Numbers of production wells and handpump wells in the Study area are 28 and 30, respectively.

The drilling plan of DPHE is attached to the Minutes concluded on 24 November 2011.

A deep well drilling plan of DPHE was formulated in the study as an Action Plan for five (5) years after the delivery of the drilling rigs.

The types of deep wells are production wells for piped schemes and handpump wells. A summary of the Action Plan is shown in Table 2.1.8. Details of the Action Plan are described in "2.3.2, (3) Implementation of the Action Plan" in this Chapter.

Table 2.1.8 Summary of the Action Plan

	Production Well	Handpump Well
Schedule	5 years from January 2015 to December 2019	
Target Area	9 Districts - 2 Districts in Dhaka Division - 5 Districts in Khulna Division - 2 Districts in Rajshahi Division	35 villages - 30 villages shown in Table 2.1.7 - 5 villages addistionally selected
Number of Wells to be Drilled	25 wells	35 wells
Number of Recipient	200,000 persons	16,425 persons
Number of Total Recipient	216,425 persons	

2.2 OUTLINE DESIGN OF THE JAPANESE ASSISTANCE

2.2.1 DESIGN POLICY

(1) Basic Policy

The basic policy on the design in the Project is as described below. The appropriate scale and specifications are decided as the equipment procurement project for DPHE.

1) Among the requested equipment such as drilling rigs and related tools and materials, the

geophysical survey equipment and supporting vehicles, equipment of which verification are confirmed.

2) Necessary equipment will be included in the procurement plan, even though such equipment is not requested: But it was requested during the discussion.

3) The technical transfer (soft component) is planned on the deep well drilling and geophysical survey to be carried out by DPHE using the procured equipment.

(2) Policy against Natural Conditions

1) Procurement of drilling rigs capable of penetrating gravel layers and drilling up to 400 m will be planned in order to develop deep ground water in the Project area.

2) Four wheel drive cars (4WD cars) will be planned since most of the access roads to the sites are not paved and become muddy.

3) The Action Plan to be carried out by DPHE is planned considering the rainy season when the condition of access becomes worse.

(3) Policy against Socio-Economic Conditions

In Bangladesh, safe water supply coverage by tube wells reached 97% in the 1990s, but suddenly decreased after arsenic contamination of shallow ground water was confirmed.

In the Study, a socio-economic survey was carried out in 30 selected villages. It revealed the following situations concerning village water supply:

- Approximately 17% of water supply facilities in the villages are shallow wells where arsenic contamination has been confirmed,
- Approximately 24% of water supply facilities in the villages are shallow wells where arsenic concentration has not been confirmed and can be detected by future inspection,
- About a half of the villagers wish to have an arsenic free water source or to confirm the arsenic concentration of the water from existing water supply facilities.

As shown above, the villagers strongly wish to have water free from arsenic. Therefore, drilling rigs capable of developing arsenic free deep ground water in the deep aquifer will be procured.

(4) Policy for Procurement, Special Circumstances and Business Customs

Drilling Rigs and related equipment are not manufactured locally. Though several local pipe manufacturers produce certain sizes of casing pipes, they cannot supply all the sizes of casing pipes. Therefore, procurement management by a Japanese supplier is difficult. Consequently, such equipment is procured from Japanese manufacturers, who have advantages on specifications and capacities suitable for the planned wells structures, drilling methods and wells prepared using sales service agents. In the same respect, supporting vehicles (trucks) are procured from Japanese manufacturers. However, pick-up trucks will be manufactured in Thailand by Japanese manufacturers, as they are not manufactured in Japan.

Concerning drilling materials and workshop equipment, no local manufacturer exists except for the above-mentioned pipe manufacturers. Therefore, drilling materials and workshop tools will be procured in Japan. However, as DPHE shall continue drilling of deep wells after the technical transfer using local materials, the handling tools shall be of a specification which enables the common use of both Japanese materials and local materials.

Drilling consumables such as gravel, cement, diesel, oil etc. are locally manufactured and stably supplied. Therefore, such materials will be procured in Bangladesh and supplied by a Japanese supplier during the period of technical instruction of drilling skills through drilling of three (3) wells.

(5) Policy on Local Contractors

In the Project, equipment installation work is composed of delivery and unpacking by the Japanese supplier. The construction work which will be subcontracted out to local contractors is not included.

(6) Policy of Improved Operation and Maintenance

It is the first challenge for DPHE to carry out drilling works down to 400 m by its own drilling teams using the equipment to be procured. DPHE's experience concerning drilling works is limited to the supervision of drilling contractors who use either their own drilling equipment or drilling equipment hired from DPHE. For this reason, DPHE does not have the organization and technical know-how to carry out deep well drilling works by direct-operation. Concerning equipment maintenance, DPHE does not have their own workshop for the machinery works as it has been done by private drilling companies who hire the drilling equipment from DPHE.

DPHE has a plan to develop their new organization for the implementation of the Action Plan. The organization includes work teams of geophysical survey, drilling, pumping test, workshop and management section. In addition, the workshop and the yard area for storage and maintenance of the equipment will also be prepared.

The Project includes technical instruction on work skills by an instructor dispatched by the Japanese supplier and on geophysical survey techniques and the drilling plan and management.

(7) Policy on Grade on Equipment

Appropriate well structure will be designed considering discharge rate of wells corresponding to their uses, drilling diameters and hydrogeological conditions.

Suitable drilling methods and drilling equipment will be selected considering technical issues such as drilling depth, diameter of well, drilling of gravel layers and sealing between the shallow aquifer and the deep aquifer.

(8) Policy on Construction Method, Procurement Plan and Construction Period

1) Country of procurement

Equipment to be procured is, 1) Drilling Equipment, 2) Supporting Vehicle, 3) Geophysical Survey Equipment and Logging Equipment, 4) Workshop Tools, 5) Drilling Materials for Technical Transfer and 6) Spare Parts. In the respects of quality assurance and after sale service, equipment is basically procured in Japan. However, pick-up trucks are not manufactured in Japan and they are manufactured in Thailand by Japanese manufacturers. Therefore, each pick-up truck will be procured.

Concerning drilling materials for technical transfer, casing materials, bit materials and mud agents are procured in Japan. Handling tools such as casing tools shall be of specifications usable to both Japanese materials and local materials, so as not to interfere with local materials which are used for DPHE's drilling works.

Local consumables for drilling for technical transfer such as gravel, cement, fuel, miscellaneous materials are procured in Bangladesh and supplied by the Japanese supplier for each drilling site, for smooth implementation. Technical instruction of the procurement plan and management through the soft component is included in the Project so that DPHE is capable of procuring the necessary materials without delay after the technical transfer.

2) Project period

Factors such as special characteristics of the drilling rig for reverse rotary drilling method, effects on manufacturing schedule of manufacturers of vehicles, compressors, generators by Tohoku Earthquake (March 2011) shall be considered in the manufacturing schedule of the equipment.

Concerning marine transportation, the departure schedule of conventional ships and container ships, transport period and local custom clearance period shall be considered.

Custom clearance, delivery, test operation, technical training for initial handling and technical instruction through drilling of three (3) wells shall be considered for the scheduling of the work after arrival in Chittagong.

(9) Standards to be Applied

The standards to be applied are ISO, BS, API, DIN, ASTM, JCS, JEC, JEM and JIS.

2.2.2 EQUIPMENT PLAN

(1) Basic Plan

The equipment requested by the Bangladesh side is drilling rigs, related equipment, supporting vehicles and geophysical survey equipment necessary for attaining the Project purpose. This equipment is used to construct deep wells (production wells and handpump wells) in the Project sites.

The procured equipment will be kept in the Tongi office of DPHE located in the north of Dhaka. The Tongi office has stores and space for parking. However, rearrangement of the space of the office is necessary to keep the whole procured equipment. If the Project is implemented, procured equipment will be kept and maintained in this office. The rearrangement plan of the Tongi office is described in "2.3 Obligation of the Bangladesh Side."

(2) Basic Equipment Plan

The specification, number to be procured and usage of the main equipment are summarized in Table 2.2.1.

Table 2.2.1 Specification, Quantity and Usage of Equipment

No.	Equipment	Specification	Quantity	Usage
1	**Drilling Rig and Related Equipment**			
(1)	Truck-mounted drilling rig	For the production wells Drilling depth: Maximum 400m Drilling method: Reverse rotary	1 unit	Drilling of production wells
(2)	Truck-mounted drilling rig	For handpump well. Drilling depth: Maximum 400m Drilling method: Mud rotary	1 unit	Drilling of handpump wells
(3)	Truck mounted unit for air lifting and pumping test	Compressor: 12/m^3、 12 bar Pump: 80 m^3/hour, 40 m^3/hour, Pumping height: 50m	1 unit	Development of production wells Pumping test
(4)	Air lifting and pumping test	Compressor: 5/m^3, 7 bar Pump: 1.0 m^3/hour, 5 m^3/hour, Pumping height: 50m	1 unit	Development of handpump wells Pumping test
2	**Supporting Vehicles**			
(1)	Cargo truck with 5 ton crane	GVW26 ton, Drive: 6x4 Loading capacity: 10 ton	1unit	Transportation of drilling tools and materials for production wells
(2)	Cargo truck with 3 ton crane	GVW26 ton, Drive: 6x4 Loading capacity: 10 ton	3 units	Transportation of drilling tools and materials for production/handpump wells
(3)	Pickup truck	Double cabin, Drive: 4x4 Loading capacity: 0.5 ton	2 units	Transportation of materials

No.	Equipment	Specification	Quantity	Usage
3	**Geophysical Survey Equipment**			
(1)	Resistivity survey equipment with analysis software	Survey method：Vertical sounding Survey depth: Maximum 500m	1 set	Geophysical survey for selection of drilling sites
(2)	Borehole logging equipment with analysis software	Measuring depth: Maximum 400m Measuring item: Resistivity (short, long), SP, Gamma Ray	1 set	Well logging for decision of well structure

1) Drilling rigs

(i) Verification of procurement

Table 2.2.2 shows the capacity of two (2) drilling rigs owned by DPHE.

Table 2.2.2 Capacity of DPHE's Drilling Rigs

Item	Rig No.1	Rig No.2
Model	Made in USA (Buffalo)	Made in France (Supplied by Netherland)
Year of Manufacture	1960	1986
Drilling Method	Direct Rotary	Direct Rotary / Reverse Rotary(Currently, reverse rotary is not workable)
Maximum Drilling Depth	335 m	240 m
Maximum Drilling Diameter	560 mm (22”)	560 mm (22”)
Hold-Back Capacity	7 tons	15 tons (actual capacity is approximately 8 tons, because of aging of rig)
Power	250 HP	Not known
Truck	10 Wheel Truck	4 wheel tractor
Drill Pipe		
Outside Diameter	2-3/8”	2-7/8”、3-1/2”
Unit Weight	10 kg/m	17 kg/m (2-7/8”) 21 kg/m (3-1/2”)
Unit Length	3 m, 6 m	3 m
Numbers	6 m x 55 pcs. 3 m x 110pcs.	3 m x 31 pcs. (2-7/8”) 3 m x 25 pcs. (3-1/2”)
Drill Collar		
Outside Diametger	5”	-
Unit Weight	131 kg/m	-
Unit Length	7.5 m (1 ton)	-
Numbers	1 pcs.	-
Drill Bit	8” to 22” Blade Bit(for soft formation) Tungsten Carbide Insert Bit (for hard formation)	
Mud Pump	750 L/min、0.7 MPa, Engine Type(350 HP)	750 L/min、0.7 MPa

Both rigs are aged because 51 years for No.1 Rig and 25 years for No.2 Rig have passed since their manufacture. The No.1 Rig is exclusive for direct rotary drilling. The No.2 Rig was originally for both reverse and direct rotary drilling. However, it is currently used exclusively for direct rotary drilling because of breakdown of the reverse pump.

The interview from DPHE's drilling staff and private drilling companies during the field survey revealed that the major drawbacks to drilling of deep water wells in the Study area were “gravel layers” and “consolidated sand layers”. Both drilling rigs of DPHE cannot cope with these drawbacks because of insufficient capacity of the pump and/or too small diameter of drill pipes. Therefore, requested drilling rigs are indispensable to develop deep ground water.

Although DPHE is currently drilling deep wells employing private drilling companies, DPHE has drilling staff with drilling experience. Therefore, it is possible for DPHE's staff to drill deep wells by those drilling staff using the procured rigs, provided that DPHE organizes drilling teams and necessary technical transfer is carried out for them.

From the discussion above, it is considered as appropriate to procure two (2) drilling rigs, because production wells and handpump wells are drilled at the same time.

(ii) Hydrogeological conditions to be considered in the selection of drilling rigs

The aquifer system in Bangladesh is not fully understood due to few investigations of detailed subsurface geology. Detailed subsurface geological investigations with soil core sampling were conducted by BGS/DPHE (2001) and JICA (2002) in the arsenic affected area. According to their results, the aquifer in the Study area is divided into three (3) layers (Table 2.2.3).

Table 2.2.3 Subsurface Geology and Aquifer Classification

Geologic Age	JICA (2002)			BGS/DPHE (2001)	This Study
	Subsurface Geology	Lithology	Aquifer Classification	Aquifer Classification	Aquifer Classification
Holocene	A formation	clay, silt, very fine sand, fine sand	First Aquifer (Shallow Aquifer)	Upper shallow aquifer	Shallow Aquifer
	B formation	fine sand, medium sand			
Late Pleistocene	C formation	sand, gravel	Second Aquifer (Middle Aquifer)	Lower shallow aquifer	
Plio-Pleistocene	D formation	clay, silt, sand, gravel	Third Aquifer (Deep Aquifer)	Deep aquifers	Aquiclude (Clay, Silt) / Deep Aquifer (Sand, Gravel)
	E formation	silt, sand			Deep Aquifer

However the definitions of the "Deep Aquifer" and the "Deep Tube Well" have been confused in Bangladesh. Understanding of "Deep Tube Well" by DPHE depends on depth only earlier. However, the separation from the shallow aquifer by an impermeable layer is also considered after arsenic identification. A deep tube well should be installed in the real deep aquifer which underlies the impermeable clayey layer. But some "Deep Tube Wells" were installed in a shallow aquifer level such as 100 to 150 m. In case of agricultural deep tube wells, these are deeper than agricultural shallow tube wells, but not as deep as 100 m. Ground water for agricultural use was certainly extracted from the shallow aquifer. In the study, aquifer analysis was conducted using the aquifer classification by former detailed investigations (BGS/DPHE, 2001 and JICA, 2002).

Most of the shallow tube wells for domestic and agricultural use are installed in the A formation of the first aquifer which is a high arsenic contaminated zone. Some of the shallow tube wells for domestic use and most of the "agricultural deep tube wells" are installed in the B formation of the first aquifer which has better permeability and less contamination by arsenic in comparison with the A formation. The second aquifer (the C formation) has good permeability due to coarser sediments including gravel, but arsenic was detected in some specific areas, for example Chowgacha Upazila of Jessore District. And the thickness of the gravel layers in the C formation varies from 60 m to 140 m from place to place. The D and E formations of the third aquifer are the main target zone of the deep tube well for drinking purposes as an alternative safe option in the arsenic affected area.

The D formation consists of various strata, such as clay layers, silt layers, sand layers, and gravel layers. The clay layers and the silt layers of the D formation function as an aquiclude, and are considered to be hydrogeologically classified as the shallow aquifer located above the D formation, and deep aquifer located below the D formation. However, according to previous investigations, it is admitted that there are areas which have no aquiclude. In those areas, since the clear aquiclude which prevents ground water flow from the shallow aquifer to the deep aquifer does not exist, it must be used carefully in the deep aquifer.

The gravel layers (mainly the C formation) which prevent the use of ground water from the deep aquifer seem to be distributed up to a depth of about 250 m maximum in the Study Area according to the results of electrical sounding of this study and the existing data. The deep aquifer that is under the gravel layers was detected by electrical sounding. The bottom of the deep aquifer may be at a depth of about 350 m or deeper.

(iii) Drilling method

i) Capacity of drilling rigs owned DPHE

In the Study Area, difficulty to drill a water well by DPHE's drilling rig because of the existence of gravel layer prevents the development of deep ground water

The causes of obstructions and their countermeasures are as follows.

ii) Cause of obstruction to drilling works by gravel layers and countermeasure

(a) Cause

As described above, DPHE has two (2) drilling rigs and they drill water wells by direct rotary drilling method. The cause of the difficulty in drilling water wells in the area where the gravel layer exists is thought to be as described below.

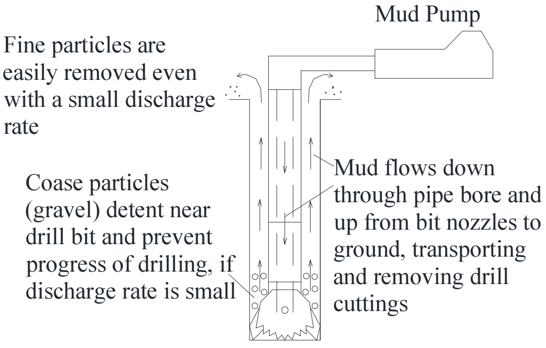


Figure 2.2.1　Drawbacks against Gravel Drilling due to Insufficient Mud Pump Capacity

For drilling by direct rotary drilling method, fine particles can be easily removed from the borehole even by small velocity of mud flow. However, larger particles such as gravel detected near the drilling bit prevent the progress of drilling, unless sufficient annular velocity of mud flow between the bore wall and drill pipe is ensured by pumping at a large discharge rate, as shown in Figure 2.2.1.

DPHE's mud pump is a small pump with capacity of 750 L/min, which produces approximately 4 m/min of velocity for drilling of 17-1/2" hole. Therefore, it is thought that an excessive decrease of penetration rate, which makes it difficult to continue drilling, will occur in drilling of the gravel layer.

(b) Countermeasures

In case of handpump wells, major parts of drilling are 14-3/4" hole (10 to 100 m) and 10-5/8" hole (100 to 400 m). By adopting a medium mud pump with capacity of approximately 1,200 L/min of discharge rate, large-bore (4-1/2") drilling pipes and drilling rig with capacity pull-back weight of 400 m of large-bore of drilling pipe, which enables pumping mud at a high discharge rate, a handpump well can be drilled by the direct rotary method.

In order to ensure the pumping rate of 1,200 L/min with the use of DPHE's drill pipes (2-3/8" to 3-1/2" diameters) for drilling down to 400 m, friction loss inside drill pipes will exceed 3 MPa, because the inner diameter of the pipes is small. Pressure of the mud pump which can be mounted on a truck is generally not more than 2 MPa. Therefore, it is necessary to adopt drill pipes of larger inner diameter (4-1/2") to reduce the friction loss inside drill pipes. A drilling rig with a larger hold-back capacity shall be selected because unit weight of 4-1/2" drill pipe (approximately 27 kg/m) is much heavier than that of 3-1/2" drill pipe (approximately 21 kg/m).

In case of production wells, major parts of drilling are the 24" hole (10 to 100 m) and 20" hole (100 to 400 m). As the hole diameter is more than 17-1/2", the effective drilling is difficult even though a medium capacity mud pump with 1,200 L/m of discharge rate is used. A hole with more than 17-1/2" diameter shall be drilled by the reverse rotary drilling method, the principals of which are described in iv) reverse rotary drilling method and directly rotary drilling method. By the reverse rotary drilling method, mud is introduced from the annular space between the hole and the drill pipes, and flows up from bit nozzles to the ground surface through the inner diameter of the drill pipe. As unit volume of drill pipe bore is much smaller than the annular space between the hole and drill pipes, larger mud flow velocity which enables the effective removal of large particles of gravel can be ensured.

For the reverse rotary drilling method, 6" reverse rods are used as drill pipes. The unit weight of 6" reverse rod is 40 to 50 kg/m and a drilling rig with larger hold-back capacity shall be selected, compared to a drilling rig using 4-1/2" drilling pipe.

iii) Cause of obstruction to drilling works by consolidated sand layer and countermeasure

(a) Cause

In Bangladesh, blade bits (often called "cutters") are mostly used for water well drilling (Figure 2.2.2). Blade bits are effective for drilling of clay, sand and gravel layers, if sufficient mud flow velocity is ensured. However, consolidated sand layers which exist in the northern part of the Study area cannot be drilled with blade bits.

Figure 2.2.2 Blade Bits for Drilling of Sand, Gravel and Clay Layers (Made in Bangladesh)

(b) Countermeasures

For consolidated layers, tri-cone bits are used (Figure 2.2.3). For the use of a tri-cone bit, 1 to 3 tons of weight on the bit shall be added, by connecting drill collars (heavy weight pipes) above the drill bit.

Each drilling rig shall have a hold-back capacity against the weight of reverse rods or drill pipes, drill collars and safety factors for pipe stacking. As shown in Table 2.2.4, a hold-back capacity of 15 tons for the drilling rig for handpump wells and 24 tons for one for production wells are required.

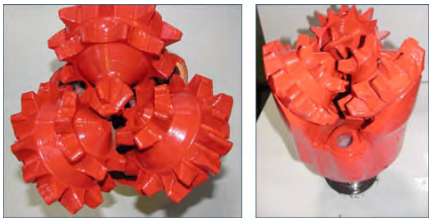


Figure 2.2.3 Tri-Cone Bits for Drilling of Hard Formations (Made in Japan)

Table 2.2.4 Hold-Back Capacity of Drilling Rig

For Handpump Well			For Production Well		
4-3/4"Drill Pipe			6"Reverse Rod		
	Unit Weigth (kg/m)	27		Unit Weight (kg/m)	50
	Length (m)	388		Length (m)	397
	Total Weigth (ton)	10.5		Total Weight (ton)	19.9

For Handpump Well			For Production Well		
8"Drill Collar			6"Reverse Collar		
	Unit Weight (kg/m)	225		Unit Weight (kg/m)	400
	Length (m)	12		Length (m)	6
	Total Weight (ton)	2.7		Total Weight (ton)	2.4
Total Weight (ton)		13.2	Total Weight (ton)		22.1
Safety Factor		1.1	Safety Factor		1.1
Hold-Back Capacity (ton)		15	Hold-Back Capacity (ton)		24

iv) Reverse rotary drilling method and direct rotary drilling method

As described above, production wells are drilled by the reverse rotary drilling method and handpump wells are drilled by a direct rotary drilling method in the Project.

In the direct rotary drilling method, mud is sent into drill pipes by a mud pump and mud flow will go up through the annular space between the hole and the drill pipe. Then, drill cuttings are removed through this process (Figure 2.2.4).

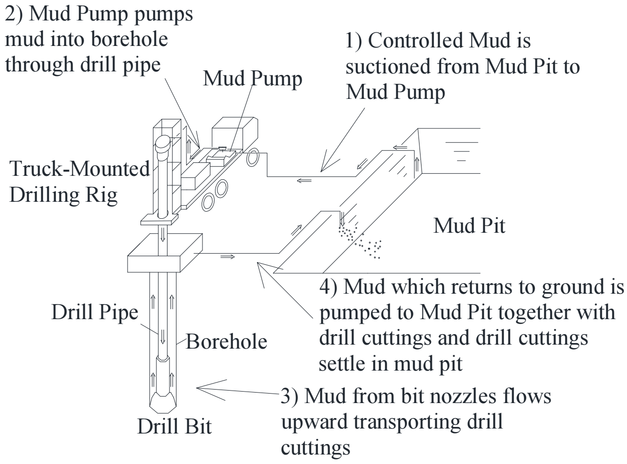


Figure 2.2.4 Principles of Direct Rotary Drilling Method

By the reverse rotary drilling method, mud is circulated by continuing following actions:

- Mud is suctioned from inside the drill pipe and pumped to the mud pit.
- Solid contents are removed from the muddy water in the mud pit and muddy water returns to the borehole through outside drill pipes by a submersible sand pump or gravity.

Drill cuttings are suctioned from the bottom of boreholes and transported by upward flow of mud to the ground surface and removed.

The capacity of the reverse pump can be larger than the piston pump (maximum 4,000 L/min). In addition, higher velocity can be ensured because section area of the drill pipe bore is much smaller than the annular space between the hole and the drill pipe. Ensuring 200 m/min of velocity of mud flow in the pipes for reverse rotary drilling method enables removal of large sizes of gravel.

The reverse Rotary method has two (2) different methods, those are suction pump method (Figure 2.2.5) and the air-lift method (Figure 2.2.6). The suction pump method has better workability than the air-lift method. However it has not been adopted for the Project, because the maximum drilling depth of suction method is approximately 100 m, is not reachable to 400 m of the target depth of the Project.

By the air-lift method, it is possible to drill down to 400 m. However, it cannot be applied to drilling from the surface to approximately 30 m, because, for the air-lift method, the specific gravity of the aerated muddy water inside the drill pipe is less than that of the muddy water outside the drill pipe. Drill cuttings are removed from the hole by the upward flow inside the drill pipe which is created by the difference of specific gravity of the muddy water. Drilling up to 400 m is possible by this method. However, drilling from the ground down to the depth of 30 m is not possible by this method, because it is not sufficient to create the required difference of specific gravity of muddy water in this section.

Though the diameter of the section from 0 to 30 m of production wells has large bores of 28" and 24", it can be drilled by the direct rotary drilling method by using strong mud. However, the drilling method shall be changed to air-lift reverse rotary drilling method after reaching 30 m of depth, because it consumes a large quantity of mud agents and drilling down deeper with strong mud will cause excessive high pumping pressure.

In order to drill production wells in the Project, the drilling equipment shall be applicable to both the direct rotary method and are-lift reverse rotary method. Therefore, the drilling equipment shall include the mud pump mounted on the rig truck, independent high pressure compressor and water swivel.

The facilities for the reverse rotary method are more complex compared to those for the direct rotary method. Furthermore, the solid contents of mud shall be controlled using instruments for solid-liquid separation such as cyclone-screens etc., in order to prevent drilling drawbacks such as clogging inside the drill pipe and pump, collapse of the bore wall caused by water level drawdown, etc.

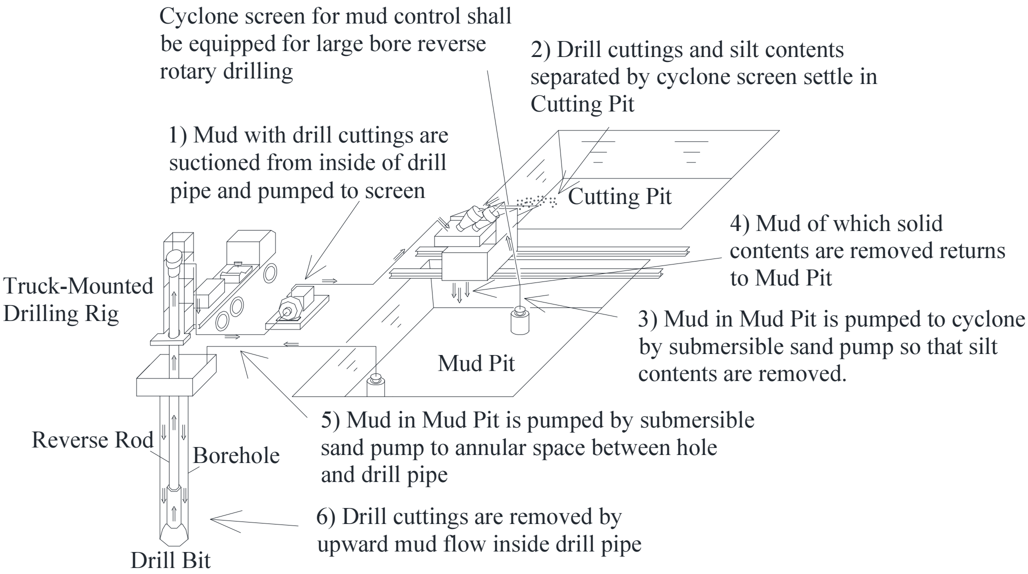


Figure 2.2.5 Principles of Suction Reverse Rotary Drilling Method

(Maximum Drilling Depth: 100 m, not adopted in the Project)

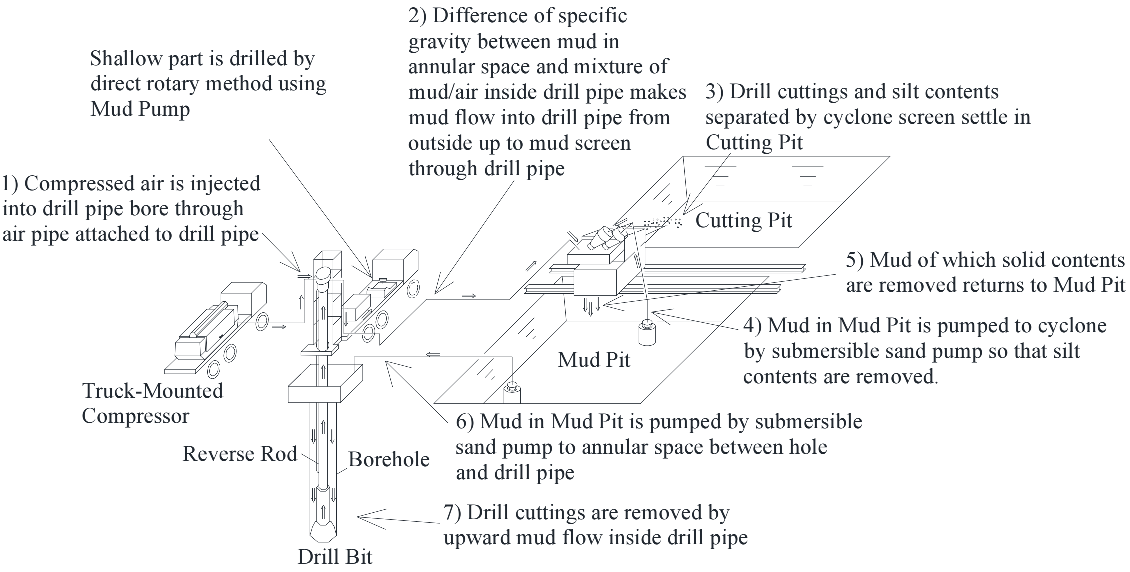


Figure 2.2.6 Principles of Air-Lift Reverse Rotary Drilling Method

(Maximum Drilling Depth is 400 m. The section from 0 to 30 m shall be drilled by the direct rotary drilling method and the section from 30 to 400 m shall be drilled by the air-lift reverse rotary drilling method.)

v) Cementing method

A sealing between the shallow aquifer and the deep aquifer and surface cementing to prevent inflow of domestic sewage shall be employed. The specifications of sealing and surface cementing are shown in Table 2.2.5. For a production well, approximately 3.3 tons of cement for sealing and approximately 3.8 tons of cement shall be mixed to produce cement slurry. Cement slurry is placed in the borehole by the cementing pump through tremie pipes. The concept drawing of the cementing work is shown in Figure 2.2.7.

Table 2.2.5 Specifications of Cementing

Item	Production Well		Handpump Well	
	Isolation Cementing	Surface Cementing	Isolation Cementing	Surface Cementing
Cement Type	Normal Portland Cement			
Specific Gravity of Cement Slurry	1.7			
Specific Gravity of Cement	3.3			
Cementing Depth (m)	285-300	0-10	285-300	0-10
Cementing Height (m)	15	10	15	10
Hole-Casing	20"Hole - 6"Casing	28"Hole - 12"Pump Housing	10-5/8"Hole - 2"Casing	17-1/2"Hole - 3"Pump Housing
Annular Volume (L/m)	181	317	54	148.9
Volume of Slurry (L)	3263	3810	978	1785
Weight of Cement (kg)	3278	3828	979	1793
Cment Bag (50 kg/bag)	66	76	20	36
Mixing Water Volume (L)	2271	2652	678	1242

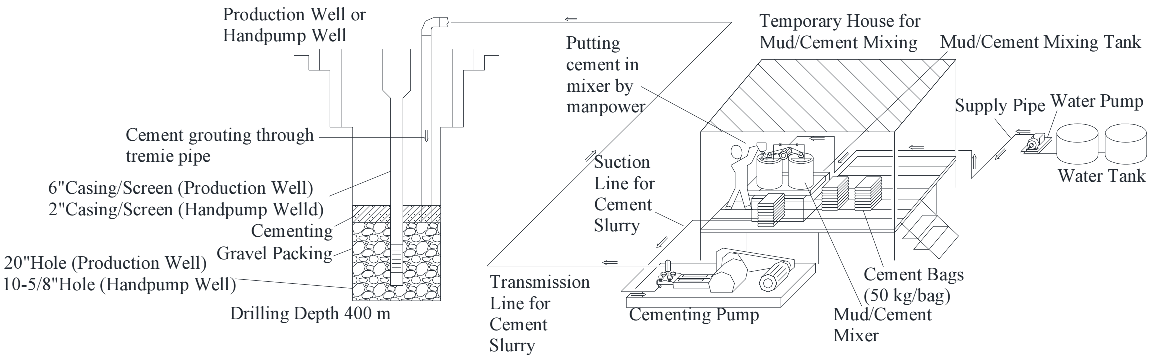


Figure 2.2.7　Conceptual Drawing of Cementing Work

vi)　Selection of casing pipe

In Bangladesh, pipes adapting the API Line Pipe Standard are generally used as casing pipes for water wells.　Casing pipes of five (5) wells to be drilled for the technical transfer will be procured in Japan, for procurement management and quality control.　The types of casing pipes are carbon steel for ordinary piping (SGP), pressure service schedule-40 (STPG Sch-40) and general structural purposes (STK).

Specifications of casing pipes are shown in Table 2.2.6.

Table 2.2.6　Specifications of Casing Pipes

Drilling Stage	Production Well				Handpump Well			
	1st	2nd	3rd		1st	2nd	3rd	
Depth (m)	0～10	0～100	0～50	50～385	0～10	0～100	0～50	50～385
Use	26"Casing	22"Casing	12"Casing	6"Casing	16"Casing	12"Casing	3"Casing	2"Casing
Pipe Type	26" STK	22" STK	12" STPG Sch-40	6" STPG Sch-40	16" SGP	12" STPG Sch-40	3" STPG Sch-40	2" STPG Sch-40
Outside Diameter (mm)	660.4	558.8	318.5	165.2	406.4	318.5	89.1	60.5
Inside Diameter (mm)	636.4	539.8	297.9	151.0	390.6	297.9	78.1	52.7
Thickness (mm)	12.0	9.5	10.3	7.1	7.9	10.3	5.5	3.9
Joint	both bevel end	both bevel end	thread	thread	both bevel end	both bevel end	thread	thread
Unit Weight (kg/m)	192.0	129.0	78.3	27.7	77.6	78.3	11.3	5.44
Length (m)	10	100	50	330	10	100	50	330
Weight (ton)	1.9	12.9	3.9	9.1	0.8	7.8	0.6	1.8
Total Weight (ton)	1.9	12.9	13		0.8	7.8	2.4	

(iv)　Well structure

Since shallow layers in the Study area (A formation and B formation in Table 2.2.3) contain lots of fine sand, they are easily collapsed.　The depth of these layers is deemed to be a maximum 100 m according to the existing data.　According to the interview with the drilling staff of DPHE and the private drilling companies, they use protection casing to prevent the collapse of the bore wall.　The surface casing is installed up to 10 m depth since the surface layer is easily collapsed and the surface part of wells shall be protected from the washing by mud flow.　Therefore, the surface casing installed down to 10 m and the intermediate (conductor) casing installed down to 100 m shall prevent the collapse of the bore wall.

C formation and E formation in Table 2.2.3 are less collapsible layers.　Therefore 1 (one) stage drilling can be adopted for the drilling wells which depth is deeper than 100 m.

According to the result of electrical sounding, it is predicted that the depth of the gravel layer (mainly C formation) is a maximum 250 m. In case thick clay exists between the gravel layer and the deep aquifer beneath the gravel layer, cement sealing shall be installed at the position of the clay layer. If the existing clay layer is thin, sealing between the shallow aquifer and the deep aquifer by throwing clay balls from the ground is not an effective sealing method. They may get stuck in the annular space before reaching the target depth. Even though they reach the target depth, they will include lots of pore spaces which will allow an inflow from the shallow aquifer. Therefore, the direct placement of cement slurry by using tremie pipes is the most effective sealing method.

The top of the gravel shall be not less than 10 m shallower than the top of the screen, with the consideration of the fall of the gravel top which may be caused by the washout of fine particles during well cleaning.

The thickness of clay layers in the deep aquifer varies from thin to thick in places. In case a clay layer with sufficient thickness does not exist near the screen top, the gravel column shall rise to its depth. Therefore, the gravel shall be packed up to 10 to 50 m shallower than the screen top. The height of the gravel column over the screen top depends on the geological conditions of the drilled borehole. The annular space above the packed gravel shall be sealed with the cement slurry.

i) Well structure of production well

(a) Specification of production well

Production wells are water sources through piped water supply in district Paurashavas. The major specifications of production wells are shown in Table 2.2.7.

Table 2.2.7 Major Specifications of Production Well

Item	Specifications
Depth	400 m
Maximum Discharge Rate	80 m^3/h
Pump	Electric Submersible Pump
Pump Housing, Casing/Screen	Pump Housing: 12”Steel Pipe Casing: 6”Steel Pipe Screen: 6”Stainless Pipe

The design policy of the above items is described as below.

(b) Maximum discharge rate

The target area for water supply with production wells is district Paurashavas. In general, 50 to 120 m^3/h of water is discharged from a production well.

In the Project, it is agreed between DPHE and the Study Team that the maximum discharge rate is 80 m^3/h in order to prevent drilling boreholes with a big diameter. DPHE adopts 120 L/capita/day as the unit water demand for water supply for district Paurashavas. If the discharge rate is 80 m^3/h and operation hours are 12 hours, approximately 8,000 persons can access water.

(c) Pump

The depth of the pump setting is estimated to be a maximum 40 m. This figure is decided by the results of “The study on the ground water development of deep aquifers for safe drinking water supply to arsenic affected areas in western Bangladesh (JICA 2002)”. The total head of the pump is calculated as 50 m considering of this setting depth and friction loss of the pipeline to the distribution tank.

General specifications of submersible pumps, which discharge rate is 80 m^3/h and total head is 50 m, are shown in Table 2.2.8.

Table 2.2.8 Specifications of Submersible Pump for Production Well

Item	Specifications
Discharge Rate	80 m^3/h
Setting Depth	40 m
Total Head (m)	50 m
Power Supply	3 phases/400 V/50 Hz
Power	18.5 kw
Start Method	Star-Delta
Minimum Casing Diameter	200 mm
Pump Diameter	186 mm
Overall Length	Approximately 2,000 mm

Pumps, riser pipes and appurtenant equipment for the water supply to residents are not included in the Project. After the drilling of the water well by DPHE's Action Plan, they will be procured and installed by the Bangladesh side.

(d) Riser pipe

The calculation of friction loss is shown in Table 2.2.9. The condition of discharge rate is 80 m^3/h and pipe length is 50 m.

The Hazen & Williams formula written as below was used for the calculation.

I = 10.666・C^-1.88・D^-4.87・(Q÷3600)^1.85

HL = I x L

I: Hydraulic Gradient (m/m)
C: Velocity Coefficient (110)
D: Pipe Diameter (m)
Q: Velocity (m^3/h)
L: Pipe Length (m)
HL: Friction Loss (m)

Table 2.2.9 Calculation of Friction Loss of Riser Pipe of Submersible Pump (Discharge Rate: 80 m^3/h, Pipe Length 50 m)

Item	Internal Diameter of Riser Pipe 100 mm (4")	Internal Diameter of Riser Pipe 80 mm (3")	Internal Diameter of Riser Pipe 50 mm (2")
Internal Diameter D (m)	0.1	0.08	0.05
Hydraulic Gradient I (m/m)	0.1	0.3	2.94
Friction Loss HL (m)	5	15	147

From the above table, the friction loss is 5 m, 15 m and 147 m with 4"riser pipe, 3" riser pipe and 2"riser pipe respectively. The bigger total head of pumps requires bigger power. Therefore, the diameter of riser pipes shall be not more than 10 m so that friction loss is less than 10 m. Consequently, the internal diameter of the riser pipe shall be 100 mm (4").

(e) Pump housing

For the urban water supply in local towns in Bangladesh, 50 to 300 m^3/h of water is pumped up from a well. In this large scale of pumping, the small diameter of pump housing will cause a quick draw down of the water level. As a result, it will cause a strong shock to the aquifer. For this reason, DPHE adopts the following rules. The size of the pump housing is 350 mm (14") when water yield is less than 80 m^3/h. Moreover, it is 300 mm (12") when water yield is more than 80 m^3/h. As the discharge rate of production wells in the project is maximum 80 m^3/h, pump housing of diameter 300 mm (12") is adopted.

(f) Number of steps and drilling depth

Considering the geological conditions, production wells have three (3) drilling stages shown in Table 2.2.10.

Table 2.2.10 Depth and Purpose of Each Drilling Stage

Drilling Stage	Drilling Depth	Geology	Purpose
1st	GL - 10 m	Surface Soil	Prevent collapse of soft surface soil by installing protection casing.
2nd	10 m - 100 m	Collapsible Sand/Clay/Gravel	In case of collapse of formations, prevent collpase by installing protection casing.
3rd	100 m - 400 m	Less Collapsible Sand/Clay/Gravel	Install casing/screen. Sufficent annular space between bore wall and casing shall be ensured for gravel packing and sealing works.

(g) Casing program

As the general size of the diameter of the casing/screen is 150 mm (6") with maximum 80 m3/h of discharge rate in Bangladesh. A 150 mm (6") casing/screen is adopted for production wells for the Project.

DPHE has the experience to have used the PVC casing/screen for water wells of down to 300 m depth. However, the strength of the PVC casing/screen is not enough for installation down to 400 m and screen cleaning by high pressure jetting to remove the clogging of the screen is not applicable to the PVC screen. Therefore, a steel casing and stainless screen have been adopted for the Project.

Diameters of borehole and protection casings are as shown in Table 2.2.11, considering of diameter of tremie pipe (inside diameter 50 mm) for gravel packing and cement sealing works.

Table 2.2.11 Design Policy of Drilling Diameter and Protection Casing of Each Drilling Stage (for Production Wells)

Drilling Stage	Drilling Diameter and Calculation Basis	Protection Casing Diameter and Calculation Basis
1st	710 mm (28") Calculation Basis：not less than 20 mm of annular space for each side is necessary	660 mm (26") Calculation Basis: shall be larger than 610 mm (24") Intermediate hole
2nd	610 mm (24") Calculation Basis：not less than 25 mm of annular space for each side is necessary	550 mm (22") Calculation Basis: shall be larger than 500 mm (20") Production hole
3rd	500 mm (20") Calculation Basis：for the installation of tremie pipe aside 300 mm (12") pump housing, not less than 90 mm (3.5") of annular space for each side is necessary	-

Following Table 2.2.11, the basic well structure of production wells of the Project is as shown in Figure 2.2.8.

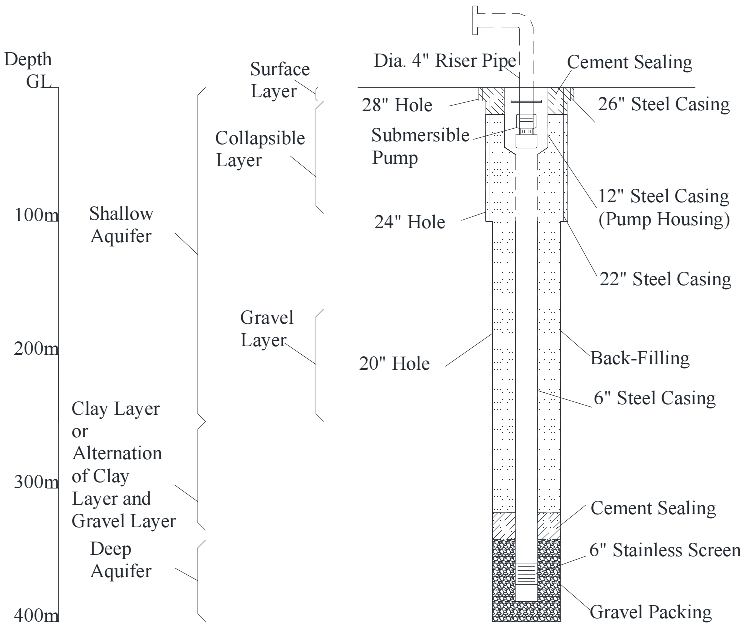


Figure 2.2.8 Basic Structure of Production Well

ii) Well structure of handpump well

(a) Use of handpump

Handpump wells are used for handpump water supply in villages. The major specifications of handpump wells are shown in Table 2.2.12.

Table 2.2.12 Major Specifications of Handpump Well

Item	Specifications
Depth	400 m
Maximum Discharge Rate	1 m^3/h
Pump	Handpump (Suction Type or Under Water Piston Type)
Pump Housing, Casing/Screen	Pump Housing: 3”Steel Pipe Casing: 2”Steel Pipe Screen: 2”Stainless Pipe

(b) Maximum discharge rate

The maximum discharge rate is 1.0 m^3/h, and it is the general capacity of handpumps.

(c) Pump

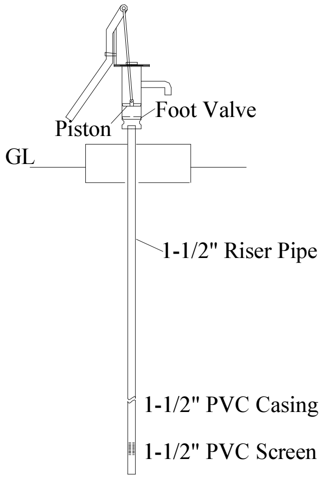
In Bangladesh, a suction type handpump shown in Figure 2.2.9 is generally used.

Since the suction head of the suction handpump is approximately 6 m, it is used for only a shallow aquifer with a high water table.

It is predicted that the water level of the deep aquifer in the target area of the Project is lower than that of the shallow aquifer. Therefore, an underwater piston type, which is shown in Figure 2.2.10, will be used in the Project.

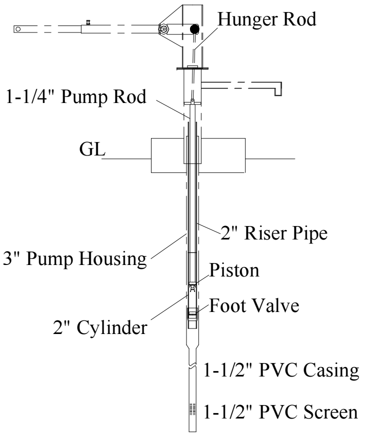
Handpumps with under water pistons can abstract water up to 30 m. Therefore, they seem to be the major handpump which will be used for the water wells under DPHE’s Action Plan.

A casing/screen of the handpump well with 1-1/2” diameter is generally used in Bangladesh, as shown in Figure 2.2.9 and Figure 2.2.10. Since the PVC pipe is not strong enough for the wells which have a depth of 400 m, steel casing and stainless screen are adopted for the Project. It is unavailable to procure a stainless screen which size is less than 1-1/2”. Therefore, the diameter of steel casing and stainless screen shall be 2”.



Casing is used as suction pipe by connecting directly to pump, as piston is located above ground.

Figure 2.2.9 Structure of Suction Type Handpump



2” Riser Pipes are set inside 3” Pump Housing.
Inside Pump Housing, 1-1/4” Pump Rods connected to piston move vertcally.

Figure 2.2.10 Structure of Under Water Piston Type Handpump

Pumps, riser pipes and appurtenant equipment for the water supply to the residents are not included in the Project. After the drilling of water wells in the DPHE’s Action Plan, they will be procured and installed in the wells by the Bangladesh side.

iii) Pump housing

In case of suction type handpumps, the pump housing is not necessary because the piston is located in the pump head above the ground.

In case of the underwater piston type handpumps, the pump cylinder shall be installed inside water wells. Therefore, the diameter of the pump housing shall be 75 mm (3”).

iv) Number of steps and drilling depth

Geological conditions in the target area for handpump wells are the same as those for production wells. Therefore, the structure of handpump wells in the Project has three (3) drilling stages and the maximum drilling depth is 400 m, as shown in Table 2.2.13.

Table 2.2.13 Design Policy of Drilling Diameter and Protection Casing of Each Drilling Stage (for Handpump Wells)

Drilling Stage	Drilling Diameter and Calculation Basis	Protection Casing Diameter and Calculation Basis
1st	445 mm (17-1/2”) Calculation Basis：not less than 25 mm (1”) of annular space for each side is necessary	400 mm (16”) Calculation Basis: shall be larger than 360 mm (14”) Intermediate hole
2nd	375 mm (14-3/4”) Calculation Basis：not less than 25 mm (1”) of annular space for each side is necessary	300 mm (12”) Calculation Basis: shall be larger than 300 mm (10”) Production hole
3rd	270 mm (10-5/8”) Calculation Basis：for the installation of remie pipe aside 75 mm (3”) pump housing, not less than 90 mm (3.5”) of annular space for each side is necessary	-

v) Casing program

3” steel pump housing, 2” steel casing and 2” stainless screen are adopted for handpump wells in the Project.

Diameters of boreholes and protection casings are as shown in Table 2.2.13, considering of diameter of tremie pipe (inside diameter 50 mm) for gravel packing and cement sealing works.

Following Table 2.2.13, the basic well structure of handpump wells in the Project is designed as shown in Figure 2.2.11.

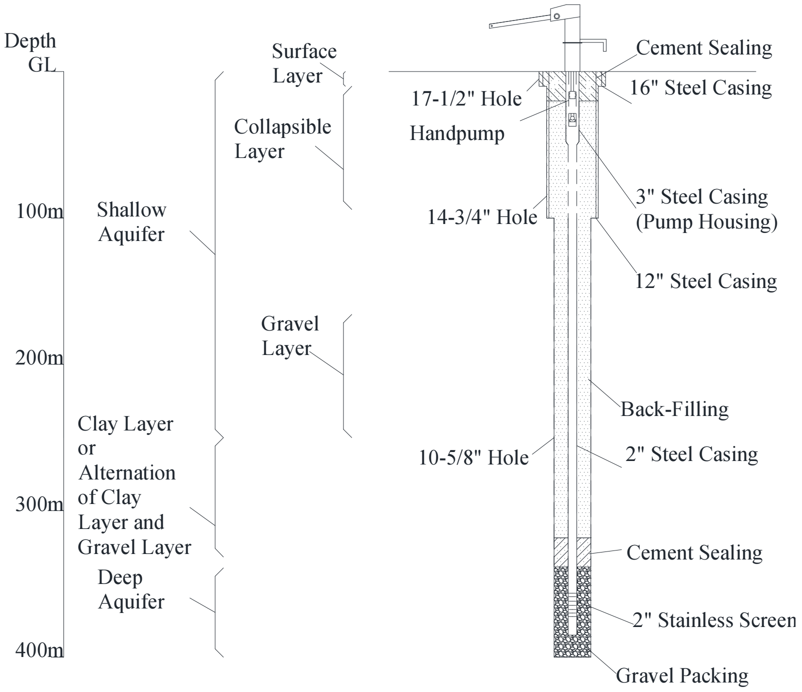


Figure 2.2.11 Basic Structure for Handpump Well

However, DPHE strongly desires to reduce the construction cost. As an option to reduce the cost, a reduced drilling diameter is proposed as an example (Figure 2.2.12). Although the well structure shown in Figure 2.2.11 is desirous for reliable cement sealing work, reducing the cost is very important for sustainable development of deep ground water by DPHE. Therefore, the construction cost and sealing reliability regarding smaller diameter drilling like Figure 2.2.12 will be examined in the Detail Design stage. Then, the well structure and required design of the equipment will be changed based on Figure 2.2.12.

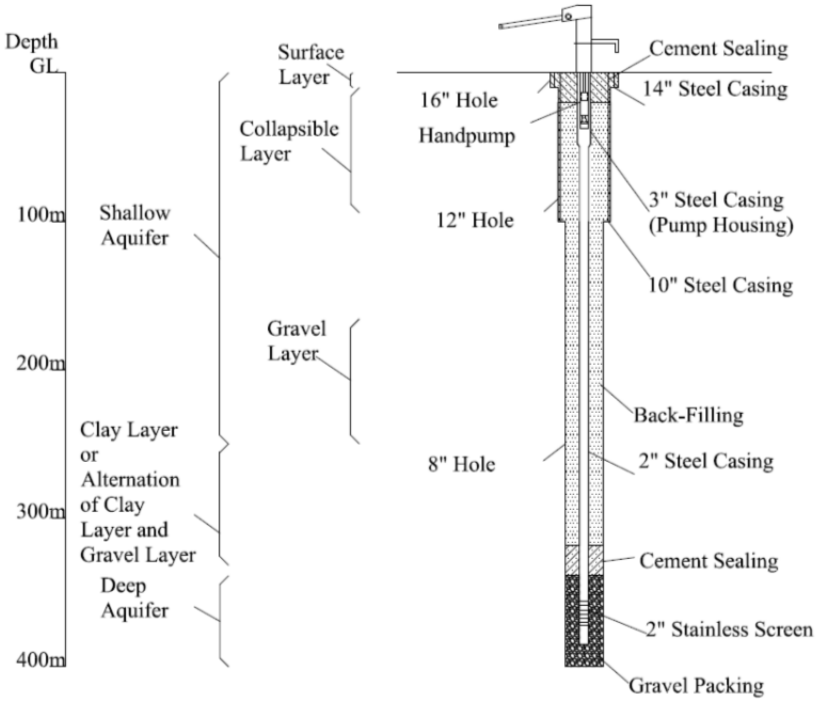


Figure 2.2.12 Example of Reduced Drilling Diameter for Handpump Well

Figure 2.2.12 shows the standard well structure for the handpump well assuming the drilling depth of 400 m. DPHE has the experience to install PVC casing to about 36o m depth of the handpump well. Therefore, in the actual drilling it is possible to change the materials of the well considering the drilling depth and the geological conditions.

vi) Production well for villages

The target water wells of the Project are, as described above, production wells for District Paurashavas and handpump wells for villages. However, a piped water supply may be established for the future in some villages where their capacity of operation and maintenance and other conditions meet the criteria of the operation of piped water supply schemes.

The maximum discharge rate of wells in villages can be estimated less than those in District Paurashava. When the maximum discharge rate is estimated in 20 m^3/h, the well structure is supposed as shown in Figure 2.2.13.

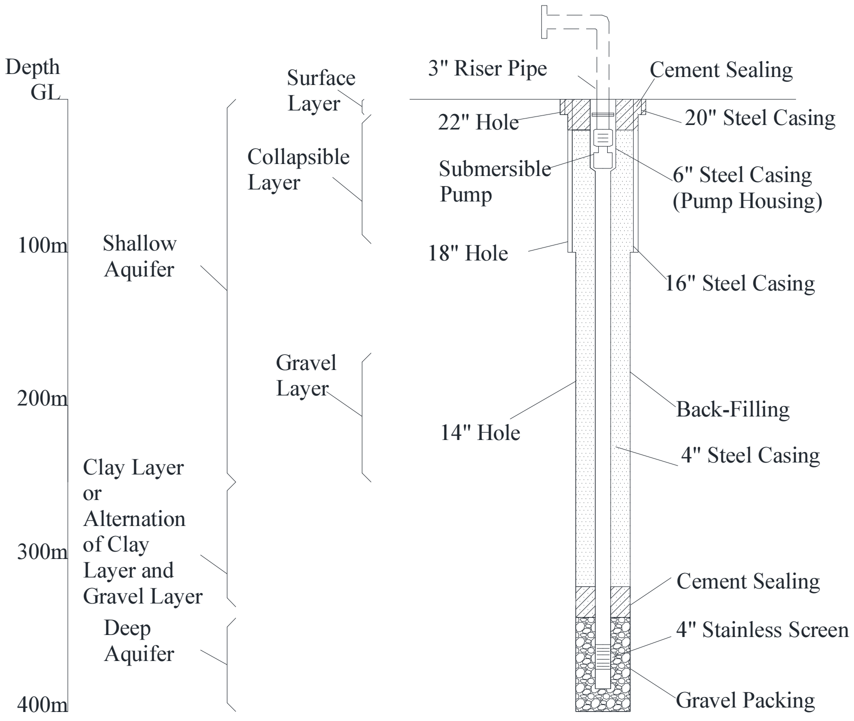


Figure 2.2.13 Production Well for Villages

vii) Reconsideration of well structure through drilling work

It is the first challenge for DPHE to drill water wells down to a maximum 400 m depth to take water from the deep aquifer. Structures of production wells and handpump wells, which are described in Figure 2.2.8 and Figure 2.2.11, are thought to be the most suitable at this stage. However, based on field experience and requirements, DPHE can modify the structure of the production well and handpump tube well to make it more effective ensuring the desirable benefit of such drilling. In that case, specifications such as diameters of boreholes, casing and screen at each stage and casing/screen materials shall be reviewed and revised as necessary.

The instruction of the examination method of well structure corresponding to each geological condition will be carried out during the instruction of drilling plan and management in the soft component of the Project.

2) Drilling rig for production wells

(i) Drilling method for production wells

The shallow part (0 to 30 m) of production wells is drilled by direct rotary drilling method and the deeper part down to 400 m is drilled by the air-lift reverse rotary drilling method.

(ii) Drilling rig for production wells

As shown in Table 2.2.4, a drilling rig with the hold back capacity of the drilling rig is not less than 24 tons.

The mud pump shall be mounted on the rig truck. Draw works, top drive head and sand reel will be attached to the rig truck. The water swivel shall be of specifications which can be used for both direct rotary drilling method and reverse rotary drilling method.

The rig truck shall be 6 x 4 drive and its gross vehicle weight of not less than 24 tons.

(iii) Mud pump for production wells

The mud pump for direct rotary drilling method shall have enough capacity to drill boreholes of 28” x 10 m and of 24” x 30 m by the strong mud method. Therefore, the delivery shall be not less than 1,200 L/min. A pump which has the pressure-residence more than 2 MPa shall be selected considering of the friction loss of the inside of 6” reverse rods.

(iv) Standard operation accessories for production wells

Standard operation accessories necessary for drilling of the production well is shown in Table 2.2.14.

Table 2.2.14 Standard Operation Accessories for Production Wells

<table>
<tr><th>Tools</th><th>Contents</th></tr>
<tr><td>Standard Operation Accessories</td><td>Drilling equipment for the drilling of 28”, 24” and 20” boreholes, 6”reverse rods, drill collars, stabilizers, subs, bits</td></tr>
<tr><td>Handling Tools</td><td>- Casing
- Casing band, pipe wrench etc. necessary for handling of casing, drill pipe etc.
- Pipe wrench etc.
- Wire slings, shackles, lever blocks for transportation of equipment</td></tr>
<tr><td>Mud Water Control Equipment</td><td>- Cyclone screen (2,000 L/min)
- 4”submersible sand pump for transition of mud to cyclone
- Submersible sand pump for the mud circulation:
6” Submersible Sand Pump 2 units
4” Submersible Pump 1 unit
- Mud Mixer: 600L x 2 units with tank
- Piping for mud circulation</td></tr>
<tr><td>Cementing Equipment</td><td>For cementing works, a cementing pump, a cementing mixer, tremie pipes are required. The cement mixer can be used as a mud mixer, and a temporary lodge
A high pressure pump is necessary to pump cement slurry through tremie pipes which diameter is small because of friction loss of inside tremie pipes.
Discharge rate is 260 L/min, required pressure against friction loss is within 1.5 Mpa. The required pressure is estimated to be less than 3.0 MPa with consideration of pressure elevation caused by the partial clogging of tremie pipes.
Therefore, cementing pump which discharge rate is 260 L/min and pressure is 3.0 MPa shall be selected.
Moreover, handling tools for tremie pipes, piping materials for suction and transmission of cement slurry shall be required.</td></tr>
<tr><td>Power Distribution Equipment</td><td>A drive head of drilling rigs and a mud pump mounted on drilling rig are driven by a truck engine through PTO (Power-Take-Off). On the other hand, the mud/cement mixer, the cementing pump, the sand pump for mud control, the water supply pump, lighting for night works are run by electricity. Therefore, power distribution instruments such as generators, distribution panels, distribution cables are needed.
Power distribution equipment is shown in Table 2.2.15. Seven (7) equipment in the list; No.1, 2, 4, 5 and 6, are used simultaneously and total power for simultaneous use is 74.4 kw.
Arrangement of each power distribution equipment and electric wiring are shown in Figure 2.2.14.
In order to supply power of 74.4 kw in total, generator which capacity is 125 kva shall be required, according to the reports of generator manufacturers.

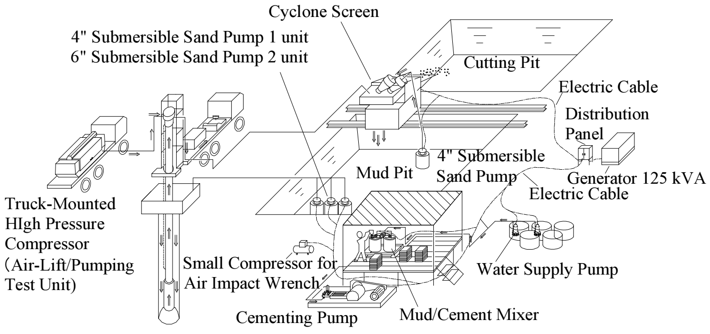


Figure 2.2.14 Circuit of Electric Equipment

In Bangladesh, voltages are 230 V for single phase and 400 V for three phases and</td></tr>
</table>

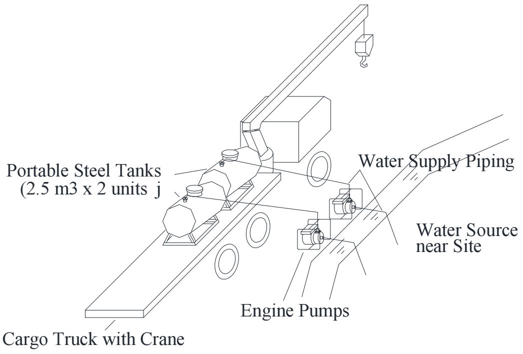
Tools	Contents
	frequency is 50 Hz. Therefore, a diesel generator which capacity is 125 kva, single phase voltage is 230 V, three phases voltage is 400 V and frequency is 50 Hz shall be selected. Electric cables and connection gears corresponding to rated powers of electric equipment shall be selected.
Water Supply Equipment	Collapsible water tanks are settled at drilling sites to store clean water. The water supply pump and piping are installed to supply water for mud/cement mixing, and washing. Two (2) units of the water supply pump, which discharge rate is 250 L/min and total head is 15 m, are selected. For transportation of water from a water source near the drilling site, a portable water tank, which capacity is 2.5 m3 in volume, and two (2) sets of engine pumps shall be selected. Arrangement of equipment for an intake of water is shown in Figure 2.2.15.  **Figure 2.2.15　Arrangement of Equipment for Intake of Water for Drilling**
Fishing Tools	Drilling accidents such as pipe stacking and/or drop of drill tools occur according to geological conditions. A hydraulic jack with 50 tons capacity and a pipe band for holding back with high load shall be selected.
Mechanical Equipment	- Engine Welder: To be used for arch welding of steel materials and casing pipes. Capacity shall be 30 to 280 A in operating current and 12.5 kw in engine output. - Arc Welding Gear: To be selected for holder, cable, welding face shield, marking chalk for welding, welding rods. - Equipment for cutting and polishing of steel materials such as disk grinder and cutting machine - Tools for mantling/dismantling of machineries such as wrenches, spanners, electric tools
Other Equipment	Other equipment such as for feeding fuel, temporary house, cement/mud mixing, temporary works, tent and temporary office

Table 2.2.15　List of Power Distribution Equipment (for Production Wells)

No.	Item	Unit	Qty.	Specifications	Use	Start Method	Power (kw)	Total Power (kw)	Simul -taneous Use
1	6"Submersible Sand Pump	Unit	2	3.2 m^3/min, Total Head 10m	For Mud Circulation	Direct	15	30	yes
2	4"Submersible Sand Pump	Unit	2	1.0 m^3/min, Total Head 15m	One for Mud Circulation, Another transmission to Cyclone Screen	Direct	5.5	11	Yes
3	Cementing Pump	Unit	1	260 L/min, Pressure 3 MPa	For transmission of Cement Slurry	Star-Delta	18.5	18.5	No
4	Motor for Cyclone Screen	Unit	2	For 9" Cyclone	Two motors for two cyclones	Direct	3.7	7.4	Yes
5	Motor for Mud/Cement Mixer	Unit	2	Mixing Capacity 600 L x 2	For Mud/Cement Mixing	Direct	11	22	Yes
6	Water Supply	Unit	2	Submersible	Water supply for	Direct	2	4	Yes

No.	Item	Unit	Qty.	Specifications	Use	Start Method	Power (kw)	Total Power (kw)	Simul -taneous Use
	Pump			250L/min, Total Head 15 m	Mud/Cement Mixer and water for washing				
7	Small Compressor for Air Impact Wrench	Unit	1	Delivery: 1.2m3/min, Pressure: 0.93 MPa	For Air Impact Wrench used for connection of reverse rods	Direct	11	11	No
Total Power (kw)								103.9	74.4

3) Drilling rig for handpump wells

(i) Drilling method for handpump wells

The drilling method for handpump wells is the direct rotary drilling method.

(ii) Drilling rig for handpump wells

As shown in Table 2.2.4, the drilling rig which capacity for hold back is more than 15 tons, is selected. The mud pumps should have draw works, a top drive head and a sand reel. Moreover, it should be mounted on the drilling rig. The rig truck shall be 6 x 4 drive and the gross vehicle weight is more than 24 tons.

(iii) Mud pump for handpump wells

The mud pump for direct rotary drilling method should have sufficient capacity in order to drill boreholes, which sizes are 17-1/2” x 10 m and 10-5/8” x 400 m. Therefore capacity of the pump should be not less than 1,200 L/min and their pressure shall be more than 2 MPa by considering the friction loss of the inside of 4-3/4” drill pipes.

(iv) Standard operation accessories for handpump wells

Table 2.2.16 shows the standard operation accessories for handpump wells.

Table 2.2.16 Standard Operation Accessories for Handpump Wells

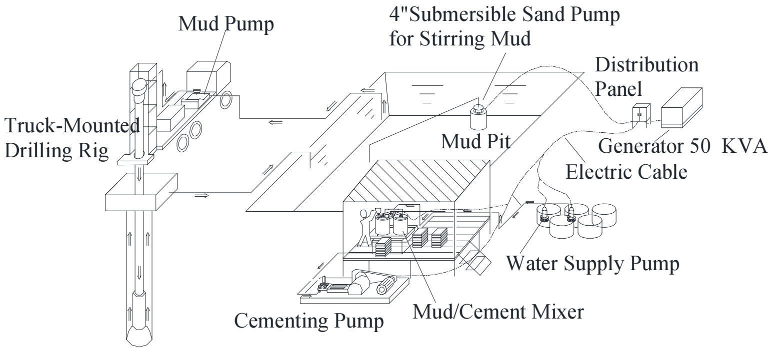
Tools	Contents
Standard Operation Accessories	Drilling equipment, 4-1/2” drill pipes, drill collars, stabilizers, subs, bits necessary for drilling of 17-1/2”, 14-3/4” and 10-5/8” boreholes.
Handling Tools	- Casing band, pipe wrench for handling of casing and drill pipe - Wire slings, shackles, lever blocks for transportation of equipment
Mud Water Control Equipment	- 4”submersible sand pump for mud stirring 1 unit - Mud Mixer: 600 L x 2 units w/tank - Piping for mud circulation
Cementing Equipment	Cementing equipment for handpump well shall be of same specifications as those for production wells.
Power Distribution Equipment	Drive head of drilling and the mud pump mounted on the rig truck are driven by engine of truck through PTO (Power-Take-Off). On the other hand, equipment such as the mud/cement mixer, the cementing pump, the sand pump for mud control, the water supply pump, lighting for night works etc. require electricity. Therefore, power distribution instruments such as the generator, the distribution panel, distribution cables are needed. Power distribution equipment is shown in Table 2.2.17. In listed four (4) equipment, No.1, 3 and 4 are simultaneously used and total required power is 31.5 kw. Arrangement of the power distribution equipment and electric wiring are shown in Figure 2.2.16.  **Figure 2.2.16 Arrangement of Electric Equipment for Handpump Wells** In order to supply power of 31.5 kw in total, generator of which capacity is 50 kva shall be selected, according to the generator manufacturer. In Bangladesh, voltages are 230 V for single phase and 400 V for three phases and frequency is 50 Hz. Therefore, diesel generator of which capacity is 50 kva, single phase voltage is 230 V, three phases voltage is 400 V and frequency is 50 Hz shall be selected. Electric cables and connection gears corresponding to rated powers of electric equipment shall be selected, too.
Water Supply Equipment for Production Well	The same equipment as that of the production well is provided.
Fishing Tools for Production Well	Drilling accidents such as pipe stacking and/or drop of drill tools occur according to geological conditions. Hydraulic inside tap, jack with 50 tons capacity and pipe band for holding back with high load in such cases shall be selected.
Mechanical Equipment for Production Well	The same equipment as that of the production well is provided.
Other Equipment for Production Well	The same equipment as that of the production well is provided.

Table 2.2.17 List of Power Distribution Equipment (for Handpump Wells)

No.	Item	Unit	Qty.	Specifications	Use	Start Method	Power (kw)	Total Power (kw)	Simul -taneous Use
1	4"Submersible Sand Pump	Unit	1	1.0 m^3/min, Total Head 15 m	For Mud Stirring	Direct	5.5	5.5	Yes
2	Cementing Pump	Unit	1	260 L/min、 Pressure 3 MPa	For transmission of Cement Slurry	Star-Delta	18.5	18.5	No
3	Motor for Mud/Cement Mixer	Unit	2	Mixing Capacity 600 L x 2	For Mud/Cement Mixing	Direct	11	22	Yes
4	Water Supply Pump	Unit	2	Submersible Pump 250 L/min, Total Head 15 m	Water supply for Mud/Cement Mixer and washing	Direct	2	4	No
Total Power (kw)								50	31.5

4) Selection of air-lift/pumping test unit for production wells

(i) Verification of procurement

A large amount of water is required to eliminate cuttings produced by drilling. For this purpose, equipment for an air-lifting (compressor) is required. It is impossible to drill deep wells without this equipment.

Moreover, a pumping test by a submersible pump is necessary in order to evaluate drilled wells.

All equipment mentioned above can be mounted on one (1) truck, and it is available for effective transfer and drilling works.

From the discussion described above, procurement of a truck-mounted air-lift/pumping test unit is verified as appropriate.

(ii) Contents of air-lift unit for production wells

i) Air-lift unit for production wells

The air-lift shall be carried out by a double-tube method in order to decrease shock on screens in the beginning of air-lifting since large quantity of water is lifted for production wells.

For the effective cleaning of wells by air-lifting, its discharge rate should be ensured at 20 m^3/h when the dynamic water level is 40 m.

The installation depth of (outer) eductor pipes and (inner) air pipes shall be 100 m. Materials of pipes are 4” SGP (Carbon Steel Pipe for Ordinary Piping) for eductor pipes and BQ Rod (inside diameter 44 mm) for air pipes.

Discharge pressure of the compressor shall be 1.2 MPa with the consideration of installation depth and friction loss inside the pipes. The amount of air delivery by the compressor shall be 12 m^3/h.

A conceptual drawing of the air lift equipment installation is shown in Figure 2.2.17.

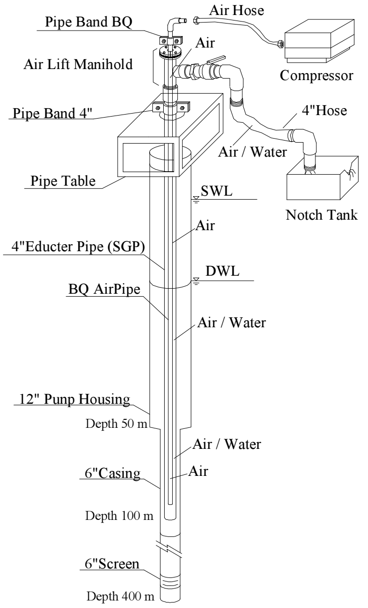


Figure 2.2.17 Connectional Drawing of Air-Lift Equipment Installation (for Production Wells)

The following air-lift equipment is selected:

- Compressor12m^3/h, 1.2 MPa 1 unit
- Eductor pipe 4” SGP, Thread-Socket connection 100m
- Air pipe BQ、Thread connection 100 m
- Air-lift manifold 1 unit
- Pipe handling tools
- Appurtenant piping

The compressor for air-lifting is concurrently used for drilling by air-lift reverse rotary drilling method.

ii) Pumping test unit for production wells

The dynamic water level of production wells is assumed to be maximum 40 m. The total head of the submersible pump for pumping test is 50 m by considering friction loss inside the riser pipes and surface piping.

The maximum discharge rate of a production well is 80 m^3/h. In order to implement proper evaluation of well capacity, two (2) types of the submersible pump (Medium capacity pump: discharge rate 40 m^3/h and High capacity pump: discharge rate 80 m$^{3/}$h) are selected from the following aspects:

(a) High capacity pump

Discharge rate 80 m^3/h, Total head 50 m, 50 Hz, Three phases x 400 V, 18.5 kw

(b) Middle capacity pump

Discharge rate 40 m^3/h, Total head 50 m, 50 Hz, Three phases x 400 V, 11.0 kw

Riser pipes are concurrently used for the above two types of pump. In order to pump water at a discharge rate of 80 m^3/h, diameter of riser pipes shall be 4”.

Capacity of the generator shall be 50 kva, it is enables to Operation of the high capacity submersible pump (18.5 kw).

Conceptual drawing of pumping test equipment installation is shown in Figure 2.2.18.

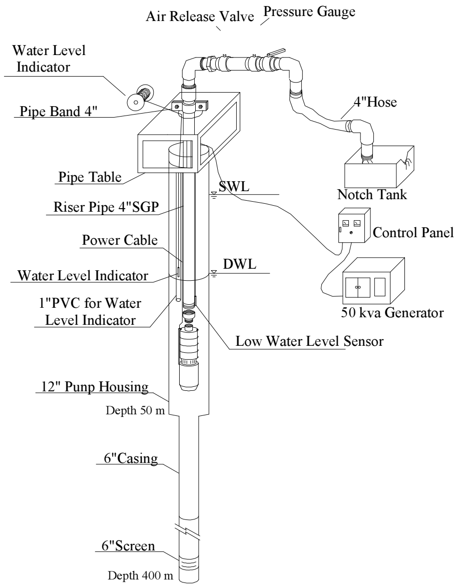


Figure 2.2.18 Conceptual Drawing of Pumping Test Equipment Installation (for Production Wells)

The following pumping test equipment is selected:

- High capacity submersible pump: Discharge rate 80m3/h, Total head 50 m, 50 Hz, Three phases x 400 V, 18.5 kw
- Medium capacity submersible pump: Discharge rate 40m^3/h, Total head 50 m, 50 Hz, Three phases x 400 V, 11.0 kw
- Riser pipe 4” SGP, Socket-Thread connection
- Pump control panel
- Pipe handling Tools
- Low water level sensor
- Power cable

- Surface piping
- Notch tank
- 50 kva Generator
- Water quality meter (Arsenic, Electric Conductivity, pH, Dissolved Oxygen, ORP (Oxidation-Reduction Potential)

(c) Truck-mounted air-lift/pumping test unit

Major equipment such as a compressor for air-lifting, the generator for pumping test, the submersible pump are mounted on the truck. It is enable the implementation of effective transportation and works (Figure 2.2.19).

Compressor and generator are fixed on truck.

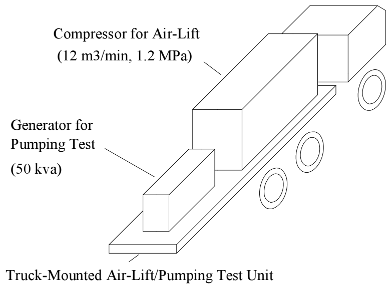


Figure 2.2.19 Air-Lift/Pumping Test Unit for Production Wells

5) Selection of air-lift/pumping test unit for handpump wells

(i) Verification of procurement

A pumping test is required to evaluate the ability of the drilled deep wells. After drilling and installation of screen pipes, cleaning inside the well shall be done by air -lifting. Equipment and materials such as compressors and pipes for air-lifting are necessary.

DPHE has staff capable of carrying out the pumping test, however they have no pumping test equipment.

Considering this situation, procurement of air-lift/pumping test unit for handpump wells is thought to be appropriate.

Those equipment and materials will be carried by cargo trucks with a crane because they are compact. Therefore, those equipment and materials are not truck-mounted.

(ii) Contents of air-lift equipment for handpump wells

i) Air-lift equipment for handpump wells

Simple equipment with single-tube method is selected for air-lifting for handpump wells since its discharge rate is not large.

The installation depth of a (single) air pipe is 100 m. The air pipe shall be a polyethylene pipe of 1" in internal diameter.

The discharge pressure of the compressor shall be not less than 0.7 MPa by considering installation depth and friction loss inside the pipes. The amount of air delivery shall be more than 5 m^3/h.

Conceptual drawing of the air lift equipment installation is shown in Figure 2.2.20.

The following air-lift equipment is selected:

- Compressor 5 m^3/h, 0.7 MPa 1 unit
- Eductor pipe 4" SGP, Thread-Socket connection 100m
- Air pipe 1"Polyethylene pipe (roll type) 100 m

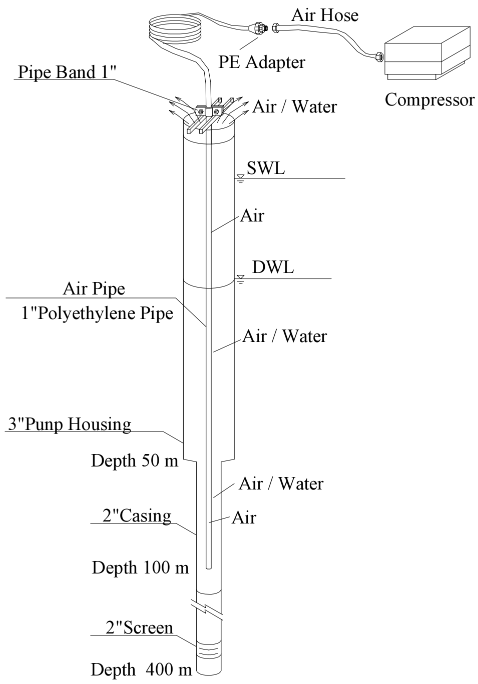


Figure 2.2.20 Conceptual Drawing of Air-Lift Equipment for Handpump Wells

- Pipe handling tools
- Appurtenant piping

ii) Pumping test equipment for handpump wells

The dynamic water level of production wells is assumed to be a maximum 40 m. The total head of the submersible pump for pumping test is 50 m with consideration of friction loss inside the riser pipes and the surface piping.

The maximum discharge rate of production wells is 1 m^3/hour. Therefore, a submersible pump, with a discharge rate of 1 m^3/h and total head is 50 m, is selected.

As it is a small pump, 1-1/2" Polyethylene pipe shall be selected as riser pipes, and the structure shall be simple.

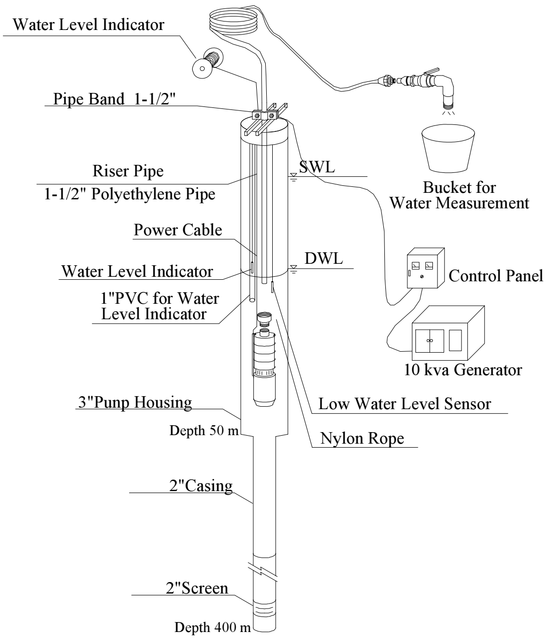


Figure 2.2.21 Conceptual Drawing of Pumping Test Equipment Installation (for Handpump Wells)

The capacity of the generator shall be 10 kva, and it is enables to operate a high capacity submersible pump (1.5 kw).

A conceptual drawing of pumping test equipment installation is shown in Figure 2.2.21.

The following pumping test equipment is selected:

- High capacity submersible pump: Discharge rate 1 m^3/h, Total head 50 m, 50 Hz, Three phases x 400 V, 1.5 kw
- Riser pipe 1-1/2" Polyethylene pipe (roll type)
- Pump control panel
- Pipe handling Tools
- Low water level sensor
- Power cable
- Surface piping
- Notch tank
- 10 kva Generator
- Water quality meter (Arsenic, Electric Conductivity, pH, Dissolved Oxygen, ORP (Oxidation-Reduction Potential)

6) Supporting vehicles

(i) Cargo truck with a crane

i) Cargo truck with a crane for production wells

(a) Verification of procurement

As shown in Table 2.2.18, one (1) production well needs totally 90 tons of equipment and materials excluding water and fuel for drilling. It is an amount equivalent to 12 trucks of 10 ton loads. During drilling works, a cargo truck with a crane is used for transportation of water (approximately 270 m^3) and fuel (approximately 30 m^3). Another cargo truck with a crane is required for equipment moving within sites and for transportation from the vicinity. However, DPHE has no suitable vehicles to allocate to the Project.

Therefore, it is considered as appropriate to provide two (2) cargo trucks with a crane.

Table 2.2.18 Quantity of Equipment to be Transported for a Production Well

Equipment	Weight (Tons)	Necessary Number of Trucks
Casing Pipes	27.8	4
Reverse Rods, Collar	22.3	3
Cement, Mud Agent	25	3
Major Equipment (excluding Air-Lift/Pumping Test Unit)	15	2
Total (Tons)	90.1	12

(b) Specification of cargo truck with crane for production well

Equipment for drilling works of production wells includes lots of heavy equipment and tools such as generator, casing pipes, reverse rods. Therefore one (1) cargo truck shall be equipped with a five (5) ton crane and another shall be mounted with a three (3) ton crane.

Therefore two (2) cargo trucks with the crane shown in Table 2.2.19 are selected.

Table 2.2.19 Specifications of Cargo Truck with Crane for Production Wells

Type	Qty.	Technical Specifications
Cargo Truck with 5 Tons Crane	1 unit	Gross vehicle weight 26 tons, Loading Capacity 10tons, 6x4, with 5 tons crane, Cargo: Length 6.9 m, Width 2.3 m
Cargo Truck with 3 Tons Crane	1 unit	Gross vehicle weight 26 tons, Loading Capacity 10tons, 6x4, with 3 tons crane, Cargo: Length 6.9 m, Width 2.3 m

ii) Cargo truck with crane for handpump wells

(a) Verification of procurement

As shown in Table 2.2.20, approximately 50 tons, equivalent to 7 trucks of 10 ton load, shall be transported for a handpump well, excluding water and fuel for drilling. During drilling works, a cargo truck with a crane is used for transportation of water (approximately 90 m^3) and fuel (approximately 14 m^3). Another cargo truck with a crane is used for equipment moving within the site and for transportation from the vicinity. Therefore, procurement of two (2) cargo trucks with a crane is verified as appropriate.

Table 2.2.20 Quantity of Equipment and Materials to be Transport for a Handpump Well

Equipment	Weight (Tons)	Necessary Number of Trucks
Casing Pipes	11	2
Reverse Rods, Collar	13.2	2
Cement, Mud Agent	8	1
Major Equipment	15	2
Total (Tons)	47.2	7

(b) Specification of cargo truck with crane for handpump well

Equipment for handpump well drilling does not include equipment, which weight is more than 3 tons. Therefore, two (2) cargo trucks equipped with three (3) tons crane shown in Table 2.2.21 are selected.

Table 2.2.21 Specifications of Cargo Truck with Crane for Handpump Wells

Type	Qty.	Technical Specifications
Cargo Truck with 3 Tons Crane	2 units	Gross vehicle weight 26 tons, Loading Capacity 10 tons, 6x4, with 3 tons crane, Cargo: Length 6.9 m, Width 2.3 m

(ii) Pick-up truck

i) Verification of procurement

For moving of drilling teams which carry out drilling works night and day, transportation in the vicinity and transport of logging equipment, two (2) pick-up trucks are required. However, DPHE has no suitable vehicles to allocate to the Project. Therefore, procurement of two (2) pick-up trucks is verified as appropriate.

ii) Specification of pick-up truck

Specification of the pick-up truck is shown in Table 2.2.22. One if for production wells and another is for handpump wells.

Table 2.2.22 Specifications of Pick-Up Truck

Type	Qty.	Technical Specifications
Double Cabin Pick-Up Truck	2 Units	Gross vehicle weight 2.5tons, Loading capacity 0.5 tons, Body: Length 4.7 m, Width 1.6 m

(iii) Water tank lorry

Two (2) water tank lorries were requested for the transportation of water for drilling works. However, it is planned to transport water for drilling by the cargo trucks with the crane using portable water tanks. Therefore, procurement of the water tank lorries are excluded from the Project.

7) Geophysical survey and logging equipment

(i) Verification of procurement

It is necessary to collect hydrogeological information such as the distribution depth of gravel layers and the target aquifers in order to formulate the drilling plan of deep wells in the Project area. It is also required to carry out well logging after completion of the drilling in order to decide the well structure.

Although DPHE has two (2) sets of geophysical survey equipment, they are allocated to other projects, therefore, it is not possible to use them in this Project. Regarding logging equipment, DPHE will procure two (2) sets of machines for other project. However, they have not been purchased yet (as of the end of January 2012).

DPHE has Hydrogeologists for the geophysical survey and well logging, therefore, it is possible to carry out the geophysical survey and well logging by themselves if the technical transfer is appropriately carried out.

From the above discussion, it is appropriate to procure one (1) set of geophysical survey and logging equipment.

(ii) Specification of resistivity survey equipment

The geophysical survey equipment should be the resistivity survey equipment with interpretation software which enables vertical electrical sounding to depth of the maximum 500 m.

Output voltage shall be not less than 400 V and output current shall be not less than 1,000 mA.

Standard accessories such as measuring cable, battery, battery charger, computer, GPS shall also be procured.

(iii) Specification of logging equipment

The logging equipment shall be capable of detecting a depth of 400 m in the borehole of which diameter is 20” or more.

Items of measurement are SP (spontaneous potential), resistivity (short and long) and natural gamma ray.

Standard accessories such as logging prove, winch, battery, battery charger and computer shall be selected.

8) Workshop Tools

(i) Verification of procurement

The workshop is indispensable for operation and maintenance of the equipment if the Project is implemented. DPHE has a plan to provide a new workshop, however, DPHE has not necessary workshop tools. Therefore, it is considered as appropriate to provide workshop tools from the viewpoint of smooth implementation of the Project.

(ii) Composition of workshop tools

The specifications of the workshop tools for the maintenance of the drilling equipment are as follows.

i) Electric/engine tools

Electric/engine tools for the maintenance of an engine welder arc welding tools, grinder, and compressor.

ii) Handling tools

Handling tools are for moving and transportation of heavy equipment and materials such as lever blocks, hand pullers, wire slings, nylon slings and shackles.

iii) Mechanical tools

Mechanical tools for the maintenance of machines and machining are composed of tool set spanners, wrenches and hummers.

iv) Other tools

Other tools are electric testers, saws, levels, etc.

v) Storage

Storage tools are racks and tool boxes for storing tools in the store house.

vi) 20 feet Container

Three (3) units of 20 feet containers shall be installed for storing of spare parts.

9) Drilling materials for technical transfer

The following drilling materials for drilling of three (3) wells for technical transfer shall be provided.

(i) Drilling bit material

Geological formations to be drilled in the Project are mainly sand/clay layers. Blade bits are used for the drilling formations. However, consolidated hard sand formation distributes n the certain areas in Nawabganj District. Tri-cone bits are used to drill in such hard formation. These blade bits and tri-cone bits shall be included in standard operation accessories for production wells (equipment No.: 1-1-2, Table 2.2.30) and for handpump wells (equipment No.: 1-2-2, Table 2.2.30).

Blade bits are mostly used in the Project. The edge of the blade bits will be worn out by the drilling. Therefore, it is necessary to replace the metal chips installed at the edge of the blade bits for the future. For the replacement of metal chips, tungsten carbide metal chips corresponding to each bit size, brazing glue, composite rods for super hard facing (super hard tungsten carbide chips), overlay rods (supporting brazing glue for composite rods) and flux (coating material) are necessary.

Bit materials for wells shown in Table 2.2.23 shall be provided.

Table 2.2.23 List of Bit Materials

Material	Unit	Quantity
Metal Chip for 28"Blade Bit	sets	2
Metal Chip for 24"Blade Bit	sets	2
Metal Chip for 20"Blade Bit	sets	5
Metal Chip for 17-1/2"Blade Bit	sets	2
Metal Chip for 14-3/4"Blade Bit	sets	3
Metal Chip for 10-5/8"Blade Bit	sets	11
Composit Rod	kg	100
Overlay Rod	kg	10
Flux (100g/can)	cans	10

(ii) Casing material

Technical specifications and necessary quantity of casing pipes and screen pipes for drilling of three (3) wells are shown in Table 2.2.24. Unit length is 6.0 m for 26" and 22" casing pipes and 5.5 m for other sizes. The damage rate is estimated as 15%. It is included in the total length of pipes per well.

Table 2.2.24 Necessary Quantity of Casing Materials for Technical Transfer

Item	Production Well					Handpump Well				
Casing Diameter	26"	22"	12"	6"	6"	16"	12"	3"	2"	2"
Casing Type	STK Steel Casing	STK Steel Casing	STPG Sch-40 Steel Casing	STPG Sch-40 Steel Casing	SUS Wire Wound Screen	SGP Steel Casing	STPG Sch-40 Steel Casing	STPG Sch-40 Steel Casing	STPG Sch-40 Steel Casing	SUS Wire Wound Screen
Unit Length (m)	6	6	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
Installation Length per well (m)	10	100	50	308	22	10	100	50	308	22
Damage Rate	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Necessary Length per well (m)	12	115	58	354	25	12	115	58	354	25
Numbers of Pieces per well	2	20	11	65	5	3	21	11	65	5
Numbers of Well	2	2	2	2	2	1	1	1	1	1
Total Numbers of Pieces	4	40	22	130	10	3	31	11	65	5

These casings and screen pipes are procured in Japan for smooth implementation of the technical transfer. However, after the completion of technical transfer, DPHE will continue the implementation of their action plan using local casing pipes. Therefore, the casing bands shall be of the type which can be commonly used for both Japanese products and local products.

Technical specifications of local casing pipes are shown in Table 2.2.25. The difference in outer diameter between Japanese casing pipes and local casing pipes is 5.3 mm in maximum. Therefore, casing bands to be procured in the Project can be commonly used for both products.

Table 2.2.25 Specifications of Casing Pipes (Local Products)

Drilling Stage	Production Well				Handpump Well			
	1st	2nd	3rd		1st	2nd	3rd	
Installation Depth (m)	0～10	0～100	0～50	50～380	0～10	0～100	0～50	50～385
Diameter	26"	22"	12"	6"	16"	12"	3"	2"
Pipe Material	26"API LinePipe 5L-B	22"APILinePipe5L-B	12-3/4"APILinePipe 5L-B	6-5/8"APILinePipe 5L-B	16"APILinePipe5L-B	12-3/4"APILinePipe5L-B	3-1/2"APILinePipe 5L-B	2-3/8"APILinePipe 6L-B
Outside Diameter(mm)	660.0	559.0	323.8	168.3	406.0	323.8	88.9	60.3
Inside Diameter (mm)	637.8	538.4	303.2	154.1	390.2	303.2	77.9	52.5
Thickness(mm)	11.1	10.3	10.3	7.1	7.9	10.3	5.5	3.9
Connection	both bevel ends	both bevel ends	threads	threads	both bevel ends	both bevel ends	threads	threads
Unit Weight (kg/m)	177.62	139.37	79.65	28.22	77.63	79.65	11.31	5.42
Length (m)	10	100	50	330	10	100	50	330
Weight (tons)	1.8	13.9	4.0	9.3	0.8	8	0.6	1.8
Total Weight (tons)	1.8	13.9	13.3		0.8	8	2.4	

(iii) Mud agent

Production wells and handpump wells are drilled using bentonite-CMC mud. The necessary quantity of bentonite is estimated as shown in Table 2.2.26. The necessary quantity of CMC is estimated as 0.8% of the total quantity of bentonite.

Table 2.2.26 Necessary Quantity of Mud Agent (Bentonite and CMC)

Item		Bentonite	CMC
Production Well	Quantity per well (ton)	20	0.16
	Number of Wells	2	2
	Total Quantity (ton)	40	0.32
Handpump Well	Quantity per well (ton)	5.1	0.04
	Number of Wells	1	1
	Total Quantity (ton)	5.1	0.04
Grand-Total (ton)		45.1	0.36
Unit Weight per Bag (ton)		25	10
Number of Bags		1,804	36

(iv) Consumable materials

In order to complete deep wells, the following materials are necessary besides above-mentioned bit materials, casing materials and mud agent.

It is difficult for the supplier to deliver all of the materials at once. The necessary quantity of materials for each deep well shall be supplied according to the progress of the drilling works. Therefore, these materials will be purchased in Bangladesh and supplied by the supplier during the period of the technical transfer. The transportation materials will be carried out by DPHE using cargo trucks with the crane to be procured in the Project.

i) Cement

Cement will be supplied for isolation cementing (sealing) between the shallow aquifer and the deep aquifer and for surface cementing to prevent the inflow of domestic sewage. The necessary quantity of cement is shown in Table 2.2.27.

Table 2.2.27 Necessary Quantity of Cement

Item		Necessary Quantity of Well Gravel
Production Well	Quantity per well (ton)	7.1
	Number of Wells	2
	Total Quantity (ton)	14.2
Handpump Well	Quantity per well (ton)	2.8
	Number of Wells	1
	Total Quantity (ton)	2.8
Grand-Total (tons)		17
Unit Weight per Bag (kg)		50
Number of Bags		340

ii) Well gravel

As shown in Figure 2.2.8 and Figure 2.2.11, annular space between the bore wall and the screen pipes shall be packed with gravel in order to prevent collapse of bore wall and to filter water from the aquifer. The required quantity of gravel is shown in Table 2.2.28.

Table 2.2.28 Necessary Quantity of Gravel

Item		Necessary Quantity of Well Gravel
Production Well	Quantity per well (m^3)	23.31
	Number of Wells	2
	Total Quantity (m^3)	46.62
Handpump Well	Quantity per well (m^3)	6.91
	Number of Wells	1
	Total Quantity (m^3)	6.91
Grand-Total (m^3)		53.53

iii) Fuel and oil

Fuel and oil for operating machinery and vehicles for transportation of staff and materials will be provided by the supplier. The necessary quantity of fuel is shown in Table 2.2.29.

Table 2.2.29 Necessary Quantity of Fuel

Item		Necessary Quantity of Fuel
Production Well	Quantity per well (L)	30,535
	Number of Wells	2
	Total Quantity (L)	61,070
Handpump Well	Quantity per well (L)	13,995
	Number of Wells	1
	Total Quantity (L)	13,995
Grand-Total (L)		75,065

Besides fuel, oil for operation and maintenance of machines such as grease, molybdenum grease, engine oil, gear oil and compressor oil will be also provided by the supplier.

iv) Gas welding tools

Gas welding tools such as cylinders and regulators of oxygen and acetylene, hoses, burners, nozzles are needed for machining and repairing of blade bits and casing preparations. However, their specifications are different between Japanese products and local products. Therefore, three (3) sets of above-mentioned gas welding tools will be purchased in Bangladesh and provided by the supplier for drilling teams and the workshop.

Oxygen and acetylene will be refilled by the supplier according to the situation of the drilling works during the technical transfer.

v) Miscellaneous materials

Installation of the drilling equipment, mud and water pipe lying, electric cabling, construction of temporary houses is needed at each drilling site. However, the required materials shall be different at each site. Therefore, miscellaneous materials such as piping materials, lumber, steel product and electrical materials are constantly needed.

Such miscellaneous materials will be provided by the supplier during the technical transfer.

10) Spare parts

Spare parts for two (2) years shall be procured for engines or motor powered machineries, Supporting Vehicles, pumps, the geophysical survey equipment and the logging equipment.

11) Spares for emergency

In the Project, one (1) set of three (3) types of submersible pump, which are of high, medium and low capacities, are procured. In order to cope with the breakdown of these pumps during the pumping test, one (1) spare pump for each type should be procured as well.

(3) List of Equipment to be Procured in the Project

The list of equipment to be procured in the Project is shown in Table 2.2.30..

Table 2.2.30 List of Equipment to be Procured (1/2)

Equipment	Unit	Qty.	Technical Specifications
1. Drilling Equipment			
1-1 Truck-mounted Drilling Rig and Tools (20" x 400 m) (for production well)			
1-1-1 Truck-mounted Drilling Rig (for production Well)	unit	1	Drilling Capacity: 400 m with 28" to 20" borehole with 6" O.D. reverse rod by air-lift reverse rotary driling method (maximum 30 m by direct rotary drilling method) Mast: Hook load capacity 32,000 kg Drive Head: Loading capacity 25,000 kg Drawworks: Max. single line pull 8,000 kg (24,000 kg by 3 lines) Mud Pump: Duplex piston pump, Delivery 1,500 L/min, Pressure 20 kg/cm^2
1-1-2 Standard operating accessories (for Production Well)	set	1	6"Reverse Rod, Reverse Collar, Sub, Bit etc.
1-1-3 Handling Tools (for production well)	set	1	Casing Band, Wire Sling, Spanner etc.
1-1-4 Mud water controle equipment (for production well)	set	1	Submersible Sand Pump, Mud Screen, Mud Mixer, Appurtenant Piping etc.
1-1-5 Cementing equipment	set	1	Tremie Pipe, Cementing Pump
1-1-6 Power distribution equipment (for Production well)	set	1	Generator (125 kva), Distribution Panel, Distribution Cable, Light etc.
1-1-7 Water supply equipment (for production well)	set	1	Portable Water Tank, Collapsible Working Water Tank, Water Supply Pump, Appurtenant Piping etc.
1-1-8 Fishing tools (for production well)	set	1	Band for 6"Reverse Rod, Hydraulic Jack etc.
1-1-9 Mechanical equipment (for production well)	set	1	Engine Welder, Cutting Machine
1-1-10 Other equipment (for production well)	set	1	Tools etc.
1-2 Truck-mounted Drilling Rig and Tools (10-5/8" x 400 m) (for hand pump well)			
1-2-1 Truck-mounted Drilling Rig (for handpump Well)	unit	1	Drilling Capacity: 400 m with 17-1/2" to 10-5/8" borehole with 4-3/4" O.D. drill pipe by direct rotary driling method Mast: Hook load capacity 24,000 kg Drive Head: Loading capacity 14,000 kg Drawworks: Max. single line pull 6,000 kg (18,000 kg by 3 lines) Mud Pump: Duplex piston pump, Delivery 1,200 L/min, Pressure 20 kg/cm^2
1-2-2 Standard operating accessories (for handpump Well)	set	1	4-3/4"Drill Pipe, Drill Collar, Sub, Bit etc.
1-2-3 Handling Tools (for handpump well)	set	1	Casing Band, Wire Sling, Spanner etc.
1-2-4 Mud water controle equipment (for handpump well)	set	1	Submersible Sand Pump, Mud Mixer, Appurtenant Piping etc.
1-2-5 Cementing equipment	set	1	Tremie Pipe, Cementing Pump
1-2-6 Power distribution equipment (for handpump well)	set	1	Generator (50 kva), Distribution Panel, Distribution Cable, Light etc.
1-2-7 Water supply equipment (for handpump well)	set	1	Portable Water Tank, Collapsible Working Water Tank, Water Supply Pump, Appurtenant Piping etc.
1-2-8 Fishing tools (for handpump well)	set	1	Inside Tap, Outside Tap, Band for 4-3/4"Drill Pipe, Hydraulic Jack etc.
1-2-9 Mechanical equipment (for handpump well)	set	1	Engine Welder, Cutting Machine
1-2-10 Other equipment (for handpump well)	set	1	Tools etc.
1-3 Truck-mounted Air-Lift/Pumping Test Unit			
1-3-1 Air compressor (for production well)	unit	1	12 m^3/min., 12 bar, 110 kW
1-3-2 Cargo truck for mounted air lift / Pumping test unit (for production well)	unit	1	GVW 26 tons、Loading Capacity 10 tons、6 x 4 drive、with 5 tons crane, Cargo width 2.3 m, Length 6.9 m
1-3-3 Air lift equipment (for production well)	set	1	BQ Air-Pipe, Air-Lift Head
1-3-4 Pumping test equipment (for production well)	set	1	High Capacity Submersible Pump (80 m^3/h、Total Head 50 m、3 phases, 400 V、18.5 kW)、 Medium Capacity Submersible Pump (40 m^3/h、Total Head 50 m、3 phases, 400 V、11 kW)、 Riser Pipe 4"SGP Thread, w/Socket
1-3-5 Generator for pumping test (for production well)	unit	1	45 kVA、50 Hz、3 phases, 400 V
1-4 Air Compressor for hand pump well			
1-4-1 Air compressor (for handpump well)	unit	1	5 m^3/min.、7 bar、36 kW
1-4-2 Air lift equipment (for handpump well)	set	1	Air-Lift Head、1"PE Air Pipe
1-4-3 Pumping test equipment (for handpump well)	set	1	Low Capacity Submersible Pump (1.0 m^3/h、Total Head 50 m、3 phases, 400 V、1.5 kW)
1-4-4 Generator for pumping test (for handpump well)	unit	1	10 kVA、50 Hz、3 phases, 400 V、

Table 2.2.30 List of Equipment to be Procured (2/2)

Equipment	Unit	Qty.	Technical Specifications
2. Supporting Vehicle			
2-1 10 Ton Cargo Truck with 3 Ton Crane (For Production Well)			
2-1-1 Truck-Mounted 5 tons Crane Truck	unit	1	GVW 26 tons, Loading Capacity 10 tons、6 x 4 drive, w/ 5 tons crane, Cargo width 2.3 m, length 6.9 m
2-2 10 Ton Cargo Truck with 3 Ton Crane (For Production Well)			
2-2-1 Truck-Mounted 3 tons Crane Truck	unit	3	GVW 26 tons, Loading Capacity 10 tons、6 x 4 drive, w/5 tons crane, Cargo width 2.3 m, length 6.9 m
2-3 Pick-up Truck			
2-3-1 Pick-up Truck (for production well)	unit	2	Double Cabin, 4 x 4 drive, GVW 2.5 t. Loading Capacity 0.5 ton, Body Length 4.7 m, width 1.6 m
3. Geophysical Survey Equipment			
3-1 Resistivity Survey Equipment (with analysis software)			
3-1-1 Resistivity Survey Equipment (with analysis software)	set	1	Survey Method：Wenner Method Sounding Survey Depth：Maximum 500 m Output Voltage：not less than 400 V Output Current： not less than 1,000 mA
3-2 Logging Equipment (with analysis software)			
3-2-1 Logging Equipment (with analysis software)	set	1	Applicable Well Diameter ：φ20” Measuring Depth ： not less than 400 m Measuring Item ： Resistivity (Short and Long), SP, Natural Gamma
4. Workshop tools			
4-1 Workshop tools			
4-1-1 Electric / Engine tools	set	1	Engine Welder, Threading Machine etc.
4-1-2 Handling tools	set	1	Wire Sling, Lever Block etc.
4-1-3 Mecanical tools	set	1	Spanner, Wrench, Vice etc.
4-1-4 Other workshop tools	set	1	Electric Tester, Electric Code Reel, Annealed steel wire etc.
4-1-5 Storage cabinet	set	1	Shelf for Tools, steel rack etc.
4-1-6 Steel container 20'	unit	1	Used 20' Container
5. Drilling Materials for Test Well Drilling			
5-1 Drilling Materials for Technical Transfer			
5-1-1 Casing material	lot	1	Steel Casing, Stainless Screen
5-1-2 Drill bit material	lot	1	Metal Chip, Composit Rod
5-1-3 Material for mud water	lot	1	Bentonite, CMC etc.
6. Spare Parts for Equipment			
6-1 Spare Parts			
6-1-1 Spare parts < Truck-mounted Drilling Rig and Tools (20" x 400 m) (for production well) >	lot	1	
6-1-2 Spare parts < Truck-mounted Drilling Rig and Tools (10-5/8" x 400 m) (for hand pump well) >	lot	1	
6-1-3 Spare parts < Cargo truck for Air-Lift/Pumping Test Unit >	lot	1	
6-1-4 Spare parts < Air-Lift/Pumping Test Unit (for Production well) >	lot	1	
6-1-5 Spare parts < Air-Lift/Pumping Test Equipment (for Handpump Well) >	lot	1	
6-1-6 Spare parts < Cargo Truck with 5 Ton Crane (For Production Well) >	lot	1	
6-1-7 Spare parts < Cargo Truck with 3 Ton Crane (For Production Well) >	lot	3	
6-1-8 Spare parts < Pick-up Truck >	lot	2	
6-1-9 Spare parts < Resistivity Survey Equipment (with analysis software) >	lot	1	
6-1-10 Spare parts < Logging Equipment (with analysis software) >	lot	1	
6-1-11 Spare parts < Workshop tools >	lot	1	
7. Spare for emergency			
7-1 Spare for emergency			
7-1-1 Spare for emergency < Submersible pump >	lot	1	

2.2.3 OUTLINE DESIGN DRAWING

The conceptual drawings for the production well and handpump are shown in Figure 2.2.22 and Figure 2.2.23.

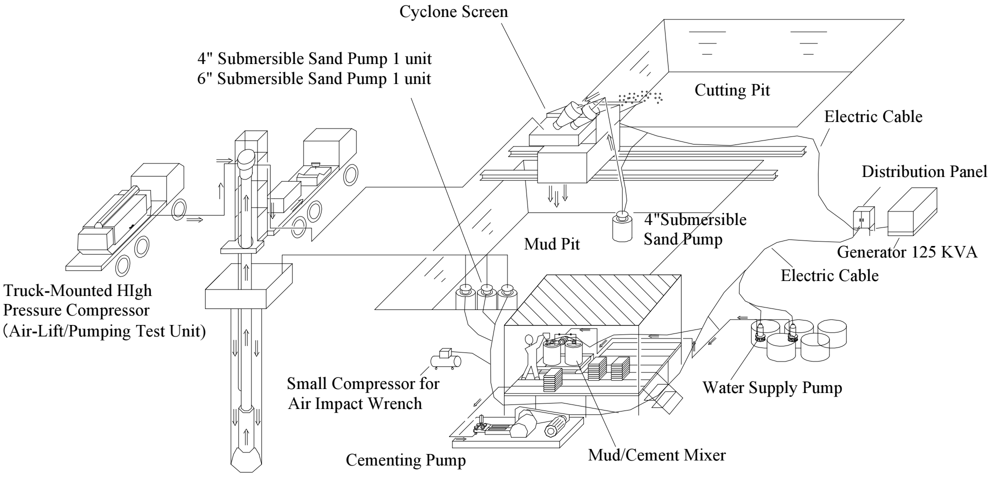


Figure 2.2.22   Conceptual Drawing of Arrangement of Drilling Equipment on Site (for Production Wells)

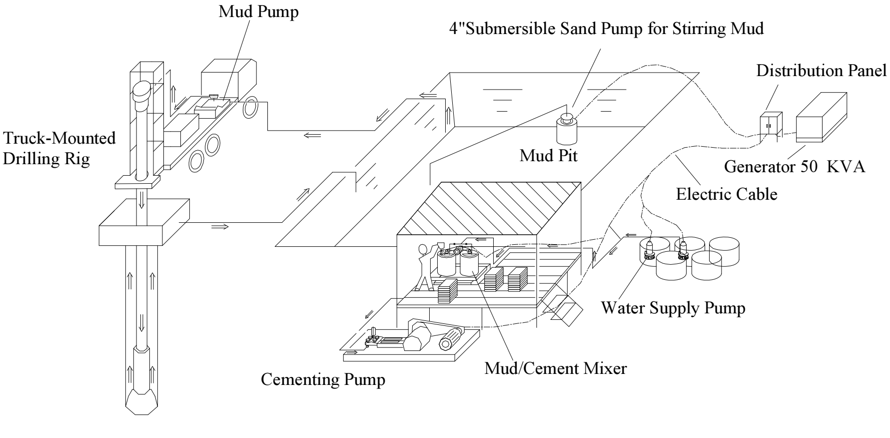


Figure 2.2.23   Conceptual Drawing of Arrangement of Drilling Equipment on Site (for Handpump Wells)

2.2.4 IMPLEMENTATION PLAN

(1) Implementation Policy

Equipment for this Project will be procured in Bangladesh, Japan or third countries for aspects of effective procurement processes, O&M and price. In the procurement processes, availability of consumables, spare parts and an O&M structure should be considered. In addition, equipment to be procured should adapt to conditions of the usage environment.

(2) Implementation Conditions

1) Preparation of the Bangladesh Side

The consignee of the equipment is DPHE, implementation agency of the Project.

The Bangladesh side should make sure smooth implementation for import of equipment such as custom clearance and registration of vehicles since dispatched engineers from the supplier conduct commissioning such as unpacking, checking and initial operation training of equipment before delivery to DPHE.

The Bangladesh side also should take note of effective procedures for import permission, tax exemption and custom clearance.

2) Transportation of equipment

The supplier should confirm transportation conditions and make sure prompt custom clearance and delivery. Moreover, they should take care of safety aspect during transportation.

(3) Scope of Works

Procurement allocations of major equipment are shown in Table 2.2.31.

Equipment will be basically procured in Japan. However, pick-up trucks will be procured from Thailand since they are manufactured by Japanese companies there.

Some materials to be used for activities of the technical transfer such as cement, gravel for packing, gas welding materials and fuel are not included as equipment to be procured, and they will be provided by the supplier during drilling works for the technical transfer.

Table 2.2.31 Procurement Allocation of Major Equipment

Equipment		Procurement condition in Bangladesh	Country of Procurement
1.	Drilling equipment		
	Drilling rigs and standard drilling accessories	Drilling rigs are not manufactured in Bangladesh. Therefore, they will be procured in Japan considering aftercare.	Japan
	Air-lift/pumping test equipment	Generator and compressor are not manufactured in Bangladesh. Therefore, it is impossible to mount them on cargo trucks with crane in Bangladesh.	Japan
2.	Supporting Vehicles (Pick-up trucks and cargo trucks with crane)	They are not manufactured in Bangladesh. There is an agent of Japanese company in Dhaka.	Thailand (Manufactured by Japanese company)
3.	Geophysical survey equipment and logging equipment		
	Resistivity survey equipment	They are not manufactured in Bangladesh. Therefore, they will be procured in Japan considering aftercare.	Japan (Japanese, European or American Products)
	Logging equipment	They are not manufactured in Bangladesh. Therefore, they will be procured in Japan considering aftercare.	Japan (Japanese, European or American Products)
4.	Workshop tools	It is desired to procure Japanese products because of aftercare.	Japan
5.	Drilling Materials for technical transfer		
	Drill bit and casings	Although local companies manufacture certain sizes of steel pipes, there is no specialized supplier in Bangladesh, who can supply them in a lump. Therefore, delivery time and/or quality are unstable.	Japan
	Mud agent (bentonite, CMC, well cleaner)	There is no manufacturer in Bangladesh. Although it is available to procure an Indian product in a local market. There is no specialized supplier in a lump. Therefore, delivery time and/or quality are unstable.	Japan
	Cement	Available to procure since they are produced in Bangladesh.	Bangladesh (Provided by the equipment suppliers during drilling works for technical transfer)
	Well gravel	Available to procure since they are manufactured in Bangladesh.	Bangladesh (Provided by the equipment suppliers during drilling works for technical transfer)

(4) Consultant Supervision

The consultants and the equipment suppliers should supervise the following procedures in order to efficiently implement bid, design, procurement, manufacture, transportation and delivery.

1) Supervision by the consultant

- Confirmation and collation of shop-drawings submitted by the supplier
- Discussion with DPHE about acceptance of equipment before shipment
- Inspection of manufactured equipment (by witnessing inspection or review of reports)
- Inspection of equipment before packing (by review of inspection reports)
- Meeting with inspectors for Witnessing inspection of equipment quality before shipment
- Supervision of carrying-in and unpacking
- Supervision of initial handling training
- Supervision of pre-delivery inspection
- Witness of delivery of equipment
- Confirmation of completion of equipment operation instructions

2) Supervision by the supplier

- Preparation, confirmation and collation of shop-drawings
- Management of equipment manufacturing
- Inspection of manufactured equipment
- Inspection of equipment before packing
- Witness of pre-shipment inspection
- Carrying-in and unpacking
- Adjustment and test operation of the equipment
- Initial handling training
- Pre-delivery inspection
- Delivery of equipment to DPHE
- Operational instruction of the equipment through drilling works of three (3) wells to DPHE (drilling skills and maintenance methods for equipment)

(5) Quality Control Plan

The following inspection will be implemented for quality control by the supplier and the consultant.

1) Confirmation and collation of shop-drawings

Inspectors of the suppliers and the consultant shall review and modify shop-drawings prepared by the supplier in order to assure the quality of functional specifications.

The process will take 0.5 month for the inspectors of the supplier and 0.4 month for the consultant's inspectors.

2) Product Inspection

Consultants will carry out the factory inspection of manufactured equipment based on approved shop-drawings. The inspection will be implemented by witness inspection of the factory or review of inspection reports submitted by manufacturers. The consultants will inspect drilling rigs, drilling tools, generators and compressors by witness inspection of the factory.

The process will take 0.4 month for the inspectors of the suppliers and the consultant respectively.

3) Inspection before shipment

Number and quantity of procured equipment will be inspected before packing.

The necessary period for this inspection will take 0.23 month for the inspectors of the supplier and the consultant respectively.

4) Equipment collation check before loading

A third party organization will conduct pre-shipment inspection for equipment to be procured in Japan and in third countries (e.g. pick-up trucks manufactured in Thailand).

Inspectors of the supplier shall witness this inspection for equipment to be procured in Japan.

This process needs 0.1 month for the inspector of the suppliers.

5) Delivery Inspection in Bangladesh

After adjustment and test operation, procurement supervisors of the supplier will inspect equipment with DPHE staff, the procurement engineers of the consultant and residential procurement engineers of the consultants. It will be conducted for 0.5 month.

After the delivery inspection, the equipment will be delivered to DPHE.

(6) Procurement Plan

Drilling equipment, supporting vehicles, geophysical survey and logging equipment, workshop tools and drilling materials for the technical transfer will be procured in Japan. Regarding supporting vehicles, pick-up trucks manufactured by Japanese company will be procured in Thailand.

Trucks will be transported by a conventional ship from Yokohama Port to Chittagong Port by sea. Afterwards, they will be transported to Dhaka in-land. Other equipment will be transported by a container ship by the same route with trucks.

The conventional ship has monthly operation and the container ship has almost daily service between Yokohama Port and Chittagong Port.

Pick-up trucks will be transported by container ship from Bangkok Port or Laem Chabang Port to Dhaka through Chittagong Port.

The container ship has a weekly service between Thailand and Bangladesh.

(7) Operational Guidance Plan

1) Initial operation training plan

Drilling instructors of the supplier shall have technical training about major machineries such as two (2) drilling rigs, supporting vehicles, generators and compressors to DPHE's staff after carrying in, unpacking, test operation and adjustment. Meanwhile, the equipment maintenance instructors shall give guidance about equipment maintenance to the DPHE's staff.

In addition, initial operation training of geophysical and logging equipment will be carried out by the manufacturer's instructors in the same period.

2) Operation Instruction Plan

After initial handling training, DPHE will drill two (2) production wells and one (1) handpump well (totally three wells) for the technical transfer during six (6) months.

Drilling instructors and equipment maintenance instructors of the supplier will provide technical training about drilling and equipment maintenance techniques to DPHE's drilling teams and workshop mechanics during this period.

The consultants and the equipment suppliers should supervise the following procedures in order to efficiently implement bid, design, procurement, manufacture, transport and delivery.

(8) Soft Component (Technical Assistance) Plan

1) Background of soft component plan

"The project for the Ground Water Investigation and Development of Deep Ground Water Source in Urban and Rural Areas in the People's Republic of Bangladesh" is to provide drilling rigs, supporting vehicles and geophysical survey equipment in order to construct deep wells in the area where shallow ground water is contaminated by arsenic and gravel layers are distributed above the arsenic free deep aquifer.

In Bangladesh, water supply facilities with shallow ground water source became familiar, and water supply coverage by tube wells reached 97% in early1990s. However, it was confirmed in 1993 that the shallow ground water was contaminated by arsenic. The water supply by tube wells was, however, interfered with after contamination of shallow ground water by arsenic was confirmed in 1993. A survey by the British Geological Survey (BGS) and

Department of Public Health Engineering (DPHE) revealed the surface water was contaminated in wide areas in Bangladesh. Then, the arsenic content of shallow ground water was more than the Bangladesh standard (0.05 mg/L) in about 29.3% of the wells out of 5 million wells. Furthermore, it was confirmed that about 33 million people were exposed to arsenic and about 38,000 people had been poisoned. Afterward, water supply coverage was suddenly decreased down to less than 70%.

Deep wells have been drilled as an alternative source of water supply since about 2000. The main alternative water source has been deep ground water until now. Reflecting this situation, the National Strategy for Accelerated Poverty Reduction (FY2009-2011) emphasized the importance of studying the development possibility of the deep ground water as an alternative water source.

In December 2011, Sector Development Plan (FY2011-25) (SDP) officially launched: SDP shows the development plan for the water and sanitation sector for 15 years to 2025.

A ground water study by JICA, “The study on the ground water development of deep aquifers for safe drinking water supply to arsenic affected areas in western Bangladesh” was carried out covering Jessore, Jhenaidah and Chuadanga Districts during the period from 2000 to 2002. The study confirmed the existence of arsenic free ground water in the deep aquifer distributed more than 200m depth below the gravel layer. At the same time, the study also revealed continuity of the deep aquifer by interpreting the results of test well and data of existing wells. Therefore, the study suggested the possibility for arsenic free water in the deep aquifer distributed in the area where no test well was drilled.

Considering the situation above, DPHE has been developing deep ground water. It is necessary to construct deep wells which reach the deep aquifer penetrating gravel layers for safe water supply in the target area. However, construction of deep wells has not been developed in the target area because the capacity of drilling rigs of DPHE is not enough to drill gravel layers.

The Project targets to improve safe water supply coverage in the target area by accelerating of development of deep ground water through providing drilling rigs, capable to penetrate gravel layers, and to improve the capacity of DPHE’s staff on deep well drilling techniques.

It is required to drill deep wells with a maximum depth of 400m for developing deep ground water in the target area. In addition, sealing between shallow aquifer and deep aquifer is indispensable to prevent mixing of ground water in both aquifers.

DPHE has been constructing wells by employing private drilling companies. Private drilling companies borrow two (2) rigs from DPHE and carry out drilling works together with a rig operator of DPHE. The drilling supervisor of DPHE sometimes visits the drilling sites to manage the works. Although DPHE has staffs which have experience of actual drilling works and supervision at the sites, DPHE has no techniques and drilling rigs to construct deep wells penetrating gravel layers in the target area. Private drilling companies also do not possess such techniques and drilling rigs, therefore, it is impossible to develop deep ground water in the target area.

About 5.26 million people are obliged to use arsenic contaminated water in the target area. It is desired that private drilling companies move into the drilling works to develop deep ground water in the target area.

In order to realize this concept, DPHE will carry out the Action Plan and establish the drilling techniques to construct deep wells in the area where gravel layers are distributed. As mentioned above, DPHE has experience to supervise private drilling companies, but DPHE has no experience to manage its own drilling teams. Drilling rigs are lent to private drilling companies and they are maintained by private drilling companies. Private drilling companies do not have experience to drill to the depth of 400m penetrating gravel layers. Therefore, it is necessary for two (2) drilling teams of DPHE to continue the construction of deep wells till such drilling technique takes root in Bangladesh. For this purpose, the drilling teams of DPHE are requested to acquire techniques for construction of deep wells, penetration through grave layers, seal between the shallow aquifer and the deep aquifer, pumping test and maintenance of rigs. For effective implementation of the Action Plan, it is necessary for the responsible staff of DPHE to master the skills for planning and management on deep well drilling projects to be carried out by the own drilling teams. Drilling techniques will be transferred by drilling engineers and mechanical engineers to be despatched by the supplier. Skills for planning and management will be transferred by engineers of the consultant through the soft component, since transfer of those skills is difficult for the supplier's engineers.

For construction of deep wells, it is required to select the drilling sites by ground water investigation including geophysical survey and to formulate a drilling plan. However, no Hydrogeologist of DPHE has enough skills of geophysical survey.

Therefore, the techniques for planning and management of deep well drilling and geophysical surveys will be transferred to the staff of DPHE through the soft component. Contents of technical transfer are shown in Table 2.2.32.

Table 2.2.32 Items and Contents of the Soft Component Program

Items	Contents of Technical Instruction
(1) Drilling Plan and Management Instruction	1) Drilling Plan (Field and Classroom) - Well Design, Process Planning, Quality Management Program, Procurement Planning, Equipment Maintenace and Management Planning 2) Drilling Management(Field and Classroom) - Drilling Management, Drilling Record Management - Procurement and Transport Management -Equipment Maintenace and Management 3) Pumping Test (Field and Classroom) 4) Workshop Operation
(2) Geophysical Survey Instruction	1) Survey Plan (Classroom) 2) Measurement Procedure（Data Acquisition） (Field) 3) Data Analysis (Field and Classroom) 4) Hydrogeological Interpretation(Classroom) 5) Maintenance of Equipment (Workshop)

Among the techniques to be transferred by the supplier's engineers, techniques related to prevention of obstacles for ground water development such as drilling of gravel layers and sealing will be transferred to DPHE's staff as well as the staff of private drilling companies, in order to raise awareness of such techniques. The cost of participation in the soft component for private drilling companies will be borne by the Bangladesh side. Selection of participants in the soft component from the private drilling companies shall be fairly conducted.

2) Objective of soft component

The objective of the soft component is that the engineers of DPHE master the techniques for the appropriate development of deep ground water by themselves. DPHE should advance the deep ground water development in the target area by using the equipment of geophysical surveys and the drilling rigs which are procured when the Project is implemented. DPHE has no experience of geophysical surveys for ground water development and drilling of deep wells which reached to the deep aquifer below the gravel layers. Therefore, the training of geophysical surveys and formulation of the drilling plan and management will be carried out in the soft component.

For implementation of the Action Plan using the equipment to be procured in the Project, DPHE is planning to develop an organization shown in Figure 2.2.24.

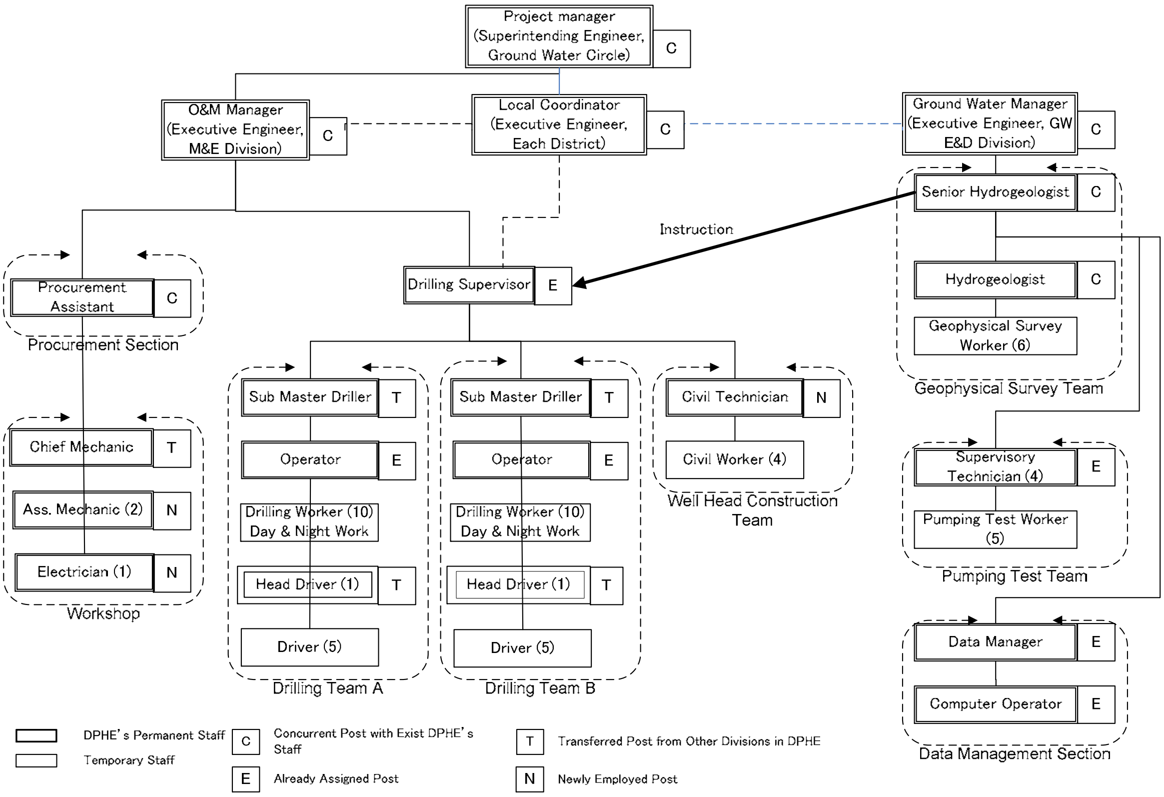


Figure 2.2.24 Implementation System for Action plan of DPHE (Draft)

A hydrogeologist will be the target trainee for geophysical survey technical transfer. The trainee will be in charge of planning and implementation of geophysical surveys, and formulation of the drilling plan based on the interpretation of the results of geological surveys. Engineers who manage drilling works, pumping tests and workshops, listed in Table 2.2.34, are the target trainees on formulation of the drilling plan and management. Figure 2.2.25 shows the process related to drilling works. In the figure, skills related to “2. Drilling Work” is work at a site and other processes are the ones which will be implemented by these engineers at management level.

Table 2.2.33 shows the current skill level and the experience of the trainees in each department and their target levels to be achieved by the end of technical transfer and within three (3) years after the completion of the soft component.

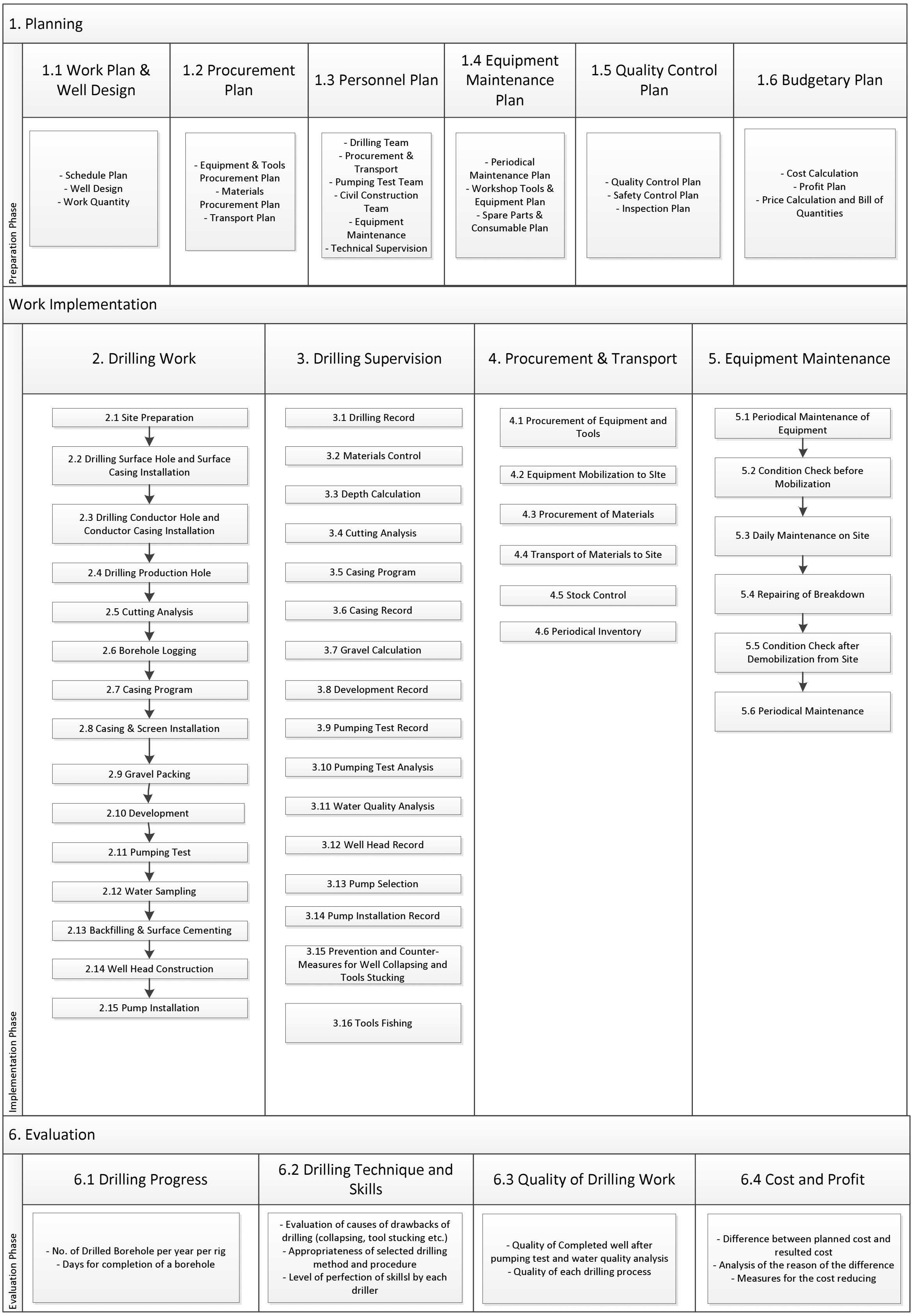


Figure 2.2.25 Processes of Drilling Work

Table 2.2.33 Current Level of the Trainees and Target Achievement

Item of technical instruction	Experience and current level of the trainees	Technical level to be achieved by soft component	Technical level to be achieved within three years after the completion of the soft component
Geophysical survey	No experience of geophysical survey.	To learn the process of formulation of geophysical survey plan, implementation of geophysical survey, and interpretation and hydrogeological interpretation of the acquired data.	To acquire the skill for the appropriate work implantation and interpretation through the experience of the process mentioned in the column on the left side.
Drilling plan and management	They have experience of work management through contract works of private drilling companies. However, no experience with drilling work, equipment procurement and management on equipment transportation by the DPHE directly managed way	To understand the process of formulation of well drilling work, implementation and evaluation of the work. To be able to directly manage the works by DPHE themselves.	To be able to run the work effectively and to be able to review and revise the implementation and management plans through the experience of formulation of drilling plan, procurement plan, transportation plan and implementation of evaluation of the plans by the DPHE directly managed way.
Pumping test plan and management	They have experience of drilling management through contract works of private drilling companies. They have technical experience with decision of pumping test and instruction of the test. No experience with equipment procurement, human resource allocation plan and the management by the DPHE directly managed way	To be able to run the work directly by DPHE themselves by understanding the process of formulation of pumping test plan, pumping test management, data interpretation and evaluation	To be able to run the work effectively and to be able to review and revise the implementation and management plans through the experience of formulation of pumping test, interpretation of the test, implementation of the test and evaluation of the test by DPHE themselves.
Maintenance and management of equipment	Equipment maintenance of DPHE owned drilling rigs are conducted by private drilling companies which use the drilling rigs. Therefore, they do not have experience with regular maintenance, procurement plan and management of necessary parts and workshop. Workshop will be newly organized and the chief mechanic of workshop has experience of equipment maintenance through such as operation and maintenance of water facilities in DHPE.	To be able to manage equipment maintenance and the workshop by understanding the process of equipment maintenance, plan for workshop management, implementation and evaluation of workshop.	To be able to run the equip maintenance effectively and to be able to review and revise the implementation and management plans through the experience of equipment maintenance plan, workshop management plan, implementation and evaluation of equip maintenance and workshop by DPHE themselves. To acquire the skill for counter-measure for breakdown of the equipment and spare part replacement since the frequency of breakdown and replacement of spare parts increase after one (1) to two (2) years use of equipment.

Table 2.2.34 shows the list of the target for the soft component.

Table 2.2.34 List of Trainees of the Soft Component

Position	Geophysical survey	Drilling plan and management	Pumping test plan and management	Equipment maintenance plan and management
Project management (Superintending Engineer)	B	B	B	B
Equipment maintenance (Executive Engineer, Mechanical-Electrical Division)		A		A
In charge of ground water management (Executive Engineer, Ground Water Division)	B		B	
Senior Hydrogeologist	A		A	
Hydrogeologist	A		A	
Drilling Supervisor		A		
Sub Master Driller (2 persons)		B		
Assistant engineer of procurement management				A
Chief Mechanic				A
Total	4	5	4	4

Note) A: Participate to all the training/ B: Participate partially to the training

3) Expected output of soft component

(i) Technical instruction of drilling plan and management

<Output 1-1>: Acquisition of skill for formulating an appropriate drilling plan (including Well Design, Process Planning, Quality Control Plan and Procurement Plan) and skill for operation management for the engineers of DPHE

In order to implement the drilling works efficiently based on the Action Plan, the engineers of the management level (Project Manager, Drilling Manager et al) of DPHE need to acquire not only on-site skills but also skills for formulating the appropriate drilling plan and operation management.

Therefore, the engineers of DPHE need to master the following techniques.

(1) Selection of Drilling Sites

The drilling sites will be selected based on the results of field surveys, geophysical survey, and the discussions with the persons in charge, etc.

(2) Well Design

Well design will be decided based on depths and diameters of wells, drilling methods, diameters and materials of casing pipes.

(3) Process Planning

The process plan will be made in considering depths of the wells, the geological conditions in the site and the drilling techniques that will be needed to drill wells.

(4) Procurement and Transport Planning

The procurement and Transport Plan will be formulated with consideration of selection of a drilling rig and supporting equipment, the drilling materials and calculation for the quantity of the drilling materials.

(5) Personnel assignment Planning

The personnel assignment plan is necessary for drilling works.

(6) Quality Control Program

The processes for drilling will be clarified and a quality standard and an inspection plan in every process will be made. A safety plan will be also introduced.

(7) Drilling Management

The engineers of the management level related to the drilling works will master the techniques of drilling management based on the drilling plan.

The instruction in creating drilling process flow and a drilling technique manual (including a style of a drilling record) will be carried out cooperatively with the activity of the drilling skill instruction by the supplier.

The following things are the items of the drilling skill instruction.

Drilling engineers of the supplier will give technical instructions on operation methods of a reverse rotary drilling method, a direct rotary drilling method and drilling skills at a field (including drilling gravel layers, sealing method for isolation of the shallow aquifer and the deep aquifer). Equipment maintenance engineers of the supplier will give technical instructions on equipment maintenance skills.

<Output1-2>: Acquisition of skills for making an appropriate pumping test plan, operation management of pumping test and analysis of the test results for the engineers of DPHE

For proper use of water which is pumped up from the deep aquifer using deep tube wells which will be drilled, it is needed to determine the appropriate ability (water yield and water quality) and effect to the surrounding environment and the aquifer from the result of pumping test. Therefore, technical transfer for the pumping test implementation plan, equipment procurement, transfer and interpretation methods will be implemented by the consultant as the soft component.

Therefore, the engineers of DPHE need to master the following techniques.

(1) Pumping Test Plan

It includes a plan of equipment procurement, transport and personnel assignment.

(2) Operation Management of Preliminary Test, Step-Drawdown Test, Constant Discharge Test and Recovery Test

It includes templates of records for each test.

(3) Method of Analysis of Result of Pumping Test (Non-equilibrium method)

Analysis of aquifer parameters (transmissivity coefficient, storage coefficient etc.) is calculated with Theis' formula

(4) Method of Analysis of Result of Pumping Test (Equilibrium method)

Analysis of well loss and specific yield are calculated by using s-Q chart

(5) Method of Analysis of Result of Pumping Test (Selection of specification of pumps)

Specification of pumps is selected based on the result of pumping test.

The drilling engineers who are dispatched by the supplier will instruct the handling procedure of the equipment for pumping test and methods of data acquisition.

<Output1-3>: Acquisition by the engineers of DPHE of skills for formulating the appropriate equipment maintenance plan and skills for operation management

In order to maintain the drilling rigs at a proper state and to carry out drilling works in the Action Plan without delay, the following abilities are needed: engineering ability at a field for equipment maintenance, a formulation of the appropriate equipment maintenance plan by workshops of management group which will consist of DPHE engineers from the equipment maintenance department (equipment maintenance administrators, procurement management assistants etc.), procurement of necessary consumables and spare parts based on the equipment maintenance plan, acquiring skills for regular maintenance of equipment and management of repair works and ability to run workshops properly. The Japanese consultant will give technical instructions for these management abilities regarding equipment maintenance.

Therefore, the engineers of DPHE need to master the following techniques.

1) Maintenance plan for equipment

It includes formulation of contents for regular maintenance for each equipment and annual maintenance schedule.

2) Procurement plan for consumables and spare parts

It includes formulation of procurement plan by calculating the amount of necessary consumables and spare parts for regular maintenance and repair works.

3) Management plan for workshops

It includes formulation of annual regular maintenance activity, allocation of human resource and budgetary provision.

4) Implementation management for equipment maintenance

Moreover, it includes recording equipment maintenance for proper implementation of drilling activities.

The drilling engineers and equipment maintenance engineers of the supplier will give technical instructions for the following matters: operation methods for drilling digs, drilling tools, supporting equipment such as a compressor and a generator etc. and workshop tools and skills for drilling and equipment maintenance.

<Output 1-4>: Acquisition of evaluation skills for drilling works, pumping tests and equipment operation management for the engineers of DPHE

Activities for capacity development of engineers of DPHE related to output 1-1 to 1-3 through on-the job training of three (3) well drillings, preparation of the equipment for the drilling works and equipment maintenance after use.

Technical transfer is repetitively conducted through a series of drilling works from planning of well drilling, preparation of drilling works to management of drilling works and evaluation of drilling results. A system will be introduced to determine whether the plan and the management were appropriate or not and to improve the plan and management when needed by DPHE themselves at the end of each drilling work. This is for self-development of DPHE. The consultant will give these technical instructions.

The outputs on these activities are as follows.

1) Evaluation and improvement skill for formulation of the drilling plan and implementation of drilling works

2) Evaluation and improvement skills for formulation of the pumping test plan and the implementation plan of pumping tests

3) Evaluation and improvement skills for formulation of the equipment maintenance plan and implementation of equipment maintenance

<Output 1-5> : Acquisition of skills for preparing a regular action plan progress report for the engineers of DPHE

DPHE will prepare progress reports of the Action Plan every six (6) months and submit the report to JICA Bangladesh office. Therefore, the soft component includes a technical instruction for preparation of the progress report.

The contents which will be included in the technical instructions are as follows.

1) Skills for preparation of the report on geophysical survey result

2) Skills for preparation of the report on drilling works of production and handpump wells

3) Skills for preparation of the report on well ability evaluation by pumping test

4) Skills for evaluation of progress of the plan and formulation of an improvement plan

(ii) Technical instruction of geophysical survey

<Output 2-1> : Acquisition of a skills for formulation of an appropriate geophysical survey plan for the engineers of DPHE

For the selection of well drilling sites, there is a need to determine a suitable geophysical survey method and line setting for the target aquifer based on existing hydrogeological data and, topographical conditions in the target area, and expecting well depth and well structure. The engineers of DPHE need to master skills for formulation of the appropriate geophysical survey plan.

<Output 2-2> : Acquisition of survey skills using procured geophysical survey equipment for the engineers of DPHE

The engineers in DPHE need to implement appropriate geophysical surveys in the field by using the geophysical survey equipment which will be procured in the Project. Therefore, they need to be able to perform the following matters.

1) Implementation of appropriate geophysical surveys depending on site conditions

2) Proper decision making on whether quality of acquired data is suitable for geological conditions and ground water interpretation

<Output 2-3> : Acquisition of interpretation skills of the geophysical survey and acquisition of a skills to prepare the drilling plan at the target area for the engineers of DPHE

The engineers in DPHE need to acquire skills for the proper interpretation of geophysical surveys and formulation of the drilling plan based on the interpretation. Therefore, they needed to be able to perform the following matters.

1) Proper interpretation of acquired data and estimate the hydrogeological structure

2) Formulation of the detailed drilling plan based on interpretation results

3) Revision of the drilling plan based on actual drilling results

<Output 2-4> : Acquisition of an ability for appropriate maintenance of the geophysical survey equipment for the engineers of DPHE

Handling methods and regular maintenance greatly affect the frequency of malfunction and life span of the geophysical survey equipment. For the appropriate maintenance, the engineers of DPHE need to acquire the following knowledge.

1) Contents of daily maintenance and implementation methods

2) Contents of regular maintenance and implementation methods

3) Repair works in case of breakdown

Regarding the handling method and maintenance of geophysical survey equipment, the Japanese supplier will explain the initial handling training. For actual use, equipment maintenance and management ways will be instructed in the field.

4) Means of verification for output

(i) Technical instruction of drilling plan and management

Means of verification to assess the outputs which were set in (3) 1) are as follows.

Means of Verification for Output 1-1

The consultant will confirm the drilling plan and the drilling records which engineers of DPHE will prepare.

Means of Verification for Output 1-2

The consultant will confirm the pumping test plan and analyse the records of the pumping test which engineers of DPHE will prepare.

Means of Verification for Output 1-3

The consultant will confirm the equipment maintenance plan and the operation management records which engineers of DPHE will prepare.

Means of Verification for Output 1-4

The consultant will confirm the reports of drilling works evaluations, pumping test evaluations report and operation management evaluations which engineers of DPHE will prepare.

Means of Verification for Output 1-5

The consultant will confirm the progress reports of the Action Plan progress report which engineers of DPHE will prepare.

(ii) Technical instruction of geophysical survey

Means of verification to assess the outputs which were set in (3)2) are as follows.

Means of Verification for Output 2-1

The consultant will confirm the survey plan which engineers of DPHE will prepare.

Means of Verification for Output 2- 2

Consultant will confirm the following matters which engineers of DPHE will conduct

1) Suitable selection and arrangement of survey line at the sites

2) Appropriate measurement

3) Appropriate data acquisition

Means of Verification for Output 2- 3

The consultant will confirm the following matters which engineers of DPHE will prepare.

1) The survey data

2) The Geophysical survey result

3) A hydrogeological section at measuring sites

4) The survey result report including hydrological section at measuring sites

5) The drilling plan and its revision

Means of Verification for Output 2- 4

The consultant will confirm the following matters which engineers of DPHE will prepare.

1) Management procedures of daily maintenance and regular maintenance

2) Management checklists of daily maintenance and regular maintenance

3) Maintenance records

5) Activities and input in soft component program

(i) Technical instruction of drilling plan and management

Activities needed for achievement of the purpose and outputs of the soft component related to the drilling plan and the management are as follows.

Output 1-1 Activities related to technical instruction of drilling plan and management

1-1-1 Preparation of lecture material and manual

1-1-1-1 Preparation of exercise material for the drilling plan
1-1-1-2 Preparation of a drilling record form
1-1-1-3 Preparation of a drilling plan formulation manual
1-1-1-4 Preparation of a drilling management manual
1-1-1-5 Preparation of an exercise material for preparation of drilling reports

1-1-2 Technical course

1-1-2-1 Introduction of the drilling plan and management
1-1-2-2 An exercise of preparation of the drilling plan
1-1-2-3 Field training of drilling management
1-1-2-4 An exercise for preparation of the drilling report

Output 1-2 Activities related to the technical instruction of planning, management and interpretation of pumping test

1-2-1 Preparation of lecture materials and manual

1-2-1-1 Preparation of pumping test planning and management manual
1-2-1-2 Preparation of exercise material for preparation of the pumping test plan
1-2-1-3 Preparation of exercise material for interpretation of pumping test
1-2-1-4 Preparation of exercise material for pump selection

1-2-2 Technical course

1-2-2-1 Introduction to the pumping test plan and the management of pumping test
1-2-2-2 An exercise of preparation of the pumping test plan
1-2-2-3 An exercise of pumping test interpretation
1-2-2-4 An exercise of pump selection

1-2-2-5 Field training of pumping test management

Output 1-3 Activities related to the technical instruction for the equipment maintenance plan and management

1-3-1 Preparation of lecture materials and manual

1-3-1-1 Preparation of the equipment maintenance plan manual
1-3-1-2 Preparation of the exercise materials for the equipment maintenance plan

1-3-2 Technical course

1-3-2-1 Introduction to equipment maintenance plan and management
1-3-2-2 Exercise of preparation of equipment maintenance plan

Output 1-4 Activities related to the technical instruction to evaluation and improvement

1-4-1 Preparation of Lecture materials and manual

1-4-1-1 Preparation of a drilling work evaluation manual
1-4-1-2 Preparation of a pumping test evaluation manual
1-4-1-3 Preparation of an equipment maintenance evaluation manual
1-4-1-4 Revision of the manuals

1-4-2 Technical course

1-4-2-1 An exercise of drilling work evaluation
1-4-2-2 An exercise of pumping test evaluation
1-4-2-3 An exercise of equipment maintenance evaluation

Output 1-5 Activities related to the technical instruction of progress report preparation

1-5-1 Preparation of Lecture materials and manual

1-5-1-1 Preparation of the drilling work evaluation manual

1-5-2 Technical course

1-5-2-1 An exercise of progress report preparation

Details of the activities related to the technical instructions of the drilling plan and management are shown in Table 2.2.35.　The period indicated in the table includes holidays and site transfers.

(ii) TechnicAl instruction of geophysical survey

Activities needed for achievement of the purpose and outputs of the soft component related to geophysical surveys are as follows.　The activities will be divided into Part-1 and Part-2.

●Part-1

1) Explanation and discussion I

1-1) Explanation and discussion about objectives, contents and an implementation schedule of the soft component

2) Classroom lecture I: Introduction of geophysical surveys and the survey plan (activities related to output 2-1)

2-1) An explanation of outline and basics of geophysical surveys

2-2) Technical instructions of the geophysical survey plan depending on the target aquifer and purpose

3) Field training (activities related to output 2-2 and 2-4)

- 3-1) An explanation of specification of the geophysical survey equipment and notices on handling
- 3-2) Technical instruction of line setting of geophysical surveys, equipment operation and measurement procedures
- 3-3) Technical instructions of evaluation of acquired data (distinction of irregular data and noise)
- 3-4) Technical instructions of maintenance of the equipment

4) Classroom lecture II: Interpretation of acquired data and hydrogeological interpretation (activities related to output 2-3)

- 4-1) Technical instructions of interpretation methods of acquired data
- 4-2) Technical instructions of hydrogeological interpretation

5) Progress report (Part-1)

- 5-1) Report on progress of the training (Part-1)

●Part-2

6) Explanation and discussion II

- 6-1) An explanation and discussion of contents and the implementation schedule of Part-2

7) Classroom lecture III: Formulation of the drilling plan (activities related to output 2-3)

- 7-1) Technical instructions about formulation of the drilling plan (selection of the drilling sites and well structures)

8) The exercise of geophysical surveys (activities related to output 2-1and 2-2)

- 8-1) Formulation of the geophysical survey plan by the trainees
- 8-2) Implementation of the surveys in the field by the trainees

9) The exercise of formulation of the drilling plan (activities related to output 2-3)

- 9-1) Interpretation of acquired data by the trainees
- 9-2) Hydrogeological interpretation of the interpreted results by the trainees
- 9-3) Formulation of the drilling plan by the trainees

10) Evaluation of understanding and reconfirmation of the content of the training (activities related output 2-1 to 2-4)

- 10-1) Evaluations on the degree of understanding of the trainees
- 10-2) Reconfirmations of the contents of the training

11) Progress report II

- 11-1) Reports on achievement of the training

Details of the activities related to the technical instructions of the geophysical surveys are summarised in Table 2.2.36. The period indicated in the table includes holidays and site transfers.

Table 2.2.35　Details of the Soft Component for Drilling Plan and Management

Content of activity	Purpose	Target	Implementation method	Period	Implementation resource【Responsibility】	Output/Report
Output 1-1 Activities related to technical instruction of drilling plan and management						
1-1-1 Preparation of lecture material and manual						
1-1-1-1 Preparation of exercise materials for drilling plan	For preparation of the drilling plan	DPHE drilling management staff, staff of private drilling companies	Content will be discussed with DPHE	0.40 months	Japanese consultant/interpreter【Japanese side】	Exercise materials for the drilling plan
1-1-1-2 Preparation of drilling record forms	For appropriate drilling records	DPHE drilling management staff, staff of private drilling companies	Content will be discussed with DPHE	0.40 months	Japanese consultant/interpreter【Japanese side】	Drilling record forms
1-1-1-3 Preparation of the formulation manual for the drilling plan	For formulation of the drilling plan	DPHE drilling management staff, staff of private drilling companies	Content will be discussed with DPHE	0.40 months	Japanese consultant/interpreter【Japanese side】	Formulation manual for the drilling plan
1-1-1-4 Preparation of the drilling management manual	For appropriate drilling management	DPHE drilling management staff, staff of private drilling companies	Content will be discussed with DPHE	0.40 months	Japanese consultant/interpreter【Japanese side】	Drilling management manual
1-1-1-5 Preparation of the exercise materials for preparation of drilling reports	To acquire the knowledge about preparation of the drilling reports	DPHE drilling management staff, staff of private drilling companies	Content will be discussed with DPHE	0.30 months	Japanese consultant/interpreter【Japanese side】	Exercise materials for preparation of drilling reports
1-1-2 Technical course						
1-1-2-1 Introduction to the drilling plan and management	Explanation of introduction of the drilling plan and management	DPHE drilling management staff, staff of private drilling companies	A lecture for explanation purpose will be held	0.10 months x 1 time	Japanese consultant/interpreter【Japanese side】	-
1-1-2-2 Exercises of preparation of the drilling plan	To acquire the knowledge for formulation of the drilling plan by an exercise	DPHE drilling management staff, staff of private drilling companies	Manual for plan formulation and exercise materials will be used	0.10 months x 3 times	Japanese consultant/interpreter【Japanese side】	Drilling plan
1-1-2-3 Field training of drilling management	To acquire the knowledge about drilling management and drilling records at a field	DPHE drilling management staff, staff of private drilling companies	Drilling management and record forms will be used	0.10 months x 8 times	Japanese consultant/interpreter【Japanese side】	-

Content of activity	Purpose	Target	Implementation method	Period	Implementation resource 【Responsibility】	Output/Report
1-1-2-4 Exercises for preparation of the drilling report	To acquire the knowledge about the drilling report	DPHE drilling management staff, staff of private drilling companies	Exercise materials will be used	0.10 months x 3 times	Japanese consultant/interpreter 【Japanese side】	Drilling report
<u>Output 1-2 Activities related to technical instruction of planning, management and interpretation of pumping test</u>						
<u>1-2-1 Preparation of lecture material and manual</u>						
1-2-1-1 Preparation of pumping test planning and the management manual	For formulation of pumping test and management	DPHE pumping test management staff	Contents will be discussed with DPHE	0.3 months	Japanese consultant/interpreter 【Japanese side】	Pumping test planning and the management manual
1-2-1-2 Preparation of exercise material for preparation of pumping test plan	For formulation of the pumping test plan	DPHE pumping test management staff	Contents will be discussed with DPHE	0.3 months	Japanese consultant/interpreter 【Japanese side】	Exercise materials for preparation of the pumping test plan
1-2-1-3 Preparation of exercise materials for interpretation of pumping test	For interpretation of pumping test	DPHE pumping test management staff	Contents will be discussed with DPHE	0.3 months	Japanese consultant/interpreter 【Japanese side】	Exercise materials for interpretation of pumping test
1-2-1-4 Preparation of exercise materials for pump selection	For pumping selection	DPHE pumping test management staff	Contents will be discussed with DPHE	0.3 months	Japanese consultant/interpreter 【Japanese side】	Exercise materials for pump selection
<u>1-2-2 Technical course</u>						
1-2-2-1 Introduction to the pumping test plan and management of pumping test	Explanation of introduction of the pumping test plan and management	DPHE pumping test management staff	A lecture for explanation purpose will be held	0.03 months x 1 time	Japanese consultant/interpreter 【Japanese side	-
1-2-2-2 Exercises of preparation of the pumping test plan	To acquire the knowledge about for formulation of the pumping test plan by an exercise	DPHE pumping test management staff	Manual for plan formulation and management and exercise materials will be used	0.07 months x 2 times	Japanese consultant/interpreter 【Japanese side】	Pumping test plan
1-2-2-3 Exercises of pumping test interpretation	To acquire the knowledge for interpretation of pumping test by the exercises	DPHE pumping test management staff	Exercise materials will be used	0.10 months x 2 times	Japanese consultant/interpreter 【Japanese side】	Pumping test interpretation result
1-2-2-4 Exercises of pump selection	To acquire the knowledge for pump selection considering the result of	DPHE pumping test management	Exercise materials will be	0.10 months x 3 times	Japanese consultant/interpreter	Result of pump selection

Content of activity	Purpose	Target	Implementation method	Period	Implementation resource 【Responsibility】	Output/Report
	pumping test by the exercises	staff	used		【Japanese side】	
1-2-2-5 Field training of pumping test management	To acquire the knowledge about pumping test management at a field	DPHE pumping test management staff	Manual for plan formulation and exercise materials will be used	0.10 months x 2 times	Japanese consultant/interpreter 【Japanese side】	Record of pumping test
Output 1-3 Activities related to technical instruction equipment maintenance plan and management						
1-3-1 Preparation of lecture material and manual						
1-3-1-1 Preparation of the equipment maintenance plan manual	For formulation of the equipment maintenance plan	DPHE equipment maintenance staff, staff of private drilling companies	Contents will be discussed with DPHE	0.3 months	Japanese consultant/interpreter 【Japanese side】	Equipment maintenance plan manual
1-3-1-2 Preparation of exercise materials for equipment maintenance plan	For formulation of the equipment maintenance plan	DPHE equipment maintenance staff, staff of private drilling companies	Contents will be discussed with DPHE	0.3 months	Japanese consultant/interpreter 【Japanese side】	Exercise material for equipment maintenance plan
1-3-2 Technical course						
1-3-2-1 Introduction to the equipment maintenance plan and management	Explanation of introduction of the equipment maintenance plan and management	DPHE equipment maintenance staff, staff of private drilling companies	A lecture for explanation purpose will be held	0.03 months x 1 time	Japanese consultant/interpreter 【Japanese side】	-
1-3-2-2 Exercise of preparation of the equipment maintenance plan	To acquire the knowledge of equipment maintenance by exercises	DPHE equipment maintenance staff, staff of private drilling companies	Manual for plan formulation and exercise materials will be used	0.10 months x 1 time	Japanese consultant/interpreter 【Japanese side】	Equipment maintenance plan
Output 1-4 Activities related to technical instruction to evaluation and improvement						
1-4-1 Preparation of Lecture material and manual						
1-4-1-1 Preparation of the drilling work evaluation manual	For evaluation of drilling works	DPHE drilling management staff	Contents will be discussed with DPHE	0.30 months	Japanese consultant/interpreter 【Japanese side】	Drilling work evaluation manual
1-4-1-2 Preparation of the pumping test evaluation manual	For evaluation of pumping test	DPHE drilling management staff	Content will be discussed with DPHE	0.30 months	Japanese consultant/interpreter 【Japanese side】	Pumping test evaluation manual
1-4-1-3 Preparation of the equipment maintenance evaluation manual	For evaluation of equipment maintenance	DPHE drilling management staff	Content will be discussed with	0.30 months	Japanese consultant/interpreter	Equipment maintenance

Content of activity	Purpose	Target	Implementation method	Period	Implementation resource【Responsibility】	Output/Report
			DPHE		【Japanese side】	evaluation manual
1-4-1-4 Revision of the manuals	For revision of the manuals regarding the drilling plan and management, pumping test and management and equipment maintenance and management	DPHE drilling management staff	Contents will be discussed with DPHE	0.40 months	Japanese consultant/interpreter 【Japanese side】	Manuals (revised versions)
1-4-2 Technical course						
1-4-2-1 Drilling work evaluation exercises	To acquire the knowledge for the evaluation of drilling works	DPHE drilling management staff	The evaluation manual will be used	0.03 months x 1 time	Japanese consultant/interpreter 【Japanese side】	Evaluation report of drilling work
1-4-2-2 Pumping test evaluation exercises	To acquire the knowledge about for the evaluation of pumping test	DPHE pumping test management staff	The evaluation manual will be used	0.03 months x 1 time	Japanese consultant/interpreter 【Japanese side】	Evaluation report of pumping test
1-4-2-3 Equipment maintenance evaluation exercises	To acquire the knowledge about for the evaluation of equipment maintenance	DPHE equipment maintenance staff	The evaluation manual will be used	0.03 months x 1 time	Japanese consultant/interpreter 【Japanese side】	Evaluation report of equipment maintenance
Output 1-5 Activities related to technical instruction of progress report preparation						
1-5-1 Preparation of Lecture material and manual						
1-5-1-1 Preparation of the drilling work evaluation manual	For formulation of progress reports	DPHE drilling management staff	Contents will be discussed with DPHE	0.07 months	Japanese consultant/interpreter 【Japanese side】	Progress reports preparation manual
1-5-2 Technical course						
1-5-2-1 progress reports preparation exercises	To acquire the knowledge of preparation of progress reports	DPHE drilling management staff	The formulation manual will be used	0.03 months x 1 time	Japanese consultant/interpreter 【Japanese side】	Progress reports

Table 2.3.36　Details of the Soft Component for Geophysical Survey

Content of activity	Purpose	Target	Implementation method	Period	Implementation resource 【Responsibility】	Output/Report
Part-1						
1. Explanation and discussion Ⅰ						
1-1) Explanation and discussion about the objectives, contents and implementation schedule of soft component	To obtain the agreement from the related personnel (DPHE) in Bangladesh side about purpose, contents and schedule of the soft component	Related personnel in DPHE	Explanation and discussion based on the Soft Component Plan	0.03 months	Japanese consultant/interpreter 【Japanese side】	
2. Class room lecture I : Introduction to geophysical survey and survey plan (activities related to output 2-1)						
2-1) Explanation of outlines and basics of geophysical surveys	For deep understanding for outlines and basics of geophysical surveys	Geophysical survey staff of DPHE	Class room lecture(lecture and technical instruction by the consultant)	0.23 months	Japanese consultant/interpreter 【Japanese side】	Geophysical survey plan
2-2) Technical instruction of geophysical survey plan depending on target aquifer and purpose	For preparation of the geophysical survey plan depending on the target aquifer and purpose					
3. Field training (activities related to output 2-2 and 2-4)						
3-1) Explanation of specification of geophysical survey equipment and handling cautions	For understanding of the specification of geophysical surveys and the appropriate handling of the equipment	Geophysical survey staff of DPHE	Field training (lecture and technical instructions by the consultant)	0.47 months	Japanese consultant/interpreter/geophysical survey assistants【Japanese side】	Geophysical survey data
3-2) Technical instruction of line setting of geophysical surveys, equipment operations and measurement procedures	To acquire the techniques for appropriate line setting of geophysical surveys and measurement					
3-3) Technical instructions of evaluation of acquired data (distinction of irregular data and noise)	To acquire the techniques for distinction of irregular data and noises					
3-4) Technical instructions of maintenance of the equipment	To acquire the knowledge for the appropriate maintenance of the equipment					Procedures of equipment maintenance, checklists, maintenance records
4. Class room lecture II: Interpretation of acquired data and hydrogeological interpretation (activities related to output 2-3)						
4-1) Technical instructions of interpretation methods of acquired data	For interpretation of acquired data	Geophysical survey staff of DPHE	Class room lectures (technical instruction by the consultant)	0.14 months	Japanese consultant/interpreter 【Japanese side】	Geophysical surveys interpretation result

Content of activity	Purpose	Target	Implementation method	Period	Implementation resource 【Responsibility】	Output/Report
4-2) Technical instructions of hydrogeological interpretation	For hydrogeological interpretation					Hydrogeological sections of the survey points
5. Progress report (Part-1)						
5-1) Reports on progress of the training (Part-1)	Make reports about achievement of the training to the related personnel in DPHE and get understanding from them	Related personnel in DPHE	Report the progress	0.03 months	Japanese consultant/interpreter 【Japanese side】	Progress reports （Part-1）
Part-2						
6. Explanation and discussion II						
6-1) Explanation and discussion of contents and the implementation schedule of Part-2	Explanation and discussion about contents and the schedule of Part-2 to related personnel in DPHE	Related personnel in DPHE	Explanation and discussion based on the Soft Component Plan	0.03 months	Japanese consultant/interpreter 【Japanese side】	
7. Class room lecture III: formulation of drilling plan (activities related to output 2-3)						
7-1) Technical instruction about formulation of drilling plan (selection of drilling position of drilling and well structure)	To acquire the knowledge for appropriate selection of drilling site and well structure based on interpretation result and hydrogeological interpretation	Geophysical survey staff of DPHE	Class room lecture(technical instruction by the consultant)	0.23 months	Japanese consultant/interpreter 【Japanese side】	Drilling plan
8. Exercise of geophysical survey (activities related to output 2-1and 2-2)						
8-1) Formulation of geophysical survey plan by the trainees	For appropriate formulation of geophysical survey plan only by the trainees (geological survey staff of DPHE)	Geophysical survey staff of DPHE	Formulation of geophysical survey plan and implementation of geophysical survey at a field (assistance from the consultant)	0.3 months	Japanese consultant/interpreter/geophysical survey assistant【Japanese side】	Geophysical survey plan
8-2) Implementation of survey at field by the trainees	For appropriate implementation of geophysical survey only by the trainees					Geophysical survey data, checklists
9. Exercise of formulation of drilling plan (activities related to output 2-3)						
9-1) Interpretation of acquired data by the trainees	For appropriate interpretation of acquired data only by the trainees	Geophysical survey staff in DPHE	Formulation of drilling plan (assistance from the consultant)	0.17 months	Japanese consultant/interpreter 【Japanese side】	Geophysical survey interpretation result
9-2) Hydrogeological interpretation of the interpreted result by the trainees	For appropriate hydrogeological interpretation only by the trainees					A geophysical survey reports including

Content of activity	Purpose	Target	Implementation method	Period	Implementation resource 【Responsibility】	Output/Report
						hydrogeological sections of the survey points
9-3) Formulation of drilling plan by the trainees	For appropriate formulation of ground water development plan only by the trainees					Drilling plan
10. Evaluation of understanding and reconfirmation of the content of the training (activities related output 2-1 to 2-4)						
10-1) Evaluations on a degree of understanding of the trainees	For evaluation on the degree of understanding of the trainees	Geophysical survey staff of DPHE	Evaluate the understanding of the trainees based on the geophysical survey result reports and the drilling plan which will be prepared by the trainees/reconfirmation of the contents of the training based on the understanding	0.17 months	Japanese consultant/interpreter 【Japanese side】	
10-2) Reconfirmations of the contents of the training	For reconfirmations of the contents of the training depending on the understanding					
11. Progress report II						
11-1) Reports on achievement of the training	To make reports about the achievements of the training to the related personnel to DPHE and get understanding from them	Related personnel in DPHE	Report the progress	0.03 months	Japanese consultant/interpreter 【Japanese side】	Progress reports

6) Procurement plan of implementation resource of soft component

(i) Technical instruction of drilling plan and management

The personnel to be assigned to implement the Drilling Plan and Management Instruction in the Soft Component Program are as follows.

i) A Japanese consultant (in charge of Instruction on drilling plan and management)

The consultant instructs formulation of the implementation plan for the following five (5) categories: the instructions on the drilling plan and management (related to output 1-1), the instructions on the pumping test plan/ management/ analysis (related to output 1-2), instruction on equipment maintenance plan and management (related to output 1-3), the instructions on the evaluation and improvement plan (related to output 1-4) and the instructions on progress reports.

The consultant also instructs schedule management of activities, management of the program, contacting and reporting to the client and related organizations of Japan, discussions and coordination of the program to related personnel, preparation of the necessary lecture materials and manuals, and technical instructions to trainees.

ii) An interpreter (locally-hired)

It is difficult to have communication with most of the management staff of the drilling works in DPHE in English. Therefore, an interpreter between English and Bengali is required.

iii) An office boy (locally-hired)

A large amount of documents such as manuals and lecture materials have to be prepared. Therefore, an office boy is required to support these works.

(ii) Technical instruction of geophysical survey

Personnel to be assigned to implement the geophysical survey instruction in the soft component program are as follows.

i) A Japanese consultant (in charge of instruction on geophysical survey)

The consultant instructs formulation of the soft component implementation plan, schedule management of activities, management of program, contacting and reporting to the client and the related organizations of Japan, discussions and coordination of the program to the related personnel. The consultant is also in charge of the technical instructions on the geophysical surveys to the trainees.

ii) An interpreter (locally-hired) and six (6) workers for geophysical survey

It is difficult to have communication with most of the staff under the geophysical survey department in DPHE in English. Therefore, an interpreter between English and Bengali is required.

The technical instruction on the geophysical survey includes actual measurement in the field (0.77 months). During this period, six (6) workers are required as workers.

7) Implementation schedule

(i) Technical instruction of drilling plan and management

The soft component for the technical transfer on the drilling plan and management is to be conducted using the equipment which will be procured in the Project. Therefore, the implementation of the soft component will be commenced after the delivery of the equipment.

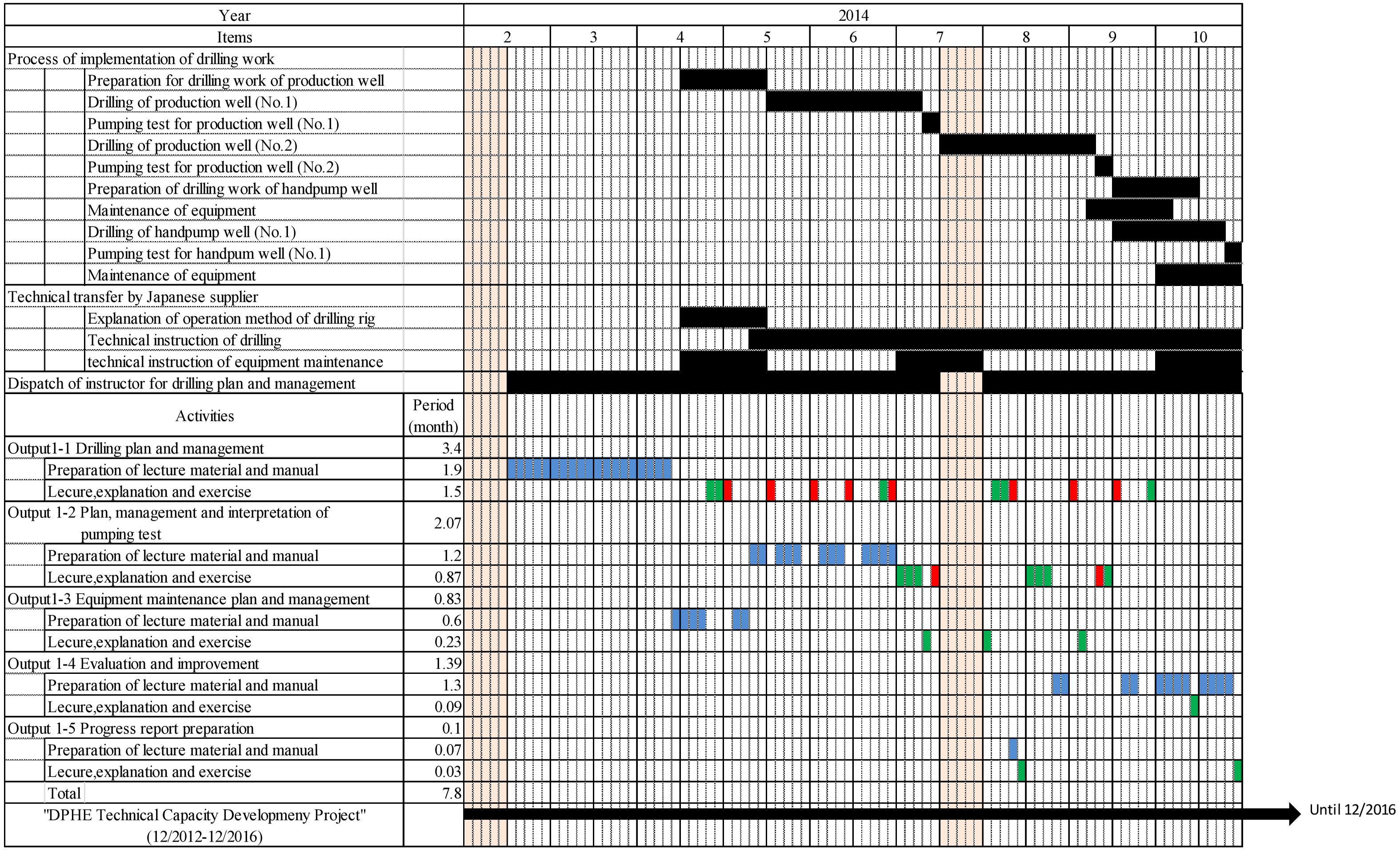
The implementation schedule is indicated in Table 2.2.37.

(ii) Technical instruction of geophysical survey

The soft component for the technical transfer of the geophysical surveys is to be conducted using the geophysical survey equipment which will be procured in the Project. Therefore, the implementation of the soft component will be commenced after the delivery of the equipment.

The implementation schedule is indicated in Table 2.2.38.

Table 2.2.37 Time Schedule of the Soft Component for Drilling Plan and Management



Year / Items	Period (month)
Process of implementation of drilling work	
Preparation for drilling work of production well	
Drilling of production well (No.1)	
Pumping test for production well (No.1)	
Drilling of production well (No.2)	
Pumping test for production well (No.2)	
Preparation of drilling work of handpump well	
Maintenance of equipment	
Drilling of handpump well (No.1)	
Pumping test for handpum well (No.1)	
Maintenance of equipment	
Technical transfer by Japanese supplier	
Explanation of operation method of drilling rig	
Technical instruction of drilling	
technical instruction of equipment maintenance	
Dispatch of instructor for drilling plan and management	
Activities	Period (month)
Output1-1 Drilling plan and management	3.4
Preparation of lecture material and manual	1.9
Lecure,explanation and exercise	1.5
Output 1-2 Plan, management and interpretation of pumping test	2.07
Preparation of lecture material and manual	1.2
Lecure,explanation and exercise	0.87
Output1-3 Equipment maintenance plan and management	0.83
Preparation of lecture material and manual	0.6
Lecure,explanation and exercise	0.23
Output 1-4 Evaluation and improvement	1.39
Preparation of lecture material and manual	1.3
Lecure,explanation and exercise	0.09
Output 1-5 Progress report preparation	0.1
Preparation of lecture material and manual	0.07
Lecure,explanation and exercise	0.03
Total	7.8
"DPHE Technical Capacity Developmeny Project" (12/2012-12/2016)	

(8 M/M - transfering period 0.2 M/M = 7.80 M/M)

🟦 Preparation work for lecture material and manual
🟩 Technical lecture (class room)
🟥 Technical lecture (field)

Table 2.2.38 Time Schedule of the Soft Component for Geophysical Survey

Part-1

Soft component activity Part-1		Man-month (M-M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
			Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	
Item	Content of work/training																																
Move	Japan->Bangladesh	0.07 M-M	🟩																													🟩	
Explanation/discussion I	Explanation and discussion of purpose, contents and schedule of soft component	0.03 M-M		🟩																													
Class room lecture I	Introduction to geophysical survey plan and formulation of survey plan, specification of survey equipment (Activities related to output 2-1)	0.23 M-M			🟩	🟩	🟩	🟩	🟩	🟩	🟩																						
Field training	Line setting, handling of the equipment, measurement procedure, evaluation of acquired data (distinction of irregular data and noise) (Activities related to output 2-2 and 2-4)	0.47 M-M										🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩								
Class room lecture II	Interpretation of acquired data and hydrogeological interpretation (Activities related to output 2-3)	0.17 M-M																								🟩	🟩	🟩	🟩	🟩			
Progress report I	Report the progress of the training (Part 1)	0.03 M-M																													🟩		
Human resource allocation plan (Geophysical survey technical instruction)		1.00 M-M	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	

Part-2

Soft component activity Part-2		Man-month (M-M)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
			Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	Fri	Sta	Sun	Mon	Tue	Wed	Thu	
Item	Content of work/training																																
Move	Japan->Bangladesh	0.07 M-M	🟩																													🟩	
Explanation/discussion II	Explanation and discussion of contents and schedule of soft component part II	0.03 M-M		🟩																													
Class room lecture III	Formulation of drilling plan (Activities related to output 2-3)	0.23 M-M			🟩	🟩	🟩	🟩	🟩	🟩	🟩																						
Field training	Formulation of drilling plan, implementation of geophysical survey by trainees (assistance by the consultant) (Activities related to output 2-1)	0.30 M-M										🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩													
Exercise for formulation of drilling plan	Interpretation of acquired data, hydrogeological interpretation of the interpretation result, appropriate drilling site selection/well structer (Assistance by the consultant) (Activities related to output 2-3)	0.17 M-M																			🟩	🟩	🟩	🟩	🟩								
Evaluation of dgree of understanding and reconfirmation of contents of	Evaluation of dgree of understanding, reconfimation of contents of the training (Activities related to output 2-1 to 2-4)	0.17 M-M																								🟩	🟩	🟩	🟩	🟩			
Progress report II	Report the progress of the training	0.03 M-M																													🟩		
Human resource allocation plan (Geophysical survey technical instruction)		1.00 M-M	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	

8) Output of soft component

(i) Technical instruction of drilling plan and management

The outputs and the reports of the Soft Component are shown in Table 2.2.36. The completion reports of the soft component will be submitted to the implementation agency of the Bangladesh and Japanese sides.

(ii) Technical instruction of geophysical survey

The outputs and the reports of the Soft Component are shown in Table 2.2.37. The completion reports of the soft component will be submitted to the implementation agency of the Bangladesh and Japanese sides.

9) Matters to be borne by Bangladesh side

For the implementation of the two components of the soft component, matters to be borne by the Bangladesh side are as follows.

(i) Soft component for the technical transfer on drilling plan and management

- ☐ To ensure the schedule of the trainees (DPHE staff for drilling management, pumping test and equipment operation management) is open during the training period
- ☐ Cost to attend field training for the trainees of the Bangladesh side
- ☐ Reservation of the place for the lectures
- ☐ Information about necessary procedures to the relevant organizations such as divisions and villages since the equipment to be procured will be used for the technical transfer of drilling works, and the cost needed for the information transfer and necessary procedures
- ☐ Cost for necessary materials in case other materials than the procured equipment are needed due to geological conditions during drilling works for the technical transfer

(ii) Soft component for the technical transfer on geophysical survey

- ☐ To ensure the schedule of the trainees (DPHE staff for geophysical survey) is open during the training period
- ☐ Cost to attend the field training for the trainees of the Bangladesh side
- ☐ Reservation of the place for the lectures
- ☐ Information to the relevant organizations such as divisions and villages for surveys in the fields

(iii) Matters to be done by Bangladesh side after completing the soft component

- ☐ Reservation of continuous staff and budget to implement geophysical survey and drilling works based on the action plan
- ☐ Continuation of technical improvement activities for engineers to master the technological levels required for efficient implementation of the action plan based on knowledge mastered through the soft component about geophysical survey, drilling works, pumping test, and equipment operation management
- ☐ Continuation of support activities for entry of private sector drilling companies to promote the deep ground water development in the areas distributed gravel layers
- ☐ Continuous activities of establishment of a monitoring system for quantity and quality of water during drilling works and during using wells, construction of a database for

aquifers, a construction of a database for observation wells, etc..

(9) Implementation Schedule

1) Manufacturing period of the equipment

Drilling rigs take the longest time for manufacturing compared to other equipment to be procured under this Project. Drilling rigs procured by the Japanese Grant Aid Projects are generally for direct rotary method and their drilling ability up to 200 m deep. Their manufacturing period is approximately six (6) months.

Drilling rigs to be procured under this Project are for the reverse rotary method and their drilling ability is up to 400 m deep. These require special equipment for rig manufacturers, and the period of their design and manufacturing takes more time compared with that of normal rigs.

The period for rig manufacturing is estimated eight (8) months under this Project.

2) Delivery period and necessary procedures

After manufacture at the factory, each procedure for delivery of the equipment from the factory to Dhaka will take the following period.

Domestic transportation (Factories – Warehouses in Yokohama Port)	0.17 months
Inspection before packing	0.40 months
Packing	0.23 months
Pre-shipment inspection	0.03 months
Tax clearance	0.10 months
Shipment	0.07 months
Subtotal	1.00 months
Marine transportation (Yokohama Port – Chittagong Port)	1.50 months
Unloading	0.23 months
Tax clearance	0.27 months
Domestic transportation (Chittagong Port – Dhaka)	0.50 months
Subtotal	1.00 months

The period to be taken for delivery from the factory to Dhaka is 3.50 months.

3) Work Period for Installation of Equipment

The installation processes will take the following period.

Carrying in / unpacking	0.50 months
Adjustment / preliminary operation	0.50 months
Instruction for preliminary operation	0.50 months
Instruction for operation	6.00 months
Total	7.50 months

4) Period for Inspection and Check

The inspection period is not included in the implementation schedule since it is conducted in the same period as the inspection for preliminary operation.

5) Estimation of period for Procurement

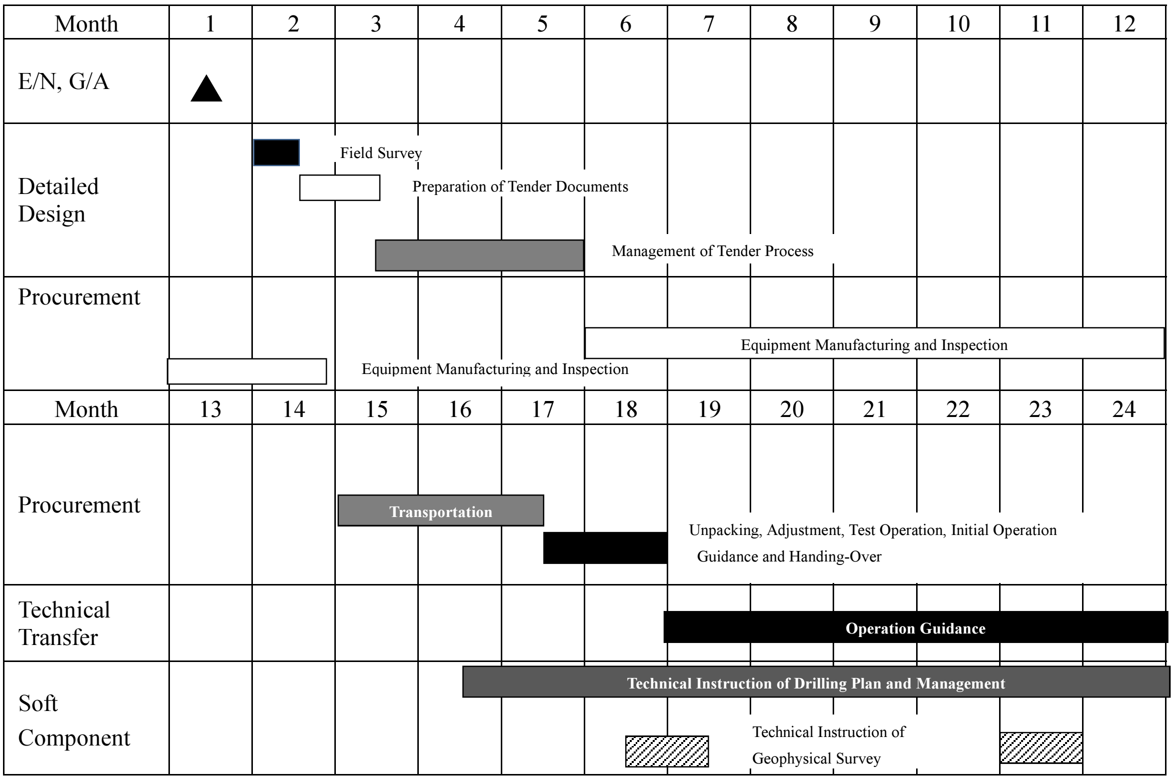
According to the above 2.2.4 (9) 1) to 4), procurement period is calculated as follows.

Manufacturing period	8.00 months

Procedures / transportation period	3.50 months
Installation etc.	7.50 months
Total	19.00 months

The total schedule of the Project is shown in Table 2.2.39.

Table 2.2.39 Implementation Schedule



2.3 OBLIGATIONS OF THE GOVERNMENT OF BANGLADESH

In implementation of the Project, the obligation of the Bangladesh side is as follows

2.3.1 GENERAL ISSUES

- To bear an advising commission of the Authorization to Pay (A/P) and payment commission to a Japanese bank for the banking services based on the Banking Arrangement (B/A)
- To ensure prompt unloading and customs clearance at the port of disembarkation in Bangladesh and to assist internal transportation of the products
- To exempt tax and custom clearance of the products at the port of disembarkation
- To accord Japanese nationals whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into Bangladesh and stay therein for the performance of their work
- To maintain and use properly and effectively the equipment provided under the Grant Aid
- To bear all the expenses, other than those to be borne by the Grant Aid, necessary for the transportation and installation of the equipment
- To give due environmental and social consideration in the implementation of the Project
- To facilitate the data and information necessary for the Detailed Design Study for the Project
- To get approval necessary for the implementation of the Project

2.3.2 SPECIFIC ISSUES IN THE PROJECT

Issues to be implemented by the Bangladesh side before delivery of the equipment by the Project are as follows.

(1) To organize two (2) Drilling Teams and a Geophysical Survey Team

DPHE has staff for well drilling, but they are supervising local contractors without drilling wells by themselves. No well is currently drilled as a direct undertaking work by DPHE.

With regard to a geophysical survey, two (2) pieces of survey equipment were newly purchased by DPHE but no survey team exists in DPHE.

If the Project is implemented, DPHE has to select drilling sites for deep wells by using the geophysical survey equipment provided in the Project, to formulate a drilling plan and to drill deep wells. In order to accomplish these tasks, it is necessary for DPHE to organize a drilling team and a geophysical survey team.

(2) Provision of Workshop and Depot for Equipment, Materials and Supporting Vehicles

In this Project, a total of 9 vehicles (Drilling rig x 2, Cargo truck x 1, Crane truck x 4, pick-up truck x 2), drilling and workshop equipment will be procured. In order to maintain them, the Tongi DPHE office/depot shall be improved to make a depot and a workshop by DPHE before delivery of them. Figure 2.3.1 shows the current layout of the Tongi DPHE office/depot. Most of the existing sheds and outdoor spaces are occupied with various goods. Unusable goods and waste shall be removed. Aged sheds shall be repaired or demolished to construct a new shed. Figure 2.3.2 shows the layout of the improved Tongi DPHE office/depot.

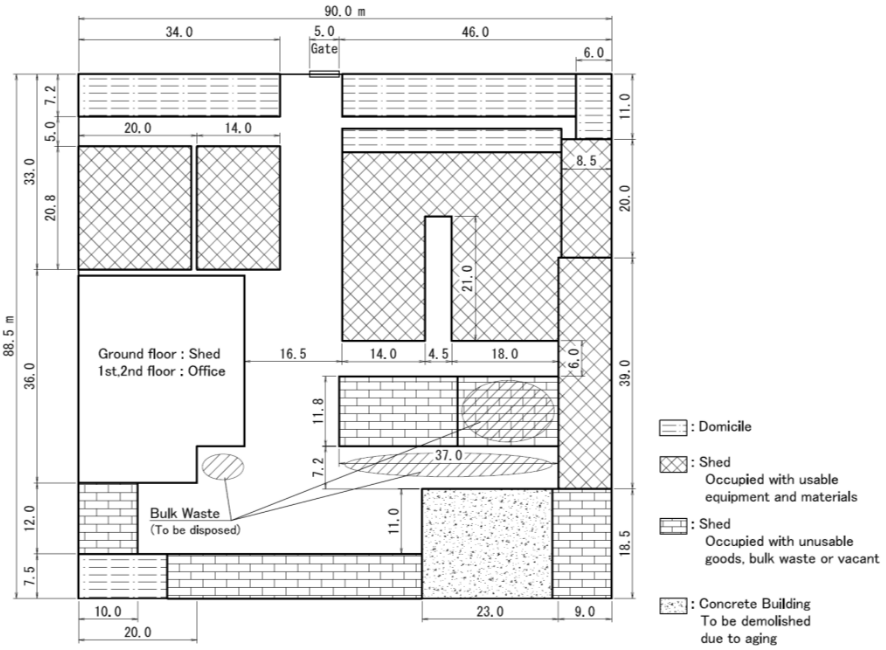


Figure 2.3.1 Layout of the Current Tongi DPHE Office/Depot

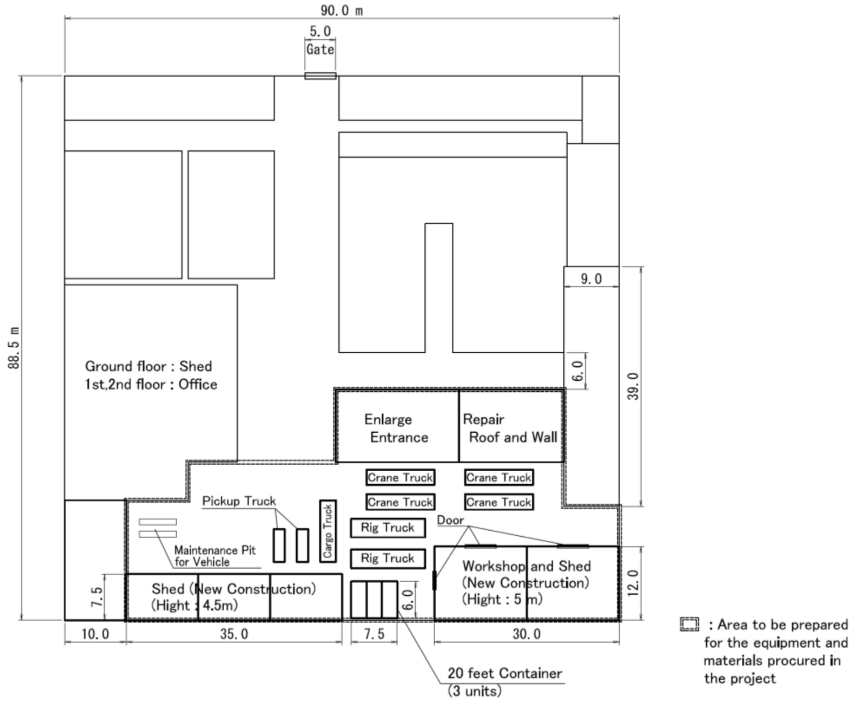


Figure 2.3.2 Layout of the Improved Tongi DPHE Office/Depot

Procured equipment and materials will be carried by many container trailers. Because around 21 pieces of 40 feet dry-container are expected to be carried in Tongi DPHE office/depot space may be not enough to unload goods. DPHE shall prepare temporal space near DPHE office/depot to unload procured goods for about 2 weeks.

(3) Implementation of the Action Plan

1) Drilling Plan of the Bangladesh Side

DPHE has the following basic principle on the drilling of deep wells in the arsenic contaminated area.

- District Paurashava: Deep wells for water sources of the piped water supply are mainly drilled (production wells).
- Villages: Deep wells for handpump wells are basically drilled (handpump well).

According to the plan, a total of 43 production wells and 256 handpump wells will be drilled up to the year 2017. However, in case of Paurashava, there are two areas, the urban area and the rural area, therefore, suitable type of wells will be selected considering each situation.

Numbers of production wells and handpump wells in the Study area are 28 and 30, respectively.

The drilling plan of DPHE is attached to the Minutes concluded on 24 November 2011.

2) Action Plan (Drilling Plan of DPHE for 5 years)

A deep well drilling plan of DPHE was formulated as an Action Plan for five (5) years after the delivery of the drilling rigs.

The types of deep well are production wells and handpump wells. A summary of the Action Plan is provided in Table 2.3.1.

Table 2.3.1 Summary of the Action Plan

	Production Well	Handpump Well
Schedule	5 years from January 2015 to December 2019	
Target Area	9 Districts shown in Table 2.3.3 - 2 Districts in Dhaka Division - 5 Districts in Khulna Division - 2 Districts in Rajshahi Division	35 villages shown in Table 2.3.6
Number of Wells to be Drilled	25 wells	35 wells
Number of Recipient	200,000 persons	16,425 persons
Number of Total Recipient	216,425 persons	

In the Project, two (2) production wells and one (1) handpump well will be drilled for technical transfer to the Bangladesh side of the deep well drilling technique. For this purpose, a field survey was conducted by the Study Team. As the result the field survey, the type of deep well was changed in two (2) sites after discussion with DPHE considering the situation. The contents of the change are as follows.

- The drilling of a production well was planned in Paurashava, Chuadanga Sadar, Chuadanga District, Khulna Division, but it was changed to a handpump well because the site was located in a rural area instead of an urban area in Paurashava.
- A handpump well to be drilled in Shanila village, Pabna District, Rajshahi Division was changed to a production well because the site was located in an urbanized area.

(i) Production well

Drilling sites for the deep well are District Paurashavas in nine (9) Districts included in the drilling plan of DPHE. A total of 28 production wells will be drilled in the plan against the number of production wells to be drilled in the action plan is 25. Accordingly, the drilling plan of DPHE was revised to adjust the number of production wells of the action plan (25 wells) reducing the number of wells in Jessore District from seven (7) wells to four (4) wells, since seven (7) wells in a district is relatively larger than other district. Paurashava- wise number of production wells is shown in Table 2.3.2.

Table 2.3.2 Number of Production Well to be Drilled in Paurashava

Division	District	District Paurashava	Number of Production Well
Dhaka	Faridpur	Faridpur Sadar	2
	Manikganj	Manikganj Sadar	3
Khulna	Chuadanga	Chuadanga Sadar	3
	Jessore	Jessore Sadar	4
	Jhenaidah	Jhenaidah Sadar	2
	Kushtia	Kushtia Sadar	2
	Meherpur	Meherpur Sadar	3
Rajbari	Nawabganj	Nawabganj Sadar	3
	Pabna	Pabna Sadar (including Bera)	3
Total			25

The population and water supply condition of the target Paurashavas are shown in Table 2.3.3. According to DPHE, water supply coverage in nine (9) District Paurashavas selected reaches 97% of the piped water supply and 30% of the handpump supply, however it decreases to less than 60% in the dry season due to drying up of ground water in the wells particularly in handpump tube well caused by lowering of the water table. Therefore, water supply coverage of these Paurashavas is considered as 60% in the Study.

The served population is about 1,211 thousand people against the total population about 2,019 thousand people assuming water supply coverage as 60%. Therefore, the target population is about 808 thousand people.

Table 2.3.3 The Population and Water Supply Coverage of Nine (9) District Paurashavas (2012)

Division	District	District Paurashava	Population	Served Population	Unserved Population
Dhaka	Faridpur	Faridpur Sadar	198,727	119,236	79,491
	Manikganj	Manikganj Sadar	80,491	48,295	32,196
Khulna	Chuadanga	Chuadanga Sadar	171,315	102,789	68,526
	Jessore	Jessore Sadar	391,717	235,030	156,687
	Jhenaidah	Jhenaidah Sadar	255,065	153,039	102,026
	Kushtia	Kushtia Sadar	143,222	85,933	57,289
	Meherpur	Meherpur Sadar	56,788	34,073	22,715
Rajshahi	Nawabganj	Nawabganj Sadar	312,565	187,539	125,026
	Pabna	Pabna Sadar	408,896	245,338	163,558
	Total		2,018,786	1,211,272	807,514
			100%	60.0%	40.0%

A total of 25 production wells will be drilled in five (5) years as shown in Table 2.3.4, since the necessary duration of drilling for one (1) production well is estimated as 60 days (2 months).

Table 2.3.4 Number of Production Well to be drilled by the Procured Rig

Item	Number of Well
Duration of drilling for one well	2 months/well
Transfer between the sites, maintenance of equipment	2 months/year
Number of well possible to drill in five (5) years	5 wells/year, 25 wells/(5 years)

The number of production wells to be drilled in the Action Plan is 25 wells. As one (1) production well is capable to supply water to 8,000 persons, a water supply to 200 thousand persons becomes possible. Conditions of this assumption are as follows.

- Ground water yield per one (1) production well: 80 m^3/hour (assumed based on the hydrogeological conditions and existing study data)

- Pumping duration: 12 hours/day
- Unit water demand: 120 L/capita/day (standard of DPHE for piped water supply in urban area)

(ii) Handpump wells

One (1) well is planned to be drilled in each target village shown in Table 2.1.7, totaling 30 wells. However, five (5) wells were added to the Action Plan because it was possible to drill 35 wells in five (5) years as shown in Table 2.3.5.

Table 2.3.5 Number of Handpump Wells to be Drilled by the Procured Rig

Item	Number of Well
Duration of drilling for one well	1.5 months/well
Transfer between the sites, maintenance of equipment	1.5 months/year
Number of well possible to drill in five (5) years	7 wells/year, 35 wells/(5 years)

The following conditions were applied for the selection of additional five (5) villages based on the discussion with DPHE.

- Five (5) Unions were selected considering the high priority. Then, one (1) Union is selected in one (1) District to avoid concentration in a District.
- The village of the second priority was selected since the village of the first priority was already selected.

In Manikganj District, no access of the drilling rig to the selected village was confirmed, therefore, Kotkandi Village (the 3rd priority) was alternatively selected. The village is located next to the village of the second priority.

The target 35 villages for the action plan were finally decided as shown in Table 2.3.6.

Table 2.3.6 The Population and Water Supply Condition of 35 Villages (2012)

District	Upazila	Union	Village	Population	Served Population*	Unserved Population
Faridpur	Faridpur Sadar	Aliabad	Bhajondanga	4,348	2,355	1,993
			Bhilmamudpur	10,137	1,275	8,862
		Kaijory	Purbo Gangabardi	2,900	1,431	1,469
		Krishunanagar	Bhadukudia	640	366	274
		Majchar	Dayarampur	4,027	1,831	2,196
Manikganj	Harirampur	Kanchanpur	Kutirhat	832	46	786
			Kotkandi	2,043	76	1,967
Rajbari	Rajbari Sadar	Dadoshi	Pakurikanda	1,138	700	438
Chuadanga	Alamdanga	Baradi	Anupnagar	1,373	213	1,160
			Kachikata	691	94	597
		Jehala	Betbaria	697	203	494
	Chuadanga Sadar	Paurashava	Hochockpara	-	-	-
	Damurhuda	Howli	Boro Dudhpatila	2,256	1,514	742
		Natipota	Boalmari	1,705	1,038	667
Jessore	Chaugachha	Chaugachha	Daskin Kyarpara	1,999	420	1,579
			Bergomindapur	3,044	639	2,405
		Jagadishpur	Marua	2,959	1,434	1,525
		Patibila	Purahuda	1,555	617	938
		Phulsara	Baruihati	817	417	400
Jhenaidah	Jhenaidah Sadar	Padmakar	Achintanagar	1,481	1,065	416
	Mahesgpur	Fatepur	Krishna Chandrapur	1,341	849	492

District	Upazila	Union	Village	Population	Served Population*	Unserved Population
Kushtia	Bheramara	Dharampur	North Bhabanupur	5,632	2,724	2,908
		Junidah	Jagshar	4,834	3,123	1,711
		Mokarimpur	Nawdakhemediar	2,904	2,222	682
	Daulatpur	Pragpur	Pakuria	2,140	1,042	1,098
Meherpur	Meherpur Sadar	Amihupi	Alampur	1,541	674	867
		Kutubpur	Subidpur	4,799	2,372	2,427
Nawabganj	Nawabganj Sadar	Char Anupnagar	Anupnagar	5,795	3,251	2,544
		Maharajpur	Moharajpur	25,845	3,625	22,220
		Ranihati	Ghorapakhia	3,573	605	2,968
			Bohrom	2,858	462	2,396
	Shibganj	Chhatrajtpur	Satrajipur	6,940	1,524	5,416
Pabna	Bera	Masumdia	Khanae Bari	1,715	1,162	553
		Natun Bharenga	Morichapara	1,240	1,020	220
		Ruppur	Boronagaon	659	511	148
Totak				116,458	40,900	75,558

Note *: Population of Hochockpara village is included in that of Chuadanga Sadar (Population data of Hochockpara Is not available).

(iii) Number of Recipients by the Action Plan

One (1) production well is capable to supply water to 8,000 people. Therefore, a total of 200,000 people can be served by 25 production wells. On the one hand, one (1) handpump well has the capacity to serve water to 500 people. In case the unserved population is less than 500 people in a village, the served population by one (1) handpump well is the same as the unserved population in such a village. If 35 handpump wells are drilled by the Action Plan, the number of recipients is 16,425 people. Therefore, the total number of recipients by the Action Plan will be 216,425 people at the completion of the Action Plan in 2019.

Change in water supply conditions by implementation of the Action Plan is shown in Table 2.3.7.

Therefore, the implementation of the Project will contribute to improve water supply coverage by enabling the carrying out of the Action Plan.

Table 2.3.7 Change in Water Supply Conditions by Implementation of the Action Plan

	2012			2019				
	Population	Served Population	Water Supply Coverage	Population	Served Population by existing schemes	Served Population by the Action Plan	Total Population Served	Water Supply Coverage
9 Paurashavas	2,018,786	1,211,272	60.0%	2,182,481	1,211,272	200,000	1,411,272	64.7%
35 villages	116,458	40,900	35.1%	125,897	40,900	16,425	57,325	45.5%
Total	2,135,244	1,252,172	58.6%	2,308,378	1,252,172	216,425	1,468,597	63.6%
Without Implementation of the Action Plan					1,252,172	-	1,252,172	54.2%

(iv) Implementation schedule of the Action Plan

25 production wells and 35 handpump wells will be drilled in the Action Plan. Among them, two (2) production wells and one (1) handpump well will be drilled in the technical transfer (Soft Component). Therefore, the implementation schedule for the Action Plan is formulated for the remaining 23 production wells and 34 handpump wells. The technical transfer in the Project is planned to be completed in December 2014. Accordingly, the Action Plan will be commenced on January 2015 and completed in December 2019. The implementation schedule is shown in Table 2.3.8.

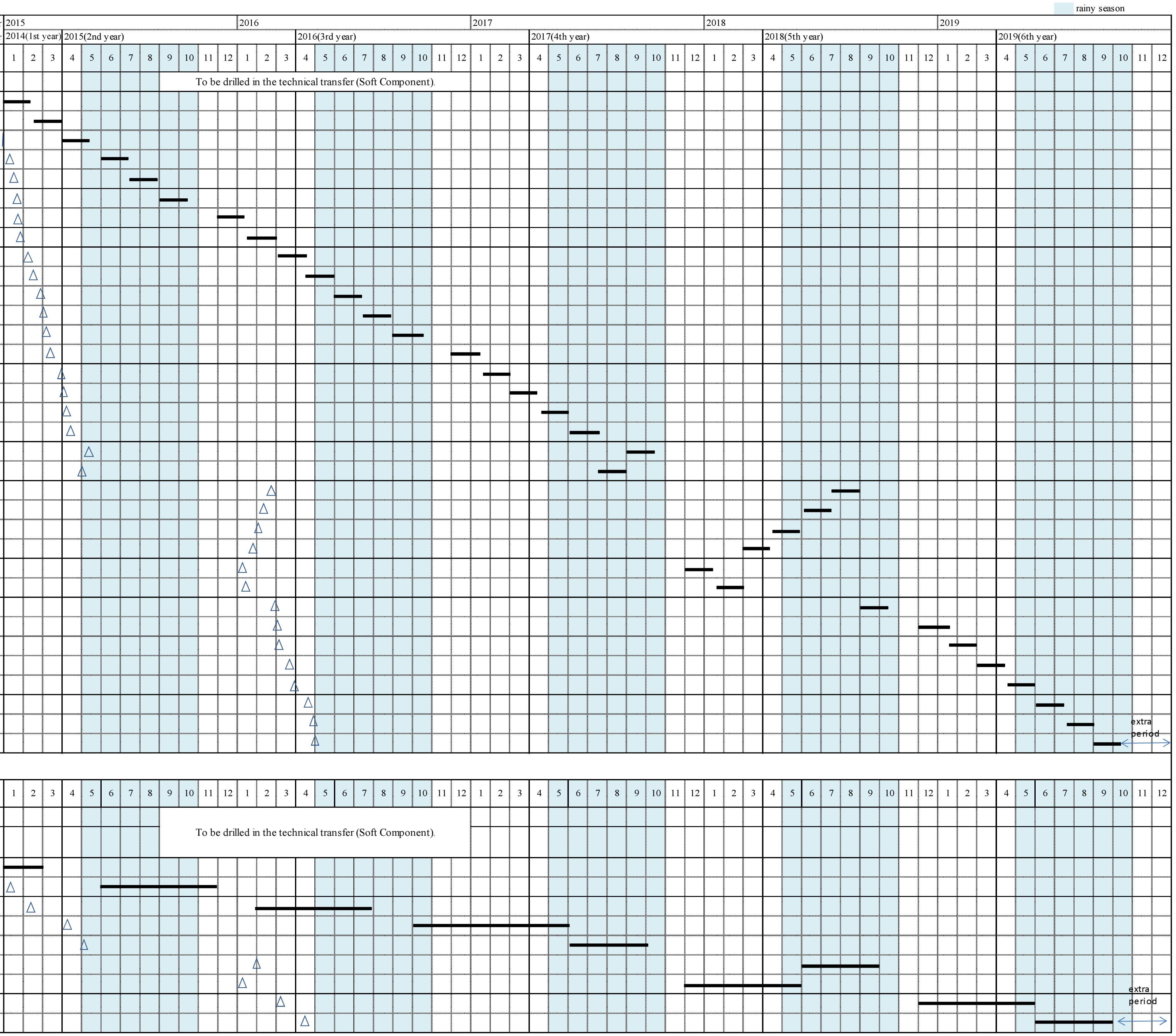
Table 2.3.8 Implementation schedule of the Action Plan

Handpump Well

Division	District	Upazila	Union	Village
Khulna	Jessore	Chaugachha	Jagadishpur	Marua
Dhaka	Faridpur	Faridpur Sadar	Aliabad	Bhajondanga*
				Bilmamudpur*
			Kaijory	Purbo Gangabardi
			Krishnanagar	Bhadukdia
			Majchar	Dayarampur
	Manikganj	Harirampur	Kanchanpur	Kotokandi
				Kutirhat
	Rajbari	Rajbari Sadar	Dadshi	Pakurikanda
Khulna	Chuadanga	Alamdanga	Baradi	Ampnagar
				Kachikata
			Jehala	Betbaria
		Chuadanga Sadar	Paurashava	Hochockpara
		Damurhuda	Howli	Boro Dudhpatila
			Natipota	Boalmari
	Jessore	Chaugachha	Chaugachha	Bergobindapur
				Daskin Kyarpara
			Patibila	Purahuda
			Phulsara	Baruihati
	Jhenaidah	Jhenaidaha Sadar	Padmakar	Achintanagar
		Maheshpur	Fatepur	Krishna Chandrapur
	Kushtia	Bheramara	Dharampur	North Bhabanupur
			Junidah	Jagshar
			Mokarimpur	Nawda Khemediar
		Daulatpur	Pragpur	Pakuria
	Meherpur	Meherpur Sadar	Amjhupi	Alampur
			Kutubpur	Subidpur
Rajshahi	Nawabganj	Nawabganj Sadar	Char Anupnagar	Anupnagar
			Maharajpur	Moharajpur
			Ranihati	Bohorom
				Ghoraparakhia
		Shibganj	Chhatrajitpur	Satrajitpur
	Pabna	Bera	Masumdia	Khanae Bari
			Natun Bharenga	Morichapara
			Ruppur	Boronagaon

Production Well

Division	District	Upazila	Union	Number of Planned Wells
Dhaka	Faridpur	Faridpur Sadar	Paurashava	1
Rajshahi	Pabna	Bera	Paurashava (Shanila Village)	1
Dhaka	Faridpur	Faridpur Sadar*	Paurashava	1
	Manikganj	Manikganj Sadar	Paurashava	3
Khulna	Chuadanga	Chuadanga Sadar	Paurashava	3
	Jessore	Jessore Sadar	Paurashava	4
	Jhenaidah	Jhenaidah Sadar	Paurashava	2
	Kushtia	Kushtia Sadar	Paurashava	2
	Meherpur	Meherpur Sadar	Paurashava	3
Rajshahi	Nawabganj	Nawabganj Sadar	Paurashava	3
	Pabna	Pabna Sadar	Paurashava	2



Legend
△ : Geophysical Prospecting
▬ : Drilling

*) Geophysical prospecting in Bhajondanga, Bilmamudpur(Handpump Well) and Faridpur Sadar(Production Well) will be carried out from June to December 2014.

(v) Cost for the Implementation of the Action Plan

If the Project is implemented, the equipment and materials will be delivered in 2014. DPHE has a plan to drill deep wells for five (5) years after the delivery of the equipment following the Action Plan prepared in the Study.

The period of the Action Plan is five (5) years from 2015 to 2019. During this period, DPHE will drill 25 production wells for piped water supply and 35 handpump wells. The related cost (mentioned in Table 2.3.9) shall be borne by DPHE. However, the cost for materials of deep wells to be drilled during the technical transfer (Soft Component): Two (2) production wells and one (1) handpump well will be covered by the Japan's Grant.

Table 2.3.9 The Cost for Implementation of the Action Plan

Item	Unit	Unit Cost (thousand BDT)	Quantity	Total (thousand BDT)
Geophysical Survey	site	46	54	2,484
Construction of Production Wells	site	6,963	23	160,149
Construction of Handpump Wells	site	2,403	34	81,702
Operation and Maintenance of Workshop	year	725	5	3,625
Operation and Maintenance of Depot	year	435	5	2,175
Materials for Operation and Maintenance	year	1,450	5	7,250
Total				257,385

(4) To bear the Cost for Implementation of Technical Transfer (Soft Component)

The following two (2) technical transfers are planned in the Project in order to strengthen the capacity of the Bangladesh side.

1) Technical transfer on planning and management of deep well drilling techniques
2) Technical transfer on the geophysical survey

The cost to be borne by DPHE is salary and daily allowance of staff who attend the technical transfer, and necessary materials for deep well drilling for two (2) production wells and three (3) handpump wells except those to be covered by the Japan's Grant.

DPHE is requested to properly maintain the equipment procured by the Japan's Grant. DPHE is also requested to submit reports every six (6) months on the progress of the Action Plan to the JICA Bangladesh Office.

2.3.3 THE COST TO BE BORNE BY DPHE

The cost to be borne by DPHE is summarized in Table 2.3.10.

Table 2.3.10 The Cost to be Borne by DPHE

328.9 million BDT (About 340.08 million yen)

Item	Cost (lakh BDT)	Cost in Yen (thousand yen)
(1) Expense for Bank Arrangement	7.04	728
(2) Cost for custom clearance and custom duty	558.91	57,791
(3) Cost for preparation of the workshop and parking	100.00	10,340
(4) Cost for implementation of Soft Component Technical Transfer	11.12	1,150
(5) Cost for implementation of Technical Transfer	38.10	3,940
(6) Cost for implementation of the Action Plan	2,573.85	266,136
Total	3,289.02	340,085

2.3.4 SHARING OF EXPERIENCES AND TECHNIQUES

Neither donors nor private drilling companies have developed deep ground water in the Project area. It is desirous to share the experience and technique obtained through the Project with donors and private drilling companies, in order to accelerate the development of deep ground water in the Project area. Therefore, the following measures are proposed to share the experience and techniques.

<Before commencement of technical transfer on the drilling technique by the supplier>

DPHE is advised to announce the briefing of technical transfer to the private drilling companies. In the briefing, DPHE will recruit attendance to the technical transfer by explaining the following contents of the technical transfer.

(1) Management of deep well drilling through the Soft Component by the consultant

(2) Deep well drilling technique by the supplier

<During the technical transfer>

DPHE will give the chance to private drilling companies to attend the technical transfer on the deep well drilling technique, (1) specific technique for drilling of deep wells in the area where gravel layers are distributed, (2) technique of prevention of arsenic contamination (especially sealing technique).

Technical transfer will be done to the staff of DPHE together with the staff of the private drilling companies.

<After completion of the technical transfer>

DPHE has been holding a National Water Supply and Sanitation Technology Sharing Workshop every year to share effective technologies.

2.4 PROJECT OPERATION PLAN

2.4.1 CURRENT SYSTEM IN DPHE

DPHE has drilled deep wells using its own two (2) drilling rigs by employing contractors selected by tender. If the contractors need to use a DPHE's rig for executing the deep well drilling, DPHE will lend the rig to the contractor. Such contractor is responsible to maintain and manage the rig before and after the drilling work. The drilling work is executed under the supervision of the Mechanical-Electrical Division of the Ground Water Circle, DPHE. The staff responsible for management of drilling rigs belongs to the Equipment Unit under the Mechanical-Electrical Division.

A pumping test is carried out after completion of the drilling work by employing a drilling contractor under the supervision by Ground Water Division.

DPHE drilled 32 production wells during past five (5) years, averaging 3.2 wells/year/rig, as shown in Table 2.4.1.

Table 2.4.1 Number of Production Wells Drilled in Past 5 Years

Rig	2007	2008	2009	2010	2011	Total
Rig A	10	5	6	2	7	30
Rig B	1	0	0	0	1	2
Total	11	5	6	2	8	32

Unit: well

The water quality of the deep wells is analysed by the Chemical Analysis Unit, Water Quality Surveillance Circle. The drilling and pumping test data are kept and managed by the Data

Management Division, Water Quality Surveillance Circle.

The organization chart of Ground Water Circle and the Water Quality Monitoring and Surveillance Circle is shown in Figure 2.4.1.

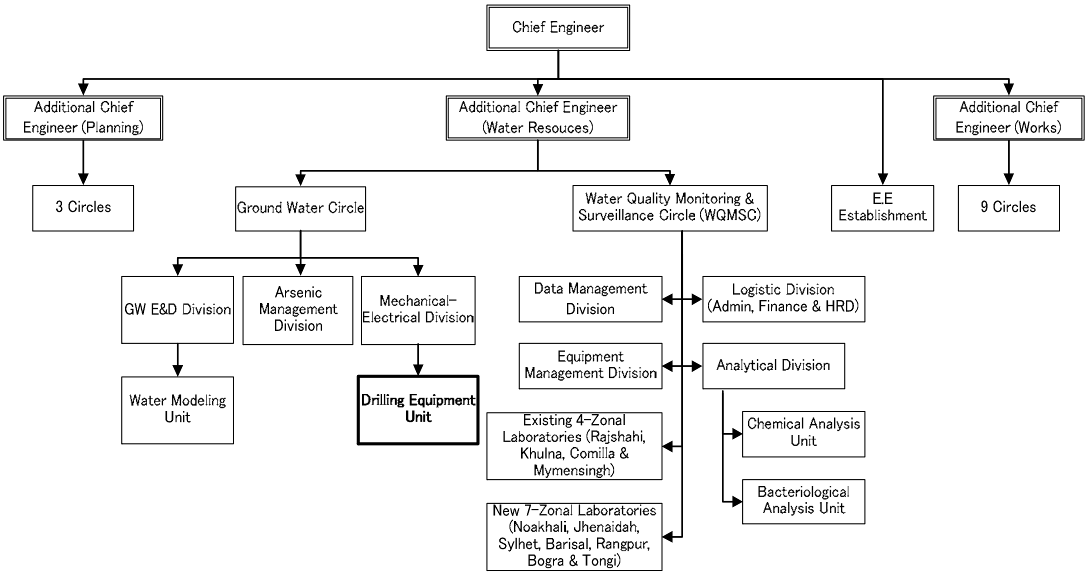


Figure 2.4.1 Organization Chart of Ground Water Circle and Water Quality Monitoring and Surveillance Circle, DPHE

2.4.2 IMPLEMENTATION SYSTEM OF THE PROJECT

(1) Organization of DPHE

The current organization of the Ground Water Circle of DPHE is shown in Figure 2.4.2.

The Ground Water Circle of DPHE will be the implementation agency of the Project. The organization shown in Figure 2.4.3 is required to operate and management of the equipment provided by the Project if the Project is implemented.

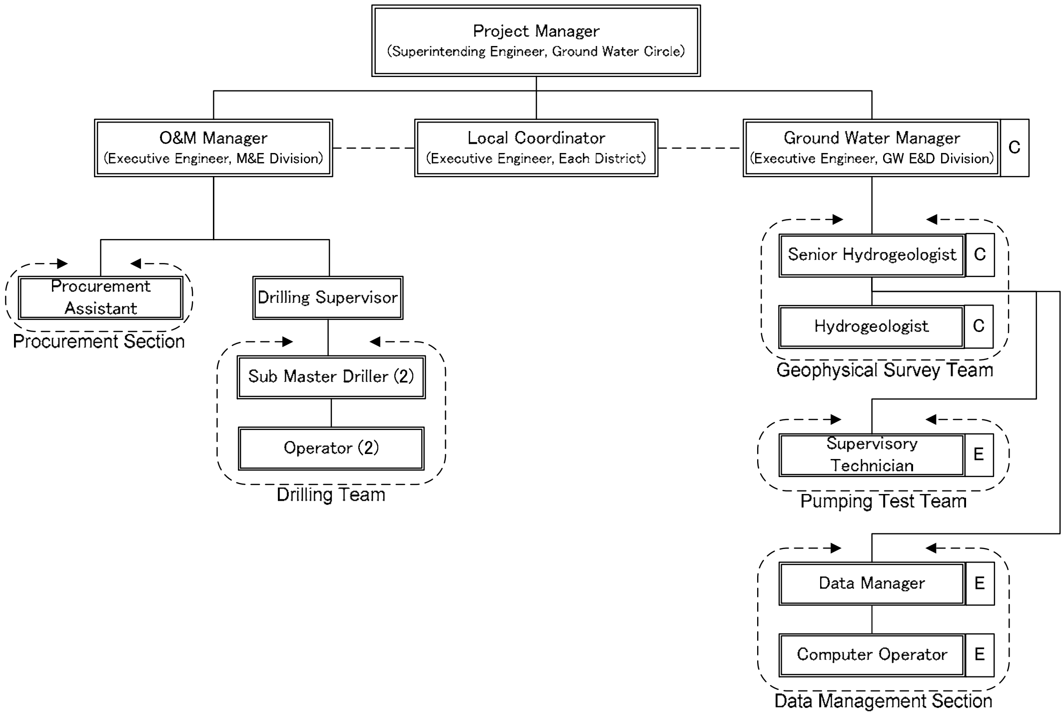


Figure 2.4.2 Current Organization of the Ground Water Circle of DPHE

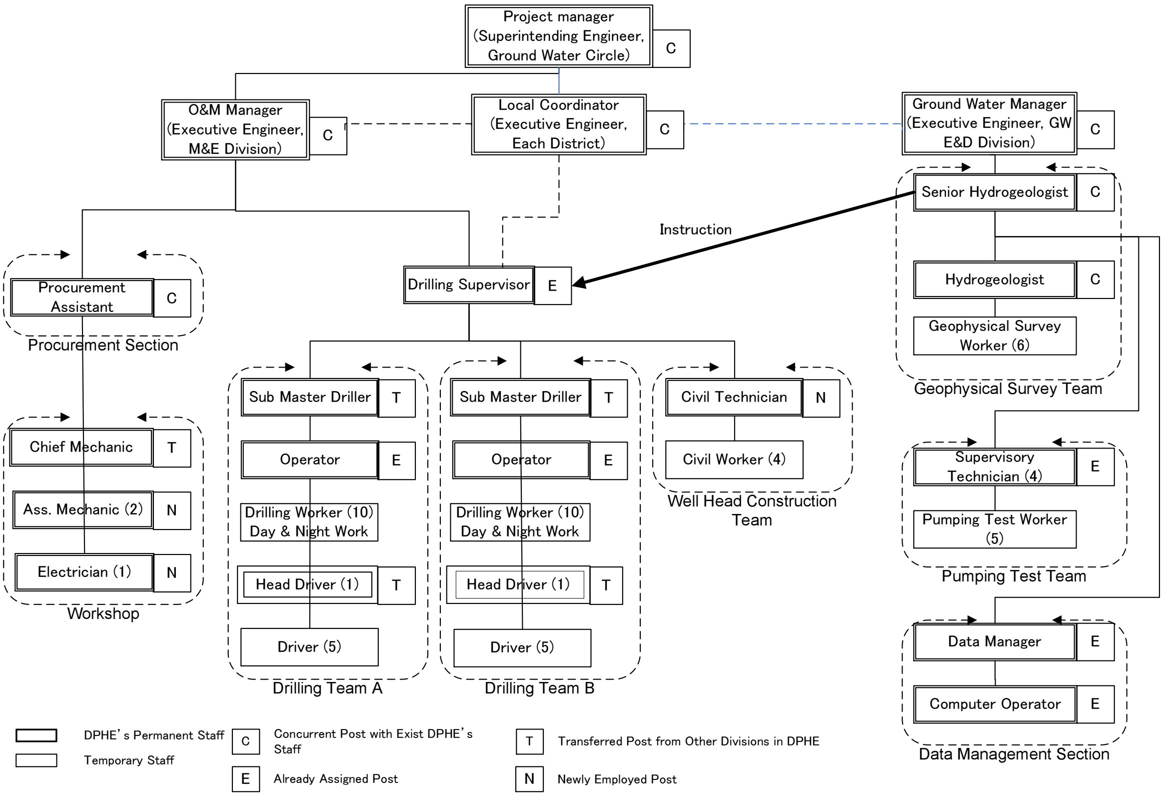


Figure 2.4.3 Required Organization of the Ground Water Circle of DPHE for Implementation of the Action Plan

The implementation of the Action Plan is totally managed by the Superintending Engineer of the Ground Water Circle. Under him, Mechanical & Electrical Division and Groundwater Exploration & Development Division are the organization of the actual implementation.

Table 2.4.2 Task of Responsible Person in Charge for Implementation of the Action Plan

Person in Charge	Task
Executive Engineer of Mechanical-Electrical Division	- Management of drilling work by rigs - Procurement and maintenance of the drilling rigs
Executive Engineer of Ground Water Division	- Hydrogeological interpretation, judgement and instruction - Supervision of pumping test and interpretation of the test result - Management of the data

It will not be required to recruit new staff for the posts shown in double lines in Figure 2.4.3, because they will be allocated to the existing staff of DPHE. DPHE will keep the current deep well drilling system, therefore, some parts of the posts will be entrusted to the private drilling companies. The posts shown in single line are temporary staff to be employed when necessary

DPHE will provide a suitable workshop and depot for maintenance of the drilling rigs.

(2) Preparation of Workshop

The office of the Mechanical-Electrical Division is located at Tongi in Dhaka City and has a parking space for trucks and storages for materials. The 1st floor of the office is composed of three (3) storages. DPHE will disposition the existing materials in the office and repair the inside of the office to provide the workshop and storage for the materials to be procured in the Project.

(3) Obtaining Depot

The office of the Mechanical-Electrical Division has not enough space for parking of vehicles and materials to be procured by the Project although the office has a parking space for several trucks. Therefore, DPHE will provide space for a depot near the office to keep vehicles and materials to be procured by the Project.

(4) DPHE Budget

Table 2.4.3 shows the budget of DPHE from 2006/2007 to 2011/2012 fiscal year.

Table 2.4.3 Budget of DPHE

Item	Fiscal Year					
	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012
Development Budget	19,995.56	27,738.00	29,666.00	39,580.00	37,057.00	61,254.79
Expenditure	16,939.58	24,786.26	26,102.87	37,570.24	35,923.72	60,821.88
Non-Development Budget	7,580.64	9,438.90	11,349.53	11,678.95	14,267.29	14,272.35
Expenditure	7,580.64	9,438.90	11,349.53	11,678.95	14,267.29	14,272.35
Total Budget	27,576.20	37,176.90	41,015.53	51,258.95	51,324.29	75,527.14
Total Expenditure	24,520.22	34,225.16	37,452.40	49,249.19	50,191.01	75,094.23

(Unit：lakh BDT)

The development budget of DPHE has been steadily increased in every fiscal year. In 2011/2012 fiscal year, it reached 3.1 times of the budget of 2006/2007 fiscal year.

The implementation cost of the Project to be borne by the Bangladesh side is estimated as about 328.9 million BDT. Preparation of the cost is agreed to be budgeted considering the implementation schedule between the Bangladesh side and the Japanese side in the Minutes.

2.4.3 OPERATION AND MAINTENANCE OF PROCURED EQUIPMENT AFTER COMPLETION OF THE PROJECT

DPHE will be in charge of operation and maintenance when drilling rigs and related equipment are procured by the Project. The system of DPHE which is necessary for operation and maintenance was mentioned in “2.4.2 Implementation System of the Project.”

DPHE will continue drilling work of deep tube wells according to the Action Plan after the Soft Component using the equipment to be procured. The operation and maintenance system of the procured equipment after the implementation of the Action Plan will be the same as that during the implementation of the Action Plan. Therefore, the operation and maintenance system which was mentioned in in “2.4.2 Implementation System of the Project” will be continued.

In drilled deep tube wells, production wells will be connected to existing piped water supply facilities which are managed by district Paurashavas. The connection method and the exact length of the connection pipeline cannot be calculated at this moment since the connection point with the existing piped water supply facilities will be decided after completion of construction of the production wells. However, the length is estimated to be about 1-2 km. According to DPHE, the construction cost for the connection pipeline will be about 12 lakh BDT/km. Therefore, when the average connection length is assumed as 1.5 km, the total cost for the connection will be 45 million BDT for the 25 production wells.

Regarding handpump wells, handpumps will be installed after completion of construction of the deep tube wells. A No.6 pump can be installed when the water level is up to 6 m below the ground level. A Tara pump will be installed in case the water level is more than 6 m. The installation cost for a handpump is about 19,000 BDT for the No. 6 pump and about 140,000 BDT for the Tara pump. Operation and maintenance of the handpumps will be carried out by community people.

2.4.4 WATER QUALITY MONITORING OF DEEP GROUND WATER

About the water quality of deep tube wells which will be drilled in the Project, there is a need to evaluate whether the water quality is suitable for drinking or not by conducting water quality analysis at the completion of the drilling works. Regular water quality analysis is also necessary after starting to use the wells as water sources since the water quality could possibly be changed. Therefore, this Project suggests a water quality monitoring plan by DHPE as indicated in Table 2.4.4. DPHE Ground Water Circle will be in charge of the entire water quality monitoring system and DPHE district offices where the deep tube wells are located will be in charge of conducting the monitoring. The monitoring results should be reported to DPHE Ground Water Circle smoothly.

Table 2.4.4 Water Quality Monitoring Plan

Item	Contents
Department in Charge of Monitoring	DPHE Ground Water Circle
Monitoring Implementation Office	DPHE district offices at where deep tube wells exist
Monitoring Period	Once in the rainy season and once in the dry season (twice annually)
Analysis Items	25 parameters indicated in Table 2.4.5
Analysis Accuracy	For analysis accuracy, it is desirable to obtain multiple samples from each well and analyse these samples.
Analysis Laboratory	DPHE central laboratory, Zonal laboratories*.

*Regarding the laboratories to analyse the water samples, the central laboratory is capable of analysing all the parameters (25 parameters), however, zonal laboratories are incapable of analysing six (6) parameters: Nitrite, Nitrate, Ammonia, Sodium, Potasium and Sulphate. Therefore, there are two (2) alternative analysis systems.

(1) 19 parameters are analysed in the zonal laboratories and remaining six (6) parameters are analysed in the cantral laboratory.

(2) All the paramaters are analysed in the central laborator,

Table 2.4.5 Parameters on Water Quality Analysis

Paramaeter		Unit	Bangladesh Drinking Water Standard	WHO Guidelines for Drinking Water Quality (2011)
1	Total coliform bacteria	count/100mL	0	0
2	Faecal coliform	count/100mL	0	0
3	Arsenic (As)	mg/L	0.05	0.01
4	Fluoride (F)	mg/L	1	1.5
5	Nitrate (NO3)	mg NO_3/L	10	50
6	Nitrite (NO2)	mg NO_2/L	1	3/0.2
7	Manganese (Mn)	mg/L	0.1	-
8	Total hardness	mg/L	200-500	-
9	Calcium (Ca)	mg/L	75	-
10	Magnesium (Mg)	mg/L	33-35	-
11	Iron (Fe)	mg/L	0.3-1	-
12	Chloride (Cl)	mg/L	150-600	-
13	TDS	mg/L	1,000	-
14	Ammonia (NH3)	mg/L	0.5	-
15	pH	-	6.5-8.5	-
16	Taste	-	Not offensive	-
17	Odour	-	Odourless	-
18	Colour	TCU mg Pt/L	15	15
19	Turbidity	NTU	10	5
20	Temperature (T)	^{0}C	20-30	-
21	Electric Conductivity (EC)	mS/m	-	-
22	Sodium (Na)	mg/L	200	-
23	Potasium (K)	mg/L	12	-

Paramaeter		Unit	Bangladesh Drinking Water Standard	WHO Guidelines for Drinking Water Quality (2011)
24	Bicarbonate (HCO3)	mg/L	-	-
25	Sulfate (SO4)	mg/L	400	-

2.4.5 SUGGESTION ON COUNTERMEASURE WHEN WATER QUALITY ANALYSIS PARAMETER ABOVE STANDARD IS CONFIRMED

In case the result of water quality analysis reveals the existence of parameters above the Bangladesh drinking water standard, it is impossible to supply drinking water without any countermeasures. Especially when arsenic concentration is above the standard, there is a possibility of the onset of arsenicosis symptoms. Therefore, this Project suggests following the alternative countermeasures.

(1) Access Control to Deep Tube Well

Usage of ground water with water quality parameters above the standard should be banned as drinking water, cooking water and water for dish washing. However, usage of the ground water as other usage is possible.

(2) Installation of Arsenic Iron Removal Plant (AIRP)

In Bangladesh, many Arsenic and Iron Removal Plants (AIRP) exist and they are working effectively against reducing of arsenic and iron concentrations above the standard. Installation of AIRP is a possible countermeasure since usage as drinking water is possible when arsenic and iron concentrations are below the standard. The general installation cost for an AIRP is about 5 lakh BDT. Figure 2.4.4 shows the standard AIRP structure.

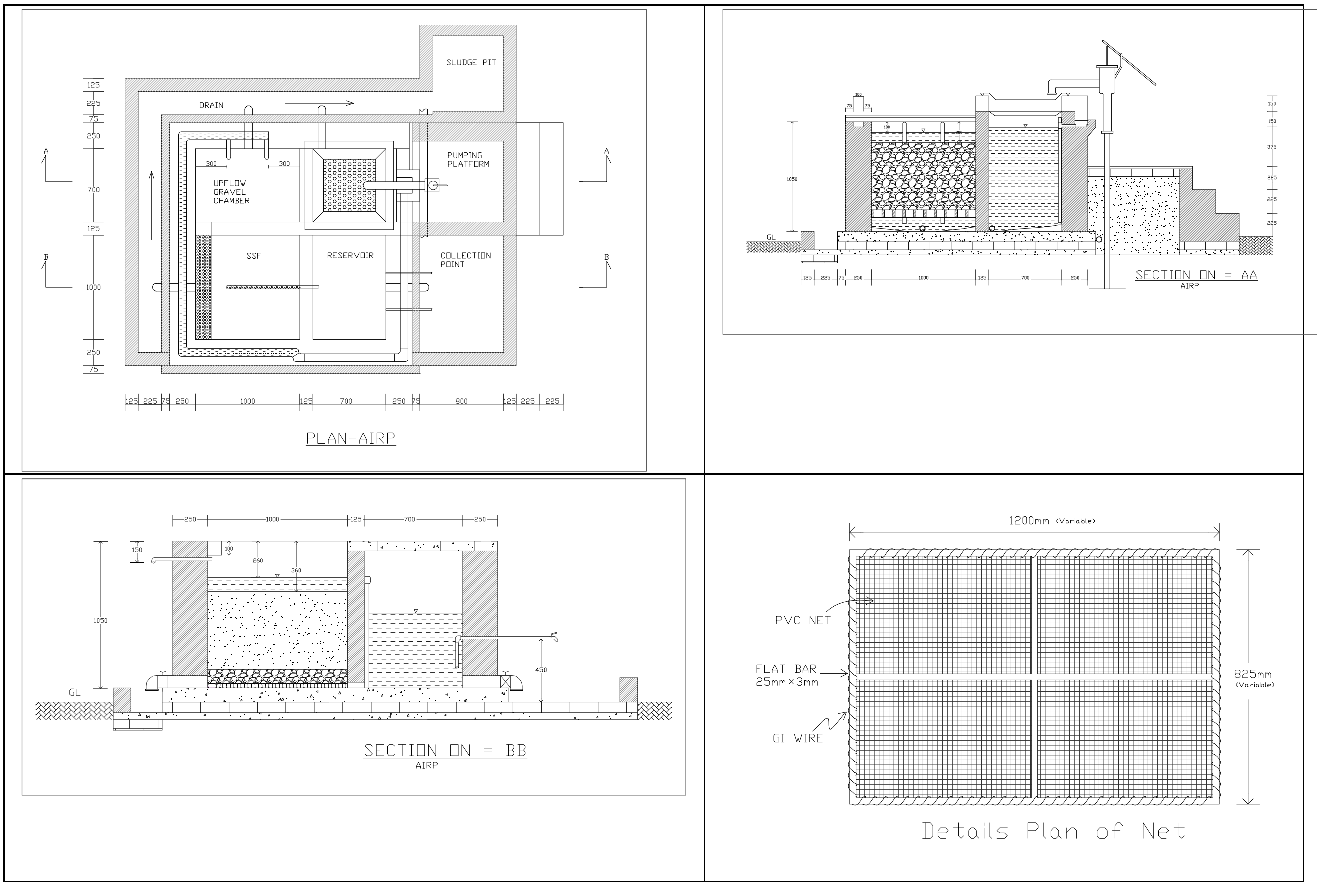


Figure 2.4.4 Regular AIRP Structure

(3) Re-drilling of Deep Tube Well

A deep aquifer does not consist of a unique aquifer but consists of multiple aquifers. There is a possibility that water quality changes when the aquifers are different from each other. Therefore, drilling of a different deep tube well is another countermeasure in case a water quality analysis parameter above the standard exists. It is difficult to understand that the aquifer for a drinking water source is suitable when the data is insufficient. However, as drilling of deep tube wells proceeds and data of aquifers is accumulated, characteristics of the aquifer will be revealed, and it will be possible to realize a suitable aquifer before drilling.

2.5 PROJECT COST ESTIMATION

2.5.1 INITIAL COST ESTIMATION

The approximate cost to be borne by the Bangladesh side is summarized in Table 2.5.1.

Table 2.5.1 Cost to be Borne by the Bangladesh Side

328.9 million BDT (About 340.1 million yen)

Item	Cost (lakh BDT)	Cost in Yen (thousand yen)
(1) Expense for Bank Arrangement	7.04	728
(2) Cost for custom clearance and custom duty	558.91	57,791
(3) Cost for preparation of the workshop and parking	100.00	10,340
(4) Cost for implementation of Soft Component Technical Transfer	11.12	1,150
(5) Cost for implementation of Technical Transfer	38.10	3,940
(6) Cost for implementation of the Action Plan	2,573.85	266,136
Total	3,289.02	340,085

Condition of the cost estimation is as follows:

- Date of estimation : January 2012
- Exchange rate : 1 US$ = 78.64 Japanese Yen
  : 1 BDT = 1.034 Japanese Yen
- Construction period : The Project is carried out in one (1) phase, Detailed Design and Purchasing Stage.
- Other : The Project is implemented under the Japan’s Grant Aid Assistance Scheme

2.5.2 OPERATION AND MAINTENANCE COST

Operation and maintenance costs for the equipment are estimated as shown in Table 2.5.2.

Table 2.5.2 Operation and Maintenance Costs for Equipment

Item			Cost per year（BDT）
Store keeper for workshop			288,000
Fuel for generator etc. in workshop			163,000
	Cost per site（BDT）	Quantity of site per year（site）	
Drilling equipment for production well (including supporting trucks)	220,000	5	1,100,000
Drilling equipment for handpump well (including supporting trucks)	67,000	7	469,000
Geophysical survey equipment and Logging equipment			80,000
Total			2,100,000

CHAPTER 3 PROJECT EVALUATION

3.1 PRECONDITIONS OF PROJECT IMPLEMENTATION

The contents of the Project are to provide drilling rigs, related equipment and supporting vehicles, as well as technical transfer on the deep well drilling technique and geophysical survey. Preconditions on the Bangladesh side for the implementation of the Project are as follows.

3.1.1 GENERAL ISSUES

- To bear an advising commission of the Authorization to Pay (A/P) and payment commission to a Japanese bank for the banking services based on the Banking Arrangement (B/A)
- To ensure prompt unloading and customs clearance at the port of disembarkation in Bangladesh and to assist internal transportation of the products
- To exempt tax and custom clearance of the products at the port of disembarkation
- To accord Japanese nationals whose services may be required in connection with the supply of the products and the services under the verified contract such facilities as may be necessary for their entry into Bangladesh and stay therein for the performance of their work
- To maintain and use properly and effectively the equipment provided under the Grant Aid
- To bear all the expenses, other than those to be borne by the Grant Aid, necessary for the transportation and installation of the equipment
- To give due environmental and social consideration in the implementation of the Project
- To facilitate the data and information necessary for the detailed design study for the Project
- To get approval necessary for the implementation of the Project

3.1.2 SPECIFIC ISSUES IN THE PROJECT

Issues to be implemented by the Bangladesh side before delivery of the equipment by the Project are as follows.

- To organize two (2) Drilling Teams and a Geophysical Survey Team
- Provision of Workshop and Depot for Equipment, Materials and Vehicles
- Provision of the Budget for Implementation of the Action Plan
- To bear the Cost for Implementation of Technical Transfer (Soft Component)
- To submit half-yearly progress report to JICA

3.2 NECESSARY INPUT BY THE BANGLADESH SIDE

Necessary input by the Bangladesh side for attaining the Project target is as follows.

3.2.1 CONNECTION OF THE PRODUCTION WELL TO THE EXISTING PIPED WATER SUPPLY SYSTEM

The production well drilled in the Action Plan will be used as the water source of the existing piped water supply system. Since one (1) production well is capable of supplying water to about 8,000 persons, it is desirous to connect the well to the existing piped water supply system as soon as possible after completion of the drilling work in order to improve the water supply potential.

3.2.2 INSTALLATION OF HANDPUMP ON THE HANDPUMP WELL

One (1) handpump well is expected to have the capacity of supplying water to about 500 persons. Therefore, it is desirous to install a handpump on the handpump well immediately after completion of the drilling work for the improvement of the water supply service to the community people.

3.2.3 TO CONTINUE DEEP WELL DRILLING AFTER COMPLETION OF THE ACTION PLAN

In order to improve water supply coverage, it is important for the Bangladesh side to continue the deep well drilling using the drilling rigs provided by the Project, after 2019 when the Action Plan is completed.

3.2.4 DISSEMINATION OF THE PROJECT EXPERIENCE

Neither donors nor private drilling companies have developed deep ground water in the Project area. It is desirous to share the experience and technique obtained through the Project with donors and private drilling companies, in order to accelerate the development of deep ground water in the Project area. Therefore, the following measures are proposed to share the experience and techniques.

<Before commencement of technical transfer on the drilling technique by the supplier>

DPHE is advised to announce the briefing of technical transfer to the private drilling companies. In the briefing, DPHE will recruit the attendance to the technical transfer by explaining the following contents of the technical transfer.

- Management of deep well drilling and geophysical survey through the soft component by the consultant
- Deep well drilling technique by the supplier

<During the technical transfer>

DPHE will give the chance to private drilling companies to attend the technical transfer on the deep well drilling technique, (1) specific techniques for drilling of deep wells in the area where gravel layers are distributed, (2) technique of prevention of arsenic contamination (especially sealing technique).

Technical transfer will be done to the staff of DPHE together with the staff of the private drilling companies.

<After completion of the technical transfer>

The technique and experience which is obtained in the Project and during the implementation of the Action Plan should be shared with relevant organizations in the National Water Supply and Sanitation Technology Sharing Workshop which is held every year.

3.3 IMPORTANT ASSUMPTION

In order to realize and sustain the effects of the Project implementation, the following external conditions are required.

- Policy on rural water supply of Bangladesh to develop deep ground water as the alternative safe water source is continued.
- Relevant persons who received technical transfer in the Project pursue the deep well drilling work.

3.4 PROJECT EVALUATION

3.4.1 RELEVANCE

The target area of the Project is the area where shallow ground water is contaminated by arsenic and development of deep ground water is difficult by the drilling rigs owned by DPHE and the present drilling techniques used by DPHE due to distribution of gravel layers. Community people in the target area include poor people. About 216 thousand people in nine (9) District Paurashavas and 35 villages receive safe water supply by implementation of the Project.

Water supply coverage by the exiting water supply systems is 58.6% in 2012, therefore, remaining people are obliged to use deteriorated water and/or arsenic contaminated water. If deep wells are constructed by the Project, safe water can be used and it will reduce the arsenicosis patients and water borne diseases. Such a positive socio-economical spreading effect is expected by implementation of the Project.

In Bangladesh, National Policy for Safe Water Supply & Sanitation 1998 advocated to supply a basic level of safe water to all nationals. The National Strategy for Accelerated Poverty Reduction (FY2009-2011) was orientated to use deep ground water as the alternative source of arsenic contaminated shallow ground water. Furthermore, the Sector Development Plan (2011-2015) launched in December, 2011 sets up the development target to 2025. It meets the national goal to accelerate the development of deep ground water in the target area where deep ground water is the only alternative source by improving the capacity of DPHE on deep ground water development.

Since the target area of the Project is mainly rural areas, the implementation of the Project contributes to improvement of the life of community people and stabilization of the people's livelihood from the viewpoint of basic human needs to supply safe arsenic free water to the people. Taking measures against arsenic contamination of ground water is one of Japan's strategic assistance issues. Therefore, the implementation of the Project meets Japan's assistance policy.

3.4.2 EFFECTIVENESS

(1) Quantitative Effectiveness

Deep wells are constructed in the Project after procurement of the drilling rigs and related equipment: 25 production wells in nine (9) District Paurashavas and 35 handpump wells in 35 villages. In addition, capacity of DPHE to develop deep ground water will be improved by the technical transfer. Through these inputs, the quantitative effectiveness shown in Table 3.4.1 is expected.

Table 3.4.1 Quantitative Effectiveness by the Project

Index		Base Line (2012)	Target (2019)	Quantitative Effect
Water supply coverage in target District Paurashavas and villages	Served Population	1,252,172 persons	1,468,597 persons	+ 216,425 persons
	Water Supply Coverage	58.6 %	63.6 %	+ 5.0%

(2) Qualitative Effectiveness

The implementation of the Project is expected to have the following qualitative effects.

- The growth rate of arsenicosis patients and the prevalence of waterborne diseases are decreased as the quality of drinking water is improved.
- Working hours and learning time of the women and children who have mainly been engaged in fetching water are increased since the fetching work of water is decreased.

3.4.3 CONCLUSION

As discussed in 3.4.1 and 3.4.2, it is evaluated that the relevance to implementation of the Project is high and great effectiveness is expected.

3.5 MONITORING ON THE EFFECT OF CONSTRUCTION OF DEEP WELLS

The Project aims to construct deep wells for safe water supply to the community people living in the area where arsenic contamination of shallow ground water is confirmed. Relevance and effectiveness of the Project were confirmed in 3.4.1 and 3.4.2.

DPHE will continue the construction of the deep wells for safe water supply using the equipment procured in the Project.

The effect of the construction of the deep wells can be evaluated by changing in the factors, ratio of arsenic contaminated water source, number of arsenicosis patients and water supply coverage considering the Project purpose. Therefore, DPHE is requested to evaluate the effect of the deep well construction by collecting the data described above in the target area through the district offices.

Table 3.5.1 shows the ratio of arsenic contaminated water sources, the number of arsenicosis patients and water supply coverage in the target villages. These data are used as base line data in the monitoring and evaluation of the effect of the deep well construction.

Regarding the frequency of the monitoring, it is considered that once every three (3) years is enough because progress of the deep well construction is 5 production wells and 7 handpump wells in a year.

As the monitoring and evaluation system, district offices of DPHE will collect necessary data and transfer the data to DPHE headquarters. DPHE will carry out monitoring and evaluation of the deep well construction using the data collected. It is expected that the ratio of arsenic contaminated water sources and the number of arsenicosis patients will decrease and water supply coverage will increase.

Table 3.5.1 Ratio of Arsenic Contamination, Number of Arsenicosis Patients and Ratio of Water Supply in Target Villages

Name of Target Village	Ratio of Arsenic Contamination (%)	Number of Arsenicosis Patients	Ratio of Water Supply （%）
Bhajondanga	44	20	54.16
Bilmamudpur	87	97	12.58
Purbo Gangabardi	49	19	49.34
Bhadukdia	49	19	57.19
Dayarampur	53	15	45.47
Kotkandi	96.19	1	3.72
Kutirhat	94.37	7	5.53
Pakurikanda	36.44	25	61.51
Ampnagar	84	85	15.51
Kachikata	83	20	13.6
Betbaria	70	40	29.12
Hochockpara*	-	-	-
Boro Dudhpatila	30.56	191	67.11
Boalmari	37.09	47	60.88
Bergobindapur	-	104	20.99
Daskin Kyarpara	-	44	21.01
Marua	-	146	48.46
Purahuda	-	12	39.68
Baruihati	-	43	51.04
Achintanagar	25.68	41	71.91
Krishna Chandrapur	34.59	86	63.31
North Bhabanupur	50	61	48.37
Jagshar	33.21	110	64.6

Name of Target Village	Ratio of Arsenic Contamination (%)	Number of Arsenicosis Patients	Ratio of Water Supply（%）
Nawda Khemediar	20.92	116	76.52
Pakuria	49.74	71	48.69
Alampur	54.84	165	43.74
Subidpur	48.85	49	49.43
Anupnagar	42.01	8	56.1
Moharajpur	85.45	20	14.03
Ghoraparakhia	82.48	113	16.93
Bohrom	83.33	132	16.17
Satrajitpur	77.33	80	21.96
Khanae Bari	60	27	67.76
Morichapara	75	13	82.26
Boronagaon	70	24	77.54

*Population of Hochockpara village is included in that of Chuadanga Sadar and population data of Hochockpara is not available. Therefore, data for ratio of arsenic contamination, number of arsenicosis patient and ratio of water supply are not available.